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No. I.—JANUARY, 1894.

ORIGINAL ARTICLES.

I.—CORAL IN THE "DOLOMITES" OF SOUTH TYROL.

By Miss MARIA M. OGILVIE, D.Sc. (Lond.).

(Part I.)

I.—General Character of the Scenery—The Interpretation of the Mid-Triassic Succession given by the "Coral Reef Theory."

AT the meeting of the British Association in Nottingham, in August of last year, a joint discussion on "Coral Reefs" was held by the sections of Zoology and Geology.[1] Prof. Sollas, in opening the discussion, referred to the "Dolomites of South Tyrol" as a country affording brilliant examples of Fossil Coral Reefs. He demonstrated this by sections taken from the well-known work of Mojsisovics, and showed several photographs of some of the more imposing dolomite mountains—Schlern, Langkofl, and Sella—which had been explained as reefs of Triassic age. In the course of the discussion, Dr. Hickson said he believed there were no corals in these so-called fossil reefs. Dr. Rothpletz corrected this statement, saying briefly that there were corals in the dolomite and limestone rock, along with other groups of marine animals, but that many of the sections shown by Prof. Sollas were incorrect. Prof. Bonney emphasized the ample evidence of Coral life in many parts of the district which he had visited.

I may be pardoned for recapitulating the part of the discussion bearing on South Tyrol, as I wish to state here the conclusions which I have formed with regard to Coral Reefs from my geological work in that neighbourhood. So far as South Tyrol gives countenance to one theory of the growth of Coral Reefs or the other, it supports in the main Murray's theory and not Darwin's. It displays striking analogies with the observations of recent reefs made by Agassiz in the West Indian and Caribbean Seas, by Dr. Guppy in the Solomon Islands, by Dr. Murray on the Barrier Reef of Tahiti and the Great Chagos Bank, by Prof. Semper in the Pelew Islands, by Dr. Rein, Dr. Sydney Hickson, and others. Some of the special points of correspondence may be indicated at once. Volcanic eminences formed submarine platforms in the Triassic ocean of South Tyrol, on which Corals built in Wengen and Cassian time. One special

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[1] An account of the discussion is given in "Nature," October 12th, 1893.

ridge, south of Gröden and Enneberg, apparently the outermost at that time, formed the basis for a more or less continuous barrier-like chain of reefs, behind which (*i.e.* to the north) deposits collected of a different nature from the ordinary marine deposit of the Southern Ocean. These deposits include in their uppermost horizons the wonderful Cassian fauna of Enneberg, and probably the faunal conditions of the Cassian-Enneberg sea of Triassic South Tyrol may be justly compared with these of the Caribbean Sea at the present day. At a later Triassic period, in Raibl time, banks of reef-coral were formed on raised beds of ordinary submarine deposit. On the other hand there is every reason to suppose that in the particular periods of Trias in South Tyrol pre-eminent for the growth of Coral Reefs, the sea-floor was undergoing extensive movements of subsidence, subject to oscillation in the near vicinity of volcanic action. In the St. Cassian area, between the two main periods of Coral growth an interval of quiet subsidence intervened, marked in many places by the cessation of Coral growth and the accumulation of a marine deposit enclosing calcareous algæ.[1]

The Wengen and Cassian Coral Reefs of Gröden, Enneberg, and Upper Fassa have remained, with but rare exceptions, limestone. The actual thickness attained by the individual lenticular Coral Reefs or the Coral Banks is in no case very great, seldom more than 150 feet, and usually much less. The steep slope of the outer chain of reefs was mainly composed of volcanic rock with interbedded reef-limestones. As negative evidence it may be mentioned that the so-called "Dolomite Reefs," viz. the thick dolomite massifs of Schlern, Sella, etc., have originated as marine deposits and not Coral Reefs, probably calcareous in the greater part of their thickness, and only in their upper horizons originally dolomitic. The reef-like appearance assumed by these dolomite massifs is in small measure due to the variation in the character of contemporaneous Triassic deposits, but it is chiefly the result of the movements of the rocks in Tertiary time.

I have selected for the sketch-map[2] a long stretch of country between the Eisack Valley, with the Brenner railway on the west, and the Ampezzo Valley on the east. The map displays at a glance the characteristic physical features. Precipitous rocks, generally of a creamy or rose-tinted crystalline dolomite, rise to great heights above green swelling passes and grazing land, or sometimes descend at once into deep gorge-like valleys. The artistic sense scarcely knows which to love most—the romantic region of fir-wood and stream and human habitation, or the wild solitariness of the rocks beyond. Villages are perched midway between mountain and ravine, looking in some of the narrower valleys as if a push would throw them into the gap below. The simple Ladinian folk wander

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[1] Mr. George Murray made the following observation in the Antilles:—"Many coralline sea-weeds living at greater depths than the Corals grow with a stout incrustation of carbonate of lime, and thus form great masses which seem to nearly rival the true Coral Reefs in bulk" ("Nature Notes," February, 1891).

[2] The Map will appear in the February Number with Part II. of this paper.

summer and winter among the rough winding paths and dilapidated huts, content to lead their cows and mow their hay. In the wider valleys the sun ripens hearty crops twice a year, and life flows on pleasantly, after a lazy Italian fashion. The barrenness of the dolomite mountain is such that even chamois rarely frequent their clefts and terraced table-lands; snow caps most of them during nine months out of the twelve, and is perpetual on the highest summits.

With the exception of a few scattered remnants of Jurassic and Cretaceous rock, the geological age of the deposits exposed throughout this country is Triassic. We are concerned with the history of Triassic deposit in South Tyrol, in the midst of which, we are told, there came a long epoch of Coral growth and reef-building. If this be true, the data of the geologist have a keen interest both for the geographer and the zoologist, whose duty it is to compare these fossil Coral Reefs with reefs now growing, and find corroboration or the reverse for the various theories which have been advanced regarding the growth of recent Coral Reefs. The chief data which geology determines, are the exact nature of the sedimentary rocks, the order in which they succeed one another, the fossil remains which they contain, and any particulars regarding the manner of occurrence of the fossils. That seems a simple enough commission, and yet in practice it is often very hard to execute, no part of it more hard in the Alps than that of determining the order in which the rocks succeed one another. For the sediments which were deposited by the great basins of water in Triassic time have since been folded and twisted and raised into entirely new positions in relation to one another. So that a rock which was once below is now alongside or even above its neighbour—or its fossils have been destroyed, or a volcanic invasion has taken place; in fact, endless accidents may have happened since Triassic time, and it requires much time and patience to unravel the mysteries introduced into a once simple succession. In a word, to be a good ancient geographer of the Trias, one must first be a wary stratigraphist.

We shall begin by quoting the succession of Triassic rocks in South Tyrol and the interpretation of it given by Mojsisovics[1]:—

RHÆTIC BEDS.

Dachstein dolomite.
Raibl marls, sandstones, dolomite.

CORAL REEFS OF	Cassian Dolomite	thinning into contemp. deposits of	Cassian marls and limestones.
	Wengen ,,		Wengen shales and volcanic ash.
	Buchenstein ,,		Buchenstein limestones and ashy rocks.

Muschelkalk (Alpine) limestone or dolomite.
Werfen shales and thin bedded sandy limestones.

PERMIAN ROCK.

The actual part which these rocks take in the landscape may be briefly described. The so-called "Coral Reefs" rise as sheer precipices 2000–3000 feet high, or dwindle to nothing. The gaunt form of their cliffs is unbroken by familiar planes of bedding. Raibl marls draw themselves as a narrow band above them, and

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[1] E. Mojsisovics v. Mojsvár, "Die Dolomit-Riffe von Süd Tirol und Venetien," Wien, 1879.

Dachstein dolomite, well stratified and often of very great thickness, builds the highest terraces and precipices. The Cassian, Wengen and Buchenstein sedimentary beds are exposed on the passes between "reefs," on their lower slopes, and over the large meadows which the people of the place call "Alpen." The Muschelkalk and Werfen series form the bed of the streams in the rapidly descending mountain valleys. It may be at once remarked that typical fossils have been found in all members of the succession. In the "reef-dolomite" fossil remains are extremely poor and scanty; plant algæ are got even more often than Corals, Gasteropods, or Bivalves. *Ammonites* occur, but usually in too meagre a state of preservation to be of much service in identifying the age of the rock.

Besides the layers of volcanic ash and lava which are interbedded with the Wengen beds, there is every here and there a massive looking volcanic rock, Augite Porphyry, which surprises the eye by its strong contrast to the dolomitic rocks. Everyone knows that Coral growth in our present seas is particularly luxuriant where volcanic action is occasionally felt, and this seems a strong argument in favour of the view which explains these Triassic dolomites as Coral limestones, largely magnesic, which were built in a volcanic sea of the far-away Trias period. The later conversion of such magnesic limestone reefs into pure dolomite also finds its parallel in recent reefs. So that the "Coral Reef Theory of the Dolomites" presents, as a theory, no problem which is not in harmony with recognized facts, unless we except the enormous thickness attained by the reefs, and the occurrence on their upper surfaces and slopes of an appearance which Mojsisovics observed and called "overcast bedding."

A geological theory, however, stands by virtue, not of its probability argued from Nature's Present, but its absolute fitness to the facts observed in Nature's Past. And, when the same facts may bear two or even more explanations, the theory which is to stand in Science must fight for its position as the fittest survivor! We have to ask ourselves if the Coral Reef theory offers the only probable explanation of the dolomite cliffs. The mere occurrence of a couple of thousand feet of limestone or dolomite is part of the A B C of Geology, when taken as the accumulation of ordinary marine deposit. Dachstein dolomite is such a rock, and it still carries testimony of its origin in the numerous *Megalodon* bivalves and other fossils which it contains. Again, a considerable amount of variation in the thickness of any marine deposit might be expected, especially where volcanic eruption had previously disturbed the sea-floor and produced all degrees of inequalities by heaping up its ashy flows in some parts more than in others. But the special difficulty said to meet us in the case of the Cassian and Wengen dolomite of South Tyrol is, that rocks of 2000 feet in thickness rise quite suddenly from the midst of sedimentary earthy beds, and show certain curious appearances in relation to them. The dolomite rock seems to dovetail at its extremities into the marly and ashy beds, giving rise to strange anomalies in the geological succession, which could only be explained by regarding every case as one of contemporaneous deposition of different classes of rock very close to one another, so-called "Heteropism." Such difficulties can only be solved by stratigraphy, and to that we must turn for proof of the data on which the Coral Reef theory rests.

For the sake of clearness in writing, we prefer to use, instead of the triple term applied to the reef-dolomite by Mojsisovics, the single name given by von Richthofen, of "Schlern dolomite,"[1] from its characteristic occurrence at Schlern Mountain, south of the Gröden Valley.

II.—Normal Marine Formations of Mid-Trias in the Southern Alps—Submarine Volcanic Action in Upper Fassa and the neighbouring districts—The "Dolomite Reefs" of Enneberg and Ampezzo correspond to part of the Normal Marine Deposits of the South.

Whereas during the Wengen and Cassian period, volcanic activity was rife in the northern part of the area covered by the sketch-map, an accumulation of marine deposit apparently went on during a steady subsidence of the sea-floor over the southern areas. Great thicknesses of limestone and dolomite represent this period in the southern part of the South Tyrol, and in the Venetian and Bergamasker Alps. These are known in different localities as Esino limestone, Marmolata limestone, Schlern dolomite. The fauna is liable to great variation, but includes for the most part a typical assemblage of Mollusca, Echinoderms, Corals, and Gyroporellas (sea algæ). This we may regard as the *normal* oceanic formation of the mid-Triassic period in the Southern Alps.

In the Upper Fassa and Gröden, Enneberg and Ampezzo districts, intermittent outpourings of volcanic matter took place from one or more submarine craters, associated perhaps with the proximity of this part of the sea to pre-Triassic land of Palæozoic and crystalline rocks, and with Triassic earth-movement. Be that as it may, the southern rocks of Schlern dolomite, Marmolata and Esino limestones, were clearly collected in deeper waters than the contemporaneous deposits immediately to the north. This is nowhere better seen than at Schlern Mountain, where the deep-sea deposits on the south side of Schlern pass rapidly into the volcanic lavas and shallow-water deposits on the Seisser Alpe to the north. According to von Richthofen's original interpretation of this district, the upper part of the "Schlern dolomite" of Schlern was younger than any of the sedimentary beds on the Seisser Alpe, a stratigraphical fact of general import, which many geologists have since verified at this point.

Following an irregular line eastward and south-eastward, we may trace the same occurrence of stratigraphical facies. It takes place most suddenly where the Wengen lavas are thickest, *i.e.* in Upper Fassa. The dovetailing of the dolomitic and calcareous

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[1] Schlern Dolomite. *Vide* von Richthofen, "Geognostische Beschreibung der Umgegend von Predazzo, St. Cassian und der Seisser Alpe," 1860.

strata with volcanic and marly beds which takes place along this volcanic zone is therefore perfectly comprehensible in the light of every-day facts of deposition. There is no need to call the massifs of Schlern, Rosengarten, Latemar, Marmolata, etc., "Coral Reefs," merely because a thin line of heteropic division may be traced between these two areas of Triassic rock in South Tyrol. Moreover, the local recurrence of volcanic activity during a prolonged period would explain the continuance of different conditions in adjoining districts. While a simple interpretation such as the above would explain one of the main features of Triassic geology in South Tyrol, it may be objected that it would not apply within the volcanic district itself, for it is in Enneberg and Gröden, more than in any other part of South Tyrol, that the curious suddenness of the "Reefs" strikes the eye.

As I have said in a previous paper,[1] every member of the Triassic succession in South Tyrol presents variations in its thickness when followed from place to place. More especially is this true of the beds from Muschelkalk to Dachstein Dolomite. The names Cassian, Wengen, and Buchenstein mark different horizons in a series of volcanic lavas, ashy and tufaceous marls, calcareous marls and limestones, which may, lithologically considered, be united as one series. This series represents, no doubt, the upward continuation of Alpine Muschelkalk much as the Partnach beds do in North Tyrol.[2] Zones may be followed in which certain fossil genera predominate in the number of individuals and species; but the palæontological facts give us not so much a clear succession of types as an index to the facial conditions which influenced the life of the period.

For instance, *Halobia Lommeli* is a fossil bivalve which is common in tufaceous beds both of Buchenstein and Wengen age; but in Buchenstein limestones the general character of the fauna is more like that of the Muschelkalk, whereas limestones of the Wengen age contain the remains of Corals and Echinoids like those in the next following Cassian deposits. Again, *Posidonomya Wengensis* is another bivalve which gradually outnumbers *Halobia Lommeli* in tufaceous beds belonging to upper horizons of Wengen beds, and it is a fossil which again and again reappears in Cassian time always associated with the same lithological character of deposit, and shewing but slight varietal changes in its outward form. It is one of these persistent types which saw the birth and destruction of innumerable shoals of less fortunate species and genera characteristic of the Cassian limestones.

In the district of Upper Fassa there are true Augite Porphyry lavas of Lower Wengen age, which appear more or less interstratified with grits and tuffs. In the Enneberg districts, *i.e.* north of Upper Fassa, the lavas pass into black earthy tuffs and crumbling grits, in which the fauna is very limited and fragments

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[1] "Contributions to the Geology of the Wengen and Cassian Strata in South Tyrol," by M. M. Ogilvie," Quart. Journ. Geol. Soc., vol. xlix. p. 47, February, 1893.

[2] "Ueber die Entwicklung u. Verbreitung der Partnachschichten," etc., by Dr. T. Skuphos, Jahrb. der k.k. Geol. Reichsanstalt, 1893, Bd. 43, p. 178.

of plants are of frequent occurrence. Mojsisovics has proved that these invasions came from a submarine volcano, probably in Upper Fassa, which "lay on the edge of the district of greater subsidence" to the south. "In Triassic time, as we are taught by the history of the Triassic reef masses, a certain protraction took place in the subsidence going on at the edge of the insular core of older rocks to the north as compared with a more rapid subsidence of the outer regions" (Mojsisovics, "Die Dolomit-Riffe von Süd-Tirol und Venetien," p. 525). We may naturally suppose that Augite Porphyry lavas formed irregular ridges on the disturbed sea-floor, more especially near the eruptive centre. From the beginning of this period we trace a marked difference in the deposits and fossil remains of the non-volcanic and volcanic areas respectively south and north of the Upper Fassa ridge, and even considerable variation within the shallow volcanic sea itself. A representation of the sea-floor in this period is given in Diagram I.

Corals found abundant "coigns of vantage" and were aided by Echinodermata to form communities of organic life, often prevented from farther growth by new volcanic invasions, but ever and anon settling down afresh. The remains of these form the "Cipit blocks" and "Cipit limestones," which were first observed by von Richthofen amid Cassian marls on the slopes below Schlern. Mojsisovics recognized similar limestones appearing intermittently over the whole area eastward. I have given special attention to the relations of these limestones with the contemporaneous rocks, and shall at once describe the more interesting results.

They, and not the mountains of Schlern dolomite, deserve the name of "Coral Reefs" in South Tyrol. They never attain any great thickness; generally in highly volcanic periods they formed mere isolated blocks composed of colonies of Corals and Echinoderms, and closely wedged amongst tuffy marls. In less volcanic periods continuous beds spread over a larger area—sometimes suddenly swelling out in lenticular fashion, sometimes perceptibly thinning into deposits full of other classes of animals. Stratigraphically considered, they occur as the equivalents of Cassian and Wengen strata, and in a less degree of Schlern dolomite and Raibl strata, and they follow certain fairly definite laws of distribution. Diagrams I. II. and III. represent successive stages in the history of the heteropic deposition in South Tyrol during this part of the Triassic era; Diagram IV. represents approximately the occurrence of Cipit Limestones in the contemporaneous series of rocks. In the Upper Fassa and Schlern districts the Cipit or reef-limestones occur at various horizons in the midst of volcanic earthy Wengen beds, or associated with sedimentary beds containing *Halobia Lommeli, Posidonomya Wengensis,* etc. They continue upwards in that district to the base of the Schlern dolomite, but are associated, north of the Schlern Mountain, in their higher horizons with characteristic Cassian fossils.

In Gröden Joch and in Enneberg, the Cipit Limestones do not make their appearance until the Wengen beds are giving place to

Cassian. The block-like structure observed in the Schlern and Fassa district becomes less prominent in Enneberg, and we are rather presented with thick unevenly bedded limestones full of *Cidaris* spines and Thecosmilian Corals, more rarely with Brachiopods and small Mollusca.

These are immediately succeeded in Enneberg by the great mass of thinly-bedded typical Cassian beds. The latter, therefore, correspond on Stuores meadows to the upper part of the Cipit Limestones of the Seisser Alpe and Sella Joch, and to some part of the lower horizons of Schlern dolomite at Schlern, and at Sella and Sasso Pitschi. Sometimes the outpouring of volcanic material, which was constantly recurring in Upper Fassa, caused the sudden disappearance of the rich fauna of Enneberg. During the short periods of disturbed deposition which then ensued, Echinodermata, even more than Corals, peopled the seas.

Thin beds of Limestone were thus formed at intervals amid tufaceous sediments of Cassian age, but the main thickness of Cassian beds in Enneberg is composed of soft marls and limestones full of the remains of Brachiopods, Mollusca, and many species of non-reef-building Corals. This fauna lived, I believe, in an inner area of quiet water, secluded from the Southern Ocean by the Cipit reefs and volcanic rocks, some deeper channels being left free.

Whereas the Wengen and Cassian beds retain their tufaceous character, in greater or less degree, throughout the whole district of Enneberg, they show it much less in the corresponding deposits of Ampezzo. Fine, unfossiliferous shales and clays take the place of the tufaceous grits, and although Corals and Sponges occur in hard limestones of Cassian age, they are seldom in sufficient magnitude to form any appreciable reef-like thickening. The same is true of the northern or "Abtey" part of Enneberg, and of the deposits of Seeland Valley and Misurina, north-east of Ampezzo. Hence Cipit-Limestone building flourished most in the volcanic areas of Gröden and Upper Fassa. I observed, however, in the higher horizons of Cassian strata at Ampezzo thick, reef-life extensions of Limestones, mostly one mass of the spines of *Cidaris Hausmanni.* They form bands of rock between softer beds, and are present as well in the undisturbed series below the Schlern dolomite of Lagazuoi as in the disturbed succession near the small Lago Majorera to the east (close to the Falzarego road). The stratigraphical facts afford evidence that the Cassian marls are both in Enneberg and Ampezzo succeeded by a dolomitic rock, and never conformably by fossiliferous Raibl sandstones and marls. As might be expected from the occurrence of an upper palæontological zone of Cassian beds in the Ampezzo districts (Upper Cassian—*vide* M. M. Ogilvie, *loc. cit.* pp. 46, 47), the dolomite rock which succeeds Cassian strata did not everywhere begin to be deposited at the same time.

In the south-west, where a true marine formation had been continued throughout the Wengen and Cassian period, the deposit has only sometimes a stratified appearance. Mojsisovics has ascribed some parts of the Latemar and the mountains still further west to a lagoon formation; but he describes a large, originally continuous, dolomite mass, "with the Schlern for the most northerly, and the Piz, near Sagron, for the most southerly point," as an immense Reef. The Marmolata Mountain and the Mount Alto de Pelsa "are two important continuations of this mass, jutting out in peninsular fashion into the eastern district" (*vide* "Horizontal Extension of the Dolomite Reefs in Lower Wengen Time," Mojsisovics, *loc. cit.* p. 482). In the case of Schlern, where the upper part of this rock is stratified and the lower apparently unstratified, we are told that the lower part is Coral Reef, the upper part is lagoon deposit. But in many portions of this western "Reef," it has been proved that the remains of algæ and mollusca form the important part of the deposit. Whether stratified or unstratified, there is no reason why the Schlern dolomite of this Western "Reef" should not be regarded throughout simply as a lagoon and marine formation. In no single case has it been proved that reef-coral continuously built vertical cliffs of Coral rock during the mid-Triassic period of subsidence represented by Esino limestone, Schlern dolomite, etc.

This typical calcareous or dolomitic rock in the south-west of the district succeeds in the northern and eastern areas, in greater or smaller thickness, the volcanic series and the marls and limestones of Wengen and Cassian age, gradually succeeding the upper horizons of the series towards Enneberg and Ampezzo. The so-called Schlern dolomite "Reefs" of these areas can never be said to be contemporaneous with the marls at their own base unless, as in the case of the Schlern Mountain, denudation has allowed the rock to remain standing over such an extensive area that the dolomite of one portion is contemporaneous with the marls underlying the dolomite further north. To express the same fact somewhat differently, the fossiliferous marls and limestones of Enneberg were not laid down against Coral cliffs, but form a deposit belonging to a definite palæontological horizon, and succeeded by a dolomitic or calcareous rock of marine or lagoon formation. For this dolomitic or calcareous rock between the fossiliferous deposits of ascertained Cassian and Raibl age in the Enneberg and Gröden district, it is best to preserve the name of Schlern dolomite,[1] as no sufficient faunal distinction has yet been carried out between different horizons of the said dolomitic rock in the south-western area of its complete development.

I must refer the reader to my sections and maps already published for further proofs of the conformable succession of Schlern dolomite on the Cassian beds in Enneberg. I shall now recapitulate the main conclusions which may, I think, be drawn from what I have already stated:—

1. The frequent occurrence of Coral remains in the "dolomite" country is a fact, often repeated, but somewhat vaguely applied, bearing with it no evidence whatever of the Coralline origin of the "dolomites" themselves.

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[1] Schlern dolomite: In using the expression "dolomitic or calcareous rock" I wish to take nothing for granted as regards the original or subsequent dolomitization of the rock. This question is outside the immediate interests of the paper.

2. The Coral remains occur sometimes in isolated blocks, sometimes in large clumps of rock perforated by *Thecosmilia* species of Coral, and often full of fragments of Echinoderms. These blocks or clumps occur in the midst of fine volcanic mud, or the calcareous and dolomitic matter of the contemporaneous marine sediment, and form more or less continuous beds with lenticular reef-like expansions. The name they go by is "*Cipit Limestones,*" and they vary from 10 feet to 150 feet in thickness.

3. "Cipit Limestones" are of episodal occurrence throughout the mid-Triassic era, appearing at entirely irregular horizons of all Triassic strata between the Muschelkalk and Dachstein dolomite. At the same time, in the area under discussion, there is one horizon pre-eminent for the interbedding of Cipit Limestones, that is, the Cassian.

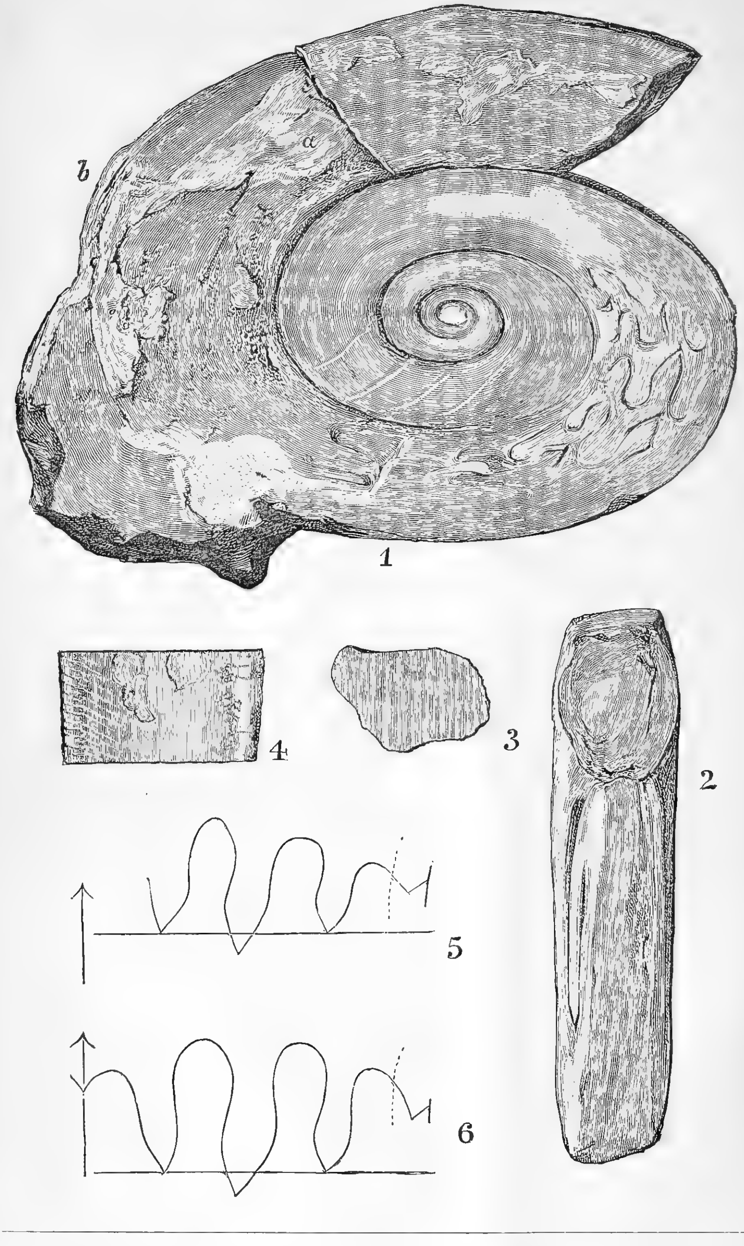
4. In its lithological character and faunal distribution, the Wengen and Cassian period shows marked heteropism. While in deeper seas algæ grew and Mollusca prevailed, there was, not far from the island coasts of the mid-Alpine core of rocks, a zone of submarine volcanic eruption. Lavas and ashes were swept intermittently over the sea-floor. Along the hem of this volcanic girdle communities of Corals and Echinoderms settled and formed a series of small barrier reefs (Cipit Limestones), frequently interrupted in their growth by fresh lavas. On the outer, seaward side, marine deposits continued to increase in thickness over a sinking basin; on its inner side, at first only a few mud-loving species of *Halobia*, *Posidonomya*, etc., could exist, but later the Cassian fauna enjoyed a varied and rapid development, and lived on good terms with the Reef-fauna of the Cipit Limestones.

5. The fossiliferous marls and Cipit Limestones of Cassian age in Enneberg are succeeded by a calcareous and dolomitic rock, which is of the same age as the upper horizons of the calcareous and dolomitic marine deposits of mid-Triassic age in the south and south-west. Taking one or two parallel lines of section north and south through the inner Cassian belt of deposit, we find that Schlern dolomite succeeds, in the west or Gröden area, an extremely irregular submarine relief of volcanic, sedimentary, and reef-rocks of Wengen and Cassian age; in the Enneberg area it succeeds reef-rocks and the famous fossiliferous Cassian marls of Stuores meadow; in the Ampezzo and easterly regions it succeeds reef-rocks and fossiliferous marls, belonging to a somewhat later palæontological zone, Upper Cassian.

6. Contemporaneous faulting and volcanic action were the cause of mid-Triassic heteropism in South Tyrol.

Hence, so far as positive evidence goes, the Coral rocks of South Tyrol in the Wengen and Cassian period are not the majestic mountain massifs of dolomite, but much less obtrusive, lenticular masses of limestone. And one general law may be said to govern the Wengen and Cassian period in Gröden, Enneberg, and Ampezzo, a wandering north-eastwards of the Wengen and Cassian fauna (including the special reef-fauna of the Cipit Limestones) consequent on the cessation of volcanic activity along the immediate southern boundaries of the Cassian-Enneberg sea, and the increasing subsidence of these areas. During the subsiding movement, sea algæ and large Mollusca pressed northward. The shallow-water Cassian-Enneberg fauna, no longer enjoying the same favourable conditions as before, retreated into more and more limited localities and gradually gave place to its lineal descendants, the shallow-water fauna of Raibl times. This transitional period paved the way for the complete recovery of normal conditions in Fassa, Gröden, and Enneberg. As Mojsisovics has said, South Tyrol in Raibl times "participated once more in the general movements of Alpine areas."

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



Prolecanites compressus, J. Sby. sp.

FIGS. 1–5. Carboniferous Limestone, near Cork, Ireland.
FIG. 6. Carboniferous Limestone, Scarlet, Isle of Man.

II.—ON THE IDENTITY OF *ELLIPSOLITES COMPRESSUS*, J. Sowerby, WITH *AMMONITES HENSLOWI*, J. Sowerby.

By ARTHUR H. FOORD, F.G.S., of the Royal Dublin Society, Dublin; and
G. C. CRICK, Assoc.R.S.M., F.G.S.,
Assistant in the Geological Department, British Museum (Nat. Hist.).

(PLATE I.)

(i.) *Introduction.*

ELLIPSOLITES COMPRESSUS, J. Sowerby (Min. Con. vol. i. p. 84, pl. xxxviii. 1813), has been hitherto usually regarded as a Nautiloid,[1] and referred either to *Nautilus* or to *Discites*.

During an examination of the collection of Mr. Joseph Wright, of Belfast, by one of the present writers, a fossil from the same horizon, and almost the same locality as the type-specimens of *Ellipsolites compressus* of J. Sowerby, was observed, so much resembling Sowerby's species (but exhibiting also the character of the suture-line) that a comparison with, and a re-examination of, Sowerby's types was suggested.

Mr. Wright has very kindly lent us this fossil, so that we have been enabled to compare it closely with Sowerby's figured specimens, both of which are in the British Museum (Natural History), and we would take this opportunity of returning to Mr. Wright our sincere thanks for the loan of his specimen, which has served to throw much light upon the character of Sowerby's species.

When describing his species, Sowerby was evidently unacquainted with the suture-line, for, in speaking of the larger of the two specimens which he figured, he says "the crystallization seems to have helped to obliterate the chambers, if there were any," and, in referring to the smaller of the two specimens, he says nothing whatever about the septa. After very careful examination we have not been able to detect any trace of septa in the larger specimen, but in the smaller example the suture-line is somewhat indistinctly visible at about the commencement of the last whorl.

(ii.) *Description and determination of a specimen in the collection of Mr. Joseph Wright, Belfast.*

Mr. Wright's specimen is considerably larger than the larger of the two specimens figured by Sowerby, which, by the way, is a little

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[1] *Nautilus compressus*, J. Fleming, Brit. Anim., 1828, p. 231; *id.* De la Beche, Geological Manual, 1831, p. 448; *id.* Goldfuss, in v. Dechen's Handb. d. Geognosie, 1832, p. 536; *id.* T. Weaver, Trans. Geol. Soc. [2], vol. v. 1837, p. 22; *id.* L. Agassiz, in E. Desor's Translation of Sowerby's Min. Con. 1842, p. 27; *id.* R. Griffith, Notice respecting the Fossils of the Mountain Limestone of Ireland, as compared with those of Great Britain, and also with the Devonian System, 1842, p. 21; *id.* A. D'Orbigny, Prod. de Paléont., vol. i. 1850, p. 110; *id.* C. G. Giebel, Fauna der Worwelt, vol. iii. 1852, p. 178; *Nautilus* (*Discites*) *compressus*, J. Morris, Cat. Brit. Foss., 2nd ed. 1854, p. 308; *Nautilus compressus*, L.-G. de Koninck, Faune du Calcaire Carbonifère de la Belgique (Annales du Mus. Roy. d'Hist. nat. de Belgique, vol. ii.), pt. i. 1878, p. 122; *Discites compressus*, R. Etheridge, Fossils of the British Islands, vol. i. Palæozoic, 1888, p. 310; *id.* A. H. Foord, Cat. Foss. Ceph. Brit. Mus. (Nat. Hist.), vol. ii. 1891, pp. 86 and 91; *id.* A. H. Foord and G. C. Crick, GEOL. MAG. Dec. III. Vol. X. 1893, p. 253.

larger than the figure. It is somewhat elliptical, its diameters being 172 mm. and 142 mm. respectively. It was obtained from the Carboniferous Limestone of Little Island, Queenstown Harbour, opposite Blackrock, the locality which yielded Sowerby's types.

The sides of the whorls, especially in the septate portion of the shell, are flattened, feebly convex, their greatest convexity being at about the middle of the lateral area; the sides of the body-chamber are slightly inflated. In the outer whorl the portion of the lateral area adjoining the periphery becomes somewhat concave. The periphery is flattened, and bounded on either side by a subangular edge; at the commencement of the outer whorl the periphery is rather convex in the centre and somewhat concave between the centre and the subangular border. As the shell increases in size the peripheral area becomes more flattened, and its edges more prominent (see Fig. 4), so that the concavity of the portion of the lateral area adjoining the periphery becomes more pronounced. Rather more than three and a half whorls can be counted, but the central portion of the fossil—*i.e.* up to the point where the diameters of the shell were 11 mm. and 9 mm. respectively—is wanting. The inner area of the whorl is well defined, and slopes towards the umbilicus; this slope has probably been increased by the distortion which the specimen has suffered owing to the cleavage of the rocks in which it was imbedded. The slope is apparent, though less distinctly marked on the body-chamber, and where the shell is absent this inner area is scarcely defined on the cast.

The latter half of the outer whorl is occupied by the body-chamber; it bears only fragments of the shell. One side of the septate portion of the specimen is covered by the test. This exhibits an almost perfectly smooth surface; there are no traces of longitudinal lines on any of the inner whorls. On the last part of the septate portion, that is, on the first half of the outer whorl, there are, however, very faint indications of fine transverse curved lines sweeping forward near the periphery. A constriction near the commencement of the last whorl follows the course of these transverse lines, and doubtless indicates the form of a previous aperture. The form of the constriction cannot be clearly made out on the periphery. The other side of the last half whorl of the septate portion is denuded of the test, so that the septa are shown very distinctly.

Some fragments of the test remaining on the body-chamber are very well preserved. They show that on the lateral area of the body-chamber the test was nearly smooth, marked only with fine, subregular, faintly-incised lines about one millimetre apart (see Fig. 3), which extend in an almost radial direction over the middle portion of the side of the whorl and sweep forward as they approach the periphery, meeting the margin of the latter at an angle of about 50°, and forming on the subangular margin prominent imbricating lines. These fine lines cross the inner area of the portion of the whorl forming the body-chamber in a rather shallow curve, concave forwards.

Owing to a fracture, a portion of the cast of the body-chamber can be detached from the rest of the specimen. Its anti-peripheral side displays a concave impressed zone, bounded on either side by a rounded ridge, which bears a very shallow longitudinal groove. Where denuded of the test this anti-peripheral area shows "epidermids," which on the concave portion have the form of short, rather coarse, interrupted, transverse, impressed, wavy lines, but at the ridges on either side they become much finer and more pit-like. The condition of the fossil is such that these epidermids cannot be definitely made out on the sides of the body-chamber; but on the periphery, near its subangular margin, their punctate character can be distinctly seen.

The character of the septa (see Fig. 5) suggested at once a comparison with such forms as "*Ammonites Henslowi*," J. Sowerby,[1] and "*Goniatites vinctum*," J. de C. Sowerby.[2]

The type of the latter species, from the Upper Devonian of South Petherwin, Cornwall, is in the Woodwardian Museum, Cambridge, but according to Sowerby's figure its suture-line differs from that of Mr. Wright's specimen in having fewer lobes on the lateral area.

One of the specimens of "*Ammonites Henslowi*" figured by Sowerby is also in the Woodwardian Museum, Cambridge, and there are some examples of the species in the British Museum (Natural History). A specimen in the Sowerby collection in the latter Museum, although a cast and partly imbedded in matrix, exhibits the convex periphery with a small portion of shell adhering to the periphero-lateral margin, indicating the former presence of a prominent ridge at this part.

The writers, however, are greatly indebted to Miss C. Birley, of Manchester, for the loan of an interesting series of examples, whereby most of the characters of this species are clearly shown. All these specimens are casts and exhibit no trace whatever of the shell-structure.

A comparison with these specimens showed that the septa of Mr. Wright's example agree perfectly with those of Sowerby's species (see Fig. 6), and the general characters of the shell also agree. In Sowerby's species the sides of the whorls are flattened, but they have their greatest convexity at about the middle of the lateral area as in Mr. Wright's specimen. The subangular edges of the peripheral area are shown only at one part of Sowerby's specimen, but an example of his species in the Sowerby Collection in the British Museum (Nat. Hist.) exhibits this character and they are particularly well shown in two of Miss Birley's specimens. This character appears, however, to be seen usually only in specimens which have a portion of the body-chamber preserved, for, whilst an example of more than 180 mm. in diameter, but consisting only of

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[1] Min. Con., vol. iii. p. 111, pl. 262, April, 1820. Sowerby figures two specimens; that represented in the upper figure is in the Woodwardian Museum, Cambridge; the whereabouts of the other specimen is unknown to the present writers.

[2] Trans. Geol. Soc. [2], vol. v. pl. 54, fig. 18.

the septate portion of the shell, does not display the subangular character of the peripheral edges, the two specimens which exhibit this character best are only 138 mm. and 145 mm. in diameter respectively. The same two examples show also the concavity of the portion of the lateral area of the whorl adjoining the peripheral region as well as the inflation of the sides of the body-chamber observable in Mr. Wright's specimen.

There cannot, therefore, be any doubt, we think, as to the species to which Mr. Wright's specimen must be referred. It clearly belongs to the species which Sowerby described as *Ammonites Henslowi.*

(iii.) *Comparison of Mr. Wright's specimen with Sowerby's types of* ELLIPSOLITES COMPRESSUS.

J. Sowerby figured two specimens to illustrate his species *Ellipsolites compressus*; as we have already stated, both figured specimens are in the Sowerby Collection in the British Museum (Natural History). In the larger of these specimens we have failed to find any trace of the septa, but the general characters of the shell—its evolute form; the wide umbilicus; the shape of the whorls, the form of the periphery, the flattening of the sides, their feeble convexity and the position of their greatest convexity, the nature of the inner margin—agree so closely with those of Mr. Wright's specimen that there cannot, we think, be any doubt of their identity.

In the small specimen figured by Sowerby the suture-line is somewhat indistinctly visible, as we have already remarked, at about the commencement of the outer whorl. When this is compared with the suture-line on the inner whorl of a large specimen of "*Ammonites Henslowi*" at a point where the diameter of the shell is about the same as that at the place where the suture-line is seen on the specimen, the two are found to closely resemble each other. The nature of the surface of Sowerby's specimen, however, does not enable us to follow its suture-line as well as we could wish, but the small specimen agrees so well in its general form and rate of increase with the larger specimen figured by Sowerby, and moreover is from the same locality, that it is most probable they are examples of the same species.

The smaller of the two specimens has some resemblance to M'Coy's figure of *Goniatites discus.*[1] In the "[Sir Richard] Griffith Collection" of the Museum of Science and Art, Dublin, there is an example of this species which agrees so well with M'Coy's figure (except that the figure is reversed) as to size, form, and even the fracture of the end of the last whorl, that it may be M'Coy's type, although there is no information with the specimen to that effect. It is a natural cast, partly buried in matrix. Although a portion of the surface of the fossil has been ground away to show the suture-line, this was still somewhat indistinct, but by slightly polishing the

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[1] F. M'Coy, Synopsis of the Characters of the Carboniferous Limestone Fossils of Ireland, 1844, p. 13, pl. ii. fig. 6.

specimen at the point where the suture-line was seen to be present, after very careful examination we have been able to satisfy ourselves that the first lateral lobe is not divided, as M'Coy's figure indicates, but that it terminates in a single point; and further, that the peripheral (or external) lobe is not V-shaped, as M'Coy represents, but that it is shaped somewhat-like the lateral lobes, being slightly contracted above, expanded below and terminating in a rather acute point. We notice that at one part of the specimen the peripheral lobe appears to be V-shaped, but the posterior portion of the lobe is not sharp, and the whorl has here been ground away to a depth of more than one-half of a millimetre, a considerable amount, since the height of the whorl when complete was only nine millimetres.

In all the specimens of "*Ammonites Henslowi*" that we have been able to examine, the peripheral lobe is V-shaped, but as we have not been able to observe the periphery of a young shell, *i.e.* of a shell of about the same diameter as M'Coy's *Goniatites discus*, we cannot say if at this age the peripheral lobe is V-shaped or if it has the form of the lateral lobes, as in M'Coy's species.

Although the latter is evidently closely allied to Sowerby's species, M'Coy's *G. discus* appears to have been not only a less rapidly increasing, but also a smaller shell, for in the specimen above referred to, which is about 42 mm. in diameter, about one-third of the last whorl is occupied by the body-chamber.

We do not think it possible that Sowerby's *Ellipsolites compressus* can be a badly-preserved specimen of what he later on described as *Nautilus complanatus*,[1] from the Carboniferous Limestone of Scarlet in the Isle of Man, for, in describing the latter shell, Sowerby states that the periphery is rounded, and it must be observed that his type has, according to his figure, a large portion of the body-chamber preserved. Further, in the latter species the greatest thickness of the whorls is at the margin of the umbilicus, whereas in *Ellipsolites compressus* it is at about the middle of the lateral area.

We arrive, therefore, at the conclusion that Mr. Wright's specimen is specifically identical with the two examples figured by Sowerby as *Ellipsolites compressus*, and that all three specimens are examples of the species which Sowerby described later as *Ammonites Henslowi.*

(iv.) *Observations on the Name of the species.*

Having established the identity of Sowerby's *Ellipsolites compressus* with his *Ammonites Henslowi*, it remains for us to offer some remarks upon the name of this shell.

(*a*). First as to the genus:—

In the first place we will consider the name *Ellipsolites compressus.*

The genus *Ellipsolites* was founded by Denys de Montfort[2] in 1808, his type being *E. funatus*, a cretaceous Ammonite from Mount St. Catherine, near Rouen. To de Montfort's genus Sowerby referred three species from the Carboniferous Limestone, Blackrock, near

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[1] Min. Con., vol. iii. 1820, p. 109, pl. 261. The type-specimen is in the Woodwardian Museum, Cambridge.

[2] Conchyliologie systématique, 1808, vol. i. p. 86.

Cork, viz. *E. funatus*,[1] *E. ovatus*,[2] and *E. compressus*,[3] regarding the first, although from the Carboniferous Limestone, as specifically identical with de Montfort's type. The suture-line of *E. compressus*, not to speak of the other two species, excludes it absolutely from de Montfort's genus.

De Haan,[4] in 1825, placed Sowerby's *E. compressus* in the comprehensive genus *Planulites*, Montf.[5] (or, as he preferred to spell it, *Planites*), but even if this name be retained in a restricted sense, de Montfort's type differs so considerably from Sowerby's species that the two cannot be placed in the same genus.

In 1831 Parkinson,[6] observing that "two very different shells have [had] been placed under the genus *Ellipsolithes* (Sowerby), both oval and discoidal shells; but one possessing the involved whirls and the plain septa of *Nautilus*, and the other the whirls, apparent on both sides, and the winding septa of *Ammonites*," divided the genus, and gave the name *Nautellipsites* to the former, referring to it (pl. vi. fig. 3) the *E. ovatus*, J. Sowerby, and the name *Ammonellipsites* to the latter, referring to it the *E. funatus* and *E. compressus* of Sowerby, the figure of his type (pl. vi. fig. 4) of this division probably representing Sowerby's *E. funatus*. Even if Parkinson's name *Ammonellipsites* be retained, it must be used for the group of shells allied to *E funatus* of Sowerby, a shell which differs considerably from Sowerby's *E. compressus*.

Münster[7] prefaces the description of his *Goniatites spurius* with the remark, "near to *Ellipsolites compressus?* Sowerby Tab. 38," and Bronn in his "Index Palaeontologicus" (p. 545) regards Sowerby's *E. compressus* as a synonym of Münster's *Goniatites spurius*; but Münster's description of the suture-line of the latter suffices to show that the two species are not identical.

Sowerby seems to have considered *E. compressus* to be an Ammonoid, for, writing in 1821[8]—eight years after the publication of the description of his species—he says:—"The genus *Ellipsolithes* must certainly be abolished, and its species ranged under *Ammonites*, the oval form being quite accidental." Many authors,[9] however, not having seen the septa, regarded Sowerby's species as a *Nautiloid* and referred it, either to the genus *Nautilus*, or to the genus *Discites*, but the character of the septa, as now recognized, at once excludes it from these divisions.

According to our present knowledge of *E. compressus*, we cannot rightly adopt any of the interpretations, which, so far as they are known to the writers, have hitherto been given of this species.

Let us consider in the next place the name *Ammonites Henslowi*.

[1] Min. Con., vol. i. p. 81, pl. xxxii. 1813.

[2] Ibid. p. 83, pl. xxxvii. 1813.

[3] Ibid. p. 84, pl. xxxviii. 1813.

[4] Monog. Ammon. et Goniat., 1825, p. 93.

[5] Conchyliologie systématique, 1808, vol. i. p. 78.

[6] Introduction to the Study of Fossil Organic Remains, 1822, p. 164.

[7] Planul. und Goniat., 1832, p. 30; Beiträge, Heft i. 1843, p. 23.

[8] Min. Con., vol. iii. p. 167, footnote.

[9] See footnote, antea, p. 11.

This species has been referred also to *Ceratites*,[1] *Aganides*,[2] and *Goniatites*,[3] usually, however, to the latter.

Owing to the badness of the figure which accompanies his description, de Montfort's genus *Aganides*[4] has been variously interpreted[5]; but, whatever de Montfort's figure is intended to represent,[6] Sowerby's *A. Henslowi* is a very different shell, as regards both form and suture-line, and certainly cannot be assigned to the genus *Aganides.*

Although placed in the genus *Ceratites* by de Haan,[7] the author of the genus, the suture-line of *Ceratites*, as that genus is now restricted, differs widely from that of *A. Henslowi.*

Ammonites Henslowi is referable to the genus *Goniatites*, of authors, but this, like *Ammonites*, is now considerably subdivided. The division into which Sowerby's species falls has been named by Mojsisovics *Prolecanites*,[8] and it is to this genus that Sowerby's species is now usually referred.[9]

(*b*) Next as to the species:—

Of the two names given by Sowerby, *Ellipsolites compressus* was described in 1813, and *Ammonites Henslowi* in 1820; therefore, according to the law of priority, the specific name *compressus* must supersede that of *Henslowi.*

Hence the name of the shell under consideration becomes *Prolecanites compressus*; and *Ellipsolites compressus*, J. Sowerby, and *Ammonites Henslowi*, J. Sowerby, are synonyms of it.

EXPLANATION OF THE PLATE I.

Prolecanites compressus, J. Sby., sp.

FIG. 1. Lateral aspect of a specimen in the collection of Mr. Joseph Wright, Belfast. About ½ nat. size.
,, 2. Front aspect of the same. About ½ nat. size.
,, 3. Portion of the test (marked *a* in Fig. 1). Nat. size.
,, 4. A portion of the periphery, as seen at the point marked *b* in Fig. 1, showing the subangular borders and the sculpture of the shell. Nat. size.
,, 5. The suture-line marked *c* in Fig. 1. Nat. size.
,, 6. Suture-line of a specimen (No. C. 3496) from the Carboniferous Limestone, Scarlet, Isle of Man, presented to Brit. Mus. (Nat. Hist.) by Miss C. Birley.

FOOTNOTE.—While this paper was in the press, Mr. Wright has, through one of the writers, kindly presented the specimen (here described) to the British Museum.

[1] *Ceratites Henslowi*, de Haan, Monog. Ammon. et Goniat., 1825, p. 157.

[2] *Aganides Henslowi*, A. D'Orbigny, Prod. de Paléont., vol. i. p. 115; *id.* F. M'Coy, Brit. Pal. Foss., 1855, p. 564.

[3] *Goniatites Henslowi*, J. Phillips, Geol. Yorkshire, pt. 2, 1836, p. 236, pl. xx. fig. 39; *id.* d'Archiac and de Verneuil, Trans. Geol. Soc. [2], vol. vi. 1842, p. 329; *id.* J. Morris, Cat. Brit. Foss., 2nd ed. 1854, p. 303; *id.* C. Barrois, El marmol amigdaloide de los Pirineos (Boletin de la Comision del Mapa geologico de Espana, vol. viii.), 1881, p. 9, pl. C. figs. 3*a*, 3*b*, 3*c*; *id.* R. Etheridge, Fossils of the British Islands, vol. i. Palæozoic, 1888, p. 311; etc.

[4] Conchyliologie systématique, 1808, vol. i. p. 30.

[5] See notes on de Montfort's genus by F. B. Meek, Geol. Surv. Territ., vol. ix. 1876, p. 494.

[6] P. Fischer (Manuel de Conchyliologie, 1880-87, p. 380) states that the species figured by de Montfort is *Goniatites rotatorius*, de Koninck.

[7] Monog. Ammon. et Goniat., 1825, p. 157.

[8] E. v. Mojsisovics, Abhandl. d. k.k. geol. Reichsanst., vol. x. 1882, p. 199.

[9] *Prolecanites Henslowi*, E. v. Mojsisovics, *loc. cit.*; *id.* K. A. von Zittel, Handb. d. Palæont., vol. i. 1884, p. 421; *id.* E. Holzapfel, Palæont. Abhandl., Dames and Kayser, n.s. vol. i. 1889, p. 42, pl. iii. fig. 14, pl. iv. figs. 2, 4, 7; *Goniatites* (*Prolecanites*) *Henslowi*, J. Seunes, Comptes Rendus, vol. cxv. 1892, p. 681.

III.—Note on a New Species of *Æpyornis* (*Æ. titan*).

By C. W. Andrews, B.Sc., F.Z.S.

In a collection of vertebrate remains from the south-west coast of Madagascar, recently received in the British Museum, there occur numerous bones belonging to, at least, three species of *Æpyornis*. Among them are two tibio-tarsi, right and left, of gigantic size, much larger than any hitherto described. Both these bones are, unfortunately, considerably damaged at the upper end, the right one alone showing any portion of the proximal articular surface. They both, without doubt, belong to the same species, though probably not to the same individual. The left, which on the whole, is the better preserved, may be taken as the type of the species which it is proposed to call *Æpyornis titan*.

A very massive femur from the same collection probably belongs to the same species. There are also several more or less imperfect femora, which are slightly smaller and of rather different proportions. All the bones have a very fresh appearance.

The *tibio-tarsus* has the following dimensions in centimetres, those of *Æ. maximus*, Is. Geof. and *Æ. Hildebrandti*, Burck. being quoted for comparison from the memoirs of Milne Edwards, Grandidier, and of Burckhardt.

Measurements of the tibio-tarsi of *Æpyornis*.	*Æ. titan.*	*Æ. maximus.*	*Æ. Hildebrandti.*
Length	80·0[1] cm.	64·0 cm.	48·5 cm.
Width of distal end	17·0 ,,	13·5 ,,	8·2 ,,
Width of shaft at the narrowest point...	7·5 ,,		
Circumference at the narrowest point ...	20·7 ,,	15·5 ,,	11·0 ,,
Shortest antero-posterior diameter	4·5 ,,		

The shaft of the bone is slightly curved with the concavity inwards. The anterior surface of the lower two-thirds is flat and is bounded on either side by ridges, the inner being the stronger, which separate it from the lateral surfaces. The upper portion is traversed by a *linea aspera*, which is continuous with the lower end of the pro-cnemial crest and runs downwards and inwards, reaching the inner border of the bone about 32 cm. from its distal end; here it is continuous with the inner ridge above mentioned. Immediately above the articular surface is a longitudinal ridge with a rugose tubercle at its lower end. Between this and the inner border is the groove for the extensor tendons of the digits, deepest distally and soon dying away as it is traced upwards. The extensor bridge is unossified. The lateral and posterior surfaces form a continuous curve, nearly semicircular in section in the middle of the shaft, but becoming flattened posteriorly as the bone widens towards the distal articulation. The shaft is also flattened externally near its lower extremity. The surface of attachment for the fibula closely resembles that in *Æ. maximus*. The condyles project considerably forwards, the inner being the larger and more prominent. Their

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[1] This measurement is taken from the right-hand specimen and is only approximate.

lateral surfaces have large pits for the insertion of ligaments, that in the ectocondyle being about 2·5 cm. deep. Behind these pits are large rough tuberosities. The intercondylar surface is only slightly depressed, and, though faintly convex from side to side, does not show the strong ridge figured by Burckhardt in *Æ. Hildebrandti.* The upper portion of the bone is too imperfect for description.

The *left femur*, which is provisionally referred to the present species, is nearly complete, only the upper part of the massive trochanter and the anterior part of the condyles being lost. Its dimensions are as follows:—

Measurements of the femora of *Æpyornis*	*Æ. titan.*	*Æ. maximus.*	*Æ. Hildebrandti.*
Approximate length	41·5 cm.	32·0 cm. (? true length)	
Circumference of shaft at the narrowest part	27·3 ,,	27·0 cm.	15·8 cm.
Width of shaft at the same point	9·2 ,,	9·1[1] ,,	5·0 ,,
Width of distal end (approximate)	21·0 ,,	19·0 ,,	10·0 ,,

The neck is short and thick, measuring 23 cm. in circumference; its anterior surface is very rugose. The upper articular surface of the trochanter is flat and continuous with that of the head, from which it slopes steeply upwards and outwards, widening rapidly. The trochanter seems to have risen considerably above the head, but does not form a crest strongly projecting forwards, as in *Dinornis.* On the posterior surface, near its junction with the neck, is a pneumatic foramen, the exact size and shape of which cannot be determined owing to the fracture of its edges. The passage into which this foramen opens is very large, measuring about 3 cm. from side to side and 1·5 cm. from before backwards; this runs down to about the middle of the shaft, where it terminates in the complex bony network with which the bone is almost entirely filled, as can be seen in one of the smaller femora which is broken across. The shaft is narrowest about 12 cm. below the upper surface of the neck; at this point it is oval in section, the short diameter being antero-posterior. The flattening becomes much more pronounced as the bone widens out towards the condyles, so that just above these the anterior face is only slightly convex from side to side. The lower portion of the posterior face is occupied by the popliteal fossa; this is triangular in outline, the lower side being formed by a very strong rounded intercondylar ridge, the inner by a rough border terminating above in a blunt tubercle, while externally the side of the fossa slopes gently up, passing imperceptibly into the posterior surface of the shaft. Several pneumatic foramina open into this fossa, the largest measuring 7 by 5 mm. The condyles, which are very massive, are unfortunately somewhat incomplete. The outer projects about 5 cm. beyond the inner and has a rough concave external surface. The articulation for the fibula is narrower relatively than

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[1] This measurement is taken from a cast in the British Museum. It seems probable that this femur does not belong to *Æ. maximus*, but to the present species.

in *Dinornis.* The intercondylar fossa is scarcely perceptible and the rotular surface is little depressed; owing to fracture it cannot be seen how far the condyles projected forwards beyond its level.

In the same collection is a very incomplete proximal end of a metatarsus, perhaps belonging to this species.

IV.—AUGEN-STRUCTURE IN RELATION TO THE ORIGIN OF THE ERUPTIVE ROCKS AND GNEISS.[1]

By J. G. GOODCHILD, F.G.S., H.M. Geological Survey.

AMONGST the rocks whose original structures have been more or less deformed by metamorphic agencies the geologist very commonly meets with curious eye-like inclusions of mineral matter, which are generally known by the name of augen. Close investigation of a large series of rocks exhibiting these eyes brings to light the fact that under this name are classed two essentially different kinds of structure. In the one, the kernels or eyes are manifestly the unsheared portions of the rock, whose sheared portions constitute the schist that envelops the eyes. In the other kind of augen structure the eyes consist of crystalline minerals, whose development as such is shewn to be posterior to the shearing to which the matrix has been reduced, by the fact that the eyes of crystalline matter have not participated in the shearing, but are bright and generally unfractured throughout. It is here suggested that the term "flaser structure" should be confined to the results of uncompleted shearing, where the eyes were formed contemporaneously with the movements; while to the structure seen in the rock containing the crystalline augen developed after the shearing movements had ceased, it is suggested that the term "augen structure" should be restricted.

Augen structure occurs under two sets of conditions. In the one, the constituents out of which the augen have been formed were already in existence within segregating distance, when the rock was first subjected to metamorphic action, and their development is merely a case of regeneration under plutonic conditions, whose general nature will be discussed presently. In the other set of augen, the rock in which the structure occurs did not originally contain the whole of the constituents that were essential for the formation of the eyes. Part of these constituents must, therefore, have been introduced from an outside source, some time late in the history of the rock, but possibly only a short time prior to the date when the causes concerned in the development of the augen came into action. In the simpler case, where the constituents existed within the rock from the first (which may be typified by augen amphibolite), a crystalline development has been set up in the rock at various disconnected points, while the surrounding material, although very generally granulitised, still remains in a schistose state.

Assuming that heat, co-operating in any one of various ways with chemical action, is an essential factor in the generation of the

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[1] This is substantially part of a Lecture on the "Causes of Volcanic Action," delivered under the auspices of the Royal Scottish Geographical Society at Edinburgh, December, 1892.

crystalline matters under notice, our chief difficulty in attempting to explain these facts lies in accounting for the generation of the conditions necessary for fusion, at isolated centres within a rock, while the matrix, consisting of the very same mineral matter, should remain unfused. The molecules, in some way or another, have been locally placed under such conditions as to permit of their taking up different positions from what they had when first acted upon; and yet the conditions referred to have been in action only at certain points, or along certain zones, contiguous to others that have not been so affected. It seems obvious from this consideration that the result cannot be due to the simple action of heat from an external source, such as would arise either from contact with molten masses, or from any heat proceeding from the earth's interior.

This and other reasons of the same kind have led the author to advocate the view, previously advanced by others, that the chief cause of the high temperature prevailing within the earth's crust lies in the conversion of the motion arising from earth-creep into heat. It is assumed that the heat generated in this way augments with depth below the surface, until a temperature is ultimately reached which is higher than that necessary to fuse the most refractory of the rock constituents. Amongst many other causes that contribute to bring about such differential movements of the earth's crust, and therefore to generate subterranean heat, the author is disposed to rank lunar attraction as one of the chief. Where earth-creep takes place under comparatively small superincumbent pressure in the presence of water, the rocks are simply deformed, crushed, or ground, or otherwise affected, by causes which are chiefly of a mechanical nature. At greater depths differential movements give rise to what Teall has aptly termed plastic deformation—the rock material being actually made to flow in the direction of least resistance, so that what may be termed dynamo-fluxion structure is impressed upon the rock.

Good examples of this plasticity of solids when compelled to change their form under great pressure are afforded in the mechanical arts in the process of moulding from the solid metal the nickel bullet cases in use in the British army. A "burr" of sheet nickel is forced, cold, through a succession of annular dies, the first one giving rise to a shallow cup with thick sides, while the passage through each successive die increases the depth of the cup and lessens the thickness of its sides, until in the end a tube of solid metal of the required thinness and length is fashioned. The rate of movement and of pressure have to be carefully adjusted to each other so as to obtain the requisite degree of plasticity without permitting the motion to be converted into a degree of heat sufficient to produce actual fusion from the pressure employed.

In the case of subterranean movements affecting rocks at great depths, the temperature, generated by the conversion of the motion into heat ,must generally be more than sufficient to bring about the fusion of even the most refractory of the rock-forming minerals. When subjected to the great undulatory movements which have certainly affected the earth's crust, even at great depths from the surface, the deeper-seated rocks must constantly tend to pass into the molten condition, but are prevented from melting owing to their fusing point being raised in consequence of the superincumbent pressure. But if this superincumbent pressure is relieved while the rocks are in the potentially molten condition referred to, they pass at once into the molten state. The same result follows, of course, if the temperature rises while the pressure remains constant. A relief of pressure is thus equivalent in this case to a rise of temperature, and is, for several reasons, the more likely cause of fusion.

Once these rocks are reduced to the molten condition they tend to eat their way upward in any direction of least resistance—the place of the material flowing upwards being at first taken chiefly by the colder masses of rock, which sink within the magma as fast as they are quarried from the sides of the vent. On arriving within a few miles of the surface the heated rock occludes H_2O and is thereby rendered more fluid, and at the same time receives an additional impulse through the elastic force exerted by the included gases. These finally impel the molten rock to the surface, and when the communication between the plutonic zones of fusion and the surface of the earth is finally established, a volcano is the result.

The products of dynamo-metamorphism may not reach the surface, but may be arrested at any horizon between their starting-point and the surface. Volcanic products therefore graduate downward through the trappean into the plutonic rocks, which, in their turn, terminate, at great depths, against the zones of dynamo-fusion.

When once volcanic action has commenced, the place of the ejected material is partly taken by the downward subsidence of the volcanic centres, partly filled in by a lateral flow of rock-material towards the deeper parts of the foci. As this movement itself takes place under enormous pressure, it not only tends to produce schistosity in the rocks within the zones affected, but it must at the same time give rise to a further evolution of heat.

Such results as those just noticed follow when the relief of pressure upon a potentially molten mass acts *per saltum*. This mode of relief must often come into action, more especially in connection with the subterannean explosions, which are due to the sudden access of water to greatly heated masses, or to the sudden relief afforded when the tension of the vapour thus imprisoned overcomes the resistance. But in quite as many cases, more especially within the deeper zones of the earth's crust, the relief of pressure is directly connected with the translation of the great terrestrial undulations from one part to another. Such undulations, as a rule, may be supposed to travel at very slow rates, so that it may require an interval of many thousands of years for an upward phase of an undulation to pass into a phase of movement in the opposite direction. Assuming that differential compression of the rocks acted upon is one of the results of all such undulatory movements, it would follow that, by slow degrees, the locus of greatest pressure travels with the undulation, and gives place, also by very slow degrees, to one in which the pressure would be at a minimum for that depth from the surface. Rocks affected in that manner must, almost of necessity, undergo more or less shearing, and as it is well known that heat travels through sheared rocks more readily along their planes of schistosity than in directions transverse to them, higher temperature prevails there from that cause alone. But schistose rocks, subjected to lateral pressure, must give way more readily along their own planes of maximum structural weakness than along any others. Consequently, even a slight separation of the rock along these planes gives rise to a relief of pressure, which, by degrees, tends to bring about a gradual fusion at the points where the relief of pressure has been greatest. The fusing points attained in such a case would bear a definite relation to the ratio between the initial and final pressure while the temperature remained constant.

If, now, the earth movements cease, or the temperature falls, the fused portions of the rock gradually crystallise out, and eventually appear as augen set in a sheared matrix composed of the very same minerals which have not had any opportunity of returning to the crystalline condition. This local fusion, through gradual relief of pressure acting upon rocks that are in a potentially molten condition, forms the starting point of some phenomena of considerable interest in the history of rock structures. The two examples so far considered have been those of rocks consisting mainly of amphibolite. In the one case, these have been sheared into phacoids by mechanical action without any subsequent chemical rearrangement of the minerals affected. In the other case, molecular rearrangement has been superinduced upon the results of mechanical deformation, and amphibolite augen have been formed. But in many cases the rocks acted upon have been of much less simple composition, and have included the constituents of more than one or two minerals. In rocks of such nature the fusing point of any one mineral of the compound may differ considerably from that of the others. Assuming that three such minerals are present, which for the present purpose may be denoted respectively by A, B, and C, the fusing point of one of them—A, under given conditions, may lie below that of B; while B in its turn fuses, under the same conditions, at a lower temperature than C. If now the entire compound be subjected to a temperature which is sufficent under a low pressure to fuse C, but which temperature is, at the same time, counteracted by heavy pressure, so that not only C, but B and A, remain unfused, the minerals will all remain practically unaffected. But if the temperature rises sufficiently to fuse A under the same pressure, or if, what amounts to the same thing, the pressure is slowly and gently eased off, then A may pass into the molten state, leaving B and C as they were. Similarly with a further relief of pressure, the temperature remaining as before, B also may pass into a condition which permits of its re-arrangement within the rock, C remaining still unaltered. A gradual fall of temperature now permits C to impress its form upon B as crystallization follows; and in its turn, A, being the last to consolidate, is moulded ophitically around both of its associates.

This is a necessary consequence of crystallization following a gradual increase of temperature which falls short of the degree requisite for the fusion of the most refractory minerals in a rock compound. It may come into play as much in a rock heated by contact metamorphism as in one whose temperature is raised by dynamic causes. I have in mind some cases I have lately seen in which thick piles of pyroxene-labradorite rocks, which were originally lavas, dykes, and sills, have been invaded by extensive protrusions of rocks of acid composition at some period subsequent to the outpouring of the lavas. The result, it appears to me, is that the parts of the lavas which were the last to consolidate from the original molten condition, that is to say, the glassy magma and the pyroxenic constituents, were afterwards fused again in the reverse order of their original cooling, as the temperature of the invading mass began to affect that of the older volcanic rocks around it. But as the melting point of both the felspars and the remaining rock constituents was never reached during the invasion, these minerals remained as they were. Eventually the temperature declined, the pyroxene and the minerals composing the original glassy magma crystallised out, and, around the contact zones, the lavas, dykes, and sills reconsolidated as holocrystalline rocks with ophitic structure, and with a plutonic instead of volcanic facies.

Analogous changes to these must, I conceive, frequently have taken place in connection with rocks undergoing plutonic metamorphism; only in these cases the partial rearrangement of the constituents was due to the heat generated directly by dynamic causes, and as a consequence of the gradual and partial relief of pressure while the rocks in question were in a potentially molten condition.

The nature of the minerals resulting from any given change of this kind is absolutely dependent upon the nature of the constituents present within segregating distance of the zones affected. If, for example, alkalies are deficient during any given stage of metamorphism, neither the felspars, nor any other mineral into whose composition the alkalies enter, can result. This has always been the great stumbling-block in the way of those who have attempted to account for the origin of gneiss, for example, from metamorphosed sediments. It is certain, from the very nature of the case, that the alkalies must have been removed from the constituents of the sedimentary rocks long prior to the date of their rearrangement in a stratified form. It has very properly been objected to the extreme views held by metamorphists that no kind of fusion or rearrangement of any kind is competent to metamorphose an ordinary greywacke into a granite, for the simple reason that the most important constituent of one of the essential minerals of the granite, to wit, the potash of the felspars, did not originally occur in the material acted upon. Yet the study of highly metamorphosed rocks whose sedimentary origin is beyond a doubt, shows that, by some means or other, secondary felspar has been formed within such rocks, and in those in which the effects of dynamo-metamorphism has been carried to an extreme, felspar in a crystalline form has begun to develop in conspicuous quantities. In other words, a rock that was originally deficient in potash is known to contain a considerable percentage of that alkali after the rock has been subjected to dynamo-metamorphism. Now, as the presence of crytalline felspar is an essential feature in gneiss as well as in granite and other rocks, it becomes a matter of considerable importance to determine the source of the potash and other alkalies in question. Unfortunately the evidence available as yet is but scanty, and will hardly suffice for more than a working hypothesis such as that here propounded :—

When an eruptive rock, such as granite, is exposed to the action of surface agencies, its constituents, as Mr. Teall remarks, eventually became separated into an insoluble and a soluble set. The first goes to make up sandstones and shales, etc., while, in a soluble form, the alkalies are carried away by running water. Part of the alkaline matter goes into the soil, whence some of it is re-extracted by plants. Whether the whole of it does so is certainly open to question. It is far from unlikely that small percentages are carried downward through the soil by percolating water, and are eventually returned to the inner zones of the earth's crust, whence they originally started. The remainder of the alkalies, not absorbed by the earth, is carried out to sea, into which rivers are, and have always been, pouring considerable quantities of both potash and soda, etc., which have been set free from the surface of the land by weathering. What becomes of all this alkaline matter? The sun's heat distils only fresh water from the surface of the ocean, leaving its dissolved salts behind. Unless there are some agencies at work using up the alkalies as fast as they arrive, they must go on accumulating, and the balance of nature eventually be disturbed in this matter. Algæ take up some of the potash; but algæ die in the water, and so restore to the sea what they have originally taken from it. Glauconite and other minerals containing potassium compounds may use up another part. But even these remain where they were formed. Is it not more likely that both potash and soda in small quantites are slowly returning to the inner zones of the earth's crust by downward percolation from the surface of the land and the bottom of the sea? The quantity may not be great at any given period; but great geological results more often ensue from comparatively feeble causes acting through long periods of time than from those of a more energetic character.

Downward percolation from the surface of the land and the bottom of the sea may not be the only source of the alkalies required for the regeneration of felspars. At the high temperatures prevailing where rocks are undergoing plutonic metamorphism, what can be more likely than that emanations of both potassium and sodium in some mobile form should arise from the metallic zones of the earth's crust, and thence permeate the heated rocks within range of their influence? For several reasons I am disposed to regard this as the chief source of the restored alkalies, and to consider such intromissions an essential factor in the conversion of metamorphosed rocks of sedimentary origin into their succeeding plutonic, trappean, and volcanic forms.

Once these constituents are restored to the rocks undergoing plutonic metamorphism, the regeneration of the felspar ensues almost as a matter of course; and it is difficult to see what there is to limit its development except the quantity of silicate of alumina already existing within the rock, and the percentage of matter subsequently introduced from without.

It appears that the earlier stages of development of the felspar take the form of isolated granules occurring interstitially amongst the other constituents, and are contemporaneous with the development of granulitic structure. Subsequently, a further development takes place along the planes of structural weakness as the pressure is gradually relieved, and the felspar takes the form of augen.

Development of felspar does not end with the formation of isolated augen; for although the typical and the commonest occurrence is that of eyes consisting of single individuals, it is by no means uncommon to find small nests collected at particular centres, which, in this case, as in the other, evidently mark the points where there has been a local relief of pressure during one of the thrusts. From small knots or nests of this kind every gradation can be traced into those remarkable aggregations of rock-forming silicates to which the term pegmatite is generally applied. True pegmatites, as here understood, are generated within the rock, their constituents graduate interstitially into the parent mass, and in every case they date from a period in the history of the rock long subsequent to that of its consolidation. In their composition and their general aspect pegmatites may agree with certain "giant granites," and both pegmatite and "giant granite" agree in the fact that they are usually coarser parts of the parent mass, that they are related to this in mineral constitution, and that they graduate into it, so that the line of demarcation between the later rock and the earlier is indefinite in both cases. But "giant granites" are contemporaneous with the last stages of consolidation of the rock in which they occur, and are confined exclusively to plutonic rocks; whereas pegmatites are of much later date than their host, and they occur exclusively in rocks that have undergone more or less deformation by plutonic causes at a period anterior to their development. From intrusive veins they differ in the important fact that in many cases it can be shewn that they both originate and terminate as augen do, within the enclosing rock, instead of being offshoots of larger plutonic masses adjoining, which is necessarily the case with an intrusive vein.

Pegmatites, like their component augen, appear to be generally formed along pre-existing planes of structural weakness, as it is along such planes that relief of pressure most commonly ensues as a consequence of lateral thrusts during the upward phases of terrestrial undulations. Hence pegmatites shew a marked tendency to run in rudely parallel zones, which conform to the planes of schistosity, or to any other pre-existing planes of structural weakness existing at the time.

Pegmatite bands develop in increasing proportion as we approach the zones of maximum metamorphism, so that, where their development has proceeded to any great length, they impart to that particular zone of rock the appearance of bands of crystalline felspar, etc., graduating at their sides into other bands, which consist of more or less distinctly granulitized schist. A closely-welded rock compound of that nature is, in all essential respects, a truly foliated rock, and it is difficult to state in what respect it differs from many rocks that are comprehended under the term gneiss.

In other words, granulitic structure develops into augen; augen extend until they pass into pegmatite; pegmatites aggregate until they impart to the compound, of which they form a part, the character of a true gneiss.

Augen structure in rocks is, according to this view, one of the earlier modifications whose later developments lead, in the one direction, into the rocks of eruptive origin, and, in the other direction, into truly foliated rocks, such as gneiss. The difference in the final result in either case is due to the mode in which the relief of pressure acted upon the rocks while they were in potentially molten condition, arising from dynamic causes. The pressure was relieved abruptly, and entirely, in the case of the eruptive rocks, and by very slow degrees and, only partially, in the case of the foliated rocks.

This view of the origin of certain gneisses by dynamo-fusion does not preclude the adoption of the theory of the formation of other gneisses by differential movements acting upon an igneous mass in its later stages of original consolidation. This is so evidently the mode of origin of many undeformed gneisses that I have for some time past employed for different types of original gneiss such names as granite gneiss, granitite gneiss, syenite gneiss, diorite gneiss, gabbro gneiss, etc., to express this fact. Nor does it preclude the possibility of some forms of gneiss having originated in any other manner not here referred to. Nevertheless, I venture to submit that this view of the common origin of certain eruptive rocks and gneisses by means of variations in the relief of pressure upon superheated masses may fairly claim to rank as a useful working hypothesis, seeing that it enables us to account for the intimate association, on the one hand, of gneiss with true schists, and on the other with the eruptive rocks, both plutonic and volcanic; and also that it presents a satisfactory explanation of the intimate association of gneisses with the deeper-seated cores of mountain ranges, of whatever age, or wheresoever situated.

V.—On the Three Glaciations in Switzerland.

By C. S. Du Riche Preller, M.A., Ph.D., A.M.I.C.E., M.I.E.E., F.C.S., F.G.S.

UNTIL very recently it was thoroughly recognised that in post-Tertiary, viz., Pleistocene or Diluvial times, there occurred in Switzerland, as elsewhere, two glaciations which covered the Alps and the greater part of the Swiss lowlands, and between which intervened a genial or interglacial period. The repeated advance of Swiss glaciers was first established by Escher von der Linth and Heer, more especially upon the evidence of the lignite slate deposits near Durnten and Wetzikon, which fringe the edge of what was at one time the Limmat and is now the Glatt valley, to the N.E. of Zurich, and were formed during the interglacial period referred to. But since Prof. Penck and others have been led, on the strength of fluvio-glacial evidence, to recognise in the Bavarian and Austrian Alps not only two, but three, alternately recurring glaciations, evidence to the same effect has, within the last two years, been brought forward also in Switzerland, more especially by Dr. Du Pasquier; and as the district of Zurich, owing to the building operations and public works constantly in progress, abounds, perhaps more than any other part of Switzerland, in quarries and excavations of all kinds, I recently took occasion to examine in this locality various glacial deposits, which may be taken as typical examples of the successive glaciations.

Introductory.—Before dealing with those glacial deposits, it will be convenient to briefly refer to the molasse and nagelfluh formation which immediately preceded the glacial epochs. The Miocene molasse formation, composed of mud, clay, and sand, which was derived by denudation from the younger rocks of the Central Alps and hardened into marl, limestone and sandstone, spread more or less over the whole of the Swiss lowlands, and formed a flat freshwater basin, with a sub-tropical flora and fauna and a mean temperature which, according to Heer's calculation, was 18·5 degrees Centigrade (68 F.) or more than double that of the present mean temperature of 9° Centigrade or 48° F. This molasse basin was subsequently filled up and more or less completely covered by that characteristic fluvial conglomerate known as nagelfluh, whose pebbles were derived chiefly from the detritus of the Central Alps. The nagelfluh in the Canton of Appenzell, in the north-east corner of Switzerland, contains pebbles derived from rocks which do not now exist on the northern slopes of the Alps, but are related to rocks such as occur in Southern Tyrol at Botzen, at Lugano and elsewhere on the southern slopes. This fact led Prof. Heim to argue that those pebbles are derived from what are now the Southern Alps, and that the crest line of the Alps was at one time much more to the south than it is now. That in some parts the divide of the two main watersheds may have been somewhat more to the south is not improbable,[1] and that the upheaval of the Alps brought about important deflections of river courses is certain; but there is no reason why such rocks as those of Botzen and Lugano should not have existed also more to the north, whence they were washed away by the Alpine rivers and their débris were deposited as pebbles of the Miocene

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[1] In a recent paper "On the Engadine Lakes" I showed—and this is also Prof. Bonney's and Prof. Heim's view—that the crest line of the old Inn watershed was about six miles more to the south than it is now; but on Prof. Heim's theory the crest line of the Julier Alps and Hinter-Rhine watershed, if placed in a line with Lugano and Botzen, would have been 35 miles further south than it is now, a conjecture for which there is no evidence.

nagelfluh. Upon the sub-tropical molasse age, essentially one of slow accumulation and spreading of clay, sand, and mud, followed in early Pliocene times the formation of the Alpine and sub-Alpine valleys, partly as the effect of thrusting, folding and upheaving of the Alps, partly by the action of Alpine rivers, whose erosive power had become greatly enhanced by the greater fall of the upheaved, and, moreover, more or less denuded Alpine slopes. It may, therefore, be assumed that by the end of this Pliocene period of erosion, as distinguished from the Miocene period of accumulation, the Alps and the principal Alpine, as well as sub-Alpine, valleys presented, broadly speaking, the general outlines which they exhibit now.

First Glaciation.—The valley-making of Pliocene times was accompanied by a gradual drop of temperature, due probably to an increase of precipitation, viz. of snow and rainfall in the Alps raised considerably above their former level; and so great was this climatic change that the latter part of the Pliocene age was marked by a general advance of the Alpine glaciers and a first glacial invasion of the Swiss lowlands. This first glaciation of Pliocene, viz. Tertiary age, is evidenced by the so-called hollowed-out or "löcherig" nagelfluh, which is quite different and distinct, not only from the molasse or Miocene conglomerate bearing the same name, but also from the gravel deposits of subsequent glaciations. The qualification of "hollowed-out" (löcherig) was first given to this nagelfluh by Escher von der Linth, owing to the holes left in the clayey and calcareous cement by pebbles which had been decomposed and washed out by chemical action. Mousson, Escher von der Linth, and Gutzwiller recognized it as a glacial deposit much more recent than the molasse. Wettstein, writing in 1885,[1] did the same, but included it in the later (then first) glacial period; Prof. Heim, as recently as 1891,[2] speaks of it tentatively as perhaps belonging to an older glaciation. But as early as 1885 and 1886, Prof. Penck[3] and Prof. Brückner[4] had recognized three distinct glaciations in the Bavarian and Austrian Alps, and had pointed out the close analogy between the "Deckenschotter" or sheet-gravel of those Alps, and the Swiss fluvio-glacial deposits;[5] and it was not till quite recently, viz. 1891–92, that Swiss geologists, and first among them Dr. Du Pasquier, took the plunge and adopted the same view. Of the various deposits of this Pliocene nagelfluh which I have examined, there are more especially two very instructive ones, one on the Utliberg near Zurich, and the other near Baden, about fourteen miles below Zurich. As is seen from the diagram, the summit of the Utliberg is formed by Pliocene hollow nagelfluh, which rests on moraine or boulder-clay, and this in its turn rests unconformably on Miocene molasse and nagelfluh. An erratic block of Miocene nagelfluh, which was found in 1883 imbedded in the moraine and below the hollow nagelfluh,

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[1] A. Wettstein, "Geologie von Zurich und Umgebung, 1885." This gifted young geologist lost his life on the Jungfrau.

[2] Naturf. Gesells. Neujahrsblatt, 1891.

[3] Vergletcherung der Deutschen Alpen, 1885; Der Alte Rheingletscher, 1886.

[4] Vergletcherung der Salzach Gebietes, 1886.

[5] Fluvio Glaciale Ablagerungen der Nordschweiz. Geol. Karte Schweiz, 1891.

is still preserved on the Utliberg. This moraine, which is much older than the moraine on which the town of Zurich is chiefly built, passes gradually into moraine sand or surface moraine; and this again passes into hollow nagelfluh, which forms a cap with perpendicular sides from 60 to 100 feet in depth. The superposition referred to is exceedingly characteristic, and leaves no doubt whatever as to the fluvio-glacial origin of the hollow nagelfluh, viz. as having been deposited, not by the glaciers themselves, but subsequently by the streams emerging from them, and following, in the main, the lines of the moraine deposit. The occurrence of this Pliocene nagelfluh at such an altitude of 872 metres (2880 feet) above sea-level, or 460 metres (1520 feet) above the present level of the Limmat valley at Zurich, led Prof. Heim and also Prof. Muhlberg, an authority on the glacial deposits of the Aare Valley, to conjecture that that nagelfluh had been deposited by a stream flowing at that altitude between the glaciers of the Zurich and Zug valleys;[1] but the occurrences of the same Pliocene nagelfluh not only on the other side of the Zurich lake, but throughout the north of Switzerland, in a line between Zurich and the Rhine, clearly show, as Dr. Du Pasquier also points out, that it is not a local fluvio-glacial deposit, but forms part of the Swiss Deckenschotter as a whole.

The deposit near Baden is to be found in a ravine locally called the "Teufelskeller," situated at about 470 metres above sea-level, viz. about 1300 feet lower than the summit of the Utliberg. It constitutes perpendicular banks thirty to a hundred feet in height, and shows all the characteristics of the Utli deposit, which by the much larger rounded off pebbles and the extremely hard cement consisting of thin calcareous films or skins, distinguish it from the younger fluvio-glacial gravel deposits of the Limmat valley. In this occurrence its composition is more or less uniform, and the banks descend too much below the surface of the ground to show either the moraine or the molasse on which it rests; but on the other side of the same hill there is a quarry about 40 feet in vertical depth, which is not mentioned in Dr. Du Pasquier's admirable work, and in which I found distinct evidence of the hollow nagelfluh becoming towards the base of the quarry gradually a finer and looser conglomerate, and passing into sand and surface moraine as shown in the diagram. The principal constituents of the hollow nagelfluh are here, as on Utliberg and elsewhere, quartzite,

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[1] Prof. Heim, Neujahrsblatt, 1891. Prof. Heim argues that the glaciers preserved the Limmat and other lake valleys from being choked up by surface moraine, since they carried it on their backs and thus served as a bridge. But these valleys must have been, and were, filled up to a considerable extent by ground moraine, part of which was subsequently again removed by fluvial erosion. Judging from the depth at which the ground moraine must have been deposited at the bottom of some of these preglacial or Miocene valleys, and the altitude at which sheet-gravel is found (3300 feet above sea-level at the Bachtel east of Zurich, and 3500 feet near Bregenz on Lake Constance), the glaciers must in many places have reached a thickness of 2000 feet and more. Above Amsteg, in the Reuss valley, the glacier scratches reach up to 6600 feet, and in the Rhone valley (Canton Vaud) even up to 11,000 feet altitude above sea-level.

hornstone, nummulitic limestone, dark Alpine limestone, derived from the detritus of Miocene nagelfluh, red limestone or sernifite, green or so-called Tavayanaz sandstone, and other rocks of the Glarus Alps. Pebbles of Julier and Puntaiglas (Rhine watershed) gabbro, granite, and diorite which abound in the later glacial deposits, are absent in this nagelfluh: hence the inference that its constituents are derived exclusively from the Glarus Alps.[1] Some other very large deposits of hollow nagelfluh occur in the Aare Valley and below Turgi, near Kaiserstuhl on the Rhine, and on the Irchel, bordering on the Rhine and situated about half-way in a line between Zurich and Schaffhausen. The deposits named, together with other intermediate ones, vary in altitude above sea-level from 300 to 872 metres or, roughly, from 1000 to 3000 feet, thus forming a belt of fluvio-glacial deposit, which may, therefore, be also taken as indicating the contour line and limit of the terminal moraine of the first Upper Pliocene glaciation.

Second Glaciation.—Upon a long interglacial Upper Pleistocene period of erosion, followed a second and far more extensive glaciation, which covered the whole North of Switzerland to Basle and the Jura, while to the south-west the Rhone glacier advanced as far as Lyons. Of the glacial deposits of this period I examined, among others, the very typical deposit laid open in a quarry on the so-called Allmend of Zurichberg, viz. on the hill above the town, on the right of the lake and opposite Utliberg, at an altitude of about 570 metres or 1890 feet above sea-level. In this deposit the boulder-clay, showing the usual characteristics of larger and smaller more or less angular blocks with polished and striated surfaces, passes gradually into gravel-bearing moraine sand or surface moraine, which, in its turn, is covered by a thin layer of alluvial soil. This gradation, shown in the diagram, is observable in every one of the numerous smaller quarries, excavations and foundations for building purposes on the Zurich hills flanking the lake on the right bank, seeing that these hills are entirely covered with the deposits of the second glaciation resting on molasse. The gravel-beds of the Limmat valley, which are so extensively quarried below Zurich, and reach as far as Turgi, Waldhut, and Basle, are the fluvio-glacial deposits of this second glaciation, and the characteristic feature of all the three gradations, viz. of boulder-clay, moraine sand, and the glacier-stream deposits, is that their material is largely derived from rocks of the Grisson Alps, such as granite and Marmels gabbro[2] of the Julier Alps (Hinter-Rhine) and of Puntaiglas granite and diorite (Vorder-Rhine), showing that in Middle Pliocene times there existed a connection between the Rhine and Linth valleys and that the glaciers of the former considerably reinforced those of the latter.

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[1] Puntaiglas granite and diorite are derived from the classic locality or valley of the same name, descending from the southern slopes of the Tödi group to the Vorder-Rhine valley near Truns. Sernifite is a red limestone derived from the Sernf valley in the Glarner Alps from Glarus to Elm.

[2] Marmels gabbro is derived from the classic locality of that name, situated in the Oberhalbstein or Sur valley (Julier Pass) of the Grisson Alps.

Third Glaciation.—The enormous second glaciation, during which the North of Switzerland must have presented an appearance similar to that of Greenland at the present time, was followed, after another interglacial (Middle Pleistocene) period, by the third glaciation, the last of diluvial times. Among the deposits of this last glaciation are those on the low range of hills on the left bank of the lake above Zurich, and here I examined more especially the extensive quarries on the summit of the ridge and near the Froschen-lake, close to the high road which connects Thalweil (on the lake) with Gattikon (in the Sihl Valley). In these quarries (540 metres or 1780 feet above sea-level) the moraine sand and boulder-clay reaches 30 to 60 feet in depth. The deposits consist largely of calcareous and also siliceous sand, bearing a great many large angular blocks, together with smaller ones, partially rounded-off, polished and striated. The deposits in the mounds overlying the gravel beds of second glaciation near Killwangen, between Zurich and Baden, which I also examined, present similar features, but the characteristic feature which distinguishes all these deposits from those of the second glaciation consists in the blocks and pebbles, viz. grey, red, and black limestone, green sandstone with black spots, derived exclusively from the Glarner Alps, viz. from the Linth watershed, the granites and other rocks of the Julier Alps and the Vorder-Rhine, viz. of the Rhine drainage area, being entirely absent. This fact affords substantial proof that in Upper Pleistocene times, viz. at the time of the third glaciation, the connection between the Rhine and Linth systems was already severed by the saddle thrown up by the Setz and Tamina at Sargans. The Linth glacier, properly speaking, did not advance beyond Baden; on receding it halted at Killwangen, and subsequently was for a long time stationary near Zurich, as evidenced by the terminal moraine walls which are so characteristic of that town.

Conclusion.—After the great folding, thrusting, and raising of the Alps in Miocene and Pliocene times, coinciding with the formation of the principal Alpine valleys, and accompanied by great climatic changes, we have, therefore:—

(1) A first glaciation and filling up of the valleys by glacial deposits, the limit of glaciation or terminal moraine in the North of Switzerland being a curve between Zurich and the Rhine at Kaiserstuhl and Irschel, and the axis of the main glacier pointing in the direction of Waldshut, the present confluence of the Aare and Rhine systems.

(2) A second glaciation, which, in the North of Switzerland, spread to the foot of the Jura, to Basle, and the Rhine.

(3) A third glaciation, which did not spread beyond the limits of the first, viz. to within 10 miles below Zurich on the one hand, and to the Rhine as far as Schaffhausen on the other, while the tongues of the Reuss glacier advanced to within about six miles of Turgi and Aaran, the Aare glacier to within ten miles of Olten, and the northern tongue of the Rhone glacier extended along the base of the Jura to about four miles beyond Soleure in the present Aare valley.

The general limit of this last glaciation in the North of Switzerland would therefore be indicated by a curve from Schaffhausen to Zurich and Soleure.[1]

Upon each of these periods of filling up, there followed an interglacial period of erosion, during which the rivers swept away and carried towards the sea the greater part of the accumulated glacial deposits. The first of these interglacial periods must have been very long and the erosive action very powerful, seeing that in the North of Switzerland the belt of hollow nagelfluh and isolated occurrences of moraine, such as that of Utliberg, are the only surface remains of the vast amount of material which the first Pliocene glaciation deposited, both through direct and through fluvio-glacial action. The second interglacial period was of much shorter duration; Heer estimated it at 6000 years; but it lasted at any rate long enough to produce the lignite deposits near Durnten, Wetzikon, Uznach, and Rorschach and the similar lignite bands near the Lake of Thune, which escaped or resisted the erosive action of the old Linth and of the Kander respectively; and, together with the débris-cone in the Lorze valley near Zug, constitute indisputable evidence of that second interglacial period.[2] The third period of glaciation and filling-up was succeeded by our own alluvial time, which is again a period of active erosion. This is evidenced by such rivers as the Rhine, the Aare, and the Limmat, of which the former has at various points eroded all the successive glacial and fluvio-glacial deposits[3] down to the solid rock, and has thereby

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[1] Broadly speaking, the three glaciations are typically represented in the Zurich District by the three ranges of hills running parallel to the lake, viz.:—

1st glaciation, moraine of	Utliberg or Albiz range, mean altitude		2600 feet.
2nd ,, ,,	Zurichberg ,,	,,	1800 ,,
3rd ,, ,,	Gattikon hills, and belt of moraine walls in Zurich	,,	1500 ,,

above sea-level, or 1150, 450, and 150 feet above lake-level respectively. In all cases, the moraine rests on molasse. Quite recently I had occasion again to examine these deposits in the company of Prof. Bonney.

[2] Among the deposits of the second interglacial period should be further noted the "Löss," viz. the fine sand and loam which occurs extensively along the foot of the Jura, as well as in the Rhine valley near Rhinfelden and Basle, and also in the Aare valley near Aaran, and again near the confluence of the Aare and the Rhine, and generally rests on the fluvio-glacial deposits of the second glaciation. By some geologists this Löss has been held to be simply mud, deposited by rivers when in flood; by others as the product of chemical metamorphism; and again by others, such as Professors Richthofen and Muhlberg, as of Æolian origin, viz. as blown sand, this latter theory being the one now in vogue. Further interglacial evidence is afforded by the so-called lake-chalk of Zurich, viz. the chalk which separates out of the lake water, and a deposit of which was found in the bed of the Limmat at the lower end of the lake, between the moraine of the second and third glaciations.

[3] The fluvio-glacial deposits or gravel-beds of the second and third glaciations, which in the North of Switzerland extend along the principal rivers to their confluence with the Rhine, and thence and beyond to Basle, are called by Dr. Du Pasquier the Upper-Terrace and Lower-Terrace Gravels respectively. The moraines of the second and third glaciations are called by Swiss geologists the "outer" and "inner" moraines respectively; Dr. Du Pasquier, in deference perhaps to these time-honoured designations, and also to those of "first and second glacial periods," or "last" and "penultimate" glaciation, terms the Pliocene (hollow nagelfluh) glaciation the "old" glacial period; I have called them simply first, second, and third glaciations.

produced the rapids of Kaiserstuhl, Laufenburg, Rheinfelden, and others, while similarly the Aare has in various places, *e.g.* at Brugg and Laufthor, eroded the gravel and moraine of the three glaciations down to the molasse, and the Limmat at Wettingen below Zurich, and again between Baden and Turgi near its confluence with the Reuss and Aare, is now eroding the molasse itself.

The following Table shows at a glance the succession and extent of the three glaciations:—

Interglacial?	Alluvial	Present time	Erosion of valleys	Peat-moors on ground moraine.[1]
Third Glaciation	Upper Pleistocene	Diluvial	Filling-up ,,	Terminal moraine: Schaffhausen, Zurich, Soleure.
Second Interglacial	Middle Pleistocene		Erosion ,,	Interglacial lignite deposits: Durnten, Kander, Zurich lake chalk, Lorze débriscone Löss.
Second Glaciation	Middle Pleistocene		Filling-up ,,	Terminal moraine: Schaffhausen, Basle, Jura.
First Interglacial	Lower Pleistocene		Erosion ,,	(Formation of Alpine lakes.)
First Glaciation	Upper Pliocene	Tertiary	Filling-up ,,	Terminal moraine: Schaffhausen, Zurich, Soleure.
			Erosion ,,	(Formation of Alpine and sub-Alpine valleys.)
Nagelfluh and Molasse	Lower Pliocene Miocene		Filling-up ,,	(Sub-tropical fresh water basin.)

As regards, in conclusion, the question whether we live in another genial interglacial period, and have to face the contingency of a further recurrence of glaciation and of a refilling of the valleys following upon the present period of erosion, that contingency is not nearly so remote as might appear. During the present century the Alpine glaciers have shown considerable fluctuations. In the first quarter of the century, they steadily advanced, and this advance reached it maximum between 1820 and 1830. They then receded, but after various fluctuations advanced again between 1850 and 1860. Then followed another period of shrinkage, the glaciers reaching a minimum in 1880, since which time there has been a fresh advance at an ascertained average rate of 100 metres or about 330 feet per annum, say one foot per day. These fluctuations are easily accountable when we consider that the mean annual temperature within a given district or watershed not infrequently varies as much as 3° C. or about 6° F. in consecutive years, and that a decrease of

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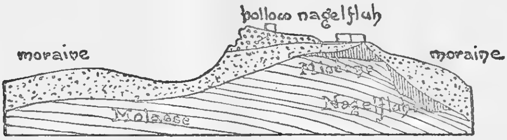
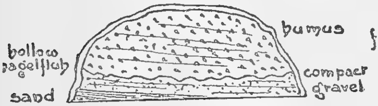
[1] Peat-moors, such as those in the Glatt valley N.E. of Zurich and on the hills (Zurich berg) which separate that valley and the lake of Zurich, are always an infallible criterion of ground moraine underlying them. This ground moraine or boulder-clay generally rests on the bottom of pre-glacial molasse valleys; it offers great resistance to the percolation of water and even to fluvial erosion, and remains compact. Hence the soil overlying the boulder-clay does not favour cultivation. Surface moraine or moraine sand, on the other hand, is highly conducive to vegetation, owing to its permeability and the consequent decomposition of alkali producing vegetable matter.

only 1° C. is sufficient to cause the snow-line to descend about 300 feet while the glaciers advance, unite, and spread at a much more rapid rate. A gradual drop of the present mean temperature of sub-Alpine Switzerland of 2° C., viz. from 9° to 7° C. would suffice to bring the glacier-terminals from their present mean level of 3800 feet down to 2800 feet, and a further drop to 4° C. or 39° F. would bring them again to the level of the lakes of Constance, Zurich,

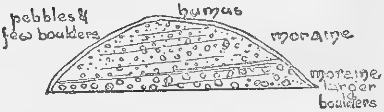
1st. Glaciation.
Section Summit Utliberg Zurich. (870 m.= 2870 ft. a/s.l.)



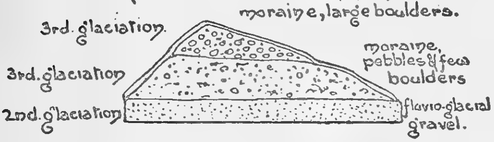
1st. Glaciation.
Section Quarry Baden.
(470 m.= 1550 ft. a/s.l.)



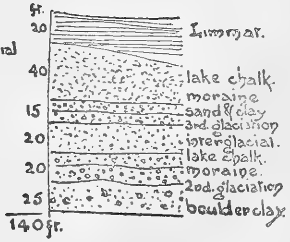
2nd. Glaciation.
Section Allmend Quarry Zurich.
(570 m.= 1880 ft. a/s.l.)



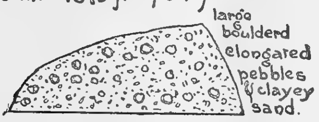
2nd. & 3rd. Glaciation.
Section Killwangen Quarry.
(420 m.= 1380 ft. a/s.l.)



Section of Limmat-bed.
Zurich.
(409 m.= 1350 ft. a/s.l.)



3rd. Glaciation.
Section Gattikon Quarries.
(550 m.= 1810 ft. a/s.l.)



Lucerne, Thune, and Geneva. But climatic changes of such comparative magnitude, so far as they are dependent on purely local phenomena, could only be brought about by a new gradual upheaval or upward thrusting of the Alps, which would largely increase the area, and therefore the quantity of precipitation; in the meantime, there is now indisputable evidence of three glaciations having already taken place. Sufficient unto the day is the evil thereof.

VI.—NOTES ON THE COMPOSITION OF CLAYS, SLATES, ETC., AND ON SOME POINTS IN THEIR CONTACT-METAMORPHISM.

By W. MAYNARD HUTCHINGS, Esq.

MR. TEALL, in his very interesting and suggestive address to the Geological Section of the British Association at Nottingham, alluded to the composition of sediments (clays, etc.) as compared with that of older sedimentary rocks, and specially to the amount of alkali contained in them.

At the time he made his remarks I was engaged on some analyses of clays, with a view to gaining information on this particular point, in connection with studies of clays and slates which I have been carrying on for some years, and on which I have published papers in this MAGAZINE on former occasions. The results of these analyses, and some considerations arising out of them, I propose to give as the first item of these present "notes."

For reasons which I stated on a previous occasion, I have taken for special study the series of clays and shales which occur in the Coal-measures, and of these I have used for detailed microscopical examination only such occurrences as were *not* in contact with Coal-seams. I did this because, wherever a bed of clay or shale has had a seam of Coal immediately above it, we may assume that it has served as the soil on which the vegetation grew which produced the Coal, and has thus been deprived of large amounts of alkali, and so altered in its chemical composition in a manner which would not apply to quite similar deposits of sediment in other formations. Also beds of clay and shale occurring with Coal are often broken up,—are unstratified,—and so affected mechanically as well as chemically, and rendered less suitable for the observations I had in view.

I have always maintained, and still maintain the more strongly the more I examine them, that the clays and shales of the Carboniferous beds represent the waste of granitic or gneissic areas practically "pure and simple," and that they are in all respects the counterparts of the sediments which gave the materials for the principal masses of slates and slaty grits of the older geological formations. But there was always an apparent *chemical* difficulty in the way, inasmuch as the published analyses of these carboniferous clays showed so little alkali that they could not be supposed capable of yielding slates of average composition unless some means were assumed by which alkali could be added, and no such means could be suggested for which there is any evidence. This difficulty was also pointed out to me by others, among whom was my friend Mr. Teall himself.

I was convinced from microscopical work, levigations, etc., that in the clays examined there was much more potash-mica than would be represented by the alkalies usually reported in the analyses on record. In considering these analyses several points must be kept in view. For one thing, just the clays which I avoided as being *abnormal* from a geological standpoint are those of most industrial importance, and therefore most analysed; a clay being usually a better "fireclay" the less alkali it contains. Then again, many of the analyses are old and were made when the determination of alkalies was not so easy and so accurate as it has been since the Lawrence Smith method came into general use. In many analyses, again, alkalies were simply determined "by difference," and the figures are worse than useless. In many other cases potash only is given, and it is not too much to say that many "technical" analyses are not carefully enough made to render them available for scientific purposes.

It would not serve any useful purpose here to quote a large number of analyses of "fireclays," but the following figures may be of interest. They give the average percentages of silica, alumina, and potash in a series of eight analyses made by Mr. E. Riley on clays from the Dowlais Coal-field. Mr. Riley's name is an assurance of the accuracy of any analyses made by him:—

	Silica.	Alumina.	Potash.
Maximum	67·12	34·76	4·19
Minimum	44·25	21·18	1·21
Average	53·39	28·91	2·11

It may be remarked that Mr. Riley has not determined soda, though this is present in all fireclays,—according to my own examinations being usually about one-fourth of the amount of potash. Moreover, the average amount of water and organic matter in the above analyses was 11·63 per cent. The loss by ignition of an average slate is about 3 per cent. only, so that for purposes of comparison the alkali in the above figures would have to be increased about 8 per cent.

I have made with the greatest care a series of six analyses. For this purpose I used the material in my possession in the form of a number of cores from a bore-hole put down in the Coal-field at Aspatria, near Carlisle. The bore-hole was 800 feet deep, and the specimens represent various beds of sandstone, shale, and clay, with the gradations between them. For microscopic examination I have made sections of this material from eighteen different points.

The analyses of the sandstones and very quartzy clays and shales would have no special interest. I have selected samples of very fine-grained clay representing beds at various depths from 330 feet to 685 feet, and one bed of more quartzy material. None of these were in contact with Coal. The clays are very compact and hard. Ground with water they are exceedingly plastic.

No. 1 contains a good deal of quartz, which is seen under the microscope as evenly dispersed grains. Nos. 2–6 are among the finest-grained clays I have seen. The quartz present is so finely divided that it cannot be detected at all among the mica, etc., in slides, and can only be found by levigation. No felspar can be detected at all. They are the most completely micaceous samples in my possession, and it is safe to say that very nearly all this mica is newly formed *in situ.*

The analyses were made on samples dried at 220° F.

Titanic acid has not been determined, and is therefore contained in the silica and the alumina of the analyses. Taking the careful research of Mr. Riley on the presence of titanic acid in clays as a guide, we may reckon its amount as rather over 1 per cent. Its determination was not important for the purpose of these analyses. The iron present is all given as ferric oxide, though a small part of it is in the state of ferrous oxide. This partly causes the excess in the analyses. Traces of phosphoric and sulphuric acid, etc., have not been determined. From these analyses it will be seen that these clays would be capable, chemically considered, of transformation into very typical "clay-slates." *Mineralogically* they *are* clay-slates, having already undergone all, or nearly all, the mineral changes requisite to constitute the normal (unaltered) slates. Nothing more is needed but physical changes, such as compacting, arrangement of mica in a plane, increase of *size* of mica, etc.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Silica	66·30 p.c.	59·28 p.c.	56·85 p.c.	59·25 p.c.	53·57 p.c.	54·46 p.c.
Alumina......	18·95 ,,	21·85 ,,	24·58 ,,	21·93 ,,	24·53 ,,	23·75 ,,
Ferric Oxide	4·35 ,,	5·80 ,,	5·30 ,,	5·65 ,,	6·51 ,,	6·80 ,,
Lime	0·60 ,,	0·45 ,,	0·52 ,,	0·55 ,,	0·76 ,,	0·85 ,,
Magnesia ...	1·04 ,,	1·24 ,,	0·94 ,,	1·42 ,,	1·81 ,,	1·78 ,,
Potash	3·18 ,,	4·13 ,,	3·78 ,,	4·21 ,,	4·34 ,,	4·54 ,,
Soda	0·54 ,,	1·18 ,,	1·44 ,,	1·08 ,,	0·97 ,,	0·89 ,,
Water.........	5·35 ,,	6·25 ,,	7·15 ,,	6·21 ,,	7·65 ,,	7·53 ,,
	100·31	100·18	100·56	100·30	100·12	100·60

The analyses of slates are very numerous, and there is no need to burden this paper with a reproduction of them; but, for comparison, I have taken, at random, eight analyses given by Roth in his "Allgemeine Geologie," 1890, among a list of analyses of slates from various parts of Europe.

	Silica.	Alumina.	Potash and Soda.
Maximum	65·84	27·93	6·06
Minimum	50·01	17·10	3·26
Average	57·93	22·76	5·07

Or again, taking nine analyses given in Renard's work on the slates of the Ardennes, the figures are—

	Silica.	Alumina.	Potash and Soda.
Maximum	61·57	31·95	6·07
Minimum	45·60	15·96	2·39
Average	57·20	21·87	4·36

It will be seen how striking is the approximation of the average figures of these seventeen analyses, and also how closely they agree with the average figures in the analyses of fireclays made by me.

Further, in making these analyses I had in view the question as to whether or not kaoline is present in these clays to any extent.

I have not been able to definitely satisfy myself by microscopic examination on this point, but have rather come to the conclusion that it is either absent or only very subordinate, and I think the analyses confirm this view, as regards these special samples at all events.

Seeing that no felspar is detected in them, we may assume that the alkali present is combined in the very abundant mica, and we can calculate by Tschermak's formulae, as Renard does in his slate analyses, the alumina that would be required to form muscovite, with a proportion of paragonite due to the soda. If we do this, we find that the alumina required is respectively: No. 2=19·39 per cent., No. 3=19·54 per cent., No. 4=19·15 per cent., No. 5=19·04 per cent., and No. 6=19·29 per cent., leaving only 2·46 per cent., 5·04 per cent., 2·78 per cent., 5·49 per cent., 4·46 per cent., available for kaoline or any other combinations.

These figures are on the assumption that only the *alkali* is present in the mica, requiring alumina in proportion. But it is more than probable, as Renard considers, that part, at least, of the magnesia, and perhaps some of the lime, are also combined in this mica, in which case a good deal more alumina would be required, though this would be partly compensated, possibly, by the replacement of some alumina by ferric oxide. At any rate, these calculations are able to show that not very much kaoline can be present in these clays as they now are. And the evidence, chemical and microscopical, leads to the belief that, supposing kaoline formed a part of the original deposits, as it probably did, it was either sparingly represented or has been altered since. The same arguments, supported by analyses, apply equally to many slates in which no felspar can be detected, in which mica is the only mineral present which contains alkali, and in which very little alumina is available after calculating what is required for this mica.

Of course there is no doubt that there are clays, in the Coal-measures and elsewhere, whose analyses show that a great deal of silicate of alumina is present as such. Some of the "fireclays" are examples of this, owing to removal of alkali by vegetation from the original felspar, and perhaps also from the mica originally deposited. And there are *slates* of similar composition in the older formations. They are, however, few in proportion to what may be called normally composed slates.

The mistake is often made of speaking of clays as if they were largely, or mainly, composed of the *chemical* waste of felspars, and as if this must always be kaoline. As I have previously shown, an examination of any series of the gradations from fine-grained clays into shales and sandstones disproves this completely. There is a great deal of felspar present which has been brought down as such. A decomposing felspar will be more easily broken up by denudation, and with the products of decomposition there will be carried away the fragments of the mineral itself, together with other felspar fragments not necessarily from decomposing crystals. In the coarser parts of the deposits this felspar has partly survived; in the finer mud it has all passed into secondary products. We know, from the experiments of Daubrée and others, how rapidly and easily felspar is decomposed when in a very fine state of division. So far as I have been able to follow the subject, this decomposition, after deposit in these clays, leads to the formation of mica and not of kaoline. Continued attention, which I have paid to the alteration of felspar in granites, and also in andesites and other rocks, confirms me in the opinion that there also, though both occur, micaceous decomposition is very much more usual than kaolinitic. And it is quite reasonable to suppose that when kaoline is deposited together with much felspar, biotite, muscovite, etc., the changes which afterwards take place, involving as they do a micaceous alteration of the felspar with liberation of alkaline silicate in solution, may effect a conversion of more or less of the kaoline into mica, a process chemically quite simple, and quite probable under the conditions of pressure and temperature we know to have existed.

The examination, microscopical and chemical, of the materials from this bore-hole has also been of interest as showing the very uniform conditions as to nature of deposit of this not inconsiderable thickness. It will be seen that the five seams of fine-grained clay, separated though they are by very much coarser beds, and deposited at what must have been good long intervals of time, yet show only comparatively small variations in composition.

On a future occasion I hope to deal with some of the more modern clays, having different compositions from those now under consideration, and I think also more or less different origins. Clays such as I allude to have not, I consider, played any noticeable part in providing the materials for the older slates and grits.

In the Geological Magazine for October, 1891, I contributed some "Notes on the altered Coniston Flags at Shap," in which, among other things, I dealt with the question of newly-formed felspar in these rocks and with the nature of the "clear spots" observed in them. To these two points I wish now to recur, having continued to study these special rocks at Shap, and also having paid much attention to similar rocks in general.

As regards newly-formed felspar at Shap, Harker and Marr, in their work on these rocks, had stated that they looked on its presence as probable, but they did not definitely assert it. I had made every effort to make sure on this point, but was obliged to state that I could not obtain any *proof*, by microscopic tests, of its presence.

I must now retract this and say that not only is new felspar present in these rocks, but that it is at some parts of the exposure very abundant in the "mosaic" which is well developed near the granite. This altered conclusion is due to some extent to the additional number of very thin sections examined, of which I have now a series from over twenty points along the limited exposure in Wasdale Beck; but is due much more to improvements in the appliances I have used. A few remarks on this subject may not be out of place here.

Everybody who has tried to do much work on *minute* mineral sections in convergent polarized light, using, say, $\frac{1}{8}$ inch objectives, knows what a terribly unsatisfactory thing even the best rotating stage is. It is not too much to say that "that way madness lies." I had a "Dick" microscope made for me by Swift and Son, fitted with a good condenser. The benefit of the change to this instrument can only be fully understood by those who have tried it; one regrets every hour wasted in using the old rotating-stage horror! But the full advantage of the change for the special class of work in question was only realized when my friend Mr. Dick persuaded me to use a $\frac{1}{12}$ inch oil-immersion objective, a thing that would have been quite out of the question with the rotating-stage. The optic figures obtained by its use (of course in combination with a suitable condenser, and with a sufficiently small perforation in the diaphragm under the eye-piece) are quite good and certain where those got by means of a high-angled $\frac{1}{8}$ inch are too indistinct to be of any value, or where the mineral under observation is so small in area, and so thin in section, that the $\frac{1}{8}$ inch gives no figure at all.

Thus, these contact-slates have to be sliced extremely thin in order that there may not be any superposition of minerals, and in these very thin sections nothing but optic figures in convergent light can usually safely decide whether given grains of the mosaic are quartz or felspar, the felspar-grains being without cleavage.[1]

There are also very great advantages in using these lenses for other special purposes outside of the study of optic figures, as for the examination of minute structures, enclosures, etc. Those petrologists who are using these high-power immersion-lenses (there is no need to stop at $\frac{1}{12}$ inch) will, I think, fully concur in what I have said above, and in the desirability of encouraging their use by others who may still regard them as rather outside the requirements of the petrological microscope.

In the altered slates at Shap, then, felspar is plentiful. In some slides there appears to be almost as much felspar as quartz in the limpid mosaic. The grains of it, like those of the quartz, are rich in enclosed microlites and have frequently the more or less sharply bounded polygonal outlines so characteristic of both these minerals in fully developed mosaics of contact-rocks. This mosaic, or "tesselated" structure, when at its best, is so very like the cells of a honeycomb that in German literature it is frequently spoken of as "honeycomb-like." This is such a very good description of it that it is almost a pity the word is already appropriated among us for another meaning.

I have made the following two analyses to show the composition of the "flags" of Wasdale Beck. The same remarks apply here, as regards the non-determination of titanic acid, and the statement of all the iron as ferric oxide, as in the case of the analyses of clays already given:— (Analyses on p. 42.)

A is a sample of the rock exposed in Wasdale Beck, near the

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[1] There is an appearance to be seen in these newly-formed felspars which is of the greatest diagnostic value. This is a peculiar striation, best seen in polarized light. It does not seem to be either a cleavage or a twinning. It appears to be peculiarly characteristic of felspar formed at contacts, and has been so noted by observers. It is duly emphasized by Zirkel in his latest volume. Unfortunately it is not regular in its appearance, and there are plenty of mosaics, especially those of smaller grain, with a good proportion of felspar, in which it is not seen. Where it does appear it may be relied upon as evidence at once. All grains showing it are felspar, and I have not come across any case where grains of this sort are seen in a mosaic, where a good deal of felspar is not also present in an unstriated condition.

hotel. It is a moderately altered slate, containing a good deal of quartz. Biotite has formed in considerable amount, but the quartz is still distinctly clastic. No sign of felspar is seen, and there are here no "spots." *B* is from a point about three-quarters of a mile away up the stream, almost the highest exposure in the Beck, and about 300 to 400 yards away from the outcrop of the granite. How near it may be to the actual *contact* cannot be stated, because we do not know the contour of the granite underground; but it is certainly not very far away from it. The rock is here very completely "regenerated;" not a particle of *original* quartz remains, felspar is abundant, and there are many spots of various kinds.

	A.		*B.*
Siliça	58·55 per cent.	......	61·05 per cent.
Alumina	17·13 ,,	......	17·95 ,,
Ferric Oxide ...	8·95 ,,	......	6·54 ,,
Lime	5·90 ,,	......	1·65 ,,
Magnesia	3·85 ,,	......	3·06 ,,
Potash...	3·44 ,,	......	5·33 ,,
Soda	1·56 ,,	......	2·55 ,,
Water	1·25 ,,	......	2·64 ,,
	100·63	......	100·77

It will be noted that *B* is unusually rich in alkali for a slate, though the figures can be closely paralleled by those of some other published analyses. So far as can be judged from the appearance of the rocks and their relationship to the line of strike, the two specimens represent the same slate.

There is nothing in the analyses, in spite of the increase of nearly 3 per cent. in the total alkalies, to justify any inference that a transfer of material has taken place from the granite to the slate. The balance of the accumulated evidence on this question appears to show that such transfer is either non-existent or very rare, except perhaps at the actual junction, and the above analyses are quite in harmony with this. Slates and shales are known to vary considerably in composition, within very moderate distances, in the same layers. *A* is much more calcareous and also more ferruginous than *B*, and this causes the main difference. It will also be noted that the proportion of potash to soda is almost identical in both cases, a fact which speaks strongly against the idea of the introduction of any alkali from an external source.

Concerning the question of newly-formed felspar in contact-slates, etc., it is to be remarked that more recent observations tend to show that its occurrence is not by any means so rare as was at one time supposed. This fact is emphasized by R. Beck, in a paper in which he records his own observation of felspar in the contact-rocks of the Elbe Valley (Tschermak's Min. and Petrog. Mittheilungen, p. 13, 1893), and refers to a list of other notices of similar occurrences. I may state that having myself of late very carefully examined specially prepared slides of a good number of contact-slates, etc., from various places on the Continent, I have found them to contain felspar in frequent instances, its occurrence not having been previously recorded in published descriptions of the rocks from some of the localities. Thus, among others, notably the andalusite-hornfels of Andlau and neighbourhood is rich in felspar. Also the hornfels of Spitzenberg, in the Harz, the "Knotenglimmerschiefer" of Sauschwart, in the Erzgebirge, and several others, contain large amounts of newly-formed felspar. My own impression is that in most of the contact-mosaics of normal slates and slaty grits an examination of very thin sections, with adequate optical appliances, will show felspar to be present; that its occurrence at contacts is, in fact, rather the rule than the exception.[1]

The other point to which I wished to recur is that of the nature of the "spots" in the rock at Shap, and in contact-rocks generally.

The composition and origin of some of the "spots" and "knots" in contact-slates appear to me to be among the least understood of all the deeply interesting things concerned in the processes of contact-metamorphism. Their elucidation is surrounded with difficulties, but if they could be properly followed out and explained we should, I think, be a long way towards knowing what takes place when a rock is metamorphosed by an intruded granite, and what are some of the stages involved in bringing about the changes of which we are obliged to speak rather vaguely as re-crystallization, regeneration, molecular rearrangement, etc., etc.

That very little can be regarded as settled concerning the spots is evident from the very different descriptions and explanations, given by various observers, as to their nature and contents.

In some cases the spots (knoten) are stated to be imperfect crystals of definite minerals, or to consist of secondary products due to the decomposition of such minerals. Cordierite and andalusite, and their decomposition-products, are thus described as forming the spots, and we may add also white mica, and sometimes felspar, as playing the same part.

But it does not seem either necessary or desirable to speak of such definite mineral-occurrences under the general and vague name of "spots"; and, indeed, in those outer zones of contact-slates where the spots are most abundant and characteristic, these definite mineral grains or "imperfect crystals" are more usually absent, or only slightly represented.

Such large grains, or imperfect crystals, of definite minerals do occur in some parts of some contact-zones together with the more indefinite "spots" we are now considering, and as they are frequently

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[1] In some contact-rocks the felspar is so developed that it is only a question of a glance through the microscope, even with low powers, to make sure of its presence in quantity and that it is a new formation. Thus, in some of the contact-slates and grits (greywackes) of the Elbe Valley and the Lausitz district of Saxony there are large grains of well-cleaved orthoclase and well-twinned plagioclase, whose enclosures of biotite, quartz, etc., place their nature as contact-minerals beyond question. It is in the limpid and often fine-grained "mosaic" of such rocks that the presence of felspar appears to have been often overlooked, and in which, nevertheless, I consider its presence can nearly always be demonstrated.

It may be of use to mention that a good series of specimens of the most interesting contact-rocks alluded to above, from Saxony, can be obtained from the mineral depôt at the Mining College at Freiberg.

marked off from the rest of the rock in much the same manner, when seen in ordinary light, there is some temptation to consider them as forming part of the same processes. But I think a full consideration of them shows the fallacy of this, and that they should be considered quite separately. Nor is it at all justifiable to speak of the more indefinite spots, such as I am about to describe, as composed of decomposition-products of a mineral, as *e.g.* cordierite, unless the connection and *transition* can be absolutely proved.

As a more general thing the spots and knots are spoken of as consisting of, or containing, "aggregations of pigment," "aggregations of iron-ores," or of "dark grains," or of "carbonaceous material," or they are described as consisting of the same materials as the rock in which they occur with less of some particular mineral, often biotite or white mica; or also as representing "less developed portions of the general mass."

I have made a careful study of the spots in the Shap rocks, and of many other occurrences, in the hope of obtaining a better understanding of them. It does not seem possible to arrive at any perfectly definite and general conclusion concerning them; but certain things appear to apply to many, and to allow of some slight inferences as to their possible nature, so that it may be worth while to record a few observations made on them. This can, perhaps, best be done by describing one or two particular cases first.

Thus a "Fruchtschiefer" from Tirpersdorf, in Saxony, consists mainly of white mica, mostly lying flat in the plane of cleavage, but also a good deal lying edgewise in various degrees. There is a little quartz-mosaic, a good deal of biotite, some of it in large individuals, lots of small tourmalines, zircons, etc. The whole is rich in dark grains and plates, many of which are transparent or translucent ilmenite. The numerous spots are about the size and shape of small grains of wheat, and do not seem to have any definite relationship to the rock-cleavage. Under low power, in ordinary light, they are sharply marked off from the surrounding material by being very much richer in dark grains and plates, and by having yellow colour. The boundary of this yellow colour is mostly quite sharp. Biotite occurs in the spots as small flakes, and larger individuals of it sometimes lie partly in them and partly outside.

In polarized light, again, the spots are marked off very sharply, being much darker than their surroundings, and containing much less vividly-polarizing mica, at the same time that the contrast is heightened by an extra accumulation of such mica as a frame immediately round them. At a thicker, central portion of the slide (which, however, must be a really thin one to make out anything distinctly) the spot is seen to contain a great deal of a mosaic of small grains or flakes, or both, which cannot be all identified, but some of which is mica and some probably quartz. It can be seen that these grains, etc., lie in, and are quite distinct from, the yellow substance which colours the spot and surrounds all its contents like a sort of groundmass. In nearly all these thicker spots one gets the impression that there is, among the other constituents, more or less of isotropic matter, referable to the yellow substance, but it is not possible to make quite sure.

If other spots be examined which project out to the thinnest edges of the slide, and higher powers are used, the yellow substance is seen to be of a pale yellowish-green colour, free from any trace of dichroism, and full of an irregular network of exceedingly fine cracks or cleavages, only well seen with high powers and much lowered condenser or partly closed iris-diaphragm. In polarized light the grains and flakes of the contained minerals are again seen, and it is here possible to make sure that in among them are isotropic spaces. Some of these may be seen of such relatively large area,—so many times larger than any of the contained minerals,—that all idea of compensation by overlapping individuals is dispelled. One can satisfy oneself that what is seen consists of the yellow substance pure and simple, and that the portion examined has no action whatever on polarized light.

In addition to the appearances above described there are spots in the same slide where the yellow substance is deeper in colour, and polarizes faintly in the lowest possible grey tints. In some few cases this polarization becomes distinct enough to give a tolerably uniform, though fibrous or flaky, extinction over a good large area of the spot, the contained minerals being seen in among this with their own independent extinctions as usual. Under these conditions the yellow substance sometimes shows traces of dichroism. In this faintly dichroic and lowly polarizing form it more resembles, in its appearance in polarized light, some occurrences of serpentinous material than anything else to which I can compare it.

This same substance, varying in colour from much deeper yellow to almost colourless, and varying in its dichroism and its degree of bi-refraction, may be seen again in the spots of many other contact-rocks. Thus, in a "Knotenthonschiefer" from Andlauthal, in the Vosges, the spots again are marked off in ordinary and polarized light exactly as in the above descriptions. The yellow substance is present and of the same nature, but in the outer rims of the spots polarized light produces in it a very faintly-speckled, minutely-cryptocrystalline effect, while in the central portions it does not itself polarize but contains, as usual, a mosaic of grains, some of which are quartz, while a few may be made out as felspar, with mica. This minutely-speckled polarization is very frequent in this substance in rocks from many localities, and seems to correspond to the first stage of its passage from an amorphous to a more or less crystalline condition.

In some occurrences of "Knotenschiefer" this substance is limited to the spots, but there are others in which smaller portions of it occur more or less abundantly outside them, in among the general materials of the slates, as patches or streaks of various size. And in the more inner zones of contact, after the spots have ceased to appear, it is still often seen, usually in smaller amount but in some cases very abundantly.

(*To be continued.*)

WOODWARDIAN MUSEUM, CAMBRIDGE. CATALOGUE OF THE FOSSILS IN THE STUDENTS' STRATIGRAPHICAL SERIES. By H. WOODS, B.A., F.G.S. 8vo. pp. 23. (University Press, 1893.)

THERE is much to be said in favour of the plan, which has been carried out at Cambridge, and also in some of the principal University Museums in Germany, of forming for teaching purposes a separate series of fossils to illustrate the principal types which characterize the different stratigraphical horizons of the geological series. This catalogue, which has been very carefully drawn up by Mr. Woods, gives the generic and specific names, and the class and order of the common typical fossils occurring in each of the principal geological divisions in this country, ranging from the Lower Cambrian to the Barnwell and Barrington gravels and peat, which have been selected and arranged for the use of the students at Cambridge. Altogether the names of 558 species are given, of which 182 are from the Palæozoic, 290 from the Mesozoic, and 186 from the Tertiary rocks. As furnishing a highly useful key to the leading fossils in our British rocks, this catalogue has a practical value beyond the purpose for which it was designed. To allow of notes and additions it has been interleaved with blank pages.

REPORTS AND PROCEEDINGS.

GEOLOGICAL SOCIETY OF LONDON.

I.—November 22nd, 1893.—W. H. Hudleston, Esq., M.A., F.R.S., President, in the Chair. The following communications were read:—

1. "The Basic Eruptive Rocks of Gran." By W. C. Brögger, Ord. Prof. of Min. and Geol. at the University of Christiania, For. Memb. Geol. Soc.

In previous communications the author has maintained that the different masses of eruptive rock which occur within the sunken tract of country lying between Lake Mjösen and the Langesundsfjord are genetically connected, and have succeeded each other in a regular order. The oldest rocks are the most basic, the youngest (except the unimportant dykes of diabase) are the most acid, and between the two extremes he has found a continuous series.

He is now preparing a detailed monograph on this series of eruptive rocks, and in the present communication he gives an account of the results of his work on the oldest members.

Several bosses of basic plutonic rock, now forming a series of dome-shaped hills, lie along a north-and-south fissure-line. The most northerly is that of Brandberget in the parish of Gran, about 50 or 60 kilometres N.N.W. of Christiania, and the most southerly occurs at Dignaes on Lake Tyrifjord, about 35 kilom. W.N.W. of the same town. The prevailing rock in these bosses is a medium or coarse-grained olivine-gabbro-diabase; but pyroxenites, hornblendites, camptonites, labrador-porphyrites, and augite-diorites also occur. Analyses of the typical rocks from three localities on the north-and-south line are given, and the conclusion is reached that the average basicity of the rocks forming different bosses decreases from north to south.

The contact-metamorphism is referred to; and the presence of hypersthene in the altered *Ogygia*-shales, coupled with its absence from the same shales where they have been affected by quartz-syenite, leads the author to the conclusion that the chemical nature of the intrusive rock does, in certain cases, produce an influence on the character of the metamorphism.

Innumerable dykes and sheets of camptonite and bostonite are associated with the above-mentioned plutonic bosses. These are regarded by the author as having been produced by differentiation from a magma having the composition of the average olivine-gabbro-diabase. Analyses are given, and it is proved that a mixture of nine parts of the average camptonite and two of the average bostonite would produce a magma having the composition of the average olivine-gabbro-diabase. The petrographical variations, such as the occurrence of pyroxenites and augite-diorites, in the plutonic masses themselves are described, and attributed to differentiation under physical conditions unlike those which gave rise to the camptonites and bostonites.

In discussing the general laws of differentiation the author points out that it must have taken place before crystallization to any extent had occurred, because there is a marked difference in mineralogical composition between the rocks occurring as bosses and those occurring as dykes; and, further, that it is dependent on the laws which determine the sequence of crystal-building, in so far as the compounds which, on given conditions, would first crystallize are those which have diffused to the cooling margin, and so produced a contact-stratum, of peculiar chemical composition, before any crystallization had taken place.

2. "On the Sequence of Perlitic and Spherulitic Structures (a Rejoinder to Criticism)." By Frank Rutley, Esq., F.G.S.

This paper relates to the order in which the perlitic and spherulitic structures have been developed in a felsitic lava of Ordovician age from Long Sleddale, Westmoreland. The author having described this rock in a paper, published in the Quarterly Journal of the Society in 1884, and the accuracy of the views then expressed having been questioned, now endeavours to confirm his original statements, adducing in support fresh observations made upon this and other rocks of a similar kind.

3. "Enclosures of Quartz in Lava of Stromboli, etc., and the Changes in Composition produced by them." By Prof. H. J. Johnston-Lavis, M.D., F.G.S.

The author describes the existence of enclosures of quartz in a lava-stream at the Punta Petrazza on the east side of Stromboli, and also in the rock of the neck of Strombolicchio. He describes the effects of the rocks upon the enclosures, concluding that the quartz has undergone fluxion but not fusion, and has supplied silica to the containing lavas, thus causing an increase in the amount of pyroxene and a diminution in the amount of magnetite in the portions of those lavas that surround the inclusions and raising the percentage of silica. He suggests that such a process at greater depths and higher temperature may, under certain conditions, convert a basic rock into a more acid one, so that possibly the andesite of Strombolicchio may have been of basaltic character at an earlier period of its progress towards the surface. He offers the suggestion that other rocks or minerals once associated with the quartz have been assimilated by the magma.

CORRESPONDENCE.

LEVEL OF LAKE LEMAN.

Sir,—As Mr. Davison remarks, the level he quotes is not of reliable precision—not adequately mounted.

Would not the Pierre de Niton, in the Port of Geneva, be a more satisfactory bench mark to watch and compare with selected stations? Upon its position turns the whole of the Swiss Federal Survey.

Prof. Forel, who gives a full account of the results of levelling, does not say much as to the systems, all of which depended upon foreign (*i.e.* not Swiss) official surveys, so far as sea-level goes.

On the other hand, as compared with stations on Swiss ground, any variation of level ought to come out with certainty—and that is *the* point. I hope this interesting matter will not be lost sight of.

In Dufour's map the level of the Pierre de Niton figures as 376·64 metres. The later Siegfried map gives it as 376·86 metres, a difference of 22 centimetrès. Is this evidence of altered level or of improved exactitude?

In times when the great Rhone ice-sheet was melting back from the plains, but not as yet so notably from the mountains, would not the disencumbered land westward rise more than at the east end of Lake Leman? See Osmond Fisher's "Physics of the Earth's Crust," second edition, page 327, note 2, for equations approximately to the point. Marshall Hall.

Easterton, Parkstone, Dorset, 2*nd Nov.* 1893.

VOLCANIC SERIES IN THE MALVERN HILLS.

Sir,—The excavations for the new reservoir to the east of and below the Herefordshire Beacon have brought to light piecemeal an interesting series of beds. At no one time was there a complete exposure of them all; but as I have watched the progress of the work closely I have been able to make out with tolerable accuracy their general bearing.

The strike is nearly due north and south at this particular spot, *i.e.* parallel to the axis of the Malvern Hills. The dip 40° East.

The beds are shown by the microscope to be (commencing from the East): obsidian or very fine ash, coarse ash, and some basic rock. Some of the slides correspond in a remarkable degree with others cut from rocks further south. I hope in time to be able to establish connection between them. The whole area, however, has been subjected to so much movement and shattering that the greatest care and patience will be necessary to unravel the problem.

Great Malvern, *Oct.* 30*th*, 1893. Henry Dyke Acland.

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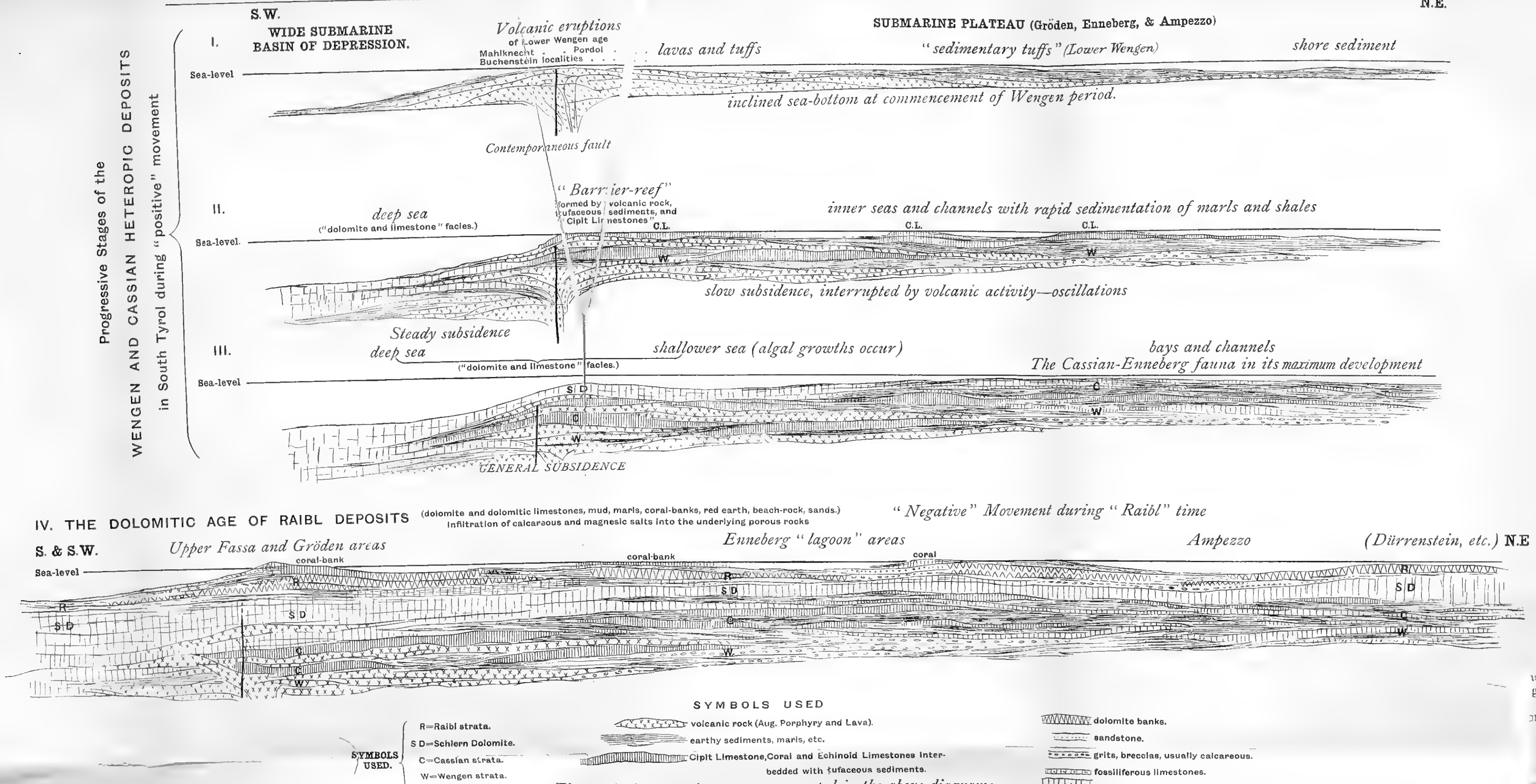
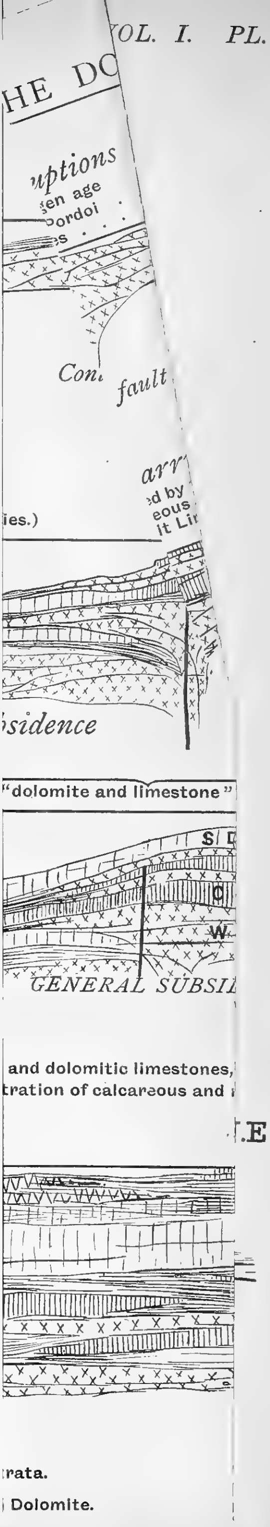
DIAGRAMS ILLUSTRATING "CORAL IN THE DOLOMITES OF SOUTH TYROL," BY MISS MARIA M. OGILVIE, D.Sc.



The vertical proportions are exaggerated in the above diagrams.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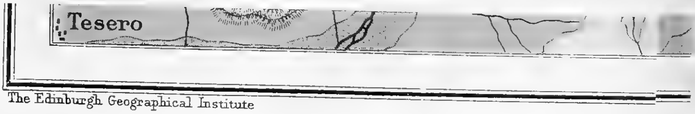

The Edinburgh Geographical Institute

GEOL. MAG. 1894.

MAP OF THE GRÖDEN, ENNEBERG, AMPEZZO, AND UPPER FASSA VALLEYS.

DECADE IV. VOL. I. PL. III.

The Edinburgh Geographical Institute

British Statute Miles 69.16 = 1 Degree
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Kilometres 111.3 = 1 Degree
0 1 2 3 4 5 6

Bartholomew, Edinr.

The Map is contoured at Heights of 1000 - 1500 and 2000 Metres.

Bartholomew, Edin^r.

The Map is contoured at Heights of 1000 - 1500 and 2000 Metres.

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

No. II.—FEBRUARY, 1894.

ORIGINAL ARTICLES.

I.—CORAL IN THE "DOLOMITES" OF SOUTH TYROL.

By Miss MARIA M. OGILVIE, D.Sc. (Lond.).

(Part II.)

(PLATES II. & III.)

(*Concluded from the January Number*, p. 10.)

III.—Transitional Dolomitic Era—Extremes of Rock-Facies in Raibl Times.

The Raibl period was the natural sequel of the variable and unequal movements which prevailed over Alpine areas in Permian and pre-Raibl Triassic time. Many basins formerly open were then enclosed; rauchwackes and beds of dolomite and gypsum were interbedded with fossiliferous deposits. Whereas, in some places, the dolomitic nature of the deposit is confined to special horizons, in the South Tyrol "Dolomites" it may almost be said to reign throughout. This makes it all but impossible to say when Schlern dolomite ends and Raibl beds begin. In the present incomplete state of our knowledge with regard to the heteropism of the Raibl series throughout the whole Alps, I have judged it best to begin the Raibl horizon at any particular place with the first appearance of a distinctly Raibl fauna, even although that fauna may not have been proved to correspond to the acknowledged lowest fauna of Raibl age in distant parts of the Alps.

To return for a moment to the succession of Schlern dolomite upon the Cassian beds of Enneberg, I found that, where Schlern dolomite rests on Cipit limestones, it has at its base a conglomeratic appearance, as if Cipit blocks had been imbedded in a beautifully fine white or reddish dolomitic mud, instead of the dingy brown and black tufaceous sediments. This is the case in several places, *e.g.* upon Pordoi and Sella Jochs, where there is no evidence of unconformity. Again, where the dolomite succeeds the thin-bedded marls and limestones of Cassian age, it does so conformably; but one and the same bed is at some parts calcareous and fossiliferous, at other parts dolomitic and unfossiliferous. Seeing that this holds good at various horizons in Lower as well as Middle Trias over the whole area of South Tyrol, we need find nothing remarkable in it from the point of view of the stratigraphical succession. Indeed, I have only mentioned these observations as an indication of the particular mode of transition from conditions of deposition favourable for the Cassian fauna to those in which the Raibl fauna was enabled to make an occasional appearance in the South Tyrol dolomites. At a very little distance above the base of Schlern dolomite all signs of Coral life disappear, and the deposit looks a homogeneous rock, although always retaining local variation in the degree of its dolomitism. At this stage the rock often shows typical Oolite structure. As regards the presence or want of stratification, it has as little to do with the question of the Coral Reef origin of the dolomite as the amount of magnesic salts in the rock—stratification is present and absent in one and the same "Reef."

In the highest horizons of Schlern dolomite there is infinite irregularity in the relations of fossiliferous and unfossiliferous beds; these horizons have been proved palæontologically to belong to the Raibl period. In them Corals and Echinoderms reappear again in some abundance in the Gröden and Enneberg districts. Dolomitic shales may be regarded as the typical sediment, giving place locally to sandstones and limestones, in which strand-faunas and plant-remains are imbedded. In one or two places Corals formed thin reef-like extensions over preceding plains of algal and marine origin. The fauna everywhere has many reminiscences of the Cassian fauna, but has marked local as well as zonal characters. Thanks to the occurrence of a few leading Molluscan types of wider distribution in Raibl strata, one or two horizons of time are clearly identifiable in the succession. Life was often made impossible, and brightly-coloured magnesian marls silted up large basins. Dolomitic mud and rauchwackes accumulated, or beds of dolomite or gypsum were separated from the water in inland seas and lagoons of what seems to have been a South Tyrol "Raibl" Archipelago. The best example of the heteropism in Raibl times is afforded by Schlern Mountain, where the stratigraphical relations of the fossiliferous well-known "Schlern plateau" Raibl beds have been carefully worked out by von Wöhrmann.[1] He says: "At one place we have a fauna exceptionally rich in individuals, in others we find the same horizon represented by a Coral bank, or by ferruginous marls wholly unfossiliferous, etc. These contrasts cannot be explained merely by the irregularity of the sea-floor, which is readily recognizable through the rapid increase or diminution in thickness of the strata; we are bound to accept current action in addition, making the relations locally so favourable that a numerous assemblage of Bivalves, Gasteropods, and other organisms were able to thrive within narrow spacial limits (for instance, the immediate neighbourhood of 'Schlern-klamm') without spreading into the surrounding area" (*loc. cit.* p. 219). I have had experience of very similar facts at Sella, Sett Sass, and Lagazuoi. On Sella, as at Schlern, a Coral-bearing dolomite of no great thickness appears amid the dolomitic shales on the plateau. Again, on visiting the top of Lagazuoi, I found unfossiliferous beds of a hard dolomitic sandstone, perfectly

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[1] Von Wöhrmann, u. Koken. "Die Fauna der Raibler Schichten vom Schlern Plateau." Zeitschrift d. D. Geol. Ges. 1892.

white, above the Schlern dolomite. From the occurrence of similar beds on the Sella massif, I took them to be of Raibl age, but followed along their dip to the north-east and saw their gradual passage into ordinary-looking yellow sandstones, with numerous fossils which proved to be the typical Raibl fauna of Travenanzes Valley. As the Travenanzes horizon is palæontologically younger than that of the Schlern plateau deposits, some part of the dolomite of Lagazuoi must in reality be of the same age as the fossiliferous Raibl beds of Schlern age. Thin beds of Cipit Limestones, like those of Cassian age, but much harder and whiter, occur at Valparola and Falzarego interbedded with the Travenanzes fossiliferous horizon.

Enough has been said to show that some of the anomalies of "Schlern dolomite" fall in the Raibl period, which has not been included by Mojsisovics in the Coral Reef epoch. Yet the heteropism of the Raibl strata adds to, and takes away from, the apparent thickness of the dolomite "reefs." It will be remembered that a younger or Upper horizon of fossiliferous Cassian strata is present in Ampezzo, which is absent in the Fassa and Gröden districts, and we know now that the upper part of the Schlern dolomite rock is contemporaneous with fossiliferous Raibl beds. Going a step farther, we can see that by thinning off the dolomite both at its upper and lower horizons, it would be probable enough, especially in the Ampezzo area, that fossiliferous Raibl strata should rest on fossiliferous Cassian strata. According to Mojsisovics, this is actually the case. My reasons for not adopting this view have been already stated (Quart. Journ. Geol. Soc. 1893, pp. 64–69). It is true that in these valleys the Schlern dolomite becomes comparatively thin, and it looks like the dolomite rock interbedded at higher horizons of Raibl strata. But even if the dolomite rock were wholly or in part contemporaneous with fossiliferous Raibl strata elsewhere (*e.g.* the Schlern plateau strata), this would in nowise afford evidence in favour of the Coral Reef theory, but only of the familiar fact of Raibl heteropism. The important feature is that the dolomite bears no evidence of Coral building, and is no thinning-out prolongation of a "reef"; but is here and elsewhere in the Cortina valleys an independent horizon of dolomite above the Cassian fossiliferous beds—it is, therefore, not Cassian "reef-dolomite." The varying relations of Cassian, Schlern dolomite, and Raibl strata are represented in Diagram IV.

The Raibl deposits pass quite gradually into the overlying true marine deposit, Dachstein dolomite, with which an important faunal link connects it. Several species of the bivalve *Megalodon* appear in the highest Raibl strata, and this is the predominating genus in Dachstein dolomite. There are dolomite shales of Dachstein age undistinguishable from those of Raibl age, and dolomitic marls make their appearance now and then in true Dachstein horizons.

The two rocks, Schlern dolomite and Dachstein dolomite, are so much alike that one experiences in the field the utmost difficulty in distinguishing them. The characteristic Dachstein bivalves so common in some parts of the rock are entirely absent in others.

Here we see an easy loophole of misconception in working out the stratigraphy of this area. How frequently it has given rise to error becomes apparent on comparing the maps or sections of different authors who have surveyed in the district!

An impression will now have been gathered of my opinion with regard to heteropism in the "Dolomites." Beyond doubt that exists, and to a very large extent; it alone explains the succession of Triassic rock in the "Dolomites." There are also reef-like communities of Corals, and of other fossil organisms, changing with the actual depth of the water and the character of the surrounding sediment. The Corals have but their fair share, along with other groups of marine life, in the thickness of any one formation, and just as important as the organic causes of heteropism are the inorganic. Most of all, the clear presentation of two epochs is necessary—the one is the volcanic period of Wengen age, when so many inequalities were introduced into the relief of the sea-floor and differential movements were set up in the basin of that part of the South Tyrol Triassic sea; the other is the Raibl period, and what it tells us of the culminating point in an age of unequal deposits and especially fluctuating conditions of level over these "volcanic" areas.

IV.—Apparent "Reef-Formations" in the "Dolomites" largely result from the particular history of Earth-movements in that area—Occurrence of Vertical and Inclined Planes of Fault in the "Dolomites"—Overthrusts—"Overcast" Bedding—Effects of Weathering.

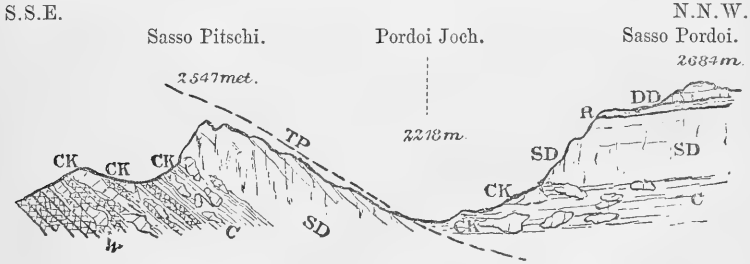
Gradually the waters of the Rhætic and the great Jurassic ocean advanced over Alpine areas and the deposits of the Triassic Archipelago lay sleeping at unknown depths below a heavy weight of marine accumulations. The South Tyrol Trias and younger deposits alike shared in the tektonic movements which passed over the Alps during the long geological "days" of Mesozoic and early Tertiary time; but probably it was not until the Tertiary mountain-making period that the series of deposits was affected by tearing or sliding movements.

Tertiary movement begins a much more difficult chapter in the past history of the South Tyrol dolomites than the period of Triassic deposition. And we might be content to omit it entirely from present consideration, were it not that it produced many results in South Tyrol which cannot be dissociated from the "Coral Reef" question. It has left its symbols indelibly written on the rocks of the country, symbols as strange and as impossible of interpretation for the early school of geologists as ever were the ancient characters on the colossal monuments of Egypt and Syria for the unpractised eye. And when we learn to read, one of the first Miocene symbols in the "Dolomite" spells "*Reef*" and is, being translated, *reduplication and faulting of rocks.*

The presence of a great number of vertical faults within the areas of Enneberg and Ampezzo has been already proved, also the influence of those in complicating the geology of the district and producing apparent reef-structure as at Sett Sass (Quart. Journ. Geol. Soc. 1893, pp. 58–77). I wish now to refer to inclined fault-planes. Mojsisovics first hinted at their occurrence in the dolomites,[1] *e.g.* "on the slopes towards the Duron Valley a partial overturning, or perhaps more correctly, over-thrusting of Werfen shales over Muschelkalk dolomite seems to have occurred. The exposures along the road leading from the Duron Valley up Col Rodella scarcely permit of any other explanation. *At the edge of the Rodella Fault-block Melaphyre dykes occur south-west of Col Rodella*" (*loc. cit.* p. 189; the *italics* are mine).

I drew attention to the occurrence of fault-planes with extremely low hade in the Dürrenstein Mountain, and again in the Buchenstein Valley, north of Arabba; but, as the subject was a large one, and as I had not then completed my survey of the Buchenstein and Sella districts,[2] I avoided treating it within the scope of my previous paper. The planes at Dürrenstein hade south, the plane I referred to in Buchenstein was an overthrust fault-plane hading north. Dr. W. H. Salomon published a preliminary note[3] of his survey in the district of Marmolata Mountain, south of the Buchenstein and Cordevole Valleys, in which he reports that two overthrust fault-planes occur on the southern slopes of Marmolata hading north.

I shall at present confine myself to one typical example of the occurrence of an overthrust plane and its explanation of an apparent "Reef" in the district personally surveyed. The example selected is Sasso Pitschi (see accompanying section), a dolomite summit south of the Sella massif. It is a reef-like mountain, standing up from the midst of Wengen beds on the Pordoi Joch. As will be seen from the description given by Mojsisovics (*loc. cit.* p. 238) the interbedding



DD = Dachstein dolomite.
R = Raibl Marls.
SD = "Schlern dolomite" and limestone.
TP = Thrust-plane.
CK = Cipit limestone.
C = Cassian strata.
W = Wengen strata.

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[1] At the British Association Meeting in Edinburgh, July 1892, Prof. Lapworth, towards the close of his Presidential Address to the Geological Section, referred to the country of the dolomites as one which he believed would be found to be cut by a great many overthrust fault-planes.

[2] I hope soon to publish a geological map of the district between Sella Joch and Wolkenstein on the West, and Cortina d'Ampezzo on the East, surveyed to scale 1 : 25,000; and to give along with it a complete statement of my results.

[3] Dr. W. H. Salomon, "Ueber den geologischen Bau und die Fossilien der Marmolata," Verh. der k.k. geol. Reichsaustalt, 7th March, 1893.

of Cipit Limestones with tufaceous rocks is peculiarly characteristic. The dolomite rock contains, especially at its base, remains of Corals and Crinoids. *Ammonites* also have been found in the dolomite. I find it impossible to consider the succession on Pordoi Joch undisturbed. On the south side, the Wengen lavas dip N.N.W. (20°–30°) and the conformable series of Cipit Limestones (Wengen and Lower Cassian age) and Schlern dolomite beds dip in the same direction at a rapidly increasing angle. The rocks on the north or Sella side are, on the contrary, remarkably horizontal, but where the terrain descends from Sella Mountain to Pordoi Joch, the strata dip slightly southward and south-eastward, *i.e.* outward from Sella (a dip which the strata exposed on the lower half of Sella massif continue to have all round its eastern side). On Pordoi Joch, therefore, we are presented with a repetition of the Cipit Limestone and the dolomite strata, owing to the passage of an overthrust plane of low hade, above the Sasso Pitschi rock. The thrust-plane hades northward and cuts away the dolomite rock of Sasso Pitschi, both in its eastward and westward extension below the Cassian beds of the Sella block. This fault affords to my mind a simple explanation of all the appearances associated with "Coral Reef":—

1. That Sasso Pitschi appears to "rise out of Wengen beds"
2. That the dolomite rock of Sasso Pitschi has a steep cliff edge to the south, and a gentle slope to the north.
3. That it thins out on Pordoi Joch, except on the western side, where it *appears* to pass conformably under the dolomite rock of Sella massif.
4. The "overcast bedding with northerly dip" said to be observed on the northern slope of Sasso Pitschi.

This last-mentioned appearance is clearly shown at Sasso Pitschi, and is by no means the only case in which I believe it to be the result of fault movement. The thrust-plane observed at Sasso Pitschi may be followed with N.N.E. outcrop close under the cliffs of Sella to Pian de Sass, where it also explains the seeming anomalies of the succession. If we now proceed to mend this broken section according to the natural succession of the district, we have a fair representation of the particular volcanic zone from east to west, already referred to (see Diagrams I.–II.). Here, where we are on the borderland of the actual passage of Wengen and Cassian strata into their deeper sea equivalents, the main thickness of these beds is composed of volcanic lavas and tufaceous deposits. The Cipit Limestones and the Sasso Pitschi "dolomite" may of course be regarded as the direct continuation northwards of the upper part of the Marmolata deposit of limestone and dolomite, continued further north over Sella, Gardenazza, etc. This is an example perfectly analogous, therefore, with the case of the heteropism at Schlern Mountain, on its southern and northern sides, and the Seisser Alpe. There is scarcely any thickness of the Cassian horizon present below the Schlern dolomite of Sasso Pitschi; the Middle Cassian or "Stuores" zone partly developed as "Cipit Limestones" on the Sella slopes, passes to the east and north-east into the thin-bedded fossiliferous marls of Enneberg, and reaches a later palæontological development on these meadows than below Sella and Sasso Pitschi.

I have dwelt at some length on this example, because it shows again the tektonic nature of some of the difficulties hitherto professedly explained by the "Coral Reef theory." We must in every case clearly decipher the twofold nature of the difficulties in South Tyrol, for, as we have seen both at Sett Sass and at Sasso Pitschi, the battle is only half fought with a knowledge of the Triassic period. In the latter case, Sasso Pitschi, the heteropism of the Wengen and Cassian strata, together with the conformable succession of "Schlern dolomite," are the stratigraphical truths observed at Pordoi Joch. The tektonic fact is the overthrusting from the north of the system or "block" of strata belonging to the Sella massif along a plane formed in this southern part by the cut and tilted ends of the strata belonging to the fault-block of Sasso Pitschi and Cima Rossi. It is not necessary for the purpose of the present article to follow farther the course of this thrust-plane, or to describe in detail others which exist in the districts of Enneberg and Ampezzo, Buchenstein and Upper Gröden. For the Pordoi overthrust is not an isolated occurrence, but one of several inclined planes of fault which pass through strata of all ages in this part of the "Dolomite Alps." Above Pian de Sass, on Sella Mountain, an overthrust fault passes through Dachstein dolomite, and just north of the Boe Spitz (the highest ridge of Sella) a fault plane with reversed hade has raised Dachstein Dolomite against Jurassic strata. The direction of these faults is S.S.W.—N.N.E., and they afford the most perfect analogy with the main faulting which has taken place in districts west and south-west. Suess says, in summing up the observations of faults in the Southern Alps (east of the Judicarian fault): "Long flexures have occurred passing locally into faults, which, running parallel to the Judicarian line, have let down the strata on the eastern side, and have caused overthrusting to the east, or more correctly from a W.N.W. direction towards E.S.E. These extend from the Judicarian line as far as the left side of the Etsch below Peri. Further, similar flexures have occurred which run more or less parallel with the Asta faults, lie south of these, and have let down the strata on the south, and sometimes overthrust them to the south. Some of the Judicarian faults swing round in sharp curves, in the proximity of the Etsch Valley, into the direction of the Asta faults" ("Das Antlitz der Erde," Bd. I. pp. 334–335). It is just such a swing-round that the inclined fault-plane of Pordoi and Sella shows, and I may state generally that the faults of Sella may be grouped with the Judicarian system, whereas those of Gröden Joch, of Buchenstein Valley, and, in short, the faults in this area which pass through anticlines of the deeper lying Triassic strata, belong to the Asta series. No hard and fast distinction can be drawn between these systems; they pass into one another and form one complicated system of movements, which may be proved even in the small district of Enneberg to have affected the positions of both Triassic and Mesozoic rocks.

By reason of these faults, the dolomitic rock has sometimes been so placed with regard to the earthy deposits below or above as to look like an independent reef from the midst of sedimentary rocks of its own age. Or it has been doubled upon itself, and thus, apparently, attains a much greater thickness. The harder rocks of Schlern and Dachstein dolomite have sometimes been pushed into new positions over the slipping substratum of earthy rocks without themselves undergoing much relative change of position or perceptible evidence of strain, except when complications are introduced by minor thrusting and faulting along the main planes. I hope to find out from specimens collected if any degree of internal change in the crystallization of the rocks may be due to thrust-strain. Visible signs of this strain are given by the "overcast bedding" at Sasso Pitschi and on the east side of Sella.

The appearance called "overcast bedding" is not always a concomitant of a thrust-plane, but is sometimes occasioned by the outward dip of the dolomite strata from the mountain. The weathering of the rock then produces a characteristic effect, *e.g.* on the west side of Dürrenstein, where the strata dip west; on the north side of Sett Sass, where they dip north; on the east side of Sella, where they dip east, etc., etc. Another form of "overcast bedding" is produced in the Cassian strata. The tufaceous or marly beds surrounding Cipit Limestone are worn or washed away more rapidly than the Limestones which gradually fall over and strew the steep slopes below the dolomite rocks. This is also a common reason why the reef-limestones predominate more, to all appearance, in the neighbourhood of the cliffs than on the less steeply inclined gradients of the "Alpen" or meadows.

A curious and particularly pleasing appearance is produced where a mountain slope of Schlern dolomite has been gradually denuded by snow and ice, wind and weather, of its Raibl "robe of many colours." Patches of greenish or reddish marls, from the size of a bean to the roof of a house, are left upon the pure crystalline whiteness of the dolomite. The sunlight sends its gleams upon it till the cold rock is lit with life, and the shimmer that runs through the leaves of an autumn forest is not more beautiful. All the more strange is the contrast to the Alpine climber when he reaches the top and finds on the other side of the mountain a giddy precipice of apparently unbedded rock. We cannot wonder that the idea of steep Coral cliffs facing the broad ocean and shelving inwards into calm bays and lagoons has long held its own in the mind of many as a fitting theory of the origin of such wonderful mountains! Beside it, any other explanation pales, and seems beset with endless complications.

For no sooner does one realize the main laws attending Tertiary movement in the "Dolomites" (a series of wide folds running, roughly speaking, east and west; anticlines segmented by steep fault-planes which meet and intercross as at Gröden Joch, or by overthrust fault-planes as in the Buchenstein Valley; synclines sinking unequally in many detached pieces, *e.g.* the Tofana and Kreuzkofl massif, Sett Sass, etc.), than new difficulties present themselves.

V.—Complete Harmony of the Geology of Enneberg in South Tyrol, with recognized methods of Alpine Mountain-making.

Since the main folding and overthrusting and East-West faulting took place, these planes of fault and the strata through which they passed have continued to suffer from movements of a vertical nature and usually in transverse direction (*cf.* Vacek's observations on North-South faults in the Etsch basin). For example, I have already referred to an important thrust-plane in the Buchenstein Valley. It may really be better called an east and west direction of overthrust faulting, for the main thrust is made up by the coincidence of several minor overthrusts, and it breaks eastwards into a number of diverging overthrusts. The whole series of faulting is cut off just west of the Arabba stream by a vertical fault of considerable throw, extending north and south, and letting down the Sella block in the west. This fault passes through the western limits of the Prelongei and Stuores meadows, while the Buchenstein over-thrust lies on the southern. Another important North-South fault occurs between Cherz and Varda, in the Buchenstein Valley, again letting down the western flank. What do we find now on the northern and eastern limits of Prelongei? Northward, the squeezed and shattered anticline of Gröden Joch passes across the meadows and is cut off by the north-south vertical fault traced southward from Heilig-Kreuz.[1] The mountains of Kreuzkofl and La Verella are let down to the east of this fault until Dachstein dolomite reaches almost the same low contours as it does at the Sella massif (eastern side), and at Sett Sass. We see, therefore, that the Cassian strata of Prelongei are pressed like a pliable plug into the midst of an ancient arena of cross-movements. And in this light the theory that the fossiliferous Cassian deposits collected in a basin more or less surrounded by high Coral cliffs of Sett Sass, Sella, Lagazuoi and Gardenazza, sinks into insignificance, for here we have something much grander! These are the processes of ages which have given us our grand Alpine Chains. The meadows of Enneberg have in *this* history one which will bear comparison with the proudest tales of Switzerland. They give us their trophy of miniature forms of mid-Triassic life; they give us also an insight into Nature's methods of mountain-making, on a miniature scale it is true, but following natural law as inevitably as did the spirals of their thousand Gasteropods, or the delicate intricacies within their myriad Brachiopods.

I must for one moment refer to the latest volcanic eruptions which took place, presumably also in Triassic time, in the districts of Predazzo and Monzoni (Fleims and Fassa Valleys). The innumerable dykes of the district often penetrate Wengen lavas and Schlern dolomite, and are said to be limited to a certain radial distance from the chief centres of eruption. The northern limit given, viz. Rodella, Canazei, and Marmolata, for the occurrence of intrusive porphyry in rocks younger than Lower Wengen, must, however,

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[1] *Vide* Q.J.G.S. 1893, "General Map," p. 70, where the important faults in the Prelongei district are drawn.

be extended to include the meadows of Prelongei, for in them I found intrusive sheets penetrating high horizons of Cassian strata,[1] and producing contact-metamorphism in sedimentary beds above and below. At Gröden Joch,[2] and in the Buchenstein Valley, dykes of porphyry occur in Lower Trias and Wengen horizons. Where they pass through Upper Muschelkalk, they have converted it *in situ* into a brecciated rock, or sheared it into shaly layers. Both on Gröden Joch and on the Buchenstein cliffs the porphyry is exposed in the main fault-lines which cut through these two anticlines of older Trias. In the Buchenstein Valley, above Varda, the volcanic rocks are hopelessly mixed up with the overthrust beds of Lower and Upper Muschelkalk and Buchenstein strata, but they are absent in the highly-folded succession of the same rocks below the thrust-plane, at Ruaz, or in the series of radiating faults below Pieve. Further detail I cannot give in these pages; I would only indicate the natural considerations which suggest themselves with regard to the age of the intrusive sheets. Two hypotheses may be stated:—(1) The intrusions of Augite Porphyry in these cases may be of Triassic age, exposed along with the Triassic rocks through which they penetrated, by later faulting and erosion. Since they, as well as the lavas of distinctly Wengen age, often occur along the path of faults, it would seem that the Judicarian-Asta system of faults followed largely ancient lines of weakness, which had been marked by the outbreak of lavas in Triassic time, or intrusions of porphyry of uncertain age. (2) The idea that the intrusions may have been associated with Tertiary movements in the Alps is not supported in Enneberg, but rather the evidence shows that at this period the volcanic rocks, both contemporaneous and intrusive, behaved as a compact, united mass, along with the sedimentary rocks.

The Buchenstein Valley finds its tektonic continuation in the Pordoi and Rodella district, where, as a previous quotation shows (p. 53), the facts appear to be in the main analogous. If we now compare the great "Eruptive Fault" of Fleims and Fassa, we find that by its throw at Sattel Joch, the northern wing of the fault is Lower Trias, faulted to the same level as Schlern dolomite on the south. The "Eruptive Fault" changes in its relations at Viesena, but it may be traced east and west through the country to a considerable distance from the actual eruptive centres. Here and there along its main line or its radiating branches, dykes of porphyry and melaphyre occur, just as in the fault-lines further north. I should think there could be little doubt that these great longitudinal fault-lines, together with the parallel Villnös fault in the north, were developed under the same general conditions, and were for the most part of pre-Tertiary origin. These faults have all been important planes of movement since Mesozoic time. Tertiary faults in some places coincide with, or cross at varying angles, lines of Triassic disturbance. Where areas

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[1] Q.J.G.S. 1893, *loc. cit.* p. 18, Map A.

[2] Cf. von Richthofen, *loc. cit.* p. 133, etc., who notes the occurrence of intrusive rocks at Gröden Joch.

already considerably faulted have been affected in this way, the ultimate results may seem conflicting. More especially might this be expected in the Fassa or Rodella districts, but no such complication would gainsay the striking analogy which the "Eruptive Fault" of Fassa presents in its main tektonic aspects with the faults of Buchenstein and the Gröden Joch.

VI.—Conclusions with regard to Coral Formations in the Dolomites.

We are now in a position to examine more closely the points of agreement and difference which Coral formations in the Dolomites present with the various theories of Coral-reef growth. Mojsisovics[1] has clearly shown to what a great extent variation in the rate of subsidence and the depth of the sea-floor has influenced mid-Triassic deposit in South Tyrol. Rothpletz, in his most recent work,[2] has discussed the entire question and brought forward the importance of submarine banks of sediment. While I have attempted to indicate an irregular sea-floor in Diagrams I. to IV., I designed those diagrams mainly to show one or two other facts of almost equal importance: (*a*) that coralline "Cipit Limestone" and Coral Dolomite form comparatively small thicknesses of interbedded rock and not the main body of the mountain masses; (*b*) that Corals began to grow in Wengen time on a submarine volcanic ridge on the northern edge of a great area of subsidence, and travelled inward and northward in Cassian time; (*c*) that extensive banks of Coral were formed in scattered localities during the Raibl period of shallower water and Dolomite deposit.

The Coral-blocks and lenticular "Cipit Limestones" were, therefore, to begin with, members of a submarine barrier-ridge, and never were strand-reefs. There was, from early Wengen time, an inner protected part of the sea whose bed, so far from being deepened in the way indicated either by Murray or Guppy, was constantly being shallowed by the rapid accumulation of shore sediment and the intermittent eruption of porphyry and lava. The movement was one of subsidence, proved by the fact that the Corals moved northwards, or inwards, in the later Cassian periods, and gave place, along the old Fassa-Gröden barrier, to the formation of marine Calcareous deposit. Probably occasional stationary intervals retarded the subsidence of this inner sea, and were, so far, favourable for Coral-growth. Several authors have called attention to the evidence of the action of currents in those areas. The vicinity of land is proved by the frequency of plant remains everywhere in the Wengen sediments. In the Cassian strata of Enneberg these are very rare; on the other hand, in the Ampezzo district, fragments of stems and leaves are common at certain horizons of Cassian and also of Raibl strata, and were not unlikely swept here by some wide river-channel from the north-west. The area of depression,

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[1] Mojsisovics, "Dolomit-Riffe," etc., pp. 505–510, and more especially for general tektonic relations, chap. xvii.

[2] Rothpletz, "Ein geologischer Querschnitt durch die Ostalpen," Stuttgart, 1894, pp. 52–67, "Ist der Schlerndolomit ein Korallenriff-Bildung"—a full discussion of the question.

south of the Fassa-Gröden barrier, extended also considerably westward; it was a basin in which, during Permo-Triassic time, volcanic activity was never long absent.

Comparing now the conditions existing in the West Indies at present, the resemblance is most striking. We read from Langenbeck[1] that barrier-reefs "have built on the outermost edge of extensive banks of sediment which have been heaped up along the whole North Coast of Cuba by sea-currents" (*loc. cit.* p. 18); and again, "It is exactly this difference in the degree of subsidence which produces the contrasts (so very characteristic of the northwest part of the Caribbean Sea) between great oceanic depths and relatively shallow portions of the sea, the two abutting almost directly on one another, united by steep slopes" (*loc. cit.* p. 24). In the Australasian Archipelago we find essentially similar physical and natural phenomena—in the Philippine Islands, the Solomon, Pelew, and Fiji Islands, etc. There too, reef-Corals show special favour for submarine ridges and plateaux in the immediate proximity of areas of strongly-marked subsidence, and very generally where volcanic agencies have recently been, or still are, active. Everyone conversant with the literature of recent Coral-reefs will recall abundant testimony of the co-operation of the same great geophysical forces which influenced the Triassic seas of South Tyrol, and made them locally suitable for the existence of beds of reef-Coral and the development of a rich fauna.

Guppy and other observers have stated that during "negative," or shallowing movement, Corals grew seldom in reef-like fashion; they tended rather to spread laterally and form extensive banks, or even terraces. This is admirably illustrated by the Coral-banks of the Raibl period. Their mode of occurrence reminds one, too, of the "Coral Oolite" beds of Jurassic deposits. The Coral rock formed in South Tyrol in Raibl time is not Limestone; it is a member of a highly Dolomitic series and is itself Dolomitic. It must be remembered that the Dolomitism of the Raibl-Dachstein period is by no means confined to South Tyrol, but is a common feature in greater or less degree in the Alps and in Keuper deposits elsewhere. The volcanic eruptions of Predazzo and Monzoni have been attributed to the early part of the Raibl period. This would conform with the local oscillations of level in neighbouring areas and the temporary "back-flow" of the water. The Pelew and Fiji Islands and the Sandwich Islands yield again good cases of analogy.

Darwin's theory demands fairly constant equipoise throughout a long geological age between the rate of growth of reef-Coral and the rate of subsidence of the reef-basis. There is *not* satisfactory evidence in favour of this in South Tyrol; my special survey in a part of the district seems to me to justify, without doubt, the position of those authorities who have contended that the immense thicknesses of "Schlern Dolomite" rock were an ordinary marine deposit and not "Coral-reefs."

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[1] Dr. R. Langenbeck, "Die Theorieen über die Entstehung der Koralleninseln und Korallenriffe und ihre Bedeutung für geophysische Fragen." Leipzig, 1890.

II.—ON SOME JURASSIC SPECIES OF CHEILOSTOMATA.

By J. W. GREGORY, D.Sc., F.G.S.;
of the British Museum (Natural History).

THE extraordinary abundance of Bryozoa of the order Cheilostomata which occurs throughout the Cainozoic era, in comparison with their scarcity in earlier formations, has often been remarked. Interesting explanations of the suddenness of their appearance have, moreover, been offered by those who do not attach so much importance, as do some, to the imperfection of the geological record. Cheilostomata are not unknown from earlier deposits: the Cretaceous system has yielded a fair number, while even as early as the Silurian species have been found. Though doubts have been thrown on these early records, there seems no sufficient reason to discredit them. Even if Prof. Nicholson's *Hippothoa inflata* (Hall)[1] should turn out to be a *Stomatopora*, which, if the figure be correct, is most unlikely, there remain many species in later Palæozoic deposits: such are those belonging to Prof. James Hall's genus *Paleschara*,[2] which Mr. Ulrich[3] accepts as Chilostomatous, though Prof. von Zittel[4] includes it doubtfully with the *Ptilodictyonidæ*. Some of the specimens of *Lichenalia*, etc., figured by Hall,[5] as well as the same author's *Cystopora geniculata*,[6] may also belong to this order.

The Jurassic fauna, however, so far contains very few records of Cheilostomata, though Prof. Nicholson[7] remarks that from the Jurassic onward there are abundant remains of this group. Michelin has figured[8] a specimen which he has named *Eschara ranvilliana*, which certainly belongs to the Cheilostomata, though until its internal structure is known it cannot be definitely placed. It must be assigned to the suborder "Athyriata" and probably to either the *Microporidæ* or *Cellariidæ*. The latter is most probable, as species of this family occur on the same horizon in England. Haime[9] has recorded two species: *Terebripora antiqua*, D'Orb., which has not been figured, and the description is insufficient to determine the order to which it belongs; his second species is the *Cellaria Smithi*, Phillips,[10] which he follows Morris[11] in definitely including in

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[1] H. A. Nicholson, Descriptions of Polyzoa from the Silurian Formation, Rep. Geol. Surv. Ohio, vol. ii. Palæontology, 1875, p. 268, pl. xxv. fig. 1. The *Alecto inflata* of Hall, Palæontology of New York, vol. i. 1847, p. 77, pl. xxvi. fig. 7.

[2] James Hall, *ibid.* vol. vi. Corals and Bryozoa, 1887, e.g. *Paleschara dissimilis*, p. 35, pl. xv. fig. 11.

[3] E. O. Ulrich, Palæozoic Bryozoa, Palæontology of Illinois, part ii. sect. vi. Geol. Surv. Illinois, vol. viii. 1890, p. 366.

[4] K. von Zittel, Handbuch der Palaeontologie, Palaeozoologie, Bd. I. Abth. I. lf. 4, 1880, p. 604.

[5] James Hall, *ibid.* vol. vi. 1887, *e.g.* pl. xxx. figs. 5 and 6; pl. xxxi. figs. 12, 17, 20, 22, and 29.

[6] *Ibid.* p. 103, pl. lxvi. figs. 7–9.

[7] H. A. Nicholson and R. Lydekker, a Manual of Palæontology, 3rd edit. 1889, vol. i. p. 634.

[8] H. Michelin, Iconographie Zoophytologique, Paris, 1846, p. 243, pl. lvii. fig. 12.

[9] J. Haime, Description des Bryozoaires fossiles de la formation Jurassique, Mém. Soc. Géol. France, ser. 2, t. v. 1854, p. 217.

[10] J. Phillips, Illustrations of the Geology of Yorkshire. Part I. The Yorkshire Coast, 1829, p. 143, pl. vii. fig. 8.

[11] J. Morris, Catalogue of British Fossils, 1843, p. 39.

Hippothoa. Phillips' figure is quite useless; but, with his usual courtesy, Mr. H. M. Platnauer has kindly lent me the type which is now in the York Museum; the species, however, certainly does not belong to *Hippothoa* as that genus is now defined.

In a paper on the British Paleogene Bryozoa[1] I pointed out the occurrence of *Onychocella* in the Jurassic, and, considering the rarity of known species of Chilostomata of this age, I take this opportunity, with the kind permission of Dr. Woodward, of describing this species and one of the genus *Membranipora.* Both specimens are in the British Museum.

Order: CHEILOSTOMATA.

Suborder: ATHYRIATA.

Family: Membraniporidæ.
Genus: Membranipora, Blainville, 1834.
Species I.: Membranipora jurassica,[2] n. sp. (Fig. 1).

Diagnosis.

Zoarium: Erect, foliaceous, bilaminate.

Zoœcia: Regularly quincuncial, form hexagonal, slightly irregular. Opesia very large. Aperture occupying the whole of the opesium and markedly clithridiate in shape. Rim apparently plain, highest on the margin of the aperture, and sloping thence to the interzoœcial sutures. Front wall very small in extent, consisting only of a narrow space at the upper end of the zoœcium, sometimes replaced by oœcium.

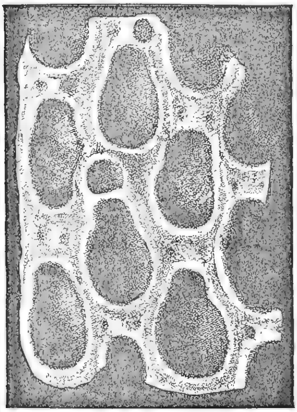

Fig. 1.

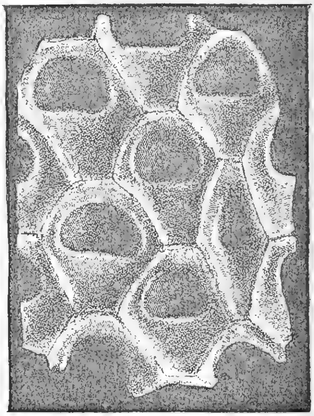

Fig. 2.

Oœcium: Cucullate, reniform in shape, surrounded by a low rim. The oœcia are sparsely scattered over the zoarium.

Avicularia: Usually a pair at the upper corners of the zoœcium,

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[1] Trans. Zool. Soc. London, vol. xiii. pt. vi. 1893, p. 239.

[2] So named as it is the first recorded Jurassic species of this genus and family.

but sometimes there is only one. The aperture is oval. They are medium in size.

DIMENSIONS: Length of a zoœcium 1·3 mm; breadth 0·85 mm.

DISTRIBUTION: Calcaire à polypiers. (Bathonian.) Ranville, Normandy, France.

TYPE: Brit. Mus. D 180.

AFFINITIES OF THE SPECIES.—This species belongs to a group which is well represented in the Cretaceous, and it is advisable to compare it with the following seven species. From *Membranipora bipunctata*, Goldf.,[1] it differs in that in the latter the aperture is oval, the zoœcia are less regular, and there is but one avicularium; the species are allied in general aspect and the structure of the rim. *M. velamen*, Goldf.,[2] resembles the new species in the shape of the aperture, but it has a more extensive front wall, larger (and possibly vicarious) avicularia, and the shape of the zoœcia is different. *M. cypris*, D'Orb.,[3] agrees in the shape of the zoœcia and the character of the rim, but has an oval aperture and no avicularia. *M. regularis*, D.Orb., agrees in the structure of the avicularia, but the other characters show that the species are clearly different. *M. tuberosa*, Novák,[4] agrees in its general characters, but it possesses numerous vibracularia and is more ornamented. Marsson's figure[5] of *M. lyra*, Hag., shows that this Maestricht species belongs to the same group, but it may be easily distinguished from *M. jurassica* by its oval aperture.

Family: MICROPORIDÆ.
Genus: ONYCHOCELLA, Jullien, 1881.
Species: ONYCHOCELLA BATHONICA, n. sp. (Fig. 2).

DIAGNOSIS.

Zoarium: Encrusting; an extensive thick crust.

Zoœcia: Skittle-shaped, the lower part being like half a hexagon, closed above by a well-rounded arc. Aperture ovato-deltoid with a blunt upper end; the lower margin is entire and but slightly curved and has a somewhat raised thin margin; the aperture is large. Front wall small, triangular, depressed; minutely granular. Raised rim, plain, non-crenulate.

Avicularia: Large, vicarious; long, tapering at each end; irregularly scattered over the zoœcium. Apertures obovate. A small, triangular front wall both above and below the aperture.

DIMENSIONS: Length of a zoœcium; 1 mm.; breadth, 0·8 mm.

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[1] *Cellepora bipunctata*, Goldfuss, Pet. Germ. Bd. I. Ht. 1, 1827, p. 27, pl. ix. fig. 7, and Hagenow, Die Bryozoen der Maastrichter Kreidebildung, 1851, p. 76, pl. ix. fig. 9.

[2] *Cellepora velamen*, Goldfuss, *op. cit.* p. 26, pl. ix. fig. 4, and Hagenow, *op. cit.* p. 97, pl. xii. fig. 1, in which the type is refigured.

[3] Pal. Franc. Terr. Cret. t. v. p. 551, pl. 607, figs. 11–12.

Flustrina regularis, D'Orb., *ibid.* p. 306, pl. 702, figs. 17–19. *Flustrina elegans*, p. 302, pl. 701, figs. 17–19, appears to be only a worn variety of this species.

[4] Novák, Beitrag zur Kenntniss der Bryozoen der böhmischen Kreideformation Denk. k. Akad. Wiss. Wien. Bd. xxxvii. Abth. II. 1877, p. 92, pl. i. figs. 1–3.

[5] Th. Marsson, Die Bryozoen der weissen Schreibkreid der Insel Rügen. Pal. Abth. Bd. IV. Ht. 1. 1887, p. 59, pl. v. fig. 17.

Distribution: Calcaire à polypiers (Bathonian.) Ranville, Normandy, France.

Type: Brit. Mus. D 181.

Affinities.—The closest allies of *Onychocella bathonica* are four species from the Cretaceous, which have been described under other generic names. It is unfortunate that there is some doubt about its nearest ally, a Maestrichtien species, described by Hagenow; in his monograph he has given two figures[1] which he assigns to the species *Cellepora* (*Discopora*) *koninckiana*; but the structure of the aperture is so different in the two, that I feel bound to assign them to different species: in his first figure the aperture is mucronate and is small; in the second (fig. 11) the aperture is elliptic, with the longer axis longitudinal, the lower margin is entire, the aperture occupies twice as large an area as in the former, and the avicularia are much larger. I therefore make Hagenow's second figure (fig. 11) into a new species under the name of *Onchyocella hagenowi.* This is the nearest ally of *O. bathonica,* but it differs in the larger size of both the avicularian and zoœcial apertures.

Onychocella piriformis (Goldf.)[2] is another ally, but has a lower zoœcial aperture, while the avicularian aperture is larger and the front wall occurs only above and not on both sides of this. *O. santonensis* (D'Orb.)[3] has a smaller mouth and longer avicularia; *O. solea* (Novák)[4] a semi-elliptical aperture with a mucronate lower margin.

The result, therefore, of the present communication is the first description of Bryozoa of the order Cheilostomata in the Jurassic; the species described belong to the two families of the *Membraniporidæ* and *Microporidæ*; but representatives in this age of the *Cellariidæ, Smittidæ,* and other families are also included in the British Museum Collection.

III.—Notes on the Composition of Clays, Slates, etc., and on Some Points in their Contact-Metamorphism.

By W. Maynard Hutchings, Esq.

(*Concluded from the January Number,* p. 45.)

After this substance has been well observed in good occurrences, it is always recognized at once, even as isolated small patches in a slide. It has a very characteristic appearance among the other constituents. It is marked off, for instance, by its special refraction from anything else that occurs in these rocks, and has other characteristics not to be missed when once observed, but not very easy to exactly describe. As soon as it ceases to be quite inert in polarized light, as soon as the speckly polarization sets in, it has also a more or less granular

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[1] Hagenow, *op. cit.* p. 95, pl. xi. figs. 10 and 11.

[2] *Eschara piriformis,* Goldfuss, *op. cit.* p. 24, pl. viii. fig. 10; Hagenow, *op. cit.* p. 75, pl. ix. fig. 6; pl. xi. fig. 6.

[3] *Eschara santonensis,* D'Orbigny, *op. cit.* p. 109, pl. 603, figs. 1–3; pl. 673, fig. 4.

[4] *Biflustra solea,* Novák, *op. cit.* pp. 94–95, pl. iii. figs. 12–16.

appearance in ordinary light with lowered condenser, which is very characteristic. In different slides, and often in one and the same slide, various stages of development may be observed in it from the first speckled appearance in polarized light up to a point where flakelets of white mica are recognized as forming in it, lying "criss-cross" in all directions. It passes in this way in some cases almost wholly into mica, with apparently other substances which cannot be identified with certainty, the transition, and connection with the original substance, being all the time distinct and beyond mistake.

In the inner zones, the "hornfels-zones," this substance is usually present in smaller amount, as already stated; but examples of its abundant occurrence are not wanting, as for instance in a hornfels from Spitzenberg, in the Harz. There is a mosaic of quartz and felspar, with brown mica and some white mica. The yellow substance lies in amongst, and surrounds, the minerals of this mosaic. It has no definite form of its own, simply occupying spaces and taking the outlines of the other minerals. It is all either in the minutely-speckly stage or variously developed from this upwards to mica; and the impression made is that if it had all developed as far as some portions of it have done, the whole mosaic-grains of the slides would be mixed in with and surrounded by white mica, as may not infrequently be observed in these contact-rocks.

Before discussing the probable nature of the substance above described, I will recur to the spots in the contact-slates at Shap. These spots are all marked off sharply by being relatively free from biotite in a rock which is very rich in that mineral, so that they appear by comparison in ordinary light as clear spaces, varying from almost colourless to a good deep yellow in some cases. The aggregations in them of anatase, ilmenite, etc., have been formerly described by Harker and Marr and myself (Quart. Journ. Geol. Soc. vol. xlvii. 1891; and Geol. Mag. October, 1891).

Examination in polarized light shows them to be of several kinds, and when a sufficient number of specimens are examined it does not appear possible to point out any special development in their nature as taking place steadily as we approach the granite. Indeed, it may be remarked of the contact phenomena in general that they are somewhat erratic as we approach the contact up Wasdale Beck, which may probably be due to irregular contour of the granite below the surface.

Harker and Marr look on these spots as being "evidently imperfect crystals, charged with a large quantity of foreign inclusions," pointing out that some of the spots are sufficiently individualized to extinguish, as to their main constituent, pretty uniformly over the whole area and frequently parallel to the longer axis. They think the mineral present is likely to be andalusite, and I was formerly of the same opinion, but after renewed examination of the slides I am no longer so. Further study of the spots of this nature, and careful comparison of them with some continental occurrences, show that cordierite is the mineral in question. It is tolerably abundant in some parts of the Shap contact near to the granite outcrop. Some slides from these parts are very closely paralleled by examples from the Elbe Valley contacts described by R. Beck (*op. cit.*), who says of some of them, "Cordierite represents the spots of the Knotenglimmerschiefer, which do not otherwise form any definite mineral." The cordierite of the Shap rocks is not in any way distinguishable from that of some of the rocks from the district described by Beck, sections of which I have examined, and also closely resembles the occurrences in rocks from the Lausitz district of Saxony. This, then, is another case in point where a definite mineral is formed in a rock wherein the real "spots" have not yet wholly died out, though less abundant than in the outer zones. There is nothing really to lend weight to the idea that any of these spots consist of andalusite, and this mineral is not detected in any of the altered sedimentary rocks at Shap.

Other spots, as previously stated, consist almost wholly of white mica, newly formed and full of quartz-grains and other things in the usual manner of this newly-formed contact-mica.

With these, and still more as we recede from the granite outcrop, are the true "spots," more or less closely resembling those above described, containing the substance in question in all its stages from amorphous, through minutely cryptocrystalline up to a definite micaceous development. And the same substance occurs in some slides outside the spots, or where these are quite absent, lying in among the mosaic minerals or surrounding them in the usual characteristic manner.

It remains to consider what may possibly be the nature of the substance seen so abundantly in the contact-slates from widely separated localities, and what are likely to be the processes to which it, and some of the other phenomena observed, owe their origin.

The first thing to remark is that the substance in question, whatever may be its exact nature, is certainly quite a *new formation.* It does not correspond to anything that can ever be observed in normal slates or shales, and we see that when it first makes its appearance in the slates, at the outer parts of contact-zones, it is mainly limited to "spots" and is in some way correlated to the "aggregations of dark grains"; also that these dark grains are very frequently to a large extent small plates of ilmenite, or crystals of anatase, or re-formed crystals of rutile, all of which either did not exist in the normal slate, or existed in a different form and not aggregated. If we consider how these aggregations of recrystallized minerals were caused, we cannot very well conceive of any process by which they migrated, recrystallized, and aggregated together *as such.* Thus, taking the simplest case, that of rutiles, in which a mineral has simply increased in size and aggregated, and not a case in which its material has reappeared in a new form, as rutile changed to anatase, or combined with iron-oxide as ilmenite, —we cannot assume that for each one of the larger and more perfect crystals seen, several of the minute "clay-slate needles" have travelled in the rock and simply combined to make one larger individual. If this could take place at all it would only be conceivable at a temperature which rendered the rock plastic, and even supposing this condition may be attained close to contact we have every evidence that nothing at all approaching to it occurs at the outer zones. We seem to have only the one explanation which harmonises with all we can observe, that this aggregation of the minerals in question is due to *solution* and recrystallization. We know that no mineral is absolutely insoluble, even in distilled water, under ordinary conditions. Rutile, *e.g.*, has been used by Dœlter as an example of this fact in his experiments. We know that increase of temperature and pressure, even in the moderate range we can command experimentally, enormously increase the solvent action of water, and that in saline solutions still greater effects can be produced.

For the observed phenomena of contact action it seems natural to conclude, and probably most people do conclude, that they can be, and have been caused by processes analogous to those in our sealed tubes and digestors. If with the comparatively moderate allowances of pressure, temperature and *time* granted to us, we can in such apparatus bring about the striking results recorded by experimenters in this direction, what may we not suppose to take place in the enormous sealed tube which is represented by deeply-bedded masses of rocks, highly heated for long periods under intense pressure, with water and solutions which cannot escape.

It may be assumed that under such conditions solutions of mineral constituents would be formed of great density, amounting to something like an " aqueous fusion " of the substances involved, and that these solutions could solidify to amorphous and more or less indefinite compounds, or would be capable, under some conditions of cooling, of giving rise to definite minerals.

It seems a not unreasonable supposition that the new substance seen in so many contact-rocks has been formed in this way, and that what we see of it represents various stages of its developments and of its residues; also that the solution supposed would have a most important part in the transformations of the minerals not originally taken up into it.

It would naturally be formed in greatest amount nearest the intruding granite, where temperature would be highest and the heat longest continued. There, also, the conditions of subsequent cooling would usually involve greater length of time and greater opportunity for recrystallization, so that in most cases we should have here least of any indefinite residue, or might often have no such residue at all left over for our observation. In the outer zones of the contacts we should have less of the dense solutions, either formed or, more likely, penetrating from the more intensely affected zones where they were abundant; but as such outer portions would soonest commence to cool again, and cool most rapidly, we should here have a larger proportion of the residues of these solutions left in an undeveloped, or slightly developed, condition.

Comparatively small portions of such solutions reaching these outer regions would tend to draw together, as little spots and patches, among the ingredients of the otherwise not much affected rock, and would consolidate in this form.

As in contact-regions generally there can frequently be observed anomalous phenomena, such as strata, or portions of strata, which have been much less or much more affected than others close to them, without our being able to explain the fact, so we have anomalies in the behaviour of these supposed dense solutions, and an inner zone may sometimes show a large amount of the less developed residual matter, as in the case of the hornfels mentioned above from Spitzenberg, and other cases of which I have specimens. A notably good example occurs in one of a series of rocks from the Elbe Valley, in which the large amount of the substance present surrounds and envelops the minerals in such a manner that a glance at a section is enough to convince the observer that it was present as a fluid medium when these minerals crystallized.

If we look at all the changes which have taken place in a well developed contact rock, like that at Shap for instance, it seems absolutely necessary, in order to explain what we see, to assume that almost all the original ingredients have been taken up into some sort of solution and completely newly formed out of it. It is not necessary to assume that they were at any one time all in solution at once, or even a very large portion of them.

A solution, or solutions, would be formed of those ingredients of the rock which were most readily acted upon by the imprisoned liquids, and the perhaps only relatively small amount of solution so formed would act as a medium for the slow solution and recrystallization of minerals, just as relatively small amounts of certain solutions and fluxes have been made to act in recorded experiments. The composition of the first solution would not be always the same. It would vary with the varying composition of the slates, etc., acted upon, but probably not in very wide limits, as the *qualitative* composition of most slates is strikingly uniform. The variation might, however, be expected to be sufficient to influence the products which would result from the crystalline development of the solutions. According to my observations the most usual development gives rise to mica in greatest quantity, but felspar and quartz also result in some cases.

Let us, finally, glance at the principal mineral changes which we know to take place in contact-metamorphism, and see what conclusions we seem justified in drawing as to how they have come about, and how these harmonise with the ideas above suggested.

(1) *Rutile.*—By universal testimony we find that in all contact-areas of slates, etc. (whether the intrusive rock is granite or a more basic rock) one of the most unfailing, as well as most sensitive, indications of commencing metamorphism is that the minute "clay slate needles" undergo an alteration by which they decrease in number and increase in size, at the same time that they become blunter in proportion to length and have more definite pyramidal terminations. This occurs so far from the intruding rock that we cannot suppose

any but very moderate thermal or other effects, due to its intrusion, to have acted; and this conclusion is borne out by the very slight effects, if any, which can be seen to have taken place in other particulars. The sedimentary rock being under those conditions of temperature and pressure due to its depth of cover, etc., the intrusion of the igneous rock may have slightly intensified the temperature at these points,—possibly also the pressure, for a time. But this has sufficed to bring about the alteration of the rutiles.

We have already considered the question as to *how* the change is brought about, and simple *solution* of the rutile appears to be the necessary process. The intrusion of igneous rock appears to have given rise to this, and as other effects are absent or so slight, we need not assume anything more than water, or perhaps a weak alkaline solution, to have come into play. The manifold forms in which the dissolved titanic acid may recrystallize have been pointed out, and we may now add brookite as a further extension of this list, R. Beck having observed its occurrence in the rocks of the Elbe Valley contacts, in a manner exactly similar to that of the Anatase at Shap.[1]

(2) *Biotite.*—Perhaps the next mineral change, in degree of sensibility, is the appearance of biotite in the slates undergoing contact-metamorphism, which is also a matter of universal observation. It takes place at considerable distances from the contact, and may be seen already far advanced before the formation of regenerated quartz-mosaic and other minerals is demonstrable.

A large number of slates, etc., contain a good deal of chlorite, which was deposited in them at a period subsequent to their formation as such, by simple infiltration processes. This chlorite is altered into biotite.

This change, like the one last considered, also cannot be explained by *direct* action of raised temperature or pressure. No amount of simple "molecular rearrangement" of chlorite under heat or pressure will make biotite of it. A portion of its water could be removed, as is required; but it has also to take up potash, and here again we must look to solutions, which in this case must contain some alkaline salt.

There are, again, many slates, shales, etc., which are wholly or almost free from chlorite, but which contain a sufficient amount of magnesia to correspond to a good deal of biotite, this magnesia appearing to have entered into combination in the new micaceous minerals existing in the slate, etc. Under contact-action biotite may be, and is, developed in such slates, and this could take place by easily conceivable molecular rearrangements.

Whether it be possible for flakes of chlorite, lying in among flakes

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[1] Even this list of changes does not exhaust the number of transformations the titanic acid may undergo. At later stages of the metamorphism it appears that part of it can be taken up into the newly-formed contact-biotite, thus ending up where it began,—combined in dark mica. Such contact-biotite has been shown, by Lang and Jannasch, to contain as much as 3.40 per cent. of titanic acid, and Beck records (*op. cit.*) cases of *decayed* contact-biotite in which rutile has once more been separated out.

of muscovite, to be converted into biotite by direct combinations with those minerals we cannot say. Probably some geologists would not doubt the power of intense pressure to bring this about. We may question whether pressure alone could do this, or anything like it, but when high temperature and water are also considered, acting at the same time, we must at least look on this method of formation as not outside the limits of consideration.

(3) *Newly-formed quartz and felspar.*—We cannot well consider the occurrence of these "regenerated" minerals separately, because though they may not occur together, yet when they do so occur their modes of formation appear to be intimately connected.

The quartz is the more frequent, and, even when felspar occurs, is the more "sensitive," occuring at earlier stages and being often largely developed before any felspar is seen.

It seems obvious that the quartz-grain of the "contact-mosaic" bears no direct relationship to the clastic grain of the original slates, etc. The latter, with its more or less angular outlines, its fluid-cavities, and its practical freedom from enclosures, has disappeared, and in its place we have the round, or in the best-developed mosaics the polygonal, grain, free from fluid cavities, and containing usually numerous microlites, biotite crystals and grains, and other enclosures, these grains of quartz fitting to one another and to the other constituents of the mosaic quite closely and exactly.

It is here still less possible to see how this change can be due to any simple re-formation of each individual grain of quartz,—to its mere recrystallization *in situ.* Neither is it due to any simple addition to its outer portions of any freshly-deposited silica. Looking at these mosaics carefully, it does not seem easy to come to any other conclusion than that the quartz in them, as a whole, has recrystallized out of some sort of solution in which were, forming or already formed, the microlites and other bodies which are now enclosed within the quartz grains.

Many fine-grained slates do not contain any distinguishable grains of quartz at all, and in these, as also in slates where such grains are plentiful, there is a good deal of exceedingly finely-divided quartz or other forms of free silica. It is equally difficult to see how this could be formed up into the larger grains of the mosaic, and charged with enclosures, without a previous re-solution and recrystallization.

Taking now the felspar, where such occurs, all the same considerations apply. The grains in the mosaic have the same characteristics as regards general outlines, enclosures, etc., and it is clear that the quartz and felspar were crystallized *together*, though there is a distinctly greater tendency in the felspar to develop idiomorphic forms.[1]

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[1] It should be noted that the "tesselated" or "mosaic" structure is by no means peculiar to the alteration of *sedimentary* rocks. At Shap, for instance, it is very beautifully developed in some of the altered rhyolitic and andesitic ashes in the contact-zone; sometimes it is quartz alone, sometimes quartz and felspar, and sometimes felspar alone which forms these mosaics.

A tesselated structure has been looked upon by some observers as quite specially a result of *dynamic* metamorphism, but this idea can, of course, no longer be enter-

It is to be noted that during the stage of metamorphism which develops the mosaic of quartz, or quartz and felspar, the biotite formed at an earlier, less intense, stage undergoes further alteration. It may be seen (as at Shap) that the earlier biotite is more ragged and indefinite in form, is less dichroic and less bi-refractive than that which exists in the mosaics nearer contact. Whether it is redissolved and recrystallized in part it does not seem possible to decide; but the biotite which is *enclosed* in the quartz and felspar is of much interest, and may give us some indications as to the degree of temperature which prevailed during the processes. In addition to small flakes and more or less definite *crystals,* we see numerous oval grains and little *balls* of biotite, whose forms seem to indicate that they were quite plastic at the time of inclosion, and we may well assume that in these zones there was a condition of aqueous fusion of sufficient intensity to melt, or soften, portions of the biotite.

The interesting question arises as to the mode of origin of this new felspar: What is it made from?

It may, I consider, be stated as a fact that *new* felspar does not exist in any normal slates, no matter how highly developed they are. I have given much time and patience in studying this special point, and have convinced myself that no regeneration of felspar takes place. In the Cornish slates no trace of felspar of any kind is seen, though these are so very highly developed. Rénard records the same absence of it in the very similar Ardennes rocks.

In Welsh slates a few grains are sometimes seen of *clastic* felspar more or less altered, and this is seen in other slates also, but such grains are rare and unevenly disseminated. At Shap, as before stated, no trace of it is seen in the less altered slates, though it is so abundant in the well developed mosaics. We have, therefore, in most cases not to deal with a recrystallization of an already existing mineral, but with the formation of this mineral from other materials. The average and normal slate is composed of the materials which make up the clays with which I dealt in the first part of this paper. The simplest explanation, and indeed perhaps the only one open to us on the evidence in our possession, is that the materials of the mica and the quartz of the slates combine, under the conditions we are supposing, to form felspar. In its decay felspar yields mica and free silica, and it is perfectly simple and easy to comprehend how, under the conditions of temperature pressure, etc., we are supposing, with the intervention of such a dense mineral solution as I have shown cause for believing to exist, the reverse process may take place, and we may have a *partial*

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tained. It may be well seen in igneous rocks. Thus, General McMahon shows it to occur in the marginal portions of Dartmoor granite (Q.J.G.S. vol. 49, p. 388), and has previously shown its occurrence in granite of the Himalayas. It is also, as is well known, seen perfectly developed in the groundmass of some quartz-porphyries, not to be distinguished, as to its structure and general appearance, or in anything except its inclusions, from some of the finer-grained mosaics of altered slates. In considering this structure in the contact-metamorphism of slates it is a point of some importance that exactly similar structures can be seen to result during the consolidation of purely igneous magmas.

re-formation of the felspar which originally formed part of the deposits of the slates, but which no longer existed in them as such.

(4) *White mica.*—In some, probably in most, contact-areas a good deal of white mica is newly-formed. It may not be always easy to trace the exact stages of the process. The original slates are usually rich in white mica to begin with, and the recrystallization of the mineral in the earlier stages of contact-metamorphism is not readily distinguishable. But in the more advanced stages we see it more plainly, and find a good deal of mica which from its general appearance and relationship to the other minerals is clearly re-formed, this being also demonstrated frequently, as to larger individuals, by their being more or less charged with quartz-grains, etc., in the same manner as are the biotite-flakes and crystals, and the other newly-formed minerals.

In addition to this mica which appears plainly to have re-crystallized in a manner exactly similar to that of the quartz and felspar, we often see also the mica of which I have spoken as appearing by various stages in the newly-formed substance to which so much reference has been made, and which in the fullest form of its development will remain as patches among the mosaic, or as fringes round its component minerals, and may not in all specimens be visibly connected with any residual portions of the substance out of which it originated.

(5) *Cordierite, Andalusite, Cyanite, Sillimanite.*—These are the minerals we may perhaps designate as more specially "contact-minerals," and we may safely say of them that the conditions of their formation, and why sometimes one is formed and sometimes another, are the points as to which we probably know least of all.

As regards cordierite, it appears to stand in a somewhat different position from the rest. It is not a silicate of alumina only, and its formation appears to take place often at a much earlier stage of the metamorphism. It is also a much less stable mineral than the others.

Looking at the composition of cordierite and the mode of its occurrence in these contact-rocks, the most reasonable supposition as to its origin appears to be that when the recrystallizations and rearrangements of the minerals commence, the cordierite, when formed, largely represents the magnesia which is combined in the mica of the slates,—mica which we call sericite and which we have good reasons to regard as muscovite into whose composition magnesia has been taken. As recrystallization of this mica takes place, it will have a tendency to purify itself, and to approach more nearly to the normal muscovite, with more potash and less of other bases; and the magnesia will be available for the formation, more usually of biotite, but under conditions we cannot specify, more or less of cordierite forms also.[1]

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[1] It seems desirable to point out that there is risk of sometimes confusing cordierite and felspar in such rocks, where the cordierite occurs as smaller grains and is not a striking constituent. In the books we are warned against mistaking cordierite and quartz; but a similar warning does not seem to be given as regards felspar. As regards quartz the risk does not appear to be great. Where there are several grains

Staurolite may be appropriately mentioned at this point. It is also not a silicate of alumina only, and from its chemical composition may be reasonably supposed to have an origin of somewhat similar nature to that of cordierite.

It does not appear to occur as frequently as the other minerals now being considered; but when it occurs it seems to form in the less intense stages of metamorphism, as for instance in the example studied by Mr. Barrow, to which reference is made below.

As regards the other minerals, the aluminous silicates, it is usually assumed that they represent the "kaoline" of the slates, etc., and there is on the face of it much in favour of this view. If this be so we should expect rocks rich in alkali in proportion to alumina to give little or none of these aluminous silicates during metamorphism, and there are cases where this is borne out, as at Shap for instance. But I do not think that an examination of the analytical evidence in general will show that we can make a rule of this. There are analyses of rocks very rich in andalusite, for instance, which show high percentage of alkali; and copious development of andalusite and felspar may take place together, as is seen in some of the Andlau rocks. At Shap also, we have altered rhyolitic ashes in which there is a great deal of newly-formed felspar, together with andalusite, and an unusually large development of sillimanite. Therefore it would appear as if the formation of these minerals is a more complex question than to depend simply on certain ratios among the chemical constituents of the rocks metamorphosed.

For the rest, looking at their chemical composition and their mode of appearance in our sections, their relationships to other minerals, etc., it would be even more difficult than in other cases to imagine their origination in any other way than by a dissolving-up and complete re-combination of the original materials of the slates, etc.

Concerning the conditions determining *which* of the aluminous minerals shall be formed, we have as yet very little to guide us; but in a paper of exceptional interest, recently read before the Geological Society, Mr. Barrow produces evidence to show that probably difference of temperature is the principal controlling element. In his work on a contact-region in Scotland, Mr. Barrow has observed that sillimanite, cyanite, and staurolite occur in the order named as we recede from the actual contact, and he suggests that the occurrence of each mineral coincides with a zone of temperature. He correlates this observation with the experimental

of cordierite in a slide it will nearly always be possible to prove that we have a *biaxal* mineral before us, and therefore not quartz. But in a thin section it may often happen that we cannot say whether the biaxal grain is cordierite or felspar, simply by its optic examination. Felspar grains, without any cleavages or definite forms, occur in these rocks. The refraction and bi-refraction are not sufficiently different to serve as guides when cut thin, and in many of the best occurrences of cordierite in contact-slates the dichroism of the mineral, and the "halos" round its enclosures, are not discernible at all in most grains. Enclosures, etc., may aid in discrimination, and usually do so; but I have satisfied myself that the determination is often a difficult one, and think that there is considerable chance of cordierite being overlooked in some cases in consequence.

work of Vernadsky, in which it was shown that when cyanite is heated to 1300°—1400° C. it is altered to sillimanite.

Mr. Barrow has made it appear very probable that in the hotter zones of contact sillimanite will be formed, that cyanite will take its place when a certain limit of lower temperature is reached, and staurolite will occur in the still cooler outer zone. No doubt these observations of Mr. Barrow in this particular district will cause the point to be carefully studied elsewhere.

Mr. Barrow further infers from Vernadsky's experiment that we may conclude that in the "sillimanite zone" of contact-rocks there has been a temperature of 1300°—1400° C. or over. This seems rather straining the matter; and certainly attempts in the past to draw conclusions as to rock-temperatures from experiments on minerals in the laboratory have not been so happy in their results as to encourage repetition, however tempting a system of "recording pyrometers" in the rocks may appear. It does not seem in the least necessarily to follow from Vernadsky's experiment, either that the sillimanite in the rocks was produced from cyanite, or that the formation of sillimanite *instead of* cyanite in the hotter zones indicates that the temperature was 1300°—1400° C. or that there need be any definite relationship whatever between the temperature at which it forms in these rocks and that at which it may be produced, from another mineral, in a laboratory-furnace.

If contact-metamorphism be due entirely to the thermal effects of the intrusive rock, as now seems usually to be believed, we should expect to see these effects always the same, in kind, on the same variety of rocks undergoing metamorphism, and the alterations due to a dolerite should not differ from those due to a granite. In the main this seems to be borne out, but there are some important points which still call for a good deal of attention.

I may state that so far as my own observations go, in which I am still engaged, there is, for instance, a formation of the same substance, due to the same causes, as I have described above; but it is present in less amount, and a larger proportion of it remains in the amorphous, or slightly developed, state. Also there is much less formation of "mosaics" and these again much less developed. These facts can be easily understood by having regard to the relative smallness of the masses of igneous rock acting in the observed occurrences, and the consequent less *time* during which recrystallization would be able to go on.

It does not appear that isotropic substance is much mentioned by observers of altered slates, etc., at *granite*-contacts; but it is frequently spoken of where the intrusive rock has been "diabase."

The most striking difference, however, between acid and basic contacts, so to speak, lies in the fact so often recorded, and backed up by so much evidence, microscopic and chemical, that there is a transfer of material from the intruding basic rock to the slates, etc.; a transfer which is large in proportion to the relatively small masses of igneous rock concerned in it. It is shown by the increase of *soda* in the altered rocks, chemically considered, this increase being again represented mineralogically by the formation of albite and probably other soda-bearing felspars.

The transfer has been disputed by some observers, but the evidence is too strong to be denied, even if it may be proved that there are exceptions. It has also been suggested that the transfer has not taken place at the time of intrusion,—that it is not a contact-phenomenon at all,—but is due to later processes connected with the decay of the igneous rock. This is a point still calling for investigation.

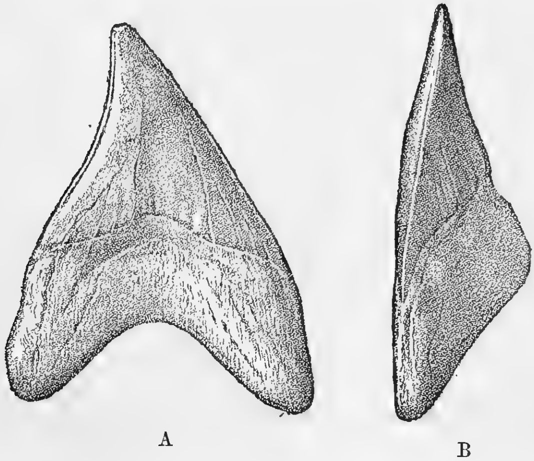
I hope later on to deal with the subject of these basic contacts, as I am at present engaged in examining a large series of such rocks.

All that I need here remark is that I have fully satisfied myself of the transfer of soda, and of the presence in some cases of large amounts of isotropic material due to contact-action.

IV.—NOTE ON A TOOTH OF *OXYRHINA* FROM THE RED CRAG OF SUFFOLK.

By ARTHUR SMITH WOODWARD, F.L.S., F.G.S.

ALL the Selachian teeth hitherto obtained from the English Crags referable to the genus *Oxyrhina* are much compressed antero-posteriorly, and are thus slender in proportion to their size. They are now commonly regarded as representing a single extinct species, *Oxyrhina hastalis* of Agassiz,[1] and the same form of dentition is abundant in the Pliocene of Italy, besides occurring in other Tertiary deposits in various parts of the world. In Italy and Belgium, however, these comparatively slender teeth are accompanied by a few



Tooth of *Oxyrhina crassa*, Ag., natural size, from the external (A) and lateral (B) aspects; Red Crag, Hemley Hall, near Woodbridge, Suffolk. [Collection of T. W. Reader, Esq., F.G.S.]

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[1] Smith Woodward, "Catal. Foss. Fishes, B. M.," pt. i. p. 385; E. T. Newton, "Verteb. Pliocene Dep. Britain" (Mem. Geol. Surv. 1891), p. 106, pl. ix. fig. 15.

others of the same genus of very robust proportions; and some of these have received the names of *O. Benedeni,*[1] *O. gibbosissima,* and *O. Forestii,*[2] while others have been identified with *O. crassa* and *O. quadrans.*[3] So far as the present writer can judge, none of these robust teeth are capable of being satisfactorily distinguished from the species *O. crassa* of Agassiz, originally described from the Miocene of the Rhine Valley;[4] and it is under the last-mentioned name that they are recorded in the British Museum Catalogue.

It is now of interest to announce that the same form of robust tooth has lately been obtained from the English Pliocene. The specimen was discovered by Mr. T. W. Reader, F.G.S., in the Red Crag of Hemley Hall, near Woodbridge, and it is shown of the natural size from the external and lateral aspects in the accompanying figures. As indicated by its shape, the tooth must have occupied a postero-lateral position in the mouth, probably in the upper jaw; and a specimen most closely approaching it is described by Lawley from the Pliocene of Italy under the name of *Oxyrhina quadrans.*[5]

In general aspect, of course, the new fossil is at first sight suggestive of a tooth of the so-called *Otodus obliquus*, wanting the lateral denticles. The specimen, however, is quite unabraded and has not the appearance of a derived fossil; while it is certain that the absence of denticles is not the result of fracture. It may be that some such robust teeth are abnormal examples from the dentition of *Otodus obliquus*; but, in default of all proof of this possibility, it seems advisable to retain the nomenclature here adopted.

V.—AN ANCIENT GLACIAL SHORE.

By T. MELLARD READE, C.E., F.G.S., F.R.I.B.A.

IN a cutting of the Seacombe Branch of the Wirral Railway at the present moment is to be seen a deposit which cannot be other than a glacial shore.[6] It is about 18 inches thick, covered by a bed of Boulder-clay some 8 feet thick, and has been exposed by the cutting for a distance of 16 chains running south-east and north-west, to the south-east of the point of intersection of the Railway with Poulton Road. The rise is 16 feet in this distance at a regular up-grade towards Poulton Road, and the average level about 60 feet above O.D. Transversely to the Railway it is about level, and over the whole of the area—1056 feet by 30 feet=3520 superficial yards—the deposit occurred and was excavated by the steam navvy. The bed is composed of pretty clean sand with some small gravel, and is crowded with shell fragments in all stages of decay. It is precisely like a modern beach in constitution, extent and slope, but what renders the fact more certain is the

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[1] H. Le Hon, "Prélim. Mém. Poiss. Tert. Belg." (1871), p. 6, with figure.

[2] R. Lawley, "Nuovi Studi Pesci, etc., Colline Toscane" (1876), p. 31.

[3] R. Lawley, *ibid.* and "Studi Comp. Pesci foss. coi viv. generi *Carcharodon Oxyrhina,* e *Galeocerdo*" (1881), p. 112, pl. iv. (*Oxyrhina*), fig. 2.

[4] L. Agassiz, "Rech. Poiss. Foss." vol. iii. (1843), p. 283, pl. xxxvii. fig. 16.

[5] *Op. cit.* 1881, pl. iv. (*Oxyrhina*), fig. 2.

[6] I am indebted to Mr. Henry Beasley, the Hon. Sec. of the Liverpool Geological Society, for calling my attention to this interesting bed.

great quantity of clay balls or boulders mixed with the sand. These balls are covered over their surface with small gravel, shells and sand, picked up as they rolled about on the beach, just like the mud balls we find on the shore at Crosby at the present day. On being cut into with a knife these clay balls are seen to be formed of ordinary compact brown Boulder-clay, and they are pretty hard. The contractor, Mr. Davies, who is much interested in the geology of the cutting, tells me that these clay balls are found all over the area in great profusion, and as far as I tested the bed, which I did in at least half-a-dozen places, I found the statement correct. He also informed me that the bed is underlain by silt, but it has not been tested more than a few feet deep. I picked up and brought away about twenty clay balls varying in size from 3 inches down to $\frac{3}{4}$ inch diameter, some of them being spherical and others ellipsoidal in form.

These balls or boulders can, I believe, only be found on the shores of tidal seas, where they get partially dried during the recession of the water twice in 24 hours, and more dried at neaps. If they were constantly immersed they would get dissolved.

In the GEOLOGICAL MAGAZINE for 1878, p. 571, I described the formation of clay boulders from the Estuarine clay on the Crosby shore, and shortly afterwards was informed by the late Mr. Binney, F.R.S., that he had found similar boulders in the Boulder-clay in a railway cutting near Crumpsall[1] 207 feet above the sea-level. But such boulders are not only made from stiff clay; the recent mud deposits yield them also, and, as I said before, they are quite a common phenomenon on our shore. I have seen a few in drift on other occasions, but in nothing like the regularity and profusion shown in the instance I am describing.

Glacialists who are satisfied with no explanation of drift phenomena which does not ascribe everything to land-ice continually ask those of more moderate views who still believe the sea had a considerable share in the work to show them shore-lines. With this object I forward these lines, and there is no doubt the ancient beach is much more extensive than the portion touched by the excavation.

I may add that glacial striæ bearing N. 25° W. are to be seen on the Keuper Sandstone when bared of Boulder-clay, in the same cutting, but at a higher level and more to the north-west.

POSTSCRIPT, *December 6th.*—Since the above was written the excavations from Poulton Road to Mill Lane have disclosed a continuation of the beach a fresh distance of 10 chains. At this western extremity the clay boulders occur, but not in such profusion, and the sand increases in thickness. Allowing for the curve in the line, the plane of the beach is continued at the same slope. The laminations of the bed south-east of Poulton Road are now very apparent, and thin beds of small clay balls are intercalated in the laminæ.—T. M. R.

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[1] See "On Boulders of Clay from the Drift" by E. W. Binney, Proc. Lit. and Phil. Soc. of Manchester, 1879, p. 40.

VI.—Post-Glacial Man in Britain.

By William Shone, F.G.S.

THE relative position of post-Glacial Man to post-Glacial geology has been a rather neglected field of research. This borderland between the domains of the Archæologist and the Geologist appears to have been treated as neutral ground, yet entombed in it are the relics of Neolithic Man and the first evidences of the dawn of civilization. It may be alleged that the splendid results of cave exploration have given us a better idea of man's evolution from a savage to a civilized existence than could have been obtained from any other source. Whilst this must be admitted, cave research can furnish very little evidence of the great physical changes which went on outside such abodes. If for instance man can be proved to have been an inhabitant of Western Europe during the Glacial epoch, the gradual change of the climate from frigid to temperate may have had a powerful influence in modifying his habits and thereby assisting his development from the state of a rude savage to that of a civilized man. Deposits in caverns aid very little in this work. They are for the most part choked-up subterranean water-courses, and it follows that any deposits found therein may have been subjected to much disturbance. The most slender evidence derived from cave deposits is even by such distinguished geologists as Prof. Hughes and Prof. Boyd-Dawkins thought quite sufficient to determine the momentous question whether Palæolithic Man was Glacial or post-Glacial. Prof. Boyd-Dawkins decides the matter in his "Early Man in Britain," p. 192, in the following very summary manner:—

"Palæolithic man has left no traces of his presence in the caves of Castleton and Matlock. They have, however, been met with in several caverns in Wales, such as those of Pembrokeshire and Monmouthshire in the south, and in that of Pont Newydd, near St. Asaph, in North Wales. In the latter a human molar tooth has been found, as well as a *quartzite implement and rude splinters and chips of quartzite, of the same type as those of the red sand and in the caves of Cresswell. The pebbles of which these are made have been obtained from the Glacial deposits in the neighbourhood. We may therefore conclude with Professor Hughes, that the Palæolithic hunter was here after the district was forsaken by the glaciers and the sea, or in other words, in post-Glacial times, as in the parallel case offered by the river-deposits of Bedford and Hoxne. It must also be remarked that the leptorhine Rhinoceros and the Hippopotamus, as well as the straight-tusked Elephant (*E. antiquus*), Bear, Bison, Reindeer and Horse, are found with the quartzite implements in the Pont Newydd cave, which may therefore be classified with those of Yorkshire and the lower strata in Mother Grundy's Parlour."

Mr. Morton, F.G.S. (Geology of the Country around Liverpool, second edition, pp. 188, 189) makes the following comments upon the passage: "Professor Boyd-Dawkins, F.R.S., objects to the Pont

Newydd caves being pre-Glacial, on the ground that stone implements were found in them made from rock which occurs as boulders in the Drift in the neighbourhood; but it seems quite as possible that man may have obtained the stone from its original locality, or from moraines in the early period before the district was submerged, as it had been brought near to the cave in the form of boulders." Mr. Morton's conclusions are further strengthened by the occurrence of veins of quartzite in the neighbouring Wenlock Shale of the Moel Fammau range. Such a suspicion being possible at once destroys our confidence in the assumption that the quartzite implements of Pont Newydd prove Palæolithic Man to be post-Glacial. Then follows the important statement by Professor Boyd-Dawkins, viz.: "The presence of the leptorhine Rhinoceros, Hippopotamus, and straight-tusked Elephant, probably marks the earliest phase of the occupation of the caves of Europe by the Palæolithic hunter."

If Britain were inhabited by this early race of Palæolithic hunters they must have traversed large areas of the surrounding country in search of food. In the excitement of the chase it is inconceivable that they should not have left many a lost weapon, which would to-day testify to their existence in post-Glacial times. Taking England from the Midlands to Berwick-on-Tweed, was ever country so delved to make roads, harbours, mines, canals, railways, and great towns and cities, yet no trace of this Palæolithic hunter or of his contemporaries "the leptorhine Rhinoceros, Hippopotamus, and straight-tusked Elephant," has ever been found over this area upon a post-Glacial surface or in post-Glacial strata.

NEOLITHIC MAN.

How different in the case of Neolithic Man; his relics are spread far and wide over the land. A little careful study of the geographical and topographical distribution of his relics, as recorded in Sir John Evans's "Ancient Stone Implements of Britain," will soon afford ample proof. Neolithic Man belongs to the surface period. On the Yorkshire Wolds his flint implements are scattered in profusion, occuring in a foot of soil resting upon Chalk. Wherefore the absence of the quartzite or flint implements of Palæolithic Man, if he be post-Glacial? Again, if we search the Western shores, we find the weapons of Neolithic Man, as at Delamere, Beeston, and Tarporley in Cheshire, upon the surface of the Glacial drift. Any trace of Palæolithic Man is absolutely unknown. If we examine the extensive low-lying plains, bordering the coast-lines of Cheshire and Lancashire, the submerged peat and forest beds of these counties have never yielded the slightest clue of Palæolithic Man or of the Mammalia characteristic of the Palæolithic age.

If, over that portion of Britain which was covered by the Glacial Drift, Neolithic Man was post-Glacial, and early Palæolithic Man of Pont Newydd pre-Glacial, the Glacial Drift must fill the gap between. In that case the Drift will be the equivalent of the various gradations of Palæolithic Man in the driftless areas of Belgium and France. There are two points which would appear to strengthen this conclusion: the negative one, viz. the absence of any evidence of Palæolithic Man over the areas covered by the Glacial Drift; and the positive evidence of the amelioration of the climate of Western Europe at the close of the Glacial epoch, corresponding to the amelioration of climate which characterized the end of the Palæolithic age and the advent of Neolithic Man. The retreat of the Boreal Mollusca northwards at the close of the deposition of the Drift is a very significant fact if it be considered in conjunction with the dispersion of the Mammalia northwards and Alpwards at the termination of the Palæolithic age.

In considering the relations of Britain to the events of the Glacial epoch, it should be borne in mind that our Island was situated on the confines of that portion of the Northern Hemisphere which suffered glaciation. It was one of the last places the ice-sheet reached, and one of the first from which it retreated. The supposed great time required for the formation of the Glacial Drift and the post-Glacial deposits has blocked the way to any successful attempt to synchronize the Drift with the older river and cave deposits, containing the relics of Palæolithic Man and his Mammalian contemporaries. There are, however, no internal evidences in the Drift deposits indicative of any great antiquity. We frequently find them resting upon glaciated surfaces so perfectly polished, and with delicate striæ so exquisitely preserved, that it might have been but yesterday that the glacier which caused them had retreated, and not, as some affirm it to have been, thousands of years ago. Then, if we examine the Boulder-clay we meet with Foraminifera embedded in it, yet despite their long emtombment their shells show no signs of decay.

The Drift rarely exceeds 300 feet in thickness. If it were formed at the rate of a quarter of an inch per annum, a little over 15,000 years would suffice for its accumulation.

We possess, of course, no geological data for the foregoing or any other geological calculation of the measure of the duration of the time represented by the Glacial Drift. Therefore, no reasonable objection on the ground of the great lapse of time required for the formation of Glacial and post-Glacial strata can be taken against synchronizing the Palæolithic age with the Glacial Drift, and Neolithic Man with post-Glacial times.

* Query: "felstone," for which see Prof. Hughes' most interesting paper upon the "Drifts of the Vale of Clwyd" (Q.J.G.S. vol. xliii. p. 107). It is quite immaterial, however, to the argument, whether the implements found in the "Pont Newydd" cave were composed of "quartzite" or "felstone," as both rocks would have been equally accessible.

VII.—The True Horizon of the Mammoth

By Mark Stirrup, F.G.S.

In the abstract of the proceedings of the meeting, on November 8th, of the Geological Society of London, I notice that on the reading of Dr. G. M. Dawson's "Notes on the occurrence of

Mammoth-remains in North-West America" the author cites the presence of Mammoth bones in a layer of clay *resting on* the "ground-ice" formation of the northern coast of Alaska and other areas.

I drew attention to this position of the Mammoth bones *above* the solid ice both in North Siberia and Alaska, as proved by several explorers, in my paper on "The True Horizon of the Mammoth" (Geol. Mag., No. 345, p. 107, March, 1893), in which I claimed for the Mammoth an existence long after the period assigned for its extinction by Sir Henry H. Howorth.

I see that Sir Henry, in the discussion of the paper, very naturally disagreed with the conclusion of Dr. Dawson as to the age of what is called by American geologists the "ground-ice" formation, and was of opinion "that this ice has accumulated since the beds were laid down in which the Mammoth-remains occur, and that the ice was not there when the Mammoth roamed about in the forests where he and his companions lived."

Furthermore, he is reported to have said that "humus and soil cannot accumulate upon ice, except as a moraine," both of which statements are controverted by the explorations of recent and competent observers who have examined these regions.

In support of my contention I need only refer Sir Henry to the explorations of Dr. W. H. Dall in the Alaskan regions (which I quoted in my previous paper), and to the evidence of other observers which Dr. Dall summarizes in the Bulletin of the United States Geological Survey, No. 84, pp. 260–267, recently issued. Dr. Dall, speaking of the "ground-ice" formation, says "a remarkable formation has been recognized in many places in the northern part of Alaska, in which solid beds of ice of considerable thickness perform the functions of rock strata and are covered by beds of blue clay containing numerous remains of Pleistocene mammals, or by beds of alluvium which sustain a layer of turf, with ordinary profuse herbage of the region, or even small thickets of birch, alder and other small Arctic trees."

These mammalian remains include, among others, tusks, teeth and bones of the Mammoth, *E. primigenius*, bones of *Bison antiquus*, and the Musk Ox. The mode of origin of this ground-ice formation is undoubtedly difficult of explanation, but its position *beneath* the Mammoth-bearing beds is uniformly the same, whether in the cliffs of the coast or in those bordering the Alaskan rivers.

Dr. Dall, referring to the stratigraphical position and mode of accumulation of the bones, says, "that all the circumstances point toward the view that the ice *preceded* and subsequently *co-existed* with animals whose remains are now found in its vicinity."

Lieut. J. C. Cantwell, United States Revenue Marine, reporting on the Kowak river ice-cliffs discovered by him in 1884, says "they are composed of solid ice, covered by a layer of dark-coloured earth, uniformly about 6 feet thick, the whole rising to the height of 15 to 150 feet, with trees 4 to 8 inches in diameter growing on the surface."

He goes on to say, "quantities of Mammoth tusks were observed in this clay and its débris, where undermined by the stream. These clays were doubtless of the same age as those in which the Mammoth-remains are found at Elephant Point, *over* the ice-cliffs.

In consideration for your valuable space, I refrain from quoting further evidence as to the superposition of the Mammoth-beds over the solid ice stratum.

The question of the food supply necessary to the existence of the extinct herbivorous mammals which once roamed those arctic plains, seems to be settled by the actual existence of an abundant, though arctic, flora in these apparently inhospitable wastes.

Travellers speak of the dense thickets of willow, through which they have to push their way, and also of the luxuriant growth of grass covering the peaty or clayey soil.

Moreover, Dr. Dall mentions, singular as it may seem, the fact of dwarf birches, alders, 7 or 8 feet high, with stems 3 inches in diameter, and a luxuriant growth of herbage, including numerous very toothsome berries, growing with the roots less than a foot from perpetual solid ice.

Sir Henry Howorth's explanation of the mode of formation of these massive beds of ice by filtration of water through the soil is certainly inconsistent with the structure and purity of the ice. The ice, 50 to 150 feet thick and upwards, where exposed in sections of the cliffs, is described by several observers as pure, clear ice. Dr. Dall says "the ice in general had a semi-stratified appearance, as if it still retained the horizontal plane in which it originally congealed. The surface was always soiled by dirty water from the earth above. This dirt was, however, merely superficial."

The facts that I have thus briefly cited are wholly opposed to Sir Henry Howorth's assumption that the present is the coldest period known in recent geological times in Siberia and Alaska, and further, I contend that the elaborate arguments and conclusions embodied in his "Mammoth and the Flood" and his "Glacial Nightmare," so far as they rest on his assumption of the pre-Glacial age of the Mammoth, receive no support from the evidence derivable from North Siberia and Alaska.

REVIEWS.

I.—ZUR HISTOLOGIE DER FALTENZÄHNE PALÄOZOISCHER STEGOCEPHALEN.

On the Histology of the plicated (folded) teeth of Stegocephali. By H. CREDNER. Abhandl. der mathemat.-physischen Classe der K. Sächsischen Ges. der Wissenschaften. Band xx. No. iv. Mit vier Tafeln und fünf Textfiguren. Royal 8vo. pp. 477–552. (Leipzig, 1893.)

WITHIN the last thirteen years Professor Credner has made us acquainted with the Stegocephali and Saurians of the Permian limestone near Dresden, from the smallest salamandrine

Branchiosauri up to the huge *Sclerocephalus* with almost inch-long teeth.[1] Their variety in external appearance, as well as in the extreme specialization of their skeleton, in which they diverge in a more or less degree towards the Reptilia, is so extraordinary that we have to look for their progenitors in still more remote periods. On the other hand, the less varied teeth, studied in the present Memoir on the dentition of *Sclerocephalus labyrinthicus*, Gein. sp., are proved, by their histological details, to be ultimately the homologues of the minute teeth of certain ichthyous scales, and at the same time throw an unexpected light in an opposite direction, inasmuch as we begin to have a clue as to the primitive form and the evolution of the Vertebrate tooth in general.

In the first chapter, the dentigerous bones of the buccal cavity (viz. the premaxilla, maxilla and mandible the anterior alæ of the pterygoid and the palatine), as well as almost all the bones of the skeleton, are shown by their characteristic structure to be *dermal bones*, nearly related to the *Ganoid* scales. The dermal bones of the cranium, particularly, prove to be the exact homologues of these last, as they are composed of the same three strata: (1) a thin basal stratum of calcareous lamellæ (*Basalschicht von Kalklamellen*), followed by (2) a much thicker stratum of osseous tissue, which is distinguished chiefly from that of the enchondral bones of the rest of the skeleton (including the quadrate and articular of the mandibular articulation) by a dense system of blood-vessels (*Haversische Canäle* of Klaatsch), extending in a horizontal direction, according to the plane of the greatest extension of the bone. (3) The minute external covering of the osseous plates is formed by a delicate layer of *Osteodentine*, which, in the dentigerous bones, continues directly into the dentine cones of the small cuspidate teeth.

The same homology exists between the minute palatine teeth of *Sclerocephalus* and the small teeth of the *Ganoid* scales; both are cuspidate dentine cones, provided with a delicate enamel cap and a large pulp; their basal expansions are fused into the layer composed of a modification of dentine (*Ganoin*), which covers the second stratum above described.

The histological structure of the large jaw teeth is closely investigated on ten transverse sections, and leads the author to the conclusion that these plicated teeth (*Faltenzähne*) of *Sclerocephalus* owe their origin to the coalescence of the elements (*Anlagen*) of numerous most primitive teeth, similar in shape to those on the palatine bones; whereas the cement-ridges (*Cementleisten*) of the jawbones are formed by a fusion of the basal layers of the jaw teeth.

All the larger teeth, uni- or multi-cuspidate, of the *Eotetrapoda*, and consequently likewise of the higher Vertebrates generally, are thus shown to be *polysynthetic*, viz. produced by a fusion of the pulps of numerous tooth-germs (*Zahnanlagen*), so that they do not represent primitive, but phylogenetically acquired structures.

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[1] H. Credner, Die Stegocephalen und Saurier aus dem Rothliegenden des Plauenschen Grundes bei Dresden, Part I–X (Zeitschr. d. Deut. geolog. Gesellschaft, 1881–1893).—H. Credner, Die Urvierfüssler (Eotetrapoda) des Sächsischen Rothliegenden. Berlin, 1891, etc.

To the above modification of the *Concrescence* Theory of Kükenthal and Röse cannot be applied the reproach that "it comes from a one-sided Morphology which regards only the wonderful, though mutilated, chapters of Embryology when the untorn pages of Palæontology are at hand."[1]

II.—UEBER DIE GLIEDERUNG DER FLÖTZFORMATIONEN HELGOLANDS. Von W. DAMES. Sitzungsber. der k. preuss. Akad. d. Wiss. zu Berlin, 1893. pp. 1019–1039.

ON THE DIVISIONS OF THE STRATIFIED FORMATIONS OF HELIGOLAND. By Prof. Dr. W. DAMES.

IT is quite natural that the little rocky islet of Heligoland, lately transferred from the British to the German Empire, should have been examined by its new possessors with that warm interest which generally accompanies recently acquired ownership, whether by persons or by nationalities. From a geological point of view the rocks of this islet had been considered to show a pronounced relationship to those of the English coast on the other side of the North Sea, but Prof. Dames, who has spent several weeks this last Autumn in studying its geology, maintains in the present paper, and we think successfully, that they bear the closest resemblance to those of Schleswig Holstein and other areas in North Germany, and consequently that Heligoland is but an advanced post of German territory, with which, geologically, it has had an almost unbroken connection since the close of the Palæozoic period.

Hitherto the rocks of Heligoland have been referred to the Triassic, Jurassic and Cretaceous formations, but Professor Dames states that Jurassic strata are absent altogether. The lowest beds on the main island consist of reddish-brown, thick-bedded calcareous clays, with traces of copper ores, which are closely similar, petrologically, to the strata of Zechstein age in Schleswig Holstein, and to those on the same horizon on the flanks of the Harz Mountains. Conformably overlying the Zechstein on the main island are red and green speckled clays, sandstones and dolomites, considered of Lower Bunter age—in these a characteristic rib of a Triassic saurian has been found. The Middle and Upper Bunter beds probably come in beneath the North Sea, between the main island and the Wite Klif. This latter is of a yellowish clayey limestone or dolomite, containing mollusca characteristic of the Lower Muschelkalk. The Middle and Upper divisions are represented by beds of gypsum and glauconitic limestones and dolomites.

The rocks succeeding the Upper Muschelkalk dolomites contain fossils of Lower Cretaceous age similar to those of the Speeton Clay of Yorkshire and of Simbirsk, in Russia, and the following zones have been recognized by the author in the so-called Töck beds:

1. Zone of *Belemnites pistilliformis,* with *Exogyra Couloni* and *Pecten crassitesta,* belonging to the Neocomian.
2. Zone of *Belemnites brunsvicensis,* with large undescribed species of *Crioceras.*

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[1] See American Journal of Science, December, 1893, p. 448.

3. Zone of *Belemnites fusiformis* and *Terebratula sella.* Nos. 2 and 3 are Aptian.

4. Zone of *Belemnites minimus.*

5. Zone of *Schlönbachia inflata.* Nos. 4 and 5 belong to the Upper Gault; the Middle Gault seems to be absent.

The rocks referred to the Upper Cretaceous are only exposed at ebb-tides; they have hitherto been considered only to represent the Upper Chalk with flints, but Dr. Dames has ascertained from the fossils, partly in the rocks *in situ,* partly in the boulders, that the Cenomanian is present with *Terebratula depressa*; and of Turonian age there is a reddish chalk with *Inoceramus mytiloides*; a white chalk with flints containing *Inoceramus Brogniarti*; and a yellow chalk with *Scaphites Geinitzi* and *Holaster planus.* Of the Senonian, three zones are represented, viz. that of *Inoceramus lobatus,* of *Belemnitella quadrata,* and of *B. mucronata.* No Tertiary strata are present.

The observations of Dr. Dames have very materially increased our knowledge of the geology of this interesting islet, and we are glad to note that he has promised to bring out a detailed description of the fossils present in its rocks, which will be quite as highly appreciated by British as by German geologists.

G. J. H.

III.—MEMOIRS OF THE GEOLOGICAL SURVEY OF THE UNITED KINGDOM; THE JURASSIC ROCKS OF BRITAIN. Vol. III. THE LIAS OF ENGLAND AND WALES (Yorkshire excepted). By HORACE B. WOODWARD, F.G.S., President of the Geologists' Association. 8vo. pp. xii. and 399, with a Map and 89 Woodcut Illustrations. (London: Kegan Paul, Trench, Trübner, and Co., Ld., 1893.) Price 7*s.* 6*d.*

IN the GEOLOGICAL MAGAZINE for September, 1893, pp. 415–421, we gave a notice of volumes I. and II. of this Memoir dealing with the Jurassic Rocks of Yorkshire, by C. Fox-Strangways, F.G.S.; the present volume, comprising the Lias of England and Wales, by Horace B. Woodward, F.G.S., is the first instalment of his work and forms an important and acceptable addition to our knowledge of the Jurassic rocks of Britain, south of the Humber.

"The present volume," says Sir Archibald Geikie, "has been prepared entirely by Mr. Woodward. His training in the field-work of the Survey had made him intimately acquainted with the Jurassic rocks, for, between the years 1867 and 1874, he was engaged under Mr. Bristow, the late Director for England and Wales, in re-surveying the Secondary formations in the south-west of England and the south of Wales."

In the introduction the author treats of the term Jurassic, and of the extent of these rocks in Britain, with their relation to the formations above and below them. In dealing with the history of the Jurassic rocks the place of honour is naturally given to William Smith, who, in his earlier work, was specially identified with the Oolitic rocks of the south-west of England, and many of whose names are still retained to designate their subdivisions. A table of these is given, and also one showing the principal subdivisions of the Jurassic rocks from Dorsetshire to Lincolnshire. The sequence of the rocks, their changes, with their stratigraphical and palæontological subdivisions, their fauna and flora, and characteristic fossils are discussed.

Mr. Horace Woodward then gives a general account of the Lias formation and its organic remains, illustrated by numerous figures of fossils. The opinions of Dr. Sorby and Mr. J. J. H. Teall on the microscopic structure of the Lias are also quoted. A table is given of the principal zones in the Liassic rocks with the names of the Ammonites by which they are characterized. Attention is also given to the origin of the limestones, many of which are considered to be largely of sedimentary origin.

Here, in the text, and also in the Catalogue of Liassic fossils at the end of the Memoir (see pp. 330 to 378), they are given "under the generic name *Ammonites*, because confusion must have arisen if any attempt had been made to employ the subgeneric names. These names, indeed, may be of service to the specialist who confines his attention to the Ammonites, but they are of biological rather than geological importance. Some of the names, indeed, have been changed again and again since this Memoir was commenced, and many of the species, unfortunately, are so split up that the multitude of names is simply bewildering, and they become of little or no service to the stratigraphical geologist. In some cases the same specific name has been applied to *mutations* of different subgenera of Ammonites! a course much to be deprecated, for it is likely that, if accepted as new *species*, the names will eventually be replaced by others."

The author then gives a general description of the Lower Lias, its zones, organic remains, and characteristic fossils, with details of the area over which it occurs, from the coast of Dorsetshire to the Mendip Hills, together with sections along the coast and inland. Other areas recorded are Harptree and Chewton Mendip, Radstock, Keynsham, Bath, Bristol, Westbury-on-Severn, Gloucester, Cheltenham and Tewkesbury. Thence we pass from Evesham to Stratford-on-Avon, Banbury, Rugby, Market Harborough, Barrow-on-Soar, the Vale of Belvoir, Lincoln, Frodingham, Shropshire and Cheshire, and as far as Cumberland, these latter localities possessing "outliers" of the basement beds of the Lower Lias.

The Middle Lias is treated in a similar manner with its zones of *Ammonites spinatus* and *margaritatus*. Figures are also given of various characteristic Middle Lias fossils, with a list of all the organic remains. Then follow local details of the areas over which the Middle Lias extends, in Dorset, Somerset, Gloucester, Oxford, Northampton, Warwick, Leicester, Rutland, Lincoln, and Shropshire.

The Upper Lias, with its zones and characteristic remains, is dealt with as in the preceding divisions, including the topographical area over which it extends. Many new facts are recorded, especially with reference to the Lias of Lyme Regis, to that of South Wales and of Shropshire. The record of a new boring at Mickleton in Gloucestershire, affords evidence that there we have the greatest known thickness of Lias in this country—no less than 1,360 feet.

The chapters on economic geology, treating of Lime and Cement, of Artificial Stone and of Building Stone, Ornamental Marble, of Iron Ore, etc., of Agriculture, Soils, and Water Supply will be read with interest by all those who, as landed proprietors, have a stake in the prosperity of the areas embraced in this Memoir. The Chalybeate Springs of Bath, Cheltenham, and the surrounding country are extremely numerous and many of them of great historical antiquity and virtue.

The fauna of the Lias formation is one of the richest of the British Islands, not only in Flying, Walking, and Swimming Reptiles, but in Fishes and Mollusca; and especially in that remarkable group, the Cephalopoda, by aid of which the various zones of the Lias have long been characterized, the Brachiopoda, Crustacea, Worms, Echinodermata, Corals, and Foraminifera are also well represented, whilst remains of Plants, numerous Insects, Flying Pterodactyls, Dinosaurs, and Crocodiles proclaim the presence of a contiguous continent, the shores of which were washed by the Liassic seas.

Owing to the inferior quality of the paper on which it is printed, this valuable Memoir is presented to the public under great disadvantage; for, notwithstanding the fact that numerous illustrations have been lent to adorn its pages, they are mostly so poorly printed as to fail to express clearly the objects which the artist has drawn. This censure on the printing in no wise detracts the vast amount of arduous scientific labour, the results of years of patient field-work by Mr. Woodward, which this Memoir has involved; nor must we omit to commend the admirable list of fossils, with their respective horizons, occupying just 50 pages of small print, drawn up by the author with the assistance of his colleagues, Messrs. Sharman and Newton. Unfortunately this catalogue does not include all the Liassic fossils of England and Wales, because the species from Yorkshire are given in the Memoir by Mr. Fox-Strangways (above referred to), and only those Yorkshire fossils which occur south of the Humber are mentioned in Mr. Woodward's list.

To obtain a full record of the Liassic fossils of England and Wales, it will be necessary, therefore, to combine the catalogues given by Mr. Fox-Strangways with that contained in the present volume. Surely this might have been done by the officers of the Survey—by mutual agreement—and so the public-at-large, or at least the scientific public, instead of grumbling, would have had reason to laud and magnify the Director-General and his staff for ever! We shall look with interest for the appearance of volume iv. with the Lower, and of volume v. with the Middle and Upper Oolitic divisions of the Jurassic rocks.

IV.—THE STORY OF OUR PLANET. By Prof. T. G. BONNEY, D.Sc., LL.D., F.R.S., F.G.S., etc. 8vo. pp. xvi. and 592, with 6 Coloured Plates and Map, and about 100 Illustrations. (London: Cassell and Co., Ld., 1894.) Price 31*s.* 6*d.*

IN writing "The Story of Our Planet," the author has aimed to produce a companion volume to that by Sir Robert Stawell Ball, entitled "The Story of the Sun." Prof. Bonney thinks, and rightly, that there is already an ample supply of text-books, guides and handbooks, in the English language to satisfy the requirements of every living student, but, besides this class, there is a still larger body of intelligent educated persons who feel much interest in the history of the earth on which they live but who have neither the leisure, nor the inclination, to master the technicalities of any one branch of science, or to enter into their minute details: for this reason the author has striven, by avoiding too many references, and especially dry scientific terms, to make a really readable book for the public at large.

In the introductory chapter the author briefly alludes to the historical records of the rocks, and the fossils which they contain. After this introspection of the earth he proceeds to its extrospection, in relation to the other planetary bodies and the sun. He then deals with the land-regions, their distribution over the globe, and the manner in which they are raised up in the continents and depressed in the oceanic areas. From this he passes to the consideration of the aerial region, and he discusses the great air-envelope of our globe, and the movements to which it is subjected. The waters of our planet next claim attention; this section is illustrated by some useful coloured maps of the ocean-basins; that on p. 38 of the ocean-currents is, however, hardly satisfactory as a process-block, and a far better diagram ought to have occupied its place.

In part 2, the author describes the work performed by Nature's agents in sculpturing and moulding the solid framework of our globe. The first agent being the atmosphere, naturally includes the action of sun and wind in the disintegrating of rocks and soils, and the formation of sand-dunes and rock-pillars. It is difficult sometimes to define the limits of the action of sun and wind apart from that of rain and rivers, except, of course, in *so-called* "rainless districts."

The transporting power of rivers is next discussed and the means by which they remove the solid crust of the earth, both in suspension and solution. The action of ice as a sculptor of the rocks, and as a carrier of material from higher to lower grounds, and in the distribution of erratics over land and sea, is also described and illustrated.

The work of the ocean, although limited to the margin of the land, produces considerable changes, by additions and subtractions, along our coast-lines, and by alterations in the contours and the depths of channels near the mouths of rivers, and by the changes in shoals, sandbanks, etc.

Under the title of "the Proletariat of Nature," by which the author evidently means all the lower forms of animal and vegetable life, the Mosses, the Lichens, the Foraminifera, Radiolaria, Sponges and Corals, Professor Bonney discusses the effects which these humble but prolific organisms produce, either as conservators of the surface—as in the cases of Lichens, Mosses, and vegetation generally—or as actual builders-up of earth-masses, as in the case of Coral-reefs, etc.

Part 3 is devoted to the consideration of changes from within; commencing with movements of the crust of the earth, illustrated by the well known example of the Columns of the Temple of Serapis and the terraces on the Coast of Norway; and by faults and flexures of the strata; by volcanic action and its effects, on earthquakes, and the internal changes produced upon rock-masses within the crust itself.

Part 4 deals with the earth's story in past ages, and treats of meteors and the earth's beginning; of the eras and subdivisions in geological history, and the processes of reasoning by which they have come to be recognized; and so we pass from the Archæan era, to "the building of the British Isles," of Europe, and other continents; and, following the author, discuss the earth's life-history.

Part 5 embraces some theoretical questions, such as the "Age of the Earth;" "the permanence of ocean-basins and land-areas;" on "climatal changes," and "the distribution and descent of life."

This work is essentially, what its author intended it should be, a pleasant readable book. Most of its facts are the common property of many other such volumes on Physical Geography and Geology, such as Élisée Reclus' "La Terre," with a little more geology added, after the manner of "Lyell's Principles." The smallest possible space is given to the so-called Life-History of our globe, a subject which appears to us to be worthy to hold a place of far greater importance in the History of our Planet. If we except the figures of some of the fossils given, the illustrations are, as a rule, of a high class and will render the book attractive to the general reader, for whom it is intended.

We think this is a volume which will have many readers, both amongst young and old.

V.—ANNALS OF BRITISH GEOLOGY, 1892. A DIGEST OF THE BOOKS AND PAPERS PUBLISHED DURING THE YEAR—WITH OCCASIONAL NOTES. By J. F. BLAKE, M.A., F.G.S. 8vo. pp. 310, with 100 Illustrations. (London: Dulau & Co. 1893.)

PROFESSOR BLAKE is to be greatly congratulated on the third annual appearance of this most useful work. Whilst the volume is arranged almost precisely on the same lines as last year (*vide* GEOLOGICAL MAGAZINE, 1893, p. 134), certain changes have been introduced. The critical notes are no longer dispersed amongst the text, but wisely gathered together in the form of an Introductory Review, "which," says the author in his preface, "can scarcely be objected to if we admit the principle that 'thou shalt not muzzle the ox that treadeth out the corn,'" especially, we might add, if he treadeth not *on* the corn—of another.

The illustrations are now, as far as possible, of full size and interspersed in the body of the text. All new British species, save those in the Palæontographical Society's volume, are figured, with some few others of special interest.

We are still of opinion that the "Foreign Geology (published in

Britain)" were better omitted altogether, and fail also to see the object in practically such a work as that by Hudleston and Wilson.

Beyond this we have no adverse criticism to offer, and most sincerely deplore the necessity Professor Blake will be under of abandoning this work in the future unless the present volume meets with sufficient support. Aid should certainly be given him not only by individual geologists, but by those societies, large and small, that in many quarters of the British Islands are formed to promote the study and progress of the science of geology.

Unfortunately the principal society does not consider Records are "instituted for the purpose of investigating," or aiding in the investigation of, "the mineral structure of the earth;" whilst it is hopeless to expect the Geological Survey of the United Kingdom to be as enterprising as its American equivalent in the United States, and to undertake a work of utility such as this.

Those prepared to support Professor Blake should remember, "bis dat, qui cito dat!"

REPORTS AND PROCEEDINGS.

GEOLOGICAL SOCIETY OF LONDON.

I.—December, 6th, 1893.—W. H. Hudleston, Esq., M.A., F.R.S., President, in the Chair. The following communications were read:

1. "The Purbeck Beds of the Vale of Wardour." By the Rev. W. R. Andrews, M.A., F.G.S., and A. J. Jukes-Browne, Esq., B.A., F.G.S.

The authors have obtained better evidence than previously existed for calculating the thicknesses of the several parts of the Purbeck series in the Vale of Wardour, and comparing the different subdivisions as developed in that Vale with those exposed in othe localities. Putting together 22–24 feet of basement-beds of the Lower Purbeck strata seen in the Wockley section, 21 feet in Ridge Quarry, and 17 feet in Teffont Quarry, more than 60 feet of Lower Purbeck Beds are actually seen, and allowing for the gap between the Wockley and Ridge sections, 70 feet seems a fair estimate of the average thickness of the Lower Purbeck strata.

In the Teffont and Chicksgrove quarries, a little over 12 feet may be measured between the basal clay of the Middle Purbeck Beds and the Cinder Bed; while the great cutting on the Teffont line shows 19 feet of strata above the Cinder Bed, and the beds of Dinton cutting may be all on a higher horizon; so that an estimated thickness of 32 feet for the Middle Purbeck Beds is probably below the mark.

The clay and sand in the Dinton cutting must be 18–20 feet thick, and between its summit and the top of the second seam of calcareous grit there is a thickness of at least 8 feet. This grit forms the floor of Dinton Well, about 40 feet deep; hence there is a thickness of at least 66 feet of Upper Purbeck strata, and probably more than 2 and less than 12 feet in addition.

A comparison is instituted between the Purbeck Beds of the Vale of Wardour and those of the Dorset coast, etc., and some remarks are made upon the physical conditions under which the beds were deposited.

2. "On a Picrite and other Associated Rocks at Barnton, near Edinburgh." By Horace W. Monckton, Esq., F.L.S., F.G.S.

The object of this paper is to describe a cutting on a new railway in Barnton Park, where there is an excellent exposure of picrite. It consists of serpentinized olivine, augite, mica, iron oxide, and a little plagioclase-felspar, with a variable amount of interstitial matter. In many respects it comes very near to the picrite of Inchcolm, which island is 4½ miles north of Barnton cutting. It differs from the picrite of Bathgate, and the probability is that the Barnton rock is an offshoot from the same magna as that which supplied the Inchcolm rock.

Besides the picrite other igneous rocks from the same cutting are described—in particular, a rock with porphyritic crystals of a green mineral replacing olivine, or more probably augite, and a great quantity of brown mica in small flakes and crystals. It is suggested that the name of mica-porphyrite might be given to this rock.

3. "On a variety of *Ammonites* (*Stephanoceras*) *subarmatus*, Young, from the Upper Lias of Whitby." By Horace W. Monckton, Esq., F.L.S., F.G.S.

The author describes an ammonite found by himself in 1874 near Sandsend, 3 miles north-west of Whitby. He thinks it was not actually *in situ*, but lying with a number of nodules on the floor of an old alum-pit, although he has no doubt that it is from the Alum Shale of the Upper Lias. A peculiar arrangement of the costæ as they cross the siphonal area distinguishes the specimen from other Whitby ammonites known to the author. It bears a strong resemblance to a shell figured as *A. subarmatus* by D'Orbigny, "Terr. Jurass.," pl. lxxvii., but is unlike the figures of that species given by other authors.

II.—December 20th, 1893.—W. H. Hudleston, Esq., M.A., F.R.S., President, in the Chair. The following communications were read:—

1. "On the Stratigraphical, Lithological, and Palæontological Features of the Gosau Beds of the Gosau District, in the Austrian Salzkammergut." By Herbert Kynaston, Esq., B.A. (Communicated by J. E. Marr, Esq., M.A., F.R.S., Sec.G.S.)

This paper, after referring to the previous literature of the subject, treats of the situation and physical aspects of the Gosau Valley, the distribution of the Gosau Beds, their stratigraphy, palæontology, and geological horizon, and the physical conditions under which they were deposited, and comparison is instituted between the Gosau Beds and the equivalent beds of other areas. The author shows that Hippurites occur at two horizons in the Gosau Beds,—a hippurite-limestone immediately above the basement-conglomerate being characterized essentially by *Hippurites cornu-vaccinum*, which is overlain by *Actæonella-* and *Nerinæa*-limestones and an estuarine series, and above these is a second hippurite-limestone characterized essentially by *Hippurites organisans.* It is pointed out that Toucas similarly distinguishes two Hippurite zones in Southern France; the lower, characterized essentially by *H. cornu-vaccinum*, being placed by him at the top of the Turonian System, whilst the second, with *H. organisans*, is referred to the summit of the Senonian; and the author gives reasons for regarding the Gosau zones as the equivalents of those of the South of France, in which case the Gosau Beds will represent the uppermost Turonian and the whole of the Senonian, *i.e.* the zones of *Holaster planus, Micraster, Marsupites,* and *Belemnitella mucronata* in England, whilst the upper unfossiliferous beds may be the equivalents of the Danian Beds.

The strata are, on the whole, of shallow-water origin, and were deposited in shallow bays in the Upper Cretaceous sea of Southern and Central Europe, on the northern flanks of the Eastern Alps. Probably towards the close of Upper Cretaceous times the southern area of the Gosau District was cut off from the sea to form a lake-basin in which the upper unfossiliferous series was deposited.

2. "Artesian Borings at New Lodge, near Windsor Forest, Berks." By Prof. Edward Hull, M.A., LL.D., F.R.S., F.G.S.

The boring described in this paper was carried down from a level of about 220 feet above Ordnance-datum, through the following beds:—

	Feet.
London Clay ... ... Lower London Tertiaries	214
Chalk	725
Upper Greensand	31
Gault	264
Lower Greensand	7

The Chalk was hard, and contained very little water; but on reaching the Lower Greensand the water rose in the borehole to a height of 7 feet from the surface.

The author discusses the probability of the Lower Greensand yielding a plentiful water-supply in the Windsor district.

3. "Boring on the Booysen Estate, Witwatersrand." By D. Telford Edwards, Esq. (Communicated by the President.)

An account is given of a boring on the Booysen estate, situated about 2 miles from Johannesburg, and about 5000 feet south of the nearest point of outcrop of the "Main Reef" of the Witwatersrand. The "Bird-Reefs" crop out generally at a distance of 4000 feet south of the main Reef.

The borehole, 1020 feet deep, passed through sandstones (often micaceous), quartzites, and conglomerates, the last-named having a collective thickness of 91 feet 7 inches, the two thickest reefs being respectively 26 and 22 feet thick. The dip of the beds was 35°. Traces of gold were obtained. All the reefs were highly mineralized, principally with iron-pyrites, and belonged to the "Bird-Reef" series which overlies the Main Reef.

III.—January 10th, 1894.—W. H. Hudleston, Esq., M.A., F.R.S., President, in the Chair. The following communications were read:—

1. "On the Rhætic and some Liassic Ostracoda of Britain." By Prof. T. Rupert Jones, F.R.S., F.G.S.

In this paper the published observations on the occurrence of these Microzoa in the Rhætic and Lower Liassic strata of England, chiefly in Gloucestershire and Somerset, by the Rev. P. B. Brodie, H. E. Strickland, C. Moore, and others, are first of all recorded; and the various notices of the so-called *Cypris liassica* in various palæontological works are considered. Numerous specimens submitted by the Rev. P. B. Brodie, the Rev. H. H. Winwood, and Mr. E. Wilson, and some few examined in the Geological Society's collection, have been studied, with the result of determining, it is hoped satisfactorily, the characters and alliances of *Darwinula liassica* (Brodie) and of six or seven other species found in the same and the associated series of strata. The *Darwinula globosa* (Duff), from Linksfield, Morayshire, is also critically re-examined as one of this interesting series of Rhætic Ostracoda. The other species belong for the most part to *Cytheridea*; thus most of them probably lived in brackish or estuarine waters.

2. "Leigh Creek Jurassic Coal-Measures of South Australia: their Origin, Composition, Physical and Chemical Characters; and Recent Subaerial Metamorphism of Local Superficial Drift." By James Parkinson, Esq., F.G.S., F.C.S.

This paper contains an account of the lignitic coal of Leigh Creek and associated rocks. Analyses are given, as illustrating comparisons between the Leigh Creek coal and Jurassic and other coal-bearing rocks found elsewhere. The author discusses the origin of the Leigh Creek deposits, and describes certain peculiarities noticeable in the superficial materials, which he discusses in another paper.

3. "Physical and Chemical Geology of the Interior of Australia: Recent Subaerial Metamorphism of Eolian Sand at ordinary atmospheric temperature into Quartz, Quartzite, and other stones." By James Parkinson, Esq., F.G.S., F.C.S.

South of the Flinders Range fragments of stone of all sizes are found on the ground, the origin of which the author discusses. He maintains that they were formed by subaerial metamorphism of Eolian deposits.

CORRESPONDENCE.

ACTION OF GLACIERS.

Sir,—I wish to call the attention of geologists more experienced than myself to the Eidfjordsvand, in Norway, from which I think important lessons may be learnt.

The Eidfjordsvand is a lake about 4 miles long and 245 feet deep, and is remarkable for its desolate grandeur. The river that forms the Vöringfos flows through it into a branch of the Hardangerfjord, which is called the Eidfjord, and is about three-quarters of a mile below the lake.

Between the lake and the fjord is the old delta of the river, rising, I should say, 150 feet above its present level.

The problem is, how can the delta be where it is, without the lake being filled? My explanation is that the lake has been filled by the delta, and has been cleared out by a glacier. If this explanation be correct it has important bearings on the action of glaciers. I do not think, from its position at the head of a branch fjord, remote from the sea, where the tides must necessarily be weak, that what I have called a delta can be entirely, or even mainly, a sea-beach; this point, however, might be investigated by someone who could devote more time to the question. William Churchill.

New University Club, St. James's Street, s.w.

THE SUBMARINE CRUST.

Sir,—It is obviously a matter of interest to obtain some knowledge, however slight, about the constitution of the earth's crust beneath the great oceans. The fact that they are covered by a deep layer of water, while it precludes the possibility of examining the subjacent rocks directly, gives an opportunity for gaining some information about them from considerations based upon their attractive force upon the water itself. I have accomplished something in this direction in chap. xvii. of my "Physics of the Earth's Crust," supplemented by chap. xxvi. added in an Appendix.

In his "Introductory Review" to "Annals of British Geology, 1893," Professor Blake has thrown a doubt upon my work. In fact he has given it as his opinion that my calculations are unsound. Your Magazine is not a suitable medium for a mathematical discussion, but I hope you will allow me just to say, that I do not admit the validity of any of the three objections he has formulated; but affirm them to be altogether erroneous. O. Fisher.

Harlton, Cambridge.

OBITUARY.

THE REV. GEORGE GORDON, LL.D.

NEWS has reached us of the death of this veteran geologist, at the advanced age of 92. Born in the Manse of Urquhart, Morayshire, on 23rd July, 1801, the son of the late Rev. William Gordon, minister of Glenlivet, he entered Marischal College, Aberdeen, in 1815, graduated in 1819, and afterwards studied divinity at Aberdeen and Edinburgh. He was licensed to preach by the Presbytery of Elgin in 1825, and was presented to the parish of Birnie in 1832 by the patron, Francis, Earl of Moray.

He was thus for 67 years a minister of the Church of Scotland, 57 years of which he ministered uninterruptedly to the parish of Birnie, near Elgin. He was the second oldest minister in the Church, and one of the two oldest graduates of the University of Aberdeen.

From his youth upwards Dr. Gordon was devotedly attached to the study of Natural History. In 1839 he published "Collectanea for a Flora of Moray," which is regarded as a standard authority on the botany of the county, and he was instrumental in adding the plant *Pinguicula Alpina* to the British flora. He also contributed papers on the fauna of Moray, with which he was equally conversant, to the "Zoologist." As regards archæology, and in fact in all matters of local antiquarian interest, he was an industrious collector, and might always be found to the front investigating anything new about anything old. In the branch of geology, there has been nobody in the neighbourhood of Elgin who has pursued a closer study nor acquired such an intimate knowledge of the subject. The formation of the Old Red Sandstone, in particular, long engaged his attention, and nothing could excite in him a livelier interest than any new discovery of fossil remains. In fact in every such case it was customary for the finder to appeal to Dr. Gordon of Birnie for an explanation.

He was ever ready to impart his knowledge to others, and felt pleased when anyone sought to share in his investigations: his enthusiasm even at the great age of 90 being most encouraging to witness. Among his geological services may be mentioned the procuring of remains of a number of fossil reptiles from the Elgin Sandstone, some of which have been described by Prof. Huxley, others quite recently by Mr. E. T. Newton; the more recent discoveries include a number of very remarkable forms, and one of these, a new *Dicynodont* genus, has been named *Gordonia*. Dr. Gordon maintained steadfastly the view that the Elgin Sandstones belonged to one continuous series of Old Red Sandstone age; a view that is not supported, however, by palæontological evidence.

His efforts in connection with the Elgin Museum are well known. Along with other gentlemen of kindred tastes, he was influential in founding the Elgin and Morayshire Literary and Scientific Association.

Although in November last nobody would have expected on seeing him walking along the street with the briskness and vigour—one might almost say of youth—which so characterized him, that his end was so near. But a severe cold, caught at the end of the month, developed other complications, which at his great age it was impossible to resist; and it was not with surprise that many received the sad intelligence of his death, which occurred at his residence of Braebirnie, Elgin, on the morning of Tuesday, 12th December.[1]

MR. T. C. J. BAIN, OF THE CAPE COLONY.

Mr. Thomas Charles John Bain, son of the eminent South-African Geologist, Andrew Geddes Bain,[2] lately died at Rondebosch, near Cape Town, September 28th, 1893, aged sixty-four. He inherited his father's taste for engineering, travel, and geological research, with a strong constitution for withstanding hardships of work and travel in the wildest parts of the Cape Colony. In 1854 he succeeded his father as the Inspector of Roads (after an Assistantship for six years) and District Railway Engineer. In 1874 he was the District Inspector of Roads, and in 1888 he became Geological and Irrigation Surveyor. He was a J.P. for the whole of the Western Province. The magnificent roads and passes in the Colony are monuments of the skill of father and son; and with both of them opportunities for observation and discovery were not neglected; but geological results of great importance followed the noting of sections and the unearthing of fossils, particularly of the numerous great and small reptilian bones and skeletons. Several of these are known specifically by the appellation of *Bainii,* after either the father or the son. One particularly interesting skeleton of the great *Pariasaurus Bainii* was unearthed by Mr. T. Bain and Prof. H. G. Seeley, near Fraserburg, in the Nieuweld Range, about two years ago, and is now mounted perfect in the British Museum (Natural History), London, and represented by a good model, life-sized, in the Museum at Cape Town.

Mr. Thomas Bain furnished some of the earliest Reports on the Colonial gold-fields of Kuysa and Prince-Albert; and of late had been successful in boring for water in British Bechuanaland and elsewhere.

The widow survives, with four sons, and four married and three unmarried daughters. One of the sons is under the Civil Commissioner of Albany, and one in the Public Works Department; and we may fairly hope that, though the Country has lost such good and useful public servants as A. G. and T. C. J. Bain, yet some of the surviving successors of those eminent men may further advance the scientific status of the Colony, and add to its prosperity and importance by elucidating its geological structure, thereby increasing the benefits derived from agriculture, stock-growing, and mining; especially by the aid of good water-supply and irrigation. T. R. J.

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[1] We are indebted to the *Moray and Nairn Express,* of December 16, for most of the above particulars.

[2] An obituary notice of Mr. A. G. Bain appeared in the Geological Magazine for January, 1864, pp. 47, 48. Mr. Thos. Bain is mentioned therein as an already known geologist.

THE
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NEW SERIES. DECADE IV. VOL. I.

No. III.—MARCH, 1894.

ORIGINAL ARTICLES.

I.—Four Theories of the Age and Origin of the Dartmoor Granites.

By A. R. Hunt, M.A.

FOUR Theories of the Age and Origin of the Dartmoor Granites have been lately current, viz. :—

(1) The ordinary Plutonic of Sir H. de la Beche.
(2) The Laccolitic-Plutonic of Mr. W. A. E. Ussher.[1]
(3) The Volcanic of Mr. R. N. Worth.[2]

The above all assume the exclusively post-Carboniferous age of the granite, owing to its intrusion into the adjacent Carboniferous rocks; one of the best attested facts in geology.

(4) The combined pre-Devonian non-intrusive and post-Carboniferous intrusive (both plutonic), advanced by myself in 1889.[3]

Mr. Ussher has recently withdrawn his provisional[4] laccolitic hypothesis, on stratigraphical grounds, in favour of one which is practically equivalent to No. 4.[5]

As it is impossible to compress the work of some four years into a magazine article, the present paper must be confined to a sketch of my main argument.

My friend Mr. Worth has, with characteristic generosity, lent me the diagrammatic woodcut illustrating his ideal volcano; accompanied by the following remark: "Please do not limit your views of me; you owe it to yourself to make your case as strong as possible, and we shall not differ outside our theories." A too generous opponent indeed, and one hard to oppose.

The following woodcut was published to illustrate Mr. Worth's paper, "The Dartmoor Volcano," Trans. Plymouth Inst. 1888–89.

Mr. Worth brought his theory in the plainest language before the Geological Society in 1889, when it was discussed by our leading petrologists, apparently accepted by Prof. Bonney and Mr. Hudleston, and not objected to on principle by anyone.[6]

Primâ facie, however, there seems a serious objection to Mr. Worth's volcanic hypothesis, as it involves the "Elevation-crater theory" pure and simple.[7]

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[1] Trans. Devon. Assoc. vol. xx. p. 154.
[2] "The Dartmoor Volcano," Trans. Plymouth Institution, etc., 1888–89.
[3] Trans. Devon. Assoc. vol. xxi. p. 238. [4] Trans. Devon. Assoc. vol. xx. p. 156.
[5] Proc. Som. Archæological Soc. vol. xxxviii. p. 204.
[6] Q.J.G.S. vol. xlvi. pp. 80–82.
[7] See Geikie, Text Book of Geology, pp. 241, 242.

[The publication of this article has been unavoidably delayed.—Edit. Geol. Mag.]

I would venture to submit this preliminary point to geologists before making any attempt to discuss the volcanic theory of Dartmoor in detail.

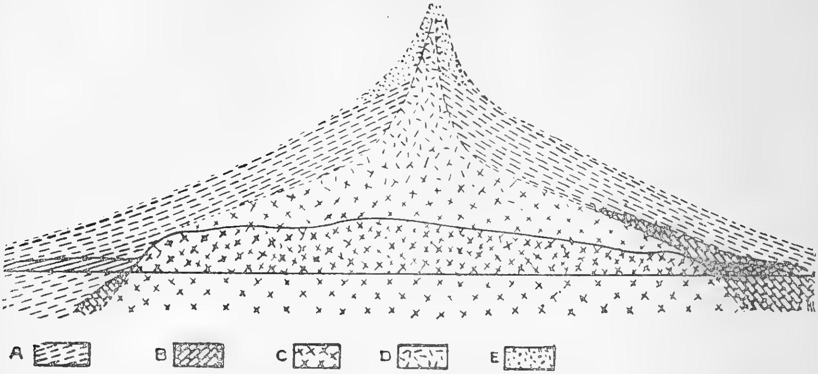

Fig. 1. “Diagrammatic Reconstruction of Dartmoor.

It must be understood that this sketch is diagrammatic and has no pretensions to scale, and that it is mainly suggestive and purposely made as simple in its conditions as possible. All below the horizontal line, which represents datum, is purely hypothetical; and all above the curved line, which indicates generally the present surface contour of the Moor and bordering rocks from north to south. This superstructure has been removed. A, represents Carboniferous rocks; B, Devonian; C, Granite; D, Felsite; E, Volcanic Material and Ejectmenta. The wedge-like intrusion of the granite has tilted and broken through the upper or Carboniferous rocks, and has thrust as well as heaved the lower or Devonian.”

My own pre-Devonian hypothesis was first advanced at the Tavistock meeting of the Devonshire Association; on which occasion the following epitome of my paper. with the valuable comments of the President, Mr. W. H. Hudleston, F.R.S., appeared in the “Western Morning News.” As reporters could have made nothing of so technical a subject, I conclude that the President's remarks were personally revised for the Press, as was my own abstract.

“*The Age of the Granites of Dartmoor and the English Channel.*

Mr. A. R. Hunt read a paper on the Relation of the Granites of Dartmoor to the Granites of the English Channel. The author drew attention to the following points of difference between the granites of Dartmoor and those trawled in the English Channel:—The Dartmoor granites were characterized by fracture, by the frequent presence of tourmaline, and were not gneissose. The Channel granites indicated compression, were sometimes hornblendic, and were associated with gneisses. The Dartmoor granites were intersected by injected and infiltrated veins. No veinstones (though such were very durable) had been forthcoming from the Channel. The quartzes in the Dartmoor granites and in both classes of veins contained fluid inclusions of brine, with cubic crystals of salt. No salt had been detected in the Channel granites. Chiastolite occurred on the borders of Dartmoor, kyanite in the Bolt schists bordering the

Channel[1]—chemically identical, they differed only in specific gravity, the heavier mineral indicating the greatest compression. From these facts the author argued that the Channel and Dartmoor granites were both originally of pre-Devonian and probably of Archæan age. That after the deposition of the Devonian and Carboniferous rocks, the Dartmoor area was fissured by the same earth-movements which compressed the Channel area. The sea obtained no access to the Channel granite, but penetrated the Dartmoor area. The crushing of the lower rocks supplied the heat, whilst the sea supplied the water, which under high pressure dissolved the Archæan granite to be reconsolidated with salt here and there caught up in its quartzes. The reconstituted granites traversing the culm slates were truly post-Carboniferous; but the mass of Dartmoor is Archæan, occasionally altered by super-heated brine accompanied by boracic acid.

"The President said it was unquestionable that a very ingenious theory had been propounded by Mr. Hunt, although very different to that which had been hitherto held by most geologists. Without going very closely into the question, or dealing otherwise than superficially with the paper, he thought it was perfectly clear that the Dartmoor granite and the Channel granite were of quite a different age, and had an entirely different origin. To that extent he was in conformity with the views of the author. But the granites were quite different mineralogically. There was one very great difference, namely, that the Channel granites were not metalliferous in the way that the Dartmoor granites were. There were no granites in the British islands which were so metalliferous as the Devon and Cornwall granites, and it appeared to him that they had a very different origin to other granites. For that simple reason, as regarded the age of the Dartmoor granite, it appeared to him that the usual view that it was post-Carboniferous was the one most in accordance with the facts of the case, as far as he had been able to judge. But when they came to the differences of the mineral composition of these granites, he thought they had further proof that the alteration of Dartmoor granite had been produced subsequently by the numerous fissures formed. These fissures had been more or less injected by corroding aqueous vapours containing large quantities of chlorides and fluorides of heavy metals. These crystals of salt, which Mr. Hunt had found in such considerable quantity, he thought (it) excessively probable had been formed from hydrochloric acid gas acting on the soda in the rocks. That appeared a very much more reasonable explanation of the origin than that they came from the sea, or had anything to do with the sea whatever."

The question as to the marine or plutonic origin of the brine-inclusions referred to is of transcendent importance in connection with the question as to whether the water ejected by volcanoes is of meteoric or marine origin, or derived from the interior magma.

Hypotheses that might meet the case of pure water might well fail to explain the presence of the chlorides of sodium and potassium.

Having carefully examined the rocks in the light of Mr. Hudleston's

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[1] Note. Withdrawn, Geol. Mag. 1892, p. 291.

suggestion, I submitted the question to the British Association at Leeds. The following extract is from the published abstract of my paper:—

"The theory of the marine origin of the saline inclusions in the Dartmoor rocks seems to harmonize well with the view commonly entertained that the chlorine and chloride of sodium emitted by volcanoes are derived from the sea.[1]

"In the case of volcanoes the presence of hydrogen and chlorine may be accounted for by the dissociation of the water and of the chloride of sodium by the intense heat, and the combination of the two gases thus formed would result in the production of hydrochloric acid.

"In the case of the cooler granites there is no question of dissociation and of gases, but of the entanglement of brine and steam at more moderate temperatures.

"Thus the access of salt water to highly heated rocks seems to account for some of the more important gases emitted by lavas and of the more characteristic fluid inclusions caught up by granites.

"An alternative theory, that the crystals of salt in the Dartmoor rocks 'had been formed from hydrochloric acid gas acting on the soda in the rocks,' does not seem to the author to account for the crystals in the quartz-veins of the culm slates, or to explain the complete permeation of the granite by the chloride of sodium. Moreover, the one theory accounts for the presence and origin of the hydrochloric acid as well as of the soda, whereas the other has to assume the previous existence of soda and the advent of hydrochloric acid from unknown quarters."[2]

The very title of this paper was omitted from the newspaper reports, it being dismissed as being merely of local interest!

Mr. Ussher's last paper referring to Dartmoor appeared in 1892, and General Mc'Mahon's in 1893. In the discussion which ensued on the reading of the latter, Professor Bonney is reported to have said that "In his opinion Mr. Ussher's theory was quite untenable. If the fusion of a peripheral portion of the Dartmoor mass was due to crushing . . . . Was there any evidence that a rock could be fused by pressure alone, any more than by a gentle stewing in sea-water which also had been suggested? . . . No good was done for science by proposing hypotheses which, in avoiding one difficulty, raised a number of others far more formidable."[3] On the same occasion General Mc'Mahon said that "the word used by Mr. Ussher was 'fusion,' and it was applied to the results of the N. and S. squeeze on the rigid and obstructing pre-Devonian rocks."[4]

There seems great misapprehension here. So far from Mr. Ussher attributing fusion of the Dartmoor granite to "pressure" or "crushing," or to a "N. and S. squeeze," he seems never even to have used the terms "pressure" or "crushing" in reference to the granite, and his only suggestion of a possible source of heat appears to be "a rise of the isogeotherms or plutonic action" (a quotation from

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[1] See Characteristics of Volcanoes, J. D. Dana, p. 8.

[2] Report Brit. Assoc. 1890, p. 815. [3] Q.J.G.S. vol. xlix. p. 397. [4] *Loc. cit.* p. 397.

my own paper). He also states that "the metamorphism (in the granites) was produced *after*, and perhaps as a new phase in, the great dynamic movements to which the contortion and cleavage of the Palæozoic rocks are due."[1] And in another place we learn that the fusion of the obstructive masses took place *after* the mechanical effects produced by their obstruction had attained their maxima.[2]

So far as I can gather from a careful study of Mr. Ussher's and General McMahon's papers, Mr. Ussher's almost incidental references to the behaviour of the granite itself (for his main point is the sedimentary rocks) have been misapprehended.

It would almost appear, however, that Prof. Bonney's questions, whilst missing their mark in Mr. Ussher, force me to take the defensive, owing to my having written—"The crushing of the lower rocks supplied the heat."[3] This hypothesis, whether tenable or not, is fairly orthodox, for, assuming that "pressure" is used here for friction or crushing (the results of pressure), we may turn to Mallet for experiment, and to Callaway for observation. Mr. R. Mallet, F.R.S., has the following passage in the Quarterly Journal of the Geological Society:—"The writer has thus shown that crushing alone of rocky masses beneath our earth's crust may be sufficient to produce fusion."[4] Describing a particular rock, Dr. Callaway writes in the same publication:—"During the metamorphism partial fusion, resulting in plasticity, took place. This effect is found so often to occur where the shearing is at its maximum, while the adjacent rock is merely a crushed solid, that the generation of heat by the shearing-process becomes a probable inference."[5]

It may be as well to point out that I never suggested a crushing of any portion of the Dartmoor granites that has ever been seen by man. As already stated, the Dartmoor granites as exposed to view are "characterized by fracture,"[6] and instead of indications of pressure there is every sign of relief of pressure. Felspars and quartzes are occasionally split by divisional planes and re-cemented; but I know of no instance even of dislocation, much less of crushing or shearing, in the main mass of the granite. However, there is nothing to prevent the upper crust having been in a state of strain, while lower horizons were under stress, so, in these latter, dynamic action may well have supplemented the earth's heat in producing the comparative moderate temperatures indicated by the granite. With respect to the "fusion . . . . by a gentle stewing in sea-water" referred to by Professor Bonney, it is possible my critic may have misunderstood the following sentence, viz. "altered . . . . by *moderate* heat in the presence of salt water."[7] By moderate heat I merely meant a temperature not much, if at all, exceeding the critical temperature of water, and the term was used relatively to volcanic temperatures, which latter seem inadmissible if only because they would dissociate the elements in the chloride inclusions.

[1] Proc. Somerset Archæological Soc. vol. xxxviii. p. 217.
[2] *Loc. cit.* p. 208.
[3] See *ante*, p. 99.
[4] Q.J.G.S. vol. xxxi, p. 517.
[5] Q.J.G.S. vol. xlix, p. 422.
[6] See *ante*, p. 98.
[7] Report Brit. Assoc. 1889, p. 570.

The particular point I desire to emphasize on the present occasion is the intimate association in the Dartmoor area of fluid inclusions, containing cubic and other crystals, with fluid inclusions consisting apparently of plain water.

FIG. II.

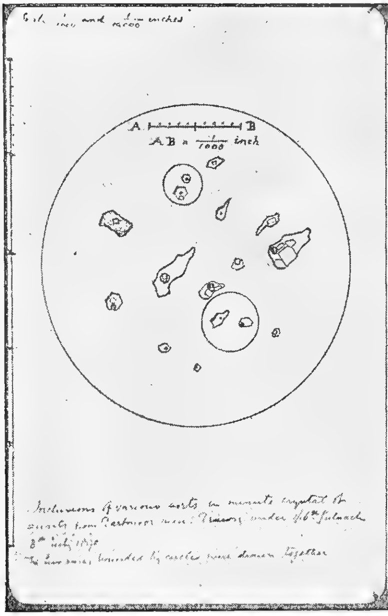
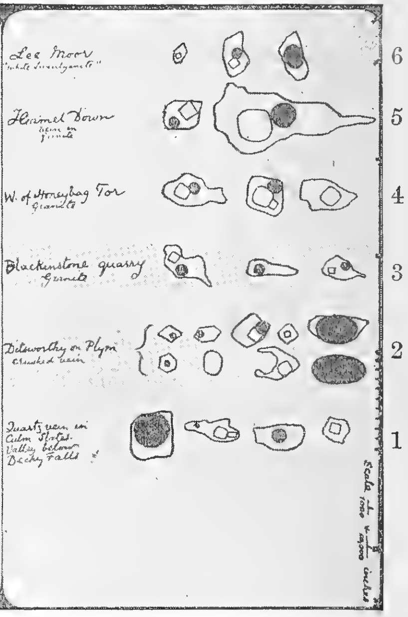


FIG. III.



In a slice of a veinstone from near Manaton there is an hexagonal crystal of quartz about $\frac{1}{30}$ inch in diameter. The gradual growth of this crystal is defined by tourmaline and tourmaline microliths.[1] It is crowded with inclusions, both irregular and with crystalline outlines (*i.e.* negative crystals). We can see that it has never been viscid, plastic, or colloid, or anything else than a mineral gradually crystallized out from solution.

Within this crystal, and not more than $\frac{1}{20000}$ inch apart, there are two inclusions, both of them negative hexagons, with small bubbles; but one contains a cube, and the other contains none. There is also a negative hexagon with a relatively large bubble, $\frac{1}{5000}$ inch distant from an irregular inclusion with a very minute bubble.

Among the liquid inclusions, as figured above (Fig. II.), there is a tourmaline microlith which seems to have caught up a cube of some chloride during crystallization. The inclusions drawn are selected, and not in their relative positions, excepting the two couples within small circles.

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[1] See Trans. Devon. Assoc. vol. xxi. p. 261, plate, fig. 3.

On the second cut (Fig. III.) are drawings selected from six specimens, of which the five lower ones deserve special notice, viz., commencing with the lowest:—

(1) Quartz vein in Culm slates, valley below Becky Falls.

(2) "Ditsworthy—vein is intrusive in a tongue of slate which extends into the granite across the Plym valley from Ringmoor—a very narrow strip." (Worth.)

Quartz, decomposed felspar, white mica, brown tourmaline decomposing into green. A very remarkable rock, with inclusions (as shown above) varying to the utmost extreme.

Fig. IV.

(3) Blackinstone Quarry, and (4) Honeybag Tor, ordinary granites.

(5) Hamel Down, quartz-felspar-tourmaline vein; negative crystal apparently based on the rhomboidal prism.

It will be observed that the same type of liquid inclusions, in similar variety, can be traced from the simple quartz vein, through various injected or infiltrated compound veins, to the ordinary granite of Dartmoor.

Description of Fig. IV. :—

(1) Liquid inclusions in a quartz-vein in Culm slate in the valley below Houndtor Wood, south of the Becka brook.

(2) Liquid inclusions in the quartz of Trowlesworthite.

(3) Inclusions with one and two liquids in a granite (No. 20) trawled in English Channel (for comparison).

(4) Liquid inclusions from normal porphyritic Dartmoor granite, Heytor Quarries.

(5) Liquid inclusions in a crystal of Apatite enclosed in the quartz of Trowlesworthite (No. 2). The Apatite contains plain fluid; the quartz, water and cubic crystals.

All magnified according to linear scale of $\frac{1}{1000}$ inch as given.

The following description of a contact slide between coarse granite and a micro-granite vein in Lustleigh Cleave applies with equal accuracy to the Ditsworthy vein figured above :—

(1) Irregular inclusion with cube; hexagon with cube; rhomb with cube.

(2) Irregular inclusion with cube and bubble; hexagon with cube and bubble.

(3) Irregular inclusion with bubble; hexagon with bubble; gas inclusion.

The chief absent variety here is one present in the Ditsworthy rock, viz., the simple fluid inclusion without cube or bubble; it may possibly have been present and been overlooked.

These extreme variations are all of them intelligible in the case of the veinstones, as we may regard the fissures, in which the latter were crystallized, as tubes capable of resisting any pressure. Then with volcanic heats below and cooler regions above, and with the fissures charged with saline and acidulated waters, we seem to have all the apparatus ready prepared for a laboratory experiment on a grand scale, calculated to produce the phenomena we now see in the resultant veinstones. But how are we to account for these identical phenomena when occasionally reproduced in the main mass of the granite? Is it possible to apply the explanation that meets the case of the veins, or is there any alternative explanation forthcoming?

On the assumption that Dartmoor as a whole was, in Carboniferous times, a liquid or viscid magma, how are we to explain the differences of pressure and of solubility of chlorides, indicated throughout almost every cubic inch of its mass? No explanation has ever been offered, geologists having found it far more easy to minimise the importance of the facts than to account for them.

It is usually admitted that the tourmaline of Dartmoor is commonly a secondary mineral; or, as its presence implies the introduction of two new elements into the granite (fluorine and boron), it is perhaps more accurately described as an imported mineral. Assuming the existence of an ancient granite, a sufficient explanation suggests itself, both of the presence of the imported tourmaline and of the imported chlorides. If a piece of granite be heated in an ordinary fire, even to a bright red heat, and cooled, its general appearance is not much affected; it is still rigid enough to be sliced for the microscope, but differential expansions in its dissimilar minerals have rendered it permeable by fluids, as can be readily tested by a dye, such as aniline. Now, if a deep-seated granite were exposed to alterations in temperature sufficient to set up such differential expansions, the most compact rock would be minutely cracked throughout, and be rendered permeable by liquids and gases, especially under pressure. The doctrine of the rise and fall of the earth's internal heat through the crust, by the deposition and denudation of sediments, has long been accepted by geologists. All we require is an application of this doctrine to Dartmoor, so that our granite, before or during Carboniferous times, should have suffered sufficient alterations of temperature to render it porous, and so lay it open to the invasion of solvent liquids or gases. Indeed, many granites are so rotten and decomposed, from whatever cause, that they suck up fluids like a sponge.

Now a porous granite being granted, there is little further difficulty; for although some modern geologists decline to entertain the hypothesis that sea-water could gain access to heated granite and set up chemical changes therein, the weight of the evidence is against them. Years before a section was cut, or the chlorides in liquid inclusions discovered by Dr. Sorby, the almost omniscient De la Beche, with well nigh incredible foresight, pointed out the probability of saturated solutions of salt being accumulated in granite, by sea-water obtaining access to the rock when highly heated.[1] De la Beche also pointed out the important chemical effects which the various salts dissolved in sea-water might be expected to have on the granite itself.[2]

Given a porous granite, covered by sedimentary rocks thick enough to bring the internal heats within reach of a superincumbent ocean, and we have all the machinery requisite for the solution of quartz[3] and silicates; and, with the addition of fluorine and boron, for their redeposition in a variety of forms such as quartz, tourmaline, topaz, fluor spar, and triclinic felspars; all of which occur as introduced minerals in the west country granites.

The late Mr. J. A. Phillips has recorded the occurrence of saline water in Huel Clifford mine, 1320 feet below the sea-level.[4] Prof. Le Conte has calculated that at a depth of 10,000 feet below the surface the temperature would be 230 F.,[5] a very moderate depth in terms of ocean soundings, being 1666 fathoms. But even 230 F. is a temperature not to be neglected, seeing that the glass tubes of the water guages of ordinary locomotives become corroded.

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[1] Report on the Geology of Cornwall, Devon, etc., p. 378.

[2] *Loc. cit.* p. 387.

[3] Mr. J. B. Hannay has kindly informed me that he has dissolved quartz in superheated steam and produced transparent quartz crystals thereby.

[4] Phil. Mag. 1873 (2), p. 32.

[5] *Loc. cit.* p. 45.

However, in the case of Dartmoor, there is no necessity to limit the temperature to that of the isogeotherm of the granite itself in post-Carboniferous times; as, on our hypothesis of the rock being permeable by liquids, the heated gases and liquids may have been derived from much lower levels.

But to return to the evidence of the associated saline and fresh-water inclusions: these seem to indicate a consolidated granite, subsequently heated, cracked, and permeated by liquids. The question at once arises whether this granite, the original granite of Dartmoor, first consolidated before or after the deposition of the adjacent Devonian and Carboniferous rocks? If after their deposition, it is inexplicable how a mass of heated, deep-seated granite, supposed by many to be even volcanic in character, twenty miles in diameter, and which as such must have taken centuries to cool, could have had so little effect on the adjacent sedimentaries as to fail in every known instance to obliterate the exact point of contact. If before their deposition, then the granite is pre-Devonian, which is the point of my argument.

It seems likely enough that a partial aqueo-igneous solution of the ancient Dartmoor granite, accompanied by earth movements in post-Carboniferous times, would have resulted in the injection of the dissolved material into fissures of all kinds, and especially into the main lines of weakness between the granite and the adjacent sedimentaries. Thus all the local contact-alterations, so insufficient if attributed to the action of the main mass of the granite on its primary consolidation, would find an adequate cause in the contact of the newer intrusive or re-constituted granites, which, so far as I am aware, never occur in any considerable mass relatively to the whole crystalline area.

It would greatly facilitate further research in the Dartmoor area, if the following three points could be definitely decided :—

(1) Whether the volcanic hypothesis is tenable?

(2) Whether the chlorides in the quartzes are of marine or plutonic derivation?

(3) An explanation of the immediate juxtaposition of brine and fresh-water inclusions.

It is to be regretted that the problems connected with fluid inclusions excite at the present time so little interest, even when not treated with absolute contempt. Some of them are perplexing enough. Take for example Trowlesworthite.[1] In my slide of this rock a certain crystal of Apatite (identified by Mr. Harker) contains liquid inclusions with small and active bubbles and with no indication of chlorides; whereas the quartz contains some inclusions with salts and others apparently without. This rock thus presents even greater complications than the granite mentioned by Dr. Sorby in which the felspars contained fresh water and the quartzes brine.[2]

At the time that Dr. Sorby delivered his Presidential Address to Section C. at Swansea, it was generally supposed that while super-

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[1] See Worth, Trans. Dev. Assoc. vol. xix, p. 494.

[2] Rep. Brit. Assoc. 1880, p. 570.

heated water dissolved solids, superheated steam above the critical temperature did not do so. The brine and freshwater inclusions were therefore explicable on the hypothesis that the felspars caught up compressed non-solvent steam above the critical temperature, and that the quartzes caught up solvent water under that temperature. Of late years, however, experimentalists seem agreed that compressed gas above the critical temperature has even greater solvent properties than the superheated liquid under that temperature. Thus the hypothesis that the purity of the water in different minerals may be owing to the inclusion of highly compressed non-solvent steam above the critical point seems to break down. It seems possible that certain experiments made by Mr. J. B. Hannay may clear up this particular difficulty. According to Mr. Hannay,

(1) "Gas must have a certain density before it will act as a solvent, and when its volume is increased more than twice its liquid volume its solvent action is almost destroyed" (Proc. Roy. Soc. vol. xxx. p. 486).

(2) "Retaining the volume the same, the higher the temperature the greater the solvent power" (Proc. Roy. Soc. vol. xxx. p. 486).

(3) "The vaporous state can be clearly defined as a distinct state of matter."

"A vapour over a liquid holding a coloured solid in solution is colourless, but on passing the critical temperature the whole becomes coloured" (Proc. Roy. Soc. vol. xxxiii. p. 321).

Thus, according to Mr. Hannay, superheated water under the critical point is a solvent liquid. Superheated steam under the critical point is a non-solvent vapour. Superheated steam over the critical point is a gas, and, if compressed to two volumes of the liquid and less, is a solvent.

In the case of the felspar and apatite above referred to, if these minerals crystallized below the critical temperature, but under pressure not sufficient to compress the vapour into liquid, they would enclose compressed non-solvent vapour, which would ultimately condense into fresh water. Another explanation of these minerals enclosing plain water, even above the critical point, would be the absence of chlorides, or of soluble minerals alien to the growing crystals, during the process of crystallization.

Liquid inclusions of the normal type in granitoid rocks contain plain water with mobile, and sometimes very active, bubbles. Inclusion of salts are exceptional. The presence of fresh water during crystallization of the quartz would account for the one sort; and the presence of sea water would account for the other. The difficulty lies in the rapid alterations from fresh water to salt, and *vice versâ*.

The analogy of the marine boiler and engine, with condensation of fresh water in the condenser, and possibly in the cylinders, and with accumulation of brine in the boiler, suggests a possible explanation of these complicated inclusions, viz. heat acting on salt water under pressure producing rapid alternations of brine, steam, and fresh water, during the crystallization of the minerals concerned. It may be noticed that the variations are often so great, and the alternations apparently so rapid, within very minute areas, say $\frac{1}{10000}$ of an inch, that the hypothesis of any general fluidity or viscosity of the rock-masses in which such inclusions occur is very difficult to reconcile with the phenomena observed.

As exception has been taken in the columns of the GEOLOGICAL MAGAZINE to my attempting problems beyond my powers, I may mention that I have repeatedly thrown this Dartmoor question aside as too overwhelmingly difficult; on the other hand it has seemed a pity that observations which may be of use to other workers should be entirely lost.

It may also be borne in mind that the last words written hitherto by Dr. Sorby on the subject of inclusions and crystalline rocks, are the significant ones, as true now as when they were addressed to the Geological Section of the British Association in 1880—"There is still much to be learned respecting the exact conditions under which some of our commonest rocks were formed."

POSTSCRIPT.—Fig. 4 represents five distinct groups of inclusions, drawn separately with the camera lucida, the inclusions of each group being in their relative positions. The five drawings for the purpose of the process block were marshalled on a sheet of white paper and reduced by photography.

II.—WOODWARDIAN MUSEUM NOTES.

CERTAIN FOSSILS FROM THE LOWER PALÆOZOIC ROCKS OF YORKSHIRE.

By SIDNEY H. REYNOLDS, M.A., F.G.S.

(PLATE IV.)

I UNDERTOOK this description of certain fossils from the Lower Palæozoic rocks of Yorkshire at the request of Mr. Marr. The late Mr. Thomas Roberts had begun the piece of work, but left it unfinished. Nearly all the fossils referred to were collected by a party of Cambridge geologists, under the guidance of Prof. Hughes, in the Summer of 1889. The fossils come from two horizons, viz.:—

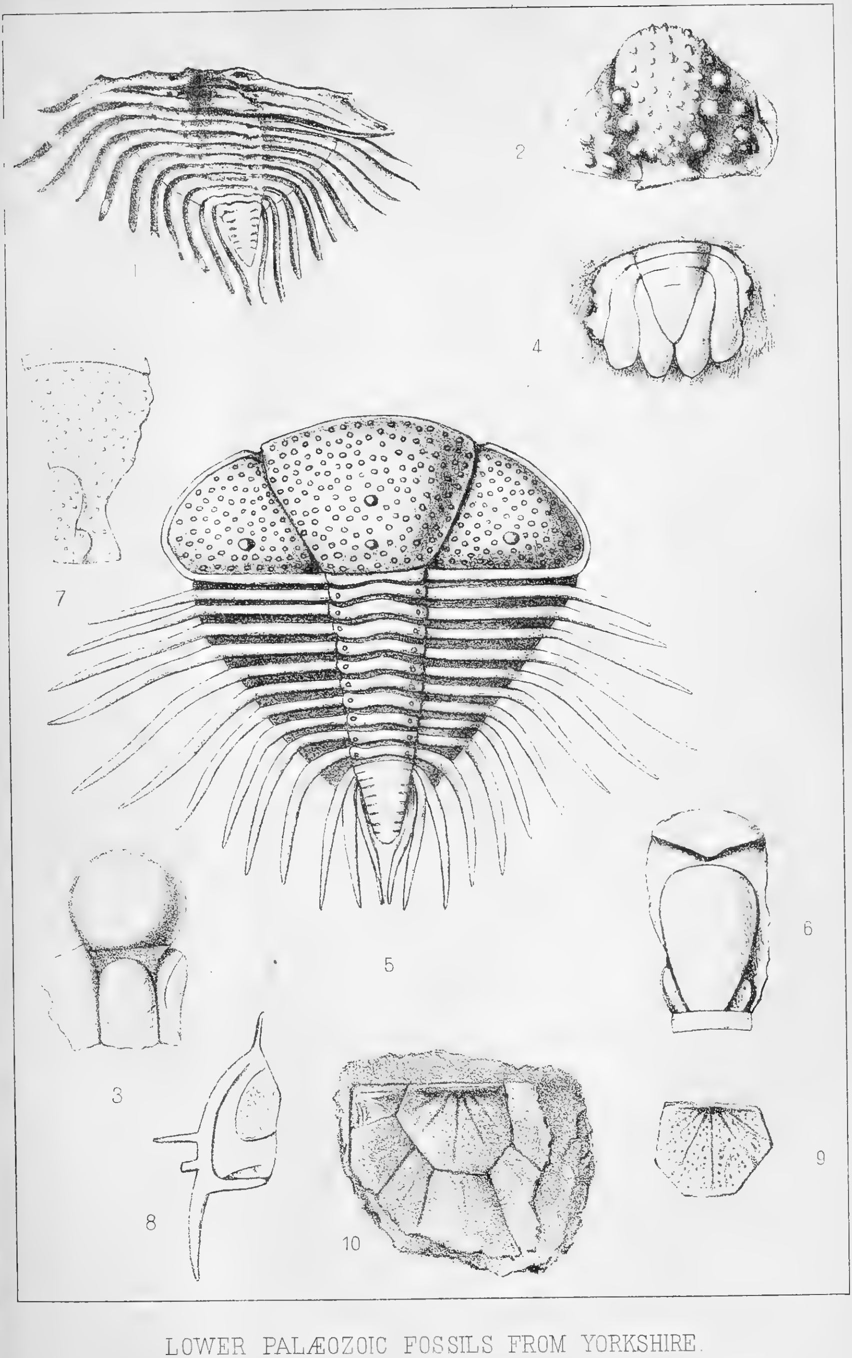
1. The *Phacops elegans* zone=Stockdale Shale series (Valentian) of Wharfe.
2. The Bala beds=Coniston Limestone series of Norber Brow and Wharfe.

Mr. Marr (GEOL. MAG., Dec. III. Vol. IV. No. 1, 1887) records the following species from the Stockdale Shale series of Wharfe:—

Petraia, sp.
Phacops elegans, Boech and Sars.
Cheirurus bimucronatus, Murch.
Encrinurus punctatus, Emmr.?
Leptæna quinquecostata, McCoy.

To these may be added:—

Illænus, sp.
Encrinurus punctatus. var. *arenaceus*, Salt.
Harpes judex, Marr and Nich.
Staurocephalus, cf. *Murchisoni*, Barr.
Cyphaspis, cf. *rastritum*, Törnq.
Cyphaspis, sp., cf. *Burmeisteri*, Barr.



LOWER PALÆOZOIC FOSSILS FROM YORKSHIRE.

Note.—I have to acknowledge my great indebtedness to Mr. Marr for much help in the examination of these obscure fossils.

These fossils are all small, and are generally very poorly preserved. *Encrinurus punctatus*, var. *arenaceus*, fig. 2, is represented by a well preserved glabella with the fixed cheeks attached. Several heads, fig. 3, of *Staurocephalus*, cf. *Murchisoni*, and one tail, fig. 4, were found. *Cyphaspis*, cf. *rastritum*, fig. 6, has at the anterior end of the head a triangular area which extends back and nearly meets the glabella. *Cyphaspis*, sp., cf. *Burmeisteri*, fig. 7, has a very short glabella, less than half as long as the head. *Harpes judex* is represented by a fragment of the limb.

The following species may be added to the list recorded by Mr. Marr, from the Bala beds of Norber Brow :—

Agnostus trinodus, Salt.
Ampyx ? rostratus, Sars.
Staurocephalus (*Sphærocoryphe*) *unicus*, Thom.
Dindymene Hughesiae, Roberts M.S.
? *Ateleocystites*.

The ? *Ateleocystites*, figs. 9 and 10, comes from the Bala beds of Wharfe, the other species are all from those of Norber.

Staurocephalus unicus, fig. 8, is not at all well preserved, but the two prominent spines on the margin are sufficient to distinguish it. An imperfect tail was also found. A specimen of *Dindymene* is recorded by Mr. Marr, and he refers it provisionally to *D. ornata*, Linnars. Mr. Roberts had commenced a description of it, and found it to differ from any species previously described. He proposed to call it *D. Hughesiae* after its discoverer, Mrs. T. McKenny Hughes.

DESCRIPTION OF DINDYMENE HUGHESIAE.

(PLATE IV. Figs. 1 and 5.)

Length and breadth each somewhat less than an inch. Head occupying about one-third of the total length, semicircular in shape, without cheek-spines. Glabella and cheeks considerably inflated. Glabella much wider in front than behind, separated from cheeks by very deep grooves. Glabella bears two, and each of the cheeks bears one large tubercle. A narrow border extends right round the cheeks, and the whole surface of the glabella and cheeks is minutely granulated. No eyes or facial suture. Thorax with ten segments, each segment of axis marked by a pair of small laterally placed tubercles. Pleuræ greatly prolonged into spines, those of the 3rd, 4th and 5th being longest. Spines of anterior pleuræ form a nearly straight line with proximal parts of pleuræ, spines of the next pleuræ are somewhat curved, and those of the last few pleuræ are bent back nearly parallel to the pygidium. Axis of pygidium less than half as long as thorax, marked by slight furrows, which do not extend completely across it. Pygidium has 3 pairs of pleuræ, all of which are bent back nearly parallel to the axis, while the last pair are nearly in contact with the axis.

D. Hughesiae resembles *D. ornata*, Linnars., but has the following distinguishing characters :—

1. The glabella bears only two well marked tubercles, and these are arranged in a line with the axis.
2. The cheeks each bear a single tubercle.
3. There is no evidence as to the occurrence of cheek spines.
4. The margin of the axis is tuberculate.
5. The pleuræ of the middle thoracic segments are longer than those of the posterior thoracic segments.

D. Hughesiae differs from *D. Frederici Augusti*, Barr., in having two instead of one tubercle on the glabella and one on each cheek, also in having the pleuræ much longer and non-tuberculate.

It differs from *D. Haidingeri*, Barr., which comes decidedly near *D. ornata* in having more tubercles on the glabella and in the greater length of the pleuræ of the middle thoracic segments.

D. Cordai, Eth. and Nich., differs from *D. Hughesiae* in having a pyriform glabella without tubercles.

Note.—I have had to rely only on figures and descriptions in comparing *D. Hughesiae* with the other species.

NOTE ON A CYSTIDEAN ? ATELEOCYSTITES.

(PLATE IV. Figs. 9 and 10.)

This specimen was found in the Bala beds of Wharfe by Rev. A. Pagan. It is unfortunately not well preserved, but appears to differ considerably from any known cystidean. It appears to belong to the family *Anomalocystidæ* (H. Woodward) and to agree with the other forms figured by Dr. Woodward in the GEOL. MAG. 1880, p. 193, in the following characters:—

1. The plates are not arranged with complete regularity.
2. The anterior surface is slightly concave.
3. There are no pectinated rhombs.
4. The plates are marked by a finely wavy ornamentation.

It differs from other *Anomalocystidæ* in the ornamentation of the plates and in the apparent greater irregularity in their arrangement, though this may in part be due to crushing.

The way the arrangement of the plates is to be interpreted is not very clear, but regarding the face preserved as the anterior face, the plates of the upper (oral) surface and right side are well preserved, while those of the left side and lower surface (from which the stem would arise) are more broken. The uppermost median plate is characteristic and is marked by 5 or 6 ridges radiating from a raised point near the margin. All the plates are marked with the wavy lines characteristic of the *Anomalocystidæ*, and in addition are marked by a series of rather deep pits sometimes arranged in lines. These pitted markings are better seen on the impression than on the actual fossil. The markings somewhat resemble those on *Turrilepas*. A segment of the stem is also seen.

EXPLANATION OF PLATE IV.

FIG. 1.—*Dindymene Hughesiae*, Roberts, MS.; pygidium and posterior thoracic segments. × 3½.

,, 2.—*Encrinurus punctatus*, var. *arenaceus*, Salt.; glabella and fixed cheeks. × 6.

,, 3.—*Staurocephalus*, cf. *Murchisoni*, Barr.; part of head. × 6.

FIG. 4.—*Staurocephalus*, cf. *Murchisoni*, Barr.; pygidium. × 6.
,, 5.—*Dindymene Hughesiæ*, Roberts, MS.; restored figure. × 3½.
,, 6.—*Cyphaspis*, cf. *Rastritum*, Törnq.; fragment of head. × 6.
,, 7.—*Cyphaspis*, sp., cf. *Burmeisteri*, Barr.; fragment of head. × 5.
,, 8.—*Staurocephalus* (*Sphærocoryphe*) *unicus*, Thom.; fragment of head. × 5.
,, 9.—? *Ateleocystites*; impression of uppermost median plate. × 1.
,, 10.—? *Ateleocystites*. × 1.

Figures 2, 3, 4, 6, and 7, are from specimens found in the *Phacops elegans* zone = Stockdale shale series (Valentian) of Wharfe, Yorkshire.

Figures 1, 5, and 8 are from specimens found in the Bala beds = Coniston limestone series of Norber brow.

Figures 9 and 10 are from specimens found in the Bala beds = Coniston limestone series of Wharfe.

[The publication of this article has been unavoidably delayed.—EDIT. GEOL. MAG.]

III.—THE RAPE OF THE CHLORITES.

By Lieutenant-General C. A. MCMAHON, F.G.S.

I WAS not present when Dr. Callaway's last paper on the Malvern Rocks was read before the Geological Society, and had not the opportunity of joining in the discussion that followed the reading of the paper. The author has now given his views regarding the "Conversion of Chlorite into Biotite" in a condensed form in the GEOLOGICAL MAGAZINE (Dec. 1893, p. 535), and has expressly invited criticism on them; I venture, therefore, in response to this invitation, to give expression to a difficulty that presents itself to my mind.

It is not necessary to enter into a discussion of the authorities quoted by Dr. Callaway; but I remark in passing that two of the papers referred to profess to deal with cases of contact metamorphism, and consequently the conditions that must have prevailed in those cases are altogether different from those which govern Dr. Callaway's supposed case of dynamo-metamorphism. In cases of contact action one can readily understand how aqueous acid vapours, or liquids, emanating from the molten igneous rock under high pressure penetrated the adjoining rocks, and carried with them in solution some of the constituents of the igneous magma.

In the case supposed by Dr. Callaway the conditions are altogether different. We have to deal with a consolidated rock which contains the hydrous mineral chlorite, the anhydrous mineral biotite, and others that show a passage between the two. Dr. Callaway contends that the biotite has not been converted into chlorite by aqueous agencies, but that the hydrous chlorite has been transformed into anhydrous biotite through the action of heat. The fact that the rock contains chlorite as well as biotite, and minerals that show a passage between the two, would seem opposed to the acceptance of the author's view; but he meets this difficulty in the following way:—"The reason why in the Malvern rocks we have sometimes a decomposition of hornblende into chlorite, and sometimes a change of chlorite into biotite, is found in the difference of environment. Where the rock is slightly crushed, and there are no signs of rock-fusion, there is decomposition of hornblende; but where there is intense crushing and shearing, accompanied by a high temperature, reconstruction sets in and biotite is generated."

The heat produced locally by the crushing and shearing of the solid rock, he tell us, "often rose to the point of fusion in the shear zones." What the fusion point was the author does not tell us, but it is obvious that the fusion of rocks, such as those contemplated, must have required a very high temperature.

The intense heat, however, under Dr. Callaway's supposition, was limited to the shear zones and was quite local. In other parts of the same rock, namely those in which chlorite is now to be found, the temperature could not have risen to red heat, for at a red heat, the author tells us, chlorite loses its water.

The author accounts for the escape of water from the altered chlorite, by its having been driven off by heat. The "elimination" of the water from the chlorite, he tells us, offers "no serious difficulty." If so, the rock was, for all practical purposes, a porous rock through which water could be driven by heat.

The conditions supposed to have existed are then briefly as follows: (1) The presence of centres of *intense* heat produced by local crushing and shearing; (2) The existence of temperatures below red heat in other parts of the rock; (3) A porosity in the rock sufficient to allow water to escape from it.

Such being the conditions I am at a loss to understand how the heated chlorite, whilst parting with 12 per cent. of water and 16 per cent. of magnesia, can have acquired 2 per cent. of alumina, 8 per cent. of potash, and 11 per cent. of iron in addition to the alumina and iron already present in it.

The intense heat at the local centres would surely have driven away all the water from those centres to the cooler parts of the rock. The dehydration of the chlorite is accounted for on that supposition. This water, charged, as it probably was, with acid, may have carried away with it the 16 per cent. of magnesia, but by what agency was the additional alumina, potash, and iron conveyed to the chlorites? The water contained in the rock must have been repelled and driven away, as before stated, from the centres of heat. When this water, charged with bases in solution, was moving away from these centres, how could the iron, alumina, and potash in the pores of the rock through which the water passed have forced their way to the distressed chlorites in the face of the bombardment to which they must have been exposed by the panic-stricken molecules rushing away from the centres of disturbance? By what power was the iron, alumina, and potash moved against this stream of fugitives?

I doubt whether, under the conditions supposed, any chlorite would have remained near the centres of heat. Chlorite is readily susceptible to the action of acids; and water, even faintly charged with acids, would, at the high temperature predicated, in all probability have swept all the alumina, iron, and magnesia contained in the chlorites out of these minerals. That the acidified water should have removed 16 per cent. of magnesia and have left the whole of the iron is highly improbable, for, as far as my experience in experiments on minerals goes, I should say that iron is one of the first bases to be removed by acid solvents.

But if we are at liberty to suppose, for the sake of argument, that *none* of the iron, or alumina escaped from the chlorite, what brought the *extra* alumina, potash, and iron to the spot? Why should these bases have left other cooler and more comfortable localities, in which they were located, to force their way to the centres of molecular disturbance where crush, shear, and intense heat prevailed?

If the distressed chlorites had been beautiful females and the iron, potash, and alumina, ardent male creatures one might have accounted for their rushing through fire and smoke to reach these prizes, like Roman soldiers engaged in sacking a town, but I suppose the author is not prepared to endow his molecules with sexual qualities, and, in the absence of any explanation of that kind, I confess that I cannot imagine the nature of the fascination which Dr. Callaway's distressed chlorites appeared to have had for the iron, the potash, and the alumina situated in other parts of the rock; nor can I imagine the agency by which these bases were conveyed from the surrounding rock to the centres of intense heat. These centres were surely the foci of repulsion, not of attraction?

There can have been no flow of water laden with iron, potash, and alumina towards the heated centres, where the chlorites under consideration were, because the author's conditions involve the fact that water was driven away by the intense heat generated at those centres. By what agency then, I ask, was the iron, potash, and alumina divorced from their chemical combinations in other parts of the rock and drawn towards the chlorites?

The author admits that "it is natural that those who have not studied the evidence furnished by the Malvern rocks should adopt an old and well-known explanation of the phenomena in preference to a new and seemingly improbable one"; but surely, if Dr. Callaway asks those who have not studied the Malvern rocks to believe the "seemingly improbable theory" which he advocates in preference to a more obvious one, it is incumbent on him to explain in detail by what agency the molecular movements involved in his theory were brought about. Dr. Callaway remarks that "if this mineral transformation be an observed fact, it may seem unnecessary to discuss theoretical objections to it"; but the conversion of chlorite into biotite does not yet rank as an "observed fact." The only observed fact is that chlorite and biotite have been found in the same rock. Dr. Callaway offers a theory to account for this fact. Those who doubt the correctness of this theory have a right to ask for full proof of its genuineness before it is stamped with the Hall mark. I desire to offer one more remark in conclusion.

Dr. Callaway tells us that "the temperature of metamorphism in the Malvern rocks often rose to the point of fusion." If so, actual fusion must have been the result, and biotite cannot, in those localities, have been formed at the "expense of chlorite," for all the chlorite would have been melted down and would have been merged in the fused and fluid magma. If, on cooling, biotite crystallized out of this magma it would have been at the "expense" of the general fund of bases, and not at the expense of the chlorite. Moreover, the fused rock, unless it were subjected to shearing, or fluxion, in a partially crystallized condition, would have consolidated as a granite, not as a gneiss; and would have exhibited a granitic and not a foliated or gneissic structure.

[The Editor regrets that owing to the pressure on the space of the MAGAZINE, the publication of this article has been unavoidably delayed.—EDIT. GEOL. MAG.]

IV.—SOME NOTES ON GNEISS.[1]

By Professor T. G. BONNEY, D.Sc., LL.D., F.R.S.

MUCH light has been thrown of late years on the history of gneiss and other foliated rocks. Geological literature is beginning to bristle with such terms as regional-metamorphism, pressure-metamorphism, dynamo-metamorphism, and the like. Yet longer and less intelligible names will probably follow, which, under the guise of precision, will foster confusion. So it may be a little help to students to set down, as far as possible in plain English, the fruits of some years' study of gneisses and allied rocks. In this work I have taken nothing on trust, and have tested every inference to the best of my ability. Probably there is nothing original in the results, but they are all the outcome of personal observation, for I have always preferred questioning Nature to reading books. So, in order to economize time in searching for what has been already said, and to save studding the page with references, I will assure the reader that he is quite at liberty to suppose that "everything has been said by somebody, somewhere."

Let us begin our observations with a rock which is a fairly coarse granite, occurring in a region affected by great earth-movements, such as mountain-making, which, however, for some reason or other, has escaped with its structure practically unmodified. Such a rock sometimes may be locally indistinguishable from an ordinary granite, but very commonly a small difference is perceptible, especially on a slightly weathered surface. This has a rather fragmental aspect, the quartz and the felspar presenting a superficial resemblance to unrolled clastic grains,—as in an arkose, the materials of which have been transported only for a short distance. This resemblance does not disappear on microscopic examination. The rock, in short, has been fractured but not crushed. This structure is exhibited (not to mention other examples) locally in the granite at the entrance of the Val Rosegg (Pontresina), in the granitoid rock of Twt Hill (Carnarvon), and of Llanfaelog (Anglesey); occasionally also in the so-called Dimetian of St. Davids. This, then, may be regarded as the first stage in pressure-modification.

Next suppose this agent to have produced more marked effects, and the rock to have been definitely crushed, perhaps also slightly

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[1] It may be well to state that this paper was written some time prior to the publication of Mr. Goodchild's paper in the January Number of this MAGAZINE, and has been left unaltered.

"sheared" in addition. I have more than once described the results of such a process,[1] so far as the different minerals are concerned; hence it is needless to enter into details, and I shall confine myself to a few general illustrations of the making of a gneiss by pressure.

To exhibit the first stage we may select a porphyritic granite from near the English church at Saas Fee (Valais). The rock might be termed an "augen-gneiss." If, however, a surface transverse to the foliation be examined, the felspar crystals are fairly regular in shape, being only a little distorted or rounded at the angles, and are not conspicuously orientated. But on a surface in the direction of the foliation they appear as rather irregular, wavy streaks, parted by streaks and lines of dark mica. The annexed sketch (Fig. 1) shows a slightly more advanced stage of the same rock. The larger felspar crystals vary from lenticular to streaky in form, are sometimes cracked and slightly separated, as is indicated by lines of dark mica about the thickness of a sheet of writing-paper. The smaller felspars have been often crushed almost to powder.

1.

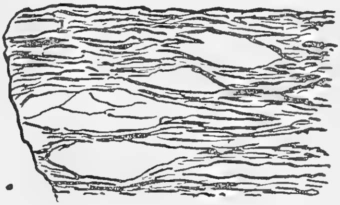

Fig. 1.—Augen-gneiss, near Saas Fee, section along the "dip plane" of the foliation (the rock near the church is a little less crushed than this, but my sketch is rather too rough to be copied).

A stage somewhat more advanced may be found in gneiss (common in boulders) on the eastern bank of the Davoser See. Here the rock hardly can be called an augen-gneiss, for generally it is a coarse, streaky, slightly wavy, foliated gneiss—constituent minerals: quartz, felspar, biotite and some white mica. But on close examination traces of the original structure can be detected, as is shown in the annexed sketch (Fig. 2), and from this stage a gradual transition can be traced backwards into a true augen-gneiss, in which the white rounded felspars are over 2″ in diameter.

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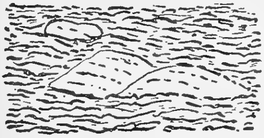

Fig. 2.—Remains of crystals in a much crushed augen-gneiss, near Davos Dörfli.

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[1] See Presidential Address, Quart. Journ. Geol. Soc. 1886, Proc. 67, 68.

Further crushing, associated with definite shearing, at last practically obliterates all distinct traces of "augen" structure. The streaks of different mineral composition, the more quartzo-felspathic and the more micaceous, especially the latter, become longer and thinner, until, as the ultimate result, we come to a fine banded rock, with laminæ so uniform as to suggest that the materials once were stratified. Excellent illustrations of this may be found in a number of large boulders strewn about the lower end of the St. Moritz lake. One block may be a rather coarse granitoid gneiss, the quartz, felspar and mica (especially) forming little streaks. Another affords a rock more markedly fissile, the surface of the slabs being slightly undulate and of a sage-green colour (from the crushed and hydrated biotite or from secondary chlorite). Slight streaks of white here and there show through the "varnish," which is very thin: that is, through the film of secondary mica forming the "sheen surface." But on examining the transversely fractured ends of slabs, we see white wavy streaks of quartz and felspar, perhaps a couple of inches long and a fifth of an inch broad at the thickest part, from which condition we are led on to a still more fissile rock, composed of alternating laminæ of white and green: the former about one-eighth of an inch thick, the latter still thinner, each of which may be traced for a length, usually, of from three to four inches; these bands, it is important to notice, not being continuous through the block. In certain extreme cases the rock is more like a mica-schist than a gneiss, but even then very thin white streaks may be detected on examining a transverse fracture. The Central Oberland and some parts of the Pennines afford many like instances. This "linear foliation" seems to be the utmost that crushing and shearing can produce, and the latter is an essential factor. To obtain this structure the rock must be granitoid and fairly coarse; where it has been also porphyritic, that probably is recorded by a little irregularity in the linear foliation, *i.e.* the occasional presence of slightly thicker and more lenticular streaks. The more regularly "lined" varieties have come, I believe, from rather coarse but non-porphyritic rocks. The more close the resemblance to a mica-schist, the more complete, in all probability, the crushing. In these cases it may be also necessary that the rock originally was rather fine-grained.

Analogous structures may be produced in more basic rocks, such as diorites and dolerites, but in them mineral changes seem to take place more easily, such as the formation of acicular hornblende, chlorite, epidote, and secondary felspar. These I have elsewhere described, so that I may sum up the result of at least ten years of study in the following statement: That pressure is a potent factor in structural and mineral change in granitoid rocks, whether acid or basic, though more so in the latter than in the former; that the resulting structures pass through a somewhat wavy or lenticular streaking to a thin banding, which may ultimately lead to an almost slate-like fissility; but that I have never found any reason to suppose that a well-marked mineral banding, such as one in which the layers may exceed a quarter of an inch in thickness, can be produced by pressure acting on a rock in which no such structure originally existed.

But there are many gneisses which are distinctly and broadly banded. Such, for instance, occur among the Laurentian rocks of Canada and Greenland, the "Hebridean" rocks of Scotland, the ancient crystalline rocks of Norway, and those of several parts of the Alps. As an example I may refer to a gneiss in the neigbourhood of Saas Fee. A huge boulder, which in all probability came from the lower part of the Mittaghorn, afforded the particular instance. The rock consists of quartz, felspar, and a greenish-grey mica, and is rather fine-grained. The banded structure is very distinct, the lighter zones consisting chiefly of quartz and felspar with small flakes of mica, the darker being richer in mica, which occurs also in larger flakes (Fig. 3). The former are usually the thicker; the latter vary from between two and three inches in thickness to little more than films. In these the mica flakes are bent into zigzags, and in the broader bands a strain-slip cleavage sometimes may be seen crossing them obliquely. This structure, the result of pressure, is clearly later than the formation of the bands.

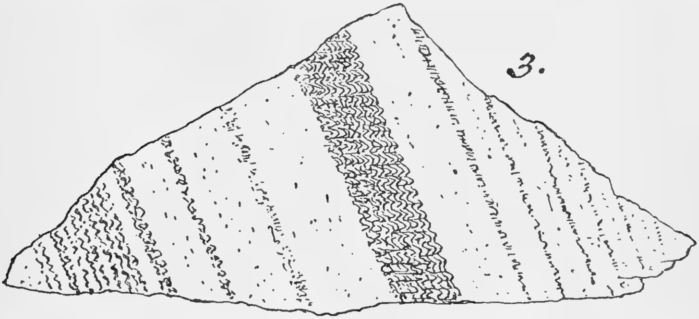

Fig. 3.—Gneiss with "rucking" and traces of strain-slip cleavage in the broadest micaceous band. Fragment about 15″ long, from part of a fallen block, near Saas Fee.

As another example a boulder may be cited which I found lying on the flank of the Schafberg at Pontresina. In this also—a fairly coarse gneiss—the mineral banding is distinct, the broadest of the more micaceous zones being nearly three inches across. But in addition to this the whole block shows an oblique "lamination" of more or less micaceous stratulæ, even in the more quartzo-felspathic bands. This structure, which is not very uncommon, curiously resembles current-bedding in a stratified rock, to which, indeed, it has been referred by more than one well-qualified observer. Formerly I should have so regarded it myself, but I am now convinced that the resemblance is illusory and that it is a result of pressure.[1]

A third example may be mentioned, because it may require a dif-

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[1] *See* Quart. Journ. Geol. Soc. Proc. 1886, p. 97.

ferent explanation. This occurs on the south side of the St. Gothard Pass, about 1900 feet above Airolo, where the road between two bridges is nearly level, and about a furlong from the foot of the second set of zigzags.

The dominant rock is a dark biotite schist, but it is locally interbanded with a light-grey granulitic rock. The latter varies from mere lines to bands one or two inches thick, which, however, are rather impersistent, thickening or thinning or splitting, generally in the course of two or three feet, and stopping sometimes with a moderately pointed end. Of this last case two explanations seem possible: the structure may be original and "fluxional" in origin, produced by a partial melting of the darker rock in consequence of the intrusion of the lighter one, the two then moving on together; or it may be due to the crushing of a solid mass, in which the one rock formed veins in the other. I have examined, however, a good many cases in which a "veined" mass has been crushed and somewhat sheared, and, while I cannot deny that this explanation is a possible one here, I feel bound to remark that, if so, the case is a rather exceptional one. But it seems to me impossible thus to explain either the first two cases or the very numerous instances of banded gneisses which I have seen in many lands and extending over large areas. In regard to these, as it appears to me, we must choose between two hypotheses: that of fluxional movements anterior to complete consolidation in a mass not perfectly homogeneous, and that of the metamorphism of a stratified rock. For reasons which I will state presently, I think the latter to be only rarely applicable, and the former to be generally the correct one. This, as has been shown in papers already published,[1] must be the origin of some banded gneisses in Sark,[2] and (we may perhaps add) at the Lizard. Fluxional structure undoubtedly, as I believe, sometimes occurs in the gabbro of the Lizard Peninsula,[3] and of the Saas valley,[4] in the diorites of Guernsey, and in the dolerite of Mount Royal (Canada). Most of these instances of mineral banding are afforded by districts on which pressure has not produced any marked effects. Some rocks at the Lizard certainly show pressure-metamorphism, but not in the vicinity of the banded gabbros, where the serpentine in which they are intruded is practically undisturbed, and even in the Alps the tough gabbros have not seldom succeeded in resisting it. Still, as some persons are sceptical on this matter, it may be interesting to add another case where veins of intrusive granite exhibit a well-banded structure which cannot be explained by anything but a movement of the material while still in a plastic condition. This may be found in a mass of ice-worn rock near the base of the Allalin glacier. Granite veins, generally narrow, break in all directions through a mass of greenish schist (the *Grüner schiefer* of the Swiss geologists), apparently not having any necessary connection with the foliation, which is conspicuous in the latter and is probably the result of pressure. This, however, cannot have pro-

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[1] Quart. Journ. Geol. Soc. 1892, p. 122.

[2] *Ibid* 1891, p. 464.

[3] *Loc. cit.* p. 483.

[4] Phil. Mag. 1892, p. 237.

duced the structure of the granite, which is roughly parallel with the sides of the veins, and thus inconstant in direction. The granite is moderately fine-grained, consisting of quartz and felspar, with only a little white mica. Taking one vein, about six inches wide, as an example (Fig. 4), we find the outer band (rather more than one inch thick) somewhat more coarse-grained than the rest, the felspar varying in size from large hemp-seeds to very small peas. The next band is richer in quartz; the interior differs somewhat from both and seems to exhibit a slight fluxional structure. Parts of some of the veins were rather more micaceous, that mineral also occurring in streaks, sometimes apparently connected with small inclusions of the green schist. The banding may be very clear for three or four feet, then may become less distinct; one vein may show it, another not. A movement of the constituents where the mass was not yet perfectly consolidated is rendered probable by the rounded form of the felspars, and this hypothesis alone seems possible as an explanation of the banding.

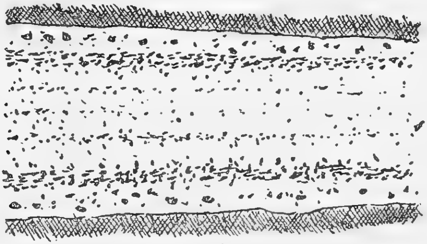

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Fig 4.—Vein of streaky and banded granite intrusion in green-schist. Rock near the foot of the Allalin glacier. Diagrammatic, the spots indicating the more conspicuous felspar-grains.

In regions such as the Alps, which have been more than once affected by great earth movements, there is always a possibility that after a structure had been produced by one set of disturbances, the mass in the lapse of time might become completely consolidated—perfectly cemented as it were, by secondary mineral deposits—after which it might be modified by a new set of earth movements. This, very possibly, may be the history of certain banded gneisses, generally rather fine grained, in which the layers of mica, though very regular, are quite thin—hardly thicker than a stout piece of cardboard; such, for instance, as the rather fine-grained gneiss which occurs on the east coast of Scotland about and to the north of Muchals. But I have never been able to find any proof of the notion that a broad banding can be produced by any amount of crushing in an ordinary holocrystalline rock, while I have demonstrated, as I venture to think, that it can come from movements anterior to the consolidation of the mass; so that while we may admit the possibility of the former explanation being true for a certain group of rocks in which the bands of mica or of other minerals are thin, we must deny it in all cases where they are even moderately thick.

But was the old notion entirely wrong? Cannot a gneiss be in any case an altered sedimentary rock? Beyond all doubt not a few schists have thus originated: all calc-schists and quartz-schists; many mica-schists; perhaps also some hornblendic and chloritic schists. I am aware that it has been suggested that certain basic rocks might be changed into calc-schists. It is true a hornblendite or a pyroxenite might produce an ophicalcite, but both these are rare rocks; also certain calc-mica schists might come from rocks of the doleritic group; but I doubt whether we have evidence of such transmuting power as would produce on the one hand anything like a marble or one of the purer calc-schists, on the other a rock so siliceous as certain quartz-schists. They are interbedded and associated; they alternate with and graduate into one another, now rapidly, now slowly; they present macroscopic resemblances to stratification, even more perfectly than the examples which we have considered above, while, in the case of not a few, the possibility of an igneous origin is excluded by their mineral composition. There seems, however, no reason why a sediment of the proper chemical composition should not, as a result of metamorphic processes, be changed into a gneiss. But, as a rule, clays (for to some variety of this rock we must look) are rather deficient in alkalies, and seem to produce micas and minerals such as andalusite more readily than felspar.

In cases of contact alteration, though felspar occurs more frequently than has been supposed, it seems not to be very common; while pressure appears to bring about the conversion of felspar, where it already exists, into quartz and white mica. Into these minerals, indeed, it sometimes appears to break up without any such disturbing cause.[1] No doubt felspar of secondary origin is a more common constituent of crystalline schists than has hitherto been supposed, and the mineral has been often overlooked in consequence of the close resemblance to quartz which this variety presents, but this fact, so far as our present knowledge goes, is more applicable to the products of basic than of acid igneous rocks, and does not seem likely to remove our difficulties in the case of gneisses.

It is not, however, possible for a rock like the Torridon sandstone to be reconsolidated by secondary enlargment of its constituent grains, and to pass back, as do some quartzites, into a really crystalline condition; thus producing a rock similar to one of the Laurentian gneisses? Such a change would be theoretically possible, but it is not easy to find satisfactory evidence that it has really occurred. The Torridon sandstone of Scotland, the *grès felspathique* of Normandy, where they have been subjected to pressure, approach nearer to the mica-schist group, the felspar disappearing in the manner already mentioned. I have not myself seen any marked case of contact-metamorphism in either of these rocks, so that I cannot be certain what would be the effects of raising them to a fairly high temperature under moderate pressure and in the presence

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[1] Quart. Journ. Geol. Soc. 1888, p. 36.

of water. Of course cases can be found where a gneiss is *imitated*, such as the so-called Carboniferous gneiss of Guttannen.[1] Here, however, the rock has not been restored, in any proper sense of the word, to a crystalline condition; it is only a somewhat consolidated "arkose" like the Torridon sandstone, which also has been slightly modified by subsequent pressure. Hence it has no more claim to the name of gneiss than certain very remarkable specimens of the Torridon rock have to that of granite. Pebbles of this rock (or of one exactly like it) sometimes so closely resemble granite that I have found it necessary to examine them under the microscope before I could feel satisfied as to their clastic character. In such cases as these Nature has been perpetrating a forgery and setting a trap for unwary geologists.

Still, notwithstanding these difficulties, I think it would be rash, in the present state of our knowledge, to deny the possibility of gneiss being produced by the alteration of a sedimentary rock. Among certain quartz-schists (not quartzites) I have occasionally found interstratified bands or beds, including grains of felspar, for which it seemed as reasonable to infer a clastic origin as for the other constituents—that is to say, they were probably enlargements of a fragment of felspar. This mineral occasionally is sufficiently abundant to make the rock petrographically a quartzose gneiss. With direct evidence such as this, and the indirect evidence afforded by the formation of secondary felspar in certain cases of contact-metamorphism and in some crystalline schists, it would be unwise to deny the possibility of gneiss having been formed by the metamorphism of a sedimentary rock. Still, I think this origin will prove to be a rather exceptional one, and the masses produced comparatively thin and limited in extent.

We conclude, therefore, that the term gneiss covers a group of rocks rather different in character and very different in history. One (a common type) is a gneiss in consequence of an original structure, and remains very nearly in its original condition. Another (also common) owes its structure to pressure acting on a rock which had already solidified and had become crystalline. A third (probably rather rare and exceptional) is the result of the metamorphism of materials which were originally clastic. It is very probable that each of these groups will be found to possess distinctive structures: to some of them I have already invited attention; others will doubtless be discovered during the next few years. The enquiry is as promising as it is interesting and success is probable, if the investigators remember that work in the field must go hand in hand with the study of structures under the microscope. These methods, when united, may be fertile, but when dissociated they can only result in a false conception and a bringing forth of wind.

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[1] Quart. Journ. Geol. Soc. 1892, p. 390.

V.—NOTES ON THE SKIDDAW SLATES.

By J. E. MARR, M.A., F.R.S., Sec.G.S.

THE Woodwardian Museum has for many years contained a fine series of Skiddaw Slate fossils. In 1890 this was increased by the addition of many specimens obtained by the members of Prof. Hughes' Long Vacation party, and immediately afterwards the University acquired, by donation, the valuable collection of the late Mr. Kinsey Dover. Prof. Nicholson has also presented a large number of Graptolites. When time permits, I hope to be able to describe our unrivalled collection of Skiddaw Slate fossils; meanwhile, a few notes on the distribution of these organisms will throw such light on the development of the Skiddaw Slates as is required for the elucidation of the detailed structure of the district, a task which Mr. Harker and I shall attempt to perform ere long.

For a considerable period the Skiddaw Slates were unhesitatingly correlated with the Arenig rocks of North Wales. The late Mr. Clifton Ward was the first to return to the opinion, long ago formed by Sedgwick, that representatives of much older deposits might occur amongst these slates. In the volume of this MAGAZINE for 1879[1] he remarks: "The physical evidence inclines one to believe that the Skiddaw Slates include the Arenig Slates, the Arenig Grit, the Tremadoc Slates, and the Lingula Flags." Mr. Ward drew up his subdivisions almost entirely on physical evidence, and, indeed, treated (as was customary at the time) the evidence yielded by the Graptolites as of little practical utility. A study of these Graptolites shows that he was quite correct in his view that the slates were not entirely formed during Arenig times, but the actual divisions which he proposed, as shown in the map and sections accompanying his paper and in the explanations thereof, do not stand the palæontological test.

The term "Skiddaw Slates" has been used for all sedimentary and contemporaneous volcanic deposits of the Lake District and neighbourhood which lie below the great volcanic group known as the Borrowdale Series, and in that sense it will be used in this paper, though no attempt will be here made to discuss the character of the junction between the two groups at different places.

Although the general use of the term has been as above, nevertheless other deposits, which are undoubtedly of very different age, have been at times included in the Skiddaw Slates, as, for instance, the Drygill Shales, described by Prof. Nicholson and myself in this MAGAZINE.[2]

The main outcrop of the Skiddaw Slates lies north of the mass of volcanic rocks constituting the central hills of Cumbria, and, owing to the existence of an anticlinal fold, separates those volcanic rocks from their equivalents in the Caldbeck Fells and the comparatively low country north of Bassenthwaite Lake. This outcrop appears to be continuous (though in one place covered by the Carboniferous con-

[1] GEOL. MAG. 1879, Dec. II. Vol. VI. p. 124.

[2] GEOL. MAG. 1887, Dec. III. Vol. IV. p. 339.

glomerate near Ulleswater) with that of the Skiddaw Slates, ranging in a N.N.W—S.S.E. direction, from the east side of Saddleback to the neighbourhood of Shap, across the eastern extremity of Ulleswater. Another mass of Skiddaw Slate forms the prominent hill of Black Comb at the southern end of Cumberland, and a subsidiary outcrop occurs near Dalton-in-Furness. A large part of the Isle of Man is also occupied by Skiddaw Slates. To the east of the Lake District beds referred to these slates are found in the Cross Fell Inlier, and are mapped by the Geological Surveyors in the small inlier of Teesdale; and it has been suggested by Mr. Aveline that a portion of the green slates of Ingleton is referable to this group.

The general characters of the Skiddaw Slates have been frequently described. Almost every variety of arenaceous and argillaceous deposit may be found, besides volcanic ashes and lavas. They are distinguished by a general absence of calcareous matter. The Graptolites, which it is the object of the writer to consider more particularly, are generally found in, though by no means universally confined to, the black or blue-grey argillaceous members of the group. These Graptolitiferous argillaceous rocks may be frequently traced in bands running parallel with the general strike of the rocks, and extending for a greater or less distance in this direction. They have been largely worked by local observers, especially by the late Mr. Kinsey Dover and Mr. Postlethwaite in the neighbourhood of Keswick, the result being that our richest collections have been gathered from the vicinity of that town; and many localities away from it, which are rendered classical by the work of the earlier exponents of the palæontology of the Skiddaw Slates,—Salter, Harkness, Nicholson, and others, still require much examination before their faunas can be considered thoroughly known.

The following list of Graptolites, compiled from the Woodwardian Collection, the writings of various authors, notably Nicholson, and, after brief examination of the collection of Mr. Postlethwaite and that in the Keswick Museum, will be sufficient to allow us to draw important conclusions:—

LIST OF GRAPTOLITES FROM THE SKIDDAW SLATES.

Didymograptus affinis, Nich. Barf; Carlside Edge; Eggbeck; Ellergill.

,, *bifidus*, Hall. Outerside; E. of Dodd Wood, Keswick; Doddick Fell, Saddleback; Eggbeck; Ellergill.

,, *indentus* var. *nanus*, Lapw. Outerside; Barf; Gategill, Saddleback; Glenderamakin Valley, Mungrisdale; Thornship Beck.

,, *Murchisoni*, Boeck. Outerside; Thornship Beck; Cross Fell area.

,, *fasciculatus*, Nich. Eggbeck; Thornship Beck; Ellergill.

,, *gibberulus*, Nich. Randal Crag; White Horse, N.W. of Skiddaw.

,, *Nicholsoni*, Lapw. Outerside; Barf; Carlside; Thornship Beck.

,, *nitidus*, Hall. Barf; Randal Crag; Knott Head, Whinlatter Pass; Brundelhow Lead Mine.

,, *patulus*, Hall. Outerside; Randal Crag; Eggbeck.

,, V. *fractus*, Salt. Barf; Dodd, Brackenthwaite; New Brow Quarry, Upper Lorton.

,, V. *fractus*, var. *volucer*, H. O. Nich. Outerside.

,, *extensus*, Hall. Outerside; Randal Crag; Knockmurton, near Lamplugh Cross.

Azygograptus Lapworthi, Nich. Barf; N.E. of Sleet How, W. of Braithwaite; Hodgson How; Carlside Edge.
,, *cœlebs*, Lapw. Ellergill.
Janograptus? sp. Brunstock Scar, below Randal Crag.
Tetragraptus Bigsbyi, Hall. Outerside; White Horse Fell; Great Knott, Randal Crag; Bassenthwaite Sand Beds; Gibraltar, Skiddaw (in chiastolite slate).
Tetragraptus bryonoides, Hall. Outerside; Barf; Randal Crag; White Horse Fell; Frozen Gill.
,, *quadribrachiatus*, Hall. Outerside; Scale Hill, Crummock; Aiken Gill (Scawgill); N.E. of Grizedale Pike; Carlside Edge; Barf.
,, *Headi*, Hall. Barf; S. end of Randal Crag.
,, *crucifer*, Hall. Barf.
,, *fruticosus*, Hall. (Recorded by Lapworth.)
Dichograptus Sedgwicki, Salt. Braithwaite; Mire House, near Skiddaw.
,, *octobrachiatus*, Hall. Outerside; Carlside Edge; Slape Crags above Hole Gill, Brackenthwaite.
,, n. sp. Outerside.
Loganograptus Logani, Hall. Outerside; Barf; Randal Crag.
Trichograptus gracilis, Nich. Thornship Beck; Ashlock Sike?
Temnograptus multiplex, Nich. Near Peelwyke (not *in situ*); New Brow Quarry, Upper Lorton; How, Scale Hill.
Schizograptus reticulatus, Nich. Barf; Carlside Edge; Scale Hill.
Trochograptus? *vagans*, Nich. Scale Hill.
Bryograptus ramosus, Brögger. Barf.
,, *Callavei*, Lapw.? Barf.
Phyllograptus typus, Hall. Barf; Whiteside; Carlside; E. of Dodd Wood; Randal Crag; Glenderamakin Valley, Mungrisdale.
Phyllograptus Anna, Hall. Randal Crag.
,, *angustifolius*, Hall. Barf; Carlside; Whiteside; Bassenthwaite Sand Beds; Knott Head, Whinlatter; Ellergill.
,, *ilicifolius*, Hall. N.E. of Sleet How, W. of Braithwaite.
Diplograptus dentatus, Hall. Outerside; Bassenthwaite Sand Beds; N.W. of Lingside, Skiddaw; Glenderamakin Valley, Mungrisdale; Ellergill; Master Sike, Cross Fell area.
Climacograptus. Outerside; Ellergill.
Cryptograptus? *Hopkinsoni*, Nich. Outerside; Thornship Beck.
,, ? *antennarius*, Hall. Outerside; Glenderamakin Valley, Mungrisdale.
,, *tricornis*, Carr. Outerside; Ellergill.
Glossograptus armatus, Nich. Thornship Beck.
Trigonograptus ensiformis, Hall. Mosedale, near Troutbeck.
,, *lanceolatus*, Nich. Ellergill.
Dicellograptus moffatensis, Carr.? Barf; Randal Crag; Bassenthwaite Sand Beds.
Ctenograptus annulatus, Nich. Barrow, near Braithwaite; Wath Brow, near Keswick.
Thamnograptus Doveri, Nich. S.W. of Randal Crag.

So many fossils which are elsewhere considered characteristic of different horizons occur in the same locality, *e.g.* at Barf and at Outerside, and the same species recur with such frequency in strata which appear to be at different horizons, that the attempt to divide the Skiddaw Slates into different fossil zones seems at first sight impossible. Amidst rocks so contorted as the Skiddaw Slates, the lesson taught by the convoluted rocks of the Southern Uplands of Scotland must not be forgotten, and a careful study of the list above given in the light gained by examination of other areas proves the zonal classification of the rocks to be applicable here. At the same time, owing to the difficulty of obtaining good specimens *in situ* (a large number of the specimens in collections having been gathered from the loose *débris* or screes on the sides of hills) any attempt to map the Skiddaw Slates according to their zones will be fraught with unusual difficulty, and can only be accomplished by a local observer with much time at his disposal through a term of many years. Even then, the work will hardly repay the labour, for the zonal succession of the equivalents of the Skiddaw Slates will doubtless be discovered in other areas, where the slighter disturbance of the rocks will render the task one of comparative simplicity. This being the case we may at once proceed to discover what may be learnt from an examination of our present list.

In studying it we may gain much information from noticing the species which occur together on the same slab of stone (see p. 130), and also by observing what species are absent from particular localities.

In Prof. Lapworth's paper on the Geological Distribution of the Rhabdophora [1] the Skiddaw Slates are divided into an Upper and a Lower Group, but we require still further sub-divisions. These subdivisions will be considered in order, beginning with the oldest beds.

1. Tremadoc Beds.

Bryograptus Beds.—In Mr. Postlethwaite's collection is a slab (see p. 130), of black slate from Barf, covered with numerous specimens of *Bryograptus ramosus*, Brögger. The slab is shown natural size in Fig. 1, p. 130, whilst Fig. 2, is a representation of one of the Graptolites upon it enlarged two diameters. Another slab was discovered by Miss Serjeant, of Girton College, at the same place, and is now in the Woodwardian Museum. It bears fewer Graptolites, but they are in a better state of preservation. Fig. 3, shows the proximal portion of one of the Graptolites with a filiform process from the proximal end of the sicula, whilst Fig. 4, represents another Graptolite from the same slab, which is further enlarged in Fig. 5, to exhibit the impression of the virgula. The Graptolite figured by Salter [2] under the name "Branchlet of *Dichograpsus*" appears to belong to this species.

A specimen collected at Barf by Mr. E. H. Tetley, of Trinity College, and delineated in Fig. 6, possesses the characters of *Bryograptus Callavei*, Lapw. The specimen is incomplete, and shows fragments of four stipes only, but there is little doubt that it is referable to this form.

These specimens indicate the Tremadoc age of the beds containing them, for *Bryograptus* does not occur above this horizon.[3] In Norway *Bryograptus ramosus* is found low down amongst the representatives of the Tremadoc Slates, in the Lower Division of the Ceratopygeschiefer, whilst *Bryograptus Callavei* occurs in the Tremadoc Beds of the Shineton area.

Bryograptus is not found associated with any other Graptolite on the same slab in the Skiddaw Slates. Had it existed with the

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[1] Ann. and Mag. Nat. Hist. ser. 5. vol. iii.

[2] Quart. Journ. Geol. Soc. vol. xix. p. 137, fig. 12.

[3] *Tetragraptus fruticosus* of Hall, with only four stipes, has no claim to be included in the genus *Bryograptus*.

ordinary Arenig Graptolites of the area, it could hardly have escaped detection, for it must have been far from rare considering the large numbers observable on the two slabs which I have seen, and slabs with Arenig Graptolites have been collected by hundreds.

It is possible that some of the other compound branching Graptolites of the Skiddaw Slates may also be of Tremadoc age. Some forms have been doubtfully referred to *Clonograptus*, which occurs in Tremadoc rocks, but none which I have seen are specifically identical with Tremadoc species, and it is doubtful whether any of the forms are truly referable to the genus.

2. Arenig-Llanvirn Beds.

A. *Dichograptus Beds.*—The evidence upon which these beds are separated from the newer *Tetragraptus* Beds is unfortunately of a negative character, though the cumulative evidence is fairly convincing. In the first place, the general rule appears to be for the more numerously-branched forms of *Dichograptidæ* to occur in earlier beds than those with fewer stipes. When the evolution of the *Dichograptidæ* is worked out in full, I have no doubt that the reason for this will become evident. Again, *Dichograptus, Loganograptus* and *Temnograptus* are never found in association with the *Tetragrapti* of the Skiddaw Slates, *i.e.* upon the same slab. Lastly, there are areas where *Tetragraptus* is found in which *Dichograptus* does not occur, *e.g.* in the Arenig rocks of South Wales and the Bennane shales of the Ballantrae District[1]: as *Dichograptus* and *Loganograptus* are widely distributed forms, this would hardly be the case if they existed at the same time, and the probability is that the *Dichograptus* Beds are not represented, or have not been discovered, or are represented by non-Graptolitic Beds in South Wales and South Scotland.

B. *Tetragraptus Beds.*—These beds contain by far the larger proportion of Graptolites which have been obtained from the Skiddaw Slates. In the list of Graptolites above given, all the species of *Tetragraptus, Phyllograptus, Didymograptus, Azygograptus,* etc., which have other localities assigned to them than those on which Ellergill Beds only occur, are found in the *Tetragraptus* Beds. Of the Graptolites appertaining to this horizon—

Tetragraptus bryonoides occurs on the same slab as *T. Bigsbyi.*
,, ,, occurs on the same slab as *Didymograptus gibberulus.*
,, *Bigsbyi* occurs on the same slab as *Didymograptus indentus* var. *nanus.*
,, *bryonoides* occurs on the same slab as *Phyllograptus typus.*
,, *quadribrachiatus* occurs on the same slab as *Didymograptus nitidus.*
,, ,, occurs on the same slab as *T. crucifer.*
Didymograptus nitidus occurs on the same slab as *Dicellograptus moffatensis.*

The Graptolites of this division are usually preserved in black slates, but others are found in slates of a lighter colour, or even in light-coloured gritty shales.

The *Tetragraptus* Beds are probably divisible into sub-zones. For instance, *Azygograptus Lapworthi* occurs in great abundance in

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[1] *Cf.* Lapworth and Hopkinson, Quart. Journ. Geol. Soc. vol. xxxi. p. 631; and Lapworth, Geol. Mag. Dec. III. Vol. VI. p. 22.

leaden-grey gritty shales, and these shales are probably restricted to some definite horizon in the *Tetragraptus* Beds, but we have no evidence as to the exact position of that horizon. The further occurrence of *Azygograptus* in the Ellergill Beds suggests a fairly high position for the grits with *Azygograptus Lapworthi.*

Black shales with *Didymograptus indentus*, var. *nanus*, in profusion form a marked feature of these beds. They are often traceable for a considerable distance along the line of strike. The presence of these tuning-fork *Didymograpti*, which are elsewhere so characteristic of Upper Arenig and Lower Llandeilo strata, indicates that the *Didymograptus nanus* Beds form the upper division of the *Tetragraptus* Beds, which may, therefore, be divided into (1) Lower *Tetragraptus* Beds and (2) Upper *Tetragraptus* Beds, with abundance of *Didymograptus nanus.* An examination of the Graptolites associated with *Didymograptus nanus* near Mungrisdale bears out this view.

The *Tetragraptus* Beds and the overlying Ellergill Beds contain the greatest number of Trilobites hitherto discovered in the Skiddaw Slates. Most of these Trilobites belong to the "Llanvirn" fauna. I hope to refer to them at greater length in another communication.

3. Ellergill Beds.

These beds are usually recognizable with ease by their peculiar earthy nature. Their fauna is also different from that of the underlying rocks, and indicates a very high position in the Arenig Series. They are typically developed at Ellergill, Knock Ore Gill, and Ashlock Sike in the Cross Fell Area, at Thornship and Keld Becks near Shap, and in the moory country near Troutbeck Station, extending towards Threlkeld. Amongst the Graptolites which have been found in these beds are:—

Didymograptus affinis, Nich.
,, *bifidus*, Hall.
,, *indentus*, var. *nanus*, Lapw.
,, *Murchisoni*, Beck.
† ,, *fasciculatus*, Nich.
,, *Nicholsoni*, Lapw.
† *Azygograptus cœlebs*, Lapw.
† *Trichograptus gracilis*, Nich.
Phyllograptus angustifolius, Hall.
Diplograptus dentatus, Hall.
Climacograptus.
Cryptograptus ? Hopkinsoni, Lapw.
,, *tricornis*, Carr.
† *Glossograptus armatus*, Nich.
† *Trigonograptus ensiformis*, Hall.
† ,, *lanceolatus*, Nich.

Those marked † have hitherto been found only in this division of the Skiddaw Slates.

4. Milburn Beds.

Mr. Goodchild has applied this name to certain slates interstratified with volcanic rocks, which in the Cross Fell area appear to form a passage between the Skiddaw Slates and the volcanic series of Borrowdale. Similar beds occur in many parts of the Lake

District. Unfortunately their fauna is almost unknown, *Didymograptus Murchisoni* and *Diplograptus dentatus* being the only fossils hitherto recorded from them. They probably represent the uppermost part of the Arenig or the lowermost part of the Llandeilo formation. It is to be hoped 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.

From a study of the Skiddaw Graptolites, then, we obtain the following provisional classification of the *Graptolite-bearing portion* of the Skiddaw Slates:—

2. *d.* Milburn Beds = Uppermost Arenig or Lower Llandeilo.
   c. Ellergill Beds.
   b. *Tetragraptus* Beds { Upper, with *Didymograptus nanus*.
   Lower
   a. *Dichograptus* Beds.
1. *Bryograptus* Beds = Tremadoc Slates.

An examination of sections drawn through the Skiddaw Slates, as, for instance, those constructed by the Officers of the Geological Survey, will show that these slates are greatly contorted. The contortion is often more violent than is represented on those sections. Study of natural sections of the Ellergill Beds, for example, shows that these deposits are constantly affected by overfolds having the middle limbs faulted out, and the same thing can be frequently detected in other parts of the series. The distribution of the fossils shows that little reliance can be placed on dips as an indication of the order of succession. For instance, the fossils obtained from the screes of Barf show that the *Bryograptus* Beds, the *Dichograptus* Beds, and the two divisions of the *Tetragraptus* Beds, must be developed *in situ* in that hill, or, in other words, that part of the Tremadoc and the greater portion of the Arenig Series is included in one or two hundred feet of rock. The same beds, with the exception of the *Bryograptus* Beds, are found on Outerside, where the beds are not on the same line of strike with those of Barf. Representatives of a considerable portion of the Arenig Series must also occur at Carlside Edge, and at several other localities. The thickness of the Ellergill Beds cannot be very great, and the probability is that the whole of the Graptolite-bearing portion of the Skiddaw Slates is not many hundreds of feet in thickness. Mr. Ward calculated the total thickness of the Skiddaw Slates at from 10,000 to 12,000 feet. This is probably an over-estimate, but the whole series must be far thicker than that portion containing Graptolites. Great masses of gritty rock occur which contain no Graptolites, and to the north of Skiddaw there is a considerable spread of red and green shales, which are very unlike the Graptolite-bearing Skiddaw Slates, but resemble beds referred to the Skiddaw Slates at Rake Beck, near Melmerby, in Teesdale, and at Ingleton. As these cannot be newer than the Graptolite Beds of the Skiddaw Slates, which pass up into the volcanic rocks of the Borrowdale group, they must be older. The Graptolitic Beds are, in fact, comparatively thin masses of deposit nipped in amongst older rocks in broken synclinals. As to the age of the older rocks we have no evidence. They may be Cambrian, and some may be of even earlier date. The Skiddaw Slate period was certainly not one of continual deposition. Coarse detrital beds occur again and again. The Skiddaw Grit north of Skiddaw is often conglomeratic, and the included pebbles are of very varied type. Another conglomerate occurs on the old road from the Vale of St. John to Ulleswater, not far from Wolf Crag. It contains pebbles of slate in a greenish-grey argillaceous matrix. Many of these beds may prove fossiliferous, for they have been little searched, special attention having been hitherto paid to the Graptolitic rocks. I have obtained fragments of a large Trilobite from the banded black slates, associated with red and green slates, at the head of Hause Gill, north-east of Skiddaw. They may belong to an Arenig *Asaphus*, but may be older, and the locality deserves careful examination, for Trilobite fragments also occur in the green shales. Most of the Trilobites figured by Messrs. Goodchild and Postlethwaite[1] appear to be Arenig forms, but some may be older.

A few words may be said concerning Mr. Ward's divisions of the Skiddaw Slates. In his paper "On the Physical History of the English Lake District," he places the beds below the "Skiddaw Grit" in the Tremadoc Slates and Lingula Flags, those above that grit in the Arenig. The correlation of the very marked grit north of Skiddaw, with the much greater thickness of flaggy grits south of Skiddaw, the grits north-west of Bassenthwaite, and those near Buttermere is open to doubt. Furthermore, an examination of the map appended to his paper shows that, upon his interpretation, a great synclinal on the east side of the fault ranging down Derwentwater is brought against a great anticlinal to the west of that fault, a thing which certainly occurs in the district on a small scale, but which is difficult to imagine on so large a one. But the greatest objection to his proposed classification is furnished by the fossil evidence. According to his view, all the beds west of Derwentwater and Bassenthwaite, between the band of "Skiddaw Grit" north of Bassenthwaite and that north-east of Buttermere should be Tremadoc Slates or Lingula Flags; nevertheless, in this tract are situated Barf, Outerside, the Whinlatter Pass, Whiteside and other localities yielding abundance of Arenig fossils.

An examination of the Skiddaw Slate series shows that it is a group of deposits of great diversity of character, folded violently on a large and small scale; the uppermost beds, which are fossiliferous, represent part of the Tremadoc and the whole of the Arenig Series of North Wales. These beds are folded in boat-shaped synclines amongst what is probably a very much greater thickness of older rocks, the palæontology of which is practically unknown. It yet remains to discover the ages of these rocks, forming, perhaps, the greater bulk of the Skiddaw Slate formation, and this is a task which may well occupy the attention of local geologists for many years to come.

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[1] Proc. Geol. Assoc. vol. ix. No. 7.

(See *ante*, p. 125.

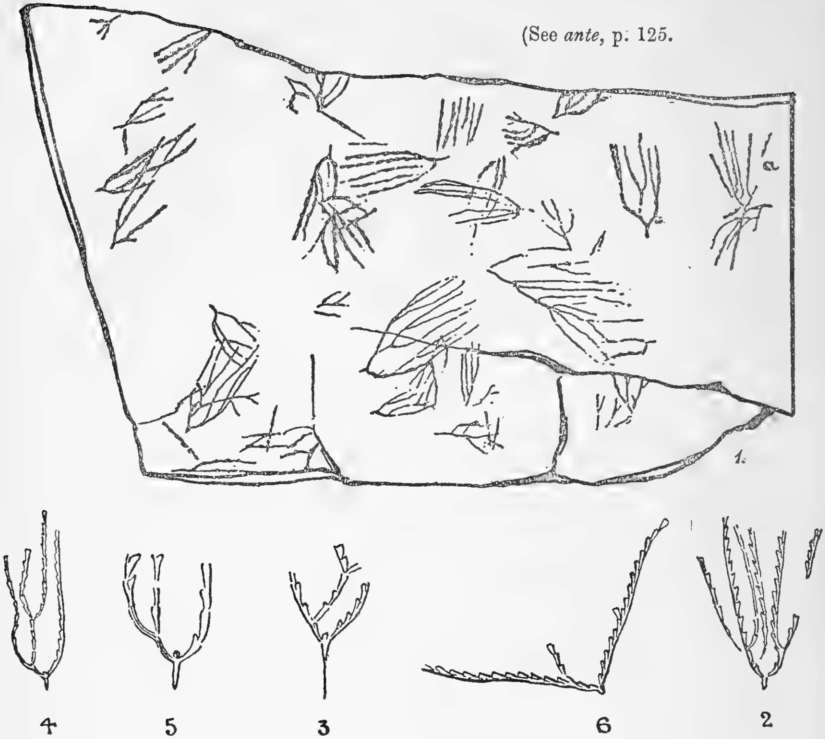


FIG. 1.—Slab with *Bryograptus ramosus*, Brög., nat. size, from Barf. Coll. J. Postlethwaite, F.G.S.
,, 2.—The Graptolite marked *a*. in fig. 1. × 2.
,, 3.—Proximal portion of *B. ramosus*. × 2. Barf. Coll. Miss Serjeant, Girton Coll.
,, 4.—*B. ramosus*. × 2. On same slab as Graptolite in last fig.
,, 5.—Proximal portion of Graptolite represented in fig. 4. × 4. Showing impression of virgula on left-hand primary stipe
,, 6.—*Bryograptus Callavei*, Lapw.? Barf. × 2. Coll. E. H. Tetley, Trin. Coll.
The specimens illustrated in figs. 3–6 are now in the Woodwardian Museum.

REVIEWS.

I.—THE CRINOIDEA OF GOTLAND. Part I. THE CRINOIDEA INADUNATA. With Ten Plates. By F. A. BATHER, M.A., F.G.S., Assistant in the British Museum (Nat. Hist.). Presented to the Royal Swedish Academy of Sciences, December 9, 1891. Kongl. Svenska Vetenskaps-Akademiens Handlingar. Bandet 25. No. 2. (Stockholm, 1893, 4to. pp. 200.)

OF the few places in the world from which fossil Crinoids can be obtained in anything like a fair state of preservation, showing stem, cup, and arms in their natural position, the Isle of

Gotland probably holds the first rank. The beautiful specimens procured during many years' close search in the well-known shales and limestones of that island have been for the most part carefully treasured in the Riks Museum at Stockholm, which thus becomes in a sense the Mecca of those who, like the author of this paper, devote themselves to the study of this group of fossils.

The Gotland Crinoids have, of course, frequently engaged the attention of the palæontologists of Sweden and of other countries as well. There is a reference to them in a mineralogical work by Bromell, recognizing their real nature, as early as 1739; and many papers by W. Hisinger, between the years 1799 and 1841, contain descriptions and figures of several species, of which the originals are still to be found in the Stockholm Museum. But the all-important work on these Crinoids is the "Iconographia Crinoideorum" of Professor N. P. Angelin, which was published posthumously under the auspices of the Royal Swedish Academy of Sciences in 1878. It is illustrated by 29 quarto plates, which Angelin left behind at his death, already lithographed, whilst the descriptive text in his own manuscript was edited for publication by his former colleague, Prof. S. Loven, who undertook the *Cystidea*, and by his successor, Prof. G. Lindström, who edited the main portion relating to the Crinoids proper. The comprehensive significance of Angelin's work may be understood from the fact that it contained descriptions and figures of 173 species of Crinoids, included in 42 genera, whereas, previous to its appearance, only 13 species, probably belonging to about 10 genera, were known from Gotland. In the interval since the publication of the "Iconographia" many important notices of the Gotland Crinoids have appeared at different times from such authorities as Von Zittel, Neumayr, Wachsmuth and Springer, P. H. Carpenter, F. A. Bather and others, but these appear to have been mainly founded on the published work of Angelin. A critical examination of this work and a comparison of its descriptions and figures with the original types in the light of the knowledge of the present day, was felt to be an absolute necessity to make it available for solving some of the crucial questions of Crinoidal structure and classification, more particularly in connection with British Silurian Crinoids; and this induced Mr. Bather to undertake a revision of the type-forms of Angelin and of such others as have been since discovered in Gotland. The authorities of the Riks Museum at Stockholm, amongst whom may be mentioned the well-known names of Professors S. Loven and G. Lindström, deserve the heartiest thanks of their fellow-workers in science for the facilities given to Mr. Bather to carry out his work, and a similar recognition will be awarded to the Royal Swedish Academy of Sciences for their truly liberal spirit in printing the results of the investigation in their Transactions and in the English language.

In this first section of the work the author treats only of such of the Gotland Crinoids as belong to the Order "Crinoidea Inadunata" of Wachsmuth and Springer. These are considered to be the simplest forms of the group, and are characterized by having all the brachials free, and no interradial plates enter the dorsal cup unless in the posterior interradius. About 40 species of this group have been found in Gotland: 18 of these were described by Angelin, 6 by other authors, and 16 are quite new. They are included in 10 genera, only one of which, *Gothocrinus*, is new, and they belong to 7 families, all previously recognized. The following is the list:—

Family Pisocrinidæ. *Pisocrinus pilula*, de Kon., *P. ollula*, Ang., *P. pocillum*, Ang.
,, Heterocrinidæ. *Herpetocrinus Fletcheri*, Salter, *H. convolutus*, Hall, *H. Ammonis*, n. sp., *H. flabellicirrus*, n. sp.
,, Calceocrinidæ. *Calceocrinus gotlandicus*, Ang., *C.* cfr. *gotlandicus*, *C. pugil*, n. sp., *C. tucanus*, n. sp., *C. tenax*, n. sp., *C.* cfr. *tenax*, *C. nitidus*, n. sp., *C. interpres*, n. sp., *C. pinnulatus*, n. sp.
,, Dendrocrinidæ. *Homocrinus tenuis*, n. sp.
,, Euspirocrinidæ. *Euspirocrinus spiralis*, Ang.
,, Decadocrinidæ. *Gothocrinus gracilis*, n.g. et sp., *Botryocrinus ramosissimus*, Ang., *B. cucurbitaceus*, Ang., sp.
,, incert. *Streptocrinus crotalurus*, Ang., sp.
,, Cyathocrinidæ. *Cyathocrinus visbycensis*, n.sp., *C. acinotubus*, Ang., *C. striolatus*, Ang., *C. Dianæ*, n. sp., *C. glaber*, Ang., *C. muticus*, Ang., *C. distensus*, Ang., *C. longimanus*, Ang., *C. ramosus*, Ang., *Gissocrinus typus*, n. sp., *G. elegans*, Ang., *G. campanula*, n. sp., *G. umbilicatus*, Ang., *G. macrodactylus*, Ang., *G. goniodactylus*, Phill., sp. et var., *G. squamifer*, MS., *G. incurvatus*, Ang., sp., *G. verrucosus*, n. sp., *G.*, sp.

About 12 of these species occur in the Gotland beds "c" and "d," which are considered the equivalents of the Wenlock shale and Limestone in this country, whilst 32 species have been met with in the Crinoid and Coral conglomerate, bed "f", which is correlated with our Aymestry Limestone or Lower Ludlow. But two of the above species are fairly common both in Gotland and England, viz. *Pisocrinus pilula* and *Herpetocrinus Fletcheri*; the only other species occurring in the two regions are *Herpetocrinus Ammonis*, *Calceocrinus nitidus*, *Cyathocrinus acinotubus*, *Gissocrinus goniodactylus*, et var., and *G. squamifer*, so that, as the author remarks, the Crinoids afford but little assistance in correlating the strata in the two countries.

Although Mr. Bather adopts Wachsmuth and Springer's classification for the order Inadunata, he now substitutes, in place of their suborders, "Larviformia" and "Fistulata," the new divisions of the "Monocyclica" and "Dicyclica," the former possessing only one circlet of interradially situated basals, the latter having an additional circlet of infrabasals, radially situated between the basals and the stem. The Monocyclica will include all the genera placed in the Larviformia, with the possible exception of *Cupressocrinus* and the Gasterocomidæ, and the further additions of the Hybocrinidæ, Calceocrinidæ, Catillocrinidæ and perhaps *Belemnocrinus*. The Dicyclica, again, will comprise the three families of the Dendrocrinidæ, Decadocrinidæ and Cyathocrinidæ, and the provisional families Carabocrinidæ and Euspirocrinidæ. In this division there is a more regular pentamerous symmetry in the cup-plates than in the Monocyclica, and it is only in the right posterior radial-plate that traces of bisection ever occur. This new arrangement is put forward tentatively, but the author claims that it is more philosophical than that for which it is substituted.

Among the many points of interest brought to light by Mr. Bather from the study of the Gotland Crinoids (and of those from the corresponding beds in this country) is the discovery of an anal plate in the dorsal cup of *Pisocrinus*, which thus determines the posterior interradius and proves the azygous plate to be a true radianal. This involves a complete change in the hitherto received orientation of the calyx plates in this genus, and brings it into harmony with the rest of the Monocyclica. The author proposes to add the genus *Calycanthocrinus* to the family Pisocrinidæ, as defined by von Zittel, and to remove from it *Catillocrinus*, Troost, on account of the absence of a radianal plate in this form.

In the family of the Heterocrinidæ are included the genera *Iocrinus*, Hall, *Heterocrinus*, Hall (*non* W. and S.), *Ectenocrinus*, S. A. Miller, *Ohiocrinus*, W. and S., *Anomalocrinus*, Meek and Worthen, and *Herpetocrinus*, Salter=*Myelodactylus*, Hall. This latter is the only genus represented in Gotland, and a nearly complete account of its morphology, mainly based on specimens of *H. Fletcheri*, Salter, from Dudley as well as from Sweden, is given. This genus is best known from the peculiar manner in which the stems with their two rows of cirri occur coiled up on the surface of the rock, giving a fanciful resemblance to a huge centipede; it is also further noticeable from the curious mistakes which have been made in the determination of fragmentary specimens referred to it. The forms first placed in the genus were some ossicles or joints of the stem, which Professor Jas. Hall mistook for portions of the arms and pinnules of the Crinoid, and described them as belonging to a distinct genus, which he named *Myelodactylus*. On this error Mr. Bather remarks, that "it should have been clear that the specimens, whatever they were, were not the brachials of a Crinoid; for the 'tentacles' were represented as two to each ossicle. *In no Crinoid is there more than one pinnule to a single brachial: such an occurrence is an evolutionary impossibility.*" (The italics are the writer's.) Prof. Hall's mistake was pointed out by J. W. Salter, who correctly described the stem and crown of the Crinoid, and, on the ground that the name proposed was based on false ideas, substituted for it the name *Herpetocrinus*. Strangely enough, in the present paper, Mr. Bather describes as the *stem* of a new species, *Herpetocrinus scolopendra*, an open helicoid coil with two short cirri to each ossicle; this *stem* is stated "to very closely resemble the arms of a Crinoid with cirri coming off as pinnules; with this important difference that each ossicle bears two cirri" —which is pronounced above to be an evolutionary impossibility. After this description was printed off, the clearing away of the matrix from the supposed stem and cirri revealed that these bodies were furnished with a ventral groove, and consequently that they were genuine arms, each brachial having a pair of pinnules in spite of the evolutionary impossibility of such a fact. The difficulty, however, is easily overcome by the author in pronouncing the pinnules to be "false," on the ground that though their structure is similar to that of true pinnules, yet they are articulated in the middle, instead of at the further end of the brachial!

In the family Calceocrinidæ are included the following genera: *Castocrinus*, Ringueberg, *Euchirocrinus*, M. and W., *Calceocrinus* (Hall), Ringueberg, and *Halysiocrinus* (Ulrich), Bather. These four genera are considered to represent an evolutionary series and not divergent branches, so that many forms of an intermediate nature might be expected to occur. A list of all the known species of these genera is given. *Calceocrinus* is the only genus of the series known in Gotland; one species had been described by Angelin, and to this six new ones are added by the author. One of the new forms, *C. pinnulatus*, differs from the type and all the other species in this genus in the possession of pinnules on the arms and in the plan of arm-branching.

Of the suborder Dicyclica, the first family treated is the Dendrocrinidæ, which is distinguished from the Decadocrinidæ by the continuous dichotomy instead of the single bifurcation of the arms, and from the Cyathocrinidæ by the constant occurrence of a plate in the anal area, the wide radial facet, and the more delicate tegmen. This family is divided into the Dendrocrinites and the Scaphiocrinites; in the former are included the genera *Merocrinus*, *Ottawacrinus*, *Dendrocrinus*, *Mastigocrinus*, *Homocrinus*, and *Parisocrinus*. Of these, only *Homocrinus*, Hall, is represented in Gotland by one species; the genus had only previously been known in America.

The family Euspirocrinidæ definitely includes only the genus *Euspirocrinus*, Ang., but two other genera, *Closterocrinus* and *Ampheristocrinus*, are associated with it provisionally. *Euspirocrinus* is described as possessing the dorsal cup of an advanced Dendrocrinite with the tegmen of a Cyathocrinite, whilst its arms might belong to either of these groups. The character of the tegmen of the calyx is well shown in an example of *E. spiralis*, figured by Angelin (Icon. pl. iv. figs. 7*d. e*), and reproduced on a larger scale by the author (p. 111, fig. 14). In this the food-grooves from the arms are continued along wide channels formed by the depressed edges of the large heart-shaped deltoidal plates, and these channels pass directly into the peristome, which is bounded on four sides by the deltoids and on the fifth by the madreporite plate. The channels are covered over by the ambulacral plates, which are fitted into small depressions in the deltoids.

The family Decadocrinidæ, previously proposed by Mr. Bather, may be divided into several series, but only one, Botryocrinites, is represented in the Gotland Silurian. This division includes the genera *Botryocrinus*, *Barycrinus*, *Vasocrinus*, *Atelestocrinus*, and a new genus, *Gothocrinus*, which is said to possess a *Dendrocrinus* cup with *Botryocrinus* arms. Under *Botryocrinus*, Ang., in addition to *B. ramosissimus*, Ang., the author also places *Sicyocrinus cucurbitaceus*, Ang., distinguished by its peculiarly curved ventral sac, which is built up of a median dorsal row of plain hexagonal plates lying between similar rows of plates folded on their outer sides, and thus it differs hardly at all from the ventral sac of *B. ramosissimus.* The author failed to find any pores or slits in the ventral sac, but there appears to be an anal opening bordered by small plates nearly at the base on the posterior side of the sac (pl. vi. fig. 183).

The genus *Streptocrinus,* W. and S. (= *Ophiocrinus,* Ang., not Salter,), cannot at present be placed in any recognized family. The only known species, *S. crotalurus,* Ang., sp., is solely represented by mere fragments, amongst which are the curled-up pinnulated arms, supposed at first to be the stems with cirri of a species of *Herpetocrinus.* The paired pinnules possess a broad V-shaped ventral groove, covered by quadrangular plates similar to those of the brachials. The author considers that they have arisen as merely processes of the brachials, and they are termed, as already mentioned, "false" pinnules.

The important family of the Cyathocrinidæ is defined as Inadunata, Fistulata, Dicyclica, with no radianal or tube-plate in the anal area of the dorsal cup; with the anal x-plate either present in the cup or raised above it; with five arms, simple and dichotomous, and with a rather solid tegmen. To *Cyathocrinus* itself 14 species from Gotland were referred by Angelin, but some of these turn out to be synonyms, and others were not well founded, so that now only 9 species remain, and two of these are new forms. In *C. acinotubus,* Ang., and in some other species of this genus as well, the author describes and figures some very interesting structural features in the ventral covering-plates of the arm ossicles, which exhibit a very elaborate arrangement of their articulating surfaces. Each covering-plate appears, from the exterior, to be divided by a suture, and on the interior there is a small round ossicle. The edges of the ventral groove are also marked off into concave subcrescentic facets for the articulation of the covering-plates, and each facet has a median notch. The proximal articulating portion of the covering-plates is similarly marked off. These structures are well shown on pl. vii. figs. 208–213, 243–247, and pl. viii. figs. 249–250, 254–256.

The genus *Gissocrinus,* Ang., is numerously represented in Gotland, and 10 species are described. This genus has generally been considered as differing from *Cyathocrinus* only in having three instead of five infrabasals, but the author points out that it is further characterized by the very distinct axial ridging of the cup-plates, the lateral compression of the distal portions of the arms, the elevated or cornice-like rim at the distal ends of the brachials, the strong transverse folding of the plates of the ventral sac, and its length and lateral compression. The covering-plates of the brachials in some species are even more complicated than in *Cyathocrinus.* In some instances, as in *G. typus* for example (pl. viii. figs. 273–275), they form such a close-fitting series that it is difficult to see how the food-grooves can have communicated with the exterior, unless it were at the distal ends of the arms.

The above desultory notes on the contents of this Part (I.) will, perhaps, enable even those not specially acquainted with fossil Crinoids to understand, to some extent, the importance of Mr. Bather's work in relation to these organisms. The minutely detailed descriptions which he has given of the structural characters of the different species, and the abundant and faithful illustrations, render the particular features on which their classification depends easy of recognition, and thus will amply compensate for the brief diagnosis and the artistically (but too frequently erroneously) restored figures in Angelin's great work, which have not seldom proved confusing to the more critical students of the present day. We very cordially congratulate the author on the amount and excellence of the work performed during the "vacations" of two years, and the Swedish Academy on their success in getting their almost unrivalled collection of Crinoids made available for the service of science a second time. We cannot, however, conclude this notice without expressing a feeling of regret that the grand collection of British Silurian and Carboniferous Crinoids in our own Natural History Museum should up to the present remain practically undescribed and unknown to the scientific world. Mr. Bather has, indeed, commenced to describe them in some papers which have appeared at intervals since 1890 in the Annals and Mag. Nat. Hist., but, when we compare the humble scale of these with the elaborate Part I. now before us, the contrast is so striking that we are tempted to enquire why there should not be prepared a "non-vacation" work on the fossil Crinoids in the British Museum, on the same pattern as that which our author has so well carried out for the Swedish Academy by way of a holiday exercise? The writer of the review on Angelin's Iconographia, which appeared in this MAGAZINE in 1878, commented on the neglect in the treatment of these organisms in our country, but scarcely anything has been done in the interval to remedy it. It is high time that the reproach should be removed, and it is to be hoped that before long our home Crinoids will be as adequately treated as those of Gotland.

G. J. H.

II.—UEBER EIGENTHÜMLICHE OBSIDIAN-BOMBEN AUS AUSTRALIEN. Von HERRN ALFRED W. STELZNER in Freiberg i. S. Zeitschr. d. Deutschen geolog. Gesellschaft, Jahrg. 1893, pp. 299—319, pl. vi.

ON SOME PECULIAR OBSIDIAN-BOMBS FROM AUSTRALIA.

THE bombs described by Dr. Stelzner in this paper were found on the surface of the ground at Kangaroo Island, S.W. of Adelaide; in the region of Macdonnel Range in Central Australia; and in the great Victoria desert between the Everard Range and the Fraser Range. Similar bombs are also reported to occur in other parts of Australia, more particularly in the North and West; and Charles Darwin, in the "Volcanic Rocks of the Island of Ascension," describes and figures a fragment of a similar bomb found on the sandy plains between the Darling and the Murray.

In none of the areas in which these bombs occur is there any indication of either active or extinct volcanoes, and the question of their distribution is a problem which the author does not attempt to solve.

The specimens all consist of a black compact and homogeneous glass, with a very few small and isolated gas inclusions, but no crystals of any kind. The specific gravity varies between 2·41 and 2·52. There is no doubt that the bombs are really of Obsidian, and that they are volcanic in origin. One specimen is polyhedral in form, others are rounded or ellipsoidal, with the peculiarity that they appear as if built up of two distinct halves, one somewhat flattened and larger, the other more convex and smaller. In two instances the form is that of a button-shaped mushroom ; as if the smaller of two rounded thick-walled shells had been pressed into the concavity of the larger. One specimen is a hollow sphere, which may have been simply a large bubble enclosed by glassy walls. In this hollow bomb and in the mushroom-like forms there are on the larger and flatter hemisphere, and on this only, from four to six ring-like elevations parallel with the equatorial margin, as well as fine straight or wavy lines, having a meridional direction ; and further, this flatter half has a distinctly varnished appearance in contrast with a dull aspect on the other more convex half of the bomb.

The peculiar form of these bombs, and the pittings and other markings on their surfaces, are attributed to the resistance which they encounter in their flight through the atmosphere, and their individual differences probably depend on the greater or lesser plasticity of the lava when the explosion takes place, and the varying rapidity of the projectile and the consequent varying force of the resistance of the atmosphere. The bombs examined range from 15 mm. to 55 mm. in their greatest diameter.

III.—1. PRESIDENTIAL ADDRESS: THE CRETACEOUS SYSTEM IN CANADA. By J. F. WHITEAVES. (Transactions of the Royal Society of Canada, Section IV. 1893, pp. 3–19.)

2. NOTE ON THE RECENT DISCOVERY OF LARGE UNIO-LIKE SHELLS IN THE COAL-MEASURES AT THE SOUTH JOGGINS, NOVA SCOTIA. By J. F. WHITEAVES. (Transactions of the Royal Society of Canada, Section IV. 1893, pp. 21–24.)

1. THE first of these papers contains an interesting summary of the Cretaceous system of Canada from the palæontologist's standpoint, and as it proceeds from the pen of one of the best authorities on the American Mesozoics the views put forth in it carry weight.

The literature of the subject dates from the year 1857, at which time F. B. Meek, that most accomplished of American palæontologists, described some fossils from the Cretaceous rocks of Vancouver Island (Trans. Albany Institute), and in the same year Dr. J. S. Newberry discussed the age of the rocks associated with the Coal on Vancouver Island, and concluded upon palæontological evidence that they were Cretaceous. In the following year, Dr. B. F. Shumard (Trans. St. Louis Academy of Sciences) described some fossils from the Cretaceous rocks of the Nanaimo River. He was followed, in 1859, by Prof. Leo Lesquereux, who, in the 27th volume of the American Journal of Science and Art, described some fossil plants from the same rocks belonging to the genera *Populus*, *Quercus*, and *Cinnamomum*, which, however, he regarded as of Miocene age. Captain Palliser's explorations in British North America were fruitful in palæontological results, worked out by Dr. (now Sir James) Hector. In the same year (1859) fossils collected in the country between Lake Superior and the Red River Settlement, and between the latter and the Assiniboine and Saskatchewan rivers, were sent to Mr. E. Billings, then palæontologist to the Geological Survey of Canada, who found that the specimens supplied "almost indisputable evidence that a considerable part of the territory belongs to the Cretaceous period, or the great Chalk formation so largely developed in the Old World." In 1861 Dr. Hector, in a paper on the geology of the country between Lake Superior and the Pacific Ocean (Palliser's Expedition, 1857–60), compared the Cretaceous rocks east of the Rocky Mountains with those of Vancouver Island, and published an ideal vertical section of the Cretaceous system in British North America, which agrees in part with Meek and Hayden's Upper Missouri section. Lists of the Cretaceous fossils were contributed by Mr. Etheridge; but most of the fossils were only determined generically. Nineteen species were recorded, all marine mollusca. Eleven of these were from various localities now called Manitoba and the districts of Assiniboia, Saskatchewan and Alberta, and eight from Nanaimo, Comox or Valdez Inlet. No less than thirteen of the species are identified with Texan or Mexican species. Again, in 1861, Meek described the following Cretaceous fossils from Vancouver and Sucia Islands, viz.: *Dosinia tenuis*, from Nanaimo; *Inoceramus subundatus*, *Baculites occidentalis*, *Ammonites Vancouverensis* and *Nautilus Campbelli*, from Comox; *Ammonites complexus*, var. *Suciensis*, from Comox and the Sucia Islands; and *Baculites inornatus* from the Sucia Islands. A few plants were described in 1863 by Dr. Newberry (Boston Journ. Nat. Hist. vol. vii.), viz. *Aspidium Kennerlyi* and *Taxodium cuneatum*, from Nanaimo; also *Populus rhomboidea* of Lesquereux and a *Sabal*, afterwards described by Sir J. W. Dawson under the name of *Sabal imperialis* (Trans. Royal Soc. Canada, sec. 1). The first volume of the Palæontology of California (1864) contains descriptions, by W. M. Gabb, of two new species from Nanaimo, viz. *Hamites Vancouverensis* and *Pecten Traskii*. Since the confederation of the provinces of Canada in 1867, much work has been done upon the Cretaceous rocks of Manitoba and the North-West Territories and in the Rocky Mountains and British Columbia by Sir J. W. Dawson, Doctors Selwyn, G. M. Dawson, R. Bell, and J. W. Spencer, and by Messrs. J. Richardson, R. G. McConnell, and J. B. Tyrrell. In summarizing the results of the work of these geologists Mr. Whiteaves follows the Cretaceous rocks in a direction from east to west geographically, and in a descending order geologically, thus: (1) Manitoba and the North-West Provinces; (2) the Rocky Mountain region; (3) British Columbia, inclusive of the islands off the Pacific Coast; (4) the Yukon district.

In Canada, as in the United States, it is found convenient to adopt a single division of the Cretaceous system and to draw the line between the Upper or Later and the Lower or Earlier North American Cretaceous, as nearly as possible at the base of the Dakota Group, or of that of its local representative.

Manitoba and the North-West Territories.—In these regions all the Cretaceous rocks, as yet examined, appear to be referable to the Upper or Later North American Cretaceous, as defined above. "It is still doubtful," observes Mr. Whiteaves, "whether the Laramie formation of Canada should be regarded as forming the summit of the Cretaceous or the base of the Tertiary system, though, at present, the consensus of opinion among geologists would seem to favour the former view. In mapping the northern part of the district of Alberta, Mr. Tyrrell found that the Laramie there is divided into two series, and has expressed the opinion that its upper portion, which he proposes to call the Pascapoo series, is of Eocene age, and that its lower portion, which he calls the Edmonton series, and which is equivalent to Dr. Dawson's 'St. Mary River series,' of Southern Alberta, is Cretaceous. This division is based mainly upon palæontological evidence, and more especially upon the circumstance that the Edmonton series is now known to contain numerous remains of Dinosaurs (*Lælaps*, etc.), and that it is the highest horizon in Canada at which Dinosaurs are known to occur." The divisions adopted for the rocks of Manitoba and the North-West Territories are: (1) The Laramie, in whole or in part; (2) The Pierre-Fox Hills or Montana formation; (3) The Belly River series; (4) The Niobrara-Benton, or Colorado formation; (5) The Dakota. It was found that in this region it was no longer practicable to separate the Fox Hills group from the Fort Pierre group, nor the Niobrara from the Benton.

The Rocky Mountain Region (inclusive of the Foot Hills).—In this region the Cretaceous rocks occupy the bases of narrow troughs in the Palæozoic rocks. The fossils consist of the remains of plants or of marine invertebrata. By means of the plants Sir J. W. Dawson recognized three horizons in this region, viz. (1) The Mill Creek series; (2) The Intermediate series; (3) The Kootanie series. The following estuarine or purely marine divisions of the distorted Cretaceous rocks of this region have been recognized: (1) The Laramie; (2) The Pierre-Fox Hills, or Montana formation; (3) The Niobrara-Benton, or Colorado formation; (4) The Devil's Lake Deposit.

British Columbia and the Islands off the Pacific Coast.—The Cretaceous rocks of this region are taken in the following order: (1) The Nanaimo group of Vancouver and the adjacent islands; (2) The

Queen Charlotte Island series; (3) The Cretaceous at other localities in the province. It is judged from palæontological evidence that the lower and middle, or most fossiliferous, subdivisions of the Nanaimo group are referable to the Upper or Later rather than to the Lower or Earlier North American Cretaceous. The Queen Charlotte Island Cretaceous has been thoroughly investigated, first by Mr. James Richardson, and later by Dr. G. M. Dawson. Numerous fossils have been collected by both these explorers, and they have been described by Mr. Whiteaves in his "Mesozoic Fossils," published by the Geological Survey of Canada. Cretaceous rocks occur also at Tatlayoco Lake, Jackass Mountain, Sigutlat Lake, and the Iltasyouco River, all on the mainland.

The Yukon District.—This district, though included in the North-West Territories, is geologically more nearly related to British Columbia, and it is therefore considered here. Fossil plant remains (reported upon by Sir William Dawson) were found by the members of Dr. G. M. Dawson's exploring expedition of 1887–1888 (Geol. Surv. Canada, 1889). Some new species of marine invertebrates were also obtained by Dr. Dawson at Rink Rapids, viz. *Discina pileolus* (afterwards changed to *D. Dawsoni*), *Cyprina Yukonensis*, *Schlœnbachia borealis*, and *Estheria bellula* (Contributions to Canadian Palæontology). Finally, in 1888, Mr. R. G. McConnell discovered rocks holding *Scaphites*, resembling one of the Benton species, on the Porcupine River, fourteen miles below the mouth of the Bell River, and further down the Porcupine he found sandstones full of one of the varieties of *Aucella Mosquensis.*

No less than 108 species of fossil plants have been recorded or described, up to the present time, from the Canadian Cretaceous, exclusive of the Laramie, or 179 species including the Laramie; and 358 species of animal remains from the undoubted Cretaceous rocks of the Dominion are now known, or 394 if the Laramie be included. Mr. Whiteaves concludes his Address by saying that "a comparatively small portion of the Cretaceous rocks of Canada has been examined in any detail, and more or less isolated areas of these rocks are known to exist in parts of the Canadian North-West, about which scarcely any other information has been obtained. Still, the facts, as summarized in this Address, are sufficient to show that substantial additions to our knowledge of the geographical distribution, of the economic products, and of the fossil flora and fauna of the Cretaceous rocks of Canada, have been made within the quarter of a century that has elapsed since the confederation of the Provinces."

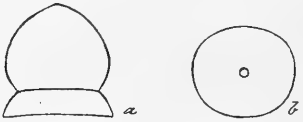
2. In the second paper before us an account is given of the discovery of two very large Unio-like shells, for which the author proposes the new generic name *Asthenodonta* (ἀσθενης, weak, in the sense of feebly developed; and οδους, a tooth). In passing in review the literature of the subject of the ancient representatives of *Unio*, *Margaritana* and *Anodonta*, it is remarked that fresh-water shells belonging to these genera have not yet been satisfactorily recognized in rocks older than the Trias. In justification of the rejection of

these names for fossil genera, Mr. Whiteaves quotes the late Dr. S. P. Woodward (Manual of the Mollusca, p. 414) that the molluscan genera of the older rocks "are believed to be nearly all extinct, for although the names of many recent forms appear in the catalogues of Palæozoic fossils, it must be understood that they are only employed in default of more exact information." Thus the *Anodonta Jukesii* of Forbes, from the Upper Old Red Sandstone of Ireland, is the type of the recently proposed genus *Archanodonta*; and, similarly, the species described as *Unio* by Sowerby, Phillips and others, from the Coal-measures of Great Britain, are now referred to *Anthracosia* or *Anthracomya*. "But although there is at present no satisfactory evidence of the existence of any of the recent genera of Unionidæ in rocks of Palæozoic age, the family seems to have been then represented by extinct genera, such as *Amnigenia* (and possibly *Archanodonta* in the Devonian), by *Naiadites* or *Anthracomya* in the Carboniferous, and by *Palæomutela* and *Palæopleidon* in the Permian." The specimens of *Asthenodonta Westoni* (the subject of the paper) were found associated with large fragments of *Sigillaria* and *Lepidodendron*, leaves of *Cordaites*, and a piece of the lower jaw of a reptile. The stratigraphical position of the sandstones in which the remains occurred is believed to be between Coal Groups 31 and 32 of Sir J. W. Dawson's South Joggins section, as described in the Accadian Geology. The external contour of *Asthenodonta Westoni* is not unlike that of large specimens of the freshwater pearl mussel (*Margaritana margaritifera*, Linn.), but the beaks are more nearly terminal and the posterior termination of the valves more pointed below. The test is very thick, and shows nacreous structure under the microscope. There are no traces of lateral teeth in either valve, and the hinge dentition as a whole, so far as it can be ascertained, is in some respects comparable with that of *Anthracosia*. Until, however, the hinge dentition of both of its valves is more perfectly known, the exact systematic position of *Asthenodonta* will be uncertain; but it is considered by its describer to represent an aberrant and extinct type of Unionidæ. The length of the most perfect specimen collected was 200 mm.; height in the centre 90 mm.; maximum breadth or thickness of the two closed valves, about 42 mm.; thickness of the anterior end of the test of one valve, 9 mm. ARTHUR H. FOORD.

IV.—THE PROTOCONCH OF *ORTHOCERAS*. By J. M. CLARKE. (The American Geologist, Vol. XII. August, 1893, pp. 112–115.)

THE fortunate discovery of a perfect specimen of the extreme apex of an *Orthoceras* has enabled Mr. J. M. Clarke to supply information, hitherto wanting, as to the nature of the protoconch or initial chamber of that genus. Specimens showing the penultimate chamber, with external cicatrix, have long been known, both from the Carboniferous limestone of Belgium and from the Triassic beds of St. Cassian. De Koninck has figured the Belgian examples (Ann. Mus. Roy. d'Hist. Nat. Belg.), Hyatt those of St. Cassian

("Genesis of the Arietidæ"). Branco regarded the cicatrix-bearing conical end of the shell in *Orthoceras* as the embryonal shell or protoconch ("Anfangskammer"), but Hyatt, observing a wrinkled, wart-like lump at the apex of the St. Cassian specimens, came to the conclusion that this was the true protoconch, and assumed from its shrunken condition that it was originally composed of conchiolin and hence easily destructible. The specimen (see Figure) which is the subject of Mr. Clarke's very interesting communication was found in the Styliola limestone of the Genesee shales, on Canandaigua Lake, New York State, in an association of species which represents the earliest appearance in North America of the [Upper Devonian] fauna of *Goniatites* (*Gephyroceras*) *intumescens*, Beyrich. The specimen "consists of the first or apical chamber of the shell, to which the protoconch is attached. The upper end of the specimen shows the first septum . . . . to be circular and with a central sipho. The lateral walls of the first chamber taper rapidly to the plane of conjunction with the protoconch, and its depth is about one-half that of the latter. The protoconch itself is semi-ovoid in shape, and when compared with those of *Orthoceras* previously described or figured [in the shrunken condition] is of very large size. It shows no indication of shrinking or other irregularity and its distal extremity is perfectly smooth. The length of the entire specimen is ·85 mm.; that of the protoconch, ·60 mm.; and the diameter of the first septum, 1 mm." Mr. Clarke observes in the concluding part of his paper that "it is probable that this protoconch has been derived from a shell so young that atrophy and wrinkling have not manifested themselves, as they may have done with the more mature development of the shell. This, I believe, is the only recorded observation of the protoconch in Palæozoic forms of *Orthoceras*, and its shrunken condition in the post-Palæozoic forms may have a phyletic significance." ARTHUR H. FOORD.



a. Outline of the first chamber of an *Orthoceras* with protoconch attached; *b*, base of the first chamber (*a*) showing siphuncle. Greatly enlarged.

REPORTS AND PROCEEDINGS.

GEOLOGICAL SOCIETY OF LONDON.

I.—January 24th, 1894.—W. H. Hudleston, Esq., M.A., F.R.S., President, in the Chair. The following communications were read:

1. "The Ossiferous Fissures in the Valley of the Shode, near Ightham, Kent." By W. J. Lewis Abbott, Esq., F.G.S.

The fissures occur in a promontory of Kentish Rag between two tributaries of the Shode. There are four fissures in this promontory, striking at right angles to the valley. Details of the physiography of the area in which the fissures occur are given in the paper. Three of the fissures have obviously been in contact with the surface, and from these the bones appear to have been dissolved out. The fourth does not reach the top of the Rag, and, further, is sealed by an aragonite-lined chamber with stalactitic floor and ceiling. This fissure is from 2 to 6 feet wide and about 80 feet deep, and is filled with a heterogeneous collection such as constitutes the flotsam and jetsam of streams, along with materials derived from the rock in which the fissures occur. Several thousand bones were found, also twelve species of aquatic and land shells, an entomostracan, *Chara* and other vegetable remains have been procured.

The author gives reasons for concluding that the fissures have never been re-opened since they were first closed by the materials introduced into them by the river, and that all the contained fossils belong to one and the same geological period. He points to the discovery of species not before found in Pleistocene beds as only a repetition of what has occurred in other sections he has worked, and remarks also that the increase of species is corroborative of a suggestion of Mr. C. Reid that the more we discover of the smaller creatures of this and the preceding age, the more they approximate to those of our own times. Even if we were to exclude from the lists all the species not previously found fossil elsewhere, we still have an extensive assemblage of the older Pleistocene forms, which must have lived during the filling of the fissures, and this, therefore, fixes the filling operation as having occurred in Pleistocene times.

2. "The Vertebrate Fauna collected by Mr. Lewis Abbott from the Fissure near Ightham, Kent." By E. T. Newton, Esq., F.R.S., F.G.S.

The vertebrate remains collected by Mr. Lewis Abbott are passed in review, and, as far as possible, specifically identified: they represent mammals, birds, reptiles, and amphibians; but no fishes have been found. In all, forty-eight different forms have been recognized; three, or perhaps four, are extinct; eleven are extinct in Britain, but are still living elsewhere; twenty-one are living in Britain, but are known to be Pleistocene or Forest-bed forms; and twelve are species now living in Britain which have not hitherto been recognized in Pleistocene or older deposits.

Among the more important species found in this fissure, but extinct in Britain, may be noticed, besides *Elephas primigenius*, *Rhinoceros antiquitatis*, and *Hyæna*, the *Ursus arctos*, *Canis lagopus*, *Myodes torquatus*, *Myodes lemmus*, *Microtus gregalis*, *M. ratticeps*, *Lagomys pusillus*, *Spermophilus*, and *Cervus tarandus*. The name of *Mustela robusta* is proposed for some limb-bones intermediate between the Polecat and Marten, and the remains of an extremely small Weasel are noticed as a variety of *Mustela vulgaris*. Although the large number of living species gives a recent aspect to this series of remains, the evidence, it is believed, points rather to their being all of Pleistocene age, and most nearly allied to the fauna of British caves.

RAPID ELEVATIONS: A SELF-CRITICISM.

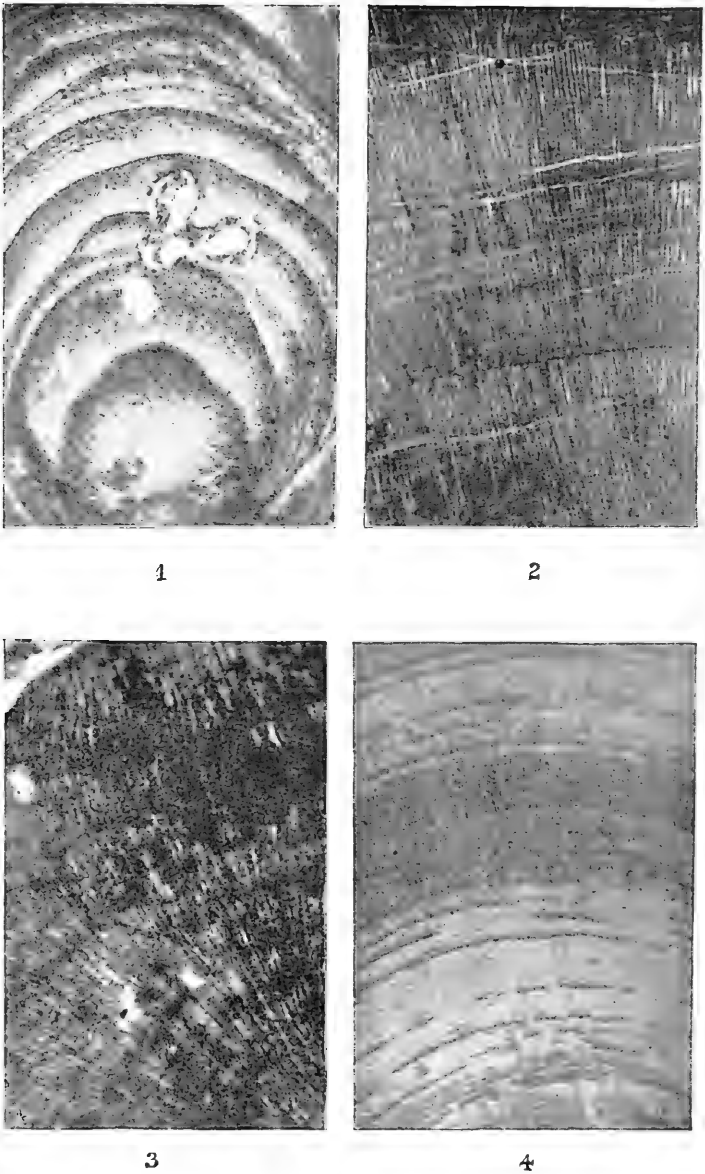
SIR,—In the GEOL. MAG. for 1892 (p. 405), I published a note on the possible effects from Rapid Elevation of submerged lands, in reference to Prof. Prestwich's paper on the Rubble Drift of southern England. In it I said: "Most violent Japanese earthquakes exhaust their potency in vibrations measured by inches or less." I am not aware that any measurement of vibrations have, even now, given any larger values. But after reading a paper by Prof. Koto on the great Japanese earthquake of October, 1891, it does not seem correct to say that their potency is exhausted in small vibrations. Prof. Koto gives both descriptions and photographs of effects from this prodigious convulsion, and these include the formation of a visible fault-line more than 70 miles long, with a relative horizontal displacement of its two sides along its direction, of from 3 to 6 or even as much as 12 feet in length, and with a relative vertical displacement producing a step along the fault, whose height sometimes reached 20 feet.

Prof. Koto gave attention to the question whether this step was due to a rise of the region on one side, or a fall of that on the other. We might expect that the effects on watercourses would have afforded a criterion; however, he judges that the evidence is insufficient for a decision. He regards fall as more probable, but mentions that, while in general the western side of the fault is lower, along one portion it is higher, and concludes that here at any rate must be an uplift, for which accordingly he conjectures an explanation. His conclusion is natural and probable. Still it is not quite impossible that the cause of the dislocation may here have changed sides of the fault. If water be drawn off from a frozen canal, the sinking ice breaks with a longitudinal crack; but we should not be surprised to find the two sides of the crack irregular in their relative levels. Prof. Prestwich's theory assumes rapid elevations. The throw of this fault is thus not proved to be an elevation. Also how rapid was it? This most interesting question does not seem to have occurred to the investigator. He describes a great shock, followed by less intense repetitions so numerous that 100 were counted during the remainder of the day, and 300 in the day following. Their frequency diminished, yet so gradually that after the lapse of a fortnight they still averaged more than one per hour. Surely these numerous disturbances had a share in the visible effect. What part was produced by them, what part by the great convulsion? How nearly was the change "instantaneous?" The slope of the fault-step is described as being the angle of repose of the material; but this would be the natural result of frequent shocks, and affords no argument as to the change being a single effect. Any evidence on this subject would be most interesting and valuable.

It appears, then, that this Japanese Earthquake does not afford an undoubted instance of such a Rapid Elevation as Prof. Prestwich's theory assumes. Nevertheless the argument in my note against the credibility of the theory is weakened, for one of my main data is now not unquestionable.

E. HILL.

THE RECTORY: COCKFIELD, R.S.O. SUFFOLK.



1 2 3 4

FIG. 1.—Vertical section of *Lithothamnion*.
FIGS. 2–4.—Vertical sections of *Solenopora*.

To illustrate Dr. Alex. Brown's paper.

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

No. IV.—APRIL, 1894.

ORIGINAL ARTICLES.

I.—ON THE STRUCTURE AND AFFINITIES OF THE GENUS *SOLENOPORA*, TOGETHER WITH DESCRIPTIONS OF NEW SPECIES.

By ALEX. BROWN, M.B., M.A., B.Sc.;
Assistant in the Natural History Department in the University of Aberdeen.

(PLATE V.)

IN the present paper I propose to give the results of a series of investigations carried on in the Zoological Laboratory of the University of Aberdeen. Through the kindness of Professor Nicholson, I have had access to his admirable collection of specimens of *Solenopora*, Dyb., and I have also had the privilege of using his extensive series of microscopic preparations of the same. With such material, and with additional preparations, I have been enabled to examine, not only species already described, but also a number of new species, of which I shall in this paper give brief descriptions. From examination of all these forms, I find it now practicable to determine the true nature of the genus *Solenopora*, Dyb.

This genus has been described from time to time under various names; but there is no doubt that *Stromatopora compacta* of Billings, *Tetradium Peachii* of Nicholson and Etheridge, *Solenopora spongioides* of Dybowski, and *Tetradium Peachii*, var. *Canadense* of Foord, are in reality names of the same organism. This particular form, described under these various names, is known as occurring in the Ordovician rocks of Canada, Esthonia, Scotland, Wales, and Shropshire; and will doubtless ultimately be detected in other regions in strata of corresponding age. A full description of the species, under the title of *Solenopora compacta*, Billings sp., was given in 1885 by Prof. Nicholson and Mr. R. Etheridge, jun. (GEOL. MAG. Dec. III. Vol. II. p. 529). At a later date Prof. Nicholson further described another species, *Solenopora filiformis*, from the Craighead Limestones (GEOL. MAG. Dec. III. Vol. V. p. 15, 1888). Still more recently specimens were obtained from the Great Oolite of Gloucestershire and Yorkshire, which, though differing in structural detail, can be readily recognized as another species of the genus *Solenopora*. Thus, the geological range of this organism can be now extended from the Ordovician series to the Jurassic rocks. Additional specimens have also been examined from Esthonia, and from Craighead, Girvan; these showing important structural peculiarities, and reminding one at once of the well-known Nullipores and other calcareous Algæ of the present day.

In a monograph on *Solenopora compacta* (Geol. Mag. Dec. III. Vol. II. p. 529), Professor Nicholson refers the genus *Solenopora* temporarily to the Hydrozoa; but he says that "if evidence can be obtained, proving decisively the existence of a *cellular*, and not a *tubular*, structure in *Solenopora*, then the reference of the genus to the calcareous Algæ will follow as a matter of course." Now, from recent investigations carried on upon all the forms enumerated, and from a comparison of structure of these with those of Tertiary and recent Corallineæ, I have been led to the decisive conclusion that the genus *Solenopora* is in reality an ancient form of the same great group, to which our existing *Corallina*, *Amphiroa*, *Melobesia*, and *Lithothamnion* belong. Before discussing this subject in detail, however, it will be advisable that I should give a brief description of the various species of *Solenopora* with which I am at present acquainted.

I. Description of Species.

1. *Solenopora compacta*, Billings sp.

Stromatopora compacta, Billings. "Palæozoic Fossils" (1861–65).
Tetradium Peachii, Nicholson and Etheridge, jun. Ann. and Mag. Nat. Hist. ser. iv. vol. xx. p. 166 (1877).
Solenopora spongioides, Dybowski. "Die Chaetetiden der Osbalt. Silur. Form." p. 124; taf. ii. figs. 11*a*, *b* (1877).
Tetradium Peachii, var. *Canadense*, Foord. Contrib. Micro. Pal. Sil. Rocks, Canada, Geol. Survey, 1883, p. 24.
Solenopora compacta, Nicholson and R. Etheridge, jun. Geol. Mag. Dec. III. Vol. II. No. 12, p. 529. Dec. 1885.
Solenopora compacta, Nicholson. Geol. Mag. Dec. III. Vol. V. No. 1, p. 15, Jan. 1888.

"This species occurs in subspheroidal masses, from the size of a hemp-seed up to the dimensions of an orange. External surface lobulate. Fractured surface has a porcellanous, sometimes fibrous aspect, and is usually white or light-brown in colour. The fractured surface also shows signs of a more or less obvious composition out of concentrically-disposed strata" (Nicholson).

In vertical section the cells are elongated, arranged in a radiating and parallel fashion, and are often disposed in concentric layers. Diameter of cells about $\frac{1}{17}$ mm. The cells have distinctly undulating walls (Fig. 1).

In tangential section the cell-walls appear sinuous, and in many cases traces of active cell-division are observed. Certain specimens show a distinct variation in the size and form of the cells. In these two sets of cells are to be noted—one set small, with a wavy or polygonal outline; the other set large, elongated or oval in form, and scattered irregularly amongst the smaller cells. The large cells represent the spore-producing cells (sporangia), and the small the ordinary tissue-cells of the organism (Fig. 2).

Varieties.—There exist certain varieties of the above species which differ from the type-form, either in the size of the tissue-cells, or in the structure and form of the cell-walls.

Solenopora compacta, var. *Trentonensis*, nov. var. This variety, illustrated in Fig. 2, is found in the Trenton Limestones, and varies somewhat from the type. The tissue-cells have their walls somewhat polygonal, and only feebly sinuous. Cell-division, too, is not observed to be in the same state of activity as exhibited in the ordinary forms.

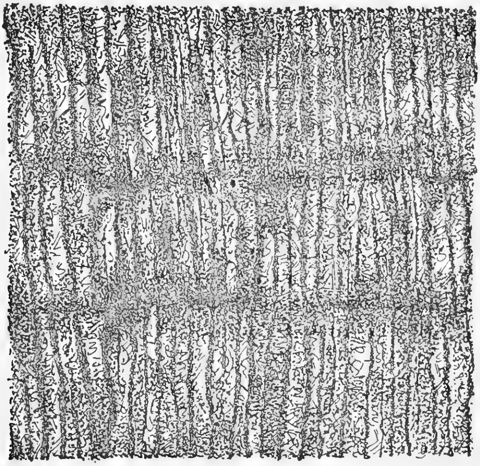


fig 1

FIG. 1.—Long. sect. *Solenopora compacta*, Bill. sp., × 50 d., showing concentric arrangement of cells.

Solenopora compacta, var. *Peachii*, Nich. and Etheridge, jun. Prof. Nicholson has noted that certain specimens obtained from the Craighead Limestones, Girvan, Ayrshire, possess much wider cells than any other form examined. They are alike, in every

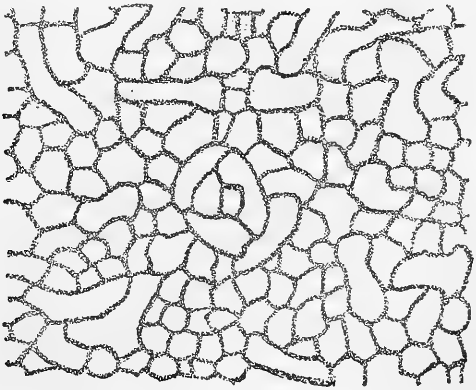


fig 2

FIG. 2.—Tang. sect. *Solenopora compacta*, Bill. sp., from the Trenton Limestones, × 100 d. Larger cells seen in section are the spore-producing cells (sporangia).

other particular, to the typical species described from Canada and Esthonia, and so he distinguishes the Ayrshire forms as a special variety—*Solenopora compàcta,* var. *Peachii.*

Observations.—It is observed that throughout the whole of the above species increase takes place for the most part by longitudinal division of the tissue-cells, and that the cells tend to grow in length more than in breath. Not only so, but there seems to exist a species of sub-dichotomy or sub-trichotomy by which two or three peripheral cells arise from the outer end of a more central cell (see Fig. 1). This process has also been found to occur in certain of the calcareous Algae[1] (e.g. *Lithothamnion*). Transverse division occurs in other species, and in the description of the following forms it will be seen that there are types, very like *Solenopora compacta,* in which cell-multiplication by transverse fission is the rule. Even in the present species such a mode of increase is by no means entirely absent.

Formation and Locality. — Ordovician, Craighead Limestones, Girvan, Ayrshire; Trenton and Black River Limestones, North America; Limestones of Saak, Esthonia, where it makes up great beds of limestone, most of the examples in this case being comparatively small. Dr. Dybowski also obtained it from Herrküll, Esthonia, in beds of Ordovician age ("Borckholm beds" of Friedrich Schmidt). The specimens examined are from the collection of Prof. Nicholson.

2. *Solenopora lithothamnioides,* n.sp. (Pl. V. Fig. 2.)

The single specimen examined shows that this species occurs in conical masses of the size of a walnut. Its fractured surface has a distinct porcellanous aspect, and exhibits a greyish-brown colour. It possesses the concentrically laminated structure characteristic of the genus. It is much harder and more compact in texture than any of the other species.

In vertical section distinct concentrically arranged layers of cells are seen. Each layer is composed of numerous cells arranged in parallel rows. The walls of the cells are slightly sinuous, when examined with a high power. The transverse divisions between the cells are thinner than the vertical divisions, and in many cases are obliterated, leaving fine concentrically disposed clear markings. Cells $\frac{1}{14}$—$\frac{1}{28}$ mm. long and $\frac{1}{10}$—$\frac{1}{20}$ mm. broad. In tangential section the cells are more or less rounded and only slightly sinuous in their outline. The cell-walls are thinner than in *S. compacta.*

Observations.—This species is nearly allied to *S. compacta,* and differs mainly in the character and form of its cell-wall, in the greater regularity of the concentric layers, and in the fact that each concentric layer is composed of parallel rows of small cells. As regards the last point, the same may be true of *S. compacta,* if we are to accept the presence of the commonly observable fine concentric clear spaces as indicative of the original divisions between

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[1] A. Rothpletz, "Fossile kalkalgen aus Familien der Codiaceen und der Corallineen." Zeitschr. d. Deutschen geolog. Gesellschaft, Jahrg. 1891.

the cells. These spaces are well displayed in specimens from the Trenton limestones and from Esthonia, which specimens are assuredly examples of *Solenopora compacta.*[1] In the specimens of *S. compacta* hitherto described no definite proof has been found that these spaces do correspond to cell-walls. In *Solenopora lithothamnioides,* however, distinct walls are seen which agree in position with the clear markings seen also in the same species (see Pl. V. Fig. 2).

Formation and Locality.—Ordovician (Silurian?), Shalloch Mill, near Girvan, Ayrshire. (Coll. H. A. Nicholson.)

3. *Solenopora nigra,* n.sp. (Pl. V. Fig. 3.)

This species presents itself in small oval, ovate, or rounded masses up to the size of a pea. It has always a dark appearance, and it is very difficult to prepare good transparent sections from it. When fractured the concentric arrangement in layers is well seen, and the surface presents a porcellanous or somewhat fibrous aspect. In vertical section the distinct concentric layers of cells peculiar to the last species are not nearly so manifest. The cell-walls are thick, dense, and feebly sinuous, the transverse equalling the longitudinal in thickness. Cells $\frac{1}{30}$—$\frac{1}{60}$ mm. wide and about $\frac{1}{6}$—$\frac{1}{17}$ mm. long. The cells near the point from which radiation proceeds are much narrower and longer than the peripheral cells. The whole cellular tissue often tends to assume a fan-like appearance. In tangential section the cells appear rounded or oval, and somewhat sinuous in their outline. Walls thick, and cell-division active (Fig. 3).

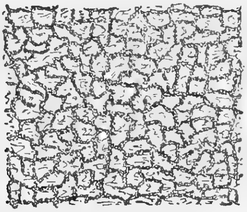

fig 3

Fig. 3.—Tang. sect. *Solenopora nigra,* n.sp., from Esthonia. × 50 d.

Observations.—This species occurs in great masses of limestone, of which it is one of the principal constituents, and such is the appearance of a mass of this limestone that one might readily mistake it for an ordinary Nullipore limestone such as we meet with in the Tertiary series. One is struck, also, with the similarity in form, appearance, and arrangement of the cells, to what is

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[1] These concentrically arranged clear spaces were alluded to by Prof. Nicholson in the Geol. Mag. Dec. III. Vol. II. No. 12, p. 533, December, 1885. He showed there also that, corresponding to the clear spaces in the tubes, there were interruptions in the longitudinal walls.

found in the species to be next described, viz. *Solenopora Jurassica*, Nicholson.

Formation and Locality.—Ordovician Limestones, Saak, Esthonia, Russia. (Coll. H. A. Nicholson.) Here it occurs along with *S. compacta* and *S. dendriformis.*

4. *Solenopora Jurassica*, Nicholson (MS.).

This form occurs in subspherical masses varying from the size of a marble to that of an orange or even larger. The fractured surface has a porcellanous appearance, and shows the arrangement in concentric layers very markedly. Each layer has a reddish-brown colour internally, fading into a whitish appearance externally.

In vertical section the cells are arranged in a radiating fashion. They have about the same diameter as those of *Solenopora compacta* (about $\frac{1}{17}$ mm.), and their length varies from $\frac{1}{7}$ mm. to $\frac{1}{3}$ mm. The arrangement of the cells is upon the same principle as in *Solenopora nigra*, and they do not group themselves into layers corresponding to the concentric strata seen with the naked eye. The cell-walls are very distinct, and not sinuous. The transverse walls are slightly concave on the peripheral side (Fig. 4). Certain zones are observed to have their walls either very indistinct or obliterated by crystallization. These zones correspond to the more lightly coloured portions of the concentric layers of the mass as visible to the unaided eye. Some sections show oval or rounded spaces here and

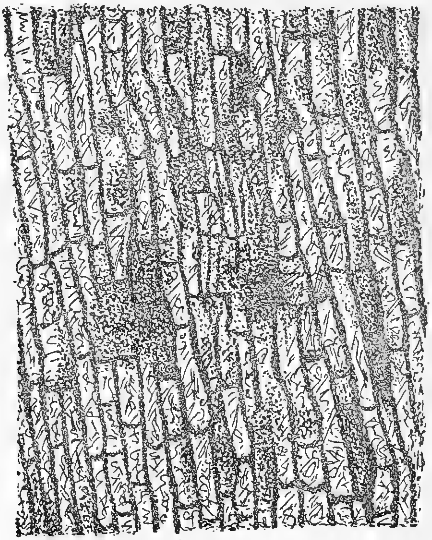

fig 4

Fig. 4.—Long. sect. of *Solenopora Jurassica*, Nich. (MS.), from Chedworth, Gloucestershire. × 50 d.

there, which are, in all probability, the remains of the reproductive organs (conceptacles). In tangential section the cells appear more or less rounded, and also often polygonal. Cell-division is active, and where the cells are not polygonal intercellular spaces are observed to be present. In certain sections are found spaces of a rounded or oval character; and, further, in the same specimens, are observed at intervals clusters of cells arranged in a rosette-like fashion (see Fig. 5). This latter condition may simply be due to the results of cell-division; but to this I shall refer later on. The empty spaces may be all that is left of former reproductive organs.

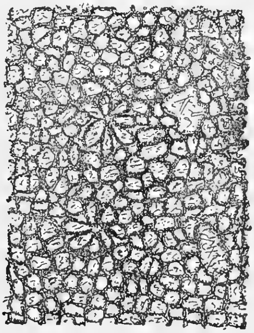

fig 5

Fig. 5.—Tang. sect. of *Solenopora Jurassica*, Nich. (MS.), from Malton, Yorkshire, showing rosette-cells and spaces (conceptacles). × nearly 50 d.

In one specimen from Malton these spaces are arranged in a row, but there was great difficulty experienced in getting good sections for examination, on account of the imperfect state of preservation.

Observations.—This is the only species of Jurassic age yet known. It occurs under the same conditions as the other species. The form of its cells has already been shown to be similar to those of *Solenopora nigra*. The distinct nature of cell-walls, both transverse and longitudinal, places it apart from all the other species.

Formation and Locality.—Jurassic, Great Oolite, Chedworth, Gloucestershire, and Malton, Yorkshire. (Coll. H. A. Nicholson.)

EXPLANATION OF PLATE V.

Fig. 1.—Vertical section of a Tertiary Nullipore (*Lithothamnion*), from "Leitha-Kalk" of Austria. × 25 d.

,, 2.—Vertical section of *Solenopora lithothamnioides*, n.sp., from Shalloch Mill, Girvan, Ayrshire. The specimen shows concentric layers of cells, each layer being composed of numerous cells arranged in parallel rows. × 12 d.

,, 3.—Vertical section of *Solenopora nigra*, n.sp., from the Ordovician Limestone of Saak, Esthonia. × 25 d.

,, 4.—Vertical section of *Solenopora fusiformis*, n.sp., from Craighead, Girvan. A great part of the specimen is destroyed, and the structure obliterated by secondary crystallization. × 12 d.

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

II.—On the Sand-grains in Micaceous Gneiss from the St. Gothard Tunnel; and on some other Difficulties raised by Prof. Bonney.

By Dr. F. M. Stapff.

FROM the "Annals of British Geology," 1892, No. 533, p. 294, I find that Prof. T. Bonney doubts the occurrence of sand-grains in the Guspis micaceous gneiss,[1] as stated by me in various reports on the geology of the St. Gothard Tunnel, and repeated on p. 17 of my "Remarks on Prof. Bonney's paper on the Crystalline Schists and their relation to the Mesozoic rocks in the Lepontine Alps."[2] The question being of some general interest, and not only of importance for the comprehension and classification of the crystalline schists in the Lepontine Alps, I think it desirable to repeat here the *observed facts*, and to present to the notice of the readers of the Geological Magazine some *autotype prints* of the rock in question. I am the only geologist who has seen these beds in situ, when they were opened by the St. Gothard Tunnel; and it would be rather difficult for anyone to make out their outcrops along the line of profile through the Guspis Valley and below the actual moraine of the St. Anna glacier, without taking into consideration the faults and thrusts in this tract, which are indicated on my geological map of the St. Gothard Railway and on the profile of the tunnel.

I beg leave to quote a passage from the geological records kept during the construction of the St. Gothard Tunnel (Geologische Durchschnitte und Tabellen über den grossen Gotthard-tunnel; Spezialbeilage zu den Berichten des Schweizerischen Bundesrathes ueber den Gang der Gotthardbahnunternehmung, 1874–1882; Zürich Orell Füssli), which refers to the bed No. 130; 7262, 4 m. from the northern entry (*loc. cit.* p. 178–9):—

"No. 130; 1879, Sept. 4th; *ditto* (fine-grained rather dense gneiss) *with sandy quartz-grains*; 7262, 4 to 7278, 3 m.; false-stratification 20 W. and 77 E. to 5 E. and 64 W., average 11 W. and 82 W. Samples taken at 7262, 4. Fine-grained, rather dense, micaceous gneiss, rough, almost tufaceous (but not porous), of reddish-grey colour and confused parallel structure, which is indicated by shreds of brown mica. In this groundmass grains of *quartz* and *felspar* of the size of a peppercorn and smaller are disseminated, whence the rock assumes a porphyritic structure. Some crystalline outlines of dull, whitish, faintly glittering *felspar* may plainly be recognized. The grains of *glassy* and milky quartz show an iridescent, glossy, conchoidal fracture; they are *rounded*, with some crystal facets here and there; enveloped by thin mica-films (macroscopically visible), which can readily be loosened and picked out from the groundmass. The presence of *calcspar* is indicated by effervescence, especially around the quartz-grains; other *accessory minerals* are: *pyrites* and rarely minute fragments of *tourmaline*.

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[1] See Correspondence, Geol. Mag. 1892, p. 90.

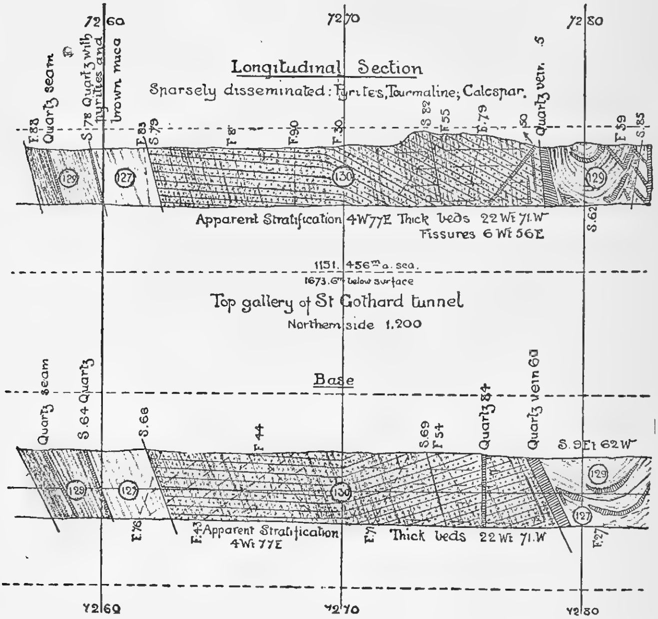
[2] Geological Magazine, January, 1892, Dec. III. Vol. IX. pp. 6–21.

Microscopic observations.—The contours of the larger quartz-grains (as far as they have not been broken out by the grinding operations) are rough but not splintery; the grains are partially wrapped in some longer pellicles or shorter split scales of brown mica. Other grains are surrounded by a garland of fine mica films, which occasionally seem to extend into the quartz-grains. *Calcspar,* together with occasional quartz splinters, is deposited in these mica envelopes, and is attached to the sandy quartz-grains without visible traces of abrasion. Each sandy quartz-grain forms *a single individual,* which is almost always fractured, with or without slight dislocation and torsion of the fragments. The cracks are often covered by a brownish-green substance. In the interior of the quartz-grains may be observed some *microscopic inclusions* of *opaque dust,* specks of *pyrites,* some of *mica,* a few small *lacunæ* (pores), and some short thin *colourless needles.* Here and there a fern-like figure is dimly seen, perhaps indicating the face of a microscopic crack, rather than any microlithic material. Most of the *plagioclastic felspar* is twinned, and the fine twin-striations are visible (in polarized light) though the felspar is in a state of advanced decomposition and intermixed with clusters of *mica scales,* which veil the striations. Though the outlines of the felspars are not so distinct as those of the quartz-grains, they are yet better defined and more clearly individualized than those of the ordinary crushed felspars in the micaceous gneiss; and thus they convey the impression of being porphyritic inclusions rather than indigenous constituents of the micaceous gneiss. The groundmass surrounding the grains of quartz and plagioclase is a compressed mixture of *quartz, felspar* and *two kinds of mica,* the films of which induce an indistinct parallel structure. A little *calcspar* also makes its appearance, partly in isolated granules, partly in larger groups of polysynthetic twins, which are cross-barred with the other minerals, so that it sometimes appears to be a constituent mineral, and sometimes a later-formed accessory cement. Microscopic accessories are *pyrites* (also *pyrrhotine*) in irregular masses, grains, and small crystal groups; and minute, but easily recognized, fragments of *tourmaline.* (So far microscopy.)

This rock appears to be one of the most curious from the interior of the St. Gothard massif. If it really be psammitic, as one may suppose from the foregoing, then all the stratified beds bored through in this massif must also be of sedimentary origin. It recalls to mind the *sericite slates* of the Ursern Valley, with their *glossy sand-grains*; a similar, though less characteristic, rock occurs at 5560–5600 m. from the southern entry. On newly-opened wall-surfaces in the gallery, the quartz-grains appeared to be arranged like *pearls in strings* (scarcely visible in hand-specimens); the strings did not agree with the *parallel structure* of the rock, but rather with its false-bedding (or secondary schistosity); and hence the interpretation of this feature, and of the rock itself, becomes still more complicated. At its margins the bed No. 130 is penetrated by compact veins of quartz and felspar, and further on it passes over into the ordinary micaceous gneiss. . . . ."

To this almost verbal translation I add Fig. 1, a copy from my *original survey sheets* (deposited in the archives of the St. Gothard R. R., Lucerne), after which the plate xxx. (northern side) of the "Geologische Durchschnitte" has been arranged and lithographed. It shows a longitudinal section and a base view of the bed No. 130, as exposed in the top gallery of the tunnel between 7260 and 7280 m. N. (Particulars, which are not relevant to the present question, are omitted.) The *parallel structure* of the rock (S. on drawing), as indicated by the orientation of the mica scales, the course of the parallel quartz-bands, and the boundary faces of the bed, strikes and dips N.E. and S.E., as is commonly the case on the north side of the St. Gothard; whilst the *supposed stratification* ("mock" or "false stratification") is directed N.N.W., dipping W. and E.; and the *quartz-grains are disposed in the same direction.* Having been accustomed to regard the "false stratification" wherever it was met with in the St. Gothard as "secondary," I cannot help confessing that the arrangement of the quartz-grains, in accordance with the "secondary stratification," would witness against the sedimentary origin of the bed in question. But this testimony is at once overborne and reversed if we conceive that this *stratification to all appearance* (beds between limiting faces) *is here the original one,* and that the parallel structure (S. of drawing) of the rock is a secondary phenomenon. Hand-specimens of the rock *support* this opinion, as the mica pellicles are fitted and *stretched* so as to indicate a *linear*

Fig. 1.



rather than a *plane* parallelism; but recently-exposed large faces of the rock allowed a more satisfactory decision to be arrived at.

As some 70 examples (belonging to as many St. Gothard Collections) of the rock in question are preserved in different Museums, it would not be difficult for anyone to examine its petrographical details. I give here (Fig. 2, natural size) an autotypic print of a polished face, which has recently been cut from a specimen in the direction of its most visible "parallel structure," as indicated by the mica; but some wavy undulating bands on the design indicate another orientation, which almost agrees with the trend of the imbedded quartz-grains. The quartz-grains (white spots on drawing) are, by their shape and lustre, easily recognized and distinguished from the felspar grains, and I cannot give a better description of their form, size, number and distribution, than can be seen in the figure.

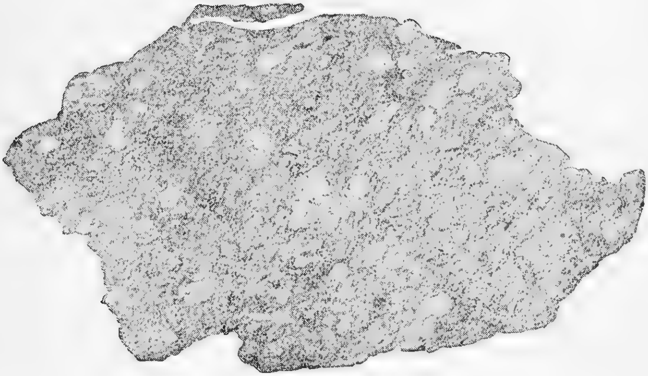


Fig. 2.—Natural size. Micaceous gneiss with sand-grains. Bed 130 (north) St. Gothard Tunnel.

The autotypic figures 3 and 4, which are taken by microphotography from my original thin slices (described in the "Geologische Durchschnitte und Tabellen" beforenamed) reproduce respectively *a grain of quartz* and *a grain of felspar* magnified 16–17 times. In order to show the *marginal lines* between the groundmass and the imbedded grains as clearly as possible, I have taken the photograph by polarized light; but by this method other particulars have been obscured or are not shown.

The quartz of the grains is apparently different from the constituent quartz of the enveloping micaceous gneiss. The former agrees with the quartz crystals occurring in *porphyries,* the latter with the quartz in *granites* and *gneisses.* Each quartz-grain of our rock forms a single crystallographic individual, which is frequently split, in one direction by a few clear parallel fissures, and in other directions by single irregular cracks. Sometimes the fragments of the fractured grain have not been at all dislocated, and then the polarization colour is homogeneous throughout the whole grain; in some other cases there has been an insignificant displacement, and this is the case with the quartz-grain here figured; but these quartz-grains *never* present such a brilliant, polymorphous and polychromatic variegated mosaic as the small particles of quartz which enter into the constitution of the micaceous gneiss. Their polarization colours are somewhat dull, and fade away concentrically from the interior outwards, just as in the case of quartz crystals in porphyries.

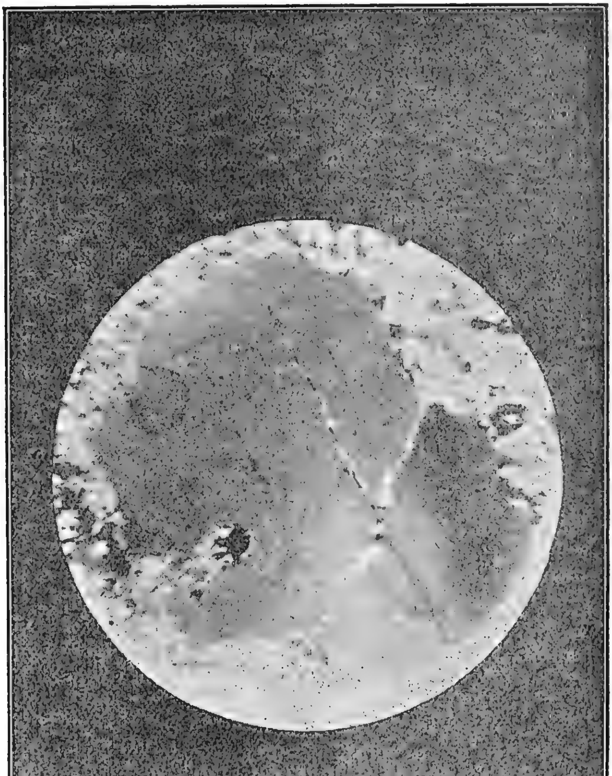


Fig. 3.—Quartz-grain in micaceous gneiss, No. 130 (north) St. Gothard Tunnel. Enlarged 16–17 times. Photographed in polarized light.

The *microlithic* (and other) *inclusions* in the quartz-grains are larger but neither so frequent nor so varied as those in the magmatic quartz-splinters. The thin, colourless, brilliant prismatic needles—not visible in figure—and the rhombic sections,[1] seemed to offer a special character since they were missing in the magmatic quartz-splinters; but later I found them also in the *holes* from which the quartz-grains had been broken out (abundantly), and finally outside the edge of the thin slice (rarely); whilst they were *wanting in another freshly-made microscopic section.* They seem *not to be connected with the material of the rock.* Some few microscopic scales of *brown mica* are deposited *on the cracks* in the quartz-grains; they appear to be later deposits and not inclusions in the crystallizing quartz. But some doubt may arise with regard to rare microscopic patches of brown mica and quartz, *i.e.* of the *enveloping material,* which appear to be inclusions, though they may quite as well be deposited above or below the grains, or they may be terminal points of lateral inclusions in bays of the quartz-grains (see figure). Small (microscopic) granules of *calcspar* likewise occur on *cracks* traversing the quartz-grains; and without doubt they have been deposited there *à posteriori,* just as well as the calcspar on the margin of the grains. The same cannot so decidedly be said about the granules of calcspar, which are interwoven in the texture of the micaceous gneiss; the less so, as they proved to be *dolomitic.*

The shape of the quartz-grains is always *roundish polygonal;* short, straight fragmentary edges of a crystal are interrupted or connected by curves and small fracture-lines; but the outline is by no means fringed by filaments or threads entering and losing themselves in the enveloping material. No regularity whatever can be recognized in the crystallographic orientation of the grains, either with respect to each other or towards the surrounding minerals; the different quartz-grains exhibit very different orientations and individual colours when the slice is moved between unaltered Nicols. And just as little can any *fluidal structure* be noticed around the grains. Short segments are wrapped up in extended pellicles of mica, which stick close to the outline of the grain and leave but little room for the deposition of other mineral particles; for the rest, small brown mica scales intermixed, to form a minute mosaic, with broken quartz (and some grains of felspar, calcspar, etc.) environ the foreign quartz-grains; and it is seen that the mica pellicles are twisted around the quartz-grains in such a way that longitudinal and cross sections alternate in one and the same profile. Hence the cavity from which a quartz-grain has broken out seems to be lined by a cuticle of brown mica; but, if that same cuticle is cut through, the sections vary very considerably at different places.

The demarcation line between a quartz-grain and its envelope is seldom quite clean and smooth. Microscopically seen it is, for the most part, rough, and small pellicles of mica and granules of quartz are attached to it (squeezed in, to all appearance); just as we see

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[1] Mentioned in the translation from the Geol. Durchschnitte und Tabellen.

sand-grains and gravel encrusting the corrugated surface of a pebble. The cracks and fissures are sometimes enlarged at the surface of the bay, which allows the surrounding material to invade the grain.

The *felspar-grains*, of which one is reproduced on Fig. 4, are in part *polysynthetic twins*, in part *single* or *twofold* individuals. It is not easy to determine particular felspar species in view of the extent to which they are decomposed; but even with the naked eye one can observe that some of the felspar-grains are greenish, dull, lustreless, striped and dusty (*kaolin*); whilst others are white or limpid, fresh and glossy. Commonly they present the outlines of

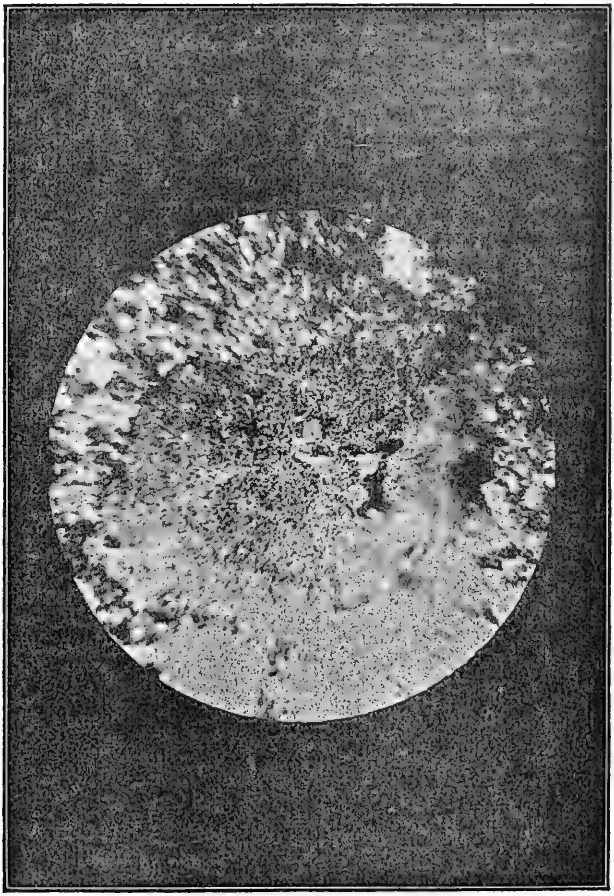

Fig. 4.—Felspar-grain in micaceous gneiss, No. 130 (north) St. Gothard Tunnel. Enlarged 16–17 times. Photographed in polarized light.

crystals, but sometimes they are rounded; or they are split, broken and torn, as felspars in the squeezed St. Gothard gneisses so often are; and hereby we learn that the same felspar simultaneously makes its appearance as an ordinary constituent of the micaceous gneiss *and* as a porphyritic inclusion in the same.

The figured grain is porphyritic though rounded. It shows no twin stripes in polarized light, and its mass is almost replaced by clusters of pellicles of *potash mica* and *kaolin.* Small *quartz-grains* and other microliths accompany the mica in the decomposed felspar, which I need not further mention.

The outline of this grain of felspar—and of others similar—is not so well defined as that of the quartz-grains (Fig. 3), and to all appearance it has coalesced with the surrounding materials; a white margin indicating in some cases the zone of intermixture.

In spite of the roundish contours of many of the felspar-grains, I am *not* inclined to consider them to be grains of felspar *sand.* The occurrence of porphyritic segregated felspar in gneissic rocks is by no means unusual; and this may be the case in the quartzitic micaceous gneiss No. 130, where the lesser part of the felspar is intermixed with the other constituent minerals, and the greater is segregated.

The preceding observations put beyond every doubt that the *quartz-grains are foreign bodies:* their material is not identical with that of the constituent quartz of the micaceous gneiss, nor are there any transitions between the two kinds; each quartz-grain is an individual, loosely imbedded in the groundmass and easily picked out of it. Some of the apparent inclusions in the quartz-grains are *later depositions* on cracks, others are *squeezed in from the outside,* and with regard to the nature of others some doubt may be reasonably entertained. The question now is: have we to deal with *sand-grains* imbedded in an (originally) *sedimentary psammitic rock;* or with a kind of *quartz-porphyry,* the groundmass of which has been decomposed in such a way that it is now a micaceous gneiss? This second view is supported by the nature of the quartz-grains, and their association with porphyritic felspar-grains; whilst it is contradicted by the actual nature of the enveloping magma, by the lack of fluidal structure, by the arrangement of the grains in accordance with the bedding of the rock (Fig. 1)—*facts which corroborate the belief in the sedimentary origin of the bed.*

Prof. Bonney doubts also "*the occurrence of organisms in the Altkirche marble*"; but I question whether many share his opinion after seeing the autotype figures of the bodies in question, which are published in the GEOLOGICAL MAGAZINE (1892, Dec. III. Vol. IX. p. 16),[1] with a footnote by the Editor (p. 17): "hand-specimens of these St. Gothard rocks are preserved in the Mineralogical Collection of the British Museum, and sections taken from the one marked No. 43 show precisely similar structures to those in the accompanying figure.—EDIT. GEOL. MAG."

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[1] Reproduced by Professor J. F. Blake, in his Annals of Geology for 1892, p. 293.

"The reference of the Piora schists to the *Carboniferous* appears (to Prof. Bonney) to be only a hypothesis"—but, as a fact, I have not made such a reference. I have not dealt with his Piora schists, and would not say anything about them but (GEOLOGICAL MAGAZINE, *loc. cit.* p. 9) "that they belong to the second of my groups (that of the grey garnet schists) and his 'Val Tremola schists' to the third and fourth group (green, black felspathic mica schists, and amphibolic rocks)." What I have mentioned about the geological age of *these* (*my own*) groups is restricted to the following lines in the GEOLOGICAL MAGAZINE, p. 7: "If this parallelization be correct, and the metamorphosed sedimentary rocks of the Ursern Valley properly determined, then we may draw the conclusion that the series of the originally sedimentary rocks on the south side of the St. Gothard begins, at the bottom of the Ticino Valley, with *Jurassic* deposits and includes *Carboniferous* at about 1833 m.[1] inside the mountain, counted from the mouth of the tunnel." *Ibid.* p. 10: "The beds, in which disthene and kindred minerals can be recognized at a glance[2] . . . . . are usually connected with the calc-mica schists and black garnet schists, but it would be premature to assert that certain geological horizons in the grey mica schists are characterized by the appearance of disthene, etc." *Ibid.* p. 19: "5 The rocks belonging to the fifth series (on my geological map of the R.R. line), viz. dolomites, grey and green mica schists . . . . have been characterized in § I.–III., where it is pointed out that they extend from the *Carboniferous to the Jurassic* age."

I have nowhere advanced the hypothesis imputed to me by Prof. Bonney that his Piora schists (*my grey mica schists of the St. Gothard Tunnel*) *belong to the Carboniferous*; and, comparing the Geological Map of the railway line (Explanation on the title-page), the designation *Carbon* (?) will be found exclusively behind the references for: "Quarzglimmerschiefer mit Chloritglimmerschieferlagen, North, Pl. V."; "Schwarze phyllitische (chloritische) Schiefer mit Kalk—Quarzit—Gneiss-streifen (Oberalpstrasse)."

On the summary profile (title-page) the designation "*Carbon*" (?) is restricted to the black schists of the Oberalpstrasse, on the north side; to the black (and green) schists on the south side, *inwards from* 1100 or 1200 m. as mentioned above; and to the well-known *Manno grits.*

In the bathrologic review (on the same sheet of the map) the schists belonging to V., viz. "Granat-Amphibol-Paragonit-Chlorit-Sericit-Kalk-Glimmerschiefer," are designated as "Archaeische[3]-Mesolithische Lückenbüsser."

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[1] My "grey garnet schists" (*sint* Prof. Bonney's Piora schists) are reckoned from 90–1142 m.; my "black and green garnet mica schists" from 1142–1833 m. (GEOLOGICAL MAGAZINE, *loc. cit.* p. 9).

[2] *Sint* Prof. Bonney's "Piora schists."

[3] In the GEOLOGICAL MAGAZINE (*loc. cit.* p. 19) I have freely confessed that the reference to *Archæan* was a mistake of mine.

III.—THE MAMMOTH AGE WAS CONTEMPORARY WITH THE AGE OF GREAT GLACIERS.

By Sir HENRY H. HOWORTH, K.C.I.E., M.P., F.R.S., F.G.S.

THERE has been a long and sustained discussion among geologists as to whether the Mammoth and its companions were pre-Glacial, inter-Glacial, or post-Glacial, or whether they could not, in fact, claim to have been both pre- and post-Glacial, and to have lived through the Glacial age, whence the name of *Dicyclotherium* proposed for the Mammoth by one writer.

These discussions have all, it seems to me, been vitiated by the postulate that the Drift, as we have it in Western Europe and North-Eastern America, was distributed by ice-sheets or icebergs. In my last published work I have devoted a large space to trying to prove that this view is a mistaken one, and that while we have ample evidence of there having at one time been much larger local glaciers, where glaciers still exist, and of there having been glaciers in many places where glaciers no longer exist, there is no satisfactory evidence of great ice-sheets having existed or being even possible and that it is impossible to assign the distribution of the Drift over a large area where it occurs, either to ice-sheets, or to ice in any form. On the other hand, I have argued that the Drift was very largely distributed by water; not by water acting by slow diurnal methods, but by water moving under the impulse of a great catastrophe. If this view be right it entirely alters the conditions of the problem about the true epoch of the Mammoth and its companions.

That the Drift, so far as our evidence goes, invariably overlies the Mammoth beds where the latter are *in situ* I have argued at great length in this MAGAZINE, and have also adduced a great deal of evidence to prove it, and this evidence keeps growing. This means that the catastrophe which distributed the Drift was subsequent to the Mammoth age, and, in fact, I have argued that it was this very catastrophe which overwhelmed the Mammoth and its companions. I believe also that it was the final chapter in the history of the so-called Glacial period (which ought really to be styled the period of Great Glaciers), and that to it we must attribute almost entirely the last changes in the configuration of large parts of the Earth's surface of any importance.

This means that while the distribution of the Drift, as we find it, was rapid and sudden and was contemporary with the extinction of the Mammoth and its companions, the period of Great Glaciers which immediately preceded that diluvial movement was also the period during which the Mammoth and its companions flourished, and that the great beasts and the Great Glaciers flourished side by side—were, in fact, contemporaneous. This view, I submit, is in accordance with the facts and best explains them. To put the case more concretely, it is that while the Highlands of Scandinavia and Scotland, the Jura and the Vosges in Europe, and the mountains of British Columbia and the Laurentian Highlands in America, were nursing large glaciers, the Lowlands in the same latitudes were occupied by forests and steppes, where abundant vegetable and animal life flourished, and that the era of Great Glaciers in Europe and North America corresponded to the current condition of things in New Zealand, where Great Glaciers exist alongside of thickets of luxuriant trees, amidst which the *Apteryx* and its companions thrive.

In order to illustrate this position we must divide the area over which the Mammoth and the Drift occur into three zones: (1) that in which Drift occurs, but not the Pleistocene beasts; (2) that in which the Pleistocene beasts occur, but not the Drift; and (3) that in which they occur together.

In regard to the first of these zones or provinces, it is remarkable that in Scandinavia, Finland and the Alpine country, and in the correspondingly glaciated districts of America, there should be a virtual absence of all traces of the Pleistocene fauna, not merely of the Mammoth and the Rhinoceros but of traces of such Arctic animals as the Musk Sheep, the Reindeer and the Ice Fox. These last creatures occur with the Mammoth and the Rhinoceros in France, Central Germany and Britain, but are not found in the Alps, in Scandinavia, or the Highlands of Scotland, although now flourishing in the highest latitudes. They seem to have abandoned those areas for others where food and other conditions made life supportable. Not only so, but we do not find that in the areas where the Pleistocene beasts occur that they are assorted according to climates, but they occur together at Zurich and on the borders of the Alps and in Scotland just as much as in Southern France. All this surely points to the sharp separation in locality, but not in time, of the Pleistocene fauna of the plains from the barren uplands. This distribution of the fauna of the Pleistocene age seems to me to afford strong evidence that the Great Glaciers of the high lands were contemporary with the existence of the Pleistocene fauna elsewhere.

If we turn from these districts to those where the Mammoth and its companions have occurred, but where there is no Drift, we shall be constrained to the same conclusion.

It is a remarkable fact that if we limit ourselves to the plains of Northern Siberia, excepting a fringe of land bordering on the Arctic Ocean which has recently risen from the sea and contains deposits of very recent marine shells, there is no evidence that a period of severe cold other than that now existing has marked the climate of Siberia since the Mammoth was extinguished. The existence of carcases in their flesh, and of very recent-looking Molluscs and tree trunks in the surface-beds of Siberia, all point to the age they represent having been the last one; and that the only glacial conditions which have existed in Siberia are those now current there, the climate having become more and more severe since the Mammoth age. This means, if evidence is to go for anything, that the Mammoth age in Siberia and North-Eastern Europe, which was its last epoch, was contemporary with the Great Glaciers elsewhere.

In regard to Siberia, Mr. James Geikie, the great champion of extreme glacial views, fully admits that there are no traces of glacial action there, and that the beds in which the Mammoth remains occur are the latest, and thus correspond to the Drift beds; and he, in fact, actually argues that "the Mammoth and the Woolly Rhinoceros may have survived in Northern Asia down to a comparatively recent date" (The Great Ice-Age, pp. 554–556, and notes). I cannot see how the conclusion can be avoided, in fact, that in Siberia the Mammoth age was strictly contemporary with the development of Great Glaciers in Europe and North-East America. Nor do I know anyone who would contest it.

What is true of Siberia is equally true of that outlier of Siberia—Alaska—which resembles it in every way, in the absence of traces of old glaciation in the preservation of great masses of remains of Pleistocene beasts in a very fresh condition, whose very freshness, as in Siberia, points to their having lived in the very latest geological period, and contemporaneously with the glaciation of the country round Hudson's Bay further east.

So much for Siberia and Alaska; but it is not possible to separate Siberia from European Russia. The continuity of conditions of the fauna and of the surface-beds is complete, as I have shown elsewhere. North-Eastern Europe is, from the point of view of physical geography, a mere western continuation of Siberia, and, as we travel southwards and westwards from Petschora land, we pass through a country whose surface-deposits are continuous, and of the same texture and having the same contents, the only difference being that the permanently frozen soil with its preserved animal mummies gives place to soil not permanently frozen, containing only skeletons; and this goes on in Russia right up to the deposit where the so-called Northern Drift begins to appear. In Siberia, where no Northern Drift occurs, the continuity of conditions goes on uninterruptedly until we reach the hilly districts of the South, where the Pleistocene remains are less frequent, but precisely the same in character, and they only disappear when we reach the widely-scattered sandy deposits containing salt-water shells, which are the evident bed of the dessicated Central Asiatic Sea of Pleistocene times.

The view here urged is, I believe, the view of Professor Nikitin and the most experienced Russian geologists.

In regard to Germany and Central Europe, Penck has devoted a special Memoir, entitled "Der Mench und Eiszeit," to show that Palæolithic Man and his companions were occupying that area while the so-called Ice-age was culminating in more Northern latitudes. In the Map in which he gives the various localities where traces of Palæolithic Man have occurred in Central Germany, he does not give one where the actual Drift occurs. It would be, indeed, singular if such a trace had, in fact, been found in that area, when we remember the rarity of the occurrence of the Pleistocene beasts in the same district; but he gives several in the zone bordering the actual Drift-zone on the south, and occupied by Loess, which is very generally accepted now as a flood-deposit closely united with the Drift. Penck says that the synchronism of Palæolithic Man with the great Ice-age does not rest on a chain of different inferences, and he concludes his detailed examination of the problem with the words, "die ältesten Spuren des Europäischen Menschen gleichalterig sind mit den Moränen der Vergletzerungen."

The same view on different grounds has been urged by the distinguished botanist Drude, who argues that a considerable vegetation survived on the high ground in Germany, while the low ground was occupied by ice, and that it was from this vegetation the present flora of the country is derived.

If we turn to America and examine the problem, either as presented by the so-called Bone Licks of Ohio or by the Driftless areas, we shall be constrained to the same conclusion. The bones of the extinct animals in both cases occupy the very latest beds and are found, so far as we can judge, at the precise horizon where elsewhere the Drift beds occur. Whitney, who described the Driftless region in Wisconsin, Iowa and Minnesota, says that it "must have formed an island at the time when the great currents from the North were bringing down the detrital materials which are spread over so vast an area in the Northern hemisphere." Of the condition of this island and its environs, Mr. J. Geikie says: "Throughout this remarkable region the remains of numerous extinct Mammalia have again and again been detected. They occur promiscuously embedded in the surface-wash, or in cracks and crevices of the limestone. The animals mentioned are Mastodon, Megalonyx, Elephant, Buffalo, Wolf, extinct species of Peccary, Racoon, and several Rodents, etc. Many of these were got in clayey loam at considerable depths from the surface. . . . . Beyond the Driftless region, however, in those tracts that are thickly covered with gravel sand, boulders and hardpan, no such Mammalian remains occur in superficial or post-Glacial deposits" (Great Ice-Age, p. 464).

The evidence then of those areas where the Pleistocene beasts occur, but not the Drift, confirms that of those places where the Drift occurs but not the animals.

Lastly, we have to deal with that zone where both occur and where, so far as I know, the Drift always overlies the Mammoth beds when the latter are *in situ*. Here we find precisely what we should expect to find if a great diluvial movement had distributed the materials formed in the glaciated highlands, and the very reverse of what we should expect to find if the Drift had been distributed by ice. The rush of waters as it went along would seize upon the loose *débris* and incoherent beds from every district which it passed over, and incorporate them with the mud and other loads which it was carrying along. Thus we find molar teeth and other bones of Mammoth, etc., which must have been lying about in a fresh unweathered condition, and we find logs of timber occurring in the Boulder-clay itself and in the associated beds, and occurring there, no doubt, as true boulders, just as we may find Ammonites from the Lias and Oolitic fossils, together with masses of granite and other primitive rocks in the Boulder-clay of the Eastern Counties. Thus we find in the Baltic lands marine shells associated with land *débris*, as we, in fact, do also in England where Molluscs from salt-water and Molluscs from fresh-water and pieces of wood, and teeth of animals occur in the same beds, being the *débris* of a widespread ruinous flood. It seems to me that all the evidence we have points to this conclusion, which I have long ago urged. The theory of the survival of the pre-Glacial Fauna and Flora is a notion that does not date from yesterday only. It is likely, I think, to grow. I have already shown in your pages what strong grounds there are for believing that the fauna and flora of Greenland, Spitzbergen, and other lands are not a re-importation after they had been depopulated by the Glacial monster, but a survival from pre-Glacial times.

Coming down to our own latitudes I never could understand how the Lusitanian forms in the flora of the South-West of England and the South of Ireland could be explained by any other theory.

The view had already been maintained by Edward Forbes. He considered that the oldest vegetation in the British Isles is that of the mountains of the West of Ireland, which, though an Alpine flora, is Southern in character, and quite distinct, as a system, from that of the Scotch and Welsh Hills. Its very Southern character, its limitation, and its extreme isolation, are evidence, he says, of its antiquity, pointing to a period when a great mountain-barrier extended across the mouth of the Bay of Biscay, from Spain to Ireland, which he attributes, hypothetically, to Miocene times. Another flora, confined to the South-west of England and uniting that promontory, is similar to that of the Channel Islands and the opposite coast of France. The existence of this flora depended upon the existence of a barrier, the traces of which still remain, from the West of France to the South-west of Britain. Here, again, we must travel beyond the Glacial period to explain the facts. Forbes argues further that the endemic animals, especially the terrestrial Molluscs, necessitate the same conclusion (Brit. Ass. Rep. for 1845, pp. 67 and 68).

Mr. Bulman has recently examined the question in Natural Science, and I will quote some of his conclusions.

He mentions the absence from England of fifty species of Mammals occurring on the Continent as a notable fact in this behalf, and pointing to our fauna being that which survived from Glacial times. If there had been a subsequent bridge it is hard to explain this absence, for, as he says, the supposition that they had not time will not pass muster; and so with the reptiles. Turning to the plants, he says that those which must have crossed the plain, on the hypothesis of a re-stocking from the Continent after the Glacial epoch, include, apparently, some of the most slowly-spreading forms. In regard to the Southern plants in Ireland, he says: "In the absence of a direct land-connection between Ireland and the North of Spain since glaciation, for which there is no independent evidence, it is difficult to understand how they can have got there;" and he goes on to argue "that a more reasonable explanation is to suppose that they were previously widely dispersed over Britain and that they were exterminated everywhere, but in the warmest corner, by the cold." In regard to the Southern Flora of Devon and Cornwall the same writer says: "The precarious foothold of many of the species, and the apparent dying out of some, are not suggestive of species migrating northwards in response to a continually ameliorating climate." Lastly, Mr. Bulman quotes the occurrence of the reeds of *Naias marina* in the Cromer Forest Bed. The only British locality for this plant is Heckling Broad, Norfolk, and, hitherto, the Forest bed is the only fossil locality. "It would be," he says, "to say the least, a curious coincidence if it had been exterminated by the ice and had then re-migrated from the Continent to one spot in Norfolk only." The species is at present a native of the temperate and tropical regions of the world (Natural Science, pp. 261–266).

Dr. Scharff has recently sent me some papers on Irish land and fresh-water Molluscs, in which he takes the same view in regard to Ireland, and it seems to me it is only by taking this view we can explain the fauna and flora of the detached islands off the British coast.

Mr. Somervail thus describes the conditions which he supposed, and what I suppose, prevailed in Scotland during the Glacial age. "All the higher part of the country would appear to have been covered with snow and ice to a considerable depth. The great valleys were filled with glaciers which reached the sea. Large tracts of the country were entirely free from ice and covered with the flora and tenanted by the fauna already referred to, and doubtless by many more of whose existence we have not as yet discovered any record. Over certain tracts small lakes existed, formed by the melting of the terminal portion of the glaciers further inland, while in and around those lakes sufficient vegetation grew to form the layers of peat which we sometimes find inclosed in the Boulder-clay" (Trans. Geol. Soc. of Edinburgh, vol. iii. p. 95).

In illustration of this position, I would quote what is actually occurring in these Northern latitudes at this moment.

Speaking of a glacier near Odde on the Hardanger Fiord, Mr. J. M. Wilson says: "The steep slope of ice terminates in a very small moraine a yard or two wide . . . . masses of fresh turf, with flowers still in bloom, are thrown up in this moraine as the inexorable mass pushes on. It is now ploughing through the sweet pastures belonging to a farm. Within a few yards of the glacier are to be found wild roses and foxgloves, ladies' mantles and holly fern, and a score of meadow flowers, with ripe raspberries and strawberries and blackberries. This is a new glacier only 50 years old." (GEOL. MAG., 1872, Vol. IX. p. 484).

The fact is, we have been pursuing a Will o' the Wisp instead of a real induction in following the lead of the cultivators of the great Glacial Myth. We must countermarch, that is plain; we must get rid altogether of the notion that half the Northern temperate zone was swathed in ice and snow, and realize it as it may be still realized in New Zealand, in the Himalayas, and the Altai Mountains, where glacier and forest are almost conterminous.

This view does away entirely with those theories according to which England, etc., etc., were stripped of their verdure and their living inhabitants and encased in a suit of frozen armour, and were then re-invaded and re-peopled by fresh importations of plants and animals which had meanwhile retired goodness knows where, and which returned again goodness knows whence, without having varied, in a mode at once simple and astounding.

The living plants and animals of these islands, with the exception of a very few extinct forms, are virtually the same as those living in the Mammoth age. It would have been strange indeed if this identity had survived an extinction of life and re-colonization of Britain. As a matter of fact, this extinction and this re-colonization are unsupported by any induction from the facts of either Geology or Natural History. They are, like many other scientific opinions, conclusions necessitated by adopting *à priori* theories. Some plants and some animals perished, no doubt, but the great bulk remained.

In discarding this conclusion we are remitted to a more rational one, namely, that the plants and animals found within our four seas, save and except those introduced by human agency, either directly or indirectly, and some waifs and strays, are the descendants of the plants and animals which were living here in the Mammoth age, which was the age of Great Glaciers, with which age the present one is, in fact, perfectly continuous, the only break having been the extinction of a few forms by the great catastrophe. This view is not popular just now, but I have no doubt whatever that it will presently prevail, and that its acceptance will clear away a great deal of difficulty and misleading intricacy from our text books, not only of Geology, but of Natural History.

The view here urged in regard to the contemporaneous existence of the Great Glaciers and a fertile champagne country side by side in the last Geological age seems to me to best explain the facts.

P.S.—I have just seen Mr. Stirrup's paper in the February Number, pp. 80–82. I am bound to say I cannot follow his logic, nor can I understand what he is after. The facts he quotes from Dall and others are well known. I do not dispute. What I do dispute is the inference that they point to the Ice beds being older than the Mammoth beds. Whatever their age, it seems to be quite certain that they must be the result of infiltration, unless trees can grow on blue ice and Mammoths browse on snow.

IV.—Further Remarks on the Tertiary (Eocene) Insects from the Isle of Wight, and on others from the Lias and Coal-Measures.

By the Rev. P. B. Brodie, M.A., F.G.S.

I WISH to make some corrections and additions to my recent paper on the Tertiary insects from Gurnet Bay, and to mention others from older formations. I have recently had an unexpected and gratifying visit from my friend Mr. Scudder, the eminent American palæo-entomologist, and if I had been aware sooner of his coming to England I should have deferred my notice of some of our British Tertiary Arthropoda until he had examined the large and varied series in my Collection. Unfortunately, he could only spend a part of two days, so that the examination was very cursory; and, of course, it would require a very long and careful examination to determine them. He thinks that the supposed eggs of insects and annelids cannot be referred to either; the former he could not identify and the latter he considered to belong to plants. Among the insect remains he detected the following:—

(1) COLEOPTERA.

Curculio.
Staphylinus.
Cheironomus.
Boccus (allied to).
Elater Buprestidæ.
Telephoridæ, and many others.

(2) HYMENOPTERA.

Ants, several genera, very numerous.
Gnats, abundant.

(3) LEPIDOPTERA.

Moth, with body and wings. A rare and very fine specimen.
Butterflies, two wings.

(4) DIPTERA.

Tipula, Crane fly, body and wings.
,, Wings.
Syrphidæ, several; and many others.

(5) NEUROPTERA.

Termites, nearly perfect, with attached wings, several.
Dragon-fly, part of, including head, thorax and one wing; several other wings.
Phryganea, wings.

(6) ORTHOPTERA.

Locusta, wings.
Gryllus, wing.

(7) HEMIPTERA.

Aphis.
Cicada, wing and bodies.

(8) ARACHNIDA.

Gastypus Woodwardii, and many others; one resembles *Epira* of Heer (P.B.B.).
Myriapoda, one example.

Among the Lias insects Mr. Scudder noticed an example of *Palæotermes*, unfortunately ill-preserved and imperfect, but it is desirable to record this genus from the Warwickshire Lias, as it may be identical with the fine and perfect insect from Barrow-on-Soar, described and figured by Dr. Woodward,[1] half of which is now in the British Museum (Natural History). In the Upper Lias, from Dumbleton, Gloucestershire, he noted two large *Neuropterous* wings as being quite distinct from *Libellula Brodiei*, the finest insect in my Collection, and to which they had been previously assigned. In the Coal-measures at Commentry, in France, there is a gigantic wing of a large, probably *Neuropterous*, insect, *Meganeura mongi*, Brongniart, the head and body of which are gone, except a thoracic portion to which enormous wings are attached. These are very long, longer than broad, with an expanse of wing almost approaching to that of a fair-sized bird. This is a most marvellous Carboniferous insect, the largest known and larger than the wing *Archæoptilus ingens*, Scudder, in my Collection, from the Coal Beds, Chesterfield, Derbyshire, showing how favourable the conditions must have been for the growth and development of certain forms of insect life in that epoch. Since then the *Neuroptera* and *Blattida*,

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[1] GEOLOGICAL MAGAZINE, Decade III. Vol. IX. p. 193, Pl. V. 1892.

so characteristic of the Coal-measures, seem to have degenerated. Many other Carboniferous insect relics are of great size, so that they must have been dinosaurs of their kind, and the *Neuroptera* became aldermanic and got fat and bulky on the well-grown and unctuous *Blatta.* A plate of this fine insect, kindly presented to me by the author, will appear in M. C. Brongniart's folio work on the Commentry insecta, in due course.

V.—CORDIERITE IN THE LAKE DISTRICT.

By ALFRED HARKER, M.A., F.G.S.

IN the February Number of this MAGAZINE, Mr. Hutchings announces that he has identified as Cordierite the mineral which constitutes the conspicuous "spots" in the metamorphosed slates of Wasdale Beck near the Shap Granite. In this connection, it may be of interest to record another occurrence of the same mineral, discovered by Mr. Marr and myself a year or two ago. It is in the metamorphosed Skiddaw Slates of the Caldew Valley in Cumberland, the locality of our specimens being south-west of the farm of Swineside. The cordierite occurs there in crystals of quite irregular shape, charged with various inclusions, original and secondary, and stained with limonite. A transverse section is about ·07 or ·08 inch in diameter, and shows the characteristic polysynthetic twinning, causing a division into six sectors when viewed between crossed nicols. In addition there is a division into an inner and outer portion by a well-marked hexagonal zone of opaque, probably carbonaceous, inclusions. The outline of the transverse section itself shows only a general correspondence with the hexagonal form, and extends as a ragged fringe into the surrounding part of the rock.

FIG. Transverse Section of Cordierite Crystal in the metamorphosed Skiddaw Slates near Swineside, × 20 [slide 1563].

The drawing is in part diagrammatic, the division into six fields being, of course, invisible in natural light.

The mineral recalls in some respects that described by Kikuchi[1] from the Waterase-gawa district in Japan; but it is not possible to make out in the Caldew occurrence all the interesting peculiarities exhibited by the much larger, fresher, and more perfect crystals studied by that author. He regards the variety which he describes as bearing the same relation to cordierite that chiastolite does to andalusite.

After Mr. Hutchings' discovery, it seems probable that cordierite will be found, if looked for, in other tracts of metamorphosed slates in this country.

VI.—JURASSIC AMMONITES: NOTES ON A PAMPHLET BY DR. EMLE HAUG.[2]

By S. S. BUCKMAN, F.G.S.

IN the twentieth volume of the Bulletin de la Société géologique de France (p. 277) a valuable paper with the above title was published. It contains three plates with a number of species, six of which are said to be new. That I cannot agree with all his conclusions Dr. Haug knows well, for, before the work appeared, the author kindly sent me copies of his proof plates for my opinion, and several letters passed between us on the subject; that he cannot agree with all my opinions on matters palæontological the author readily confesses in the present paper. Nevertheless in two cases of importance this paper does bring us more closely into agreement, as I will point out presently.

In plate viii., the first of the three plates which illustrate the work, figs. 1 and 2 are called "*Sonninia*, cf. *corrugata*, Sowerby," figs. 3 and 4, "*S. furticarinata*, Quenstedt," fig. 5, "*S. pinguis*, Roemer," fig. 6, *S.* (*Poecilomorphus*) *Schlumbergeri*, n. sp." I certainly do not agree with placing figs. 3 and 4 in the same species: the latter figure shows a more coarsely-ornamented shell, its periphery furnished with a large hollow carina *not* bordered by anything like sulci, while the periphery of fig. 3 is very distinctly so marked. With fig. 4 I should associate, not necessarily as the same species, but as something very near, figs. 1 and 2; and I should also place in proximity fig. 5, "*Sonn. pinguis*." Roemer is the author of the name *pinguis*, and, though he gave a very bad figure of his shell, I think Haug's fossil is far too strongly costate; my cabinet can show specimens much nearer the original.

Of fossils nearly, if not quite, the same as fig. 3 I have several, and can say that, with age, they do not lose their peripheral furrows, that they do not become strongly lobate like fig. 4, and that they are certainly thinner.

Plate ix. shows "*Sonn. sulcata*, (S. Buckm.);" in removing this species from *Lillia* I think Dr. Haug has rightly corrected me, though the form he figures differs in certain points from mine—

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[1] On Cordierite as a contact-mineral, Journ. Coll. Sci. Imp. Univ. Japan (Tokyo), vol. iii. (1890), pp. 313–334, pl. xxviii.

[2] Études sur les Ammonites des Étages moyens du Système jurassique.

Sonn. Buckmani, n. sp., an allied form. for which I tender my thanks—"*S. deltafalcata*, Quenstedt,"—and *Witchellia punctatissima*, n. sp.

Plate x. illustrates *S. alsatica*, Haug, now figured for the first time—a small *S. deltafalcata* which possesses connate ribs, and is thus different from those in pl. ix.—"*Witchellia complanata*" and "*W. liostraca*, Buckm.," with the specific determination of which I agree, but which I placed in my genus *Dorsetensia*—"*Witchellia regrediens*,"—"*W. Edouardiana*,"—"*W. crassicarinata*," which looks dangerously like what I should expect to be the young of my *Dorsetensia tecta*,—"*Harpoceras capillatum*, Denckmann,"—and "*H.* cf. *aalense*," an interesting species from the "*Concavum*-zone," which has ribs far too falciform for close connection with *aalensis*.

My genus *Dorsetensia* Dr. Haug has rejected: he merges it in *Witchellia*, on the ground that *Witchellia* only differs from *Dorsetensia* by the persistence, in adults, of two furrows. one each side of the carina. This difference, he contends, is not sufficient for a genus, or even for a sub-genus; but with this dictum I venture to disagree: in my opinion any one character common to several species is of generic importance, provided it be not the result of homoplasy.

I fear that a certain misunderstanding of my genus *Witchellia* is answerable for Haug's rejection of *Dorsetensia*: the author could not find "lateral tubercles" in any *Witchellia*. Now, soon after founding my genus, I wrote that some specimens showed sharp spines in the inner whorls.[1] The phrase "sharp spines" is stronger than "lateral tubercles"; and in face of this distinct assertion the author's remarks appear a little rash. The question which occurs to my mind is: Do any of the specimens which he possesses belong to my genus *Witchellia* as I should define it? On this point I think there may reasonably be some doubt; because the only species which I recognize as having any likeness to *Witchellia* is his fig. 3, pl. viii.; but this the author calls "*Sonninia*."

Dr. Haug says that my *Dorsetensia pulchra* is d'Orbigny's *Edouardiana*, and my *Edouardiana* he names afresh, "*regrediens*." I am willing to admit that, *Edouardiana* being a French species, the author ought to know more about it than I do; but, if he be correct in these statements, d'Orbigny's must be a very unfortunate drawing. My *pulchra* is practically smooth half-a-whorl sooner than the specimen shown in d'Orbigny's figure of *Edouardiana*; while, further, my *pulchra* shows in its septation the very character—a two- instead of a three-pointed superior lateral lobe—which Haug calls attention to in his *regrediens* as a distinction from *Edouardiana*.

Among the many points of interest in this work I notice one thing with satisfaction, namely, that Dr. Haug now agrees with my view as to the position of *Witchellia*:[2] he places it as "un genre voisin du genre *Sonninia*." Formerly he regarded the species now known as *Witchellia* (+*Dorsetensia*, etc.) as allied to *Grammoceras*;[3]

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[1] Descent of *Sonninia*, etc. Q.J.G.S. vol. xlv. p. 658.

[2] *Ibid.* p. 658.

[3] Beiträge Monogr. *Harpoceras*, Neues Jahrbuch für Mineral, etc. 1885. Beil-Bd. iii. p. 637.

but we have had some correspondence on this matter, and I take it as a compliment that the author can adopt my view. The change means a great deal: it signifies the removal of *Witchellia*, etc., from the family *Hildoceratidæ* into the family *Amaltheidæ*, sub-family *Sonnininæ.*

A notice of this pamphlet would not be complete without mentioning that it contains some interesting remarks about that sexual dimorphism among *Ammonites* which Prof. Munier-Chalmas has ably discussed.[1] The idea, though not novel, is certainly worthy of attention in the form it is now presented to us. I confess, however, to feeling considerable scepticism in the matter, though I have every wish to fully examine the evidence from the author's point of view, so as to do the idea full justice. MM. Munier-Chalmas and Haug evidently do not endorse the saying "*cherchez la femme*," but believe it to be necessary *cherchez le mâle*; and they think they have found him *chez les Ammonitidés.*

In concluding my remarks on this valuable contribution to Ammonite literature, I may note that the plates and many of the septal delineations are done by photography; and that on the whole the results are good.

P.S.—Since the above was written I have found that the proof-plate of *D. Edouardiana* was submitted to Dr. Haug; and that he agrees with my identification. It may be, of course, that in this matter "second thoughts" are best; I only mention it to show that I did not rely solely on my own judgment in the identification of a foreign species, but that I took the pains to get my opinion confirmed by one who is a competent authority.

REVIEWS.

I.—PALÆONTOLOGY OF NEW YORK, Vol. VIII. Part II. Fascicle II. AN INTRODUCTION TO THE STUDY OF THE GENERA OF THE PALÆOZOIC BRACHIOPODA. By JAMES HALL, assisted by JOHN M. CLARKE, Albany, New York, December, 1893. Pp. 177–317, 95 Woodcuts. (Charles Van Benthuysen & Sons.)

THIS is another and welcome instalment of Hall and Clarke's remarkable work on Brachiopoda. It treats of the earliest forms of the Rhynchonelloids, Terebratuloids and Thecidoids, and therefore concludes their valuable generic discussions upon the Palæozoic Brachiopoda.

The authors are convinced that the primitive Rhynchonelloids deviated at an early age from the same stock whence *Orthis* had been derived. They state that the earliest Rhynchonellas of which the internal structure is known are not *Rhynchonellas* in any true sense (of the type of the Jurassic *R. loxia*), "but properly connecting morphological phases between *Orthis* and *Rhynchonella*—inceptive stages of the fuller development attained in later faunas."

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[1] Munier-Chalmas. Sur la possibilité d'admettre un dimorphisme sexuel chez les Ammonitidés. Compte-rendu sommaire des Seances de la Société géologique de France, No. 14, p. 172. 1892.

The following new genera representing intermediate stages of structure are proposed for the Palæozoic Rhynchonelloids and Pentameroids:—

PROTORHYNCHA: type *Atrypa dubia*, Hall, Chazy limestone, a primitive and prolific form related to *Orthis*.

ORTHORHYNCHULA: type *Orthis Linneyi*, Nettelroth, Hudson River group, described "as a platystrophoid orthid and the closest link between the two groups."

CAMAROTŒCHIA, nom. nov., is founded on the *Rhynchonella congregata*, Conrad, from the Hamilton group.

The type, PUGNAX, sub-genus nov., is the *Conchyliolithus anomites acuminatus* of Martin, from the Carboniferous limestone. CYCLORHINA, gen. nov., type *Rhynchospira nobilis*, Hall. SYNTROPHIA, gen. nov., type *Triplesia lateralis*, Whitfield, from the Calciferous shales. PARASTROPHIA, type *Atrypa hemiplicata*, Hall, from the Hudson River group.

Linne's name *Conchidium* is restricted to plicated shells of the type of *Conchidium biloculare*=*Pentamerus conchidium* of Dalman from the Upper Silurian of Gothland. In America the species appears in the fauna of the Niagara shales. That of PENTAMERUS, Sby., is retained for smooth species without a sinus of the type of *Pentamerus lævis*. BARRANDELLA, is proposed for such Pentameroids as have the position of the median fold and sinus the reverse of those of *Rhynchonella*. CAPELLINIA is founded on a new species (*C. mira*) from the Niagara dolomites of Wisconsin which is "virtually" a reversed form of *Pentamerus oblongus*. The genus *Amphigenia* is regarded as a passage form between the Pentameroids and the Terebratuloids.

The discussion of the true Terebratuloids commences with that of the primitive type of the genus *Rensselaria*, which also unites some Pentameroid features with a brachidium resembling that of *Centronella*. "Anything more simple than the triangular loop of *Rensselaria* would be only the discrete processes of *Amphigenia* and the Rhynchonelloids."

The new sub-genus BEACHIA, based on *Rensselaria Suessana*, Hall, defines certain minor loop modifications. The names ORISKANIA, SELENELLA distinguish other variations of the Centronelloid loop. ROMINGERINA is applied to species of the *R.* (*Terebratula*) *Rominger* type, having spinulose or fimbriated loop margins. Bayle's name TRIGERIA is revived for the plicated Centronelloids like *C. Guerangeri*, de Verneuil. The Devonian genus *Cryptonella* is held to be a direct ancestor of *Magellania*. EUNELLA is the name applied to a variety with anterior apophyses broader at the base. A spinulose Cryptonelloid loop, distinguished as *Hartina*, is founded on *Centronella* (*Harttina*) *Anna*, Hartt.

The term *Cranæna* defines a Devonian variety of the Dielasmoids, somewhat intermediate in structure between *Cryptonella* and DIELASMA, and represented by *T. Romingeri*, Hall; *Cryptonella Iowensis*, Calvin, and "probably some other American species." The name of *Beecheria* compliments similiarly Dr. C. E. Beecher and is applied to a smooth variety of Waagen's genus *Hemiptychina*, type *B. Davidsoni*, sp. nov., Hall, from the Carboniferous limestone of Nova Scotia. Hall's old genus *Tropidoleptus*, 1859, maintains its position as a Terebratuloid and is now regarded "as an early representative of the important family of the *Terebratellidæ*."

The exact relations and origin of those overgrown plicated Centronelloids from Bolivia, three inches and a half long, which were named *Scaphiocœlia* by their describer, Whitfield, remain obscure, and the origin of the gigantic Stringocephalæ is still veiled in mystery. The latter, so abundantly developed in the Middle Devonian of England and Germany, have been recently discovered in the same horizon by Whiteaves in the Mackenzie River Basin of British North America.

The systematic position of the genera *Eichwaldia*, *Aulacorhynchus* the authors leave undetermined. *Lyttonia*, *Oldhamina*, and *Richthofenia* are somewhat doubtfully regarded as Palæozoic forms of the family *Thecididæ*.

Here terminate the authors' valuable generic discussions upon the Palæozoic Brachiopoda; some of the results of their critical researches have been already tabulated in Mr. Charles Schuchert's "Classification of the Brachiopoda." A final chapter on the vexed question of the classification of the genera is, however, promised by Professors Hall and Clarke, to be issued with the requisite indices to the second volume and sixty quarto plates (from xxi. to lxxxiv. inclusive), thus completing this great undertaking. Its appearance is awaited with interest as the coping-stone to a monumental work which, taken as a whole, must be regarded as the most suggestive and important production of the century concerning the general History of the Brachiopoda. It forms the natural outcome and most important manifestation of the value of the methods of the correlations of Ontogeny and Phylogeny[1] as practised by Hall, Clarke, Deslongchamps, Beecher, and the Œhlerts. It is mainly from the results obtained by these combined lines of research that we owe the enlargement of our knowledge of the evolution of the Brachiopoda—a progress too real and stable to be denied by any serious student of the recent literature of this group of organisms. To this subject we hope before long to revert.

Agnes Crane.

II.—Lower Carboniferous Crinoidea from the Hall Collection now in the American Museum of Natural History, with Illustrations of the Original Types. By R. P. Whitfield. "Memoirs of the American Museum of Natural History," Vol. I. Part I. 4to. pp. 1–37, three Plates. 1893.

THIS, the first number of a new series of Memoirs of the American Museum of Natural History, is devoted by Mr. R. P. Whitfield, Curator of Fossil Invertebrata in the Museum, to a

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[1] The most recent addition to our knowledge of this subject was a contribution by Dr. C. E. Beecher to the American Naturalist for July, 1893, entitled, "Some Correlations of Ontogeny and Phylogeny in the Brachiopoda."

republication of Prof. Hall's descriptions and diagrams of the Lower Carboniferous Crinoidea with additional comments thereon and three fine plates of the type specimens, some of which are now illustrated for the first time. The text, intercalated by numerous cuts, treats of the *Platycrinidæ, Actinocrinidæ, Cyathocrinidæ,* and a blastoid (*Orphocrinus Whitei*) from the Burlington Limestone of Iowa, Missouri, and Illinois and the Keokuk Limestone of Iowa. Mr. Whitfield follows Messrs. Wachsmuth and Springer's "Revision of the *Palæocrinidæ*" in generic nomenclature, but takes the opportunity to rectify some misapprehensions in regard to certain types chiefly arising from the fact that Prof. Hall's original descriptions, published, it should be remembered, thirty-four years ago, were not always accompanied by figures of the specimens. Some of his species have consequently been merged in genera and species of later authors. This publication is, therefore, somewhat of a reclamation of types, and will be followed by others of a similar nature giving descriptions and full illustrations from the magnificent series of invertebrate types in the Hall collection exhibited in the well-lighted galleries of the American Museum of Natural History of New York City.

A. C.

III.—THE MEAN DENSITY OF THE EARTH. AN ESSAY TO WHICH THE ADAMS PRIZE WAS ADJUDGED IN 1893 IN THE UNIVERSITY OF CAMBRIDGE. By Prof. J. H. POYNTING, D.Sc., F.R.S. Pp. i.—xix. 1–156, 7 plates. (London, 1894.)

THE subject for the Adams Prize in 1893 was "The methods of determining the absolute and relative value of gravitation and the mean density of the earth," and the essay which gained the prize is here published in accordance with the conditions of the award. Several additions have, however, been made since it was first written. A bibliography containing the titles and summaries of 45 memoirs has been prefixed. Part I., which is an account of all the experiments so far made, has been slightly enlarged. Part II. is unaltered, and is simply a reprint of the author's memoir communicated to the Royal Society in 1891, in which he describes his own determination made by means of the common balance.

In the historical discussion the geologist will find much to interest him. The accounts are full but concise, and in each case end with criticisms, which derive much of their value from being so often the results of the author's own experience. The experiments naturally fall into two classes: (1) those in which the attracting mass is a portion of the earth's crust; and (2) those which are carried on in the laboratory, the attracting mass being small, easily handled, and of more uniform density. With regard to the first class of experiments, the author concludes that "our knowledge of the distribution of the terrestrial matter is not yet sufficiently exact to enable us to obtain good values of the mean density of the earth from the observed attraction of terrestrial masses. Rather must we assume the mean density from laboratory experiments, and use the observations of terrestrial attractions for the converse problem of determining the distribution of terrestrial mass." The whole part abounds with passages such as this, which, condensed as sentences from Bacon's Essays, might form chapter headings for many a work to come. It closes with the following "summary of results hitherto obtained:"—

Approximate Date.	Experimenter.	Method.	Result.
1737–40	Bouguer...	Plumb-line and Pendulum	Inconclusive
1774–76	Maskelyne and Hutton	Plumb-line	4·5 to 5
1855	James and Clarke... ...	,,	5·316
1821	Carlini	Mountain Pendulum ...	4·39 to 4·95
1880	Mendenhall	,,	5·77
1854	Airy	Mine Pendulum	6·565
1883	von Sterneck...	,,	5·77
1885	von Sterneck...	,,	about 7
1797–8	Cavendish	Torsion Balance	5·448
1837	Reich	,,	5·49
1840–1	Baily	,,	5·674
1852	Reich	,,	5·583
1870–	Cornu and Baille	,,	5·56—5·50
1889	Boys	,,	in progress
1879–80	von Jolly	Common Balance	5·692
1878–90	Poynting	,,	5·493
1884–	König, Richarz and Krigar Menzel	,,	in progress
1886–8	Uilsing	Pendulum Balance	5·579
1889	Laska	,,	in progress

With Part II. begins the more strictly original half of the essay, "A determination of the mean density of the earth and the gravitation constant by means of the common balance."

The principle of the method is as follows: Two equal masses *A* and *B*, are suspended one from each end of the beam of a very delicate balance. A large sphere *M* is brought first under the mass *A*, and then under the mass *B*. Its attraction being removed from *A* and added to *B*, it follows that the beam turns through nearly double the angle due simply to the attraction of *M* on one mass alone. Of course when *M* is under *A* it will at the same time attract *B*, and when under *B* it will attract *A*, and these cross-attractions must be taken into account. So also would the attraction of *M* on the balance-beam and suspending-wires have to be allowed for; but this operation (most difficult on account of their irregular shape) is avoided by repeating the experiment after raising the masses *A* and *B* through known equal distances, without altering the length or form of the suspending wires. It is evident that the attraction of *M* on the beam and wires is the same in both experiments, and the change in the attraction is therefore due only to the change in the distances of *A* and *B* from *M*. From this change in attraction, the attraction at any distance can be found.

The balance, whose beam is a little over 4 feet long, was erected in a cellar at the Mason College, Birmingham, its foundation having no connection with the brick floor of the cellar. The turn-table, on which the attracting mass *M* rests, has also an isolated foundation separate from the former. The masses *A* and *B* each weigh about 47½ lbs. and the mass *M* about 338 lbs., all three being composed of an alloy of lead and antimony of specific gravity 10·4. The distance between the centres of *M* and *A* or *B* is about 12½ inches in the lower position of the latter, and about 24½ inches in their higher position.

To magnify the tilting of the balance, a double-suspension mirror was used, similar to that employed by Messrs. G. H. and H. Darwin in their experiments on the lunar disturbance of gravity. The mirror is suspended by two eye-holes on a fine silk thread, one end of which is attached to a small bracket projecting from the lower end of the pointer of the balance, the other to a fixed bracket close to the former, so that the plane of the mirror is perpendicular to that of the balance. The distance between the points of support of the silk thread being $\frac{4}{25}$ of an inch, and the length of the balance-pointer 2 feet, it follows that the mirror turns through an angle 150 times as great as the balance-beam.

In the room over the cellar and close to a hole in the floor are the telescope, provided with cross-wires, and a scale illuminated by a lamp. The light from the scale is reflected by an inclined mirror in the cellar so as to meet the double-suspension mirror horizontally, is reflected by it and by the inclined mirror again, and returns to the telescope. If the balance-beam turns through a very small angle, the image of the scale seen in the telescope is shifted over the cross-wires. Two small riders, each weighing one centigramme, are arranged so that their points of support are on the balance-beam at a distance of one inch on either side of the knife-edge. One being raised from the beam, the other is lowered on to it, and the number of divisions of the scale corresponding to the deflection of the beam so produced is compared with the number of divisions corresponding to the deflection produced by the attraction of *M* being taken away from *A* and added to *B*. This ratio gives the increase in the weight of *A* or *B* due to the attraction of *M* when vertically below it.

It will be unnecessary here to enter further into the details of the experiment, or to describe the numerous precautions taken to ensure accuracy. The chief disadvantage of the method is that "the disturbances due to air-currents are greatest in the vertical direction, that of the displacement to be measured," and the larger the apparatus the greater are the errors produced by them. If the experiment were to be repeated, the author would make the apparatus small, for it could then be kept at a more uniform temperature and it would be more handy to adjust. "At the same time," he concludes in his characteristic manner, "it is only fair to say, on behalf of the large apparatus, that some errors have been magnified on a like scale till they have become observable, and so could be investigated and eliminated. Starting with a small apparatus they would probably never have been detected, and would, therefore, have appeared in the final result."

The value obtained for the mean density of the earth is 5·4934, and will now no doubt take its place as the standard value. Sooner or later, perhaps, unsuspected sources of error may be pointed out, methods of greater refinement may be discovered, and the result just quoted may be superseded by others more reliable. For the present, one more "magnificent experimenter" has given the thought of years to a problem that lies just within our grasp, and we may well rest content with a work which is one of the best examples we have of the fine patience that ennobles science.

C. DAVISON.

IV.—THE SEISMOLOGICAL JOURNAL OF JAPAN, Vol. II. 1893 (corresponding to vol. xviii. of the Transactions of the Seismological Society of Japan): Edited by Prof. J. Milne, F.R.S.

(1) J. Conder. An architect's notes on the great earthquake of October, 1891: pp. 1–91.
(2) J. Milne. Abstract of a report [on the earthquakes and volcanic phenomena of Japan] to the British Association: pp. 93–109.
(3) E. von Rebeur-Paschwitz. On the observations of earthquake-waves at great distances from the origin, with special relation to the great earthquake of Kumamoto, July 28th, 1889: pp. 111–114.
(4) P. Mayet. On the five mile water-level: pp. 115–117.
(5) F. Omori. On the overturning of columns: pp. 119–122.

The first and last papers of this invaluable Journal are chiefly interesting to architects in earthquake countries. Prof. Milne gives an abstract of his last report to the British Association, the full text of which will probably be published and readily accessible before this notice appears. Dr. Mayet advocates the construction of the long water-level suggested by Prof. Milne in the first volume of the Journal, but the latter adds a note in which he prefers the erection of horizontal pendulums at what would be the terminal stations of the level.

In a short paper Dr. von Rebeur-Paschwitz introduces a subject of great importance. The severe earthquake of Kumamoto (Japan) occurred on July 28, 1889, at 11.40 p.m., Tokio time, or 2h. 20·9m., Greenwich time. At about 2·28 p.m. (G.M.T.) horizontal pendulums at Potsdam and Wilhelmshaven, in Germany, showed perturbations of moderate size and duration, and others, again, somewhat similar in character, at 6·6 p.m. Supposing the disturbance to have spread out from Kumamoto and travelled in opposite directions round a great circle of the earth to a point midway between Potsdam and Wilhelmshaven in the times recorded, the average velocities in the two directions must have been 2·2 and 2·3 kilometres per second respectively. The hypothesis thus agrees with the observed phenomena, but "we will have to depend on future observations to remove the last doubt about the possibility of earthquake movement being observable at enormous distances."—C. D.

V.—PROCEEDINGS OF THE COTTESWOLD NATURALISTS' FIELD CLUB FOR 1892–1893. Vol. XI. Part I. 1893.

THIS Part contains the address of the retiring president, Mr. W. C. Lucy, who gives an account of the work of the session, and of the excursions made to Woolhope, Bath, Cleeve Hill, and Newent. He refers in particular to the Drifts of the Cotteswold area, and also gives a section of the Coalfield near Newent.

There is, in addition, an elaborate paper by Mr. Etheridge "On the Rivers of the Cotteswold Hills within the Watershed of the Thames and their importance as supply to the main river and the Metropolis." This paper gives in detail much of the information brought before the late Royal Commission on Water Supply by Mr. Etheridge.

VI.—HANDBOOK TO THE COLLECTION OF BRITISH POTTERY AND PORCELAIN IN THE MUSEUM OF PRACTICAL GEOLOGY. 8vo. pp. 178, with 132 Illustrations. London: Printed for Her Majesty's Stationery Office. Price 1s.

A NEW edition of the Catalogue of the Pottery and Porcelain in the Jermyn Street Museum has long been wanted. The Third Edition, by Trenham Reeks and F. W. Rudler, was published in 1876. The present work, which has been prepared by Mr. Rudler, is arranged so as to form a Handbook rather than a Catalogue. Thus the matter is arranged throughout in a readable form, with references only to particular specimens, instead of containing descriptions of all the objects on exhibition. The work is brought up to date by additional information, and thus forms an authoritative guide to the student.

REPORTS AND PROCEEDINGS.

GEOLOGICAL SOCIETY OF LONDON.

I.—February 7th, 1894.—W. H. Hudleston, Esq., M.A., F.R.S., President, in the Chair. The following communications were read:

1. "On some cases of the Conversion of Compact Greenstones into Schists." By Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.

By the path leading from the Bernina Hospice to the Grüm Alp (Engadine) some masses of compact green schist are seen, intercalated in a rather crushed gneiss. They prove to be intrusive dykes modified by pressure. Microscopic examination of specimens from these reveals no trace of any definite structure indicating an igneous rock; a slice, cut from one of the masses within an inch or so of a junction, shows it to be a foliated mass of minute chlorite or hydrous biotite, with granules of epidote (or possibly some sphene) and of a water-clear mineral, perhaps a secondary felspar. An actual junction shows a less distinct foliation and some approach to a streaky structure. A slide from the middle of another dyke (about 18 inches thick) exhibits a more coarsely foliated structure and minerals generally similar to the last, except that it may contain a little actinolite and granules of hæmatite (?), and the clear mineral, in some cases, seems to be quartz. The structure and most of the minerals appear to be secondary. Chemical analysis shows the rock to have been an andesite. A specimen from a third dyke is generally similar, but is rather less distinctly foliated.

A somewhat similar, but rather larger intrusive, mass by the side of the Lago Bianco shows more actinolite and signs of primary felspar, with other minerals. Here the rock retains some likeness to a diabase. The resemblance of certain of these rocks to somewhat altered sediments is remarkable. The author considers the bearing of this evidence upon other and larger masses of "green schist" which occur in the Alps, and expresses the opinion that their present mineral structure may be the result of great pressure acting on more or less basic igneous rocks.

2. "The Waldensian Gneisses and their Place in the Cottian Sequence." By J. Walter Gregory, D.Sc., F.G.S.

The lower part of the sequence of the Cottian Alps has been universally divided into three series, of which the lowest has been regarded as a fundamental (basal) Laurentian gneiss. It is the object of the present paper to show that this rock is really intrusive in character and Upper Tertiary in age. The writer endeavours to show this by the following line of argument:—(1) The gneiss consists of only isolated outcrops instead of a continuous band, and these occur at different positions and not always at the base of the schist series; (2) the gneiss is intrusive, because: (*a*) it includes fragments of the overlying series instead of *vice versâ*, (*b*) it sends off dykes of aplite into the surrounding schists, (*c*) it metamorphoses the rocks with which it is in contact, and (*d*) the schists are contorted near the junction; (3) the gneisses are further shown to be later than the igneous rocks intrusive into the "pietre verdi" series, as these never traverse the gneiss.

No positive opinion as to the age of the overlying schists is expressed in the paper, though it is pointed out that the recent discovery of radiolarian muds in the series may necessitate their inclusion in the Upper Palæozoic. The freshness of the gneisses, the fact that these have not been affected by the early Tertiary earth-movements, and the absence of authentic specimens of the gneiss in the Cretaceous, Eocene, and Miocene conglomerate, renders their late Tertiary age highly probable.

The nature of the contact-metamorphism and the origin of the gneissic structure are discussed, and a classification offered of the earth-movements in the Cottian Alps.

II.—Annual General Meeting.—February 16th, 1894.—W. H. Hudlestone, Esq., M.A., F.R.S., President, in the Chair.

The Secretaries read the Reports of the Council and of the Library and Museum Committee for the year 1893. In the former the Council congratulated the Fellows on the prosperous condition of the Society's finances, drawing at the same time attention to the continued decrease in the number of Fellows.

The number of Fellows elected during the year was 42; of these 33 qualified before the end of 1893, making, with 6 previously elected Fellows, a total accession of 39 in the course of the twelvemonth. During the same period the losses by death, resignation, and removal amounted to 85, the actual decrease in the number of Contributing Fellows being 24. The total number of Fellows, Foreign Members, and Foreign Correspondents at the close of 1893 was 1353, as compared with 1400 on December 31st, 1892, and 1418 on December 31st, 1891.

The Balance-sheet for the year 1893 showed receipts to the amount of £2750 18*s*. 10*d*. and an expenditure of £2204 17*s*. 6*d*. Moreover, the sum of £502 15*s*. 3*d*. was expended in the Purchase of Stock, and the balance in favour of the Society on December 31st, 1893, amounted to £371 5*s*. 11*d*. The invested Funds of the Society have now reached the sum of £10,729 11*s*., and the Council state that they feel the time has now arrived when the question of safeguarding by investment the interests of Compounders may be re-opened.

The Report of the Council further referred to the completion of vol. xlix. of the Quarterly Journal, and in conclusion announced the awards of various Medals and proceeds of Donation Funds in the gift of the Society.

The Report of the Library and Museum Committee enumerated the additions made during the past year to the Society's Library, announced the completion of several sets of serials formerly imperfect, and referred especially to the large accession of British Geological Survey maps and memoirs. The Report further recorded the continuation of the work of registering the type and other specimens in the Museum by Mr. C. Davies Sherborn, F.G.S.

In handing the Wollaston Medal (awarded to Geheimrath Professor Karl Alfred von Zittel, For.Memb.G.S.) to Dr. Woodward, F.R.S., for transmission to the recipient, the PRESIDENT addressed him as follows:—Dr. Woodward,—

The Council of the Geological Society have this year awarded the Wollaston Medal to Geheimrath Dr. Karl Alfred von Zittel, Professor of Geology and Palæontology in the University of Munich, in recognition of the important services which he has rendered to palæontological science during a long period of time. Without alluding in detail to his early work on Austrian geology, much of which was published at Vienna, I wish to point out that, as Oppel's successor at Munich, he has continued to advance our knowledge of the Mesozoic fauna of Central Europe, and more especially of the interesting passage-beds betwixt the Jurassic and the Cretaceous; whilst the memoirs which he has published on these subjects derive additional value from their excellent illustrations.

Twenty years have now elapsed since K. A. von Kittel joined the expedition of Gerhard Rohlfs to the Lybian Desert, and his contributions to the geology of that region are probably the most important that have as yet appeared in relation to Egypt and the adjacent countries. It was on his return from this expedition that he commenced his *magnum opus*, 'The Handbook of Palæontology,' the first part of which was published in 1876 and the last part, relating to the Mammalia, in 1893, thus occupying an interval of 17 years' continuous labour. If proof were needed of the thoroughness of his work, we obtain it in his treatment of the fossil sponges, which he found in so chaotic a state that he applied himself to working out their relations independently, and, having discovered the key in the microscopic structure of their skeletons, was thus enabled to establish a system of classification which has been found equally applicable to recent forms.

It is scarcely necessary to remind you that our Wollaston Medallist has occupied the Chair of Palæontology at Munich for 28 years, during which time he has not only perfected the collections at the museum, but his personal teaching has attracted to his lectures students from almost all parts of the civilized world. I feel confident, therefore, that the selection of the Council will be cordially endorsed both by the Fellows of our own Society and by all, whether at home or abroad, who are interested in the brilliant record of one of the foremost palæontologists of the age.

Dr. WOODWARD, in reply, said:—Mr. President,—

I feel sure that no award of the Wollaston Medal made by the Council of this Society has ever been more popular than that made to Geheimrath K. A. von Zittel, and I only regret that his duties as Dean of the Faculty in his University, and his daily lectures, have prevented him from being present to receive the Medal in person. I shall, however, be happy to convey to him your kind expressions of appreciation for this work; and I beg permission to read to you, from a letter which I have received, the following message addressed to yourself:—

"With respectful thanks I acknowledge the unexpected honour with which the Council of the Geological Society has favoured me, in awarding to me the Wollaston Medal. I need scarcely say how highly I appreciate this distinction, conferred upon me by the most competent of scientific juries. I am really proud to have reached this highest aim for the ambition of every geologist, and I feel particularly pleased to find among the late and present possessors of the Wollaston Medal the name of H. G. Bronn, my first teacher in palæontology, and of Franz von Hauer, who directed my first steps in geological field observation.

"If, through conscientious labour, I have been fortunate enough to contribute somewhat to the promotion of our knowledge of Palæontology and Geology, I feel by your kindly recognition amply rewarded for all the pains that I may have taken in my scientific researches.

"I deeply regret that I am unable to thank you personally, Mr. President; but you may be sure that the honour you have bestowed on me will be a strong incentive to make myself more worthy of your confidence by further investigations in the wide field of Palæontology and Geology."

The PRESIDENT then presented the Balance of the Proceeds of the Wollaston Donation Fund to Mr. Aubrey Strahan, M.A., F.G.S., addressing him in the following words:—Mr. Strahan,—

The Council have this year awarded to you the balance of the Proceeds of the Wollaston Donation Fund, in token of appreciation of your geological work in several parts of England and on the Welsh Border. In solid geology you have especially distinguished yourself amongst the Carboniferous rocks of the Pennine Chain and of North Wales, whilst your contributions to our own Journal, on more than one subject in connection with the Mesozoic rocks, have evinced the interest that you take in questions arising within your own professional experience. The Glacial Drifts of the Welsh Border and the Glaciation of South Lancashire have also come under your notice in dealing with the difficult subject of Superficial Deposits. Beyond any mere assistance which the Balance of the Fund might render towards further research, the Council, by this Award, desire to express their sense of the value of the work which you have already accomplished.

Mr. STRAHAN replied as follows:—Mr. President,—

In thanking you and the Council of the Geological Society for this Award, I wish to express my deep gratification at being honoured by your selection.

During my connection with the Geological Survey I have, from the nature of the work, been engaged in so many different parts of the country that I have been unable to concentrate my attention on any one formation as closely as might have been the case, and have been led to consider some of the wider problems of geology. I trust, however, that my work has not been without service to those engaged upon the more minute zonal divisions of strata.

In every district in which I have been occupied, geologists with local knowledge have generously placed their observations at my disposal. The only return I could make lay in producing the results of my work as expeditiously and in as useful a form as possible. I take this Award as an indication that I have not been wholly unsuccessful.

In presenting the Murchison Medal to Mr. William Talbot Aveline, F.G.S., the President addressed him as follows:—Mr. Aveline,—

The Council have this year awarded to you the Murchison Medal, together with a sum of Ten Guineas, in recognition of the importance of your work as a geological surveyor. Nearly half a century has elapsed since your first communication to this Society, in conjunction with the late Sir Andrew Ramsay, on the structure of portions of Wales. Later on, we find you engaged in mapping and describing some of the Mesozoic Rocks of Central England, and it is now rather more than thirty years since you commenced your work on the Permian and Carboniferous of Nottinghamshire and Derbyshire. Still more recently you were engaged, as district surveyor, on the borders of the Lake Country, being associated with Prof. Hughes, Mr. Tiddeman, and other well-known geologists. That your supervision of the work then progressing has yielded excellent results in relation to the survey of that difficult region is a matter of notoriety.

Although it is some time since you retired from active employment I feel sure that you will be gratified to find that the record of former years is not overlooked by a generation of geologists who recognize the value of the work in which you had so large a share.

Mr. Aveline, in reply, said:—Mr. President,—

It is with feelings of great gratification I receive this Medal, founded by my former chief, Sir Roderick Murchison, whose friendship and kindness I experienced during the time he was Director-General of the Geological Survey, and in whose company I made some very pleasant geological explorations.

I am very much pleased to think that my work on the Geological Survey has been appreciated by the Council of this Society, and that they should have thought me worthy of receiving this Medal.

Mr. President, I cannot let this opportunity pass without saying a word as to another Director-General of the Geological Survey, the distinguished successor of Sir Roderick Murchison – Sir Andrew Ramsay, who for over forty years was a sincere friend of mine, and to whom I owe so much for his ready assistance and advice when he was Director of the Geological Survey; we have together worked out many a knotty point in the geology of Wales and elsewhere, tramping together many a mile of mountain and valley. I am sure, if he were living now, he would have rejoiced at the honour this day conferred on me.

I must add that among the most pleasing results of receiving this Medal are the kind congratulations which I have received from my old colleagues.

The President then handed the Balance of the Proceeds of the Murchison Geological Fund to Mr. George Barrow, F.G.S., addressing him as follows:—Mr. Barrow,—

The Balance of the Proceeds of the Murchison Geological Fund has been awarded to you by the Council as a testimony of the value of your geological work both in Yorkshire and in Scotland. As regards the former district, I would draw especial attention to your description of the geology of North Cleveland. Since your transfer to the Survey of the South-East Highlands you have evinced a remarkable aptitude for petrological studies, whilst your recent paper in the "Quarterly Journal" on the Muscovite-biotite-Gniess of Glen Clova bids fair to rank high in that category. The Council hope that this mark of appreciation may not only aid but encourage you to further research in the same direction.

Mr. Barrow replied in the following words:—Mr. President,—

I beg to thank the Council for the unexpected honour that they have done me in conferring this Award. In receiving it at your hands, Sir, pleasant memories are revived of my early geological days in East Yorkshire, when your writings were of much assistance to me. In those happy times we had no difficulty in deciding which way up the succession lay. But now, in working on the Highland Series it is often difficult, if not impossible, to decide this very elementary point, and any kindly encouragement in such work is most welcome. It is the more welcome as in this case it is a recognition that my efforts so far are not entirely without value.

In handing the Lyell Medal (awarded to Prof. John Milne, F.R.S.) to Prof. J. W. Judd, F.R.S., V.P.G.S., for transmission to the recipient, the President addressed him as follows:—Professor Judd,—

The Lyell Medal, with the sum of Forty-Six Pounds, has been awarded to Prof. John Milne, F.R.S., of the Imperial College of Engineering, Tokio, Japan, in testimony of appreciation of his investigations in Seismology. It must ever be regarded as a fortunate event, in the interests of science, when Prof. Milne went to reside in Japan. Undoubtedly his opportunities in that oscillating region have been great, but he has been fully equal to the occasion, and may with justice be regarded as the founder of seismic science in that country. His efforts in this direction are in part recorded in the annual volumes of the Seismological Society of Japan, to which he has always been one of the most important contributors. Stimulated no doubt by this good example, the Government of Japan has taken up the study of earthquakes by establishing some 700 stations for observations, so that, to use Prof. Milne's own words, "phenomena, which were formerly matters of hypothesis, are now no longer unexplained."

It is indeed the eminently practical turn given by Prof. Milne to the study of earthquakes which commends his work so effectually to geologists; and ever since his seismic experiments, in conjunction with Mr. Gray, and the reports published by the British Association on the investigation of the Earthquake Phenomena of Japan, Prof. Milne has been recognized as one of the leading authorities in this branch of science. Bearing in view, also, the delicate and costly nature of seismological apparatus, the Council feel justified in awarding a considerable sum of money, out of the Fund, to accompany this Medal.

Prof. Judd, in reply, said:—Mr. President,—

Although I rise at short notice, it is with extreme satisfaction that I receive at your hands this Award to Prof. Milne. It was my good fortune to be acquainted with the recipient of this Medal and Fund before he left this country for Japan; and during his long residence in that distant land I have had the privilege of frequent correspondence with him. The cheerful courage with which he has faced unpromising surroundings, the resourceful tact with which he has met every difficulty, and the unconquerable energy with which he has surmounted the greatest obstacles, are known to all of us. You, Sir, have referred to the admirable work done by the Seismological Society of Japan, and it is not too much to say that during a long period Professor Milne might have justly asserted "I am the Seismological Society." The foundation of that Society and the Seismological Magazine are due to the wise foresight and the unflagging energy of Prof. Milne himself, and to the efforts of the pupils whom he has instructed, and whose enthusiasm he has fired. I feel assured that the Fund which you have asked me to place in his hands will be administered in the best interests of Geological Science. It was my good fortune to know, very intimately, the founder of this Medal and Fund, and I am persuaded that the Council of this Society never more truly fulfilled his wishes and never more fully conformed to the terms of his bequest—both in their letter and spirit—than when they decided to make this Award to Prof. John Milne.

The President then presented the Balance of the Proceeds of the Lyell Geological Fund to Mr. William Hill, F.G.S., and addressed him in the following words:—Mr. William Hill,—

The Balance of the Proceeds of the Lyell Geological Fund has been awarded to you in testimony of the value of your work amongst the Cretaceous rocks of this country during the last eight years. In collaboration with Mr. Jukes-Browne, you have made communications to this Society on the Upper Cretaceous strata of East Anglia, which are recognized as being of the highest importance. Similar investigations, moreover, were prosecuted by yourself alone with equal success in Lincolnshire and Yorkshire. Your intimate acquaintance with the lithological characters of the various members of the series has materially aided your stratigraphical and palæontological knowledge in arriving at correct results. It is hoped that this acknowledgment of your services to geological science may encourage you to continue your researches.

Mr. Hill replied as follows:—Mr. President,—

I desire to convey my heartiest thanks to the Council of this Society for the Award which you have just placed in my hands. My geological work has been undertaken chiefly to fill my spare time, and I feel my reward ample in the pleasure which geological study has given me, and in the kindly reception of my papers at the hands of this Society. The unexpected honour you confer is to me more gratifying than I can well express.

You have spoken of the value of my work, but I must not forget that this is much enhanced by the help which I have received from many Fellows of the Society, and especially from one who is not often with us. I take this opportunity of thanking them most heartily. I need hardly say, Sir, that the Award will stimulate me to further efforts in the cause of Geological Science.

In handing a portion of the Proceeds of the Barlow-Jameson Fund to Mr. Charles Davison, M.A., the President addressed him as follows:—Mr. Davison,—

A sum of Twenty-five Pounds from the Proceeds of the Barlow and Jameson Fund has been awarded to you in token of appreciation of your work in geological dynamics—including under that term the study of earthquakes. In this connection I would more especially allude to your valuable notice of the Inverness earthquakes of 1890, wherein your conclusions with reference to the Great Glen of Scotland open out views of the utmost importance in relation to the Highland faults. We are also indebted to you for calculations on the movement of scree-material, based on the expansion of the stones through heat.

Geologists, I may say, are always glad to receive assistance from mathematicians, and it is to be hoped that this acknowledgement on the part of the Council of the value of your work may have the effect of stimulating you to further study in that direction.

Mr. Davison, in reply, said:—Mr. President,—

If anything could add to the welcome and gratifying character of this Award, it would be the words of kindness and encouragement that have accompanied it. For both I beg to tender my sincere and hearty thanks. I have been told, Sir, and in my own case I feel sure that it must be so, that the Council in awarding these Funds look not so much to the past as to the future. I wish I could do more than assure the Council that my best efforts will be used to prevent their kindly hopes from being disappointed.

The President then proceeded to read his Anniversary Address, in which he first gave Obituary Notices of several Fellows and Foreign Members and Correspondents deceased since the last Annual Meeting, including Prof. John Tyndall, Prof. Charles Pritchard, Mr. Thos. Hawksley, Mr. James W. Davis, Mr. Edward Charlesworth (elected in 1835), the Rev. Leonard Blomefield (elected in 1835), the Rev. W. H. Crosskey, Mr. H. M. Becher, Count Alexander von Keyserling (deceased 1891), Prof. Juan Vilanova y Piera, Prof. K. A. Lossen, Herr Dionys Stur, and Prof. Pierre J. Van Beneden. The other portion of the Address may be summarized as follows:—

In continuation of the subject of the preceding Anniversary Address, relating to some recent work of the Geological Society, the remaining portion of the paper contributed within the septennial limits is classified under two groups. In the first group are placed papers descriptive of the Newer Palæozoic Rocks, the Older Palæozoic Rocks, and the Fundamental Rocks, and on General Petrology, which relate more especially to the geology of the British Isles. This group is considered in detail, and constitutes the bulk of the Address.

In the second group are placed numerous papers which may roughly be classified under the following headings:—*Miscellaneous Geology, Foreign and Colonial*—a somewhat exhaustive division, comprising about a score of papers, dealing with many subjects in different parts of the world. African geology, especially, comes to the front in this group. *Miscellaneous Invertebrate Palæontology*—a score of papers may be thus classified. Most of these matters are for the consideration of specialists, relating to corals, crinoidea, bryozoa, ostracoda, cephalopoda, and to siliceous organisms. In *Palæobotany* there has only been one paper of any importance; whilst under the heading *Dynamical Problems* are a few papers dealing with the movement of material. A notice of the Inverness earthquake, and a communication on the origin of the basins of the Great Lakes of America complete this category.

The detailed consideration of the first group commences with the Newer Palæozoic Rocks. The Carboniferous system has not yielded any important stratigraphical papers of late years. but there have been some interesting communications respecting the Coal-measures. Questions as to the origin and faunal character of these are discussed by more than one writer, and very important deductions as to the delimitation of the marine and fresh-water beds have been drawn. The subject of Coal in the South-east of England was considered, *à propos* of a paper read at the Society some years ago, and the prospects of coal-getting at Dover and elsewhere in this part of England discussed. In Devonian geology, the structure and peculiarities of the South Devon Limestones form the subject of an interesting communication; and there are also important stratigraphical papers in this connection, more especially one written subsequent to the visit of a party from the International Geological Congress of London.

In the Older Palæozoic Rocks a considerable amount of work has been done, more especially amongst the Silurian and Ordovician of the North-west of England, where additional evidence has been furnished of the value of Graptolite-zones as a means of comparison with the Older Palæozoics of distant areas; and a further contribution has also been made to our knowledge of beds of this age in the Cross-Fell inlier. The papers dealing with the fossiliferous Cambrian are not numerous, but they are of great importance, including the recognition of a very low Cambrian fauna at the top of the Penrhyn quarries, and Sir J. W. Dawson's correlation of American with European Cambrians. The discovery of *Olenellus* in the "fucoid beds" of the North-west Highlands also serves to fix the Cambrian age of the Durness Limestone, to which formation the Altered Limestone of Strath in Skye, at one time regarded as of Liassic age, is now held to belong. The physical relations and the post-Cambrian metamorphism of the rocks of the North-west Highlands are also considered under this heading.

The Fundamental Rocks are roughly divided into three categories, viz.: the sedimentary series, the volcanics, and the crystalline schists. The first includes the Torridon Sandstone, the Longmynd rocks, the unfossiliferous Cambrians of Wales, etc. The volcanic series has already formed part of the subject of an Address from the Chair. Oddly enough, the best defined pre-Cambrian, or fundamental sedimentary series, is to be found in the North-west Highlands, a district which only a few years ago was an enigma, but which we hope may now supply a clue to regions more obscure. This, of course, is the Torridon Sandstone, which has a well-defined base and a well-defined summit. Then there are certain rocks which some regard as Cambrian, others as pre-Cambrian, such as the Howth Hill and Bray Head beds, claimed as Upper Monian. Crossing St. George's Channel, we find ourselves in Anglesey, a land of pre-Cambrian mysteries. The older rocks have been described as belonging to the Monian system, an arrangement much controverted, and this controversy has extended to Shropshire. Lastly, there is the long-standing contention as to whether the unfossiliferous Cambrians of North Wales really belong to that system or should be placed on a lower horizon. The Malvernian controversy relates, in the main, to the crystalline schists.

Under the heading of General Petrology is grouped a very large series of papers, more than sixty in number, divided roughly into two primary classes, according as they relate to the British Isles or to foreign countries, the former class being alone considered in detail. The arrangement is topographical, and the rocks under this heading may be of any age from the Archæan upwards. Scotland has yielded seven papers in this group—most of them of very great interest and importance, one or two being somewhat controversial. The subject of contact-metamorphism is raised with reference to more than one Scotch locality; and from the Lake District there has been a communication on the Shap Granite and associated igneous and metamorphic rocks, which again brings this question into prominence. Some of the papers relating to Wales have already been dealt with in a previous Address, but the subjects of the Variolite and also of the Nodular Felstones of the Lleyn are noticed on the present occasion. In Devonshire the rocks formerly known as "felspathic traps" have been described as basalts and andesites; whilst the igneous origin of the Dartmoor Granite has been maintained against one of those theories which from time to time crop up with respect to this well-known *massif*. Allusion is also made to the controversy with respect to the Start rocks. There have been four papers dealing with the Lizard peninsula, in which questions as to priority of the several igneous masses and as to the origin of the banded gneisses are entertained. It cannot be doubted that considerable progress has been made of late towards a recognition of the true character of these rocks, which, for the extent of territory they occupy, are perhaps without equal in point of interest throughout the British Isles. The Address concludes with a notice of the rocks of Brittany and the Channel Isles, which have attracted the attention of more than one author.

The Ballot for the Council and Officers was taken, and the following were duly elected for the ensuing year:—*Council*: H. Bauerman, Esq.; W. T. Blanford, LL.D., F.R.S.; Sir John Evans, K.C.B., D.C.L., LL.D., F.R.S.; Prof. A. H. Green, M.A., F.R.S.; J. W. Gregory, D.Sc.; Alfred Harker, Esq., M.A.; G. J. Hinde, Ph.D.; T. V. Holmes, Esq.; W. H. Hudleston, Esq., M.A., F.R.S.; J. W. Hulke, Esq., F.R.S.; Prof. J. W. Judd, F.R.S.; Prof. C. Lapworth, LL.D., F.R.S.; R. Lydekker, Esq., B.A.; Lieut.-General C. A. McMahon; J. E. Marr, Esq., M.A., F.R.S.; H. W. Monckton, Esq., F.L.S.; Clement Reid, Esq., F.L.S.; F. Rutley, Esq.; J. J. H. Teall, Esq., M.A., F.R.S.; Prof. T. Wiltshire, M.A., F.L.S.; Rev. H. H. Winwood, M.A.; Henry Woodward, LL.D., F.R.S.; H. B. Woodward, Esq.

Officers:—*President*: Henry Woodward, LL.D., F.R.S.; *Vice-Presidents*: Prof. A. H. Green, M.A., F.R.S.; G. J. Hinde, Ph.D.; Prof. J. W. Judd, F.R.S.; R. Lydekker, Esq., B.A. *Secretaries*: J. E. Marr, Esq., M.A., F.R.S.; J. J. H. Teall, Esq., M.A., F.R.S. *Foreign Secretary*: J. W. Hulke, Esq., F.R.S. *Treasurer*: Prof. T. Wiltshire, M.A., F.L.S.

III.—February 21st, 1894.—Dr. Henry Woodward, F.R.S., President, in the Chair. The President announced that the Sixth Session of the International Geological Congress will be held at Zürich from August 29th to September 2nd, 1894. The meetings are to be divided into three sections:—

1st. General Geology, etc.
2nd. Stratigraphy and Palæontology.
3rd. Mineralogy and Petrography.

Geologists having papers to present at the meetings are requested to notify the same to the Committee, and to send a short abstract of the subject with which they propose to deal. The Circular is suspended on the Notice-Board at the Apartments of the Society for the convenience of those Fellows who may desire further information.

The following communications were read:—1. "On the Relations of the Basic and Acid Rocks of the Tertiary Volcanic Series of the Inner Hebrides." By Sir Archibald Geikie, D.Sc., LL.D., F.R.S., F.G.S.

After an introductory sketch of his connection with the investigation of the Tertiary volcanic rocks of Britain, the author proceeds to describe the structure of the ground at the head of Glen Sligachan, Skye, which has recently been cited by Prof. Judd as affording inclusions of Tertiary granite in the gabbro, and as thus demonstrating that the latter is the younger rock. He first shows that the gabbro, instead of being one eruptive mass, consists of numerous thin beds and sills of different varieties of gabbro, some of which were injected into the others. These various sheets, often admirably banded, can be seen to be truncated by the line of junction with the great granophyre-tract of Glen Sligachan. A large mass of coarse agglomerate is likewise cut off along the same line. These structures are entirely opposed to the idea of the gabbro being an eruptive mass which has broken through the granophyre. They can only be accounted for, either by a fault which has brought the two rocks together, or by the acid rock having disrupted the basic. But there is ample evidence that no fault occurs at the boundary-line.

The granophyre becomes fine-grained, felsitic, and spherulitic along its margin, where it abuts against the complex mass of basic rocks. These structures continue altogether independent of the varying distribution of the gabbros, and are seen even where the granophyre runs along the side of the agglomerate. Similar structures are of common occurrence along the margins of the granophyre-bosses and sills of the Inner Hebrides, being found, not only next the gabbro, but next the Jurassic sandstones and shales. They are familiar phenomena of contact in all parts of the world, and are sufficient of themselves to show that the granophyre of Skye must be later than the gabbro.

The author then describes three conspicuous dykes, from eight to ten feet broad, which can be seen proceeding from the main body of granophyre and cutting across the banded gabbros. One of these is traceable for more than 800 feet in a nearly straight line. The material composing these dykes is identical with that constituting the marginal portion of the granophyre-mass. It presents the most exquisite flow-structure, with abundant rows of spherulites. The author exhibited a photograph of one of the dykes ascending vertically through the gabbros. Numerous dykes and veins of the same material, not visibly connected with the main granophyre-mass, traverse the gabbros of the ridge of which Druim an Eidhne forms a part. Some of these are described in the paper, and it is shown that the flow-structure follows the irregularities of the gabbro-walls and sweeps round enclosed blocks of altered gabbro. The "inclusions" described by Prof. Judd are portions of these dykes and veins. There is not, so far as the author could discover, a single granite-block enclosed in the gabbro anywhere to be seen at this locality. He therefore claims not only that his original description of the relations of the rocks was perfectly correct, but that the evidence brought forward to contradict it by Prof. Judd furnishes the most crushing testimony in its favour.

2. "Note on the Genus *Naiadites*, as occurring in the Coal Formation of Nova Scotia." By Sir J. William Dawson, K.C.M.G., LL.D., F.R.S., F.G.S. With an Appendix by Dr. Wheelton Hind, B.S., F.R.C.S., F.G.S.

The specimens referred to in the paper occur most abundantly in calcareo-bituminous shales along the coast, at the South Joggins, and were described by the author in "Acadian Geology," in 1860. A collection of them has been submitted to Dr. Wheelton Hind. In Q.J.G.S. vol. xix. Mr. Salter referred the shells described as *Naiadites* to his new genera *Anthracoptera* and *Anthracomya*. In correspondence with Mr. Salter, the author held that the shells were probably fresh-water, and objected to the name *Anthracomya* as expressing an incorrect view of the affinity of the shells; he also stated several reasons in support of his opinions. The author continued to use the name *Naiadites*, but does not object to the division of the species into two genera, for one of which Salter's name *Anthracoptera* should be retained. Additional reasons are given for the fresh-water origin of these shells, and the author expresses his gratification that their affinities have been so ably illustrated by Dr. Hind.

Dr. Wheelton Hind believes that the "genus" *Naiadites* contains three distinct genera, for one of which the name must be retained. He proposes to retain the name for the forms called *Anthracomya*, affirming as this word does an altogether wrong affinity for the genus. (The name *Naiadites* was proposed in 1860; *Anthracomya* in 1861.)

Dr. Hind is not able to state that any of the species submitted to him by Sir J. W. Dawson are the same as British forms. The shell originally described as *Naiadites carbonaria* is, he has no doubt, an *Anthracoptera*. He gives notes on *N. arenaria*, *N. angulata*, and *N. lævis*.

CORRESPONDENCE.

PRESERVATION OF FOSSIL PLANTS.

Sir,—In answer to certain questions of a Correspondent in the December Number of this Magazine, I should like to offer the following suggestions:—

(i.) Mr. Wilmore asks why the "Carbonaceous covering" of such Coal-measure fossils as Calamites, etc., is confined to the outside of the cast. In such a plant as *Calamites* the sandstone or shale cast, which usually represents the genus in a fossil state, has frequently a layer of carbonaceous matter moulded on its surface. The sandstone or shale is simply the hardened sand or mud which fill up the hollow pith of the Calamitean stem, and the layer of coal represents the carbonized remnant of the woody and cortical tissues of the plant stem. The thickness of this coaly covering varies in different species; and it has been suggested that we may, in some cases, calculate the original thickness of the stem tissues by multiplying the thickness of the carbonaceous layer by 26. It is doubtful whether such a method should be looked to as likely to afford accurate results; but no doubt the coaly residue will vary considerably in thickness according to the diameter of the stem from which it has been formed.

In impressions of fern fronds, in which the pinnules are coated with a thin film of carbon, it is occasionally possible to trace the outlines of the original cells of the leaf.

(ii.) As to whether the carbonaceous layer on the surface of a cast represents the whole of the carbon of the plant tissues, it is difficult to say how much has escaped in a gaseous form during the gradual disorganization of the tissues; certainly the amount of carbon contained in a very thin layer must usually be regarded as the product of a much greater thickness of plant substance.

(iii.) The third question is:—"Why, in comparatively soft and little altered freestones, should the carbonaceous layer exhibit such a baked or charred appearance"? This baked or charred appearance should not merely be referred to the action of heat, but is in all probability the result of various weathering agencies and not necessarily the expression of actual charring.

Cambridge, *Feb.* 12, 1894. A. C. Seward.

THE GREAT JAPANESE EARTHQUAKE.

Sir,—In answer to some enquiries concerning the effects of the great earthquake of 1891, Professor Kotô, of Tōkyō, has just favoured me with further interesting particulars that meet some of the points mooted by the Rev. E. Hill, in this Month's Number of the Magazine, and adds something to the Professor's previous paper in the Japanese Journal of Science. In this letter he remarks: "As to the questions you put on my earthquake paper, I shall attempt to answer you in a few particulars, though I may not satisfy you, owing to my superficial geological knowledge. The uplift in vertical direction, at its maximum point, is from 5½ to 6 metres. This is, however, an exceptional one, found in Modori, in the Neo Valley. This local uplift seems to me to have been caused by the pushing up of the crust between two fault-lines by lateral pressure of the neighbouring strata (see p. 340 of my paper). In all other cases the vertical displacement is insignificant; in plains it may only be seen by slight undulation of the ground. Along hill-sides it may be seen in small landslips covered by soil, and in this case the fault could not be distinguished from ordinary landslips accompanying severe shocks. A very characteristic feature of the fault in question is the horizontal displacement along the faulting plane, by which the boundaries of field becomes discontinuous. From this displacement I could measure the amount of shift of wing relative to the opposite wing. Along the junction the soil is much disturbed and raised from the surrounding field, appearing just like tracks of a mole. At the spur of the hills this could not be well seen, as the junction is covered by fallen talus. The displacement is, therefore, best studied in cultivated fields. I have traced the Neo fault for 112 km. by the marks left in the fields by slight elevations, and by displacement of field boundaries, and the regularity and constancy of these marks. Sometimes I have traced it in wooded hills where I often lost sight of the marks, but by the help of the compass I caught the track again beyond the hills on the other side. It was a very troublesome task to keep my route right in this way.

"You ask me whether the faulting plane is *vertical* or *oblique*? I am sorry I cannot tell you which it is. As may be understood from the foregoing statement the vertical displacement, as a general rule, amounts to very little. The best opportunity for study in this direction may be that of Midori (photograph, Pl. xxxiv.), but, unfortunately, the faulting took place in alluvial ground, consequently solid strata did not come into view at the surface. As the raised mound in the fields is very narrow and sharply marked, I surmise that the faulting plane is vertical, or nearly so; if, on the contrary, the faulting plane makes large angles, with normal upon the surface, the head of shifting plane should not be so clearly marked as in the Mino-Owari district, but the proximity of fault must be much disturbed, which is not the case with ours.

"Whether the hard rocks, as well as the drift-gravel and sand, are affected by the fault is the next question you put to me, which I answer in the affirmative. As the line of fault goes through field and hills as well as mountains alike with great regularity and sharpness, I think I am justified in saying that the hard rocks are also affected by the fault. If diluvial and alluvial deposits were only affected by it, the line must be of only short distance, and may perhaps not be a straight line, but I found the line of fault crossed intervening hills and appeared again on the opposite side, keeping thereby the same direction on either side. The faulting in one case took place in a rocky crust, and must be deep-seated. Unfortunately the fault did not cross the hard, eroded valley bottom where the effect of *friction* by shifting might perhaps be observed.

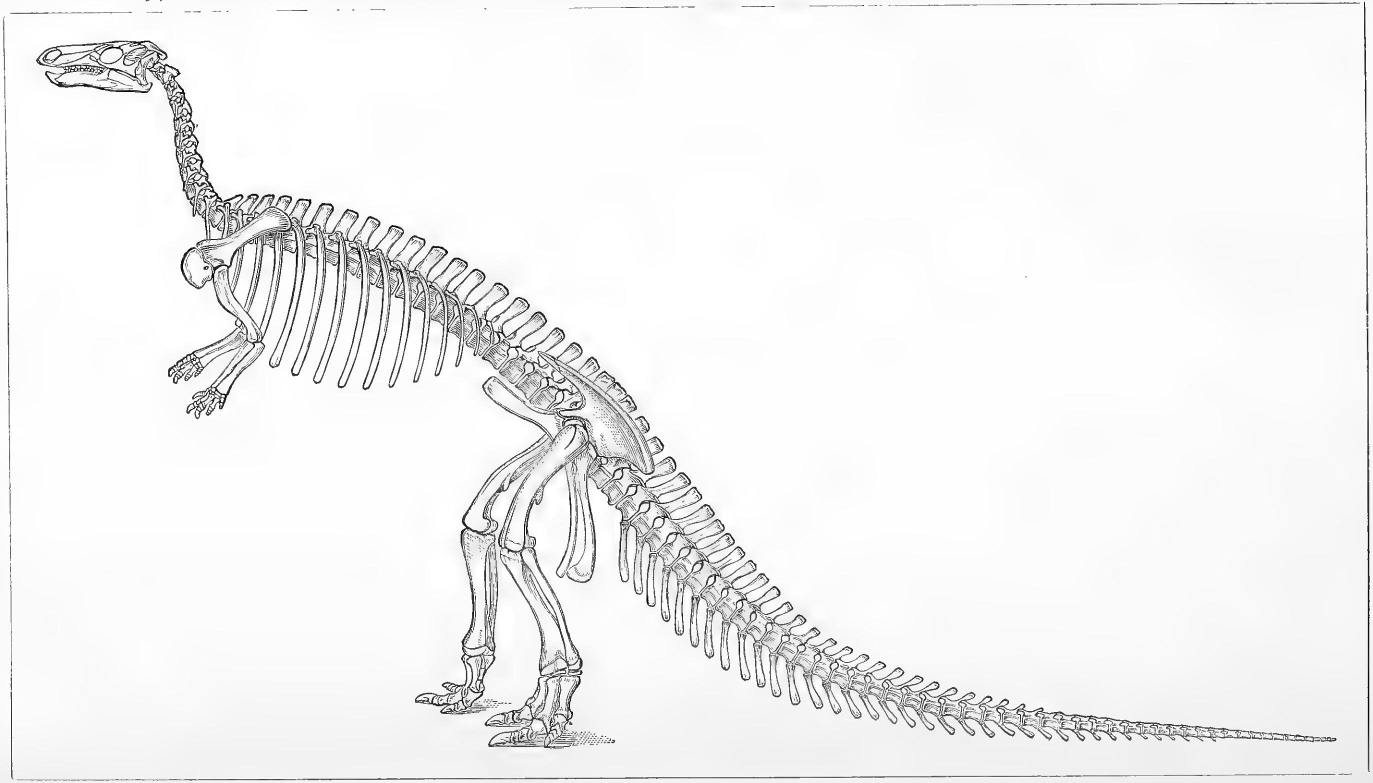
"The next question is whether the shock was of sudden or prolonged nature. As there was no sign of change in topography before the last convulsion, the shock must be a sudden one, otherwise houses standing upon the fault-line must have inclined toward one or other side before the shocks, which was not the case, at any rate I have heard of no such signs when going through earthquake-districts when I had opportunity to converse with the unhappy people. I think the faulting, which produced the last catastrophe, was what the miners call *heave*, or *blatt* of German geologists, *i.e.* the fault crossing the strike of strata complex. If the solid large mass of crust had suddenly shifted, as I think was the case in the earthquake of Japan 1891, a great amount of friction must have occurred along the plane of fault, and thereby, mechanically, heat may have been developed which may have melted the rock or produced slicken-side on the cheeks of bounding rocks. I regret much that I made no observations in this direction. Till now I have not heard of any new appearances of hot springs in faulted district. In every textbook on geology it is stated during mountain-making process faults are produced by which rock-masses slide along the dislodged plane, thereby partially melting the neighbouring rocks by the development of mechanical heat by friction, and convert a rock into another form and producing regional metamorphism. In the last sudden faulting no such changes were observed by me. Such phenomena might occur in the deeper parts of the earth-crust, but near the earth-surface, so far as I know, nothing resembling such phenomena was observed or recorded by any person."

Allow me to observe in reply to Mr. Hill's courteous letter that I do not take the great fault at all as a measure of the forces to be dealt with, but merely as an indication of their *nature*, and not as evidence of their *degree*, which can only be judged of by the results in each particular case of disturbance.

SHOREHAM, KENT.
10*th March*, 1894.

JOSEPH PRESTWICH.

WILLIAM PENGELLY, F.R.S., F.G.S.—With deep regret we record the death of this well-known geologist, who has done so much during the past forty years in the exploration of Brixham Cave, and Kent's Cavern, Torquay; in the establishment of the Devonshire Association for the Advancement of Science, and the Torquay Natural History Society. He died at Torquay on 17th March, in his 83rd year. We hope to give an Obituary Notice of Mr. Pengelly next month.



Restoration of *Camptosaurus dispar* (Marsh). $\frac{1}{30}$ nat. size.
From the Upper Jurassic (Atlantosaurus Beds) of Wyoming.

THE
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No. V.—MAY, 1894.

ORIGINAL ARTICLES.

I.—RESTORATION OF *CAMPTOSAURUS*.

By Prof. O. C. MARSH, Ph.D., LL.D., F.G.S., etc.

(PLATE VI.)

THE Jurassic deposits of Western North America contain the remains of many gigantic Dinosaurs, and various skeletons of these have been obtained by the writer, who has described the more important forms. Restorations of the skeletons of three of the most interesting genera, *Brontosaurus*, *Stegosaurus*, and *Ceratosaurus*, have already been given in the American Journal of Science and in this MAGAZINE, and another of these huge reptiles is thus represented on Plate VI. accompanying the present article. Each of the three forms previously restored was a typical member of a distinct group of the *Dinosauria*, and this is true, although in a less degree, of the present genus, *Camptosaurus*. Restorations of *Anchisaurus* from the Triassic, and *Claosaurus* and *Triceratops* from the Cretaceous, all Dinosaurs of much interest, have likewise been published by the writer in the American Journal[1] and in this MAGAZINE.

The restoration here given is based upon the type specimen of *Camptosaurus dispar*, one of the most characteristic forms of the great group *Ornithopoda*, or bird-footed Dinosaurs. The reptile is represented on Plate VI., one-thirtieth natural size. The position chosen was determined after a careful study not only of the type specimen, but of several others, in excellent preservation, belonging to the same species or to others nearly allied. It is therefore believed to be a position frequently assumed by the animal during life, and thus, in some measure, characteristic of the genus *Camptosaurus*. The present species, when alive, was about twenty feet in length, and ten feet high in the position here represented.

The genus *Camptosaurus* is a near ally of *Iguanodon* of Europe, and may be considered its American representative. *Camptosaurus*, however, is a more generalized type, as might be expected from its lower geological horizon. It resembles more nearly some of the Jurassic forms in England, generally referred to *Iguanodon*, but, as these are known only from fragmentary specimens, their generic relations with *Camptosaurus* cannot now be determined with certainty.

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[1] American Journal, vol. xli. p. 339, April, 1891; vol. xlii. p. 179, August, 1891; vol. xliv. p. 343, October, 1892; and vol. xlv. p. 169, February, 1893.

In comparing *Camptosaurus,* as here restored, with a very perfect skeleton of *Iguanodon* from Belgium, as described and figured, various points of difference as well as of resemblance may be noticed. The skull of *Camptosaurus* had a sharp, pointed beak, evidently encased during life in a horny sheath. This was met below by a similar covering, which enclosed the predentary bone. The entire front of the upper and lower jaws was thus edentulous, as in *Iguanodon,* but of different shape. The teeth of the two genera are of similar form, and were implanted in like manner in the maxillary and dentary bones. In *Camptosaurus* there is over each orbit a single supra-orbital bone, curving outward and backward, with a free extremity, as in the existing Monitor; a feature not before observed in any other Dinosaur except *Laosaurus,* an allied genus, also from the Jurassic of America. Other portions of the skull of *Camptosaurus* as well as the hyoid bones appear to agree in general with those of *Iguanodon.*

The vertebræ of *Camptosaurus* are similar in many respects to those of *Iguanodon,* but differ in some important features. In the posterior dorsal region, the transverse processes support both the head and tubercle of the rib, the head resting on a step, as in existing crocodiles. The five sacral vertebræ, moreover, are not coössified, even in forms apparently adult, and to this character the name *Camptonotus* first given to the genus by the writer in 1879 especially refers.[1]

Another notable feature of the sacral vetebræ of the type specimen should be mentioned. The vertebræ of the sacrum, especially the posterior four, are joined to each other by a peculiar peg and notch articulation. The floor of the neural canal of each vertebra is extended forward into a pointed process (somewhat like an odontoid process), which fits into a corresponding cavity of the centrum in front. This arrangement, while permitting some motion between the individual vertebræ, helps to hold them in place, thus compensating in part for absence of ankylosis. A similar method of articulation is seen in the dermal scales of some ganoid fishes, but, so far as the writer is aware, nothing of the kind has been observed before in the union of vertebræ.

In *Camptosaurus* the sternum was apparently unossified, and no trace of clavicles has been found. The pelvis of *Camptosaurus* differs especially from that of *Iguanodon* in the pubis, the postpubic branch being even longer than the ischium, while in *Iguanodon* this element is much shortened.

In the fore foot of *Camptosaurus* there were five functional digits, the first being flexible and nearly parallel with the second, thus differing from the divergent, stiff thumb of *Iguanodon.* The hind feet had each three functional digits only, the first being rudimentary and the fifth entirely wanting, as shown in Plate VI. The entire skeleton of *Camptosaurus* was proportionately more slender and delicately formed than that of *Iguanodon,* although the

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[1] This name proved to be preoccupied, and *Camptosaurus* was substituted for it. —American Journal, vol. xxix. p. 169, February, 1885.

habits and mode of life of these two herbivorous Dinosaurs were doubtless very similar.

The type specimen of *Camptosaurus dispar*, used as the basis of the present restoration, is from the Atlantosaurus beds of the Upper Jurassic of Wyoming. This species and other allied forms will be fully described in an illustrated Memoir now in preparation by the writer for the United States Geological Survey. The present restoration is reduced from a large drawing made for that volume.

II.—ON THE STRUCTURE AND AFFINITIES OF THE GENUS *SOLENOPORA*, TOGETHER WITH DESCRIPTIONS OF NEW SPECIES.

By ALEX. BROWN, M.B., M.A., B.Sc.;
Assistant in the Natural History Department in the University of Aberdeen.

(Part II.)

(*Continued from the April Number*, p. 151.)

5. *Solenopora filiformis*, Nich.

Solenopora filiformis, Nicholson, GEOL. MAG. 1888, Dec. III. Vol. V. No. 1, p. 21.

"It presents itself sometimes in the form of small rounded masses, or irregular nodules; or at other times as lobate or ramified masses of considerable dimensions. Viewed with a powerful magnifying-glass, it appears to be quite compact or obscurely fibrous" (Nicholson).

The internal structure is commonly much obscured, or even destroyed by crystallization. In vertical section the cells are arranged in radiating fashion. Cells narrower and shorter than in *Solenopora compacta*, diameter being $\frac{1}{24}$ mm. Cell-walls thin and not wavy (Fig. 6A). In tangential section the cells have polygonal walls. They appear to increase by ordinary cell-division, but the active condition has not been observed (Fig. 6 B).

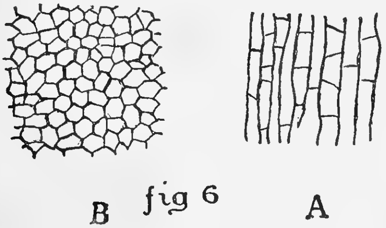

FIG. 6.—A, Long. sect. of *Solenopora filiformis*, Nich., from the Ordovician Limestones of Craighead, Girvan, Ayrshire. × 60 d. B, Tang. sect. of the same.

Observations.—This species seems to be an intermediate form between *S. compacta* and *S. Jurassica*. The cells are not so elongated as in *S. compacta*, and are more like what one finds in *S. Jurassica*; only in the latter the transverse cell-walls are concave on one side, and are as thick as the longitudinal walls, while in *S. filiformis* the transverse cell-walls are straight, and are thinner than the longitudinal walls. Further, in cross section, the cell-walls of *S. filiformis* are polygonal in form, while the same thing is found to occur very frequently in *S. Jurassica.*

Formation and Locality. — Ordovician, Craighead Limestones, Girvan, Ayrshire; occurring along with *Solenopora compacta.* (Coll. H. A. Nicholson.)

6. *Solenopora dendriformis*, n.sp.

Under this name I shall describe a species which is found occurring along with *Solenopora compacta* and *Solenopora nigra* in the limestones of Saak, Esthonia. It presents itself in minute nodules, ovate or spherical in form and dark in colour. Each nodule shows the arrangement of its parts in concentric layers.

In longitudinal section the cells appear to have a radial arrangement; cell-walls thick and sinuous; transverse walls concave on their peripheral side. The diameter of the cells in each specimen varies very greatly, this being due to the peculiar branching nature of the cells to be presently referred to. The largest diameter is about $\frac{1}{17}$ mm., but others are very much smaller. The length of the cells is about $\frac{1}{5}$—$\frac{1}{3}$ mm. or even longer.

In tangential section the cells appear to branch in all directions, especially horizontally (Fig. 7). The smaller branching processes are seen cut across in the illustration.

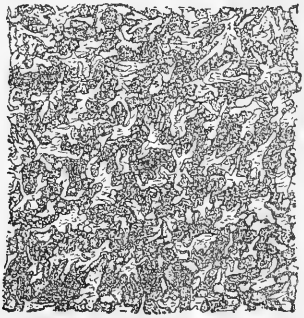

fig 7

Fig. 7.—Tang. sect. of *Solenopora dendriformis*, n.sp., from Esthonia. × 50 d.

Observations.—The important feature in this species is the extraordinary nature of the cells, branching as they do in all directions. Otherwise the nature of the skeleton is much the same as in the species already described. The position and form of its transverse cell-walls show a resemblance to what we find in *S. Jurassica* and *S. nigra.*

Formation and Locality.—Ordovician Limestones of Saak, Esthonia. (Coll. H. A. Nicholson.)

7. *Solenopora fusiformis*, n.sp. (Pl. V. Fig. 4.)

This species occurs as small white nodules, oval, ovate, or spherical in form. Concentric rings faintly seen. Its size varies from the dimensions of a pea to those of a hazel-nut. The structure is generally greatly obscured by crystallization.

In longitudinal section numerous concentric rings are seen, but many of them are altered by secondary crystallization. The cells have about the same diameter as the cells of *Solenopora filiformis*, viz. $\frac{1}{24}$ mm., but are more or less spindle-shaped, and dove-tail into one another.

In tangential section the outline of the cells is only feebly sinuous. The cells vary in size considerably on account of their fusiform nature.

Observations.—The interesting feature here is the fusiform nature of the cells, which can be more readily distinguished under a high power. In this type, the concentric rings are particularly well developed, and the general structure reminds one of such a form as *Lithothamnion.*

Formation and Locality. — Ordovician, Craighead Limestones, Girvan, Ayrshire, occurring in great quantity, and forming large masses of limestone. It is associated with *S. compacta* and *S. filiformis.* (Coll. H. A. Nicholson.)

II. Relations of the Genus *Solenopora.*

The observations previously recorded render it possible to arrive now at something like a definite conclusion as to the affinities and systematic position of the genus *Solenopora.*

In the Tertiary rocks, and among existing Algæ, we find the well known Nullipores, many of which are massive in structure. Their distribution is very wide, recent forms occurring as far north as the Arctic region. They form extensive masses of limestone, as the Tertiary era bears witness. To this group of Coralline Algæ the forms above described, as helping to give rise to thick masses of limestone during the Ordovician and Jurassic periods, appear to be closely related.

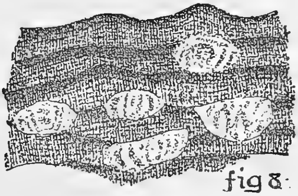

Fig. 8.—Long. sect. of *Lithothamnion fœcundum.* × 40 d. (after Kjellman).

In Fig. 8 and Pl. V. Fig. 1, the general structure of a Nullipore (*Lithothamnion*) is seen. It consists simply of a mass of cellular tissue arranged in concentric rings, which rings are often irregular. The cells are, in section, quadrilateral in shape, and are of very small size. In some specimens spaces can be seen which are the remains of the former conceptacles of sporocarps or sporangia. These cavities communicate with the exterior by means of a number of canals. The latter are generally surrounded by a number of cells having a different shape from the ordinary tissue-cells of the thallus. This is specially well seen at the external apertures of the canals (Fig. 9), where the modified cells in question give rise to a rosette-like appearance. These conceptacles may or may not be immersed in the general substance of the thallus. If immersed, then a scar or a vacant space is left to tell of their existence; or, indeed, they may be replaced by new tissue, so that no trace of the former conceptacle can be seen.

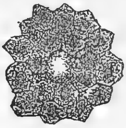

fig 9

FIG. 9.—Part of roof of "conceptacle" decalcified. × 40 d. (after Kjellman).

Regarding other forms of the Corallineæ, it is necessary to mention one or two points for comparison. In *Corallina mediterranea* there is no concentric arrangement of the tissue-cells, as there is in *Lithothamnion.* The cells, too, are larger than in the latter, and are arranged as in that genus in parallel rows, save where some cell in one of the rows has two cells attached to its distal extremity in a sub-dichotomous manner (Fig. 10). The last feature is, however, characteristic of certain extinct forms of *Lithothamnion,* according to A. Rothpletz (*op. cit. supra* p. 6).

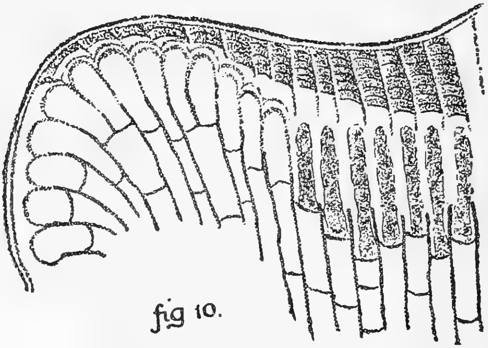

fig 10.

FIG. 10.—Long. sect. of the apical shoot of *Corallina mediterranea.* × 300 d. (after Solms-Laubach).

In *Amphiroa exilis* and *Amphiroa rigida* the concentric arrangement of cells is excellently seen (Fig. 11). The cells are fairly large, and occupy the whole space between each dark concentric line.

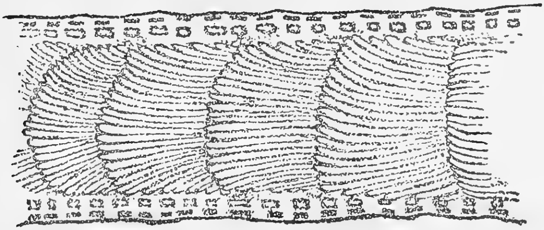

fig. 11

Fig. 11.—Long. sect. of thallus of *Amphiroa exilis.* × 160 d. (modified after Solms-Laubach).

In another form, *Melobesia deformans*, it is necessary to note the arrangement of the spore-bearing cells (sporangia) in relation to the tissue-cells of the thallus. The illustration in Fig. 12 will clearly show this, where the larger cells are tetraspore-producing cells, and the smaller the ordinary tissue-cells of the thallus.

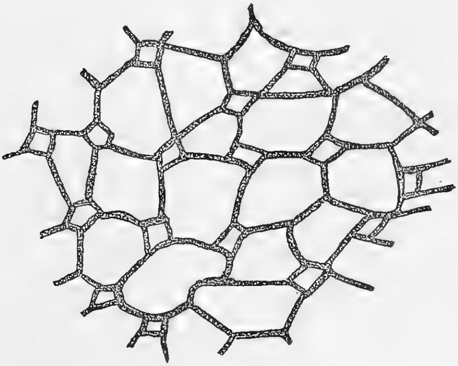

fig: 12

Fig. 12.—Surface view of the thallus of *Melobesia deformans*, showing tetrasporangia. × 450 d. (after Solms-Laubach).

Let us now examine the points wherein the ancient form *Solenopora* resembles members of the group of calcareous Algæ.

(*a.*) *Structure, Growth, and Arrangement of tissue-cells.*

In existing forms of *Corallineæ* the concentric arrangement of cells, though very general, is not always observed. As regards

Solenopora, it is most distinct in some specimens of *S. compacta* (Fig. 1), *S. lithothamnioides* (Pl. V. Fig. 2), and *S. fusiformis* (Pl. V. Fig. 4), in which species the arrangement is quite comparable to what obtains in *Amphiroa* (Fig. 11). To the naked eye mostly all these species appear to have these concentric rings. Under the microscope, however, this appearance, in many cases, is not so distinct, and the dark rings do not correspond with the junction between neighbouring concentric rows of cells; but there is a thickening over a wider area (see Pl. V. Fig. 3). This is really the condition we observe in specimens of Nullipores (*cf.* Pl. V. Fig. 1 and Fig. 8). In some cases the cause of the concentric markings is partly due to the concentric areas of secondary crystallization (*e.g.* in *Solenopora Jurassica*). Again, the appearance and structure of the cell-walls are very similar in *Solenopora Jurassica* and *Corallina mediterranea.* In both, the transverse cell-walls are concave on the peripheral side (Figs. 4 and 10). In the case of *Solenopora lithothamnioides* and *Lithothamnion,* each concentric layer is composed of numerous cells arranged in parallel rows (*cf.* Pl. V. Figs. 1 and 2), the main difference between the two forms consisting in the fact that the cell-walls of the latter are thickened over a wider area, whereas those of the former are thickened only along each of the concentric lines. In *Solenopora compacta* we find the sub-dichotomous and sub-trichotomous origin of peripheral cells, referred to in the first part of my paper. This method of increase is characteristic of *Corallina mediterranea* and *Lithothamnion* (*cf.* Figs. 1 and 10). It probably also occurs in *Solenopora Jurassica* and *Solenopora nigra.* In all the forms mentioned, both fossil and recent, increase in number of cells is more common by longitudinal than by transverse fission. It is pointed out by A. Rothpletz (*op. cit. supra* p. 6) that longitudinal fission is quite characteristic of certain extinct forms of *Lithothamnion,* and that in these this is the ordinary method of growth. Thus we have a distinct likeness in the mode of cell-division between the genus *Solenopora* and the calcareous Algæ. Lastly, account must be taken of the form of cells found in *S. fusiformis* and in *S. dendriformis.* In the former the cells lying in each concentric layer have a fusiform appearance, and to a greater or less extent dovetail into each other (Pl. V. Fig. 4). This condition is of very common occurrence in the vegetable kingdom; and, with the next point to be mentioned, affords a strong proof of the cellular nature of the genus. In *S. dendriformis* the cells in cross section show a peculiar branching condition, mostly in a horizontal direction, the branches filling up all the interspaces between the bodies of the cells. This structure forcibly reminds one of what is characteristic of certain Algæ, in which certain cells of the thallus assume a branching habit, *e.g.* in *Fucus.*

Thus the forms of the cells and cell-walls, the method of increase, and the arrangement of the tissue-cells in the various species of *Solenopora* bear strong evidence of relationship between that genus and the calcareous Algæ.

(*b.*) *Size of the cells of Solenopora.*

It may be objected that since the cells of *Solenopora* are so much larger than those of a Nullipore, the genus *Solenopora* can hardly be compared with the recent calcareous Algæ. A comparison between the cells of various genera of the Corallineæ and the cells of the genus *Solenopora,* will dispel all such objections. A glance at Fig. 13 shows the marked variations in the size of the cells of a recent Nullipore (A), of *Amphiroa exilis* (B), of *Solenopora filiformis* (C), and of *Solenopora Jurassica* (D), all being drawn to the same scale.

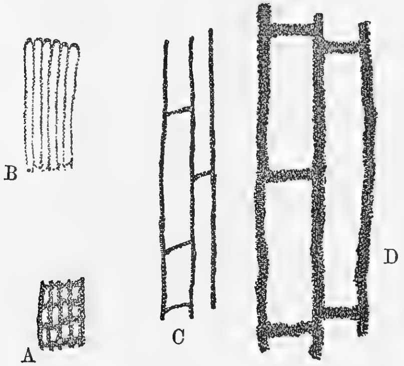

fig 13

Fig. 13.—A Cells of a recent Nullipore (*Lithothamnion*). × 160 d.
B Cells of *Amphiroa exilis.* × 160 d. (modified after Solms-Laubach).
C Cells of *Solenopora filiformis,* Nich. × 160 d.
D Cells of *Solenopora Jurassica,* Nich. × 160 d.

Such an illustration at once clears up any difficulty on the above point, for there appear to exist all gradations of size of the tissue-cells.

(*c.*) *Reproductive organs.*

Evidence in regard to these is not yet so complete as one would wish; still, examination of some specimens clearly shows traces of structures that can be accounted for in no other way than by regarding them as the remains of reproductive organs.

Thus, a specimen of *Solenopora compacta,* var. *Trentonensis,* on examination of a tangential section, is seen to possess two distinct kinds of cells, as mentioned above in the description of this species. The larger cells here (Fig. 2) are sporangia, and can be compared with the sporangia of *Melobesia deformans* (Fig. 12), where they exist as large cells among the ordinary tissue-cells of the thallus.

Again, a tangential section of a specimen of *Solenopora Jurassica,* shows certain spaces amongst the general cellular mass. These spaces are oval or circular in form, and in one specimen from Malton, Yorkshire, are arranged in a concentric row. The latter specimen, however, was so much destroyed, that one could not, with certainty, decide as to the true state of matters. Further examination of such specimens will clear up all doubt as to the existence of these spaces. In the same sections are seen clusters of cells at intervals, arranged in rosette-like fashion (Fig. 5). One is impressed with the striking similarity all this bears to the conceptacle-spaces and the canals of *Lithothamnion* (Figs. 8 and 9), the rosette-cells of *Solenopora* representing the similarly arranged cells around those canals. It is, therefore, highly probable that the spaces observed in *S. Jurassica* are really the remains of once existing conceptacles, and that the rosette-cells surrounded the passages leading into them. It will, however, require further and more extended observation to confirm such conditions as these.

(*d.*) *Modes of Occurrence.*

It may be objected that these forms, here referred to the genus *Solenopora*, are not in fact generically identical. Such an objection, however, must fall to the ground, for it is impossible to overlook the fundamental likeness which subsists among them all. They are found under the same conditions, associated in the same kind of rocks, and taking part in the formation of the same great masses of limestone, whether they belong to the Ordovician, the Silurian, or the Jurassic systems. They have, too, the same external characteristics, having the appearance of pebbles or concretions, with a lobulated or subspherical outline. On fracture the surfaces of all present a porcellanous or fibrous aspect, and exhibit the characteristic concentric structure. Many of the *Solenopora* limestones show scarcely any differences in outward and internal appearance from the ordinary Nullipore limestones; and, indeed, it is often very difficult to distinguish between them.

(*e.*) *Difficulties in retaining the genus Solenopora in the Animal Kingdom.*

In assigning the genus *Solenopora* to a definite place in the scale of life, it seems clear that, if an animal at all, it must be referred to some group or other of the Cœlenterates. But no recent Cœlenterate has zoöidal tubes as minute, or nearly as minute, as are those of *Solenopora*. This is the great difficulty in assigning to the genus a place in the Animal Kingdom. Still more, were it of animal origin, would it be difficult to account for the largely branched cells of *Solenopora dendriformis*, the fusiform cells of *Solenopora fusiformis*, and the essentially *cellular* nature of the skeleton in well-preserved examples. Taking all the evidence as we now have it, we may reasonably conclude that the genus cannot be referred to the *Actinozoa*; and "we cannot refer it to the *Hydrozoa*, for we are not acquainted with any *Hydrozoön*, living or extinct, with which *Solenopora* could be compared. It shows no features in its minute structure which remind us of the Hydrocorallines, and it assuredly presents no structural resemblance to any known type of the Stromatoporoids" (Nicholson).

On the other hand, I have been able to determine with more or less certainty that the structure of *Solenopora* is truly *cellular* and not *tubular*, a determination which Prof. Nicholson clearly foresaw as the possible result of further investigation. I have shown that the structure of the cells and cell-walls and the mode of growth are, in certain cases, exceedingly similar to those of certain recent and extinct Corallineæ; and I have further shown that the comparatively large size of the cells in *Solenopora* need not necessarily be a barrier to our regarding the genus as truly referable to the calcareous Algæ. Lastly, I have been able to demonstrate in some forms of *Solenopora* the existence of structures, which in all essential respects may be fairly compared, some with the "tetrasporangia," and others with the "conceptacles" of recent Corallineæ.

Upon the whole, therefore, the balance of evidence seems to be unequivocally in favour of the reference of the genus *Solenopora* to the series of the Nullipores. Should this view be finally established, it will be an interesting proof of the extent to which the calcareous Algæ have taken part in the formation of the older of the Palæozoic limestones, as they are already known to have done in the case of some of the Tertiary and Secondary limestones. This proof will be still further enforced if, as seems extremely probable, it should ultimately be shown that *Girvanella*, Nich. and Eth., is really referable to the *Siphoneæ verticillatæ*.

III.—ON THE RESULTS OF UNSYMMETRICAL COOLING AND REDISTRIBUTION OF TEMPERATURE IN A SHRINKING GLOBE AS APPLIED TO THE ORIGIN OF MOUNTAIN RANGES.[1]

By T. MELLARD READE, C.E., F.G.S., etc.

HAVING been honoured by an invitation to state to your Society the physical principles upon which my Theory of the Origin of Mountain Ranges is founded, I do so with the greater pleasure knowing that it will receive a searching criticism at your hands, from which I hope to derive considerable benefit. My audience hitherto having been mostly geological, the physical principles involved have been to some extent subordinated to geological conditions.

In addressing you I purpose adopting the opposite method to that in which I have expounded the process of Mountain formation, as I conceive it to have taken place, to my geological brethren. In the natural way in which the subject has developed itself in my own mind, I commenced with the facts of geology and reasoned backwards to the principles. On the present occasion I intend to state a few of the leading physical principles, and to unfold how the facts of Geology, of Mountain Upheaval and Structure have come about.

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[1] Read before the Liverpool Physical Society, January 29th, 1894.

The Earth considered as a Homogeneous Cooling Solid.

Adopting Lord Kelvin's view as stated in Thomson and Tait's Natural Philosophy (1867, pp. 711–727), that since the beginning of Geological Time the Earth has been a highly heated solid body cooling into space by being kept at a constant lower temperature at the surface, we will try and trace out the physical consequences that must follow.[1] We will, for the purposes of investigation, first assume that the globe is homogeneous throughout and that the cooling and outward flow of heat is equable on all radii, or otherwise symmetrical. Lord Kelvin assumes that at the time of first solidification the augmentation of temperature downwards, or the temperature gradient, was 1° Fahr. in 10 feet, which has gradually decreased to 1° in 50 feet, this being taken as the average at the present time.

The time that has elapsed between these two conditions hardly forms an element in our present considerations; but Lord Kelvin, in the paper referred to, worked it out to 96,000,000 years. On p. 719 is a diagram, one curve on which shows the excess of temperature above that of the surface; the other shows the rate of augmentation of temperature downwards that has taken place in 100 million years of cooling. Lord Kelvin says: "Thus the rate of increase of temperature from the surface downwards would be sensibly $\frac{1}{51}$ of a degree per foot for the first 100,000 or so; below that depth the rate of increase per foot would begin to diminish sensibly. At 400,000 feet it would have diminished to about $\frac{1}{141}$ of a degree per foot; at 800,000 feet it would have diminished to less than $\frac{1}{50}$ of its initial value, that is to say to less than $\frac{1}{2550}$ of a degree per foot; and so on, rapidly diminishing as shown in the curve. Such is on the whole the most probable representation of the earth's present temperature at depths of from 100 feet, where the annual variations cease to be sensible, to 100 miles, below which the whole mass, or all except a nucleus cool from the beginning, is (whether liquid or solid) probably at or very nearly at the proper melting temperature for the pressure at such depth."

Level-of-No-Strain.

If these conclusions be just it is very obvious that not much more than a superficial shell of the earth has been affected by cooling. A hundred miles is but $\frac{1}{40}$ part of the earth's radius. Let us see how this affects the distribution of stresses and strains in a solid homogeneous globe.

It will need a little consideration to see that there are two elements involved—radial contraction and circumferential contraction. Both radial and circumferential contraction are, as we see, practically confined to a shell 150 miles thick (800,000 feet). Commencing very gradually from zero at the surface the contraction increases in intensity until it attains a maximum at about 50 miles, it then finally graduates into a practical zero at 150 miles deep.

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[1] See also Sir W. Thomson, Brit. Assoc. Report, 1876, and Dr. C. H. Darwin, Phil. Trans. 1879, part i. It is considered that the earth is as rigid as steel, or at least glass, from the surface to the centre.

The circumferential rate of contraction of the sphere may be conceived as gradually increasing from zero at the surface in successive infinitesimal zones or shells, until the maximum contracting shell is attained, when the circumferential rate of contraction again diminishes, until practical zero is arrived at 150 miles below the surface.

In all these zones or shells the circumferential contraction is equal throughout for each particular shell. What I have called the circumferential contraction is equal throughout the circle, whereas the radial contraction differs at every point and is practically confined to $\frac{1}{25}$ of the radius.

What will happen is this: There will be one particular shell which will have the same rate of circumferential contraction as the average radial contraction taken from the point of intersection to the centre of the sphere. At this zone or surface there will be neither tension nor compression, no deformation in fact, and it is to this zone that the name of level-of-no-strain has been applied. Above the level-of-no-strain the shells will be in *compression*, beginning at zero at the level-of-no-strain and finishing at the surface with the maximum. Below, the shells will be in tension, beginning at zero at the level-of-no-strain, increasing to a maximum at about 50 miles deep, and then shading off to nothing, 150 miles below the surface.

This is a short statement of the principle I was the first to enunciate in chap. xi. of the "Origin of Mountain Ranges," published in 1886, in which I showed that the shell of compression could not be more than a few miles thick, or, to state it otherwise, that the neutral zone or level-of-no-strain between the shell in compression and the shell in tension could not be more than a few miles below the earth's surface.

I reproduce by the lantern the original diagram from the "Origin of Mountain Ranges." From this it follows that symmetrical secular cooling produces *tensile* strains in by far the larger bulk of the earth already affected by such cooling.

Previous to this demonstration it had been customary to look at the globe as consisting of a rigid crust in compression adapting itself to a shrinking nucleus without intermediate gradations. Reasoners desirous of explaining in this way the rugosities of the earth's surface, and the great evidences of lateral pressure shown by the folding of strata in mountain ranges, assumed whatever thickness they thought necessary for their theory, one well-known geologist even placing the crust in compression at 800 miles. The idea that any part of the shrinking globe was in tension did not seem to have occurred to any of the physicists or geologists who paid attention to the subject. I may add, as a matter of private history, that this conception, which had been floating about in my mind for a long time, was jotted down by me in a note five years before publication.

Since my work appeared, Mr. C. Davison contributed a paper to the Royal Society (read April 7th, 1887) entitled, "On the Distribution of Strain in the Earth's Crust resulting from Secular Cooling," in which he arrives at practically the same results as myself. He treats the problem mathematically, and locates the level-of-no-strain five miles below the surface after 174 million years of cooling. Attached to the paper is an Appendix by Prof. George Darwin, in which he calculates that after 100 million years of cooling the level-of-no-strain would be two miles deep. The Rev. Osmond Fisher has devoted a considerable amount of attention to the subject, and arrives at even a less result. I also showed that, whether we look at the earth's nucleus as solid or liquid, the level-of-no-strain would still be located in the hard shell or within the crust. Mr. Fisher has mathematically investigated the problem on the assumption that there is a liquid zone between a hard outward crust and a solid nucleus, and places the level-of-no-strain on this hypothesis of the condition of the earth's interior at four miles deep. Some people find a difficulty in taking in these conceptions. Perhaps it will help them to think of a ball of plastic clay drying. If it be dried slowly it parts with its moisture so equably that it becomes hard and solid without cracking. If, on the contrary, the drying is forced, it becomes fissured all over, because the surface portions contract more rapidly than the interior portions. This illustrates the contracting shell of the earth; but the contracting shell of the earth does not necessarily fissure, because of the weight of strata above, which keeps it solid by what I have called "compressive extension." The clay ball, however, gives no illustration of the shell of the earth, which is in compression because its matter does not gravitate towards its own centre but towards that of the earth.

Irregular condition of the Earth's Cooling.

The earth is, however, not an inert homogeneous ball, cooling equably into space, so it will be necessary to trace out the various modifying influences acting upon its surface. Chief of these is denudation and sedimentation. We may assume that in the planet's early history, volcanic action brought certain portions of the earth, either by upheaval or accumulation of ashes and lava, above the surface of the water as land. Then the land areas came under the joint influences of marine action and what is known as "subaerial denudation." The result was that large areas of the crust became covered with thick layers of sediment, lava flows, and ashes. What would be the effect of this padding upon the outflow of heat?

In 1834 Babbage, reasoning upon the causes which have produced the oscillations of level of the Temple of Jupiter Serapis, in the Bay of Baie, pointed out that the addition of sediment to any part of the earth's crust must raise the temperature of the portion of the crust it covers.[1]

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[1] These consequences are worked out in a very ingenious manner, considering the time at which it was written, by Babbage in the 9th Bridgwater Treatise, in the Appendix Note F, pp. 182–201. Sir John Herschel's views, having a somewhat similar bearing, with the addition of what is now called Isostacy, are also given in a letter to Lyell, dated 1836, and published in Note 1, pp. 202–217.

I had not read these remarkably luminous sketches of a theory of elevation and subsidences until long after the publication of my "Origin of Mountain Ranges." The ideas are far in advance of the times, but are incomplete as not accounting for lateral pressure. Columnar expansion is the only thing considered.

Let us assume, as Lord Kelvin does, that the average rate of augmentation of temperature downwards is now 1° F. in 50 feet. In the early stages of the earth's geological history, as we have seen, it must have increased very much more quickly; but we will deal with the problem under present average conditions, which is stating the case in its worst aspect for my theory. Also, it will be convenient to assume that the sediments are being laid down in a shallow trough or basin of the ocean bordering a great continent, and that the waste of a very great area of land is being deposited off shore in waters of varying depths. It is a pretty well established fact that the area of deposition in such a case is considerably smaller than the area of denudation. If we take the waste of the continental land at a mean of 1 foot in 3000 years, the rate of deposition on the average will be as much more as the basin of deposition is smaller than the area of denudation, so if it be one-third, the mean rate of deposition will be 1 foot in each thousand years. I merely give these figures just to put the matter in somewhat like true perspective.

The sediment will all be laid down at an uniform temperature, say, of 50°; but as the matter accumulates a temperature grade will be established in course of time corresponding with the temperature grade due to the secular cooling of the earth as a whole; in other words, sediments, by obstructing the outward flow of heat, will augment the temperature downwards, so that the rocks of the ocean floor upon which the sediments rest will be at a temperature due to that depth.

If a mile of sediments have accumulated—and this is a mere trifle in the sedimentary crust of the globe—and the temperature gradient is 1° for every 50 feet, the rocks originally having a temperature of 50° F. will be raised to 155·6°, and this increase of temperature will eventually affect in a diminishing degree the whole of the rocks underlying the area of deposition. This effect is described in precise language by saying that the deposition of sediment raises the "isogeotherms" or isothermal surfaces in the underlying part of the earth's crust. We have assumed for the sake of simplicity, that the sediments deposited have the same mean conductivity as has been inferred for the whole of the earth's crust. It is possible that the mean conductivity of the sediments may be less, as experimental proof has been given that rocks are better conductors along the bedding planes than across them, and underlying rocks are often on edge.[1] If the sediments are worse conductors the increase of heat downwards would be more rapid, if better conductors the rate would be less.

It will now be seen that the laying down of sediment *conserves* the heat of the underlying part of the globe, so that the rate of waste or secular cooling is not so high under sedimentary areas as under

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[1] Prof. Joseph Prestwich observes (Proc. Royal Soc. 1866): "With respect to the possibility of change in the thermometric gradient at great depths, it is known that the conductivity of wrought iron diminishes as the temperature increases." From this he infers that the thermometric gradient may increase at great depths.

the uncovered areas, and especially the areas subjected to denudation, for denudation will act, of course, in an opposite manner and depress the isogeotherms, but not at the same rate, as the mean rate of denudation—being over a larger area—is less, as I have shown, than the mean rate of deposition, which is over a smaller area.

And here I would point out that whether the covering material be aqueous sediment or volcanic ashes or lava sheets, the principle of conservation of the internal heat of the globe is the same. I think, however, that the non-conductive property of ashes would be much greater than ordinary sediments, and combined with lava sheets—whether extrusive and laid down on the surface, or intrusive like the Great Whin Sill—they would bring actual additions of heat as well as matter to the conservative covering.

As the larger part of the earth's surface, so far as we are enabled to examine it, is on the continental areas covered with aqueously derived sediment, sometimes interstratified with volcanic and plutonic rocks, and the remainder is covered with or consists of igneous rocks, such as granite or basalt, or of old gneiss or metamorphic rocks made out of any of these rocks, we at once see that we must not limit our view of the earth to that of an inert body cooling from its outer envelope into space, but of such a body subject to secular cooling and to the reactions brought about by meteorological influences and to the irregularities of cooling and consequent expansion and contraction which have taken place from the beginning of geological history, and is evidenced by all the surface phenomena with which we are acquainted.

The Shell of Compression.

We will now go back to the point from which we started and, looking at the globe as an inert mass cooling symmetrically into space, try and quantitatively examine whether the shell of compression, forced by its own gravitation to adapt itself to the shrinking globe, is sufficient to account for the corrugation of the earth's surface, together with its volcanic phenomena, as was hitherto held by most geologists, and still is by some, though in a hesitating sort of way.[1] I prefer to treat this in a very simple manner, so as to bring it within the comprehension of the ordinary mechanical mind. We have seen that, according to Lord Kelvin's results—in which, I believe, most physicists concur—the practical cooling of the earth only reaches down now about 150 miles. Let us assume that this shell, 150 miles deep, has cooled an average of 1000° since the beginning of Cambrian times. It has, of course, on the hypothesis cooled much more at the zone of greatest contraction, but almost nothing at 150 miles deep. It seems to me altogether too ample an allowance for loss of heat by secular cooling in the selected time, but, whether it be too little or too much, it will give us the sense of proportion we require to form our

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[1] See Le Conte—"Theories of the Origin of Mountain Ranges," Nature, Oct. 5th, 1893, and my examination thereof, entitled "Genesis of Mountain Ranges," Natural Science, Nov. 1893.

conception. According to a series of experiments made by myself and recorded in the "Origin of Mountain Ranges," the mean expansion of the various rocks of which the earth is composed is about 2·75 feet per mile for every 100° F. This result is well within the mark on comparison with other investigations and, as I use the coefficient throughout, if it be not absolutely correct it will be true for purposes of comparison.

The linear contraction of 150 miles of rock cooled 1000°, using this coefficient, would be 4125 feet, but, as the contraction of the shell 150 miles deep is voluminal, the contraction in thickness of the shell would be three times this, or 12,375 feet, or=2·344 miles. This would be the radial contraction of the globe from the commencement of the Cambrian, which would give us a circumferential contraction of 77,715 feet, or 14·72 miles. This radial contraction is in excess of what Mr. Osmond Fisher, a well-known mathematician and geologist, has estimated, taking the temperature of solidification at 4000° F., for the whole geological history of the globe.[1] I wish to be liberal, and it will serve my purpose.

We thus have a linear lateral movement or circumferential contraction in the shell of compression of, say, 15 miles wherewith to build up all our mountain chains and produce the rugosities of the earth's surface that have been created since the beginning of the Cambrian. These rugosities do not all exist now, as they have been planed down again and again by denudation while otherwise growing from age to age. The highest mountains of the earth are of the latest formation, viz. of Tertiary age, and it is conceded by most geologists that they are so, not because they were initially higher, but because denudation has not been at work on them so long as on the mountains of preceding periods. According to the greatest estimate of the depth of the level-of-no-strain it is only at the present time 5 miles below the surface, so that the mountain-making capacity of the shell of compression ceases altogether at that depth.

This, of course, is utterly inconsistent with the production of the phenomena of mountain chains, where we find stratified rocks forced up to the surface from much greater depths, and the granitic and gneissic axes, which form a distinguishing feature of all great ranges, give evidence of deep-seated forces acting far below the stratified crust.

Again, the volcanic phenomena cannot be explained by the lateral pressure of the contracting crust, as these again, it is admitted, have a deep-seated origin.

When, therefore, we examine this theory of mountain ranges originating from compression of the crust induced by the shrinkage of the globe we prove it quite inadequate to explain the phenomena.

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[1] Mr. O. Fisher, taking the temperature of solidification at 4000° F. and the time at 33 million years, arrives at a total radial contraction of 2 miles. If the temperature of solidification were 7000° F. and the time 98 million years, the total radial contraction would be 6 miles. These calculations cover the whole of the time since first solidification, whereas the time I am dealing with is from the beginning of the Cambrian, probably not half the time that has elapsed since the first solidification of the globe.—See Fisher, Phil. Mag. 1888, pp. 7–20.

On the contrary, we find that the cooling shell of the globe for a depth of 145 miles below the level-of-no-strain is actually contracting, but in degrees, varying with vertical position; that the stresses are tensile, rupture being avoided by the gravitation of the overlying masses closing up otherwise possible cavities by compressive extension.

But if we look at the globe as a mass which is not losing heat equably but is contracting at one locality and expanding at another, though still on the whole undergoing secular refrigeration, it will not help what is known as the "contraction theory" of mountain building. The effects calculated in this paper as possibly due to the condensation of the shell of compression will be less, more irregular, and difficult to trace out. Indeed, so much so that the disturbing causes will have far greater effect than general secular contraction, and while adding to the lateral movement in one place may efface it in another.

Effects of unsymmetrical cooling on the outer envelope of the Earth.

Having now, as far as my limited powers of exposition allow, stated for your consideration my views on the effects of symmetrical cooling on a homogeneous heated globe, comparable in size with our earth, and partly traced some of its possible geological effects on the outer envelope, it is time to consider quantitatively some of the disturbing agencies which are constantly at work to modify the sum of the results.

First then, and most important as initiating other movements, is that of sedimentation. Those who are not familiar with geology will pardon me for stating that the gross thickness of all the sedimentary formations of the earth is estimated by competent authorities at as much as 100,000 feet,[1] but it must be understood that these never occur together in one geological column. The statement is sufficient to invest sediments with considerable interest to physicists as modifying in several important ways reasoning based on hypothetical conditions, though they are hypotheses that are absolutely necessary to be made before the actual problem can be efficiently attacked.

The greatest actual thickness of sediment piled up in one spot in almost unconformable succession is found in great mountain ranges such as the Appalachians and the Alps, and has been estimated by competent geologists at from 8 to 10 miles.[2]

But below these is a mass of Archean rocks of unknown thickness which is certainly not the original unmodified crust of the globe.

The area of the sedimentaries is co-extensive with the continents

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[1] Sir A. Geikie, Pres. Address British Association, 1892.

[2] Judd, speaking of the Alps (Volcanoes, p. 295), says: "The united thickness of all sediments accumulated along this great line of subsidence between the Permian and Nummulithic periods probably exceeds 50,000 feet or 10 miles." Various American authorities estimate that the thickness of the Palæozoic system of the Appalachians reaches 40,000 feet; the Palæozoics and Mesozoics in the Wasatch 50,000; the Cretaceous in the coast ranges of California 20,000 feet, and in Shasta county 30,000 feet; the Palæozoic and Mesozoic of the Uinta 30,000.—See Le Conte—Theories of the Origin of Mountain Ranges, Journal of Geology, 1893, p. 544.

and islands, and they occupy in addition unknown regions under the seas and oceans. The Cretaceous and Tertiary rocks cover, or have covered, at least half the continental area of North America, extending through 60 degrees of latitude and being a thousand miles wide in the United States.

It is in this area the Rockies and related mountain ranges have been thrown up, involving Cretaceous and Tertiary rocks in their folds.

For the purpose of illustrating the effects of sedimentation on the earth's outer envelope as compared with that due to secular contraction we will assume an area 2000 miles long, 1000 miles wide, and 10 miles thick along a central longitudinal trough, but gradually thinning in lenticular but irregular fashion towards the edges. Let us further assume that 4 miles represents the average thickness of this group of sedimentary strata. This would augment the temperature of the bed-rock on which the sediment rests by 400° at the rate of 1° F. per 50 feet. This accession of heat would represent a linear expansion in one direction of 22,000 feet and in the other of 11,000. So that we have for one group of rocks, over what is only a local area of the globe or $\frac{1}{26}$ of the total land surface, a linear expansion of 4 miles in one direction and over 2 miles in the other to contrast with the 15 miles surface contraction of the whole globe, including land areas and ocean, since the beginning of the Cambrian.

The shortening of this area, if the shrinkage of the globe were equally divided over its surface, would only amount to $\frac{5}{8}$ of a mile in one direction and $1\frac{1}{4}$ miles in the other, through all the time that has elapsed since the commencement of the Cambrian. But for a true comparison with our sedimentary example, taking into account geological time, we may divide this by not less than 5, reducing the shortening of the area on the hypothesis of contraction to respectively $\frac{1}{8}$ and $\frac{1}{4}$ of a mile. But when we come to contrast with this the effects of cubical or voluminal expansion instead of linear, it will be seen that the thermal expansion of the rocks due to sedimentation is still more in excess of any possible accumulation of volume due to the shell of compression as possibly affected by such contraction.

The increase of temperature is not, as I have before explained, limited to the sediments; it affects in turn the whole cooling shell below and raises its temperature in a corresponding degree. I think it will be quite fair to take this as equal to raising the temperature of the outer envelope 400° to a depth of 20 miles. These are only intended to be illustrative figures, applying to a small section of the earth in space and a small section in time. If we cube up our hypothetical block when expanded, and compare it with its volume before expansion, we shall find that we have in round figures 241,000 cubic miles for mountain building and other orographic changes, as against 26,000 cubic miles produced by the approach of the shell of compression over a similar area to a similar extent; while in the second case of $\frac{1}{8}$ and $\frac{1}{4}$ of a mile the disparity is so enormously increased as to show its absolute incapacity to explain any orographic features whatever.

Effects of Local Shrinkage through Denudation.

If instead of 4 miles mean thickness of sediment being laid down on the given area of 2000 by 1000 miles, we assume that the same mass has been removed from an equal area by denudation, and, supposing the crust to be free to shrink and could sustain its own weight, the area would be surrounded by trenches respectively 2 miles and 1 mile wide at the new surface. It necessarily follows that, even if the shell of compression were to follow the shrinking area up at the same rate, there would still remain cavities or trenches below the surface. Secular contraction it is evident could not be operative in producing compression in such a case. Local shrinkage of the crust such as we have assumed does not, however, act in this way. The weight of the crust itself squeezes up all vacuities, and the area adjusts itself to its decrease of volume by normal-faulting and keying up in a wedge-like manner and by compressive extension.

We have seen that the shell of contraction due to secular cooling is a real and important factor in the earth's economy. This general shrinkage decreases in rate in areas of sedimentation and increases in areas of denudation. It may perhaps be said that if these areas adjoin one will destroy the effect of the other. Such, however, is not the case, as I have shown that the expansion is internal shading off to zero at the boundaries. In the theory of the origin of the earth's folds by secular contraction it is assumed that the folded area is compressed from the outside; on such a supposition it is a perfectly legitimate inference that the shrinking area would be followed up by the closing in of the shell of compression, and one effect would destroy the other.

I further maintain that it is a physical impossibility for a layer of the earth 5 miles deep, really but a film upon the surface of the globe, not only to shear upon itself but to convey thrust through 1000 miles of strata in an effective manner. Even if we were to assume that this shell could shear upon itself and accumulate thrust in one place, the compression would be confined to a short distance from the boundary of the area and be inoperative in the centre where mountain ranges are usually thrown up.

The compression produced by expansion is *internal* and proportional to the depth of the sediment.

This is an important rule to bear in mind, for it largely determines the axial position of the range. The mere upheaval of some of the strata in anticlinal form will determine where the lateral pressure from the surrounding sheet of strata shall be used up. When one fold is compressed another follows up against it, and so the work of mountain building proceeds. From the comparatively great depth at which the internal expansion acts, underlying rocks are forced up into gneissic and granitic cores, and these expanding laterally by gravitation force back the folded strata and compress them still more, forming in many cases what is known as fan-structure. The very movement of these heated masses of rock forced up from below brings further heated masses to increase the temperature of the sediment and crust below it. I have shown experimentally that every variation of heat which takes place goes for mountain building, an increase producing a further compression of the folds and a decrease compressive extension or normal faulting. But I feel that time is short, and I must conclude without oppressing you with further details.

Résumé.

We have thus seen that changes caused by a fluctuating and irregular distribution of temperature in the crust through unsymmetrical cooling is a much more potent factor in producing the rugosities of the earth's surface than symmetrical secular contraction. There are other phenomena that it is necessary to take into consideration in any complete theory of mountain formation, but I shall merely note them here. The fact of the existence of piles of sediment 10 miles deep, or twice the depth of the deepest parts of the existing oceans, shows that the crust has sunk in such a locus to an abnormal extent. That this is due partly to the weight of the sediments is admitted by most geologists.

With a shell of contraction of the thickness I have shown, it is easy to see that any irregular distribution of weight must affect the crust by bending it, and this means also a disturbance of heated matter below. All these disturbances lead to heating and cooling of local areas, and this I have shown is the most potent cause of orographic changes. These lateral expansions take the form of ridging up; matter is actually moved towards the axis of expansion so that the ridgings up become permanent features until removed by denudation. The result of all the investigations of underground temperature show that the rate of augmentation downwards is very variable in different localities. We also know from the existence of volcanic tracts that the heated matter of the globe is there nearer the surface, and I have little doubt that the increase of heat downwards in certain areas is much greater than 1° F. per 50 feet.[1] No doubt the cooling of the earth takes place *on the whole* as inferred by Lord Kelvin; but sedimentation as one of the conditioning agents has not received the attention its importance demands. The earth, as I have shown, is covered with sedimentary matter in thickness to be measured by miles. Sediments many miles thick have been laid down, upheaved, crumpled and folded, denuded and again covered up by other sediments, the ruins of the old, often with volcanic additions from below.

The crust of the earth is in a constant state of change, none the less effective because slow as measured by our conceptions of time. The unloading of one portion of the earth's crust and the loading of another, the checking of the outflow of heat by sediments in one area and its acceleration in another by denudation, the movement of

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[1] Prof. Joseph Prestwich, in an exhaustive discussion of underground temperature observations, suggests that 45 feet per degree is nearer to the true normal.—Proc. Royal Soc. 1886.

fused or semi-fused matter in the crust, partly consequent on the repeated heating and cooling of the outer envelope and a lateral thrust produced at each rise of temperature, with faulting and wedging up to compensate for contraction at each fall of temperature, are in my view the potent causes of the external forms of the earth as they have appeared from age to age.

IV.—ON A SECOND BRITISH SPECIES OF THE JURASSIC FISH *EURYCORMUS*.

By A. SMITH WOODWARD, F.L.S., F.G.S.

THE occurrence of a fish generically identical with *Eurycormus* of the Bavarian Lithographic stone, in the Upper Jurassic of England, has already been indicated by the discovery of a well-preserved head with some anterior vertebræ in the Kimmeridge Clay of Ely.[1] Only one specimen, however, has hitherto been recognized; and during a recent search for further evidence of the fish among British fossils the present writer has thus been gratified to find two more examples in the collection of the British Museum. The one specimen was described many years ago by Sir Philip Egerton, under the name of *Macropoma Egertoni*, and is said to have been obtained from the "Gault, Speeton"; the other specimen is an obliquely-crushed head, with part of the squamation, found by Mr. Alfred N. Leeds in the Oxford Clay of Peterborough. So far as they can be compared, these two fossils agree in every particular, even in detailed measurements; hence they must be referred, for the present at least, to one and the same species.

EURYCORMUS EGERTONI (Egerton).

1844. *Macropoma Egertoni*, L. Agassiz, Poiss. Foss. vol. ii. pt. ii. p. 174 (undefined).
1858. " " P. M. G. Egerton, Figs. and Descript. Brit. Organic Remains (Mem. Geol. Surv.), dec. ix. No. 10, pl. x.
1866. *Eurypoma Egertoni*, T. H. Huxley, *ibid.* dec. xii. p. 32.

Description of Type Specimen.—The original description of the type specimen published by Egerton is so unsatisfactory, and gives so false an impression of some of the most important features of the fossil, that it seems advisable to attempt a new account. The head and anterior abdominal region are exposed in side view, as shown in Mr. Dinkel's drawing (*loc. cit.* 1858, pl. x. fig. 1); but the specimen is so much distorted by crushing, and fractured in front, that the apparent profile of the skull is entirely deceptive. The head is compressed by accident from side to side; the small left supra-temporal plate and the larger post-temporal are displaced upwards and forwards (the hinder margin of the post-temporal being described as "occiput" by Egerton); and the greater part of the rostral region is broken away, giving a false idea of steepness in profile in advance of the orbit. The supra-temporals form a single pair of triangular plates, and the occipital margin of the skull is evidently straight.

[1] Smith Woodward, "On a Head of *Eurycormus* from the Kimmeridge Clay of Ely," GEOL. MAG. [3] Vol. VII. (1890), pp. 289–291, Pl. x.

The cranial roof-bones are very coarsely rugose and partly tuberculated; the boundaries of the squamosals are distinct. The sclerotic capsule is ossified; there is evidence of large post-orbitals; and the long, narrow supra-maxillary bone is conspicuous. The maxilla is smooth, more than twice as deep behind as in front, exhibiting the usual re-entering angle in the hinder border, and beset on the oral margin with a single, regular, close series of small slender teeth. The dentary-bone, so far as preserved, is also smooth, and on the right side three or four of the shallow sockets for the large teeth of the anterior extremity are distinctly exhibited. The rami of the mandible are much pressed together, and between them there appears the large azygous jugular plate, which extends backwards at least as far as the hinder extremity of the dentary. Behind the jugular plate there follow the branchiostegal rays; and the large bones of the opercular fold are as obscure as indicated in Dinkel's figure. Remains of vertebral centra are distinctly shown at the posterior end of the fossil, either as complete rings or as half-rings; and there are long robust ribs. The fragmentary base of the dorsal fin is evidently crushed forwards by the pressure which displaced the left supra-temporal bone; and the large pectoral fin is too imperfect for detailed description. It can be seen, however, that the pectoral fin-rays are dichotomously branched and articulated distally. The ornamented scales, as displayed especially in the dorsal region, are well described and figured by Egerton.

Description of New Specimen.—The new fossil from the Oxford Clay of Peterborough (Brit. Mus. No. P. 6912) exhibits less of the trunk than the type and is obliquely crushed from above downwards. The cranial roof is much fractured, but agrees in every feature that is comparable with the foregoing specimen, the rugosity being especially marked. As preserved, the cheek-plates, opercular bones and post-temporals are darker in colour than those of the cranial roof, comparatively smooth and with sparsely arranged fine tubercles. On the left side the characteristic hinder extremity of the maxilla is preserved, and on both sides there are traces of the long supra-maxillary bone. On both sides also there are remains of large ant-orbital and post-orbital plates. The mandible on the left side shows the front border of the coronoid elevation and part of the series of large teeth in the dentary bone; while on both sides there are traces of minute splenial teeth opposed to somewhat larger teeth on an inner element of the upper jaw. The left pre-operculum is exhibited, showing a considerable expansion in its lower half, not much bent forward, and externally ornamented with rugæ and tuberculations. The sub-operculum appears to be about twice as broad as deep, and both this and the operculum are marked with very fine tuberculations. There are no certain traces of vertebral centra or ribs; but it seems probable that an annular elevation beneath the scales at one point on the ventral aspect is a displaced ring-vertebra, while some rods seen in cross-section at the back of the fossil may possibly be ribs. Only a small portion of the clavicle remains on each side, smooth on its external face, longitudinally ribbed at its anterior margin; and nothing more than part of the base of the pectoral fin can be observed on the right side. The scales are beautifully preserved and resemble those of the type specimen.

Specific Determination.—The length of the head in each of the fishes thus imperfectly indicated would be about 0·13m., and the species represented is therefore much larger than the typical *E. speciosus* of the Bavarian Lithographic stone.[1] According to the original description, the last-named fish is also distinguished by the smoothness of all the external bones. In size and characters the head of *E. Egertoni* agrees much more closely with that of *E. grandis* from the English Kimmeridge Clay. From this, however, it also differs in the remarkable rugosity of the cranial roof-bones, and apparently in the greater breadth of the squamosal elements as compared with the parietals. *E. Egertoni* is thus the third known species of the genus.

Formation and Locality.—Although the type specimen is said to have been obtained from the "Gault" of Speeton, Yorkshire (presumably the Speeton Clay), the horizon cannot be determined with certainty, even if the record of the locality be correct; for the fish is contained in a mass of indurated clay that has been much waterworn, evidently by rolling on the beach, and the matrix exhibits no invertebrate fossils by which its age can be recognized. The fact that it agrees exactly with the new specimen from the Oxford Clay of Peterborough is almost certain proof that the original *E. Egertoni* is not a Cretaceous, but an Upper Jurassic fossil; and the discovery of further specimens in the Yorkshire cliffs will be awaited with interest for the settlement of the stratigraphical question.

EURYCORMUS, sp.

Eurycormus will probably soon be recognized as having a still wider range in British Upper Jurassic formations than is now proved; and it is worthy of note that certain vertebral rings and hypocentra, not uncommonly met with in the Kimmeridge Clay of Weymouth, are more closely paralleled by those of this genus than by those of any other known fish. One such specimen (Brit. Mus., No. P. 6176) was figured by Mr. Damon,[2] and there are several others in the British Museum (Nos. 41181, 41231, 45926). There is one detached horse-shoe-shaped hypocentrum (No. 41231*a*) bearing a pair of pedicles (each perforated transversely by a foramen) for the support of ribs; and some of the complete rings exhibit a feeble oblique line on each side, as if formed by the coalescence of horse-shoe-shaped hypocentra and pleurocentra. These rings also bear a small pedicle or raised facette on the lower part of each side.

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[1] A. Wagner, "Monographie der fossilen Fische aus den Lithographischen Schiefern Bayerns," Abh. k. bay. Akad. Wiss., math.-phys. Cl. vol. ix. (1863), p. 707, pl. iv. A smaller fish, probably to be regarded as the young of *E. speciosus*, is also named *E. dubius* by B. Vetter, Mitth. k. mineral.-geol. Mus. Dresden, pt. iv. (1881), p. 113, pl. ii. fig. 7.

[2] R. Damon, "Geology of Weymouth," ed. 2, suppl. pl. xii. fig. 9 (1880).

V.—ON CHLORITE AS A SOURCE OF BIOTITE: A REPLY.

By CHARLES CALLAWAY, D.Sc., M.A., F.G.S.

I AM much obliged to General McMahon for criticising my recent paper in the GEOLOGICAL MAGAZINE (Dec. 1893, p. 535) on the "Conversion of Chlorite into Biotite," because I have been puzzled to know the exact nature of the opposition to my views on rock-metamorphism at Malvern, and I have been haunted by the fear that perhaps after all I might have overlooked something fundamental. Happily my curiosity is now gratified, and my fear is removed, so far as one important branch of the enquiry is concerned. As my critic is so good a chemist, I may conclude that the worst has been said that can be said from the chemical point of view.

The title of General McMahon's paper, "The Rape of the Chlorites," is a little startling. One is reminded of the author of *Nana.* I must confess to a little grief that any chemical or mineral pets of mine should be charged with impropriety and lawlessness, and I shall try to show that such aspersions are unfounded.

In his second paragraph my critic concedes a great part of my theory on the origin of biotite. Referring to the authorities quoted by me in support of this theory, he states that two of them deal with "cases of contact-metamorphism." He apparently agrees with these writers, for he goes on to say: "In cases of contact action, one can readily understand how aqueous acid vapours, or liquids, emanating from the molten igneous rock under high pressure, penetrated the adjoining rocks, and carried with them in solution some of the constituents of the igneous magma." It would therefore appear that General McMahon admits the conversion of chlorite to biotite by contact action; and, if so, I want to know why he opposes my theory.

For the last four or five years I have been insisting that, in the Malvern crystallines, biotite has been produced out of chlorite by "contact action." In 1889 I wrote:[1] "The most obvious fact observable in the field is the production of the biotite. Granite-veins, if of large size, that is, six inches or more in diameter, are often surrounded by a sheath of kersantite two or more inches in thickness. Indeed, so uniform is the effect of the contact that the vicinity of veins may usually be safely inferred from the appearance of biotite in the diorite." I do not think I could have spoken more distinctly than this.

Now if, as I understand my critic to concede, the hydrous mineral chlorite may, even in the presence of "aqueous vapours and liquids," be transformed into the anhydrous mineral biotite in cases of contact action, why should it be thought necessary to confine the contact effects to the exact point where the intrusive vein touches the enclosing rock? Contact effects extend to considerable distances from the intruding mass in Cumberland, in county Dublin, and elsewhere, and why should they not extend to a few yards' distance

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[1] Quart. Journ. Geol. Soc. Aug. 1889, p. 487.

at Malvern? In the shear-zones, where most of the biotite is formed, there is usually a plexus of granite-veins, and the diorite is so minutely sheared as to become in a high degree pervious to fluid injections. Where, then, is General McMahon's difficulty? So far as I can see, he has created it for himself. Let me elucidate this point.

After describing the nature of contact action, my critic goes on to assert that "in the case supposed by Dr. Callaway the conditions are altogether different." Are they? Whence has General McMahon derived his information on the point, if not from my papers? But I have never described the conditions as "altogether different." On the contrary, I think it probable that there is not a scrap of biotite in the crystallines of the Malverns which has been produced except by "contact action." I have, of course, dwelt upon the important effects of dynamic agencies; but I have insisted with equal emphasis upon the changes brought about by the intrusive granite-veins.

I may observe in passing that General McMahon attributes to me an assertion that in rock metamorphism the combined water of the chlorite has been driven off by heat. This is not quite accurate. In my last paper, I quoted the fact that in the laboratory chlorite loses its water at a red heat as a "proof that the affinity between the water and the other constituents of the mineral is not very strong"; which is quite another matter. I have not presumed to offer a complete account of the operation of the forces that were working deep down in the crust in Archæan times. Heat, chemical energy, and pressure no doubt co-operated, and who knows what other causes may have assisted in the schist-making?

General McMahon's amusing metaphor of the "Rape of the Chlorites" is suggested by a theory of the process of metamorphism which has no basis in my writings. He supposes that his maidens, the chlorites, are in one part of the rock regarded as highly heated; and his Roman soldiers, the potash and iron,[1] in another part, considered to be much cooler. This could by no possibility have been the case. The soldiers and the maidens were living in the same house, only waiting till the affinity between them should grow strong enough to draw them into the bonds of lawful wedlock. My critic's misapprehension seems to have arisen from a confusion as to the order of events in the schist-making process.

I have frequently described sections which show a passage between a diorite and a biotite-gneiss. Where the diorite is slightly crushed, there is a good deal of liberated iron-oxide. Further along the section, where biotite begins to appear, the visible iron decreases in quantity, having been partially used up, as I have elsewhere shown, in the genesis of the biotite. General McMahon says that this iron (together with potash) has got to rush from one locality to another, like Roman soldiers sacking a town. But this is pure imagination. Surely it is quite obvious that the succession of events which we now witness in geographical series was once a

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[1] I have not taken any account of the alumina, since the percentages of that oxide in the chlorite and the biotite are roughly equal.

succession in time on the same spot. A mass of diorite begins to suffer from a crushing process, aqueous solutions, in which both carbonic acid and potash occur,[1] soak into it, and chemical changes take place. The pressure increases, shearing supervenes, the temperature rises, and certain other chemical reactions result. There is no rushing about from one place to another. All the materials for the genesis of the biotite are already present, before the higher temperatures set in.

To be more precise I will briefly state some of the actual changes, as observed in the field and the microscope, and confirmed by chemical analysis. Crystals of hornblende and felspar are lying side by side. Some of the latter contain potash, perhaps as the result of contact action. Crushing sets in, and foreign solutions enter the rock. The crystals of felspar are broken to fragments, and some of it is decomposed, alkalies and lime being liberated. The hornblende also is crushed and decomposed, chlorite, iron-oxide, and calcite being produced. The materials for the production of the biotite are present, but increased heat and pressure are necessary to excite the required chemical affinities. In an advanced stage of the metamorphism, the water of the chlorite, and some of its magnesia, are driven out, and their place is taken by iron-oxide and potash. That, at high temperatures, iron has a strong affinity for silica, is proved by the well-known fact that, in the consolidation of igneous magmas, iron-silicates come very early in the order of crystallization. According to Lagorio they come next to oxides and before any other silicates.

I do not think that General McMahon will attach much importance to his objection that, if the temperature of the rock "rose to the point of fusion," the chlorite must have been melted down and merged in the general magma, and, therefore, could not have given rise to biotite. It is sufficient to remind him that the fusing-point of chlorite is much higher than that of felspar, and that, in granite, quartz usually consolidates after felspar. It would, therefore, be exceedingly rash to assume that a temperature which would fuse quartz and felspar,[2] which form the bulk of the rock, would also melt the chlorite. My assertion that, in scores of sections, chlorite is seen to be replaced by biotite as we approach the granite-diorite shear-zones, will hardly be invalidated by such a speculative objection as this.

My critic denies that the conversion of chlorite to biotite is "an observed fact." But, surely, if Lossen, Michel Lévy, Salomon, and Rüdermann, not to mention my humble self, have observed the change, it may fairly be regarded as proved. Besides, I thought that General McMahon himself admitted that the thing might be true as the result of "contact action." I confess I do not quite understand his position.

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[1] Not necessarily contemporaneously as potassium carbonate.

[2] Professor Redway, of Mount Vernon, New York, commenting on my Malvern papers ("Science," February 9th, 1894), describes the fusion in the shear-zones as "sufficiently complete to produce plasticity."

This question of rock-metamorphism is deserving of full consideration. If I have not made myself clear to my critic, or to any other of the readers of this MAGAZINE, I shall be glad to give further explanation; and, if I am wrong, I will engage to surrender to General McMahon and his legion of Roman soldiers.

VI.—ON VARIOLITE AND OTHER TACHYLYTES AT DUNMORE HEAD, CO. DOWN.

By GRENVILLE A. J. COLE, M.R.I.A., F.G.S.
Professor of Geology in the Royal College of Science for Ireland.

WHILE examining the dykes along the coast of Mourne in the company of Mr. R. Welch, I came across an additional example of intrusive variolite, the occurrence of which seems worth recording. The mass is, in this case, a thin one, about 20 centimetres in width, narrowing and dying out as it is traced northwards; it runs in a somewhat sinuous course along the strike of the uptilted strata. Every other dyke that I have seen upon this richly favoured coast cuts across the Ordovician beds, and the present instance to the contrary may be only a lateral sheet-like offshoot from one of the familiar basalts.

This variolite occurs on Dunmore Head, just south-east of the summit of Dunmore Hill, and a little below the level of high-water. The handsome and massive variolite of Annalong[1] lies some 2½ miles to the south.

The thin intrusive sheet is minutely spherulitic upon its selvages, but passes rapidly into a typical variolite, with spherulites 3 mm. in diameter. These bodies weather out in pale tints against the dark grey-green groundmass. The specific gravity of a large typical specimen is 2·86, being nearly as high as that of the variolites of the Western Alps (2·90), while the rock of Annalong yields only 2·72.

In the example from Dunmore Head we have a variolite obviously connected with ordinary tachylyte, and it seems unnecessary to again urge the relationship between the two rocks, variolite being merely an altered form of the more coarsely spherulitic types of basic glass. Professor Zirkel,[2] in preferring to regard the rock of Annalong as a "sphaerolithführendes Diabasglas" rather than as a true variolite, practically admits the impossibility of maintaining variolite as a distinct rock-species. The name is a convenient term for specialists, like the corresponding word "pyromeride," in the classification of highly silicated rocks; and it has by far too great an antiquarian interest to be thrust aside into oblivion.

At Annalong the dyke is bounded by a film of tachylytic glass 5 mm. in thickness; but the main mass is an indubitable variolite. The rock of Dunmore Head has an altered groundmass, with traces of glass on the extreme selvage; but the spherulites are far more fresh and interesting than in the variolites that I have hitherto examined. Under the microscope they are seen to be composed,

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[1] Proc. Roy. Dublin Soc. vol. vii. (1892), p. 511.

[2] "Lehrbuch der Petrographie," 2te Auflage (1894), 2te Band, p. 704.

not of feathery bunches of felspathic rods, but of "cryptocrystalline" material with a delicate radial structure, thus resembling more closely than usual the spherulites of rhyolitic rocks. Their colour in reflected light is greyish-white, and in transmitted light grey-brown and yellow-brown; a certain amount of magnetite has formed in dusty aggregations round about them, or along the lines of junction of their component groups of fibres. As has been observed in the spherulites in the tachylyte of Ardtun, the yellow-brown material is distinctly pleochroic.

Cracks traverse the spherulites freely, passing also across the groundmass; but I have found no trace of the "pseudo-crystals" that are so prominent a feature in Continental variolites. The cracks have originated from subsequent earth-movements, probably at the time of the intrusion of the great granite masses of the Mourne Mountains, which cut off so many of these coast-dykes abruptly.[1]

Some of the spherulites, however, have been broken up by the fluid glass, which has entered in between the detached fragments and has formed a microscopic network of intrusive veins. In several cases an early phase of the rock is revealed to us by the occurrence of crystals of plagioclase as nuclei to the spherulites. These crystals have been greatly corroded by the magma round them, and many of them must have been entirely absorbed. The glass intruded into them is crowded with globulites; but its present condition does not enable us to judge of the character of the original unaltered magma.

The altered glass forming the groundmass of the variolite is, as usual, greenish; in large part it is chloritized, but epidote has only locally developed. A minute spherulitic and cumulitic structure was originally present in it, and may be very generally traced. Perlitic structure may have also occurred, but it is only obscurely discernible in one of the six sections that I have studied.

This rock gives no evidence as to whether it is the spherulitic representative of a basaltic andesite or of an olivine basalt. I have no hesitation in classing it as a variolite, and it is, I believe, the fifth known representative of this rock in the British Isles, the others being in Anglesey, the Lleyn, Co. Wicklow (near Roundwood), and at Annalong. It may perhaps be one of the "variolites" noted in 1835 by Major Patrickson, who names the rock once or twice in the region to the north of Annalong.

A very compact black rock, with minute spherical amygdaloidal vesicles, occurs as a thin dyke between Dunmore Head and Green Harbour. It has the high specific gravity of 2·93. In section it approaches in beauty the rhyolitic pitchstones of Arran, while at the same time revealing its more basic character. Feathery bundles and sheaves of felspathic materials are associated in the pale-green altered glass with long curving rods and plumes, presumably of pyroxene and magnetite. A few porphyritic crystals of plagioclase are again the only constituents sufficiently developed to be identified with absolute confidence.

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[1] "Dykes appearing on the shore which skirts the Mourne Mountains." Journ. Geol. Soc. Dublin, vol. i. p. 182.

Another section, from the selvage of a large basaltic dyke in the same area, is a superb example of palagonite, the altered tachylyte having all the clear brown translucent character that is familiar in Icelandic and Sicilian types. Spherulitic aggregates of a more dusky brown colour began to form at one stage, but were in part redissolved in the fluidal groundmass. Abundant oval yellow-brown bodies, dark upon the exterior, occur in the palagonite, and are probably the minute spherulites of the last phase of consolidation, deformed by the flow at the edges of the dyke.

It is only by the brilliant play of colours when the section is viewed between crossed nicols that one discovers that this beautiful and apparently unaltered tachylyte has passed thoroughly into the palagonitic and micro-crystalline condition.

Enough has now been noted to confirm what was remarked two years ago as to the frequency and variety of vitreous andesites and basalts on this interesting coast of Mourne. I still feel that in all probability this assemblage of dykes is of early Eocene age.[1]

VII.—An Ancient Glacial Shore.

By Joseph Lomas, A.R.C.S., F.G.S.

For some time I have had under observation the sections of drift exposed in the cuttings of the Seacombe branch of the Wirral Railway, and hope to describe them on some future occasion when the sections are nearer completion.

However, Mr. Mellard Reade has forestalled me[2] in the description of one part of the sections, and professes to have found in them evidence of "an ancient glacial shore." What does he produce in favour of the statement?

In the first place "the bed is composed of pretty clean sand with some small gravel, and is crowded with shell fragments in all stages of decay." Secondly, it is of large extent and has a gentle slope. Thirdly, rolled clay balls are found mixed with the sand.

The bed in its composition does not differ from the ordinary sands and gravels found so commonly in the glacial deposits of Lancashire and Cheshire.

Some of these contain rolled clay balls (though I have never met with a section which displays them in such abundance). Some equal or exceed the present example in extent. They often contain shell fragments, which are sometimes planed and striated like ordinary boulders. It is noteworthy, too, that the shelly deposits only occur in places where we can prove by independent evidence (such as boulder transport and glacial striæ) that the ice to reach that place must have traversed a sea bottom.

The beds are usually lenticular in shape, slope at all angles and occur at all horizons. Two or three may often be seen above each other in one section. Shall we consider all these as "ancient glacial shores?"

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[1] See Proc. Roy. Dublin Soc. vol. vii. (1892), p. 518.

[2] Geol. Mag. Feb. 1894.

Some years ago I described before the Glacialists' Association beds of gravel containing rolled clay balls, occurring at Offerton and Romiley in Cheshire. These beds form the cores of glacial mounds which can be exactly matched by mounds now being formed by glaciers in places the sea does not reach.

The most ardent supporters of the submergence hypothesis would, I think, hesitate before attributing such mounds to shore action, even though they contain clay balls.

Is the presence of clay balls in a deposit proof of shore conditions in a tidal sea? Running water may be essential to their formation, but surely there would be enough of that in the drainage system of a great glacier.

But we are told "if they were constantly immersed they would get dissolved." Why have they not been "dissolved" out in their present situation? The conditions could hardly have been more favourable, for the gravel lies between two impervious beds of boulder clay and forms a natural line of drainage.

The reason is best given in Mr. Reade's own words. The "balls are covered over their surface with small gravel, shells and sand." They are thus armour-plated, and Sir Henry de la Beche[1] pointed out the significance of this fact long ago. He shows that clay containing fine gravel would not be acted on by running water with a velocity of less than 12 inches per second.

It is then no question of getting "partially dried during recession of the water twice in 24 hours," and their presence in a bed affords no evidence of tidal action.

Glacialists will thank Mr. Reade for responding to their request to show them the shore lines of the supposed glacial sea, but to be convincing they must be supported by evidence different from that given in his paper.

Postscript.—Since the above was written an article has appeared in the *Glacialists' Magazine* (March, 1894) by Prof. N. H. Winchell, State Geologist, Minneapolis, Minn., on "Pebbles of Clay in Stratified Gravel and Sand."

He gives several instances of clay balls occurring in stratified drift in America, and in places where marine action was quite out of the question.

He concludes that clay balls "may be produced and embedded in gravel and sand which was the direct result of the wastage of the glacier, and that they are not unquestionable evidence of the former action of an oceanic shore line."

VIII.—ON THE OCCURRENCE OF PIGOTITE IN THE CAVES NEAR PORTHCURNOW, ST. LEVAN, CORNWALL.

By J. K. CREIGHTON.

HAVING heard from my esteemed friend and colleague, Mr. J. W. Wetherell, that some years ago a brown crystalline substance had been found in a cave close to the sea, and situate

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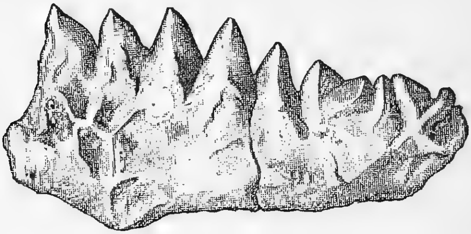
[1] Geological Manual, p. 51.

between Porthcurnow and Porthchapel, I was impelled to make a search for the mineral. Last July I succeeded in finding a cave near Porthcurnow, the small opening into which was partially hidden by masses of fallen rock; here I found after a rough examination traces of the mineral for which I was looking. In the course of the next few days I made a complete survey of the cave, which is about 75 feet long and 15 feet wide, and varies from 10 to 15 feet in height. At some distance from the opening is a large block, which permits only little light to reach the farther end of the cave; the greater part of the block is covered with a crust, varying from 1 to 15 lines in thickness, of the mineral in question; the crust had apparently been a result of the continuous drip of water from that part of the roof which is immediately above. Other crusts found at the farther end of the cave were from 10 to 30 lines in thickness. As the nature of the mineral was not known to anyone in the neighbourhood, I sent a fragment to the Natural History Museum at South Kensington, where it was examined by Mr. Fletcher. He sent me the following information:—"The dark brown fragment is opaque in the mass, but transmits light of a rich red colour through its thinner edges; it has the lustre, fracture, brittleness, low specific gravity, and indeed the general aspect, of an ordinary resin; to one's surprise, however, a flake held in a gas-flame refuses to burn. Heated on a platinum lid to a red heat, a fragment slowly burns away, and, after final heating with the blowpipe, leaves a grey ash; heated in a glass-tube open at only one end a fragment gives off much water and empyreumatic products, and leaves a black mass behind. The powdered mineral is of a yellow colour. These characters and behaviour indicate that the substance you have sent me is identical with a mineral described before the Royal Society more than fifty years ago by Mr. James F. W. Johnston, M.A., F.R.S., and named by him Pigotite after the Rev. M. Pigot, the co-discoverer."



Mr. Fletcher at the same time sent me a copy of Mr. Johnston's paper, from which I find that the resin, "which had been found as an incrustation on the sides of certain caves occurring in the granitic cliffs on the east and west coast of Cornwall," was regarded as a chemical compound of alumina, a new organic acid (mudesous acid) and water. As regards its mode of origin Mr. Johnston says "the organic constituent of this substance may be considered to be derived from the decay of the various plants which grow on the moist moorlands above, and which, being carried by the waters into the fissures of the granite beneath, combines with the alumina of the decomposed felspar; and when it reaches the air deposits itself on the roof and sides of the caverns in the form of layers, varying from a line to two or three inches in thickness."

The mode of occurrence in the cave near Porthcurnow agrees with the description given by Mr. Johnston: over the cave grow furze and bracken, and in the cave itself is a remarkable moss; fissures are visible in the roof at the farther end. The back of the cave gradually slopes towards the above-mentioned block.

The Pigotite is also found on the roof of the cave, but there has a different form, the surface being rippled and the ripple-marks being in some cases most distinct in character; in rare cases the form is serrated or dentated, and is suggestive of a mimicry of certain fossil remains, reminding one of the teeth of *Ceratodus* from the Rhætic beds (see Woodcut, p. 224). The frangibility of the mineral makes it difficult to obtain large specimens of any kind.

In the following month, from another cave only accessible at certain tides, I obtained a small amount of Pigotite with somewhat different characters; it was more transparent, and in some cases of a rich yellow colour, in others ruby red; this kind has the general form of an efflorescence.

It may be hoped that the rediscovery of this mineral may induce some chemist to make a more complete examination of so extraordinary a compound.

NOTICES OF MEMOIRS.

On the Structure of the French Alps. By Professor Marcel Bertrand. Translated from *Comptes Rendus.*

FOUR years' work in the Maurienne and Tarentaise at first led me to adopt the views of our Italian colleagues with regard to the "lustrous schists," and to consider them Palæozoic in age. This year, however, I have found conclusive sections which compel me to return to the old opinion of Lory, and to assign them to the Trias and even in part to the Lias. The proofs, which I shall give elsewhere, are closely connected with general conclusions on the structure of the region studied, and may even I believe extend to the whole chain. It is these which I wish to enumerate briefly here.

(1) The French Alps possess fan structure. The Carboniferous belt, stretching from Bourg St. Maurice to Briançon, is the centre of the fan. Along its edges on either hand there is a sort of narrow frontier zone in which the exact direction of overthrusting is uncertain; but, once this zone is passed, all the folds on the east

side incline towards Italy, and all those on the west towards France.[1]

The exceptions to this rule, such as the fans of Mont Blanc and St. Gothard, are infrequent and accidental. Side by side with classic sections of these massifs, which show fan structure, I believe that one could cite others, parallel, where it is wanting. Besides, such exceptions are only to be seen on the flanks of the "amygdaloidal massifs," to which I shall shortly refer.[2]

Towards the north-east on reaching the (Swiss-Italian) frontier the central zone swells out considerably, so as to embrace *the whole Monte Rosa massif*; in this broadened zone the folds are not inclined in any one determinate direction.

On the south the zone undergoes a more extraordinary change; instead of being occupied, as seems natural, by the most ancient rocks arranged in an anticlinal, it is made up of the most recent rocks, the nummulitic beds, and the flysch. *The central zone is marked, geologically speaking at least, not by an uplift but by a depression.* A preliminary note by MM. Kilian and Haug has told us that in this new region (nummulitic band of Ubaye) there seem to be peculiarities altogether unique in the Alps—inclined folds of pre-Eocene date. Possibly these peculiarities can be correlated with the great and sudden lowering of the central zone of the fan. However that may be, the Eocene band, from the point of view of the inclination of the folds, certainly plays the same part as the Carboniferous belt; all the western folds incline towards France, all the eastern ones towards Italy. Moreover, further on, the Mercantour massif, rising within the Eocene belt, marks a temporary return to a sharply anticlinal form. It seems to me, on comparing the folds of which the bearing is known in the intervening region, that the centre of the Alpine fan corresponds exactly with that of the Pyrenees.

(2) The plan of the folds in this part of the Alps shows *an "amygdaloidal or beaded structure"* (une structure amygdaloïde ou en chapelets), that is, the folds, while following the general trend of the chain, open out here and there round elliptical lenticles, themselves broken by new folds which have the same direction but are not prolonged beyond them. The system thus presents a series of nodes and ventral segments comparable with the foliation of an augen (amygdaloïde) gneiss, in which the folia bend round great kernels (noyaux) of quartz and felspar.

To give an idea of the importance of such kernels I will cite first

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[1] It is by virtue of this fan structure that the relatively recent date of the "lustrous schists" can be demonstrated. Throughout almost the entire range of these schists order of superposition proves nothing, because the structure is uniclinal. Fortunately certain great patches are still left on the summit of the fan. Thus not only is evidence of superposition perfectly clear, but it is such as to allow no other interpretation.

[2] There would be, it is true, an important exception if the massifs of Annes, the Chablais, the Faulhorn, and the north fold of Glarus are, as is usually maintained, true anticlinal masses. This exception would disappear if they are overthrust masses. Thanks to the work of M. Schardt, attention is now definitely drawn to this problem, which I believe to be on the eve of solution.

the example of Mont Blanc, a great kernel rising in the middle of a Liassic syncline, which shuts in round it. In the region to which I have devoted special attention, the Vanoise, Mont Pourri, with the Aiguille du Midi, the massif of the little Mont Cenis, and probably that of the Grand Paradis, all owe their existence to a like phenomenon; on the other hand, the massif of the great Sassière, and that of the Sana, are due to the sudden broadening of synclinals; in place of the ancient rocks it is the most recent ones which are here developed, but the system of folds sweeps round these widenings in just the same fashion and opens out and shuts in round them.

I do not think that we have, at least on a large scale, anything strictly comparable to this *amygdaloidal structure*, unless it be the crystalline region of the Lake of the Woods in America. Mr. Lawson derives one of his arguments from this structure to prove that the kernels formed of granitoid gneiss are eruptive in origin. Without contesting Mr. Lawson's conclusions on this ground we may point out from the structure of our Alps that this argument, if it stood alone, would be valueless.

(3) A third conclusion is the generalization of that which M. Termier has already drawn from the study of Vanoise. *On the east of the Carboniferous band metamorphism increases from west to east.* I am driven, as was M. Termier in the Vanoise, to place confidently in the Permo-Triassic the ancient chloritic gneisses and mica schists of Mont Pourri, little Mont Cenis, and of the Val Grisanche, a continuation of the "*Casanna schists*" of Gerlach. Most of these arguments apply to the augen gneisses of the Grand Paradis, that is those which have been designated central gneiss; this would be a last term of the same metamorphism. It is to be noticed that in certain masses like the Dent Blanche and Monte Rosa we see, according to Gerlach, rising like an anticlinal from under this gneiss (or Casanna schist) still more ancient gneiss pierced by numerous granite veins, whilst such veins are absolutely wanting in the massifs previously cited; this is certainly a new argument. No region offers a more favourable field for continuing those micrographic studies so brilliantly inaugurated by M. Termier in the Vanoise, and it is to be hoped that we may be able to follow up in the formation and arrangement of the minerals all the stages to what it is at present convenient to term true gneiss.

This conclusion is analogous to that which M. Lossen has established for the ancient Hercynian Chain, where the Devonian in a similar central zone, situated, however, rather south of the centre, takes the form of mica schists and gneiss. It is right also to recall that M. Suess in 1869 made out a link between certain gneisses of the Carnic Alps and the Casanna schists in attributing a Permian age to them both.

I think it right to add that in favour of this last conclusion, at least in its general form, one can at present only give arguments, and not proofs, so that it is as well to separate it from the first twopropositi ons, which appear to me to be definitely established.

REVIEWS.

I.—DESCRIPTION DE LA FAUNE JURASSIQUE DU PORTUGAL. EMBRANCHEMENT DES ÉCHINODERMES. Par P. DE LORIOL. Commission des Travaux Géologiques du Portugal. pp. 109-179; pls. xix.-xxix. (Lisbonne, 1890-91.)

THIS is the second and concluding part of M. de Loriol's admirable monograph on the Jurassic Echinoderms of Portugal. It first treats of the Irregular or Exocyclical Echinoids, of which 16 species are described, belonging to the genera *Holectypus*, *Pygaster*, *Pileus*, *Pyrina*, *Echinobrissus*, *Pygurus*, and *Collyrites*. Several of the species occur also in the corresponding Jurassic beds in this country. Of the Starfishes, only one species, *Aspidaster Delgadoi*, de Lor., has been met with, which is the type of the genus. The author considers that the well-known *Oreaster bulbiferus*, Forbes, from the Upper Chalk of this country, subsequently placed in an existing genus, *Pentaceros*, should rightly be included in *Aspidaster*. There are 34 species of Crinoids belonging to the following genera: *Dolichocrinus*, *Millericrinus*, *Pentacrinus*, *Balanocrinus*, *Extracrinus*, *Antedon*, and *Thollieri-crinus*. Some of the species are based merely on the characters of portions of the stems, more particularly amongst the Pentacrinoids, and in the genus *Balanocrinus* there are six species described wholly from joints of the stem; neither in Portugal nor elsewhere has the calyx of this genus been yet brought to light. In his description of *Eugeniacrinus caryophyllatus*, M. de Loriol points out the importance of Mr. Bather's observations on the presence of basals in a certain stage of the development of this form, which have evidently in the course of its growth been absorbed into the first radials; at the same time he thinks it correct to define the genus *Eugeniacrinus* as without basals, since in the mature stage of the animal, on which the generic characters are based, they are no longer present. In the family of the Eugeniacrinidæ, however, some genera, as *Trigonocrinus*, Bather, and *Dolichocrinus*, de Lor., have basals preserved in the calyx; but the author follows the late Dr. H. Carpenter in excluding from it *Eudesicrinus*, de Lor., which comes properly into the family Holopidæ. In another very peculiar form, *Dolichocrinus aberrans*, de Lor., likewise placed in the family Eugeniacrinidæ, basals were clearly present, and the first radials, five in number, are extremely long, and form by their union a cylindrical tube deeply furrowed in its interior.

In the first part of this monograph 95 species of Endocyclical Echinoids were described, thus bringing a total of 146 species of Echinoderms in the Jurassic strata of Portugal, of which 69 are new forms. This number is relatively small when compared with those known from the corresponding strata in France. The Lusitanian stage of M. Choffat, which comprises the higher horizons of the Jurassic strata in Portugal, is most prolific in Echinoderms. A notable feature is the enormous predominance of the Endocyclical over the Exocyclical Echinoids in the Portuguese Jurassic.

The different forms are fully illustrated in the accompanying ten lithograph plates, and we may congratulate the Geological Survey of Portugal on the satisfactory manner in which it has published this monograph.

II.—REPORT ON THE FORAMINIFERA DREDGED BY H.M.S. "GAZELLE," DURING THE YEARS 1874–76. By Dr. J. G. EGGER, etc., etc. With one Chart and 21 pages of figures. 4to. Munich, 1893. [FORAMINIFEREN AUS MEERESGRUNDPROBEN, ETC. Abhandl. k. bayer. Akad. Wiss., ii.Cl., xviii.Band, ii.Abtheil.]

NEARLY all the Foraminifera, from Nummulites downwards, are of interest to Geologists; for in many instances they go far to constitute the mass of rock; and often their particular forms, or the general facies of a series, characterize certain groups of strata. For instance, the special *Carboniferous* Endothyræ and Fusulinæ,—the poor breed of Nodosariæ and Cristellariæ in the *Lias* and *Oolites*,—the manifold arenaceous species in the *Jurassic* clays,—the well-grown Nodosariæ and Cristellariæ of the *Cretaceous* formations,—the distinctly-various *Lower-Tertiary* Nummulites,—the Polymorphinæ of the *Lower Crag*,—and the large Nodosariæ and Cristellariæ in the *Upper Tertiaries* of Italy. Some such groups are met with in existing seas; and other groups of living Foraminifera dominate here and there.

This fact is well shown in Dr. Egger's Report on the deep-sea Foraminifera obtained by H.M.S. "Gazelle," sent out by the German Government in 1874. The scientific results of this voyage were published in 5 vols. 4to. Berlin, 1888–90, excepting this Report, which has been communicated to and published by the Munich Academy of Sciences.

Precise economy has been practised in the production of text and plates. For the nomenclature and synonomy the reader is referred, for the most part, to Dr. H. B. Brady's Report on the Foraminifera dredged by H.M.S. "Challenger" (2 vols. 4to. London, 1884); and the multitudinous figures are massed in 21 pages of the text, having been copied and printed by the Meisener-Riffarth process. Thus the Porcellanous forms are closely grouped, as 189 species, in plates i. ii. and iii. at pages 26, 35, and 49; the Arenacea in plates iv. and v. with 98 species, at pages 60 and 67; Textulariæ in pls. vi. and vii. with 108 species, at pages 76 and 85; and so on with the Hyalina; Bulimina, Polymorphina, Lagena, Nodosaria, Cristellaria, Globigerina, etc., having separate pages, on which the crowded types and varieties may be studied at once, at pages 90, 114, 128, 146, 157, and 164. Eight more pages, of 411 figures, are devoted to the Rotalians and other interesting forms.

This wealth of illustrations, crowded into 21 pages, if not good as artistic plates, are yet very good and useful as galleries of portraits, bringing whole collections of types and their varieties—the heads of families and all their collateral relatives—under the eye at once and in close proximity to one another. T. R. J.

III.—CONTRIBUTIONS À L'ÉTUDE DE LA FAUNE JURASSIQUE DE NORMANDIE. PREMIER MÉMOIRE SUR LES TRIGONIES. Par A. BIGOT. Mémoires de la Société Linnéenne de Normandie, xvii^{e} volume, 2^{e} fascicule. 4to. pp. 261–345, pls. viii–xvii. (Caen, 1893.)

THE collection of fossils belonging to the Faculté des Sciences of Caen comprises a large number of *Trigonias,* which have been mostly obtained from the same beds and localities of the Jurassic series in Normandy which furnished the type specimens described by Agassiz and by D'Orbigny. The late E. E. Deslongchamps made a preliminary study of these forms, without, however, leaving behind more than a few notices respecting them; his successor, Prof. Bigot, has undertaken their investigation afresh, at the same time retaining the MS. names which Deslongchamps had bestowed upon the new species. This Memoir treats of the forms from the Inferior Oolite, the Great Oolite, and the Oxford and Kimmeridge Clays of Normandy, but it does not include those from the Lias of the same region, nor the Portland species from Bray, which latter have, moreover, been carefully studied by Munier Chalmas, de Loriol and Pellat. In all, Prof. Bigot here describes about fifty species, amongst which twenty-one are new.

In his introductory remarks, the author considers that the section "Glabræ" of Agassiz might be suitably divided into three; a grouping already in part suggested by Lycett. The first of these, "Semi-læves," includes *T. Lingonensis,* Dum., *T. Beesleyana,* Lycett, and *T. Eudesi,* n.sp., from the Lias, Bajocien and Bathonien respectively. The second, "Gibbosæ," has for its principal species *T. gibbosa,* Lycett, *T. Manselli,* Lycett, and *T. Damoniana,* from the English Portland Beds, and five other species from the Upper Jura of France. In the third section, "Excentricæ," are ranged species which commence in the Upper Jura and continue into the Cretaceous; the typical species are, *T. excentrica,* Sow., *T. læviuscula,* Lycett, and *T. Boloniensis,* de Loriol.

The detailed descriptions and excellent figures which Prof. Bigot has given of these Normandy forms are of particular interest to English students of *Trigonias,* in view of the fact that the types of more than one-third the number of the species here described belong to the Jurassic rocks of this country, and the author's review of the descriptions of Lycett, Morris and Sowerby deserves the most careful consideration. G. J. H.

REPORTS AND PROCEEDINGS.

GEOLOGICAL SOCIETY OF LONDON.

I.—March 7th, 1894.—Dr. Henry Woodward, F.R.S., President, in the Chair. The following communications were read:—

1. "The Systematic Position of the Trilobites." By H. M. Bernard, Esq., M.A., F.L.S., F.Z.S. (Communicated by Dr. Henry Woodward, F.R.S., P.G.S.)

The author, in his work on "The Apodidæ," endeavoured to show that the *Apus* was the ancestral form of all existing Crustacea except the Ostracoda, and as such might be expected to throw light upon the Trilobites. Since the publication of this work he has been studying the organization of the trilobites themselves, and the results are given in the present communication. He discusses the great variability in the number of segments shown by the trilobites; the formation of the head by the gradual incorporation of trunk-segments; the bending round ventrally of the first segment; the "wandering" of the eyes; the existence and modification of the "dorsal organ;" and especially the character of the limbs.

As a result of this discussion, he states that the zoological position of the trilobites can now be fixed with considerable probability. The features described serve to connect the trilobites with *Apus*. *Apus* must be assumed to lie low in the direct line up from the original annelidan ancestor towards the modern crustacea, and the trilobites must have branched off laterally from this line, either once or more than once, in times anterior to the primitive *Apus*, as forms specialized for creeping under the protection of a hard imbricated carapace, obtained by the repetition on every segment of the pleuræ of the head-segments, which together form the head-shield.

The trilobites may be briefly described as fixed specialized stages in the evolution of the crustacea from an annelidan ancestor with its mouth bent round ventrally, so as to use its parapodia as jaws.

2. "Landscape Marble." By Beeby Thompson, Esq., F.G.S., F.C.S.

The Cotham Stone is a hard, close-grained, argillaceous limestone with conchoidal fracture. The dark arborescent markings of the stone rise from a more or less stratified dark base, spread out as they rise, and terminate upwards in wavy banded portions of the limestones. In some specimens two "landscapes" are seen, one above the other, each rising from a distinct dark layer.

The author describes the microscopical and chemical characters of the rock, and its mode of occurrence, and discusses the explanations which have been put forward to account for its formation, especially that of Edward Owen, who in 1754 gave the first published description of the Cotham Stone, and that advanced by Mr. H. B. Woodward in the GEOLOGICAL MAGAZINE for 1892. He then proposes a new explanation to account for the formation of the rock, and maintains that its peculiar characters are due to interbedded layers of vegetable matter, which decomposed and evolved carbonic-acid gas and marsh-gas. This decomposition continued while several inches of new sediment were laid down, the result being that arborescent markings were produced along the lines taken by the escaping bubbles, and that the upward pressure of these gases, after their escape had been prevented by increasing coherence or greater thickness of the upper layers of sediment, caused the corrugations in the upper surface of the stone. He further discusses the composition of the stone, and describes experiments which he made to illustrate his views.

3. "On the Discovery of Molluscs in the Upper Keuper at Shrewley, in Warwickshire." By the Rev. P. B. Brodie, M.A., F.G.S.

Mr. R. B. Newton read a paper at the meeting of the British Association at Nottingham in 1893, on some Lamellibranchs found at Shrewley by the author of the present paper and Mr. Richards. In this paper details of the section where the shells were found are given, and their interest and importance pointed out, no shells having been previously detected anywhere in the New Red Sandstone in this country.

II.—March 21st, 1894.—Dr. Henry Woodward, F.R.S., President, in the Chair.

The President gave expression to the feelings of regret with which the Society had received the announcement of the death of Mr. William Pengelly, F.R.S., of Torquay. He had been a Fellow since 1850, and had taken a leading part in the exploration of Kent's Cavern, Torquay, and Brixham Cave.[1]

The following communications were read:—

1. "On the Origin of certain Novaculites and Quartzites." By Frank Rutley, Esq., F.G.S., Lecturer on Mineralogy in the Royal College of Science, London.

The novaculites of Arkansas have already been admirably described by Mr. Griswold in vol. iii. of the Arkansas Survey Report for 1890. One of the characteristic microscopic features in Ouachita stone is there stated to consist in the presence of numerous cavities, often of sharply-defined rhombohedral form, which Mr. Griswold considers to have been originally occupied by crystals of calcite or dolomite.

The author, while admitting that the cavities were no doubt once filled by the latter mineral, ventures to differ from Mr. Griswold, and some of the authorities he cites, concerning the origin of the rock. Crystalline dolomites, when dissolving, become disintegrated into minute but well-formed rhombohedra. As the process of dissolution proceeds these crystals may become so eroded that the rhombohedral form is no longer to be recognized. The author points out that no inconsiderable proportion of the cavities in Ouachita stone present irregular boundaries, such as the moulds of partially eroded rhombohedra would show. He then offers a fresh interpretation of these cavities, so far as the origin of the rock is concerned:—

1st. He assumes that beds of crystalline magnesian limestone have been slowly dissolved by ordinary atmospheric agency and the percolation of water charged with carbonic acid or other solvent.

2nd. That, as the limestone was being dissolved, it was at the same time being replaced by silica, which enveloped minute isolated crystals and groups of crystals, some perfect, others in various stages of erosion.

3rd. That the silica assumed the condition of chalcedony, its specific gravity, as stated by Mr. Griswold and as determined by the author, being low in comparison with that of quartz.

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[1] See Obituary, p. 238.

4th. The residuum of the original dolomite or dolomitic limestone was removed, leaving the perfect and imperfect rhombohedral cavities.

A calciferous, gold-bearing quartzite from the Zululand gold-fields is described and a similar origin is ascribed to it, but in this case the original rock appears to have been simply a limestone, not a dolomite. The gold seems to occur chiefly in the calcareous portions of the rock. The author has also been tempted to suggest a similar origin for the saddle-reefs of the Bendigo gold-field. In all of these cases the train of reasoning is based upon the conclusions arrived at in his previous paper "On the Dwindling and Disappearance of Limestones." He indicates that the stratigraphical relations of the Arkansas novaculites, as described in Mr. Griswold's Report, are such as to warrant the assumption that limestones once occurred in the position now occupied by beds of novaculite. Many collateral matters are dealt with in the paper which cannot be given in abstract; among them is an attempt to classify quartzites.

2. "Note on the Occurrence of Perlitic Cracks in Quartz." By W. W. Watts, Esq., M.A., F.G.S.

The author of this communication describes some specimens of the porphyritic pitchstone of Sandy Braes in Antrim, which are deposited in the Museum of Science and Art in Dublin, and in that of Practical Geology in Jermyn Street. They exhibit admirable examples of perlitic structure in the brown glassy matrix, and the presence of polygonal, circumferential, and radial cracks is noticed. The porphyritic crystals of quartz are traversed by curved fissures of retreat, not so perfect as those found in the glass, but better than those usually produced by the rapid cooling of Canada balsam. The fissures in the quartz are frequently prolonged into the matrix, undergoing only a very slight and almost imperceptible deviation in direction at the junction. But in addition to this the quartz is often found to act as a centre of strain, the inner cracks of the perlite being wholly in quartz, the next traversing both, and the outer ones in glass only. In other examples the outer cracks of a matrix perlite sometimes enter the quartz, while in others polygonal cracks occur, and join up in, the quartz and give off radial cracks precisely like those of the matrix. These observations lead to the conclusion that the quartz and glass must have contracted at about the same rate, and that the observation of perlitic structure in a rock with trachytic or felsitic matrix by no means proves that the rock is necessarily a devitrified glass. References are given to somewhat similar observations by Fouqué and Michel-Lévy, and by Iddings.

III.—April 11th, 1894.—Dr. Henry Woodward, F.R.S., President, in the Chair. The following communications were read :—

1. "Mesozoic Rocks and Crystalline Schists in the Lepontine Alps." By T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S., Professor of Geology in University College, London, and Fellow of St. John's College, Cambridge.

The author described the results of an examination of the infold of Jurassic rock in the Urserenthal, undertaken in the hope of finding some definite evidence as to the relations of the marble exposed near the old church at Altkirche, and the adjacent Jurassic rocks. Good sections are few and far between; for the comparatively perishable nature of the rock causes it usually to be masked by débris and turf.

The easternmost of the sections described occurs high up on the slopes north of the Oberald road. Read off from the northern side it exhibits (1) gneiss, (2) phyllites with bands of subcrystalline limestone, etc.—Jurassic, (3) a little rauchwacke, (4) "sericitic" gneiss. The next section (about 250 feet above the St. Gothard road at Altkirche) gives (1) gneiss, (2) covered ground, (3) slabby marble, (4) phyllite, (5) thicker mass of slabby marble, (6) phyllite, etc., (7) "sericitic" gneiss. The third section (just above the church) runs thus, using numbers to correspond with the last: (1) gneiss, (4) phyllite, (5) slabby marble, (6) phyllite, etc., (7) "sericitic" gneiss. It must be remembered that on the slopes of the Oberalp farther south, between the "sericitic" gneiss and the "Hospenthal schists," another dark phyllite is found, generally considered by the Swiss geologists to be Carboniferous. The marble in the third section is in places distinctly banded with white mica, and passes on the northern side into fairly normal mica-schist and quartzose-schist. The fourth section, about a mile away, on the left bank of the Reuss valley, gives a practically continuous section in phyllite and dark limestone, without any marble. In the fifth section, rather more than a mile farther, if any marble be present, it is very thin and shattered. At Realp, about 3¾ miles farther, the next good section is obtained. Here the rocks go in the following order (from the northern side): (1) gneiss, (2) phyllite and limestone, (3) subcrystalline limestone, looking very crushed, (4) the marble, (5) phyllite, etc., (6) Hospenthal schists. The last group of sections occurs near the Furka Pass. In the first, crossed by the high road, there is no marble, but a little rauchwacke on the southern side. The next one, on the slopes below the pass, seems to show two masses of the marble parted by a subcrystalline limestone like that at Realp, with phyllite above and below. Of the two masses of marble, the southern one can be traced right across the Pass, but the extent of the other is not so clear.

Examination of the marble mentioned above shows in all cases that it has been considerably modified by pressure since it became a crystalline rock. The author discusses the evidence of these sections, and maintains that the hypothesis that the marble is an older rock intercalated by thrust-faulting among Jurassic strata leads to fewer difficulties than to consider it as belonging to the same system.

In the latter part of the paper the results of a re-examination of the ravine-section in the Val Canaria, and of some studies of the south side of the Val Bedretto, are described, which, as the author maintains, confirm the view already expressed by him, viz. that the schists with black garnets, mica, kyanite, dolomite, and calcite (the last sometimes becoming marbles) are not altered Jurassic rocks, but are much older.

2. "Notes on some Trachytes, Metamorphosed Tuffs, and other Rocks of Igneous Origin, on the Western Flank of Dartmoor." By Lieutenant-General C. A. McMahon, F.G.S.

In this paper the author notices the occurrence of felsite and trachyte at Sourton Tor; of rhyolite and of aluminous serpentine at Was Tor; and of a dolerite at Brent Tor in the exact situation indicated by Mr. Rutley as the probable position of the throat of the Brent Tor volcano.

The author describes extensive beds of tuffs at Sourton Tor and Meldon, the matrix of which has been converted, by contact-metamorphism, into what closely resembles the base of a rhyolite, and which, in extreme cases, exhibits fluxion-structure, or a structure closely resembling it. The fragments included in this base are so numerous that six or seven different species of lavas may be seen in a single slide; this fact, and a consideration of the extensive area over which these beds extend, lead the author to believe that these beds are metamorphosed tuffs and not tufaceous lavas.

He then describes some beds on the flank of Cock's Tor, which give evidence on their weathered surface of an original laminated structure by exhibiting a corded appearance like corduroy cloth. These beds are composed of colourless augite, set in a base which in ordinary light looks like a structureless glass, but which between crossed nicols is seen to be an obscurely crystalline felspar.

The author compares these rocks with that portion of the Lizard hornblende schists for which a tufaceous origin was proposed by De la Beche and other writers, including Prof. Bonney and himself. He shows that the Lizard schists and the Cock's Tor rocks agree in specific gravity and in some other characteristics; and he concludes that at Cock's Tor the first stage in the conversion by contact-action of beds of fine volcanic ash into hornblende-schist had been completed, and the final stage, due to aqueous agencies, had just begun.

The paper concludes with some remarks on the relationship of the epidiorites to the rocks of volcanic origin.

CORRESPONDENCE.

GEOLOGICAL DIFFICULTIES IN THE LEPONTINE ALPS.

Sir,—Dr. Stapff's interesting paper in your April Number seems to call for a few words of explanation from myself. As regards the Altkirche marble, the problem which it presents has been discussed in a paper recently read before the Geological Society, to which I may refer. Here, it may suffice to say, that I have not denied that certain limestones near Altkirche may contain fragments of organisms, but doubt the occurrence of these in the true marble, *i.e.* we have here not only to distinguish imitative from truly organic markings (in which photographic evidence often is not sufficient), but also to settle the age of the rock in which the latter occur.

As for the Piora schists, I am sorry to have misunderstood Dr. Stapff, but think he would have done better to refer to my letter as published in the GEOLOGICAL MAGAZINE (1892, p. 90) instead of to an abstract of it, necessarily condensed. He will find my words to be "If I am right in understanding Dr. Stapff to assign the Piora schists to the Carboniferous system," etc. The fact is that I had great difficulty in coming to a conclusion both as to the exact position of the divisions which he had drawn in his published sections and paper, and as to how much was covered by the terms which he employed. The terminology of petrologists at present is rather unsettled, so that we do not seldom find difficulties of this kind arising in regard to details. But if the Piora schists are part of a series extending "from the Carboniferous to the Jurassic age," I fear that I must leave the remainder of the sentence partly quoted at the top of page 160 otherwise unaltered.

My remark as to the inadequacy of photographs to decide whether organisms occurred in the Altkirche marble applies equally to the "sand grains" in the Guspis gneiss. That a gneiss may be of sedimentary origin I do not deny, but I doubt whether it would be possible to recognize with certainty the original clastic grains, unless they had been so large as to make this term inappropriate. For instance, I have examined many quartz-schists, in which I suspected certain grains to indicate the position of original constituents, but have met with only one case which I felt would satisfy a sceptic (discovered by Mr. J. Eccles last summer), and here they were pebbles rather than grains. But I have seen many cases where a structure, due to the crushing of a crystalline rock, wonderfully simulates that of an ordinary clastic rock, so, as I have been more than once led into error in this matter, the proverb holds good, "once bit, twice shy."

T. G. BONNEY.

DR. ALEX. BROWN ON *SOLENOPORA*.

SIR,—In Dr. Brown's article on the structure of *Solenopora* there is a slight error in the horizon given for the Yorkshire specimens which should be corrected, especially as the rock in question was for some time considered to be the equivalent of the Great Oolite. The Malton specimens are obtained from the Corallian, and they are also very abundant throughout the Ayton-Brompton Coral Rag.

GEOLOGICAL SURVEY,
LEICESTER.

C. FOX STRANGWAYS.

MR. WATTS'S PAPER ON THE TARDREE PERLITE.

SIR,—On thinking over the subject of Mr. Watts's interesting paper read before the Geological Society on March 21st last, in which he endeavoured to prove — by means of very beautiful magnified sections of the Tardree trachyte—that the perlitic structure is sometimes continued from the glassy magma into the enclosed crystals of quartz, it seems to me that the essentially distinct molecular structure of the two mineral substances was not sufficiently taken into account, and that it is only on a recognition of these structures that an explanation of the phenomena can be found. I quite admit that some of Mr. Watts's sections showed that the perlitic shrinkage fissures of the glass-magma did pass into, and through, the quartz-crystals; but it is not to be inferred from this that the quartz-crystals had perlitic structure, as I shall endeavour to show. Let us consider for a moment the process of consolidation from the molten state. It is clear that the silica consolidated before the glass-magma; and in forming distinct crystals it obeyed the law of its molecular constitution, which obliges it to take the form of a hexagonal prism terminated by a pyramid. On the other hand the amorphous (or non-crystalline) magma is governed by an entirely different set of molecular forces and tries to form a series of concentric globules, somewhat as basalt on cooling often forms globular masses with concentric envelopes. The globular is the primary form of a cooling body. It is clear that the molecular constitutions of the quartz-crystal and of the non-crystalline magma are essentially different, and this distinction finds its result in the diverse forms and structures of the two. If this be admitted it will not be difficult to account for the apparent perlitic fissures traversing some of the quartz-crystals, as shown in some of the specimens. Though these have had priority over the magma in consolidation, yet they were necessarily highly heated and somewhat soft owing to the liquid state of the enclosing magma; and this being so, as the perlitic fissures were being developed in the latter they would exert a pull upon the parts of the quartz-crystals in contact, the force developed by contraction in the case of each globule of the magma tending to draw the mass towards its centre. The quartz being (as has been observed) in a somewhat soft condition would be unable to withstand this force, and in such cases it would give way; and fissures would be produced continuous with one or more in the enclosing glass-magma; bnt this does not prove that the quartz itself has a perlitic structure.

Edward Hull.

22nd March, 1894.

ON THE POSSIBLE MARINE ORIGIN OF THE LOESS.

Sir,—One of the difficulties that faced me in my paper on the "Submergence of Western Europe"[1] was the want of evidence to prove distinctly that the land had been under the sea. As, however, all the physical evidence concurred to show that the various forms of the Rubble-drift indicated a transient disturbance, I concluded that the submergence had been of too short a duration to allow of the establishment of a marine fauna in the area submerged. It was therefore with much satisfaction that I found the other day confirmation of a very unexpected character in a paper published in the last number of the "Bulletin de la Société Belge de Geologie."[2] In treating of the Loess I described a portion of it as of fluviatile origin,

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[1] Phil. Trans. for 1893, p. 903.

[2] *Ibid.* March 1894, p. 118.

whilst I considered that the high- and mid-level Loess belonged to the Rubble-drift, and was therefore of marine origin. In the paper I now refer to, by M. Xavier Stainor, he gives the analyses of some of the Belgian Loess, in which, besides the ordinary ingredients, a notable proportion of Chloride of Sodium, in one case as much as 1·17 per cent., has been found. This Loess contains the usual common land shells—*Pupa marginata, Succinea oblonga, and Helix hispida.*

JOSEPH PRESTWICH.

SHOREHAM, KENT.
April 19th.

OBITUARY.

WILLIAM PENGELLY, F.R.S., F.G.S.

BORN 12TH JANUARY, 1812. DIED 17TH MARCH, 1894.

THERE has just been gathered to his rest, in his 83rd year, one of that small band of Geologists who assisted Falconer, Busk, Lyell, Prestwich, Lartet, Christy, Evans, Rupert Jones, Boyd Dawkins, and a few others, to place upon a scientific basis that inquiry into the evidence of Pre-historic man which was systematically commenced in this country by the exploration of Brixham Cave in 1858. This work, which was carried out under the auspices of the Royal and Geological Societies by Mr. William Pengelly, of Torquay, yielded most important results, and was followed, in 1864, by a similar investigation of the historic Kent's Cavern, Torquay (originally partially explored by the Rev. J. McEnery in 1825), and, like the Brixham Cave, carried out with untiring zeal by Mr. Pengelly for a period of more than fifteen years (see British Association Reports 1865–1880).

WILLIAM PENGELLY was born at East Looe in Cornwall, January 12th, 1812. Coming to Torquay as a young man, he opened a school, which he carried on for some years on the Pestalozzian system, and was one of the first to introduce the use of the chalk and black-board in imparting instruction.[1]

The author of numerous treatises on the Devonian and Triassic Rocks of Devonshire, on St. Michael's Mount in Cornwall, and many other geological subjects, Mr. Pengelly, in conjunction with Dr. Heer, of Zurich, published a monograph on "The Lignites of Bovey Tracey," which is regarded as a most valuable scientific work. His assiduity in the collection and arrangement of specimens is testified by the magnificent series of Devonian fossils which, under the title of the Pengelly Collection, was lodged in the Museum of Oxford University by the Baroness Burdett-Coutts in connection with the Burdett-Coutts Scholarship, and also by the splendid collections of bones and flint-implements from Kent's Cavern, which he has placed in the British Museum and in the Museum

[1] Amongst his private pupils in Mathematics was Miss (afterwards the Baroness) Burdett-Coutts, who, through life, remained his staunch friend.

of the Torquay Natural History Society. Ever eager to foster a love for science among the people, and to encourage studies which had for their object the advancement of scientific knowledge, Mr. Pengelly was especially active as a lecturer, and could easily make himself understood by persons totally ignorant of science. Twenty years ago he travelled through the country as one of the most acceptable lecturers of the day. His efforts locally were equally successful. He was instrumental in 1837 in establishing the Torquay Mechanics' Institute, and seven years later, together with the late Mr. Vivian and others, he originated the Torquay Natural History Society, of which he was the Honorary Secretary for many years, and is the last of the original founders. In 1867 he started the Devonshire Association for the Advancement of Science, Literature, and Art, of which he was the President in 1867–8. From their inception he took a prominent part in these institutions, and his eminent services in many capacities have been recognized on several occasions by the members. Undoubtedly Mr. Pengelly was an enthusiast. As he said in his Manchester lecture in 1872, "the pleasure of the work is the payment," but his valuable and historic labours have not been unrecognized. A regular attendant at the annual meetings of the British Association, over the Geological Section of which he was President, and which for many years he served as Secretary. He was elected F.G.S. in 1850, and received the distinction of F.R.S. in 1863. In 1874 he was the recipient of a testimonial of between 500 and 600 guineas "in recognition of his long and valued services to science generally, and more especially for the exploration of Kent's Cavern, Torquay."

In 1877 Mr. Pengelly was awarded the "Lyell Geological Fund" by the Council of the Geological Society, and in 1886 the same body conferred upon him the "Lyell Medal" as a mark of honorary distinction, and as an expression of the Council's recognition of his valuable scientific labours.

Mr. Pengelly was presented with his portrait, painted by A. S. Cope, which now adorns the library of the Natural History Society's Museum in Babbacombe-road, Torquay. On retiring from the Secretaryship of the Society in 1890 he received an address from the members, who "desire to record the high appreciation of the invaluable services rendered to the Society by Mr. Pengelly, who for thirty-nine years has fulfilled the onerous duties of Honorary Secretary," at the same time expressing "profound regret at his retirement." Altogether the time spent in the exploration of Kent's Cavern was over fifteen years—from 28th March, 1865, to 19th June, 1880—the cost being met by the British Association and various scientific friends. Mr. Pengelly wrote no less than ninety-two separate memoirs. He was a member of the Society of Friends, but it is as a scientific man that Mr. Pengelly will be best known and remembered. Mr. Pengelly was twice married, but all his children by his first wife died; the last, Alfred Pengelly, being killed in India whilst hunting big game. He leaves a widow and two daughters, who share their father's scientific tastes.

JOSEPH BICKERTON MORGAN, F.G.S.

BORN 1859. DIED MARCH 8TH, 1894.

ON the 8th of March there passed away at Ventnor a life full of promise for work among the Ordovician and Silurian rocks. Born in 1859, Mr. Morgan was always an earnest student of nature, and one of his earliest tasks, when associated with the late Morris Charles Jones as Assistant Honorary Curator of the Powysland Museum at Welshpool, was to classify and arrange the large collection of recent shells given to the Museum by the Rev. J. Vize. He next turned his attention to the fossils in the Museum, rearranged them, and then added very largely to them from his own extensive collections, especially from the Silurian and Ordovician rocks in the immediate neighbourhood.

In 1885 a paper, published by Mr. Vine in the Quarterly Journal of the Geological Society, contained a description of a new species of *Phyllopora*, *P. tumida*, from the Caradoc rocks of Llanfyllin, and of *Thamniscus antiquus*, from the Bala volcanic ash of Middletown Hill, both collected by Mr. Morgan. Previously to this Mr. Morgan had been studying the Upper Ordovician and Silurian rocks of Powysland and the Welsh border, and had obtained a large series of fossils from beds above and below the boundary line of these formations, which he submitted to Professor Lapworth for identification. By the advice of the latter he began to map these strata, and succeeded in defining the lower limit of the Silurians with much greater exactitude than had been hitherto done, with the result of adding several hundreds of feet of rock to the Silurian system. A forecast of his conclusions on the subject was published as a paper to the British Association at Leeds in 1890, but the full paper has not yet been published. It is to be hoped that sufficient material may be found amongst his papers to allow of its publication in full.

In 1892 Mr. Morgan resolved to devote himself to scientific work, and, obtaining a free scholarship at the Royal College of Science, he came to London, and in a single year succeeded so well as to obtain the first prize at the College, together with the Murchison medal and gift of instruments and books. It was on the last day of his duties as demonstrator during the summer vacation that he took a chill, from which serious trouble ensued, compelling him to abandon work and winter at Ventnor. Here he seemed to rally, and just as his friends were beginning to hope that he might soon be well enough to resume his work, he succumbed to an attack of hæmorrhage, in the 35th year of his age. In addition to the work mentioned above, some new species of *Entomostraca* were discovered by him, while he contributed several papers, including one on Shorthorn Cattle, and one "on the Strata forming the base of the Silurian in north-east Montgomeryshire," to the Montgomery Collections, and delivered lectures at the Welshpool School of Art.

Thus a country geologically almost unknown has lost an earnest, reliable, and enthusiastic worker, one who could very ill be spared; while many of us have to mourn a kind and true-hearted friend.

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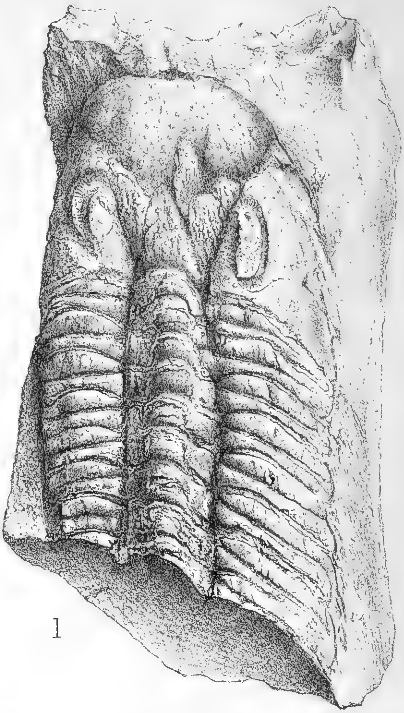

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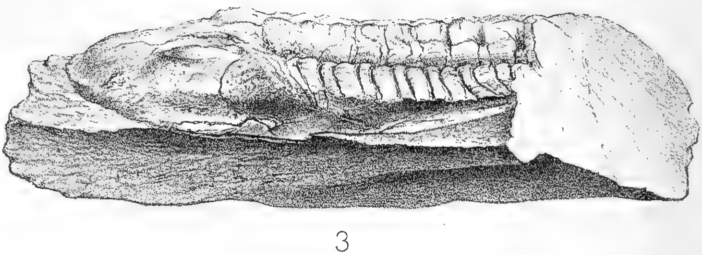

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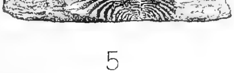

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NEW BALA TRILOBITES.

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No. VI.—JUNE, 1894.

ORIGINAL ARTICLES.

I.—WOODWARDIAN MUSEUM NOTES.

By F. R. COWPER REED, B.A., F.G.S.

(PLATE VII.)

THE sub-genus *Chasmops* of the genus *Phacops* is so rarely, if ever, found in great Britain, except as disconnected heads and pygidia, that a specimen which shows the cephalic shield attached to several thoracic rings deserves notice.

The two British species recognised by Salter (omitting the doubtful *Ch. Jukesii*) are *Ch. macroura* (Sjogren) and *Ch. conophthalmus* (Boeck ?),[1] but he apparently perceived that more than two species were included under these names (Mon. Brit. Tril. p. 38). The material in Britain available at that time, however, was not well enough preserved, and the investigation of the Continental forms of this characteristically North-European group was not sufficiently advanced to admit of a more complete discrimination. But now Fr. Schmidt's work on the Silurian trilobites of the East Baltic provinces (Mém. l'Acad. Imp. d. Sc. d. St. Petersb. vii. ser. T. xxx. No. 1) has supplied a long-felt want, and we can only regret that the British specimens of *Chasmops* generally occur in such an unsatisfactory and fragmentary condition as to preclude their indentification or comparison with those he has so fully described. The material with which he has had to deal is in a comparatively excellent state of preservation, and it is gratifying to find an English specimen which does not unfavourably compare with some of his. Such is the case with the one now described. It was discovered by Mr. F. Marr in the Coniston Limestone of Applethwaite Common near Windermere.

The head and 7–8 thoracic rings are preserved, but they have suffered considerable lateral compression, producing irregular cracks and corrugations of the surface together with some distortion. For instance, the parabolic shape of the cephalic shield is misleading, for probably it was originally semicircular and the proportion of the length to the breadth about 1 : 2. In the thorax the axis has been squeezed into greater prominence, and on the pleuræ antero-posterior wrinkles have been developed. The actual measurements of the specimen in its present state are as follows:—

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[1] According to Fr. Schmidt, Salter's species are not those of Sjogren and Boeck.

Length of head	1·35	inch
Length of glabella from neck-furrow to anterior end	1·1	,,
Width of broadest part of glabella, *i.e.* across frontal lobe	1·1	,,
Width of base of glabella	0·35	,,
Length of the 1st or "cat's ear" lobe, measured along its outer side	0·575	,,
Width of right cheek measured along the neck-furrow from the axial furrow to the outer margin	0·9	,,
Length of eye	0·375	,,
Width of eye	0·175	,,
Length of channel round eye	0·5	,,
Width of ditto	0·225	,,
Width (average) of thoracic axis	0·5	,,
Length (average) of pleura	0·8	,,
Width (average) of ditto	0·2	,,

The accompanying description refers to the crushed and distorted specimen figured. (A summary of the chief characters of the form with the proportions, which it must have possessed prior to the distortion, is given subsequently.)

The outline of the head is parabolic; the anterior end appears to be obtusely pointed in front of the glabella. The glabella is much dilated in front, and the sides converge at an angle of about 40°, but before distortion this angle must have been about 60°, and the outline of the head must have been semicircular.

The frontal and first lobes of the glabella are well marked off by deep furrows. The frontal or forehead lobe is transverse, the width 1½ times the length, but originally it must have been about twice as wide as long; the anterior border is a gentle convex-forward curve; the lateral angles of this lobe are rounded-truncate, and overhang the eyes completely, projecting beyond the straight outer side of the "cat's ear" lobes.

A Vishnu-like mark formed by two converging rows of large puncta, which may represent the position of frontal glands, extends two-thirds down the lobe from the anterior border.

The triangular "cat's ear" or first side lobes extend fully two-thirds of the side of the glabella, reaching nearly from the neck-furrow to a point in front of the eye; each of these lobes stretches nearly one-third of the way across the glabella. The largest angle of each is about 110° and points inwards, but before distortion must have approached a right angle. The anterior bounding furrow is rather sinuous, but the posterior one is straight.

In the triangular portion of the glabella left between these large embracing lobes, the second or middle lobes are represented by small, very faintly indicated, subcircular elevations, more clearly defined in front than behind, and only perceptible in the impression. The basal or third lobes are larger and transverse, but are poorly defined, and together with the middle ones are completely embraced laterally by the large first lobes. (This feature also is shown better in the impression than in the cast.)

The glabella as a whole is not particularly inflated, and, in fact, is not so high as the inner portions of the cheeks; but this is probably due in the main to the crushing to which it has been subjected.

The neck-segment is only about 0·15 inch broad, and is strongly rounded and prominent; it is separated by a strong neck-furrow from the base of the glabella, and this furrow is continued laterally as a deep narrow groove limiting the cheeks posteriorly, but it shallows and terminates before reaching the genal angles.

The cheeks are triangular, not more convex than the glabella but higher along the posterior portion of their inner border. They terminate at the genal angles in long flat spines, closely pressed against the body, and grooved by a continuation of the marginal furrow. At their fixed end they are of considerable width, but narrow at first rather rapidly to about the level of the second body-ring, beyond which the tapering is very gradual. The left spine is partly preserved and reaches down the whole seven and a half thoracic rings on that side, at which point it is broken off.

The axial furrows are narrow, but deep and straight as far forward as the anterior end of the first lobe. The cheeks rise steeply from them. At the anterior end of this first or "cat's ear" lobe the furrow curves outwards and widens into a broad groove, bounding the cheek anteriorly and overhung by the great frontal lobe of the glabella.

From the highest portion of the cheek which is adjacent to the axial furrow there is a gentle slope down to the outer margin, where a narrow rounded groove—the marginal furrow—bounds it. Outside this furrow is a broad, slightly convex, smooth border, 0·2 inch wide; this is prolonged backwards into the genal spines, and anteriorly runs round the front of the head-shield, where it is reduced to a quarter of its width by the overhanging of the frontal lobe of the glabella.

The eyes are large and lunate, extending nearly $\frac{2}{3}$ the length of the triangular first glabellar lobes. A deep crescentic channel bounds them externally, sweeping round their base. The posterior end of each crescent is about half the length of the eye from the axial furrow, and the anterior end is almost on this furrow.

The cheeks and glabella are finely granulated and covered with small round tubercles, the largest of which are situated on the triangular lobes and the portion between them. The smooth, non-tubercular character of the border offers a striking contrast.

The facial suture is seen to curve round the front of the glabella and, apparently, is supra-marginal, but this part of the specimen is not well preserved. From the rounded lateral angles of the great frontal lobe this suture runs backwards and inwards in a nearly straight line to the eye, at the posterior end of which it bends outwards in a convex-forward curve and appears to lie in a slight groove. It cuts the outer margin at a point almost on a level with the posterior end of the eye.

The axis of the thorax is very convex and is of nearly uniform width, which is rather more than half that of the pleuræ. The axial furrows are deep. The pleuræ are flattened; the fulcrum is well marked and is situated at about one-third of their length from the axial furrow. Each pleura is horizontal and at right angles to the axis as far as the fulcrum, but at this point it bends backwards at an angle of from 30° to 40° to its previous direction, and curves gently downwards to its free end, which is blunt, rounded, somewhat flattened and expanded. A deep furrow traverses each pleura obliquely from the inner anterior angle towards the middle of the free end, before reaching which, however, it dies out.

Where the crust has been preserved a few tubercles and granules are seen to occur on the axis and pleuræ, but they are not so large or so numerous as on the head.

Summary of the normal characters of this form (undistorted).

Head-shield semicircular, with an obtuse point in front. Posterior margin forms a concave-backward curve to the large spines at the angles.

Glabella much dilated in front, moderately inflated; base measures about a quarter the width of head-shield, but only one-third the greatest breadth of glabella which is across transverse frontal lobe. The sides converge posteriorly at an angle of about 60°. Frontal lobe transverse, twice as wide as long; anterior border a gentle convex-forward curve; lateral angles rounded-truncate overhanging the eyes; a V-shaped series of puncta present on anterior portion of this lobe. First side lobes ("cat's ear" lobes) extend from neck-furrow to a point in front of eyes, *i.e.* for two-thirds the side of the glabella; are triangular; inner angle about 90°; reach nearly one-third across the glabella; anterior bounding furrow sinuous; posterior furrow straight. Second or middle lobes very faint, subcircular; third or basal lobes rather more definite and wider. Both second and third pairs of lobes completely embraced laterally by first lobes. Axial furrows of glabella deep, narrow, straight as far as anterior end of first lobe, then widen and curve outwards to join marginal furrow.

Neck-segment rounded; neck-furrow deep, dies out before reaching marginal furrow.

Cheeks triangular, slightly inflated, highest along inner border.

Genal angles terminated by large flat spines, broad at base, slightly grooved, closely pressed against body-rings, extending to 8th or 9th thoracic segment.

Marginal furrow narrow, smooth, and rounded, with smooth, wide, slightly convex border external to it and forming edge of head-shield. Anterior portion of border overhung to the extent of three-fourths of its width by frontal lobe of glabella.

Eyes large lunate, near inner margin of cheeks; extend nearly two-thirds the length of the first side lobe of the glabella; outer side of base of eyes surrounded by deep crescentic channel.

Cheeks and glabella finely granulated and covered with small round tubercles, especially conspicuous on posterior part of glabella.

Facial suture supra-marginal; below eye it makes a convex-forward curve and ends on outer margin at about the level of the posterior end of the eye.

Thoracic axis about one-fifth the width of thorax; of uniform width; axial furrows deep.

Pleuræ flattened, with deep oblique furrows; fulcrum conspicuous, situated at ⅓ length of pleura from axial furrow.

Pleura horizontal and at right angles to axis as far as fulcrum; then bend back at 30°—40° to previous direction and curve slightly downwards.

Extremities of pleuræ blunt, rounded, flattened.

Crust of thorax slightly granular with few tubercles.

The form above described does not exactly agree with Salter's *Ch. macroura* (Mon. Brit. Tril. p. 37), but resembles it in the general shape and tubercular character of the head, in the cheek spines, and the course of the facial suture; but the lobes of the head, the size of the eye, and the cephalic border show important differences.

With *Ch. conophthalmus*, as described by Salter (*loc. cit.* p. 40), it has the transversely overhanging frontal lobe in common; but there are considerable points of dissimilarity in the length of the genal spines, the tuberculate condition of the head, the size of the eyes, the presence of the middle and basal lobes of the glabella, and the non-continuity of the neck-furrow with the marginal furrow.

The absence of any description by Salter of the thoracic rings of these species, and the fact that the tail of our specimen is wanting, prevent us making a more complete comparison; but so far as the comparison goes we see that our form cannot be said to agree with either of Salter's species. On turning to Schmidt's Memoir on the Silurian Trilobites of the East Baltic provinces we find there are three species with which it has several features in common. In the first place a comparison may be made with *Phacops* (s.g. *Chasmops*) *Eichwaldi* (Schmidt) (*loc. cit.* p. 117). The figures of this form given by Schmidt (taf. v. f. 8 *a. b. c.* 9) do not bear much resemblance to our Coniston Limestone specimen, but in the description of the species the characters, shape, and size of the frontal lobe of the glabella are similar, as are also the shape of the first side lobe (in *size* it seems rather shorter), the cheek margin, and the length, shape, and position of the genal spines. But there are considerable differences in the parabolic shape of the head-shield (which in our specimen is only due to crushing as has been pointed out), the finely granular, non-tuberculate or smooth surface, the total absence of the second side lobe, the more marked character of the third side lobe, the smallness of the eyes, the swelling out and subsequent tapering of the thoracic axis, and the scarcely perceptible fulcrum of the pleuræ.

Schmidt thinks that his *Ph. Eichwaldi* is very similar to or even identical with Salter's *Ph.* (*Ch.*) *macroura*.

Another species—*Ph. maxima* (Schmidt) (*loc. cit.* p. 112)—agrees in the shape of the head-shield, the character of the genal spines, and the size, shape, and extent of the first side lobe; but it differs by having only fine granulations and no tubercles, by the marginal furrow uniting with the neck-furrow, by the second and third side lobes being much more conspicuous, and by the greater breadth of the frontal lobe.

The third species deserving comparison is *Ph. Wesenbergensis* (Schmidt) (*loc. cit.* p. 115). This bears the closest resemblance to our form. The shape of the head, the genal spines, the granular and tubercular surface of the glabella, the border to the head-shield, and the second and third side lobes of the glabella are all very similar. The first lobe is usually smaller, but Schmidt states that its form varies considerably. The most important points of difference are the smaller size of the eyes, the non-tuberculate character of the cheeks, and the absence of a conspicuous fulcrum to the pleuræ.

On the whole it seems, therefore, justifiable to consider our Coniston Limestone form specifically distinct from any hitherto described; and in honour of its discoverer it may suitably be named *Ph. Marri.*

EXPLANATION OF PLATE VII.

Fig. 1. Natural cast of *Phacops* (*Chasmops*) *Marri* from the Coniston Limestone, Applethwaite Common, Windermere. Natural size.

Fig. 2. Impression of ditto.

Fig. 3. Side view of figure 1, showing genal spine.

Fig. 4. *Dindymene Hughesiæ* (Roberts MS.), Coniston Limestone Series, Norber Brow.

Fig. 5. Impression of ditto.

N.B.—By mistake the figure of the type specimen on which the restoration of *Dindymene Hughesiæ* was founded (Geol. Mag. Dec. IV. Vol. I. No. III. Pl. IV. Fig. 5) was omitted from the plate which accompanied the description in the March Number. It is, therefore, here inserted.

II.—Note on Some Appendages of the Trilobites.[1]

By Chas. D. Walcott, F.G.S.
Palæontologist to the United States Geological Survey; Smithsonian Institution, Washington, D.C., U.S.A.

(PLATE VIII.)

THE results of Mr. W. S. Valiant's long search for the appendages of Trilobites have recently been made known by Mr. W. B. Matthew, who described the material sold to the Columbia College of New York by Mr. Valiant.[2] Mr. Valiant informs me that he discovered traces of what he considered to be antennæ, and that for several years he continued collecting until he found a locality where the specimens were well preserved and showed, not only the antennæ, but legs and what he supposed to be the swimming appendages. Not having confidence that he could properly describe the specimens he sold part of his material, and in this way it came to be first described by Mr. Matthew, a student at Columbia College. His step-brother, Mr. Mitchell, continued to collect; and in August, 1893, through the courtesy of Mr. Valiant, I visited the locality

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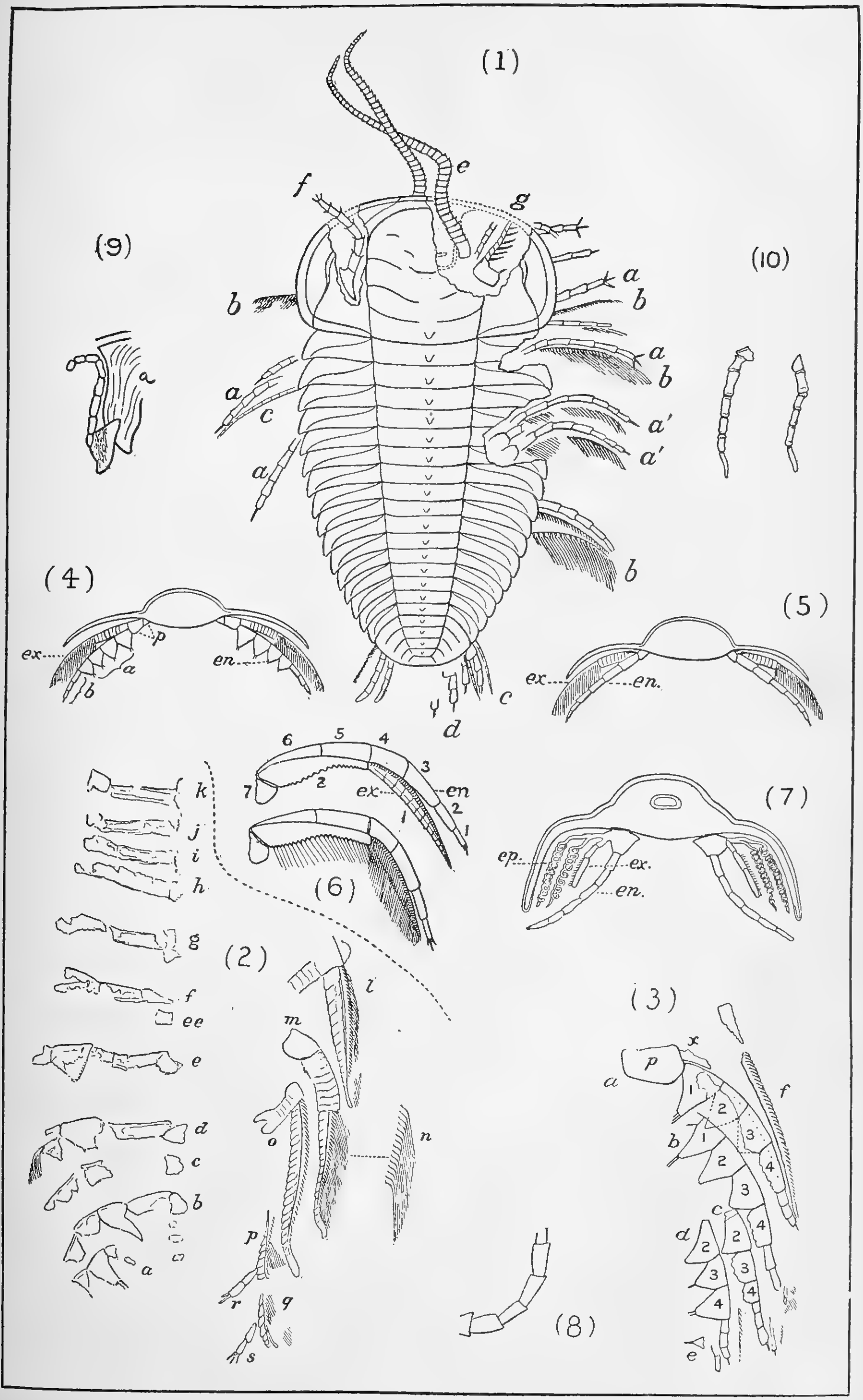
[1] Read before the Biological Society of Washington, March 24, 1894.

[2] Amer. Journ. Sci. 1893, vol. xlvi. p. 121.



Appendages of *Triarthrus Becki*, and other Trilobites.

with Mr. Mitchell and obtained a few specimens for the National Government.

The most important part of the discovery, announced by Mr. Matthew's paper, is that the Trilobita have true antennæ. The discovery of the legs and plumose appendages is also of great interest, as it adds to our information respecting the appendages of the Trilobite some of the details of another genus.

A collection was made for the Yale College Museum by Dr. C. E. Beecher, and in some notes on the thoracic legs of *Triarthrus*[1] he describes and illustrates a dorsal view of the legs of the second and third free thoracic segments. These show that the endopodite of the leg is essentially the same as in *Calymene* and *Asaphus,* and that the exopodite is unlike that of *Calymene* or *Ceraurus.*

Through the courtesy of Prof. J. F. Kemp, of Columbia College, I have examined the material studied by Mr. Matthew; and Prof. A. H. Chester, of Rutgers College, kindly loaned me for study five specimens that he purchased from Mr. Valiant. From these and the specimens in the National Museum a few notes have been taken that permit of some comparisons with the extremities found in *Ceraurus, Calymene* and *Asaphus.*[2] The limbs of *Triarthrus* differ in the details of the joints of the inner branch of the limb (endopodite) and still more in the character of the exopodite.

Cephalic limbs.—The antennæ are uniramose, and, judging from the position in which they are found, were attached to the body near the postero-lateral angle of the hypostoma (Fig. 1, *e*, Pl. VIII.). In one specimen a cephalic limb somewhat detached from its true position shows a large basal joint and six slender joints (Fig. 1, *f*). The basal joint does not show conclusive evidence of the presence of a masticatory ridge. On another specimen, however, the form of the basal joint strongly suggests that it subserves the purpose of mastication. This is illustrated at *g* in Fig. 1.

A slender jointed appendage like that attached to the basal joint of *g*, occurs between it and the antenna, and is probably a portion of another one of the cephalic limbs. No other cephalic appendages have been observed in the material at hand.

Since the publication of my articles on the Trilobite[3] I found in a section of the head of *Calymene senaria* a slender jointed limb that appears to have been an antennule. It is unlike any limb found beneath the head and thorax, and, if not an antennule, it may represent a fifth pair of cephalic limbs. This is also suggested by a section of the limbs within the head of *Calymene* (illustrated on pl. 1, fig. 9, Bull. Mus. Comp. Zool. 1881, vol. viii.). In this, a fifth limb is indicated close to the hypostoma. The Trilobite was enrolled so as to include the antennule entirely within the border of the head. A sketch, taken from a photograph of the thin section by transmitted light, is shown by Fig. 8, Pl. VIII.

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[1] Amer. Journ. Sci. 1893, vol. xlvi. pp. 467–470.

[2] The Trilobite; New and Old Evidence Relating to its Organization. Bull. Mus. Comp. Zool. 1881, vol. viii. p. 6.

[3] Bull. Mus. Comp. Zool. 1881, vol. viii. p. 191–224. Science, 1883, vol. iii. p. 279.

The hypostoma of *Ceraurus*[1] shows a rounded indentation of the antero-lateral sides, where an antennule probably passed by it. This character is strongly marked in *Sao hirsuta, Proetus bohemicus, Amphion fischeri*, etc., as illustrated by Barrande.

The character and position of the remaining cephalic limbs of *Triarthrus* are not shown in any specimens that I have examined; but, from the relations of *Calymene, Ceraurus* and *Triarthrus,* especially the two latter, it is probable that their arrangement is essentially the same.

Thoracic limbs.—Many specimens show the thoracic limbs extending out from beneath the carapace of *Triarthrus.* It was not until by a fortunate dissection that I obtained the material illustrating the limbs in position beneath the thorax. The anterior limbs are formed of a protopodite and a somewhat complex exopodite. The protopodite consists of a short basal and a long joint (Fig. 2, *d, e*), to which the endopodite and exopodite are attached. This appears to be direct in the posterior limbs of the thorax (Fig. 3, *a*), but as yet the point of attachment of the basal joint of the exopodite has not been seen in the anterior limbs.

The endopodites of the anterior thoracic limbs vary in the number of joints and in their relative length (Fig. 1, *a, a*). Two show four long proximal and three shorter distal joints. Other limbs show two smaller distal, and three or four proximal, while in several there is a more or less uniform gradation from the protopodite to the distal joint. In Fig. 1, some of these variations are indicated. In Fig. 2, eleven limbs are shown, as seen from the under side. The basal (coxal) joint is seen at *b, d, e,* and nine show the long second joint of the protopodite. At *e* and *f* a new phase is indicated by the enlargement of the proximal joints. This is marked in *a, b, c, d,* and in Fig. 3 the details are more fully shown. These joints occur on the seven posterior thoracic limbs of Fig. 2; and in the specimen from which Fig. 3 was drawn the limb opposite the the tenth segment from the pygidium shows a slightly triangular *second* (meropodite) and *third* (carpopodite) joint. In Fig. 2, the limb *a* is opposite the second free segment of the thorax anterior to the pygidium. The limbs *a* and *b*, Fig. 3, clearly show that the four proximal joints are broad and subtriangular in outline. A glance at the abdominal swimming legs of the Phyllocarida (*Paranebalia*), Schizopoda and Cumacea, suggests that the functions of these legs were both natatory and ambulatory.

The expododite illustrated by Beecher shows the dorsal surface (Fig. 6). A number, presenting the ventral surface, are shown on the right side of Fig. 2. They occur on the same specimen as the endopodites, on the left side, but have been pushed out of place. The most perfect is represented by *m.* The proximal portion is formed of a rather large basal joint and a number of short joints, seven or eight. The distal end is formed of an inner and outer segmented portion. The inner side is divided into numerous segments by oblique divisions that give the impression of a closely

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[1] *Loc. cit.* pl. iv. fig. 5.

coiled spiral. The outer side is a cylindrical, jointed, stem-like rim that is attached to the inner side, a narrow distinctly impressed line separating the two, except at the somewhat flattened tip where they merge into each other. On the outer or upper surface of the outer side numerous crenulations occur that extend into long setæ, *n*, Fig. 2; *b, b*, Fig. 1. Dr. Beecher considers the expodite as a swimming organ; but from the manifest branchial character of the exopodite and attached epipodite in *Calymene* (Fig. 7), it seems probable that this exopodite of *Triarthrus* served largely as a gill, and that the animal used the broad proximal joints of the posterior limbs of the thorax as its principal propulsion in swimming. The exopodite of *Triarthrus* looks like a consolidated exopodite and epipodite, very much as though these two organs, as they occur in *Calymene*, were merged into one.

Several specimens illustrate appendages beneath the pygidium. Some have the broad proximal joints, *d*, Fig. 1, while others show the outer rim of the exopodite, *c*, Fig. 1. The material I have seen indicates very little difference between the appendages of the posterior half of the thorax and the pygidium, except that those of the latter are less developed in size and details.

Mr. Matthew suspected the presence of a flap, formed by the anchylosing of the appendages beneath the pygidium. From the appearance of a similar structure, where the limbs are matted together along the side of the thorax, this tentative view is received with doubt. More perfect material may show distinctions not recognizable at present.

If future investigations prove, as it now seems probable, that the modified swimming joints of the endopodite are attached to ten or more of the thoracic segments, the anterior eight segments can be grouped together as the typical thorax, and the remaining segments of the body as the abdomen.

Mr. Matthew suggests that the homology between *Triarthrus* and *Limulus* may not be as close as between *Limulus, Calymene* and *Ceraurus*. This is true from what we now know of *Triarthrus*, but, if a sixth pair of cephalic limbs should be discovered in *Triarthrus* the resemblance would be strengthened. *Triarthrus* does not differ from *Ceraurus* and *Calymene* more than would be anticipated in such unlike genera. *Triarthrus* is essentially a "Primordial" type that has continued until Upper Ordovician time. It represents a large group of Cambrian Trilobites, whilst *Calymene* and *Asaphus* represent the more highly developed Ordovician and Silurian forms.

Dr. Lang held the view[1] that if a fifth pair of cephalic limbs were found, comparable to the anterior antennæ "Trilobites might then be regarded as original Entomostraca, to be derived from the same racial form as the Phyllopoda." He says, further,[2] "Xiphosura, Hemiaspidæ, and Gigantostraca are themselves again perhaps racially connected with the Trilobites. In any case, however, in the present state of science, it seems probable that all these groups are only connected at their roots with the Crustacea."

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[1] Text Book of Comparative Anatomy, English Ed. 1891, p. 415.

[2] *Loc. cit.* p. 421.

From the palæontological record I am essentially in accord with this view, but I am not yet prepared to abandon the position taken in 1881, that all these groups should be arranged under one class and not as an appendage to the Crustacea, as proposed by Dr. Lang. I would go still further, and form a class of the Trilobita and one of the Merostomata.

Two general facts lead me to think that the modern Crustacean is descendant from the Phyllopod branch, and the Trilobita from a distinct branch.[1] 1st. The Trilobite branch exhausted its initial vital energy in Palæozoic time and disappeared. 2nd. The Phyllopod branch developed slowly until after the Trilobita passed its maximum, and then began its great differentiation that approaches culmination in recent times.

When the Trilobite and Phyllopod diverged from their common ancestral Crustacean the Trilobite began at once to differentiate and to use its initial vital energy in developing new species, genera and families. Probably two thousand species and one hundred or more genera are known from the Palæozoic strata. With this great differentiation the initial vital energy was impaired, and the Trilobita died out at the close of Palæozoic time.

The Phyllopod branch continued with little variation until after the Trilobite passed its maximum, and then began to differentiate, until to-day its descendants form the class Crustacea, that corresponds to the class Trilobita in Palæozoic time. Springing from a common Crustacean base the two groups have many features in common, and in carrying out of details of structure in the limbs and gills many striking resemblances occur. It does not impress me that Trilobites were true Entomostracans or Malacostracans; they have certain characteristics in common, but these are not necessarily the result of lineal descent one from the other but are the result of descent from a common ancestral Crustacean type of pre-Cambrian time that lived in the pelagic fauna, in which all the earlier types of life were probably developed[2] and from which, as time passed on, additions must have been made to the palæontologic record of geologic time. The Phyllopoda, Ostracoda, and Trilobita are clearly differentiated in the Lower Cambrian fauna. Bernard is confident that the Trilobites may take a firm place at the root of the Crustacean system, with the existing *Apus* as their nearest ally.[3]

There is much yet to be learned from the study of *Triarthrus* A great amount of material can be readily collected at the locality near Rome, N.Y. It is also of interest to note that the locality at Trenton Falls, N.Y., from which the specimens of *Calymene* and *Ceraurus* were obtained, is only seventeen miles from the Rome

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[1] This view is only confirmatory of the result of the profound study of the Apodidæ by Bernard. (The Apodidæ; Nature Series, 1892.)

[2] See Brooks' beautiful Memoir on Salpa, with its suggestive theory of the origin of the bottom faunas of the ocean and the early geologic faunas. The Genus Salpa, Memoirs from the Biological Laboratory of the Johns Hopkins University, ii. 1893, pp. 140–177.

[3] "Nature," 1893, vol. xlviii. p. 582.

locality; that both occur within the Ordovician; and that the stratigraphic position of the bed at Rome is between six and seven hundred feet above that at Trenton Falls.[1]

EXPLANATION OF PLATE VIII.

Fig. 1.—*Triarthrus Becki* (× 3). Outline of Carapace, with appendages represented as they occur on several specimens, their relative position being retained.
  a, a, a, a. Endopodites of limbs showing variation in joints.
  b, b. Plumose portion of exopodite.
  c, c. The outer or supporting portion of the setæ or fimbriæ of *b, b.*
  d. Limbs extending from beneath the pygidium, showing large proximal joints. Those of the left side are imperfectly preserved.
  e. Antenna extending back nearly to the postero-lateral margin of the hypostoma.
  f. One of the cephalic limbs. The basal joint may be broken away on the inner side.
  g. Cephalic limb.

Fig. 2 (× 7).—Limbs attached to the under surface of an individual preserving 13 thoracic segments and the pygidium. The limbs (*a* to *k*) on the left side are mainly in place. A fracture cuts out one limb between *g* and *h.*
  a to *g.* Limbs preserving traces of the enlarged proximal joints.
  b, d. Limbs preserving the two joints of the protopodite and two of the large proximal joints.
  l, m, o. Exopodites, showing under or side views.
  n. Enlargement of fimbriæ of *m.*
  r, s. Distal joints of endopodites of right side.
  q. Portion of an exopodite showing its inner support.

Fig. 3.—Limbs occurring on the under side of an individual of 14 thoracic segments.
  a, b, c, d. Limbs with flattened, enlarged proximal, and slender distal joints.
  a. Limb preserving large joints of protopodite (*p*), four enlarged proximal joints and three slender distal joints. At *x* the point of attachment of an exopodite is shown, and in the specimen it looks as though *f* had been broken away from *x.*

Fig. 4.—Restoration of the thoracic limbs of the fifth segment anterior to the pygidium.
  en. Endopodite. p. protopodite. a. four proximal swimming joints. b. three distal joints.
  ex. Exopodite, attached to same joint of the protopodite as the endopodite.

Fig. 5.—Restoration of the thoracic limbs of the fourth thoracic segment posterior to the head.
  en. Endopodite. *ex.* exopodite.

Fig. 6.—Diagrammatic restoration of the second thoracic limb (after Beecher).

Fig. 7.—Restoration of thoracic limb of *Calymene senaria.*
  en. Endopodite. *ex.* exopodite. *ep.* epipodite. (Bull. Mus. Comp. Zool. vol. viii. 1881.)

Fig. 8.—Cephalic limb of Calymene × 3; supposed antennule.

Fig. 9.—Cephalic limb figured by Dr. Henry Woodward. (Quart. Journ. Geol. Soc. London, 1870, vol. xxvi. p. 487.) a. Side of hypostoma.

Fig. 10.—Slender jointed legs associated in same beds with Calymene at Cincinnati, Ohio.

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[1] The appendages of *Triarthrus* are replaced by iron pyrites, and are usually well preserved. The specimens of Calymene and Ceraurus from the Trenton Limestone of Trenton Falls, N.Y., were replaced by calcite, and in them there were preserved even more delicate parts than I have yet observed in *Triarthrus.* Thin sections were made of the latter and photographs obtained by transmitted light, that were used in illustrating the paper in the Bulletin of the Museum of Comparative Zoology, vol. viii. 1881.

III.—THE BASIC ERUPTIVE ROCKS OF GRAN (NORWAY) AND THEIR INTERPRETATION. A CRITICISM.

By H. J. JOHNSTON-LAVIS, M.D., F.G.S., etc.;
Prof. (pareg.) of Vulcanology in the R. Univ. of Naples.

BEING present at the reading of the abstract of my friend Prof. Brögger's paper at the last meeting of the British Association, and having listened to certain laudations thereon, I, with several others, went away with the profound conviction that our Scandinavian colleague was about to bring down upon us a mass of evidence bearing on the differentiation of rocks as irresistible and overwhelming as that of his Viking ancestors in times gone by. Since then, however, calmly reading over his admirable memoir recently published in the Quart. Journ. Geol. Soc.,[1] what was my astonishment to find that this veritable avalanche of facts brought forward to support a preconceived hypothesis is of inestimable value as material evidence to be used against the theory of internal chemical segregation, as maintained by that author.

We have described to us several comparatively small eruptive plugs of varying shape the material of which has forced its way through Silurian and Devonian shales and limestones; and considering their limited dimensions has produced intense and widespread contact metamorphism in the country rocks around them by the formation of minerals which Prof. Brögger admits in some cases to have derived part of their constituents from the metamorphosing magma; yet my friend asks us to believe that all the varieties of composition in the igneous rocks are due to chemical segregation. We are told likewise that as we examine the eruptives from north to south, we find them become less and less basic, and this is given as evidence of segregation in the magma taking place in horizontal extension; yet nothing is said of the variations in the composition of the country rock in the same direction.

In the next place the nuclear part of these eruptive stumps is shown to be less basic than the peripheral. This is just what we should expect, and corresponds with the arrangement as displayed in many other dissections of ancient volcanic districts. Prof. Brögger would have us believe that this shows the segregation of a more basic paste near the cooler walls of the cavity, and the concentration of the acid portion in the central and hotter part of the reservoir. Now these facts can be interpreted in quite a different manner. Have we not here strong evidence of the *osmotic* theory, which I maintain is the true general explanation of the variation in eruptive rock composition. A small conduit of an unknown original chemical constituent has, in passing through basic sedimentary rocks, produced in these an intense physico-chemical change and extensive development of new minerals at the expense of the loss of silica, alumina, alkalies and probably other constituents, whilst a very marked gain has taken place with regard to the amount of magnesia and lime. Without an elaborate series of analyses of the alteration products in the surrounding rocks, we can only form a most inaccurate idea

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[1] Vol. L. part 1, February, 1894, pp. 15–37.

of where, with the exception of the MgO and CaO, there has really been loss or gain.

Prof. Brögger tells us that the earlier rocks were the more basic, but he hardly gives us any *segregation* explanation why this should be. The *osmotic* theory affords very efficient reason. The first part of an acid magma penetrating limestone, or other basic strata, comes in contact with fresh unaltered rock, and can soon become basified; but in so doing it has formed a practically neutralized lining to the igneous conduit, and consequently the paste that follows will be gradually less and less affected. This earlier basified rock has partly or entirely cooled—in some cases by a re-extension upwards of the igneous matter—this cooled rock is only cracked and reinjected by the more acid paste that follows, just as Prof. Brögger describes as so common at Gran. In other cases the fissure-filling fluid material at a later date extends and breaks the earlier basic rock, enveloping it just as my Scandinavian friend describes the bostonites cutting the comptonites and enveloping rounded, and therefore to me partly eaten up, fragments of the latter, and also pieces of pyroxenite which we are told were due to "earlier crystallizations of basic composition in a paste, from which the distinct magma of the bostonite was not yet separated as a final product of differentiation."

Now how much simpler and more natural is my own explanation of the state of things as given above. Curiously, that very same morning, at Nottingham, when Prof. Brögger read his note, Prof. Sollas brought forward an admirable example of an analogous case of extraneous rock enclosures, and gave the right interpretation of it.

In the bostonite breccias the included fragments of shale are described by Prof. Brögger as being "surrounded by a basic green mass, partly of comptonitic composition," and we are expected to believe that the cooling effects of these fragments caused a more basic segregation on their surface. This phenomenon is of everyday occurrence, and well known to a geologist accustomed to active volcanoes; but so far from favouring the theory of *chemical diffusion and segregation,* it is a striking example of the contact metamorphism of a magma by its solid enclosure. As a rule, the smaller the enveloped fragment, the relatively greater is the basic shell around it; but were the result due to the cooling effect of the enclosure, the larger this was the broader should be the segregation band.

Certainly the analyses given by Prof. Brögger prove in a most striking manner the acquisition of MgO and CaO of the comptonite paste with the actual or relative loss of FeO, $Al_2 O_3$ and the alkalies from the bostonite paste.

Another fact struck me as very remarkable: the two bosses of Brandberget and Solvesberget are smaller and more basic than that of Viksjeldene, and this again is more basic than its larger rival at Dignæs. This is just what we should expect, that the less the size of the injection the greater would be the relative chemical change produced in it by the surrounding sedimentary rocks.

I am glad Prof. Brögger confirms what I have always maintained to be a general principle, that the larger the mass of any given intrusive rock of a given sized grain, the greater will be the amount of contact metamorphism; also his observation is a most valuable one concerning the difference in the type of such change in the surrounding rocks, as the composition of the acting magma varies.

Looking at this valuable evidence so lucidly worked out by Prof. Brögger in the light of no preconceived idea, we find that it *does not* in any way prove "that differentiation of the original magma has, to an essential degree, been dependent on the laws which govern the sequence of crystallization," but that it does afford the strongest evidence in favour of the differentiation of an original unique paste by the *osmotic reciprocal reaction* between it and that of the country rock that it has been intruded into.[1]

I am satisfied that when these rocks are studied in this new light and in conjunction with other eruptives of the district, it is not improbable that we shall find they are all modifications of one original paste (not that suggested by Prof. Brögger) which *possibly* might be that of the great mass of granitite of the region.

NAPLES, *March* 16*th*, 1894.

IV.—ON A NEW SPECIES OF *DIPLACANTHUS*, WITH REMARKS ON THE ACANTHODIAN SHOULDER-GIRDLE.

By R. H. TRAQUAIR, M.D., F.R.S., F.G.S.

MANY years ago, and before I entered on my duties in the Edinburgh Museum, the late Mr. C. W. Peach pointed out to me a specimen in the Hugh Miller Collection, which he was inclined to consider as new. It was a Cromarty nodule with dislocated remains, including a dorsal and a pectoral spine, of what was apparently a *Diplacanthus* of unusual size.

I did not consider at the time that the evidence was quite sufficient to warrant the description of this specimen under a new specific name; but since that time, and indeed comparatively recently, specimens have been added to the collection which fully justify Mr. Peach's surmise. Certainly they belong to an undescribed species, and this species is undoubtedly the same as that in the Hugh Miller Collection already referred to. Two of them were purchased two years ago from Mr. Damon, while one occurred in the Powrie Collection; all three are from Gamrie.

This species attains a greater size than *D. striatus*, Ag., the largest entire specimen measuring 7½ inches in length, while still greater dimensions are indicated by the spines of the example in the Hugh Miller Collection. The great distinguishing peculiarity is to be found in the external sculpture of the spines. The longitudinal ridges are fewer and broader, the intervening furrows narrower, than in *D. striatus*, and the flattened surfaces of these ridges are *again finely striated*. On the posterior dorsal spine only two lateral furrows are seen, by which two ridges are marked off in front, the space remaining behind being nearly equal to both of these.

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[1] See my paper, "The Causes of the Variation in the Composition of Igneous Rocks," Nat. Science, vol. iv. Feb. 1894.

The pectoral spine is well shown in the Hugh Miller specimen, and has the same sickle-shaped contour as that in *D. striatus*; but the ridges are, as in the case of the dorsal spines, less numerous and more flattened. The secondary striation is not observable on this spine, but it is most distinctly seen on the anterior dorsal one, which lies close to it in the same nodule. The posterior or concave border of the pectoral spine is furnished with recurved denticles, a character also found in *D. striatus,* though not noticed by either Agassiz or Smith Woodward.

The spines seem rather smaller in proportion to the dimensions of the fish than in *D. striatus.* The scales are quite similar in character.

I propose to name this species *Diplacanthus tenuistriatus,* and its recognition is certainly not complicated by any claim to revival on the part of any of the cast-aside synonyms of *D. striatus.*

Formation and Locality.—Old Red Sandstone of the Orcadian series; Cromarty and Gamrie.

REMARKS ON THE ACANTHODIAN SHOULDER-GIRDLE.

It has long been well known that the pectoral spine in *Acanthodes* was supported by a peculiar bone constricted in the middle, expanded at both extremities, and perforated along its long axis by an internal hollow or canal. This ossicle has usually been interpreted as an element of the shoulder-girdle, and designated "clavicle," or "coracoid."

Mr. Smith Woodward, however, in the second part of his "Catalogue of the Fossil Fishes in the British Museum," published in 1891, put forward an entirely different theory as to the nature of this bone. Instead of considering the bone in question to belong to the shoulder, he looks upon it as a "basal" element of the fin. In fact, as I understand the case, Mr. Woodward regards the pectoral fin of *Acanthodes* as specialized from the Selachian type by the abbreviation of the Basipterygium, and finally by the disappearance of all the basals save one.

The configuration of this element in *Acanthodes* certainly suggests strongly the idea of a bone, preformed in cartilage and ossified from the outside inwards, and leaving a conically constricted internal cavity. But there are other Acanthodian genera than *Acanthodes,* and in some of these, notably among the Diplacanthidæ, the form of the bone in question is considerably different. In *Diplacanthus* the bone does not present that hour-glass sort of shape we are familiar with in *Acanthodes,* but is pointed above, expanded and flattened below, so as to assume an appearance reminding us of a Palæoniscid clavicle. And in fact Mr. Woodward does interpret this element in *Diplacanthus* as a "clavicle," and has pointed out two small "infra-clavicular" pieces which connect in the middle line the lower extremities of the clavicles of the two sides. Moreover, he makes the possession, or not, of a clavicle into a taxonomic character: thus the Acanthodidæ have one dorsal fin and no clavicles; the Ischnacanthidæ two dorsal fins and no clavicles; the Diplacanthidæ two dorsal fins and clavicles present. Of course in the Acanthodidæ and Ischnacanthidæ the ossicle supporting the pectoral spine is interpreted as a basal piece.

Against this view of Mr. Smith Woodward I protested in a review of his work which appeared in this MAGAZINE for March 1891, and I am still as strongly as ever of opinion that the element which Mr. Woodward calls "clavicle" in *Diplacanthus* is identical with that which he considers as "basal cartilage" in *Acanthodes* and *Ischnacanthus*. And I base this opinion upon the fact that the relation of the supposed basal bone, in the one case, to the pectoral spine, is identical with that of the supposed clavicle in the other; while we may also, in the series of Acanthodian genera, trace every gradation from the most to the least claviculoid shape of the bone.

No one can doubt that the Diplacanthidæ show a more archaic type of configuration than the Acanthodidæ, and among the former the most archaic form is *Climatius*. Here the ossicle in question greatly resembles the vertical limb or upper part of a palæoniscid clavicle, being both thin and flattened, and I have not been able to discover in the specimens before me any trace of the internal tubular hollow seen in *Acanthodes*.[1] In front of the lower end there is an infra-clavicular element.

So there is also in *Parexus*, but in this genus the internal hollow has appeared in the supporting ossicle of the spine, which, though still expanded and flattened below, has become straighter and more cylindrical above, thus showing a decided step towards the "basal" bone of *Acanthodes*. And, indeed, as "basal cartilage" this very element is designated in Mr. Woodward's diagram of the shoulder of *Parexus* (*op. cit.* p. 35), while the piece on the same figure which he designates "clavicle" seems to me, from its position with respect to the anterior extremity of the spine, and also the other element just referred to, infra-clavicular in its nature. This view receives further confirmation from the fact mentioned by Mr. Woodward that these supposed clavicles meet in the middle line. In *Diplacanthus* the supporting bone of the great pectoral spine becomes again very claviculoid in shape, but the internal tubular hollow is there all the same, a fact noticed by Mr. Woodward himself (*op. cit.* p. 23). A pair of infra-clavicular elements is also seen, as already noticed, and these help to support the lesser pectoral spines.

Concerning the relations of the two pectoral spines of this genus, outer and inner, Mr. Woodward says that their axes "are inclined towards one another, and at their proximal extremity they are firmly united by a mass of hard tissue, which is probably to be regarded as the basipterygium or basal cartilage." This is a view with which I cannot agree. In the first place, even if the tissue in question were cartilage, I do not see any resemblance between it and the ossicle, which the author interprets as "basal" cartilage, in *Acanthodes*. But the appearance is, to my eye, solely due to an expansion

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[1] Since the above has been in type, I have seen in specimens of *Climatius*, preserved in the British Museum, clear evidence that in this genus the bone in question is furnished with an internal tubular hollow, as in other Acanthodei.

of the bases of the two spines, the portion belonging to each being in one of my specimens apparently divided from the other by a suture; though in others no such division can be seen.

As regards *Ischnacanthus*, it seems to me that no one can look at its shoulder without being convinced that the ossicle supporting its pectoral spine is perfectly homologous with the corresponding element in *Climatius*, *Euthacanthus*, *Parexus* and *Diplacanthus* on the one hand, and *Mesacanthus*, *Cheiracanthus* and *Acanthodes* on the other. Its upper extremity has become more cylindrical, its lower is still considerably expanded.

The shoulder-bone of *Mesacanthus* is still to some extent claviculoid in appearance, the lower half having a laminar expansion, but in *Cheiracanthus* and *Acanthodes* it has become almost quite cylindrical, save just at the lower extremity, where it joins the pectoral spine. Here I may repeat that the relation of this element to the pectoral spine all through the series of genera is so identical that for my part I cannot conceive that the bone should be in one case a "basal," in the other a "clavicle." Therefore I can also see no reason why *Ischnacanthus* should be separated and put into a family apart from the other Diplacanthidæ.

But what *is* the shoulder-bone after all? It cannot well be a basal bone, as microscopically it is, according to Reis, like the spines and scales, entirely composed of Dentine,[1] and its configuration, and association with another plate-like "infra-clavicular" element in certain Diplacanthidæ, pretty certainly indicate that it is also, like the spines, entirely superficial in its origin. I therefore must concur with Reis in considering this bone to be a "claviculoid," or a dermal structure assuming the position and functions of a clavicle.

V.—THE MOST RECENT CHANGES OF LEVEL AND THEIR TEACHING. PART I. THE RAISED BEACHES.

By Sir HENRY H. HOWORTH, K.C.I.E., M.P., F.R.S., F.G.S.

THERE are signs accumulating everywhere that the views so logically pressed to their conclusion by Hutton and Playfair, and by a great catena of geologists, since the appearance of the first edition of Lyell's "Principles of Geology," have received a certain check; and no one can read the works of the great Continental geologists without seeing that there is a tendency to reconsider the position, and to hark back to the views of another school of teachers.

While conceding that diurnal and slowly operating causes have done much to smooth and shape the superficial features of the world, many sober geologists are beginning to realize that it is to

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[1] In the substance of this bone there seem to be no vascular canals. Reis (Zur Kenntniss des Skelets der Acanthodinen. Geognostische Jahrbücher, 1890, pp. 27 *et seq.*) describes and figures dentine tubules, but these were not observed by Fritsch, who describes the structure as consisting entirely of closely superimposed laminæ (Fauna der Gaskohle und der Kalksteine der Permformation Böhmens, Bd. iii. Heft 2, pp. 54, 55).

intermittent and not to continuous and uniform conditions and forces we must attribute its greater features, its mountains, and its ocean depths, its valleys and its scarped cliffs, its chasms and its splintered pyramids, and needles of naked rock.

I know of no more elementary fact in this behalf than that presented by our own islands. That they have been subjected at different times to vast movements of upheaval and subsidence is as plain as the presence of the sun in a July sky; yet if we candidly question the evidence as to what has occurred here in historic times, which means since the Romans planted themselves here, we shall fail to find (at least I have after a diligent search failed to find) any satisfactory evidence whatever to justify the conclusion that there has been a change of level, or even any material change of outline in these islands during the interval.

No doubt there have been local invasions of the coast in Norfolk and Suffolk and Yorkshire, as there have been depositions of silt and mud in the Wash and in the marshy country round it. The Wantsum has been silted up, and the Roman ports of Richborough and Reculver are no longer ports. There have been small local invasions of the coast at Rye and Winchilsea, and there has been a corresponding accretion in Romney Marsh. The two processes have, in fact, compensated each other. Erosion of the projecting headlands and of the land exposed to rough tides has been correlative with the deposition of the products of erosion elsewhere. All this is familiar and elementary.

On the other hand, the continued existence of the Pharos at Dover Castle and the continuance until recent years of the corresponding Pharos of Caligula, at Boulogne, shows that the outline and limits of the coast at these critical points, where the rush of the Channel tide is greatest, must be very much what they were in Roman times; nor is there anywhere, so far as I know, either in the North of England or the South, satisfactory evidence that the land has risen or the sea has sunk since Roman times; while there is some evidence, like that of the Hythe canal, the terminating portions of the Roman wall in the north, and the facts collected on the Cheshire coast, to show that the respective levels of land and sea have remained unaltered.

While I am on this subject I am tempted to quote a not too familiar passage from Hutton, with whom I cannot often agree. "The description," he says, "which Polybius has given of the Euxine, with the two opposite Bosphori, the Mæotis, the Propontis, and the port of Byzantium, are as applicable to the state of things now as they were at the writing of that history. The Isthmus of Corinth is apparently the same at present as it was two or three thousand years ago. Scylla and Charybdis are still, as in ancient times, rocks hazardous for coasting vessels; the Port of Syracuse, with the Island which forms the Greater and Lesser Port, and the Fountain of Arethusa, the water of which the ancients divided from the sea by a wall, do not seem to be altered . . . . on the Coast of Egypt we find the rock on which was built the famous Tower of

Pharos, and at the eastern extremity of the Port of Ermoste the Sea Bath cut in the solid rock upon the shore. Both these rocks are to all appearances the same at this day as they were in ancient times." Similarly Murchison showed that on the Danube the remains of Roman buildings prove that no change of level has taken place since Roman times.

These remarkable facts are proofs, no doubt, of uniformity of continuous conditions having subsisted during the last eighteen centuries; but they are at the same time equally clear proofs that there was a time, or rather there have been many times, when the crust of the earth in these latitudes had more "ups and downs" than it has had recently.

Let us now proceed a step further. If we traverse the limits of recorded history and try to discover what archæological or geological evidence we can reach of the latest changes in the distribution of land and water within our four seas, we are remitted to two kinds of evidence, that of the submerged forests on the one hand, and that of the raised beaches and their associated phenomena on the other. With the submerged forests I do not at present propose to deal, but will limit myself to the raised beaches. What then is the meaning of the raised beaches?

Before we attack the main point, I wish to say something of a subordinate issue, upon which I think a great deal of baseless inference has been built. There are two places in Britain where primitive boulders occur, in which it is possible that they are quite accidental. One is on the coast of Sussex, and the other is the case of the so-called Norwegian boulders in Eastern England. Upon both of these occurrences, as we have said, very large conclusions have been based; and they would, in a measure, be justified, if these boulders were erratics, but on this point there is the gravest doubt. First, in regard to those found in the English Channel (and I am speaking of the foreign stones only) whose provénance has been much debated and in regard to which extraordinary postulates as to shore-ice and floating-ice in the English Channel have been forthcoming, in spite of the fact that the shells and other *débris* found there show *no traces* of great cold, but on the contrary are mixed with Lusitanian and southern forms. It seems to me that not only the very local distribution of these boulders, but the place where they occur, in a reach of embayed waters, are strongly against their having been regular erratics. If they had been so, assuredly we should have found others in the Isle of Wight and on the coast of the mainland east and west of it, besides the mere cluster to which I refer, and which has been so much discussed. How, then, would I account for these boulders? By the simple theory that they may be ballast which has either been thrown overboard or has come from some ship which has gone to pieces on the coast. Assuredly this is a very reasonable explanation of the facts and much more in accordance with scientific laws of evidence than the current theory, and it ought to be discussed and its possibility tested before we are called upon to face much more difficult causes.

I would apply precisely the same explanation to the so-called Scandinavian boulders of Eastern England; these boulders have been the mainstay of those who have argued in favour of a North Sea ice-sheet, which is supposed to have filled up the whole area between Scandinavia and Britain.

In my recent book on the Glacial Nightmare, I have advanced a number of arguments against this theory. Professor Bonney has recently added a new and striking one, based upon the difficulty such an ice-sheet would have in traversing the hollow trough which runs down the western coast of Scandinavia; these do not, however, exhaust all the arguments. If a portentous ice-sheet, loaded with various kinds of stone, had come all the way from Scandinavia to Britain, we should expect to find traces of its terminal moraine, and we should certainly expect to find not only a few scattered stones on the beach in Yorkshire or East Anglia, but large numbers of them inland, not only in England, but more especially in Scotland. It must be remembered also that the most characteristic of these stones, if not all of them, come not from the part of Norway opposite Britain, but the Christiania Fjord. This is very emphatically maintained by the late Prof. Carvill Lewis and the Northern geologists, whence it is most difficult to see how an ice-sheet could have travelled to Britain at all.

The fact is, the whole theory of a North Sea ice-sheet, in so far as it is based on these boulders, is a stupendous test and trial of human credulity. I believe these stones to be like those from the English Channel, merely ballast which has been thrown overboard, or left by some wrecked ships. I may say that my very acute friend Professor Hughes, of Cambridge, shares this opinion, and since I wrote this has published his views in "Nature," which I feel to be a very important support to my contention. He tells me that he once entered the hull of a wrecked ship on the coast of East Anglia which was being broken by the waves, and which contained in its hold ballast consisting of foreign primitive rocks. This seems to me to be a very useful instance of an occurrence which must have been very frequent indeed on this much exposed coast, and which furnishes a reasonable key to a problem which has mystified many people, and grateful to those who believe in sobriety as a potent factor in scientific reasoning, and who have not been led captive by the charming but delusive rhetoric of Agassiz and his scholars.

Having discussed the interfering factor involved in the foreign stones on the Yorkshire and Hampshire coast, let us now turn more directly to the meaning of the raised beaches.

They are generally taken to mean that the beaches represent the level at which the sea once stood, and we are asked to concede that these beaches prove a former submergence of the land up to the point where they occur. That they do mean this is clear enough, but it seems to me that this is not all. The really interesting question is not whether the sea once reached up to the level of these beaches, but whether its presence there was lasting and continued or merely transient and ephemeral. Do the beaches mark the result of a more or less permanent change of level in the sea margin, by which the land was upheaved, or do they merely mark the highest level of a transient wave or rush of water, such as is left by every high tide of the sea, and by every flooded river, or rushing current escaping from a lake which has burst its barriers, along the margin of its highest rush.

The former view is that which chiefly prevails among the teachers of Uniformity, who prefer to make whole continents rise and fall to explain every similar phenomenon, so long as the process is a slow one, than have recourse to any unusual displacement of water on a large scale, which must follow any such upheaval or subsidence on a much smaller scale when rapid. I must confess to being a supporter of the latter view.

In the first place I would call attention to the exceedingly sporadic and scattered character of these raised beaches. They are nowhere continuous for any distance; they consist chiefly of mere shreds and patches of gravel here and there, and not of continuous and deep shingle beaches and masses of sand with marine shells in them, such as the margins of the ocean would deposit. If there had been a continuous and widely-spread elevation of the land we should certainly have had in many places a replica of the modern strands. Not only so, but these strands would have passed continuously round all the inlets and recessed gulfs and bays of the land, where they would have been virtually proof against subsequent denudation.

Again, the sea would in this case have invaded all the lowlands within its reach, and would in that case have covered them with unmistakable marine deposits, mud and sand with marine *débris.* Of evidence of this I can find none. This applies to the low-level beaches. If we turn to the high-level ones the case is even more remarkable. When we remember the height at which the Moel Tryfaen and the Macclesfield beaches occur, it seems impossible to understand, if they mark an actual prolonged submergence to that extent, how it is that over large areas in England we do not find most unmistakable evidence of prolonged submergence in the shape of unmistakable marine deposits with the manifold wreckage of the sea, for the submergence in question must have covered a large part of these islands with a great depth of water, and according to Uniformitarian views must have done so for a long period.

I cannot, therefore, see in these beaches the proof of prolonged submergence which others profess to see, but rather the passage along the shore of a great tidal wave or rush of water, caused by disturbance of the strata somewhere, which took up a certain quantity of gravel, etc., and left it at its own high water-mark, at once a proof of its presence, and a measure of its intensity at the spot of the wave in question.

The next, and a very important, point to remember, which has been much overlooked, is the irregular height at which these raised beaches occur. If they had been due to the general upheaval of the land, we should have found assuredly some common level among them; instead of this it is scarcely possible to find any two of them at the same height. In inlets and coves they seem to rise as we go inland; elsewhere their elevation is as irregular and sloping as that of the terraces in some of the Scotch inlets is. This seems consistent not with a general and widespread elevation of the land, but with the rush of a mass of water, which when throttled in a narrow passage would rise to a higher level, and when it had free elbow room would spread out, just in the same way that we can see the Race in the Bristol Channel and in the Gulf of St. Micael spread out. Hence it does not seem to me that we have much good warranty for always separating the high- and the low-level beaches. They are possibly, if not probably, due to the same impulse and the same movement, and merely mark its varying phases, whether it was constricted or had room to flow freely. When it met with a barrier and its flow was rapid it would rise; hence, probably, the reason for the height of the beach at Moel Tryfaen. Where it had room to spread it doubtless reached far into the land until it spent itself. Hence, perhaps, the explanation of the occurrence of Whale's bones and skeletons in the low-lying districts south of the Wash, in Cambridgeshire, and the shells found in the district called the Straits of Malvern, which were once probably overrun by a great Race from the Bristol Channel. I take this to be the most rational explanation of the raised beaches and of the existence of marine *débris* in certain very local inland districts, which it has been the custom in so many geological manuals to quote as unmistakable witnesses of a general change of level of land and sea where they occur. I would extend this argument to all the cases where there is no clear evidence of the land being in an area of proved upheaval, as in Northern Scandinavia, in Greenland, and in Labrador. I would extend it also to the shell beds such as those at Uddevalla, which no stretch of the imagination would attribute to an old beach, and where I have spent many hours among them; also to some of the so-called raised beaches of Canada. I would of course except some of those cases where the shells have actually been found as they lived; but even here the greatest caution is necessary in interpreting the facts, for shells with their valves united and enclosed in clay might, under many conditions, be removed with the clay *en masse*, and thus simulate beds *in situ*. Within our seas I know of no raised beaches which can unmistakably claim to mark old sea-levels, but only the levels of one or more great cataclysmic tide or tides or waves—perhaps the very same wave or waves which spread out the drift and mixed the Boulder-clay and the gravel and sand of the Eskers with fragments of marine shells, etc.

Another question, of course, remains, and one which is very difficult of solution, namely, as to whether the various raised beaches at different levels which occur round these islands are the results of one considerable wave or of several, occurring at different times. It seems reasonable, at all events, to suppose that the low-level beaches and the high-level beaches belong to different diluvial movements. We have some evidence that one such movement took place in Northern Europe in the second century B.C. in the so-called Cimbric flood, mentioned by Florus as the cause of the migration of the Cimbri and the Teutones. The occurrence of the remains of a boat in the 20-foot beach on the Clyde points to one of these movements at least having been much later than the diluvial movement which destroyed the Mammoth and its companions. Perhaps the deposition of this beach was coincident with the so-called Cimbric flood.

These are questions, however, which the future must settle; what we are now chiefly constrained to urge is, that the raised beaches which have been supposed to index immense movements of the earth's crust, up and down, are capable of a much more moderate and much more plausible explanation, namely, that they are necklaces put about the land by the amorous sea in one of its more ardent moments, and correspond to the line of wreckage in the fields after an inundation.

VI.—THE CORRUGATION OF THE EARTH'S SURFACE AND VOLCANIC PHENOMENA.[1]

By ARTHUR VAUGHAN, B.A., B.Sc.

IT is important, in the first place, to discuss those facts concerning the Earth which must be taken into account in any attempt to deal satisfactorily with the problem before us.

To a depth of about 80 feet in Temperate regions, the earth has its temperature determined by the seasons; being warmed in summer and cooled in winter. Below this average depth the temperature remains constant throughout the year, and shows a steady increase as we go downwards. By observations made in deep borings, it is found that this increase is at the rate of about 1° F. for every 60 feet, and that this law holds true throughout a descent of several hundred feet; but that the rate of increase diminishes at considerable depths. This increase in temperature with distance from the surface points unmistakably to a large store of heat in the interior of the earth, and the increase in the rate at which temperature diminishes, as we approach the surface, agrees with what we should expect to happen if a large heated mass were allowed to cool; the nearer the surface the greater would be the rate of loss of heat, and consequently the more rapid the diminution of temperature.

The next important point to be considered is that, however the rocks near the surface may differ in composition, they are all distinguished by being divided up into larger or smaller portions by joints, bedding-plane, etc. The actual amount of separation caused by this means varies very much with different rocks; but in so far as it exists must necessarily allow of closer approximation if the rocks ever become subjected to great pressure. That this jointing is sufficient to allow of seasonal expansion is obvious, notwithstanding the fact that the difference between summer and winter temperature in continental regions is often extreme. Again, this division into smaller portions by jointing, etc., remains true at all

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[1] The author wishes it to be stated that this article was sent in on March 31st, 1894, but has not appeared earlier for want of space.—EDIT. GEOL. MAG.

depths to which observation has been carried; so that this property may be roughly said to define what is meant by the crust.

Let us now carefully consider what would be the effect of allowing a large heated mass to cool. We will first take the simplest case, namely, a sphere of homogeneous material. Considering the mass as made up of consecutive concentric shells, the outermost shell, on account of its greater exposure and closer proximity to the cooling influences, will cool faster than the next inner; but, since cooling necessarily produces contraction, and since the amount of contraction is dependent on the loss of temperature, the external shell will contract faster than that underlying it. It obviously follows that the outer shell exerts a squeezing force upon the interior, and, by compressing the mass into a smaller volume, increases its density. The interior in its turn prevents the outer shell from contracting to the full extent proper to its loss of temperature, and thus sets up a state of strain in the outer shell. Thus, progressively, each shell, by contracting upon the next inner one, increases the density of the interior, and is itself at the same time thrown into a state of strain.

A familiar illustration of this process is the brittleness induced in most metals by rapid cooling, and to minimize this state of strain recourse is had to the process of annealing. This reasoning seems to apply with equal force to the case of the earth. Each shell, as it contracts from loss of heat, compresses the included mass and increases its density; continued contraction of shell upon shell produces cumulative results in the same direction.

From this very effect also the amount of contraction will increase; for it is found that the coefficient of expansion of any material increases with its density. This, perhaps, affords an explanation of the fact that, whilst the specific gravity of the surface rocks averages about 2·5, that of the whole globe reaches 5·5.

It may, perhaps, be diffidently suggested that in a molten mass there would be a tendency to lessen the effect of differential contraction by a rearrangement of material in such a way that each successively smaller shell should have a greater coefficient of expansion to recompense it for a smaller loss of temperature.

Further, the effect of gravity upon such a molten mass would be to cause the accumulation of the heavier material towards the centre.

These two causes—the effect of gravitation on a molten mass and the subsequent effects of contraction—must be looked to as furnishing a probable cause of increased density in the interior.

To the compressing force of contraction we must also look for an explanation of the fact, established by astronomy, that the whole globe is solid. For, judging by the increase of temperature towards the centre, the rocks of the interior must be far above their melting point, and can only be prevented from melting by subjection to great pressure.

It must be doubted whether superincumbent pressure can have any great effect; for, were the whole globe composed of concentric homogeneous ellipsoidal shells, each such shell of gravitating matter must be necessarily self-supportive, and could only exert pressure upon the interior by undergoing contraction.

So far we have reasoned as if the whole globe were made up of homogeneous shells. But the crust is composed, and has been so throughout all geological time of which we have any accurate knowledge, of rocks differing greatly in their capabilities of expansion and contraction; and further the greater part of the crust has its temperature determined by earth-heat, or in other words possesses heat which it must be gradually losing. It is consequently important to obtain some idea of what would occur during the cooling of a large heated mass, where outer shells were composed of materials with different coefficients of expansion.

The first effect, caused by the cooling of the outermost shell, will be to produce a pressure upon the interior; but the strain thus set up in the outer shell will be gradually relieved by the splitting permitted between materials of different powers of contraction.

Thus the outermost shell will consist of a great number of slightly disjointed portions. This process will be continued throughout the cooling of the outer heterogeneous shells. When the interior, supposed homogeneous, begins to contract, the disjointed parts of the outer shell will be brought closer together to accommodate themselves to a smaller area—a movement of which they will always be capable without the formation of folds or rucks, since the loss of temperature is necessarily greater the nearer the surface.

Applying this reasoning to the contraction of the crust of the earth, it seems probable that jointing must ensue in the manner described above in all such rocks as have heat to lose. We do not, however, maintain that this is the only way in which such splitting can be brought about, for, no doubt, the shrinking from loss of moisture has always been a very effective cause.

We will now attempt to obtain some estimate of the amount of jointing necessary in order that the outer shells may follow a contracting interior. Let us assume a shell at the depth of a few miles to have its temperature diminished 10°, and further, let us suppose that this contraction is unresisted by a more slowly contracting interior.

For the purposes of actual calculation let us suppose the material of which the shell is composed to have a coefficient of linear contraction equal to ·00001174 (this is the coefficient of sandstone, which is intermediate between the coefficients for cast and wrought iron, and is greater than that for marble). From these data the contraction of one mile is found to be 7·2 inches. This, then, is the amount by which one mile length of the next overlying layer must be able to contract to avoid rucking up.

Putting this statement into another form; every yard of shell just overlying the contracting interior must be capable of shrinking $\frac{1}{240}$ of an inch to avoid rucking. The amount required at the surface will not appreciably exceed the above amount; for, if we imagine contraction to take place at a depth of five miles, the required amount of shrinking in each yard of arc at the surface will be approximately $\frac{4000}{3995} \times \frac{1}{240}$ of an inch.

It would seem that there could be no difficulty in assuming sufficient separation space in all known rocks to allow of this extent of approximation. But the case is in reality much stronger than appears in the above figures, for we have assumed no contraction to go on in any of the overlying rocks, whereas contraction must be in progress in all those rocks whose constant temperature exceeds the mean average surface temperature, and this at a faster rate than in the underlying interior, with the result that the separation spaces throughout the overlying shells are being increased so as to allow of additional approximation.

There would seem, then, no difficulty in accepting the idea that the crust will in general follow the contracting interior and not be thrown into folds, but will accommodate itself to a smaller area by the closer approximation of its component parts.

More space has been spent in considering this point than would perhaps seem necessary; but the theory has very generally been accepted that corrugations are caused by the shrinking away of a contracting nucleus from a consolidated non-contracting crust.[1]

It will be well, consequently, to examine what amount of corrugation could be produced on the supposition that the crust is non-contracting and incapable of accommodating itself to a smaller area. The interior is imagined to shrink away, but, by the action of gravity, the heavier areas of the heterogeneous crust are retained in contact with the shrinking nucleus. It follows, on the hypothesis of an incompressible crust, that the intermediate portions will be thrown into folds.

Employing the same data as before, and further assuming that the two areas, which, owing to the effects of gravity, sink with the contracting nucleus, are 1000 miles apart, we find by an easy calculation that the greatest possible height to which the under surface of the intermediate portions of the crust could rise is less than 5000 feet.

This is on the assumption that the crust is bent into two planes meeting above the middle point of the contracting arc. Again, since we cannot suppose the contracting nucleus to lie many miles beneath the surface, this maximum elevation will not be sensibly increased at the surface itself. It is very important to point out the favourable exaggeration involved in the data employed in the above calculation.

In the first place, owing to resistance from within, no shell could contract to its full extent; secondly, a fall of 10° would represent an enormous loss of heat in the interior; again, it is improbable that the two areas which sink with the nucleus could be so far apart; and lastly, that the crust should be thrown into the form supposed is utterly impossible, and at variance with the structure of all known mountain systems.

One further point in regard to this theory:—

Since the effect of the shrinking interior must be to draw closer together those portions of the crust which are in contact with it, the force between any two portions of the earth's crust must be one

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[1] A discussion of the later theory of Mr. Mellard Reade is contained in Part II. of this paper.

of compression. Thus any relief, sought for by the breaking of the crust, can only be found in the pushing of one portion over the other; that is to say, in the production of reversed faults. Normal faults could find no place as consequences of such a system of earth movement.

To pass on now to give what we think to be a possible and adequate explanation—

Let us suppose that some large area on the earth's surface is at considerably less distance from the centre than the surrounding regions, and that furthermore the surface rocks in such an area are maintained at a very low temperature. It follows that under such an area the surfaces of equal temperature will be at once more numerous and more crowded than under the surrounding regions—more numerous because, the surface being kept at a lower mean temperature, the range of temperature from the interior to the surface is greater and more crowded because the distance from the centre to any point of our hypothetical area is less than in the surrounding areas. In this case the distance between two points in the same radius, having stated temperatures, will be less than in the regions surrounding the area. In consequence, the transference of heat from one point to the other will be greater; or in other words the loss of heat will be greatest under the depressed area. Thus beneath such an area contraction will proceed at a faster rate.

In this place we wish to point out, once for all, that we shall simply consider the effects of contraction upon the nucleus which we imagine to be practically homogeneous at equal distances from the centre. We shall further assume that the overlying crust, being formed of heterogeneous materials, will follow a sinking interior without any rucking, for the reasons given at length above. This distinction in geneity between crust and nucleus probably means no more than that the materials composing the originally homogeneous surface shells have been rearranged by agencies, with which we are not now concerned, to form a heterogeneous crust. It will further appear, on carefully considering the areas under discussion, that the thickness of the crust may be considered to be at least small.

From the faster contraction which we have shown must take place under such an area, two results necessarily follow. In the first place there will be a great strain upon the rocks bordering upon the depressed area, since the tendency of contraction must necessarily be to draw them closer together. The effect of this strain will necessarily be in the direction of lessening the rapidity of descent from the elevated to the depressed areas, and in this attempt pressure will be produced on the underlying rocks. Secondly, on account of this very resistance to contraction, any arc traced on the area, being in the form of a broad arch, whose centre is approximately the centre of the earth, will in attempting to contract bend inwards so as to lessen its curvature, and consequently shorten its length. In performing such a movement, the underlying material will be, so to speak, squeezed out, and this will cause a real transfer from under the sinking area to beneath the surrounding regions. We may reasonably expect great compression, contortion, and plication to accompany such a movement. Such transference must cause real elevation of the surrounding regions in addition to the relative elevation due to depression of the sinking districts.

That this theory would be adequate to account for the present height of mountains seems very probable from the following considerations. The simple fact that a large area is depressed, and therefore the sea-level brought nearer the centre of the earth, implies the raising of the undepressed parts above it. Due to this cause, we obtain the same maximum height as was found possible under the theory referred to above.

In the second place, actual transfer of material from under the sinking area must add still more to the elevation caused by relative displacement.

Lastly, we have the important fact that the rate of contraction beneath such areas is far in excess of the average under neighbouring areas, and that this rate is maintained by the continual contraction of fresh portions of the heated interior, brought into contact with the cold outer layers by the squeezing out of intermediate material.

The material thus pressed out from under the contracting shell-caps and forced beneath the surrounding regions, will exert an additional strain upon the overlying crust, which, as explained above, has already been stretched by the contraction itself. In this process it is quite conceivable that great metamorphism will result from the movement under enormous pressure. But, so long as this pressure is unrelieved, no igneous rocks could possibly be generated; for, though no doubt the compression will raise the rocks upon which it acts to a temperature far above their melting point, any increase of volume which melting would imply will be strenuously resisted.

Two extreme cases must now be discussed:—

First: suppose the change from elevated to depressed areas to be spread over a large space and to be uniformly slow. In this case, the strain upon the overlying rocks will be spread over a very large area, and there will be no lines of special weakness. Here, then, we should not expect the crust to split right through at any point, but rather that it would suffer an uniform extension by the extension and development of local separation spaces, and in this way very gradually relieve the state of tension. This gradual relief from pressure might be sufficient to slowly melt the underlying materials, which, when first brought into the position contemplated, must have been under so great a pressure as to be raised above their melting point.

The slowness of the action would ensure the production of a holocrystalline igneous rock.

Secondly: suppose the change from elevated to depressed areas to be very rapid. Here we have special lines of weakness afforded by sudden bends, and the probability seems to be that at such points the crust would be unable to withstand the total strain and would split right through.

The portion nearest the sinking area would thus be drawn away from the rest of the crust, which would be raised to a higher level by the pressure from below. In this way a normal fault, or succession of such faults, would be brought about.

Again, the sudden relief from great pressure caused by this means, when the underlying rocks are far above their melting point, would result in their sudden melting. The very high temperature at which this melting may be supposed to be produced will necessarily ensure very complete liquefaction, and aided partly by the pressure from below, and partly by the increase in volume due to melting itself, the molten material will be exuded through the clefts formed in the broken crust, to rise to the surface in a flow of lava. Further, the rupture of the crust would certainly cause an earthquake, and, as we have shown, it would be natural to expect depression or elevation to be a consequence. That earthquakes are often followed by such phenomena is well known.

Again, the greatest pressure being between the stretched crust and the upward forced interior, the depth at which earthquakes would be generated on this theory seems to accord well with observed results. It merely remains now to point out where such areas as we have considered exist, and to illustrate the effects of the theory by well-known examples. In the first place the earth is flattened at the Poles, so that each Pole is about thirteen miles nearer the centre than any point in the equator. Again, the Polar regions have, for vast ages, been covered by ice, so that the ground is constantly frozen far below the surface; also the change is very gradual from elevated to depressed areas.

We should expect then that the Polar regions themselves are sinking, but that the neighbouring regions are rising, and that this should be an effect spread over large areas. These facts seem to be in accord with the observations that whilst Greenland is found to be sinking, Norway is rising.

A suggestion may here be thrown out as to a possible explanation of the events supposed to have occurred during the Glacial epoch.

Before the Glacial period there is evidence that the British Isles, as a whole, were above sea-level; but that during the period subsidence took place and that, after its departure, the Islands again rose. This seems to be in entire agreement with what the above theory would require. During the period of great cold, lasting for an enormous time, the ground must have been frozen to great depths, as is proved by borings in Siberia, where the effects are still very obvious in frozen ground, extending to several hundred feet. In consequence rapid contraction must have taken place beneath the area, together with the transfer of material from below. These two causes combined must have drawn the area down to below the sea-level. On the termination of the period, the Polar regions must again have become the principal area of subsidence, resulting in the gradual upheaval of the neighbouring regions, as evidenced by the raised beaches of Norway and Scotland which characterized the post-Glacial period.

The second class of areas, which satisfy the conditions of our theory, are the deep ocean floors. Here we have depressed areas surrounded by more elevated regions; the surface layers being maintained at a very low temperature, as determined by recent soundings. These, in general, afford examples of the case in which the passage from elevated to depressed areas is rapid. We should therefore expect to find, along the borders of such areas, evidence of volcanic phenomena. It is sufficient to quote, as illustrative examples, the vast ring of volcanoes which surrounds the Pacific Ocean. It seems also specially worthy of notice that Japan is the scene of continually recurring earthquakes. Now it is on the borders of the Pacific in the neighbourhood of Japan that we find the most rapid passage from elevated to depressed areas, for here is the deepest depression in the whole ocean. In consequence, we have here a line of great weakness, and should expect earthquakes to be most frequent if in any way dependent upon the above explained cause. As a last point of agreement with the theory, we may notice Darwin's theory of Coral reefs as pointing to the comparatively rapid sinking of the deep sea floors.

In conclusion, a few words may be said upon the necessary consequences of the truth of this theory. It points unmistakably to the permanence of continental and deep sea areas, and would indicate that the tendency has always been to deepen and render narrower the ocean basins. Perhaps, also, it points to a continual tendency to render the globe more elliptical by increasing the flattening at the Poles. It would also necessarily follow that great elevations could only take place on the borders of deep oceans, or in proximity to regions of prolonged cold. Lastly, that volcanic phenomena may be expected to occur along the coast regions of great oceans.

It may be remarked, as a necessary deduction from the first of the above statements, that the crust covering the areas with which we have dealt must be extremely thin, and that, at the bottom of the deep sea basins, we should expect to find the nearest possible approach to the primitive crust.

It is, of course, not assumed that this theory is applicable to all cases of subsidence and elevation which, when local, are no doubt due to much less potent forces, such as denudation and deposition.

(*To be continued.*)

VII.—On the alleged Conversion of Chlorite into Biotite by Contact Action.

By Lieutenant-General C. A. McMahon, F.G.S.

I HAVE to thank Dr. Callaway for the courtesy and good-humour with which he has received my criticisms on his paper in the December Number of the Geological Magazine. Would that all controversial fencing were conducted with equally well-tipped foils.

My Roman soldiers, in particular, have been received with a kindness that reminds me of the friendly meetings of the British and French officers in the Peninsular War during brief seasons of armistice. Indeed, one might almost go so far as to say that friendly intercourse with these Roman cohorts has imbued Dr. Callaway with a taste for military tactics, and has inspired him to perform a masterly change of front under cover of the active advance of a line of skirmishers.

We are now told that the conversion of chlorite into biotite is due to contact action; indeed, Dr. Callaway "thinks it probable that there is not a scrap of biotite in the crystallines of the Malverns which has been produced except by 'contact action.'" I am glad that this fact has been clearly brought out, as I unfortunately received the impression from Dr. Callaway's paper—an erroneous one as it now appears—that the conversion of chlorite into biotite was considered a case of dynamo-metamorphism.

I cannot attribute this misapprehension altogether to my own stupidity. If Dr. Callaway's language had been more precise, and to the point, I should not, I think, have fallen into this error.

My criticism was expressly confined to the four corners of Dr. Callaway's paper. In that paper he did not say that he considered the change of chlorite into biotite a contact phenomenon. He did not state that the heat required to convert a hydrous into an anhydrous mineral was due to the proximity of eruptive granite; on the contrary, he used language that seemed to point directly to the generation of heat by dynamic agencies. We were told that "the temperature of metamorphism . . . often rose to the point of fusion in the *shear zones*"; and further on he wrote, "where the rock is *slightly crushed* [the *italics* are mine], and there are no signs of rock-fusion [the fusion depending apparently on the amount of crushing], there is decomposition of hornblende; but when there is *intense crushing* and *shearing*, accompanied by a high temperature, reconstruction sets in and biotite is generated."

If Dr. Callaway wished to convert petrologists to the belief that chlorite is converted into biotite by *contact* action, I think it was unfortunate that he did not expressly say so, and that he used language that seemed to indicate a belief, on his part, that dynamic action was the cause of the conversion.

Dr. Callaway goes on to remark: "It would therefore appear that General McMahon admits the conversion of chlorite to biotite by contact action; and if so, I want to know why he opposes my theory." In other places he says that he "does not understand my position," and asks me to "elucidate" it. I trust, therefore, that I may be pardoned for entering into a discussion on this point. I shall be very brief.

I did not admit the conversion of chlorite into biotite. What I said was: "In cases of contact action one can readily understand how aqueous acid vapours, or liquids, emanating from the molten igneous rock under high pressure penetrated the adjoining rocks, and carried with them in solution some of the constituents of the igneous magma." It is certainly fair to imply from this sentence that I admit the generation of biotite by contact action; but that is not quite the same as saying that the secondary dark mica, that owes its genesis to contact action, is chlorite converted *in situ* into biotite.

I may say, in passing, that I do not deny the *possibility* of the conversion of chlorite into biotite; but if this process really does take place it must be a very complex one; and it does not follow from the admission that the thing is *possible*, or even from the further admission that it *may* conceivably take place occasionally, under special circumstances, that I believe this process to be the one usually adopted by nature.

A very important remark was made by Mr. Teall at p. 221 of his British Petrography (see also the footnote at p. 642 of his paper on the Whin Sill in the Q.J.G.S. vol. xl.) when speaking of the introduction of albite into rocks altered by diabase, that the secondary mineral was "due to the actual impregnation of the surrounding sediment by material derived from the eruptive rocks."[1]

That dark mica is an exceedingly common product of contact metamorphism, in basic eruptive rocks altered by granite, is known to all petrologists. I have several very interesting examples of this among my Himalayan specimens, and I have described one in the Records of the Geological Survey of India, vol. xix. pp. 71–77. The acceptance of a dark mica (it need not always be biotite), however, as a contact mineral, does not necessitate the acceptance of Dr. Callaway's theory. We are naturally led to ask, Is not this mica the result of direct impregnation? Must the genesis of contact-mica be preceded by the production of hydrous chlorite? For that is what Dr. Callaway's theory involves.

It would not, of course, convince Dr. Callaway to assert that dark contact-mica may often be found in rocks which do not contain chlorite, because he might allege that chlorite was there in the first instance and that the whole of it had been manufactured into biotite.

Our courts of law, in the difficult task of weighing evidence and of deciding which of two conflicting witnesses is to be believed, are very much guided by considering the *probabilities* of the case. This principle is also a most valuable one in helping scientific men to decide between rival hypotheses. In the present case we are dealing with the contact action of granite. We know that granite must have consolidated at a considerable distance below the surface of the earth; and that, consequently, a long period (measured in geological time) must have intervened between its consolidation and its exposure at the surface. The sinking of that portion of the earth's crust, and the accompanying deposition of new strata, must have ceased; and a long period of elevation and erosion must have set in. This supposition is inevitable if we have to account for the removal of some 20,000 or 30,000 feet of superimposed strata, and the exposal of granite at the earth's surface.

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[1] In 1883 I remarked with reference to a Himalayan rock: "these facts appear to me to indicate that the rock was subjected to two different processes of contact metamorphism; one process—due to heat; . . . . whilst the second process was probably the injection of matter from the granite rock, possibly in a gaseous or liquid condition, along lines that followed the original direction of lamination or cleavage." Records, G.S.I. vol. xvi. p. 137.

Whilst this granite was being slowly brought to the surface, the rocks that accompanied it must have been exposed to those potent aqueous agencies which effected so many alterations in igneous rocks, and the traces of which petrologists see in almost every slice of basic rock examined under the microscope.

The Malvern basic rocks cannot have escaped the ravages of those aqueous agencies. Is it not far more probable then that the chlorite found in those metamorphosed rocks was produced by aqueous agencies *after* the formation of the biotite by contact action, than that the chlorite was formed *before* the eruption of the granite; and, like Shadrach, Meshach, and Abed-nego, escaped absolutely unsinged from the burning fiery furnace of contact metamorphism that converted their fellows from hydrous into anhydrous minerals?

I do not think it is necessary to suppose that the chlorite in the Malvern crystalline rocks was derived from biotite; it may have been derived from some of the other minerals in the rocks. But, on the other hand, the conversion of dark mica into chlorite would not, I think, present much difficulty to a petrologist who knows the story of the conversion of olivine and augite into serpentine. The passage of micas, such as biotite and phlogopite, into members of the vermiculite group ("closely related to the chlorites") is recognised by Dana (System, 6th Edn. p. 664). If phlogopite, a magnesian mica "near biotite," can be altered into serpentine (Dana, *ib.* p. 634) there is no difficulty in believing that biotite, or a dark mica allied to that mineral, can be converted, in the wet way, into a mineral of the chlorite, or vermiculite, groups.

In the case of basic rocks containing magnesian minerals, there would be no difficulty in accounting for the accession of additional magnesia—the magnesian minerals undergoing decomposition would supply that.

Dr. Callaway gives 34 per cent. as the average proportion of magnesia in chlorite; and the actual analyses of biotite (*vide* Dana) give, in some cases, proportions as high as 28 per cent., and in the case of phlogopite as high as 29 per cent. Very little, if any, magnesia would therefore be required for the conversion of a mica rich in magnesia into chlorite. I say "if any," because Dr. Callaway's figures confessedly represent the average proportion. In actual analyses it varies greatly and sometimes falls below the average; and further the removal of portions of the other bases (a necessary part of the process) would alter the proportion of magnesia to the bases that remained.

In conclusion I think it desirable, with reference to Dr. Callaway's remarks, to reinsist on the distinction to be drawn between an observed fact and a hypothesis advanced to explain a fact. The fact actually observed is the existence of chlorite and biotite in the same rock. Dr. Callaway explains this by one hypothesis; I explain it by another. I submit that he is not entitled to allege that the conversion of chlorite into biotite is an observed fact—any kaleidoscopic brandishing of authorities before our eyes notwithstanding—until he has shown that the hypothesis he advocates is the mode actually followed by nature; and that the hypothesis I advocate is not nature's mode of action. I submit that when chlorite and biotite are found together in the same rock, under the circumstances stated by Dr. Callaway, that it is more in harmony with the probabilities of the case to believe that the hydrous chlorite was created by aqueous agencies after the intrusion of the granite than to believe that the chlorite was created before the intrusion; that the biotite was formed out of a portion of the chlorite; and that during the long ages that succeeded, aqueous agencies (contrary to our ordinary experience) either had no access to these rocks, or that (contrary to their known habit) they altogether failed to form any chlorite out of the unstable basic minerals exposed to their ravages.

REVIEWS.

I.—Peter Redpath Museum, McGill University, Montreal, October, 1893. The Canadian Ice-Age; being Notes on the Pleistocene Geology of Canada, with especial reference to the Life of the Period and its Climatal Conditions, and Lists of the Specimens in the Museum. By Sir J. William Dawson, C.M.G., LL.D., F.R.S., F.G.S., etc. 8vo. pp. 301, with 25 Illustrations. (Montreal, William V. Dawson; New York, Scientific Publishing Company. 1893.)

SIR WILLIAM DAWSON states that for thirty years he has aspired to make Canada as typical a region for the study of the Pleistocene period, as Sir William Logan made it typical for the Laurentian rocks. His guiding principles are briefly expressed in convictions that the phenomena of the Glacial period are to be explained by more active and extensive operation of the ordinary causes still existing in more northern regions; that there has not at any time been a Polar ice-cap or great continental ice-sheets; and that the astronomical theory of glacial cold is incapable of fully explaining the facts; but that the cold climate was mainly a result of geographical conditions involving a different distribution of ocean currents, and extreme local evaporation and condensation, giving rise to local glaciers of great volume and to floating ice. It is inferred that the close of the Glacial period cannot have antedated by many centuries or milleniums the first appearance of man as known in history.

The book is divided into seven chapters. The first chapter is chiefly a series of quotations mainly from the author's writings, chosen to illustrate the principles with which he starts.

The second chapter discusses the succession of deposits; which comprise a Lower Boulder-clay, with some travelled boulders and a few Arctic shells; succeeded by the Lower and Upper Leda-clay, with marine shells and drift-plants; and an Upper Boulder-clay, including sand with *Saxicava* and gravel. These deposits are found in the Lower St. Lawrence, the north shore of Lake Ontario, and the Belly River in the North-west Territory. Beneath the Lower Boulder-clay the Palæozoic rocks are glaciated; and striæ and boulders alike indicate movement from north-east to south-west, from the Atlantic up the valley of the St. Lawrence. The Boulder-clay, which by damming the more ancient valleys, forms the basins of the great Canadian lakes, is of similar character to the material of the Missouri coteau or prairie escarpment of the west, which is regarded as the deposit at the margin of a sea laden with floating ice. The Lower Leda-clay is like the deposits now forming beneath the ice in Baffin's Bay and the Spitzbergen Sea. But the Upper Leda-clay appears to indicate more temperate conditions, since nearly all its fossils have been dredged in the Gulf of St. Lawrence; and the land plants which it yields still live on the north shore of the St. Lawrence. Some of the Leda-clays occur 600 feet above sea-level, while the beds include littoral gravels and sand, so that considerable changes of level are associated with their deposition. Subsequently extensive local glaciers clothed the Appalachian chain in the east, and the Cordilleran region of the west, where the deposits have been especially investigated by Dr. G. M. Dawson, and are regarded as indicating as great an elevation of land during the Upper Boulder-clay as was attained during the Lower Boulder-clay. Only when the Cordilleran region was at its maximum elevation the region of the great plains experienced a correlative subsidence and submergence; while the intervening subsidence between the two glaciations of the Cordilleran region is associated with the elevation of the plains, which led to the formation of great lakes in which inter-Glacial deposits and peat were formed. The second elevation of the west was followed by a partial subsidence to a level of about 2500 feet, with a long stage of stability during which white muds were deposited, and when the renewed elevation took place the shore-line stood about 200 feet lower than at present.

The Lower Boulder-clay over a great part of Canada is thickly packed with boulders; though in Triassic and Upper Carboniferous areas it becomes an incoherent sand. The stones are often scratched and grooved. They are mostly from the neighbouring rock-formations. In the lower valley of the St. Lawrence they are chiefly Laurentian gneiss from the north-east. The clay fills up valleys and depressions, and is thin or absent on the high ground. The striations beneath the Boulder-clay in New England run to the south-east, but there is also a south-west direction, a south direction, and occasionally the striæ are east and west. The north-east to south-west direction is attributed to the Arctic current, especially when associated with marine organisms. But where the striæ are upon mountains they are attributed to land-ice. Thus, on the south of the St. Lawrence, the Notre Dame Mountains show striæ which descend south towards the Baie des Chaleurs, and north towards the St. Lawrence. The phenomena indicate oscillations in level of the land.

The excavation of the basins of the great American lakes in the softer members of Silurian and Devonian formations is said to be obviously due to atmospheric and river erosion during the Pliocene period, supplemented by the flow of cold ocean currents over the American land during submergence; so that the lake basins are of the same nature as the deep hollows which prolong the mouths of American rivers beneath the ocean along the American coast.

The third and fourth chapters discuss the physical and climatal conditions of the Glacial period in Canada.

Drawing a map of North America in the Pleistocene period, Sir William Dawson commemorates some of his contemporaries by giving their names to physical features of the period. "The great southern bay at the bottom of which lies the 'terminal moraine' may bear the name of Dana; the strait leading to the north-east, where the St. Lawrence now flows, may be Upham Strait; the great western opening may well be called Chamberlain Sound; and the northern bay filled with ice, in the region now occupied by Hudson's Bay, may be the Gulf of Wright. The great islands will be respectively Cordilleran and Laurentide lands, fit companions to Greenland; and the smaller eastern island, Appalachia Infelix."

But although the author uses the expression "terminal moraine," he urges that the existence of an ice-sheet which could have formed it is a physical impossibility, because there could not be sufficient evaporation and precipitation to afford the necessary snow in the interior; and secondly, because there is evidence of a depression which admitted Arctic currents through gaps in the Laurentian watershed, and down the great plains between the Laurentian area and the Rocky Mountains, as well as into the valley of the St. Lawrence. This does not in any way affect the author's belief in the great local glaciers described by Dr. G. M. Dawson, which occupied the Cordillera of British Columbia and discharged into the Yukon Valley, into Puget Sound, and into the Pacific. The former existence of glaciers on the Laurentian axis is accepted on the evidence from the Notre Dame region and the central districts of Newfoundland. The great V-shaped Laurentian axis is stated, on the evidence of the glacial striæ, to have thrown off ice on the south-east to the St. Lawrence Valley, and to the south-west towards the great plains, and to have poured its ice into the interior of Hudson Bay and the Arctic Sea. There is some evidence of a terminal moraine along the middle of Hudson Bay, which may have belonged to the inter-Glacial period.

The striation of the rocks at lower levels is attributed to the grating of pebbles included in shore-ice upon the rocky floor beneath, as the ice moved with the tide; this conclusion being based mainly on the observations of the late Dr. John Rae and of Captain Feilden, in the Arctic regions. The longitudinal direction of the striæ is attributed to the drifting of the ice backward and forward with tidal currents. It is stated that the striation produced by the sea is always accompanied with much smoothing and polishing, that the striation is not quite uniform in direction and often presents two sets of striæ, while land glaciers usually produce deep grooves as well as striæ which are more uniform in direction. It is fully admitted that it may be difficult to distinguish the effects of grounding icebergs from those of land-ice. Charles Darwin's theory of the transport of boulders, from lower to higher levels, by floating ice, on a subsiding land, affords the only satisfactory explanation, it is urged, of the occurrence of erratics in Eastern Canada at a higher level than the rocks from which they were derived. Dr. G. M. Dawson is quoted as stating that he finds himself in agreement with Dr. Hector and Dr. Hayden in attributing the glacial phenomena of the great western plain of Canada to the action of floating ice, though the rounding, striation, and polishing of the Laurentian plateau, in the region of the Lake of the Woods, is to be attributed to the ice of glaciers. Such a glacier, covering the Laurentian uplands, liberated icebergs, which, depositing boulders and sediment, formed the highlands of the second plateau, including the Touchwood Hills, Moose Mountain and Turtle Mountain. The changed climatal conditions are regarded as mainly attributable to changes in the level of land; and it is believed that the present climate of Canada is separated from that of the Glacial age by one somewhat warmer, which coincided with an elevated condition of land. The date of the Glacial period was anterior to the excavation of the Niagara gorge, which is estimated to have required from 12,000 to 15,000 years.

The fifth chapter gives a summary of local details in the regions of Canada in which glacial phenomena have been observed; and the sixth chapter is an account of the fossils found in the deposits, illustrated with figures. There is a final summary of conclusions.

The book is illustrated with useful sections and woodcut maps. Its teaching is valuable from the breadth of country examined, the variety of phenomena considered, and the breadth of view which seeks to explain each set of facts by causes which are in harmony with the physical conditions evidenced in the several regions of Canada; and although the tone of the book has more that of an advocate recapitulating the steps of his exposition, now extending over a long period of time, than may be necessary in an impartial history of the Ice-Age, the story is well told, interesting in every page, and forms a valuable epitome of laborious work.

II.—Second Expedition to Mount St. Elias, in 1891. By Israel C. Russell, United States Geological Survey. Extract from the Thirteenth Annual Report, 1891–92. Pp. 91, Maps and Plates iii.–xxi. and 6 Figures. (Washington, 1894.)

THIS Report contains the observations of a small exploring expedition, under the charge of Mr. Russell, which revisited in 1891 the glaciated regions between Mount St. Elias and the sea-coast west of Yakutat Bay, in Southern Alaska. One of the objects of the expedition was to attempt to reach the summit of this mountain, but the difficulties proved too great and no higher elevation than 14,500 feet was reached. Many valuable and important observations relating to the structure of the glacier, its drainage, the nature of the moraines, and other points were obtained, and a highly graphic description of these features is given in the Report, which deserves the consideration of all interested in glacial geology.

Mount St. Elias, from the data obtained by Mr. Russell, has an elevation of about 18,100 feet. It is the highest peak of a mountain range extending westwards from Yakutat Bay, which forms the gathering ground of an immense glacier, known as the Malaspina glacier. The front margin of this glacier is continuous for a distance of 70 miles; it covers the greater part of the area of comparatively low ground, from 20 to 25 miles in width, which extends from the base of the mountains southwards to the coast of the Pacific. The entire area of the glacier is estimated at 1500 square miles. One main lobe of the glacier extends into the open ocean and forms magnificent cliffs of ice, which are undermined by the waves, so that large masses break off and give rise to numerous icebergs. Other portions terminate before reaching the coast and from their margins numerous streams issue, highly charged with mud and gravel. The main body of the glacier forms a vast plateau of ice, the surface of which, at about five or six miles from its outer margin, has an elevation of approximately 1500 feet above the sea; the central portion is of clear white ice, free from moraine and generally undulating. It is traversed by countless numbers of crevasses. This clear central area is bounded on the south, that is, in the direction of the flow of the glacier, by a broad dark band of boulders and stones, known as the "barren moraine," and beyond this belt is a forest-covered area, in some places four or five miles in width. This forest region appears to have been covered by trees for a long period of time; they principally consist of spruces, some reaching three feet in diameter; cotton-wood trees; alders from 20 to 30 feet in height, besides a considerable variety of shrubs and bushes, and an undergrowth of rank ferns; the whole forming a mass of vegetation so dense as to be nearly impenetrable, and in order to pass through it a trail had to be made with axes and hatchets. But the most remarkable fact in connection with this forest-belt is that the morainic material, on which the trees grow, actually rests upon the glacial ice, and in some places this ice beneath the forest-covered moraine is estimated to be not less than 1000 feet in thickness. The area of the Malaspina glacier covered by forest is probably between 20 and 25 square miles. The moraine supporting the forest growth consists of boulders, earth and stones, which cover the glacier to a depth of not more than 3 or 4 feet as a rule. It only differs from the "barren moraine" in having a greater proportion of finer material between the larger stones and in the presence of a certain amount of humus derived from the vegetable growth. These forests only occur on those portions of the glacier where the ice appears to be stagnant and without motion. The occurrence of this forest-covered moraine resting on the surface of the glacier tends to throw considerable light on the origin of the ice-cliffs or "ground-ice formation" along the northern coasts of Alaska, in which the solid ice is overlaid by a layer of clay containing Mammoth remains, and this is capped by a peaty layer supporting the vegetation of the region.

Another peculiar feature of the stagnant margin of the Malaspina glacier is the presence of numerous lakelets from 30 to 60 yards in width and bounded by steep walls of ice from 50 to 100 feet in height. These lakelets are supposed to have originated by the melting back of the walls of crevasses.

Mr. Russell further describes the geology of the Chaix Hills, a range from 8 to 10 miles in length and about 3000 feet in height, which project from the sea of ice between the coast and Mount St. Elias. The strata have a gentle dip to the north, and appear to be between 4000 and 5000 feet in thickness. They consist throughout of a sandy clay, in which are numerous stones and boulders, up to 8 feet in diameter; some of these latter are polished and striated. In the finer beds molluscan shells occur, belonging to several species which still exist in the adjoining ocean. These beds are evidently formed of morainic materials deposited about the extremity of a glacier which terminated in the ocean, and similar beds are probably now being deposited in the ocean in front of the western lobe of the Malaspina glacier. The Samovar hills, more to the north-east than the Chaix range, likewise consist of stratified morainic material. Many of the boulders in these deposits are of various kinds of crystalline rocks, which must have been brought from the north by glaciers. This great thickness of stratified morainic material, originally laid down beneath the sea, and now in part raised to an elevation of over 3000 feet, will give an idea of the long period of time which has elapsed, and of the great physical changes which have taken place since glaciers first left traces of their movements in these regions.

The maps and reproductions of photographs which accompany the Report afford realistic pictures of the salient features of the region described. G. J. H.

III.—ELEVENTH ANNUAL REPORT FOR THE YEAR 1891 OF THE STATE GEOLOGIST, TRANSMITTED TO THE LEGISLATURE OF NEW YORK, JANUARY, 1892. By JAMES HALL, State Geologist. With an Illustrated HANDBOOK OF THE BRACHIOPODA. 8vo. pp. 300, 22 Plates, 286 Woodcuts. JAMES B. LYON, State Printer. (Albany, 1892.)

AN *early* copy of the Report reached us last month — a delay in publication alike unjust to the authors, and a loss to the scientific public, as this work is one of great general utility, comprising the first part of a new illustrated handbook of the Brachiopoda. Besides the formal Report and Catalogue of additions to the collections of the State Museum of New York, the volume contains a list of the types and figured specimens of the Crustacea in the palæontological collections, and a paper by Prof. John M. Clarke on *Cordania*—a proposed new genus of the Trilobita—which can be no longer referred to Barrande's misnamed genus *Phæton*, to his subsequently substituted *Phætonides,* nor to Corda's *Prinopeltsi.*

The type of *Cordania* is *Phætonides cyclurus*, Hall, a form "allied to *Proetus* in the structure of the pygidium and thorax, to *Cyphaspis* in the cephalon generally, and to *Arethusina* in its glabella in particular." Its occurrence is first noted in the Lower Helderberg of New York, with an upward range through the Hamilton group of strata.

The bulk of this Report, viz. nearly two-thirds of the text of 300 pages, all the 22 plates, and 286 intercalated woodcuts, many of which are original productions, is devoted to "An Introduction to the Study of the Brachiopoda," by James Hall, assisted by John M. Clarke, and dedicated to the use of American students. It forms not only an epitome of vol. viii. part i. of the Palæontology of New York, with a general elementary introduction preceding the clear and concise generic definitions well suited to the comprehension of students in general; but, in fact, the new handbook combines, so far as it goes, all the best features of the previous more technical and restricted summaries of Davidson, Zittel, and Œhlert, *plus* the great knowledge, experience, and literary facility of Hall and Clarke. Although the "Report" was presented to the Senate of New York January, 1891, it is well up to date, and references to various important observations recorded in 1893 are not lacking. The concluding part, dealing with the Spire-bearers, Rhynchonelloids and Terebratuloids, it is stated, will be ready for Press in October, and will not, we trust, meet with any untoward delay in publication. Part I. treats of all the Inarticulata, *Paterina* included, and of the Articulata from the Orthoids to the Productoids, and affords ample proof of its value to students as an authoritative statement of elementary facts concisely presented and elaborated and explained by excellent illustrations of structural characters.

It presents all the essential facts of the general history, distribution, shell-structure, and anatomy, with such details of embryological phases as are needed to emphasize the importance of ontogeny in clearing up obscurities in the geological and genealogical history of the class in general and of genera in particular—such a manual, in fact, as could be produced only by an expert palæontologist of great experience like James Hall. We trust further handbooks on other invertebrate groups may be forthcoming from the same source.

The first part contains a map of the distribution of the recent species and a list, alphabetically arranged, of the localized provincial faunas based on Œhlert's work of 1876–1880, amplified by later discoveries. We would suggest the addition of a chart of specific bathymetrical limit (the data could be easily derived from the publications of Davidson, Œhlert, Monterosata, and others); this, with a table of geological range of genera, would localize all needful information in one handbook. Verily the students of the Brachiopoda in the twentieth century will have great reason to be grateful to the specialists of the nineteenth who have thus consolidated the results of general researches.

Systematic classification should be the natural outcome and termination of research, not hard and fast limits outlined at the beginning, within which facts discovered later must be enclosed. As Prof. Huxley has tersely stated, the power of repeating a classification does not always imply any real knowledge of a group in a student. They are useful summaries to work by, and we expect from Prof. Hall and his indefatigable assistant, Prof. J. M. Clarke, some definite statement on this vexed point in conclusion. At present they stand alone in the rejection of family groupings of genera in name, although they seem tacitly to admit the necessity of some such grouping by writing persistently of "orthoids," "productoids," "terebratuloids," etc. This is all very well in its way, but it imposes on the student the burden of defining whether "orthoid," and other generic and subgeneric mutations, which have been described collectively by other authorities as the "Orthidæ," "Productidæ," etc., is intended to be understood, or whether the term "orthoids" is meant to define merely the eight species to which that genus is by Hall restricted.

These remarks are not offered in any carping critical spirit. It would be absurd to deny the right of the State Palæontologist of New York to formulate a new classification; no one can have a better claim in Europe or America. We note the point as a difficulty in generalization and likely to puzzle the students to whom this handbook of the Brachiopoda is addressed, and one, therefore, that should be removed in the concluding portion of this most praiseworthy manual. We have noticed the work at some length, because one would scarcely expect to find a handbook for students enclosed within the covers of an annual Museum Report. Science just now must be in "a parlous state," indeed, in America, when scientific men of acknowledged repute and standing are driven to adopt such a roundabout method of publication. It is to be presumed that Hall's Handbook to the Brachiopoda will be published separately on its completion. AGNES CRANE.

IV.—THE PAST WORLD AND ITS EVOLUTION. (Die Vorwelt und ihre Entwicklungsgeschichte.) By Dr. ERNST KOKEN. Royal 8vo. pp. 654, 117 Figures in the text, and two Maps (Plates I. and II.). (Leipsic: Weigel, 1892.)

IN the preface the author wishes us to understand that he addresses himself not to specialists, but to a wider circle of readers; we venture, however, to predict that, like Neumayr's Erdgeschichte, the present book will, before long, be found as well in the libraries of geologists and palæontologists as in those of the *Gebildete Kreise* generally.

The three first chapters (The Interior of the Earth and the Hardened Crust; The Formation of Mountains; The Notion of Time in Geology) are a sort of introduction, and are almost exclusively geological in their contents, as is chapter xii. (Quaternary and Ice Period). Chapters iv.–xi. are dedicated to the different "systems," beginning with the Cambrian and ending with the Tertiary; in these the palæontological part predominates. Chapter xiii. is dedicated to the Animal World in Quaternary times.

The author is not only conversant with the very latest work done in *every* department of the wide field covered by his subject—in this respect a comparison with Neumayr's book before mentioned shows how much nowadays even the lapse of seven years may affect the progress of science—but, what strikes us even more, so much elaborate thought and such original views are displayed in every chapter, that we admire the author as much when we dissent from, as when we agree with, him.

In the concluding chapter we are expressly told, what the attentive reader must already have become aware of, namely, that the fundamental view which guided the author is a decided uniformitarian one. The remainder and larger portion of the same chapter is dedicated to a discussion of the Evolution theory; here Dr. Koken strongly opposes the overwhelming part ascribed to natural selection.

The two maps are very acceptable, being reconstructions of the continents and seas during the Cretaceous (plate i.), and during the older Tertiary, together with an illustration of the extension of the Pleistocene Ice period in the northern hemisphere (plate ii.). They are in the main on the plan of Neumayr's reconstruction of Jurassic continents, which is also added by means of black dotted lines on the first map. Dr. Koken's maps serve not only as illustrations to the respective chapters of the text, but they are, as it were, graphic summaries of the same; they will be particularly appreciated by those who have hitherto sought in vain for some guidance of this kind when working on geographical distribution of organisms. The figures in the text are first-rate.

An English translation would prove a success to an enterprising publisher, and it might not be indispensable to many scientific workers, for the book ranks with Neumayr's *Erdgeschichte* and Prof. Suess' *Antlitz der Erde* in its clear as well as fascinating writing.

REPORTS AND PROCEEDINGS.

GEOLOGICAL SOCIETY OF LONDON.

I.—April 25th, 1894.—Dr. Henry Woodward, F.R.S., President, in the Chair.

Mr. A. R. Sawyer, referring to specimens exhibited by him from the Transvaal, Orange Free State, Cape Colony, Mashonaland, and Matabeleland (the last-mentioned collected during the recent war), remarked that gneisses and gneissose granites cover a large portion of Mashonaland, together with patches of schistose rocks and a few stratified rocks. He drew attention to the fantastic shapes assumed on weathering by the granitic gneiss, which he considered solely due to atmospheric agencies, and not to ice-action or to the effects of submersion.

The schistose rocks are, for the most part, sheared and altered igneous masses. There are numerous examples of dolerites and epidiorites passing into hornblende-schists, and of more acid igneous rocks. Masses of magnetite occur in various parts of Mashonaland, and serpentinous rocks (which probably owe their origin to the alteration of peridotites) in the north-west corner of the Victoria Gold-field.

Extremely auriferous veins occur amongst the sheared acid igneous rocks of the Umhungwe Valley in the Manica district, and gold occurs in the kaolin produced by the disintegration of these rocks. The following communications were read:—

1. "Further Notes on some Sections on the New Railway from Romford to Upminster, and on the Relations of the Thames Valley Beds to the Boulder Clay." By T. V. Holmes, Esq., F.G.S.

The author alludes to his discovery of Boulder-clay on this new railway at Hornchurch (dealt with in a previous paper, Q.J.G.S. August, 1892), and describes the finding of more Boulder-clay close to Romford during the deepening and widening of a cutting there. The Boulder-clay was on precisely the same level as that at Hornchurch, a mile and a half to the south-east, and, like it, was covered by gravel belonging to the highest, and presumably oldest, terrace of the Thames Valley system. A portion of the silted-up channel of an ancient stream-course was also found in this Romford cutting. Its relations to the Boulder-clay could not be seen, as they were not in contact, but they were alike covered by the oldest gravel belonging to the Thames Valley system. The author discusses the probable direction of the flow of this stream-course, and the way in which it was superseded by the ancient Thames. After noticing certain points brought forward during the discussion on his former paper, he concludes with a criticism on the views to which Dr. Hicks inclines in his paper on the Sections in and near Endsleigh Street (Quart. Journ. Geol. Soc. vol. xlviii. 1892) as regards the age of those beds, asserting that they are, in all probability, simply River Drift of the Thames Valley system, and consequently post-Glacial, in the sense of being later in date than the Boulder-clay of Essex and Middlesex.

2. "On the Geology of the Pleistocene Deposits in the Valley of the Thames at Twickenham, with Contributions to the Flora and Fauna of the Period." By J. R. Leeson, M.D., F.L.S., F.G.S., and G. B. Laffan, Esq., B.Sc., F.G.S.

The section described in this paper was exposed during the construction of an effluent from the Twickenham sewage-works to the Thames. Its length was about one mile.

The beds exposed were:—(1) Coarse reddish-yellow gravels, coloured blue below, lying on an eroded surface of (2) Dark-blue loam, varying in thickness, the greatest thickness seen being 3 feet, at a place where the bottom was not reached; (3) Dark sand; (4) Coarse ballast-gravel; (5) London Clay.

The loam (which is quite a local deposit) yielded eight species of Mollusca and fourteen species of plants, all still living in the neighbourhood. A number of Mammalian bones referable to seven species were lying just on the surface of the loam. Amongst the forms were Bison and Reindeer.

The authors consider that the loam was deposited in a small lake, and they allude to similarities between it and a deposit described by Dr. Hicks as occurring in the Endsleigh Street excavations.

3. "On a Goniatite from the Lower Coal-measures." By Herbert

Bolton, Esq., F.R.S.E. (Communicated by George C. Crick, Esq., F.G.S.)

Sowerby in his "Mineral Conchology" figures two fossils under the name of *Goniatites Listeri,* of which the left-hand figure is clearly *G. Listeri,* whilst the right-hand one differs considerably from it. The author gives diagnoses of *Goniatites Listeri* and of a supposed new species, which agrees with the form represented in Sowerby's right-hand figure. This species, noticed by the author, is limited to the shales forming the roof of the "Bullion" or Upper Foot seam of the Lower Coal-measures, whilst *G. Listeri* ranges from the Lower Limestone Shales to the "Bullion" seam.

II.—May 9th, 1894.—Dr. Henry Woodward, F.R.S., President, in the Chair.

Mr. Lyddekker exhibited some specimens from a collection of Argentine fossil Vertebrates which he had been allowed to select from the La Plata Museum for presentation by Dr. Moreno to the British Museum. Many of these belonged to types previously quite unrepresented in the collection of the latter. He also drew attention to his recently published monograph on Argentine Vertebrates, and stated that he hoped these results of his journey to La Plata, under the auspices of the Royal Society, would be regarded as satisfactory. The difficulty he himself had laboured under in endeavouring to understand what had been previously written in regard to the extinct mammals of Argentina was largely due to the absence of satisfactory figures; and his object had, therefore, been to figure as many specimens as possible on a large scale, in order that others might have an opportunity of judging for themselves, quite apart from his own descriptions and conclusions.

He had undertaken his previous journey somewhat unwillingly, at the wish of Sir W. H. Flower and Mr. Sclater; but he had been so interested in what he had seen that he hoped means might be afforded him of repeating his visit this year.

The following communications were read:—

1. "Carrock Fell: a Study in the Variation of Igneous Rock-masses.—Part I. The Gabbro." By Alfred Harker, Esq., M.A., F.G.S.

The paper opens with an account of the general relations of the intrusive rock-masses of the district, and proceeds to deal more particularly with the gabbro, which forms the earliest intrusion.

A petrological description of the Carrock Fell gabbro is followed by a study of the variations observed in different parts of the mass. The rock becomes progressively more basic from the centre to the margin, passing from a quartz-gabbro with as much as 59½ per cent. of silica to an ultrabasic type with as little as 32½. The latter in extreme cases contains nearly 25 per cent. of iron-ores, partly titaniferous. This is compared with the igneous iron-ores described by Vogt in Scandinavia, etc., and the probable physical cause of the remarkable variation in the gabbro is discussed.

Other modifications of the gabbro are briefly noticed, due on the one hand to metamorphism of the rock by a somewhat later intrusion of granophyre, on the other hand to the gabbro-magma having enclosed considerable masses of the basic lavas of the district, which are themselves highly metamorphosed.

2. "The Geology of Monte Chaberton." By. A. M. Davies, Esq., B.Sc., F.G.S., and J. W. Gregory, D.Sc., F.G.S.

The importance of the Chaberton district, as affording a key to the general geology of the Cottians, is explained, and the opinions of previous observers referred to. The mountain was examined from three sides—that of the Grand Vallon; the approach from Mont Genèvre by the Col de Chaberton; and that of the Clos des Morts Valley. The following are the conclusions arrived at:—

(1) The well-known Chaberton serpentine is intrusive into the calc-schists, and yields fragments to the *caryneules* of the Trias; it is, therefore, a *pre-Triassic* intrusion.

(2) There are on the mountain other fairly basic schistose rocks (quartz-chlorite-schists) which cut the Trias, and are therefore *post-Triassic.*

(3) The contorted beds in the Clos des Morts Valley are fossiliferous limestone, and it is from them that the fallen blocks previously recorded were derived. The only recognisable fossil is *Calamophyllia fenestrata,* Reuss, a characteristic coral of the Gosau beds. In spite, therefore, of the doubts of Kilian and Diener, the opinion expressed by Neumayr as to the existence of Cretaceous rock in this part of the Alps is confirmed.

(4) The earth-movements of the mountain are described; they include ordinary folds, inversions, faults, and an important thrust-plane.

(5) It is suggested that in addition to the two series of intrusive rocks above-mentioned as pre- and post-Triassic, a third series of late Cretaceous or Tertiary date may be represented in the Mont Genèvre and Rocciavré masses.

3. "Cone in Cone. How it occurs in the Devonian (?) Series in Pennsylvania, U.S.A., with further details of its Structure, Varieties, etc." By W. S. Gresley, Esq., F.G.S.

The author describes cone-in-cone structure occurring in the Portage Shales of Pennsylvania, and gives details concerning the nature of the structure as seen in these shales. He criticizes the explanation of Mr. J. Young as to the origin of the structure, and concurs in a great measure with the views of those who have suggested that the formation was due to pressure acting on concretions.

CORRESPONDENCE.

A PHYSICAL CONTRIBUTION TO DYNAMIC METAMORPHISM.

Sir,—Among recent physical researches, one of the most interesting to geologists is embodied in two papers by Prof. M. Carey Lea on "Endothermic Reactions effected by Mechanical Force."[1] The author shows by direct experiment "that mechanical force can bring about reactions which require expenditure of energy, which energy

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[1] Amer. Journ. Sci. 1893 (3), vol. xlvi. pp. 241–244, 413–420.

is supplied by mechanical force precisely in the same way that light, heat, and electricity supply energy in the endothermic changes which they bring about."

The experiments consisted chiefly in the reduction of silver, mercury, platinum, and gold, from their salts. The result was indicated in each case by a darkening of the powder, and in one case, sodium chloraurate, the reduced gold was separated and weighed.

In a first series of experiments the substance operated upon, wrapped in platinum or silver foil, was subjected to a pressure of about 70,000 atmospheres by means of a specially devised apparatus. More interesting, however, is a second series of experiments, in which similar results were obtained by grinding the powder by hand in a stout porcelain mortar, so as to give a shearing motion. The important conclusions drawn are:

(i.) That in these experiments the mechanical energy does not undergo any intermediate conversion into sensible heat. The operation may be conducted slowly or intermittently, and the apparatus does not become warmed.

(ii.) That shearing stress is enormously more effective than simple pressure.

These two points are well illustrated by the behaviour of mercuric chloride. A simple pressure of 70,000 atmospheres was not sufficient to produce any change, but trituration in a mortar for fifteen minutes caused a very evident reduction to calomel. In this instance the decomposition is one which *cannot be produced by heat.*

Although the chemical transformations involved in dynamic metamorphism are of a more complex kind than those here noted, it seems fair to conclude that, in so far as they are endothermic, they may be brought about by mechanical force only, without the intervention of heat, and that the most marked effects of this kind are to be looked for where shearing stress has been brought into play.

St. John's College, Cambridge. Alfred Harker.
May 4th, 1894.

THE DEVONIAN VOLCANIC ROCKS OF START BAY.

Sir,—In my paper "On Certain Affinities between the Devonian Rocks of South Devon and the Metamorphic Schists" (Geological Magazine, June, 1892), no attempt was made to define the horizon of any of the Devonian rocks themselves. The schists were merely referred to unaltered rocks whose position had been elsewhere declared.

In his recent address to the Geological Society, Mr. W. H. Hudleston, in noticing my paper, remarks that Lower Devonian diabases "in some districts are not by any means in evidence" (Proc. Geol. Soc. vol. 50, p. 130).

As a matter of fact the exact horizon of the Devonian diabases in Start Bay (to which the metamorphic green rocks were referred) does not affect my notes concerning them, which merely go to show that the green rocks at the Start and neighbourhood are of about the same age as the said Start Bay diabases, whether the latter be Lower, Middle, or Upper Devonian.

The stratigraphical questions of Start Bay lie entirely outside my province; but I may, perhaps, be allowed to point out how little they affect my position.

In the course of a walk from near the Start Lighthouse to Dartmouth, we may notice the following rocks:—Westward of the lighthouse, forming the cliff face, is a mass of compact greenrock, which, previously to Mr. Ussher's survey, seems to have been invariably overlooked by geological visitors. Immediately to the north are the mica-quartz-schists of Start Ridge, succeeded along the coast by a series of mica-schists which pass into the ordinary Devonians at Hallsands, with but slight indications of an important area of greenrock inland.

Devonian slates and sandstones are interrupted by volcanic rocks at Torcross, and then continue to Blackpool, where volcanic rocks reappear in force, and are considerably developed up to the entrance of Dartmouth Harbour, where the Mewstone islet and the eastern and western blackstones indicate the seaward extension of the diabases.

Now, from Hallsands to Dartmouth Harbour, the rocks including the diabases are admitted to be Devonian, of some age. If they are Lower Devonian, Mr. Hudleston tells us that in other districts Lower Devonian diabases "are not by any means in evidence." If, on the other hand, they are Middle Devonian, it is equally noticeable that the limestones (the characteristic rocks of that horizon) are absent.

If the explanation be that Middle Devonian slates and diabases are folded together with Lower Devonian slates and sandstones (with no useful fossils to assist the observer) the difficulty of the case as a purely Devonian problem is sufficiently obvious. But so far as the main problem of the age of the metamorphic green rocks is concerned, the question of the exact horizon of the Start Bay diabases, whether Lower or Middle Devonian, is of very minor consequence or interest. My point is that the sandstones, slates, and diabases north of the metamorphic boundary are the analogues of the quartz-schists, mica-schists, and green rocks to the south of that boundary; of which fact I do not entertain the shadow of a doubt.

A. R. Hunt.

OBITUARY.

CHARLES S. BEACHLER.

Born November 5th, 1870. Died April 5th, 1894.

We greatly regret to hear of the death of this young American geologist, which occurred at Crawfordsville, Indiana, on the above date, and was due to a complication of heart and lung trouble. Charles Beachler's scientific studies were begun at Wabash College, when he was fifteen years old. Here he became interested in herpetology, and made a collection of the reptiles of Indiana for the College at his own expense. Subsequently he was employed by Mr. Frank Springer to collect Crinoids from the Carboniferous beds of Crawfordsville, and the Niagara Limestone of Waldron and

St. Paul. While engaged in this work he made the best of his opportunities to study the geology of the districts visited, and made some geological excursions on his own account.

Short but interesting notes resulting from these investigations have appeared in the American Naturalist, American Geologist, and the Journal of Geology. In the autumn of last year Mr. Beachler studied and taught under Prof. J. W. Spencer, State-Geologist of Georgia, and, on his return to Crawfordsville, himself became a candidate for the post of State-Geologist of Indiana.

MISCELLANEOUS.

"HARKNESS SCHOLARSHIPS IN GEOLOGY FOR MEN AND WOMEN."—It seems difficult to devise a more pleasing or useful form in which to perpetuate the memory of one who was greatly esteemed and loved, than to establish a scholarship, as has been done by the late Mrs. Pearson of Penrith, to the memory of her brother, Professor Robert Harkness, F.R.S., F.G.S., late Professor of Geology, Queen's College, Cork.

Professor Harkness, who died in 1878, was a graduate of the University of Edinburgh, where he attended the lectures of Professors Jamieson and James D. Forbes. He was appointed to the Chair of Geology in Queen's College, Cork, in 1853, a post which he held until 1878. He was an excellent geological teacher, and contributed many admirable papers on the geology of Cumberland and Westmoreland, and other parts of England and Ireland. He was, for many years, a constant attendant at the meetings of the British Association, where his presence in Section C was as regularly expected as that of the late Mr. William Pengelly, F.R.S., and he took an active part in its meetings and discussions, as well as in those of the Geological Society whenever he could be present.

The scholarship for women, tenable at either Girton or Newnham College, Cambridge, is to be awarded triennially to the best candidate in an examination in Geology and Palæontology, provided that sufficient proficiency be shown. The candidates must be resident members of either Girton or Newnham College, in their first or second term. The scholarship will be of the value of about £35 a year tenable for three years. The next examination will be held at Cambridge in the Michaelmas Term, and the award will be made on or before November 15th, 1894.

Another Harkness Scholarship in Geology, which was also established by Mrs. Pearson to her brother's memory, is open to men and is vested in the hands of the University of Cambridge. This is awarded annually, any member of the University being eligible who has graduated as B.A., "provided that not more than three years have elapsed since the 19th day of December next following his final examination for the degree of Bachelor of Arts." The award is in the hands of a Board of Electors. We trust that this memorial to so excellent a geologist may long maintain its vitality, and form a living link between the past and present for the good of our science.

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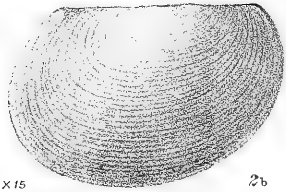

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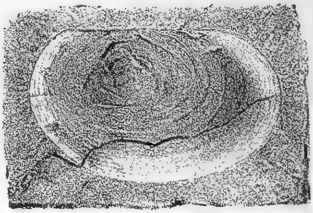

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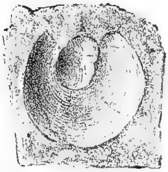

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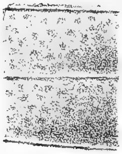

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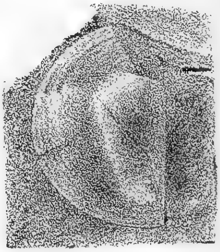

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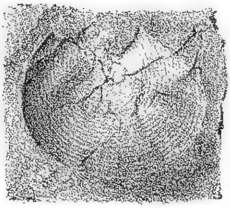

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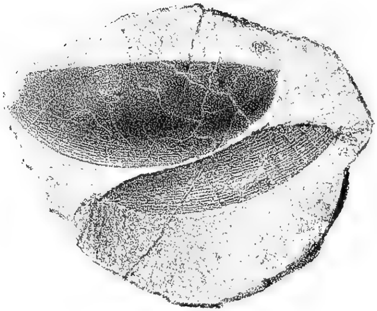

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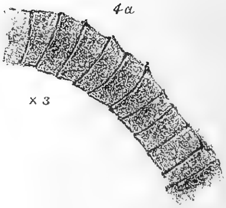

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FOSSIL PHYLLOPODA.

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

No. VII.—JULY, 1894.

ORIGINAL ARTICLES.

I.—On Some Fossil Phyllopoda.

By Professor T. Rupert Jones, F.R.S., and Dr. Henry Woodward, F.R.S.

(PLATE IX.)

THESE notes on fossil Phyllopods refer to some interesting specimens, mostly of Palæozoic age, which have come to hand since the publication of Part II. of our "Monograph of the British Palæozoic Phyllopoda" (Palæontographical Society), 1892.

Figs. 1 and 2 represent *Estheriæ* from the upper part of the great Karoo Formation of South Africa. Figs. 3 and 4 are exposed on a piece of Moffat shale from Dumfries-shire; and, Fig. 3 being a *Discinocaris,* it is probable that the two series of abdominal segments, Figs. 4*a,* 4*b,* may have belonged to that genus. Fig. 5 is a *Discinocaris* of good size, and Fig. 6 an *Aptychopsis,* both from Moffat. Fig. 7 is a rare Phyllocarid from the Devonian beds (Hamilton series) of Canada. There is also a note on a Nova-Scotian *Estheria,* without figure.

1. Estheria Draperi, sp. nov. (Pl. IX. Figs. 1*a,* 1*b,* 1*c.*)

Size: Length of valve, 16 mm. Length of hinge-line, 11 mm. Height, 10½ mm.

Valves suboblong, straight above, slightly curved below, rounded at the ends; anterior margin higher and less convex than the posterior. The interspaces on the surface are ornamented with coarse shallow pits, making an obscure reticulation (see Fig. 1*c,* which was taken from near the edge of the antero-ventral portion of the left valve, lying uppermost). The umbo is just in front of the middle of the hinge-line.

The left valve, partly preserved and much corrugated, lies on top of a slightly convex mass of dark shale, which represents the major part of the body of the animal.

In shape this specimen approaches the Permian *Estheria exigua* of Russia (Monog. Foss. Estheriæ, Pal. Soc. 1862, p. 37, pl. i. figs. 22–24) and the recent *E. Rubidgei,*[1] *E. Macgillivrayi,*[2] and *E. Dahalacensis*[3]; but has its umbo less forward than either of these. Its ornament approaches that of the last-mentioned species, and also that of *E. exigua.*

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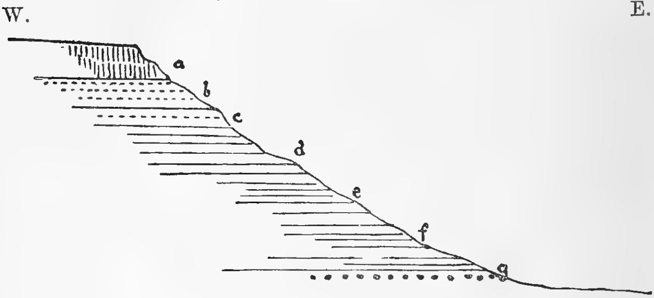
[1] Proc. Zool. Soc. 1862, p. 148, pl. xv. fig. 3.
[2] *Ibid.* fig. 5.
[3] Proc. Zool. Soc. 1849, Annulosa, p. 87, pl. xvii. figs. 2–4.

From a small bed of grey shale interstratified in the Cave-Sandstone in the uppermost part of the Karoo Formation, in Natal, above the homestead of Mr. Theodore Malder, on the eastern side of the Platberg (see the Section, Fig. 1). This is a part of the Drakensberg range, and on its western side is Harrismith in the Orange-Free-State. This *Estheria* was found by Mr. David Draper, F.G.S., of Lennoxville, Natal; and is here named after him. It is deposited in the British Museum (Natural History).

Fig. 1.

Section of the Eastern side of the Platberg in the Drakensberg.

8000 feet above sea-level.



a. Columnar Dolerite. About 400 feet thick.
b. Cave-Sandstone (with the Estherian shale). About 400 feet thick.
c. The place of the Red Beds, which are fossiliferous at Harrismith, on the western side of the Platberg, in the Orange-Free-State.
d. Molteno Beds, bearing coal in the Stormberg, High-veldt, and Natal.
e. Beaufort Beds.
f. Ecca Beds. (*c–f*. about 2000 feet.)
g. Ecca (Dwyka) Conglomerate, lying nearly horizontal in the adjacent valley of Pietermaritzburg, Natal.

2. Estheria Stowiana, sp. nov. (Pl. IX. Figs. 2*a*, 2*b*.)

Size: Length of valve, 2½ mm. Length of hinge-line, 2 mm. Height, 1½ mm.

On the piece of shale bearing *Estheria Draperi* (Fig. 1) are two very small flattened Estherian valves, one of which is shown, much enlarged, by Fig. 2. Their shape is different from that of the larger form, being sub-elliptical, much less oblong, relatively higher and more boldly curved at one end, and elliptically curved on the ventral border; with the umbo nearer to the narrow than to the broader (higher) end of the valve.

It is unusual for the umbones, and consequently the anterior part of the body, to be nearer to the smaller than to the larger end of the valves. This condition is seen in some varieties of *E. striata* (Monog. Foss. Estheriæ, 1862, pl. i. figs. 11, 13, and 15), in *E. Dawsoni* (Geol. Mag. 1870, Pl. IX. Fig. 15), and in *E. tenella*, var. (*ibid.* Fig. 16); but their umbones are much further forward than in our Fig. 2, where it is not far in front of the middle of the hinge-line. The form nearest to our Fig. 2, in this submedian position of the umbo, is the Carboniferous *E. striata*, var. *tenuipectoralis*, from the Ural (Ann. Mag. Nat. Hist. ser. 5, vol. xii. 1883, p. 246, pl. vi. fig 2). In this form, however, the antero-ventral margin has less convexity and the postero-ventral curvature is more oblique.

In *E. membrancea* (Monog. Foss. Esth. pl. i. figs. 3 and 6), although the front and ventral margins do not make so elliptical a curve, the umbo is in relatively the same position as in our Fig. 2. *E. Greyii*, from the Karoo Formation near Cradock, South Africa (GEOL. MAG. 1878, p. 100, Pl. III. Fig. 1) has a somewhat similar position for its umbo, but the dorsal margin is not straight.

Although it is just possible that these small specimens may be *young* forms, differing according to their stage of growth from such an adult as Fig. 1 (with which they were associated), yet, not having evidence of such a relationship, we propose to distinguish them by a separate name. and to call them *E. Stowiana*, in memory of the late G. W. Stow, who did much to elucidate the structure and history of the Karoo Beds, including the Cave-Sandstone, in a shale-bed of which these *Estheriæ* occur.

3. DISCINOCARIS BROWNIANA, H. Woodward, 1866.
(Pl. IX. Figs. 3–5.)

Discinocaris Browniana, H. W. and T. R. J., Monog. Pal. Phyll. Part II. 1892, p. 119, pl. xvi. figs. 12–19, 21–23.

Fig. 3. Height (length), 8 mm. Breadth, 8 mm. This is a carapace modified by pressure, slightly concave, and apparently overlying a fragment of another, which shows through the nuchal notch, or the nuchal portion has been displaced and turned partly round in the notch.

From Moffat; with the Graptolites—*Rastrites peregrinus* and *Climactograptus* (?).

Figs. 4*a*, 4*b*. Portions of two abdomens; 4*a*, 13 mm. long, and showing 12 segments, figured with the proximal end downwards to the right hand; and Fig. 4*b*, less distinct, showing 7 segments.

These are not unlike several examples of larger body-segments of *Hymenocaris*, figured in pl. xiii. of Monog. Foss. Phyll. Part II. 1892, and described at p. 79; but, as *Hymenocaris* does not occur in the Moffat shales, nor *Discinocaris* at Tremadoc, we must take for granted that these abdominal relics belong to different genera. So also there are in the British Museum other similar sets of body-rings, not so large as those of *Ceratiocaris stygia* and *C. papilio,* but belonging to smaller forms of that genus. Such examples were described by us in Monog. Foss. Phyll. Part I. 1888, p. 56, and one (*C. laxa*) was figured on pl. 8. fig. 12.

This genus also is foreign to the Moffat shales, and therefore cannot claim Figs. 4*a*, 4*b*, for itself. Indeed such segmented abdomens may and must have belonged to all the above-mentioned and to other Phyllocarids.

Fig. 5. Height (length), 10 mm. Breadth, 12½ mm. This is a rather large and characteristic carapace of *D. Browniana*, well

preserved in some respects, but slightly concave and cracked by pressure, and somewhat damaged along the upper edge.

From Garpel Linn, Moffat.

4. Aptychopsis Wilsoni, H. Woodward, 1872. (Pl. IX. Fig. 6.)

Aptychopsis Wilsoni, T. R. J. and H. W., Monog. Foss. Phyll. Part II. 1892, p. 105, pl. xv. figs. 12 (?), 15, and 16.

Half of a carapace: Height (length), 14 mm. Breadth, 8 mm.

This left-hand moiety of a carapace of good size lies apparently over a displaced fragment of another part of the carapace, which interferes with the angular shape of the nuchal notch.

From Duff-Kinnel Burn, Moffat.

Figs. 3, 4, 5, and 6 were lent by the authorities of the Carlisle Museum, for examination and description, through the courtesy of R. S. Ferguson, Esq., Lowther Street, Carlisle.

5. Elymocaris Hindei, sp. nov. (Pl. IX. Fig. 7.)

Length of valve, 24 mm. Height, 9 mm.

We have here two valves of a carapace. The right valve is nearly perfect, but has lost a piece off the hinder end, and is somewhat cracked by pressure. The other valve lies obliquely and partly embedded.

The best-preserved valve is elongate, pod-shaped, straight above, with a nearly semicircular outline below; antero-dorsal angle sharp; posterior end of the valve tapering, but fractured,—certainly not broadly truncate originally. A distinctly elevated ocular spot is visible at about one-seventh of the length of the valve, a little below the margin, in the antero-dorsal region. Delicate longitudinal striæ, parallel with the margin, interrupted, and slightly anastomosing, ornament the ventral part of the surface. This pattern passes upwards into scattered minute shallow pits; and above the middle of the valve there is a linear arrangement of fine short striæ, with shallow pits interspersed (see Fig. 2).

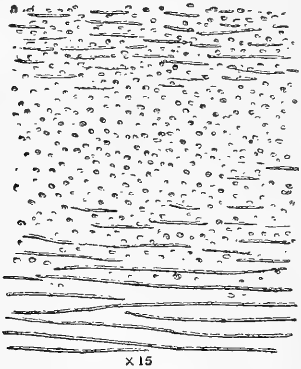


Fig. 2.—Ornament on the valve of *Elymocaris Hindei*: magnified 15 diameters.

In some features this carapace resembles *Emmelezoe elliptica* (M'Coy), Monog. Foss. Phyll. Part I. 1888, p. 68, pl. 8, fig. 1; but it is still more closely allied to *Elymocaris siliqua*, C. E. Beecher, Second Geol. Surv. Pennsylvania, P.P.P. 1884, p. 13, pl. 2, figs. 1 and 2. In size it is nearer the latter, which measures 26 by 10 mm., whilst the former measures 32 by 13 mm. It differs from both in being evidently more attenuate posteriorly (though not quite perfect); and more symmetrical in the elliptical curve of the ventral margin; and from *Emmelezoe* particularly in its frontal angle. As in *Emmelezoe*, there are no nodular eminences near the eye-spot.

Its nearest ally, however, is evidently *Elymocaris capsella*, Hall and Clarke (Palæont. New York, vol. vii. 1888, p. 181, pl. 31, fig. 4), as pointed out to us by Dr. Hinde when communicating the specimen; and, although this is smaller (15·5 by 5 mm.), its proportions are not far from being the same; and its tapering posterior extremity, its striate ornament, and general shape give a close resemblance to our Fig. 7. The greater fulness of the antero-ventral, and less convexity of the postero-ventral, margin in *E. capsella*, and the steeper front edge, with its antero-dorsal spike, distinguish it from the species before us; besides which the latter has a more prominent ocular spot.

Regarding it, then, as belonging to *Elymocaris*, and distinct from the published species of the genus, we name it *E. Hindei* after Dr. G. J. Hinde, V.P.G.S., who collected it many years since at Arkona, Ontario, Canada, from the Hamilton Group of the Middle Devonian Series.

6. Estheria Dawsoni, Jones, 1870.

Acadian Geology, 1868, p. 256, fig. 78*d*; Geol. Mag. 1870, p. 220, Pl. IX. Fig. 15; *ibid.* 1876, p. 576; *ibid.* 1878, p. 101, Pl. III. Fig. 2.

We have just now received from Sir William Dawson, F.R.S., etc., of Montreal, a fossil *Estheria*, which, though imperfect, corresponds in general characters with *E. Dawsoni*, Jones, and moreover exhibits an interstitial pitting or coarse reticulation, such as is present in several known *Estheria*, but rendered obscure by fossilization. "The shell enclosed" (writes our friend, in a letter dated April 28, 1894) "came to me, with some fossil plants, from beds in Nova Scotia, which I suppose to be Lower Carboniferous, but which some hold to be Devonian." He suggests that it looks like the species here referred to.

E. Dawsoni has been found in the Lower Carboniferous series at Horton in Nova Scotia, and in the Lower Carboniferous of Scotland.

EXPLANATION OF PLATE IX.

Fig. 1. *Estheria Draperi*, sp. nov. 1*a*, carapace with the left valve, partly preserved, lying upwards; enlarged 2 diameters. 1*b*, outline, natural size. 1*c*, portion of the ornament, magnified 25 diameters. Eastern side of the Platberg, Natal.

Fig. 2. *Estheria Stowiana*, sp. nov. 2*a*, right valve, magnified 15 diameters. 2*b*, outline, nat. size. Eastern side of the Platberg, Natal.

Fig. 3. *Discinocaris Browniana*, H. W. Modified by pressure. Moffat. Magnified 2 diameters.

Fig. 4*a*, 4*b*. Portions of two bodies or abdomens of, probably, *D. Browniana*. On the same shale with Fig. 3. Magnified 3 diameters.

Fig. 5. *Discinocaris Browniana*, H. W. Modified by pressure. Garpel Linn, Moffat. Magnified 2 diameters.

Fig. 6. *Aptychopsis Wilsoni*, H. W. Left-hand moiety of a carapace. Duff-Kinnel Burn, Moffat. Magnified 2 diameters.

Fig. 7. *Elymocaris Hindei*, sp. nov. Magnified 1½ diameters. Devonian; Arkona, Ontario, Canada.

II.—Restoration of *Elotherium.*

By Prof. O. C. Marsh, M.A., Ph.D., LL.D., F.G.S.;
of Yale College, New Haven, U.S.

(PLATE X.)

THE genus *Elotherium*, established by Pomel in 1847, represents a family of extinct mammals, all of much interest. They were first found in Europe, but now are known in the Miocene of North America, not only on the Atlantic coast, but especially in the Rocky Mountain region, and still further west. This family includes several genera, or subgenera, and quite a number of species, some of which contain individuals of large size, only surpassed in bulk among their contemporaries by members of the Rhinoceros family, and of the huge *Brontotheridæ.*

Remains of this group have thus been known for nearly half a century, yet, until recently, comparatively little had been determined with certainty regarding the skeleton, or of the skull except the dentition, although Aymard, Leidy, Kowalevsky, and others have made interesting contributions to the subject. In a late paper[1] the writer gave figures of a finely preserved skull, and also of a fore and hind foot, of one of the largest species, *Elotherium crassum*, Marsh; and in the present article an attempt is made to restore the entire skeleton of this animal, to serve as a typical example of the group.

The restoration, one-twelfth natural size, given on Plate X., represents a fully adult individual, which, when alive, was more than seven feet in length and about four feet in height. The basis of this restoration is the type specimen of *Elotherium crassum*, which was found by the writer in 1870, in the Miocene beds of North-Eastern Colorado, and described in 1873.[2] A number of other specimens since obtained in the same region, and still others from essentially the same horizon in South Dakota, all evidently pertaining to this species, were likewise used in the restoration.

The type specimen, although incomplete, includes portions of the skull, with various vertebræ and bones of the limbs and feet, and these were sufficient to determine the general form and proportions of the animal here restored. The additional specimens used are mostly in good preservation, and some of them are almost as perfect as in life. Hence, the skeleton, as represented in Plate X., is believed to be correct in all its essential features.

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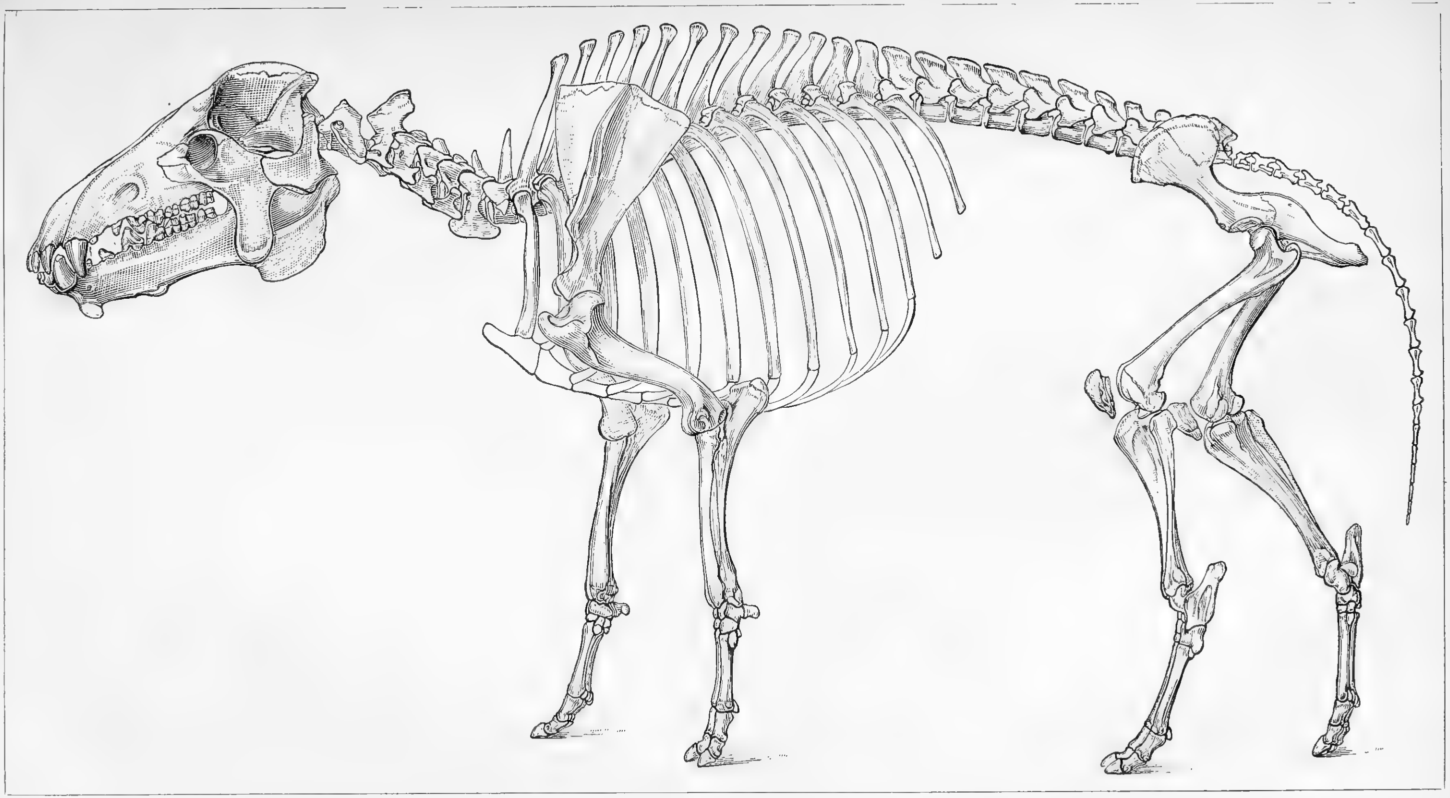
[1] American Journal of Science, vol. xlvi. p. 408, pl. viii. November, 1893.

[2] *Ibid.* vol. v. p. 487, June, 1873.



Restoration of Elotherium crassum, Marsh. One-twelfth natural size.

From the Miocene Beds of North-Eastern Colorado, U.S.A.

Looking at the skeleton, as here shown, it is evident that the most striking features are the large and peculiar skull, and the elongate and slender limbs and feet—characters that do not in themselves suggest the suilline affinities of the animal, which a closer study brings to light. The most notable points in the skull, as here indicated, are the long, pendent process of the malar bone, characteristic of some of the sloths, and the strong projections on the lower jaw. The latter supplement the malar process, but are developed to a greater degree than in any other mammals. Another feature of the skull to which the writer has already called attention is the very small brain-case, which proves that the brain itself was very diminutive. This was also true of the other known species, and was probably the main reason which led to the early extinction of the whole group.

The slender, highly specialized limbs and feet are likewise particularly noticeable in the restoration. They indicate clearly that the animal was capable of considerable speed, and this must have been of great service as a protection from its enemies. It will be seen that in each foot there are only two functional digits, corresponding to the third and fourth in man. The first digit is entirely wanting, and only remnants remain of the second and fifth.

Such reduction was, of course, a gradual process, extending over long geological periods. It indicates clearly a change of environment from the swampy home of the primitive five-toed suilline to the elevated, firm upland of later times, over which the present species and its near allies doubtless roamed. A parallel instance, still more striking, is seen in the gradual change which took place in the equine mammals, as first shown by the writer more than twenty years ago.[1]

The *Elotheridæ* were evidently true suillines, but formed a collateral branch that became extinct in the Miocene. They doubtless branched off in early Eocene time from the main line, which still survives in the existing swine of the old and new worlds.

III.—On *Temnocheilus coronatus*, M'Coy, from the Carboniferous Limestone of Stebden Hill, near Cracoe, Yorkshire.

By Arthur H. Foord, F.G.S., of the Royal Dublin Society, Dublin; and
G. C. Crick, Assoc. R.S.M., F.G.S., of the British Museum (Natural History).

THE specimens which form the subject of this paper were obtained by Mr. E. J. Garwood from the Carboniferous Limestone of Stebden Hill, near Cracoe, Yorkshire; and the writers are indebted to the kindness of Mr. Garwood for permission to describe them. Respecting the horizon and locality from which the species came, Mr. Garwood says, in a letter to one of the writers: "Stebden is a hill which Tiddeman [of the Geological Survey] describes as one of his knoll reefs, and is, in my opinion, the equivalent of the Upper Scar limestone on the south side of the Cracoe fault, where it is much more fossiliferous than on the north

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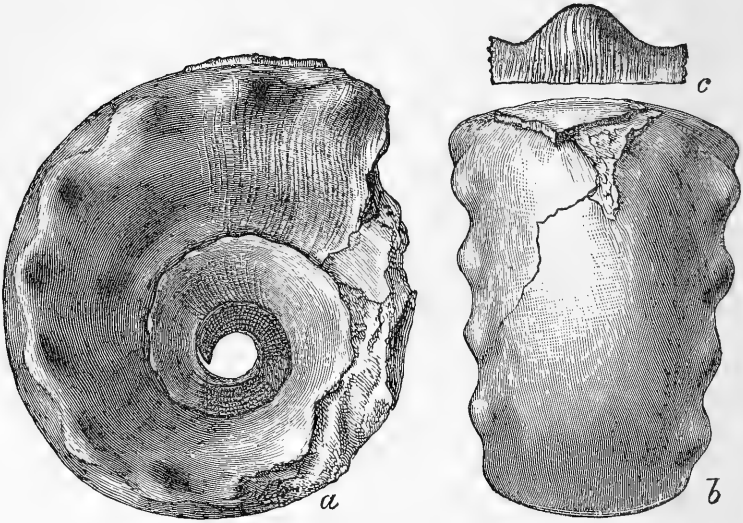
[1] American Journal of Science, vol. vii. p. 257, March, 1874.

(*i.e.* Pen-y-gent, Ingleboro, etc.)." Mr. Garwood adds: "Both of the specimens were much larger, when first exposed in the matrix; but the rock was so jointed, and the outer whorl [body-chamber?] so hollow, and replaced by calcite crystals, that only fragments of this could be obtained, and a good deal was broken before I could discover the extent of the fossil *in situ.*"

The close resemblance of the present form to the *Temnocheilus coronatus* of M'Coy will be apparent to any one acquainted with that species, either through the figure given of it in the "Synopsis of the Carboniferous Fossils of Ireland" (pl. iv. fig. 15), or by direct knowledge of the specimen itself in the Museum of Science and Art, Dublin. M'Coy's specimen, which came from the Carboniferous Limestone of Little Island, near Cork, is, however, greatly distorted by cleavage, and is apparently immature.

In his "British Palæozoic Fossils" (p. 557), M'Coy referred to this species some examples from the Carboniferous Limestone of Lowick, Northumberland, and these enabled him to amend his original description of the species. These specimens are now preserved in the Woodwardian Museum, Cambridge; one is fairly complete and four are fragmentary. They are all internal casts and bear only fragments of the test; but upon the inner whorl of the tolerably complete example there is an indication of the longitudinal ornamentation of the test, and this is just as in M'Coy's type-specimen; moreover, the dimensions and other characters of these examples agree so closely with M'Coy's type, that we think there



Temnocheilus coronatus, M'Coy.—*a*, lateral view of inner whorls of an example about 130 mm. in diameter; *b*, peripheral view of the same; *c*, tubercle of another specimen at a diameter of about 120 mm., showing the coarse lines of growth. *a* and *b* are slightly reduced, *c* is of the natural size.

cannot be any doubt as to their identity. But Mr. Garwood's specimens (there are two) are in such a fine state of preservation, and probably nearly, if not quite, mature, that they enable us to add somewhat even to M'Coy's amended description of the species. One specimen has a diameter of 125 mm.; the other, the inner whorls of which are represented in the accompanying figure (the outer being omitted to save space), was somewhat larger.

The shell consists of rather more than three whorls, and there is a central elliptical vacuity whose diameters are 10 and 7 mm. respectively. The septa are about 10 mm. apart on the periphery, where the shell has a diameter of 90 mm. The ornaments consist of a row of tubercles situated at the junction of the umbilical and peripheral borders. Beginning at about the mid-length of the first whorl as obscure undulations, the tubercles gradually increase with the growth of the shell, until at about the second whorl they have become large and prominent. They are of a flattened conoidal form and slightly elongated longitudinally. There are fourteen tubercles per whorl in an adult shell. The test is thin, its surface marked with fine striæ of growth, forming an obscurely sigmoid curve upon the sides, and bent backwards in a deep sinus on the periphery, where they become much coarser in the adult shell, especially in crossing the tubercles (see Figure). The ornamentation of the young shell is that which is characteristic of most, if not of all, of the coiled Nautiloids, including the recent *Nautilus*, viz. fine longitudinal raised lines, crossed by still finer ones, and thus forming a beautiful cancellated structure. The transverse lines become obsolete before the end of the first whorl, but the longitudinal lines die out at about the end of the first fourth of the second whorl, among the last to disappear being two lines just below the tubercles.

Some differences are observable between M'Coy's type and the Yorkshire form, the peripheral area in the former being a little wider than that of the latter, and the sides of the umbilicus rather steeper; the tubercles also are more flattened than they are in the English fossil. These differences, however, may be rightly attributed, we think, to the distortion undergone by M'Coy's specimen, the lateral pressure having widened the periphery, while at the same time altering the true form of the umbilical region. M'Coy's figure (pl. iv. fig. 15) represents a more perfect specimen than the one from which it was drawn, unless the latter has since been damaged. The only species with which M'Coy, when describing his species, compared it is the *Nautilus* [=*Cœlonautilus*] *cariniferus*[1] of J. de C. Sowerby, tuberculated species of the group now called *Temnocheilus* being probably rare at the time M'Coy wrote. But in his "British Palæozoic Fossils" (p. 558), M'Coy in referring to this species says: "This exceedingly rare species is distinguished completely from the *N. tuberculatus*[2] by the great thickness, or width, of the mouth as compared with the diameter, the much more rapidly

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[1] J. de C. Sowerby, Min. Con. vol. v. p. 130, pl. cccclxxxii. fig. 3 (excl. fig. 4).

[2] J. Sowerby, Min. Con. vol. iii. p. 90, pl. ccxlix. fig. 4.

enlarging whorls, much deeper and narrower umbilicus, direction of the flattening of the tubercles, acutely elliptical form of the transverse section of the whorls, and forward instead of backward wave of the edge of the septa at the middle of the periphery." We have examined J. Sowerby's type of *Nautilus tuberculatus*, which is in the British Museum (Nat. Hist.), and have no doubt that it is specifically distinct from M'Coy's species.

De Koninck,[1] in describing the present species from Visé, Belgium, compares it with *N. biangulatus*, J. de C. Sowerby [?= *Cœlonautilus cariniferus*, J. de C. Sowerby], and with *Nautilus tuberculatus*, J. Sowerby, and *Nautilus latus*, Meek and Worthen. He distinguishes M'Coy's species from Sowerby's and Meek and Worthen's by its smaller size, the greater relative height of its aperture, the depth of its umbilicus, and the form of its septa. As far as can be judged by the figures there seems much to justify de Koninck's identification of the Visé fossil with *Temnocheilus coronatus*; and Mr. Garwood in a letter to one of the writers expresses the same view, he having seen the specimens in the Natural History Museum at Brussels last autumn.

There is a small but well-preserved specimen in the Woodwardian Museum, Cambridge, from the Carboniferous Limestone, Settle, Yorkshire, which we think belongs also to this species.

Finally, our best thanks are due to Mr. W. W. Watts, of the Geological Survey, through whom we obtained access to Mr. Garwood's specimens, and to Prof. Hughes and his assistants, Messrs. Woods and Reed, for their kindness in allowing one of us to examine M'Coy's types in the Woodwardian Museum, Cambridge.

IV.—JURASSIC AMMONITES: NOTES ON A PAMPHLET BY PROFESSOR GUIDO BONARELLI.[2]

By S. S. BUCKMAN, F.G.S.

ITALIAN geologists have made several valuable contributions to our knowledge of the Jurassic strata of their country. Unfortunately some of their works are not known here as they deserve to be, and seem difficult to obtain. At the same time I have to acknowledge with thanks the receipt of some valuable memoirs which have been of particular service; and one of the latest arrivals is the present pamphlet.

This memoir deals with what has usually been called "Upper Lias" and "Lower Inferior Oolite"; but these terms the author proposes to replace by "Toarcian" and "Aalenian." He deals, first, with the palæontology, and mentions various well-known species, some of which we are familiar with in this country, but others are peculiar to the districts adjacent to the Mediterranean. In this connection it may be noted that *Hammatoceras* in a great measure, and

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[1] Faune du Calcaire Carbonifère de la Belgique (Annales du Mus. Roy. d'Hist. nat. de Belgique, vol. ii.), part i. 1878, p. 115, pl. xxiv. ff. 2*a*, *b*.

[2] Osservazioni sul Toarciano e l'Aleniano dell' Apennino centrale. Boll. d. Soc. geol. italiana, vol. xii. fasc. 2, pp. 195–254. Rome, 1893.

Erycites especially, belong to the Mediterranean regions; while the Lytoceratites[1] were particularly abundant—in fact, individually and specifically they would seem to have flourished, in the Mediterranean districts as compared with this country, as ten to one.

Two new genera are introduced in the present pamphlet, namely, *Paroniceras* (Prof. Parona) and *Collina* (derivation not given, but perhaps from *Collinus*, "of a hill"). The type of *Paroniceras* is *Am. sternalis* (von Buch); and concerning its value in our opinion see the appended paper on "The genus *Cymbites*." The type of *Collina* is a new species, "*gemma*," which may be described as a carinate *Dactylioceras* allied to *mucronatum* (d'Orbigny). The carination appears to be the feature which separates *Collina* from *Dactylioceras*; and if it can be shown that *Dactylioceras* split up into two branches, one of which developed a carina, and the other remained uncarinate, the genus *Collina* (? *Collinus*) will have good foundation.

Among specific names to be noted are, first, the application of Oppel's "*iserensis*" to *Am. erbaensis* (Dumortier, *non* Hauer), a very necessary correction; and, second, the new name "*Cœloceras* ? *Mariotti*" applied to *Am. Humphriesianus nodosus* (Quenstedt, Jura, pl. 54, fig. 4). This name, however, is superfluous, and must rank as a synonym; because Hyatt has already applied the name "*nodosum*" to this very figure: he called it "*Stephanoceras nodosum*."[2] It may be remarked that, in translating Quenstedt's trinomial or quadrinomial system into modern currency, the first two names, say "*Ammonites Humphriesianus*," are really generic, and are concisely written "*Stephanoceras*" or "*Cœloceras*," while the third name thus becomes specific; and, unless the restricted genus already contain the same name, Quenstedt's third name should always be used. Further, both *Cœloceras* and *Dactylioceras* have priority of *Stephanoceras*, while a name *Stephanoceros* was already in use for a genus of Rotatoria.[3]

Prof. Bonarelli places as Toarcian the *Falciferum*- to *Jurense*-zones, and as Aalenian the *Opalinum*- to *Concavum*-zones. He discusses the division between "Lias" and "Jura," and his conclusion is thus expressed (p. 254): "In the Central Apennines the most natural division between Lias and Jura which it is possible to adopt is precisely that proposed by Münster and upheld by Vacek." That

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[1] I propose this name as a sort of colloquial word, congruous with Ammonites, Ceratites, Goniatites, etc., to distinguish those genera which are certainly not true Ammonites, either in characters or by descent, namely, *Lytoceras*, *Pleuracanthites*, *Phylloceras*, *Monophyllites*, etc. They are characterized by the phylliform cells of the septa, and probably by the absence of any calcareous Aptychus or Anaptychus. Lytoceratites are biologically lower than Ammonites, though they are collateral and coeval. They were separated by Hyatt (Genesis Arietidæ, p. 4) as *Lytoceratinœ*; but this places *Lytoceratinœ* superior to *Lytoceratidœ*, whereas it should be of inferior rank. The terms *Lytoceratacece* and *Ammonaceœ* (the latter used many years ago) might indicate Lytoceratites and Ammonites respectively, and be subdivisions of *Ammonoidea*.

[2] "Genetic Relations of *Stephanoceras*," Proc. Boston Nat. Hist. Soc. vol. 18, p. 386, 1876.

[3] Hyatt, *op. cit.* p. 368 (E. B. Tawney's information).

is to say, up to the *Concavum*-zone, inclusive, is "Lias," above it "Jura." It may be remarked that no local lithological details, whether in the Central Apennines or in this country, can have the least consideration in regard to the division ultimately adopted. It must be settled solely on palæontological data; and the following facts may be noted, that, below the *Concavum*-zone, the *Arietidæ* and *Hildoceratidæ* (practically the carinate Ammonites) are dominant; after that date the *Stephanoceratidæ* hold the field. This distinction is of European, and possibly of worldwide, application; while a lithological test is of merely parochial usefulness—sometimes not even that.

V.—Note on Sediments Dredged from the English Lakes.

By W. Maynard Hutchings, F.G.S.

DR. H. C. MILL has recently made elaborate bathometric surveys of the principal English lakes, and whilst taking the soundings he has collected a series of samples of the bottom-deposits, for the purpose of microscopic study.

At the request of Mr. Marr I undertook a careful mineralogical examination of these samples, and, though nothing very striking or specially interesting has resulted from the work, it may be worth while to record in the Geological Magazine the fact of such an examination having been made, and to state the mineralogical and other observations noted.

After some preliminary experiments, the method of dealing with the sediments finally adopted was as follows. Each sample was passed through a sieve of 130 holes per linear inch, and only the material fine enough to pass this mesh was submitted to microscopic examination at all. From this first portion a second was separated by a sieve of 250 holes per inch, and from this again a fine slime was washed out by levigation in beakers; also a separation of the heavier minerals of the deposits was made by means of a solution of Sp. G.=3. The four grades of material so obtained were examined mounted in balsam and in water.

I have been much struck by the fact that most of the samples show great tenacity when dried, and great plasticity when made into a paste with water. This high degree of tenacity and plasticity was unexpected, in view of the large amount of quite angular and gritty material contained, and the relatively small proportion of mineral matter in a sufficiently fine state of division to be compared to the ordinary clays. Partly, however, these qualities are due to a considerable amount of organic matter of vegetable origin, and to abundant diatoms and other mineral organisms and their remains.

The mineralogical composition of the deposits is, in the main, exactly what would be expected from a knowledge of the rocks in the respective areas drained, though there are one or two examples of minerals which occur in the sediments in greater abundance than would have been looked for, as *e.g.* hornblende, both green and brown, occurring in lakes receiving the drainage of areas of "volcanics," though that mineral is rarely recorded as occurring in the rocks in question.

Also there is no practical difference to be observed in the nature of the deposits in different lakes which receive the waters from areas of similar general nature. Bassenthwaite, however, which receives the waste of an area of sedimentary rocks, with an almost total exclusion of "volcanics," has a deposit very different in nature from those of the other lakes.

Taking the lakes which receive the drainage of volcanic areas pure and simple, the minerals identified are:—

Quartz.
Felspars.
Garnet.
Rhombic Pyroxene (very scarce and only in Wastwater).
Hornblendes.
Muscovite.
Biotite.
Epidote.
Chlorite.
Calcite.
Zircon.
Tourmaline. } in clastic fragments only.
Rutile. }
Hematite.
Magnetite.

Amongst the felspars the varieties identified are orthoclase, albite, labradorite, anorthite, and a few bits of microcline.[1]

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[1] The felspar-fragments in these deposits are not well suited for identification of varieties, as they are to a great extent quite irregular, ragged bits, few of them showing any definite boundaries or cleavages with which to correlate extinctions and optic figures. The larger bits ($\frac{1}{130}$ inch) are mainly more or less turbid, like most of the felspars in the rocks from which they are derived; but among the smaller grains of the more finely-sifted materials there are plenty of clear fresh bits to be found.

It may be remarked, in this connection, that even with very imperfect material, both in a fragmental condition and in rock-sections, a good deal more can be done in the way of identification than is often supposed, by making use of Schuster's method of extinctions, in conjunction with a careful application of the figures in convergent polarized light. It is often not necessary to have cleavage-flakes sufficiently good to enable the *sign* as well as the *angle* of extinction to be determined. Thus, suppose we have a very imperfect flake, or an irregular bit in a slide, showing, however, one good cleavage-crack or boundary. If we find the extinction is 18°—20°, measured against this line, and if we have at the same time an undoubted emergence of a *positive bisectrix* not quite central in the field, then we know that we have albite. A similar fragment or bit in a section, giving an extinction of about 36°, with a sharp and distinct axial bar well within the field, but near its edge, will be anorthite. Other determinations may be made in this way on very unpromising material, provided the optic figures are understood and are carefully used as a guide, and no attempt is made to draw inferences except when these figures can be determined beyond question.

This is not an appropriate place in which to go more fully into this subject, which can be easily followed out by studying the details given in Rosenbusch, or in Teall's "British Petrography" or other works, as to Schuster's method, and the optic figures on the M flakes of the different felspars.

To obtain good results it is necessary, as I pointed out in previous remarks on the determination of felspar (Geol. Mag. January, 1894, p. 41), to have efficient optical apparatus. In very thin flakes, or in bits in thin sections, owing to the very low polarization-tints, it is often difficult to determine the extinctions with sufficient

The hornblende is partly green and fibrous, such as results from the alteration of augite; but a good many bits of the deep-brown compact variety occur, more probably of original volcanic origin.

The muscovite is of two kinds. In the finer portion of the materials the mica is abundant as small, usually greenish flakes of sericitic nature, such as one sees plentifully in the altered felspars, and in the mass, of the lavas and ashes of the district. In the larger-grained portions of the deposits examined there are larger flakes of muscovite than are seen in these rocks.

The biotite is all of this larger kind. It is to be recollected that the deposits contain the waste not only from the rocks of the district *in situ*, but also from the materials of the surface-drift, and it is to this latter that we must probably refer some of the minerals found, as notably the microcline and biotite and some of the larger flakes of muscovite, though in the case of Wastwater these latter minerals may have come from granitic rocks *in situ*.

Taking Bassenthwaite as representing the deposits from an area of slate-rocks, we still find closely the same *qualitative* list of minerals, but a totally different *quantitative* arrangement of them. Thus, felspar is scarce, and among it plagioclase is rare. Chlorite is also scarce, in contrast to its great abundance in the deposits from the "volcanics." The great bulk of the material consists of flakelets of slate, showing quartz and mica, and crowded with minute rutile-needles. The finest portions consist mainly of the minute scales of mica from these slates, with the rutile-needles and with a good many of the small anatase crystals characteristic of clays and shales.

Tourmaline is present, not only as clastic grains as in the other lakes, but also as the small green hemihedral crystals characteristic of the slates, etc. In the deposits from the "volcanics" the quartz, like the other minerals, is all present as angular fragments or flake-like chips; the distance it has traversed was too short to allow of any notable amount of rounding of the grains. The quartz in Bassenthwaite is largely in a more smooth and rounded form; it represents the grains which were already well worn when they were deposited as part of the materials now forming the Skiddaw slates, etc.

In Derwentwater we have a lake giving a mixed deposit, in which both "volcanics" and "sedimentaries" take part. The former, however, much predominate in an average sample for the entire lake, and the latter are only in evidence by a very few minute slate-fragments, by rutile-needles and by small crystals of tourmaline.

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accuracy. For this purpose a Bertrand quartz-eyepiece (with four quartz segments) will be found of the greatest service.

The discrimination of the felspars is, of course, of the highest importance in all petrological work, and especially so in the study of metamorphic rocks, so that too much stress cannot be laid upon the desirability of carrying it out in all cases as fully and as definitely as the nature of the material will allow. It appears to be sometimes left undone, or very vague, where there is no necessity to so leave it; or it is even left undecided whether a mineral is quartz or felspar,—an uncertainty which is seldom necessary where the mineral or minerals occur in any reasonable quantity in a slide.

VI.—NOTES ON RUSSIAN GEOLOGY.[1]

By W. F. HUME, D.Sc., A.R.S.M., F.G.S.;
Demonstrator in Geology, Royal College of Science.

III. THE BLACK EARTH.

IN a previous paper on the Loess of S. Russia, I endeavoured to discuss its character and origin, and to compare the facts observed with the results obtained by many students of the latest phases of our earth's history. In so doing I overlooked two articles on this subject, which appeared in the GEOLOGICAL MAGAZINE for 1882, and embodied the views held by Baron von Richthofen and Sir H. Howorth respectively. These may be briefly considered ere we turn to a special examination of the structure and relations of the Black Earth. An examination of Sir H. Howorth's statements reveals serious points of disagreement between the theories previously or subsequently suggested, and those which he himself holds. At the outset (*loc. cit.* p. 12) Sir Henry remarks: "Loess is not found in S. Russia, nor yet in the flat country bordering." Such a proposition would be deeply resented by the geologists of that country, and has unconsciously on my part received its answer in my previous paper, where I have shown Loess to be one of the most striking deposits of some of its southern governments, and that it presents all the most important features mentioned as characteristic by Baron von Richthofen.

But Sir Henry goes further, and having successively attempted to crush the various views held on this subject, propounds a theory of his own, which may be considered in the light of the results obtained from the particular district under discussion. The proposition practically may be stated thus: The Loess is a subterranean or volcanic product, which has been subsequently distributed by diluvial action.

This suggestion is also extended to the Black Earth, which, it is stated, is distributed about an apparently recently disturbed mountain focus, viz. the Southern Urals. So far is this from being the case that the Kharkov government, where some of the finest Black Earth districts exist, is 1000 miles from the above mountains, and over 500 miles from the Carpathian range. In reality the country is practically undisturbed, the Tertiary and Cretaceous beds having so small a dip, that the slight rolling of the strata is only observable when the conditions along a line of over fifty miles are passed in review.

Further, there are no traces of volcanic action in any of these central districts. The nearest exposures of eruptive rocks are probably the Carboniferous andesites and rhyolites of the south of the Ekaterinoslav government, the diabases (probably very old) in the W. of the same province, and the basalt mass rising through the Chalk of Central Poland.

Finally, if the Loess were of volcanic origin, it would contain traces of minerals, and possibly of structures produced under such conditions. Such evidence is not only wanting, but is *à priori* im-

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[1] For No. I. Cretaceous, see GEOL. MAG. September, 1892; No. II. the Loess, see GEOL. MAG. December, 1892.

probable. Under these circumstances the prime cause operating, according to Sir H. Howorth, in the production of Loess and Black Earth appears entirely inadequate. At the same time, Sir Henry is to be thanked for the number of facts which he has brought together after undoubtedly long and careful reading, though the interpretations he has put upon them may frequently be open to much adverse criticism.

The second theory, that of Baron von Richthofen, is set forth clearly in the same volume as the above (pp. 293–305), and further study of his views, there brought together in a small compass, only serves to strengthen my belief in the great value of his contribution to this subject.

It is not necessary here to repeat how completely the vast majority of the conclusions formulated by him with regard to the Loess have been proved to be applicable to the sandy clay of S. Russia. Further, wherever we find unbroken land-shells, and remains of a typical steppe fauna, there the presence of Loess will have, in all probability, to be attributed to the action of wind.

Baron von Richthofen points out that there are two great classes of places where the dust of continents will rest permanently, and continue to accumulate through ages:

"The first includes the central regions of continents, where the water has no drainage towards the sea, but is collected in inland basins, from whence it gradually disappears by evaporation." (For further details see p. 298.)

"The second comprises such regions as the prairies, savannas, llanos, pampas, and *steppes*, where there is an alternation of a dry and a rainy season. Where this occurs the amount of dust put in motion and distributed through atmospheric agency can reach enormous proportions." Such conditions are in a measure prevalent in S. Russia, where a very dry summer frequently succeeds the long winter snows, and an autumnal rainy period follows the summer droughts.

As regards the original glacial origin of the Loess advocated by me, Baron von Richthofen fully agrees in regarding it as partly resulting from glacial trituration. Indeed, he came to the conclusion ("China," vol. ii. p. 748) that the time of the deposition of the Loess as a steppe formation in Central Asia coincides with the Glacial era in Europe, and in Germany it appears to have been formed after the first, and before (or during) the second glaciation.

Practically, then, the differences between the views held by Baron von Richthofen, and those which I have been led to adopt, are reduced to a minimum. Indeed, one cannot but be struck with the keen appreciation of every point of importance shown by him in his classical treatises. In my previous paper I failed to comprehend how fully he had discussed the subject in its various bearings, and desire here to tender an apology for my unwitting misrepresentation.

Subsequent to the publication of my paper in the GEOL. MAG. December, 1892, Prof. Dokoutchaieff of St. Petersburg published a note in the Bulletin Soc. Géol. Belge, January, 1893, on the Loess of S. Russia, in which he rejects the æolian theory, and advocates that of glacial origin.

He considers the deposit under several heads:

1. The Loess may be of glacial, marine, lacustro-fluviatile, eluvial, or diluvial origin.

2. The fine-grained Loess of the Poltava or Nijni-Novgorod type, of uniform structure throughout its thickness (except where a few small erratic blocks are present in its lower portions), and containing terrestrial or marsh-living organisms only; this Loess, covering the watersheds and ancient slopes, *is of exclusively glacial origin*, and represents the finer constituents of the glacial mud deposited over a country already covered with vegetation, and inhabited by the typical rodents of the steppes (as the *Alactaga*, the *Spermophilus*, the *Arctomys*, and the *Lagomys*); by the Mammoth and Rhinoceros, and occasionally by the Beaver.

3. A similar Loess occurs sporadically as little islands throughout the whole of the districts bearing traces of glaciation, sometimes in the inferior sands containing erratic blocks, and sometimes in the northern brown clays; but they become less frequent as we approach the sources of the Russo-Scandinavian glacier.

The Glacial Loess occurs principally (1) at the S. and S.E. limits of the glacier itself, and (2) in that part of the open country immediately contiguous to its probable boundary. In the first case it may cover all the watersheds; in the second it will only be in those districts where the absolute height is inferior to that of the most elevated points of the neighbourhood occupied by deposits of erratic blocks. For example, in the government of Poltava the maximum height of these deposits above sea-level is 210 metres, consequently in the whole of the lower basin of the Dnieper it should only occur at heights less than 210 metres.

4. One of the most characteristic peculiarities of the Glacial Loess is the presence of the dark-grey glacial mud, forming a definite but interrupted layer, frequently attaining a thickness of over two metres. It is distributed in patches, containing many large grains of quartz, and sometimes calcareous inclusions. The humus percentage is 3.

5. In the eastern wing of the glacier, that of the Don, the Loess is a stratified, coarse, and somewhat porous clay, of a brown-grey colour, but its origin is similar to that previously mentioned.

6. The typical Loess is absent, and cannot in general exist on the very ancient portions of the earth's crust. Exceptions occur along the whole of the Dnieper Valley, at the exterior limits of the glacier, and on the littoral of the Sea of Azov, where marine are interstratified with glacial deposits; Loess possessing the type characteristics also occurs in the south of Poland.

7. The Asiatic Loess is in all probability partly glacial in origin, but may be also eluvial, diluvial, or alluvial; only in isolated regions, occupying ravines of greater or less depth, will it be distinctly of æolian derivation. Prof. Dokoutchaieff would also remove the Loess of W. Europe from the æolian category.

8. The diluvial deposits of the government of Poltava are divisible into three horizons: (1) A fresh-water marl at the base; (2) Red clay; (3) Loess; all these, however, passing gradually into one another, whether in respect of organic remains, stratigraphical position, or lithological character. There is no evidence especially favourable to the conception of more than one Glacial epoch.

9. Seeing then that the typical Loess is, in the government of Poltava, restricted to the region of inferior morainic deposits, and only extends beyond them to a slight extent; viewing the fact that it is completely analogous to glacial mud occurring in purely morainic deposits, erratic blocks also being sometimes found at its base; bearing in mind also that Loess may be found below the brown morainic clays—*the Loess must be considered as a glacial mud deposited from glacial waters.*

This valuable contribution to the discussion of the origin of Loess comes from the pen of a distinguished geologist, who possesses a wide knowledge of the superficial deposits of Central Russia and the Poltava government. It seems to be the case that the theory adopted by an observer depends very much on the district in which he first studies its characters. Those who examine it along the boundary of the old Russo-Scandinavian glacier, a boundary indicated by morainic clays containing rocks of Finnish origin, are at once led to regard the Loess as a product of glacial activities. It immediately overlies the Boulder-clay, is stratified at the base, and clings closely to the ancient line of ice-action. Others, travelling over the southern steppe-land, would be struck by the tremendous activity of the varying wind-currents, giving rise to innumerable dust-clouds, and would not fail (now that Baron von Richthofen has called attention to the importance of these phenomena) to regard these remarkable deposits as resulting from æolian action, a conclusion which would be greatly strengthened by the discovery of perfect terrestrial mollusca, and the presence of a true steppe fauna.

As to the glacial origin of some types of Loess, most students of the subject are now in agreement, and it has, as above stated, been conceded by Baron von Richthofen himself, that such may be the case.

But it is by no means restricted to the boundary of the glaciated area. It extends all along the right bank of the Dnieper, and is said to be very marked on the banks of the Don. It appears, therefore, that when the general drainage directions of the country were first marked out, the flooded waters carried the fine glacial silt with them, and it was only on the establishment of conditions similar to those now prevailing that the rivers, confined to narrower channels, were engaged in denuding the deposit which their ancestral streams had assisted to transport.

Whilst on many points we are in full agreement, Professor Dokoutchaieff scarcely does justice to the vast importance of æolian activities operating during the many years that have elapsed since steppe-conditions came into existence.

After a reconsideration of the literature of the subject, I find no reason to modify the propositions submitted more than a year ago (Geol. Mag. December, 1892). These are: I. That the Russian Loess was originally the fine mud derived by the triturating action of the ancient glacier. This view has been still more strongly urged by Prof. Dokoutchaieff. II. That it was deposited by slowly-moving waters (this would embrace the aspect adopted by Prof. Armachevsky), and was distributed by rivers in flood. This latter action would account for the great southward extension of the Loess along the valleys of the Dnieper and the Don, and would by inference suggest that the general courses of these two great streams were already marked out. The thick deposits in the Danube and Rhine valleys may be explained in the same way. Here, let me say, seems to be the time for considering that mighty diluvial change, the Deluge, which has left its mark on the old historical records and traditions of so many nations. Sir H. Howorth weakens his argument by introducing prime causes, which, it is to be feared, he will have great difficulty in proving; but as one deeply interested in modern as well as ancient history, I should be delighted if he could bring our geological data and the monumental references into perfect accord. Only by a frank acceptance of a Glacial period in some limited form, will he be able to attack the serried ranks of the Uniformitarians with some hope of success, but combining the results due to its melting, and the changes in the mountain-structure of E. Europe, he may yet hope to carry on a not unsuccessful warfare. III. The glacial and diluvial actions were mainly restricted to the earlier periods of post-Glacial history, and determined the general geographical relationships of the Loess; but it was not long ere the wind became the redistributive factor, and, acting through long years, established those numerous characteristic features which can only be explained by means of an æolian theory of origin.

Having now briefly reconsidered some of the theories with regard to the origin of the Loess, let us now turn to the study of the Black Earth as it is developed in S. Russia. It has long attracted the attention of geological observers, not only on account of its striking appearance, but also because of its rich fertility as a soil. Its wide distribution has been specially noted by Sir R. Murchison ("Russia and the Urals," p. 557), where he says: "Its N. limit is a waving line, passing from near Kieff to Tchernigov, a little to the S. of Lichvin along the 54° latitude line, then advances E. to 57° N. latitude, and occupies the left bank of the Volga between Nijni Novgorod and Kazan. It is also abundant on the Kama and Ufa." Its wide occurrence in Siberia is then noted, as also its presence on plateaux more than 1000 feet above sea-level in the Bashkir country, and on both flanks of the S. Urals. "It does not occur much in the space occupied by the Aralo-Caspian beds, nor is it found S. of the granitic axis. It lies on rocks of all ages and is found at very different levels. The northern drift is succeeded, if not actually overlapped, by the Black Earth." It has, in reality, a far greater western extension than has been ascribed to it in the above lines, and I have noticed it not only in the Jitomir district, about a hundred miles to the W. of Kieff, but also in passing from Russia into Austrian Poland. The last locality at which it was actually observed by me was Jaroslavl, a town situated on the railway between Cracow and the old city of Premysl. Beyond that point Loess alone seemed to be the prevalent surface deposit. The first point of importance is the close connection existing between the Loess and the Black Earth. Murchison included both deposits under the common term Tchernozem; but this latter, in the truest sense of the term, should be restricted to the upper strata, rich in humus contents. Schmidt regards it as practically identical with Loess (Zeits. Deutsch. Geol. Ges. vol. xxix. p. 830–31). Richthofen states: "The black colour, which is proper to the uppermost layer only, appears to result solely from the formation of vegetable mould, the deeper portions showing the brown colour of the Loess, together with its structure, although this appears to be less perfect than in the former case." Personal observation has left no shadow of a doubt on my mind as to the intimate connection between these two types of deposit. Reference has already been made as to the gradual passage from pure Loess to Black Earth observed in a ravine at Kharkov, and an example of the interlamination of the two at their point of junction has been cited from Bielgorod.

But these cases, developed on a small scale at the above localities, may attain much greater proportions. Repeatedly the dark brown humus-bearing bed forms distinct lenticular patches (often 3 or 4 feet in thickness at the centre and extending some little distance in a horizontal direction) running through the yellow clay.

The further and final stage is attained when the Black Earth forms a distinctly marked stratum, actually overlain by a true Loess. This is beautifully observed in the ravine near the railway station at Kieff, where a thick layer of Black Earth is overlain by some seven feet of Loess.

But the inter-relationships of the two deposits are still further brought out if a closer examination be made of the materials composing them. Not only does Black Earth agree with Loess in its superficial position, its existence at most varying level, its occasionally purely local development, but it possesses the same want of consistency when rubbed in the fingers. The chemical composition is in most respects similar. Thus Loess may be said to be composed of pure silica in the form of sand-grains, clays, calcareous constituents (as concretions frequently), and oxide of iron, acting as a colouring material. Compare with this the analysis of Black Earth made by Mr. H. Phillips for Murchison's work:

Silica	69·8
Alumina	13·5
Lime	1·6
Oxide of Iron	0·7
Organic Matter	6·4
Traces of Organic Matter H_2SO_4, Cl., etc. ...	1·7

The amount of silica is always very noticeable. The high percentage is due to the large number of polished sand-grains always present in samples of Tchernozem. These, however, vary greatly in size, from the grains $\frac{1}{18}$ of an inch in diameter already mentioned from Bielgorod, down to particles almost invisible to the naked eye. The variations appear in some respects, to follow the rule, that the further south the deposit the smaller the sand-grains contained in it. It would require a close examination of a large number of samples before this could be established as an absolutely proved fact.

In doing so, particular care must be taken to select the specimen from an uncultivated spot. This is now a somewhat difficult task, so much of the steppe-land having been brought under cultivation. Examination and enquiry have both, however, led to the same result—the deeper the earth from the surface the more sand-grains does it contain. Both in character, position, chemical analysis, and history, the Black Earth is thus intimately connected with the Loess, and is due to special circumstances affecting the latter.

A historical review of the whole subject is of particular interest, as showing the various possibilities which have been brought forward to account for these soils, the treeless prairies and steppes, and the sharp distinctions between present geographical conditions in N. and S. Russia. At the same time a remarkable parallelism is to be observed between the theories propounded in America, and those which have from time to time been enunciated by Russian geologists. In the Journ. Poltava Agricult. Soc. February–May, 1891, Prof. Krasnov has given an admirable summary of the latest position of these discussions as viewed from Russian standpoints. Many of his conclusions have struck me as being of such general interest that it may be advisable to include them in the present discussion, especially as they are at present practically buried in a local Russian journal. Pallas was one of the first to consider the origin of the Tchernozem. He, in common with later observers, regarded it as having been formed on the bed of a gradually-dying sea, the water-plants and other organisms of which, rotting in contact with the atmosphere, formed its mass, and gave rise to its richness in nitrogeneous products.

Murchison (*loc. cit.*) considered it as not having been formed *in situ*, but derived from the disintegration of the Black Jurassic shale, which is found in the more northern districts of the empire. He held that powerful currents had acted as the transporting agents, though no reason was assigned for the production of this rush of tumultuous waters. At the present day ice-action explains all these varied results in a more reasonable manner.

Ruprecht seems to have gone half-way in regarding the Black Earth as of grassy origin, though he still held the view that the boulders strewing the northern parts of the country had been brought thither by ice-bergs.

But, with the acceptance of the theory propounded by Nikitin, Krapotkine, and Inostranzeff, that a great fresh-water sea did not cover N. Russia, but rather that a huge ice-sheet spread over the face of the country, a new aspect was obviously given to the discussion, and it was sought to explain the phenomena by other means.

The former presence of forests was naturally regarded as necessary to account for the formation of such a soil, if all aqueous action were rigidly excluded. Thus, Bogdanoff and Polimpsest considered the Black Earth to be the humus resulting from prehistoric woods, cut down by hordes of nomads. For the extensive character of such forests they sought to find evidence in the works of Herodotus.

In his work Melpomene, Book IV., Herodotus gives some very concise descriptions of the nature of the country lying between the Dnieper (Borysthenes) and Don (Tanais). He appears, indeed, to have made this region an object of special research. For instance, it is expressly stated that the Androphages (inhabiting Volhynia) lived northward of a region of vast deserts (the great Loess-covered plains east of the Dnieper). In another place it is stated that the entire country occupied by the nomadic Scythians is without trees. (This is evidently the district we are specially considering.) And this is still more forcibly emphasized when considering the country N. of the Azov Sea. The country of the Sauromates commences at the extremity of the Palus Mœotis, and occupies the country that lies to the north; a fifteen days' journey is required to traverse it; *one sees there neither wild nor fruit-bearing trees.* Beyond this is the country of the Budins, where trees are in abundance.

It is also interesting to note that to the north of the country between the Dnieper and Don, only marshes and land without inhabitants were believed to exist.

Far, therefore, from proving the existence of former forests, Herodotus strongly argues in favour of the desert character of these regions, and indeed further cites Scythian traditions which fully confirm the view that this country was treeless ever since the earliest historical records were written.

It is necessary to emphasize these points, because some support might be lent to the opposite view, if the remarkable statements made by Mr. Floyer regarding the former fertility of many of the Egyptian wadys be considered.

The discussion in America has run to a large extent on absolutely parallel lines, and Mr. J. W. Rodway (Geographical Journal, March, 1894) has shortly resumed the views propounded, and arrived at a conclusion differing in no respect from the one now enunciated, viz. the areas in question never were timbered.

Mr. Miller Christy, in a paper read before the British Association, held that the absence of the trees was due to prairie fires, in general started by Indian tribes. But, as Mr. Rodway points out, these fires only affect the stems and branches, leaving the roots of the trees entirely untouched. That these splendid plains have not borne these growths for many centuries past, is shown by the fact, long ago observed by Murchison, that traces of root-fibres are altogether absent.

Prof. Krasnov also argues that woods do not form Tchernozem. On the contrary, they form a subsoil in which the component parts are of the size of nuts, of an ashy-grey colour, and poorer in humus than the Black Earth proper. In addition, this soil bears traces of the roots of trees, at the same time possessing considerable powers of resistance to pressure, that is, failing to crumble readily when rubbed between the fingers.

Researches in the Nijni Novgorod and Poltava governments prove that a hundred years after the cutting down of the forests the soil still preserves its original character. If woods be not the source of the rich deposit, the present character of the steppe areas may serve to furnish a solution to the problem. There are still some districts not yet touched by the agriculturist, where the virgin soil produces a rank vegetation, luxuriant or sparse according to the amount of rainfall. A notable growth is a peculiarly wiry grass, that blunts the edge of the sharpest scythe. On the great plains E. of the Dnieper, in the region not devoted to the cultivation of cereals, Euphorbiaceous plants and Compositæ largely predominate. Indeed, so favourable is the soil for the growth of the latter, that one of the Thistles, *Xanthium spinosum,* (introduced some thirty years ago with the Bohemian settlers) has become a widespreading pest, and threatens even to supplant the indigenous flora.

In travelling over these plains, I early came to the conclusion that the decomposition of these plant-remains, and the intimate intermixture of a portion of their protoplasmic contents with the particles of the Loess soil, were the true causes of the formation of Black Earth. In the autumn the dried stems which roll over the steppe, often bound together in large bundles, bear witness to the large amount of plant-waste which must then go on. At the same time the roots remain in the soil, giving rise to great matted fibrous layers which prevent the penetration of water to the lower levels. Indeed, there are circumstances in which such roots may attain the thickness of a man's thumb. Many of them will probably undergo decomposition, but, thanks to the fine-grained character of the soil, the materials necessary for the production of the humus would be concentrated rather than diffused through it.

Von Richthofen (*loc. cit.* p. 300) remarks: "The Black Earth of Southern Russia is growing (owing to dust transported by wind action). The black colour, which is proper to the uppermost layer only, appears to result solely from the formation of vegetable mould, the deeper portions showing the brown colour of the Loess, together with its structure, although this appears to be less perfect than in the former case."

Prof. Lewakowsky, of Kharkov University, has approached this interesting subject from the chemical point of view. He finds that the organic matters form, at a shallow depth, definite chemical combinations with the soil constituents, alumina, iron oxides, and calcium compounds. These compounds are exposed to the oxydizing action of the air, becoming gradually of darker tints, till eventually they form the Tchernozem itself. He explains the absence of Black Earth in forest regions as follows: The soluble organic materials which are prevented from passing into the soil, owing to the thick deposit of fallen leaves, undergo changes under the influence of the atmosphere, and become insoluble or even burnt by its oxydizing action. I would suggest that in all probability, even if these materials did sink into the ground, its loose constitution would prevent the formation of any deposit as rich as Black Earth. Owing to the matting of the roots above-mentioned, it is always necessary to remove the upper layer of black soil round any spot where trees are to be planted. Mr. Christy has maintained that trees on the treeless plains grow readily. Mr. Rodway admits this to be true in part. For Russia, I may venture to go further, and say that Black Earth is in many respects absolutely inimical to the growth of wood or forest.

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

VII.—REMARKS ON MR. MELLARD READE'S ARTICLE "ON THE RESULTS OF UNSYMMETRICAL COOLING AND REDISTRIBUTION OF TEMPERATURE IN A SHRINKING GLOBE AS APPLIED TO THE ORIGIN OF MOUNTAIN RANGES."

By A. VAUGHAN, B.A., B.Sc.

[*Addendum to paper on Corrugations of Earth's Surface.*]

AFTER I had written the above dissertation and sent it for publication my attention was kindly drawn to a paper, dealing with the same subject, communicated by Mr. T. Mellard Reade, C.E., F.G.S., to the Liverpool Physical Society, and since republished in the May number of the GEOL. MAG. for this year (p. 203).

As I was not aware, when engaged upon my own paper, of the views which Mr. Reade had expressed, I feel that some discussion of the theory put forward by that writer is of necessity demanded. Since, however, Mr. Reade's views are extremely antagonistic to those which I have already endeavoured to explain, such discussion will find its most convenient place as a brief addendum to what I have already written.

Mr. Reade's paper opens with a statement of some results arrived at by Lord Kelvin in his classical paper on the "Cooling of the Earth"; since the utmost importance is necessarily attached to the conclusions arrived at by so eminent a physicist, it is very important that such results should be quoted correctly, and also that their statement should be accompanied by a short exposition of the assumptions on which they are based. I propose then, in the first place, to point out, as plainly and briefly as possible, the method of reasoning employed and the data assumed in Lord Kelvin's essay; this I regard as especially necessary, because Mr. Reade not only mis-states some of the most important results, but also invests them with a rigidity to which the writer expressly lays no claim.

The essence of the employment of Fourier's equations depends upon assuming that we are dealing with nothing but the *conduction* of heat from point to point. Thus, no heat must be supposed to be used up or evolved in changing the physical state of the material under consideration; for example, we cannot suppose that any large portion of the mass has, during the time we are considering, passed from the molten to the solid state; for this would involve the liberation of that amount of heat which would be necessary to convert the solid rock into a molten state at the same temperature. If applied to any period during which such changes of physical state took place our equations of conduction would simply be talking nonsense; so that the first important point assumed by Lord Kelvin is that, during the whole period to which he applies his reasoning, the mass under consideration is supposed to be in the same physical state, and therefore, of course, at all times solid.

Another point to be especially noticed is that there is supposed to be nothing in the nature of discontinuity throughout the mass, or, in other words, that heat is freely conducted from layer to layer. In consequence, any portion of the mass exhibiting such phenomena would not satisfy the only condition on which our equations can be used; so that when applied to such portions our equations cannot be regarded as telling us the absolute truth. Now, as far as the interior of the earth is concerned, we can no doubt assume perfect continuity with sufficient exactness; but when we approach the surface we come upon very heterogeneous rocks, separated by bedding and other separation planes, so that we introduce an element of discontinuity.

This new element will not, to any appreciable extent, affect the general considerations put forward by Lord Kelvin, but will, on the other hand, render results deduced from our equations in the neighbourhood of the surface necessarily fallacious.

I attach some considerable importance to this condition as tending to vitiate the practical value of results concerning a level of no-strain to which I shall refer later, and also as exerting a conservative influence in the matter of the outflow of heat, and, in consequence, as tending to lengthen the time from first consolidation.

Lastly, for purposes of calculation we require to know a certain average value of the coefficient of thermometric conductivity, and this involves the two considerations of conductivity and specific heat. Of the difficulties attending such a determination, it is only necessary to point out that the variations of these two physical quantities with pressure and temperature are as yet very imperfectly known, and that, consequently, the assumption of any such coefficient for the unknown rocks of the interior must necessarily be an extremely tentative one. But, supposing such an average coefficient to have been found, it obviously would not agree at all closely with that for rocks near the surface; for, in its very character as an average coefficient, it must essentially refer to the vast bulk of the interior rocks, and not to the comparatively insignificant crust.

Thus we see another reason why, though our equations may give us exact results with regard to the interior, they cannot, for that very reason, apply rigidly to rocks near the surface. In fine we are not justified in applying Fourier's equations of conduction to rocks near the surface, or, at all events, not equations involving the same constant of conductivity as we have used for the interior.

In the next place it is important to notice the data which are assumed. Lord Kelvin assumes that, at the epoch of consolidation, the earth, or at least an outer shell of a thickness of 100 or 200 miles, was at an uniform temperature, and that the temperature of the surface was subjected to a loss of 7000° F. and then maintained at this lower temperature.

The temperature at the very start was, in consequence, uniform downwards, not a rise of 1° F. in 10 feet as, by some very curious oversight, is stated by Mr. Reade. This latter temperature gradient, which is given as that of first consolidation, was not established, on Lord Kelvin's assumptions, until 4,000,000 years later.

In this reduction of 7000° F. at the surface we have, at the best, a probable hypothesis with no pretence at exactness. The value is, of course, mainly based upon the heat set free when the earth, or a very thick outer shell, passed from the molten to the solid condition; in other words, upon the latent heat of fusion for the earth rocks.

Starting from this datum, and assuming the applicability of Fourier's equations, the temperature which at any given time existed at a given distance below the surface is easily calculated, and it is found that, after 100,000,000 years (not 96,000,000 as quoted by Mr. Reade), the temperature gradient would be 1° F. in 50 feet, which Lord Kelvin assumes as the present temperature gradient very near the surface. Since, also, this gradient varies inversely as the square root of the time from consolidation, it is easy to obtain the number of years which must have elapsed to establish any particular rate of rise of temperature with depth. For example, for a gradient of 1° in 64 feet, the time would be 160,000,000 years for the same initial reduction, and the depth to which loss of temperature would have penetrated would be 180 miles, as opposed to 150 miles on the assumption of 1° in 50.

To emphasize how broadly these results must be looked at, it is only necessary to point out that doubling the initial reduction of surface temperature would multiply the number of years before the establishment of any stated gradient by four, and that halving the coefficient of conductivity would double the time. For example, if the initial reduction were 10,000° F. the number of years would amount to about 300,000,000. This is in accordance with the wide general limits assigned by Lord Kelvin in his essay, in which he places the time from first consolidation as somewhere between 20,000,000 and 400,000,000 years.

Again, owing to the partial inapplicability of our equations to surface rocks, it is questionable whether we can, with justice, assume that 1° in 50 feet expresses the surface gradient which would have been established were the whole globe continuous. In short, the effect of discontinuity in surface rocks would seem to point to a retardation in the loss of heat and a consequent increase in time from consolidation.

To pass on now to consider the value of the assumption of a shell of no-strain: The contraction taking place in one year at any point within the earth, if unresisted, would no doubt be proportional to the loss of temperature at that point in that time, and this, assuming the truth of our old equations, would be proportional to the rate of increase of the temperature gradient at the point. We thus obtain the simple conception that the contraction will increase from the surface inwards to a certain depth and then diminish, until the point is reached at which temperature becomes uniform downwards.

The distance of such a shell of maximum contraction below the surface, estimated in the way already indicated, will be equal to $\sqrt{kt}$, where k is the coefficient of thermometric conductivity, and t the time from consolidation in years. This gives, assuming the same data as before, a depth of 38 miles. (Mr. Reade states that the value is 50, which would be the depth after about 160,000,000 years.)

From the fact of the existence of such a maximum-contracting shell, Mr. Reade has deduced with perfect theoretical correctness, so far as a homogeneous sphere is concerned, the necessary existence of a level of no-strain. In other words, there should, theoretically, be a shell, between the surface and this shell of maximum-contraction, which could contract with loss of temperature so as not to exert any pressure on the underlying mass; whilst all shells below it would, in contracting, squeeze the interior, and all shells above it would, owing to less rapid contraction, attempt to stand off from lower shells, and would, in consequence of the force of gravity, be put into a state of compression.

It becomes then a very important problem to find the depth below the surface at which this level of no-strain lies; and this appears to be easily attacked in the following manner.

Choosing any shell at a given distance from the centre of the earth, we can easily find, by the foregoing analysis, the radial contraction which has taken place in one year in any of the shells below it which suffer loss of temperature, and, by summing all these separate contractions, we obtain the whole amount by which the interior has attempted to draw itself away from our chosen shell in that time. If we equate this amount to what would be the radial contraction in one year of a sphere with radius equal to the distance of the selected shell from the centre, and further suppose the whole of this sphere to be contracting at the same rate as the given shell, we shall find the distance of such a shell from the surface. Working this problem out with our preceding assumptions I obtain a distance of a little over a mile from the surface. I have felt it necessary to give the reasoning employed, as this result differs from that found by Professor Darwin, as quoted in Mr. Reade's paper, and to whose high authority I should naturally attach great weight; but I have not, unfortunately, had the opportunity of referring to his paper.

Assuming, however, that Professor Darwin is correct in estimating the depth of this shell of no-strain at two miles below the surface, I cannot think that the result has any but a theoretical interest.

For here we arrive at a point to which, as I have shown above, the method of analysis cannot rigidly apply, not only on account of the physical discontinuity of surface rocks, but also on account of the irregular distribution of the large land and ocean areas which renders a shell at the depth of two or three miles a purely theoretical conception.

In fine I adhere to the conception, so fully explained in the beginning of my paper, that, owing to the existence of separation planes, this imaginary shell of compression settles down upon the interior rocks; so that in reality we are dealing with a vast series of shells, contracting upon and consequently squeezing each other, surrounded by a thin layer of surface rocks, which settles down upon them by closer application.

Before criticizing the theory put forward by Mr. Reade, I should like to point out the questionable strength of his disproof of the older theory.

Assuming that contraction has only affected a shell about 150 miles in thickness, he supposed this shell to have lost an average of 1000° F. since Cambrian times, and proceeds to calculate its radial contraction.

To quote his own words :—

"The linear contraction of 150 miles of rock cooled 1000°, using this coefficient, would be 4,125 feet, but, as the contraction of the shell 150 miles deep is voluminal, the contraction in thickness of the shell would be three times this, or 12,375 feet or=2·344 miles."

I fail to see how the contraction in thickness, *i.e.* the contraction of a certain line of material, can by any possibility be voluminal. But, accepting this result for the sake of argument, Mr. Reade finds that the girth of the interior shrinking sphere would be 15 miles less than that of the thin imaginary outer shell of compression; so that this represents, so to speak, the amount of looseness which has been used up in mountain-making since Cambrian times.

Here Mr. Reade leaves this part of his argument, but if we apply the above result we shall find that the elevation which could thus be produced is a very large one indeed. For suppose, to take a case far from the maximum possible, that the extra length of 15 miles in each great circle is used up in forming a cone tangential to the interior sphere. We should thus be able to form a mountain covering nearly a million square miles and rising to a height of 60 miles above the surface of the sphere. But, as Mr. Reade says, his assumptions are generous in the extreme, and I feel sure that, as referred to above, he has gratuitously multiplied them by three.

In the very simple calculation presented early in this paper, I took a coefficient not differing much from the one adopted by Mr. Reade, and made allowance for a loss of 10° C., which I believe would more than cover any one period of mountain-making. By this line of reasoning we seem to obtain a better means of comparison with actually known facts than if we estimate the total available volume which the old theory would allow for mountain-making since Cambrian times, and then attempt to compare it with the very unknown volume which has, in reality, been employed in constructing all the mountains since that period.

I now wish to examine Mr. Reade's theory, and to compare it with that put forward in this paper.

In the first place, Mr. Reade imagines a great depth of sediment to be laid down over a large area, and, to fix ideas, suggests an average depth of 4 miles of sediment deposited over an area 2000 miles by 1000 miles.

No doubt it follows, with perfect accuracy, that, as the layers accumulate with great slowness, the temperature gradient at any time during deposition will simultaneously attain its average value, and be roughly, say, 1° F. in 50 feet downwards; so that, as any layer becomes buried deeper and deeper beneath successive deposits, its temperature will continually rise.

For the same reasons, the rocks which constitute the floor upon which sediment was first deposited will suffer a continual increase of temperature. After a certain accumulation of sediment, the expansion produced by this rise of temperature will cause the underlying rocks to curve upwards, so that the curvature of any layer, which was at first approximately that of the surface of the earth, becomes increased and allows of expansion, much in the same way that a bar of iron, bent into an arc and fixed at each end, will, if heated in the middle, bend into a steeper curve.

I have taken great care to state exactly what I understand to be Mr. Reade's views, in order that my criticism may be comprehended better. I may, perhaps, just point out that this extension has, of course, the effect of a vertical lift upon the overlying mass, and that it is to this vertical motion that Mr. Reade attributes the inception of mountain ranges.

Now, it is a fair deduction from the very slow rate at which sediment accumulates, that the full effect of extension proper to any given depth of sediment will have been brought about at the time at which that depth is established. Such a process would necessarily go on until the central portion of the region was raised to the sea-level and the deposition of sediment in consequence ceased, and no further rise could take place, at least so far as due solely to expansion of underlying rocks.

The mechanism by which the fold thus formed is further compressed and raised by lateral pressure, I fail to understand; especially in the light of Mr. Reade's insistence that expansion is internal and shading off to zero at the boundaries of an area of deposition, so that any new area of sedimentation which may be established on the sides of the old fold would produce a new central fold, and not exert lateral compression on the earlier one. It is also hard to see how such an area of deposition could exist outside the first fold, except as derived by marine denudation of that fold itself.

Again, the conception that any fold is formed must necessarily imply that the rocks which form it are drawn away from the underlying mass; for it is upon the amount of lateral expansion, and not upon the comparatively small vertical expansion, that the theory rests. Hence it follows that an absolute vacuity must be formed under the fold, since in no way could a shell of expanding material exert a squeezing force on the rocks beneath. Thus the undermost of the layers which constitute the fold must support the whole weight of the overlying mass. This result does not seem to accord well with the potent effects which are attributed to the weight of overlying rocks in the direction of causing, what Mr. Reade calls, compressive extension. But, in fact, I believe that there is an element of unreality which renders the whole conception invalid.

In the first place, so far as the effect of heat upon the actual sediment is concerned, this sediment is deposited, not as solid rock, every component particle of which is in closest union with its fellows, but rather as a great number of small particles, each of which has, so to speak, plenty of elbow room. It would seem then that the effects of increase in pressure and temperature would be mostly used up in welding the rock into a dense mass; each particle expanding into the interspaces surrounding it, and the greater the resistance to general expansion the more closely would each particle be forced into union with its neighbours. This, surely, is in agreement with the actual facts observed in the lowest of a great series of conformable sedimentary strata. But, as regards the actual floor and the rocks which lie beneath it, which may be supposed to be in a dense state and not to admit of any great expansion of separate particles, I believe that the effect of expansion will only tend to minimize the contraction which, I now attempt to show, must be in progress.

It will, assuredly, be readily granted that, to allow of the accumulation of the great thickness of sediment here conceived, there must be an approximately proportional depression of the floor, and such depression must imply the curving inwards of that zone of the earth which forms the area of depression. Such inward motion must result in the reduction of curvature, and the consequent diminution of area; in other words, the floor must be contracting and must continue doing so approximately as long as sedimentation proceeds. Thus the only effect of expansion, in such an area, must be in the direction of minimizing the rate of shrinking, and, should the effects of expansion balance those of contraction, the area ceases to sink and deposition soon ends.

I will now briefly point out what I conceive to be the true phenomena which cause and accompany the deposition of a great thickness of sediment near land.

Imagine an area, such as I have conceived in the statement of my theory, to be bordered by a large land region. Owing to the more rapid contraction of our depressed area, its floor bends inwards, or the area sinks; over that portion of the area which borders our supposed land region sediment will be deposited and will accumulate to a greater and greater thickness as the area sinks. This sinking must obviously be accompanied by the actual displacement of material from underneath, which will be forced below the surrounding regions, and increase their relative height. Thus, as long as sinking continues, there is a transfer of material, squeezed out from under the depressed area, and forced below the bordering land region.

As a great thickness of sediment accumulates on the margins of the main area of depression (which is itself far from land), owing to the establishment of a temperature gradient throughout this sediment, the contraction of this border region becomes continually less and less than that of the main area of depression; and at last the region of sedimentation ceases to sink and begins to rise owing to the introduction of material, squeezed out from under the more rapidly contracting area.

To sum up, the sequence of events will be briefly as follows:—

First, when sediment is accumulating, the neighbouring land area is rising, owing to actual transference, from under the sinking area to beneath the neighbouring land region.

Secondly, this continues until, owing to the thickness of sediment accumulated, the area of deposition contracts at a much slower rate than the main area of depression, and, in consequence, is forced up by the introduction of material squeezed out from beneath that area. Thus the tendency is, as I stated above, to narrow the main area of depression.

The last point in Mr. Reade's paper, to which I wish to call attention, has reference to the effects of denudation.

As far as I am able to understand the very brief statement contained in his paper, Mr. Reade argues that, as foot after foot of rock is removed by denudation, the temperature of any point beneath is gradually lowered, so that contraction sets in, which doubtless tends to draw the rocks in such an area of denudation away from those surrounding it.

The actual results which Mr. Reade considers would follow are best given in his own words:—

"The weight of the crust itself squeezes up all vacuities, and the area adjusts itself to its decrease of volume by normal faulting and keying up in a wedge-like manner and by compressive extension."

Now to bring about normal faulting the rocks must not only split apart, which is the necessary result of contraction, but this must be accompanied by vertical displacement, and I can see no possible cause contained in the theory which accounts for the vertical sinking of one part of the area of denudation relative to another.

Again, as regards what Mr. Reade calls compressive extension, I think it is a sufficient answer to point out that contraction is greatest nearest the surface; for it is always there that the reduction of temperature must originate. In other words, the first layers to contract are the outer ones, or those under the least overlying weight; and further, in contracting, each layer must tend to assist the contraction of one lower. To bring to a close a paper perhaps already inexcusably long I will briefly recapitulate my own views on the results to be expected in such a contracting area of denudation.

In so far as contraction is general over the area, the tendency will be for the whole area to attempt to bend inwards, and the result of such a tendency is to check the introduction of material which, as I have attempted to show, is being squeezed out from beneath the neighbouring area of depression. Thus, such material will be more and more used up in raising the bordering one of sedimentation, with the ultimate production of a parallel elevation.

In so far as contraction actually produces splitting, this will, over a region with no especial lines of weakness, produce a very complicated system of joints throughout the entire mass; and, by thus slowly relieving pressure, bring about the formation of holocrystalline igneous rocks beneath.

VIII.—HOW CHLORITE IS CONVERTED INTO BIOTITE.

By C. CALLAWAY, D.Sc., F.G.S.

GENERAL McMAHON'S paper in the GEOLOGICAL MAGAZINE for June attacks my conclusion that the Malvern biotite is formed from chlorite, but leaves my evidence untouched. Indeed, a large part of the article is occupied in discussing a theory which I do not hold. I have never said that the chlorite was converted into biotite by contact-action *only*. That there may be no further mistake, let me repeat that, in the Malvern rocks, chlorite is changed to biotite by contact-action *plus* dynamic deformation.

General McMahon, in rejecting my theory, has rightly felt that he was bound to offer an alternative explanation. He is aware that the materials for the manufacture of the mica must come from somewhere, and he suggests that it may have been produced by "direct impregnation" from the granite. That the granite has impregnated the encasing diorite with one at least of its constituents, viz. potash, is one of my own points; but that it has bodily produced the biotite is simply impossible. This granite, it must be remembered, consists almost exclusively of quartz and potash felspar. An analysis of it by Mr. Player gives 1·1 per cent. of iron-oxides, and 0·3 per cent. of magnesia. Three analyses of the same rock by Mr. Timins yield about the same results, but one of them contains no magnesia. You cannot get a black mica without iron or magnesia, and it is certain that the granite could not have supplied enough of these bases for its manufacture. The encasing diorite, on the other hand, contains plenty of both bases.

General McMahon objects to my statement that the conversion of chlorite into biotite is an "observed fact." He writes that "the fact actually observed is the existence of chlorite and biotite in the same rock." So my critic believes that, merely because the two minerals lie side by side, I have inferred that the one was formed out of the other! I might as well have argued that the sugar in my tea-cup was evolved out of tea.

I will give General McMahon one or two facts, and allow him to judge whether they support his suggestion. Near the Wych, there is a very clear case of contact between diorite and granite. Both are sheared, and more or less altered. Near the contact, the hornblende of the diorite is decomposed; chlorite and iron-oxide being most conspicuous amongst the resulting products. Slides of the rock taken at the exact contact, show the decomposed diorite side by side with crushed granite. The chlorite and iron-oxide are seen to be creeping in between the fragments of granite, and forming a matrix to them. Another slide, taken from within an inch, shows the same thing; but the signs of shearing, as distinguished from mere crushing, are evident. Many other slides, selected first at intervals of an inch or two, and then at greater distances, exhibit more and more clearly the laminated structure of the ordinary gneiss, as the shearing becomes more even and uniform. Thus we see produced a gneiss in which lenticles of quartz-felspar granite are interlaminated with chlorite and iron-oxide. Here and there patches of black mica appear in the chlorite, especially round particles of the opaque iron-oxide. In the same locality, at a little distance, the chlorite is largely replaced by the mica. The evidence for the origin of this mica appears to me irresistible. It must have come from either the infiltrated products, or from the granite, or in part from both. But it could not have come from the granite, for that contains a mere trace of iron-oxide and magnesia. It must, therefore, have originated from the chlorite and iron-oxide, with, no doubt, the assistance of potash from the partially decomposed granite.

But I will give my critic another case. I will put it in a semi-diagrammatic form, merely remarking that it represents what occurs in countless sections in the Malvern Hills. The distance from A to C is usually a few feet or yards.

A	B	C
Ordinary diorite.	The same diorite, growing progressively sheared towards C, the hornblende going into chlorite, etc.; the felspar becoming corroded and yielding quartz.	A granite-diorite plexus. Chlorite of the diorite largely replaced by biotite, its felspar often deeply corroded, quartz abundant in it.

The gradation between A and C is clearly seen both in the field and in microscopic slides, of which some hundreds bearing upon this point have been examined. It is apparent in the felspars, whose changes can be followed step by step. It is equally clear in the basic minerals, the hornblende decomposing into chlorite, iron-oxide, and sometimes epidote, and the chlorite becoming banded with biotite, and, within the complex, being largely replaced by it. It appears to me inevitable that either the biotite has been produced out of the hornblende through the intermediate form of chlorite, or the hornblende has been produced out of the biotite through the same intermediary. But if the latter alternative be accepted, how is it explained that an unsheared diorite is produced out of a sheared micaceous rock?

General McMahon will perhaps suggest that there must be a break somewhere; that the biotite is decomposed to chlorite, and the hornblende is an independent mineral. This view is negatived by the fact that the hornblende and the chlorite pass into each other. A more reasonable suggestion would be that both the hornblende and the biotite are decomposed into chlorite, and that a break occurs somewhere in this intermediate chloritized rock. But this view labours under enormous difficulties. For:—

(1) There is no evidence of a break, either in the field or the microscope. The changes that take place, whether structural or mineral, proceed *gradatim*, and are similar in numberless sections.

(2) The mineral transformations proceed *pari passu* with the mechanical deformation; hornblende, for example, in the ordinary diorite changing to chlorite in the crushed and slightly sheared rock, the chlorite, in its turn, passing into biotite in the core of the shear-zones. The felspar also undergoes transformations corresponding to the degree of shearing.

(3) The uniform appearance of mica where the shearing is great and where the granite-veins are numerous, while it is nowhere seen where shearing and veins are absent, appears almost to demonstrate that these are the true causes of the generation of the mica. It would be strange, indeed, if such powerful causes produced no effect. That the mineral changes gradually increase as we approach the veined complex is quite inconsistent with the hypothesis of a break. If there be no break, it appears to me that my conclusion is demonstrated.

My excuse for again troubling the readers of this MAGAZINE on this subject is that it has a significance beyond the mere mineral change. The origin of the biotite virtually carries with it the whole theory of the metamorphism at Malvern.

REVIEWS.

I.—PALÆONTOLOGIA ARGENTINA. II. CONTRIBUTIONS TO A KNOWLEDGE OF THE FOSSIL VERTEBRATA OF ARGENTINA. By R. LYDEKKER. (Annales del Museo de la Plata.) La Plata, 1893. (Edited by Dr. F. P. MORENO, Director of the Museum.)

THIS beautifully printed and illustrated volume is the outcome of work done by Mr. Lydekker during a short visit to the Argentine Republic in the autumn of last year. The confusion that had arisen in the nomenclature of the extinct mammalian fauna of South America was very great, and it was desirable that someone well acquainted with the vertebrate palæontology of the Old World should have an opportunity of examining the material which had been the subject of so many papers, in some of which, it was evident, new genera and species had been founded with a plentiful lack of discretion. The announcement, therefore, that Mr. Lydekker was about to visit the La Plata Museum, where many of the types are preserved, was very welcome, and, in spite of the shortness of the time at his disposal, he has been able to make important additions to our knowledge of the fossil vertebrates of South America. The present volume contains three Memoirs:

(1) The Dinosaurs of Patagonia.
(2) Cetacean Skulls from Patagonia.
(3) A Study of Extinct Argentine Ungulates.

1.—This Memoir is of peculiar interest, since it contains a description of the first Dinosaurs recorded from South America. These are referred to three genera: *Titanosaurus*, *Argyrosaurus*, and *Microcœlus*, the first two of which belong to the Sauropodous group, while the third is of doubtful position. The remains ascribed to *Titanosaurus*, a genus originally founded on some caudal vertebræ from the Lameta beds (Lower Cretaceous) of India, are provisionally referred to two species, and tend to show that, in some respects, *e.g.* the biconvex first caudal vertebra, this form approached the Crocodilia more nearly than any other Dinosaur at present known. Its wide distribution, occurring as it does in India, England, and South America, is also notable, but the discovery of further remains may show that the relationship between the species from these various regions is by no means so close as it now appears. The second genus, *Argyrosaurus*, is new, and is founded on a beautifully preserved fore-limb, the possessor of which must have rivalled the largest known Dinosaurs in size. The third genus, *Microcœlus*, is also new and is represented only by a few isolated bones. A small dorsal vertebra is doubtfully referred to a member of the Theropodous group. The exact age of the deposits in which these reptilian remains are found is doubtful, but is most probably Lower Cretaceous.

The second Memoir, "On Cetacean Skulls from Patagonia," is valuable for the light which it throws on some points in the phylogeny of the group in question. The first form described is a small baleen whale, referred to the European genus *Cetotherium* and remarkable for the large size of the nasals, which partly roof in the narial chamber. Two other European genera, *Physodon* and *Hoplocetus* (*Paracetus*), are represented by skulls, hitherto unknown; and a new family, the Physodontidæ, is instituted for their reception, from the fact that the upper jaw possesses teeth, thus differing from that of the nearly related sperm whales. The Squalodontidæ are represented by a new genus, *Prosqualodon*, in which the nasals are better developed than in *Squalodon*. Moreover, the mandibular symphysis is shorter and the dentition is different, there being five (? six) molars and four premolars. The most interesting form of all is referred to a new genus, *Argyrocetus*, which is made the type of a family, the Argyrocetidæ; it is said to be most nearly related to the Platanistidæ. The notable characteristics of this genus are the possession of large square nasals and prominent occipital condyles, and the complete symmetry of the skull. The nasal opening may have been double. The deposits in which all these remains were found are not later than the Miocene and may be Upper Eocene.

In the third Memoir, "A Study of the Extinct Ungulates of Argentina," the author states that his "main object has been to find out how many of the numerous genera that have been named of late years on the evidence of more or less satisfactory materials were really entitled to stand, and also to elucidate in some degree their natural affinities." He has, however, passed over such genera as are founded on insufficient evidence or are not represented in the

Museum, and does not attempt to give a complete synonymy of those which he recognises as valid.

The suborder Toxodontia is first discussed, and its members are regarded as phylogenetically "related to the Perissodactyla, but as retaining certain features now common to the Artiodactyla, which have probably been inherited from common Condylarthrous ancestors." The suborder is subdivided into three families—the Pachyrucidæ, Typotheridæ, and Toxodontidæ. Of these the first includes two genera, *Pachyrucus* and *Hegetotherium*, the species of which are all of small size, and are characterized by the absence of internal enamel folds in the upper molars, by the antero-posterior elongation of the mandibular condyle, and, in *Pachyrucus* at least, by the possession of perfectly unguiculate feet. The author lays some stress upon the rodent-like appearance of these forms, which, however, he regards merely as the result of convergence. In the Typotheridæ is included the genus *Typotherium* only. The family Toxodontidæ embraces the genera *Toxodon, Toxodontotherium, Xotodon, Stenostephanus,* and *Nesodon.* Under most of these there is a more or less imposing list of synonyms; but the climax is reached in the case of *Nesodon,* of which no less than ten synonymous generic terms are given, while of the species *Nesodon imbricatus* and *N. patagonicus* the specific names are said to be countless. Some explanation of this unfortunate condition of affairs is to be found in the extraordinary changes, here fully described, which are undergone by the dentition at different ages in animals of this genus; but many of the names seem to have been perpetrated without a shadow of excuse.

A new suborder, the *Astrapotheria,* is established for the reception of the families Homalodontotheridæ and Astropotheridæ, which it was found impossible to include in the *Toxodontia, Litopterna,* or *Perissodactyla.*

In the *Litopterna* the author places the Proterotheridæ (including the genera *Diadiaphorus, Epitherium,* and *Proterotherium*) and the Macrauchenidæ (with the genera *Oxyodontotherium, Scalabrinia*—a name substituted for the barbarous compound *Scalabrinitherium*—and *Macrauchenia*). In this latter family the author states that there is a gradual increase in size and specialization from the older Patagonian Tertiaries to the later Pampean deposits.

In the *Perissodactyla* three genera of the Equidæ, *Equus, Hippidium,* and *Onohippidium,* are recognised, Burmeister's opinion that *Hippaplus* is merely founded on worn teeth of *Hippidium* being confirmed. Both *Hippidium* and *Onohippidium* are remarkable for the great backward prolongation of the nasal slits; *Onohippidium* is further notable for possessing enormous lachrymal fossæ.

Ribodon limbatum, a reputed tapir, is now found to be a member of the *Sirenia,* and is perhaps referable to *Halitherium* or *Prorastoma.* The Memoir concludes with an account of some of the *Artiodactyla.*

The plates, some forty-three in number, with which these Memoirs are illustrated are very beautiful examples of what may be done in this direction by photography, but at the same time the softness of outline and gradation of tone to which their beauty is due, renders it very difficult in many cases to make out details of structure, especially in the teeth.

Mr. Lydekker is paying a second visit to La Plata, and we can only hope that he will make further contributions to our knowledge as valuable as those contained in the present work, and will treat the Edentata and Marsupials as he has here done the Ungulates.

II.—DESCRIPTION DE LA FAUNE JURASSIQUE DU PORTUGAL. CLASSE DES CÉPHALOPODES. Par PAUL CHOFFAT. Première série: Ammonites du Lusitanien de la Contrée de Torres Vedras. Direction des Travaux Géologiques du Portugal. Pp. 1–82, pls. i.–xix. (Lisbonne, 1893.)

THIS is the first part of M. Choffat's Monograph of the Ammonites of the Jurassic rocks of the Torres Vedras region, under which name the author includes the Jurassic rocks of the Montejunto Chain, and those of the less elevated region, bounded on the east by the Tertiary beds of the Tagus basin, and on the south by the Cretaceous rocks extending from the Tagus to the Atlantic. The author states that he has almost completed the stratigraphical description of this region, but as this detailed account has not yet been published, he prefaces his description of the Ammonite fauna with a few remarks on the sequence of the beds.

In the rocks which succeed the Callovian two great divisions can be recognised—the Lower Malm, which the author calls "Lusitanien"; and the Upper Malm, comprising beds corresponding to the Portlandian and Pterocerian of Central Europe, and strata containing a fauna intermediate between that of the latter and that of the Lower Malm. Cephalopods are exceedingly rare in the Upper Malm, but the Lower Malm or Lusitanian has yielded the rich Ammonite fauna described in the present work.

The Lusitanian is divided into three principal divisions, which, in descending order, are (i.) the Abadia series, having a thickness of about 800 metres; (ii.) the Montejunto limestones with a thickness of from 200 to 500 metres; and (iii.) the Cabaço limestones with a thickness of about 500 metres.

The author then proceeds to a description of the species. The Cabaço beds have furnished a few specimens of *Cardioceras*, which cannot, however, be specifically identified. The genus *Phylloceras* is represented by seven species, one being new, viz. *Phylloceras Douvillei*, a species intermediate between *Phyll. subobtusum*, Kudernatsch, and *Phyll. Beneckei*, Zittel. Under *Phyll. silenum*, Fontannes, the author makes some interesting observations on this and allied species, and to this species he refers the form which Sharpe recorded from this region as *Ammonites tortisulcatus*, d'Orbigny. One species of *Lytoceras*, which the author compares with *L. Adeloides* (Kudernatsch), has been furnished by the Montejunto beds. *Harpoceras* is represented by three species, one being new, but not named, whilst *Ochetoceras*, which is regarded as a subgenus of *Harpoceras*, is represented by two already described species, and a new species (not named) near to *H. canaliferum* (Oppel). Four species of *Oppelia* are recorded; one of these is stated to be new (but not named), and described as near to *O. hectica* (Reinecke). *Neumayria* is represented also by four species, one of which (*N. Kobyi*) is new and closely allied to *Neum. Franciscana*, Fontannes. To this genus M. Choffat assigns the specimen which Sharpe doubtfully referred to *Amm. Boucaultianus*, d'Orbigny. The upper part of the Montejunto beds has yielded some very small specimens of *Olcostephanus*. For the genus *Perisphinctes*, which is numerously represented, the author adopts the classification of Sutner and Steinmann; more than forty species are recognised, seventeen of which are described and named as new. Of the ten species which are recognised as belonging to *Aspidoceras*, one is new (*A. Lusitanicum*). *Peltoceras* is represented by two species, one of which is considered to be new, but is not named. A specifically indeterminable example and a few small specimens are referred to Zittel's genus *Simoceras*, whilst the genus *Hoplites* is represented by the new species *H. Guimarãesi*. Aptychi also have been found.

The Cabaço beds exhibit a decidedly Oxfordian facies; their Ammonite fauna corresponds to that of the *transversarius*-zone, the *cordatus*-zone being represented by about 200 metres of limestones, devoid of Ammonites, separating these Ammonite-bearing beds from the underlying Callovian rocks.

The strata at the base of the Montejunto beds for a thickness of 10 metres yield Lamellibranchs which suggest affinity with those of the Cabaço beds below; but their Ammonite fauna is comparable rather with that of the *bimammatus*-zone. The Ammonite fauna of the rest of the beds presents a mixture of forms belonging to the *bimammatus*- and *tenuilobatus*-zones, thereby resembling the fauna of the *bimammatus*-zone in Central Europe. It possesses a character more Mediterranean than that of Swabia (S. Germany) and of Argovia (Switzerland); but cannot be regarded as the typical Mediterranean facies of this zone; this is found further to the south, in Algarve (Portugal).

The Ammonite fauna of the Abadia series is referable to that of the *tenuilobatus*-zone; the Ammonite-bearing beds do not rest upon Montejunto beds, but are separated from them by strata having a thickness of nearly 400 metres.

M. Choffat deserves our best thanks for so fully describing this rich and interesting fauna, which is amply illustrated in the accompanying twenty excellent phototype plates. G. C. C.

III.—Geological Survey of Canada, Alfred R C. Selwyn, F.R.S., Director. Annual Report (New Series): Vol. V. 1890–91. (Ottawa: S. E. Dawson, 1893.)

CONSIDERING the wide field embraced in the range of the Geological Survey of Canada, which extends across the continent from the Atlantic to the Pacific, one is not surprised at the bulk of the Annual Report, which now appears in two parts, containing 1566 pages of text, and various maps and illustrations. From the summary of the Director we learn that geological investigations were carried on in all the provinces of the Dominion by no fewer than twenty distinct parties, of which one was in British Columbia, one in Alberta, two in Manitoba, seven in Ontario, five in Quebec, one in New Brunswick, and three in Nova Scotia. In the Eastern provinces the survey work consists mainly in revising and adding to the details of the geology of districts which have been already examined and reported on, whilst in the North-West and in British Columbia the work is largely in exploring and mapping new areas, and one may naturally look for greater interest and novelty in the reports from these regions.

The first report, after the summary of the Director, is by Mr. R. G. McConnell on the country between the Peace River and the Athabasca River, north of Lesser Slave Lake, comprising an area of about 44,000 square miles, which is for the most part a gently undulating wooded plain, diversified with numerous lakes, muskegs, and marshes. The lakes are mostly shallow hollows in Boulder-clay; many of those of former times are now filled up. The greater part of the region is underlain by soft dark greyish or brownish shales of Cretaceous age, with but few fossils in them. They have an estimated thickness of 3000 feet, and they represent the Dakota, Colorado, Montana, and Laramie formations. The Cretaceous beds rest directly on nodular and crumbly, nearly horizontal, limestones, filled with fossils of Devonian age. Not more than 100 feet of these limestones are exposed in the Peace and Athabasca regions. The most striking geological feature of this district is the so-called Tar-sands, exposed in the valley of the Athabasca River and some of its tributaries. The Tar-sands were originally unconsolidated sands and soft sandstones, ranging from fine silt to coarse grit, and they are now thoroughly impregnated by a bituminous material which has cemented them into a coherent tarry mass. In places they form high cliffs, varying from dark-brown to jet black, from which streams of so-called tar issue in warm weather and form pools at the base of the escarpment. The Tar-sands are exposed for a distance of 90 miles along the Athabasca Valley; they are from 140 to 225 feet in thickness, and have an estimated minimum distribution of 1000 square miles. The sands themselves are clearly of Cretaceous age, of which they form the lowest local division, and they rest directly on the greyish, crumbly, evenly stratified, Devonian limestones. The enormous amount of bituminous material with which the sands are now charged is considered by the Canadian geologists to be the heavy constituents of petroleum oil which has welled up from the underlying Devonian limestones during past ages. But, strangely enough, these limestones, so far as they are exposed, are by no means specially bituminous in character, and the sources of the bituminous material in the sands are therefore attributed to underlying beds, of which at present nothing is known.

The Athabasca and Peace River regions are so thickly covered with Glacial Drift that it is only in the main drainage valleys and along the escarpments of some of the plateaux that the older rocks are shown. The basal glacial beds are stratified sands and gravels overlain by Boulder-clay, and this in places is covered by drift gravels. In some of these latter there are masses of the Tar-sands, which have been transported by the glacier, and Mr. McConnell discovered portions of this material on the plateau summit of Birch Mountain, which could only have been derived from the exposures in the Athabasca Valley at a lower level of many hundreds of feet. Accompanying the report of this district are several photographs, an index map, and sections.

Another elaborate and interesting report is that by Mr. J. B. Tyrrell on North-Western Manitoba, including portions of the adjacent districts of Assineboia and Saskatchewan. The oldest rocks of this district are Silurian, mainly limestones and dolomites, with characteristic fossils of Niagara age, which are shown near the mouth of the Saskatchewan on the west side of Lake Winnipeg, and also along the eastern shores of Lakes Winnepegosis and Manitoba. On the western borders of these lakes there is an extended belt of Devonian rocks, from 400 to 500 feet in thickness: the lower portion of these are red shales, which are overlain by thick beds of dolomites containing numerous fossils, amongst others the well-known brachiopod *Stringocephalus Burtini*, and these are succeeded by limestones and shales of Upper Devonian age. Brine springs are met with in certain areas of the Devonian, west of L. Winnepegosis.

As in the Saskatchewan region, 500 miles further west, there is here also a tremendous break in the geological succession, so that the Devonian rocks are immediately succeeded by Cretaceous shales and sandstones, of which the country to the west of the lake region is mainly formed. The lowest beds are Dakota sandstones, about 200 feet thick; these are overlain by very dark shales of Benton age, about 180 feet in thickness, followed by grey calcareous marls or shales, occasionally passing into limestones, belonging to the Niobrara division. These beds contain numerous Foraminifera, amongst which *Globigerina cretacea* is the most conspicuous species. Some layers are largely composed of the microscopic prisms of disintegrated shells of *Inoceramus*. The scales, teeth, and bony fragments of fishes are likewise abundant in these Niobrara shales, and Mr. Tyrrell discovered a thin band or bone-bed largely made up of these remains, which yielded on analysis 37 per cent. of phosphate of lime. Above the Niobrara beds are the grey soft shales of the Pierre division, which occupy the higher lands of the Riding, Duck, and Porcupine mountains, and reach a thickness of about 1000 feet. Some of these shales are highly siliceous, and they contain numerous Radiolaria, which have been determined by Dr. Rüst.

The harder rocks round the lakes of this district show very distinctly the glacial striæ, the direction of which ranges for the most part to the west of south. As an instance of the way in which the course of the glacier has overridden the slope of the country, Mr. Tyrrell records the occurrence of large boulders of Dakota sandstone which have been carried to a level of 450 feet above that of the parent rock, the nearest bed of which is 40 miles distant.

The next report is that of Dr. Robert Bell on the Sudbury Mining District to the north of Lake Huron, now noted for the presence of nickel and copper ores, which are extensively worked. The district is wild, hilly, and rocky, and the glacial boulders are often piled one on the top of another without any fine material between them. The rock succession is: (1) Laurentian gneiss and hornblende granite; (2) Huronian quartzites, greywackes, and dolomites; (3) Dark-coloured siliceous volcanic breccias and black slates, overlain by argillaceous beds and nearly black gritty sandstones probably of Upper Huronian or Cambrian age. The nickel and copper ores are always found in intimate association with the greenstones, and generally at their junction with some other rock. The microscopical characters of the Huronian rocks of this district are fully described in an appendix by Prof. G. H. Williams.

Passing over Mr. A. J. Low's Report on the Geology of three counties near Quebec, and of Mr. Hugh Fletcher on that of the counties of Picton and Colchester, Nova Scotia, we find a lengthy report on Natural Gas and Petroleum in Ontario prior to 1891 drawn up by Mr. P. H. Brumell. Since the remarkable discoveries of natural gas in the Trenton rocks of Ohio, numerous borings in search of this product have been carried out in various parts of Ontario, but the only area in which it has been found in any quantity is that between Lakes Ontario and Erie, not far from the Welland Canal. The gas occurs in a sandstone of the Medina formation (Silurian), which is here from 800 to 900 feet beneath the surface. The only petroleum-producing district in Ontario is in the county of Lambton, and the oil is found in the Corniferous limestone (Devonian) at depths from 370 to 480 feet beneath the surface. The various borings have yielded an interesting record of the distribution and depth of the Palæozoic rocks in Southern Ontario, and they show a possible maximum thickness of 4200 feet overlying the Laurentian gneiss.

A considerable portion of part ii. of the volume is occupied by a chemical contribution to the Geology of Canada by G. C. Hoffmann, and by the reports of mineral statistics and mines, which are mainly of economical importance.

The value attached by the Government of the Dominion to the Geological Survey of the country is satisfactorily shown in this Annual Report; and we are glad to notice that it is published at the moderate price of two dollars, or less than eight shillings, whilst the particular reports, and the maps, can be obtained separately at prices from sixpence to one shilling each. G. J. H.

IV.—Chinese Central Asia: a Ride to Little Thibet. By Henry Lansdell, D.D., etc. (With Three Maps and Eighty Illustrations.) In Two Volumes. London: Sampson Low, Marston, and Co. 1893.

DR. LANSDELL'S adventurous journey across the western end of Chinese Central Asia was undertaken in connection with mission work, but his book incidentally includes a considerable amount of information, more or less geological. Starting from Kuldja, after a visit to Lake Issik-kul, he crossed the Thian Shan Chain by a glacier pass—the Muz-davan—which is probably from 11,000 to 12,000 feet above the sea, and never before had been completely traversed by a European. Thence he made his way to Kashgar and Khotan in Chinese Turkestan, and finally crossed to Leh by the Kilian, Suget, Karakoram, and Saser Passes. All these are more than 17,000 feet above the sea-level, the Karakoram being 18,550 feet. The chief points of geological interest in the book are accounts of a severe earthquake at Vierny, near the Ala-tau Mountains, and of the geology of Russian Turkistan, compiled from Romanovsky and Mushketoff's map, and the descriptions of the high passes over which his journey lay. Unfortunately the exigencies of travel prevented Dr. Lansdell from forming a collection of rock-specimens, but from his own observations, and by availing himself of Russian writings, he is able to give some notion of the geology, and still more of the geography, of Turkestan and the bordering mountain chains. The book, in short, will be a valuable work of reference on districts which, till lately, were practically inaccessible to Europeans.

REPORTS AND PROCEEDINGS.

I.—May 23rd, 1894.—Dr. Henry Woodward, F.R.S., President, in the Chair. The following communications were read:—

1. "On the Stratigraphy and Physiography of the Libyan Desert of Egypt." By Captain H. G. Lyons, R.E., F.G.S.

The Nubian sandstone, wherever seen, rests unconformably on the old rocks called by Sir J. W. Dawson Archæan, and the author finds no case of alteration of sandstone by these rocks, though in one case it is altered by an intrusive dolerite.

The author considers the Nubian sandstone to be an estuarine deposit which was formed on an area afterwards gradually invaded by the Cretaceous sea. He considers the whole of the sandstone in the region which he has examined to be of Cretaceous age.

He describes a series of anticlinals, one set running W.N.W.—E.S.E., and the other N. by E. and S. by W. Many springs of the oases seem to occur along these anticlinals, owing to the beds which contain the water being brought nearer to the surface. Historical evidence is discussed which points to the Nile having reached a higher level in Nubia than it does at present, and it is suggested that variations in the level of the river were caused by earth-movement opposing obstructions to the river's flow.

The sandstone of Jebel Ahmar near Cairo is described, and its occurrence over a wide area of west Cairo is recorded. The author considers its age to be later Miocene. He believes that, with the exception of some erosion after the deposition of the Eocene beds, the greatest erosion, including the cutting out of the Nile Valley, took place in Miocene times, while a certain amount, bringing the area to its present condition, was done in Quaternary times.

This agrees with the observation of the French geologist in Algeria. The origin of the silicification of the fossil trees of the sandstone deposit is discussed, and the action of water containing sodium carbonate suggested as a cause.

2. "Notes on the Geology of South Africa." By D. Draper, Esq., F.G.S.

The district here considered includes Natal, Zululand, Swaziland, the S.E. part of the Transvaal, and the Eastern part of the Orange Free State and Basutoland. Physically it comprehends:—1. The Drakensberg Range; divided into—*a*, Mountain portion; *b*, Hill-covered plateau; *c*, Highveld plateau: 2. The terrace along its foot: 3. The coast-belt. Their main features and characteristics are described. The geological formations are:—

Karoo Beds.	Upper.	1. Volcanic Beds. 2. Cave Sandstone. 3. Red Beds. 4. Molteno Beds.
	Lower.	5. Beaufort Beds. 6. Ecca Beds. 7. Dwyka (Ecca) Conglomerate. [Bokkeveld Beds, wanting.]
	Palæozoic.	8. Gats Rand (Zuurberg) Quartzite. 9. Dolomitic Limestone. 10. Table-Mountain Sandstone. 11. Malmesbury Schists.
		12. Gneiss and Granite.

No. 1 briefly noticed. 2. This caps the hills of the plateau (1, *b*); and has yielded fossil fishes (described by Mr. A. S. Woodward, F.G.S.) in the Orange Free State. 3. These are exposed in the O. F. S., at Harrismith, about 100 feet thick, and containing a bone-breccia from which reptilian remains were described by Prof. Owen in 1854. Northwards the Red beds change to a dark grit; and siliceous tree-stumps occur in the upper part. 4. These are the well-known coal-bearing beds of the Highveld plateau (1, *c*) and Natal, including the terrace (2) north of the Tugela River, and Zululand. The lower 500 feet of these beds in Natal carry coal better than that of the Highveld, but have been let down to a lower level (about 2000 feet). In Natal they thicken northwards. On the coast-line in Natal and Zululand portions are at a still lower level and dip seaward at 20°. Anthracite occurs at St. Lucia Bay. 5. These form hill-side crags along the edge of the terrace (2); and die away northwards near the Pongolo River. 6. The "Pietermaritzburg Shales" of Dr. Sutherland; also die out northwards near that river. 7. The "Glacial Conglomerate" of Dr. Sutherland; exposed in high crags in the deeper gorges of the terrace (2); stratified and ripple-marked; horizontal inland, but near the coast dipping seaward with the overlying beds. A patch, much rippled and containing few pebbles or boulders, lies horizontal in the coast-belt (3) of Zululand and Swaziland at least 1000 feet lower than the main body seen along the terrace (2). No. 7 stretches from St. John's River, through Pondoland and Natal to Zululand, thins out and disappears near the Pongolo. Intrusive and flat diorites were noticed in it. A definite list of the strata of this conglomerate, where it is 138 feet thick in Zululand, is given; and the author does not regard it as of glacial origin. No 9 is treated of in the next paper.

3. "On the Occurrence of Dolomite in South Africa." By D. Draper, Esq., F.G.S.

A peculiar calcareo-siliceous rock, near Lydenburg, described by Messrs. Penning and Crutwell as "Chalcedolite," and a similar rock mentioned by Mr. Penning, F.G.S., as overlying the "Black reef Series" of the Megaliesberg formation, are recognised as dolomite. Mr. C. Alford, F.G.S., has described a "calcareous quartzite," as passing into dolomite and ultimately into chert, and known as the "Elephant rock" in Transvaal, sometimes cavernous with underground waters. From his own experience Mr. Draper has recognised the "Elephant rock" in the Potschefstroom, Lichtenburg, Malmani, and Lydenburg districts as a real dolomite, with interstratified siliceous bands, weathering into a brown earth like manganese oxide, and superficial siliceous débris. It has its place between the Table-mountain Sandstone and the quartzite of the Gats Rand (=Zuurberg quartzite of the Cape). It has auriferous veins in Malmani and Lydenburg. Dr. Schrenck has noticed a similar dark blue dolomitic limestone in Great Namaqualand. The deep water holes in it in Malmani are comparable with those found by F. Galton in West Central Africa. The great caves in Mashonaland may belong to it. The extensive tufaceous deposits in Griqualand-West, the Transvaal, and Orange Free State were probably derived from this extensive dolomite.

4. "Contributions to the Geology of British East Africa." By J. W. Gregory, D.Sc., F.G.S.

The author describes moraines, striæ, glacial lake-basins, perched blocks, and *roches moutonnées* below the present limits of the glaciers of Mount Kenya, which he maintains to indicate the existence of a "calotte" or ice-cap extending at least 5,400 feet farther down the mountain than the termination of the present glaciers, and possibly farther, for in the belt of forest detailed observations could not be made.

He agrees that this more extensive glaciation was produced by a greater elevation of Mount Kenya, and that any theory of universal glaciation is unnecessary, and indeed opposed by many facts in African geology.

He discusses the probable influence of this former glaciation on the meteorological conditions of the surrounding area and the distribution of its flora and fauna.

II.—June 6th, 1894.—Dr. Henry Woodward, F.R.S., President, in the Chair. The following communications were read:—

1. "On the Banded Structure of some Tertiary Gabbros in the Isle of Skye." By Sir Archibald Geikie, LL.D., D.Sc., F.R.S., F.G.S., and J. J. H. Teall, Esq., M.A., F.R.S., Sec.G.S.

After calling attention to the previous references to the pseudobedding and banding of the gabbro-masses of the Inner Hebrides, the authors describe the rocks which form the rugged ridge of Druim-an-Eidhne, near the head of Glen Sligachan. This ridge is made up of parallel beds, sheets, or sills disposed in a general N.N.W. direction with a prevalent easterly dip. Four distinct types of gabbro occur:—(1) dark, fine-grained, granulitic gabbros; (2) well-banded gabbros; (3) coarse-grained massive gabbros; and (4) pale veins of a highly felspathic gabbro. The relative ages of the banded and granulitic gabbros have not been definitely settled; but the coarse massive gabbros are certainly intrusive in the banded series, and the pale veins cut all the other varieties.

The paper deals mainly with the banded gabbros. They occur in successive sheets or sills which vary from a few feet to many yards in thickness, and consist of parallel layers of lighter and darker material which correspond in direction with the trend of the sheets, and are usually inclined to the east or south-east at angles ranging from 20° to 30°. In some cases the bands can be seen to have been puckered or folded.

The minerals entering into the composition of the banded, as also of the other varieties, are labradorite, pyroxene, olivine, and titaniferous magnetite. The banding is due to a variation in the relative proportions of the different constituents, and especially in the amount of magnetite. Some narrow bands and lenticles are composed entirely of pyroxene and magnetite. The variations in chemical composition are illustrated by three analyses by Mr. Player. The microscopic characters of the rocks are described, and it is shown that the minerals of the banded gabbros have not been crushed or broken since they were formed.

The authors conclude that the banding is the result of the intrusion of a heterogeneous magma, and that similar banding in certain portions of the Lewisian gneiss may have been produced in the same way.

2. "On the Microscopical Structure of the Derbyshire Carboniferous Dolerites and Tuffs." By H. H. Arnold-Bemrose, Esq., M.A., F.G.S.

The paper deals with the petrography of the Toadstones or igneous rocks of Derbyshire. Brief reference is made to the work of previous petrographers, the age of the rocks, and the question as to the number of beds. The outcrops mapped by the Geological Survey, and several additional ones, have been examined, and the results given in a table for the purpose of the paper and for future reference.

The Toadstone is divided into massive rocks or lavas, and fragmental rocks or tuffs. The former consist of olivine-dolerite, either with granular or with ophitic augite, and olivine-basalt. The rock is often very fresh, but in some places is altered to a diabase. The principal constituent minerals are described. A pseudomorph of olivine, optically like biotite and somewhat like Iddingsite but differing from it chemically, is fully described.

The latter portion of the paper deals with the tuffs, which are much more extensive than has been hitherto supposed. Specimens are described, taken from thirteen outcrops.

3. "On the Origin of the Permian Breccias of the Midlands, and a Comparison of them with the Upper Carboniferous Glacial Deposits of India and Australia." By R. D. Oldham, Esq., F.G.S.

The author first describes the Permian breccias of the Midland Counties of England, which he had the opportunity of examining at Eastertide of the present year. He describes the characters of the breccias, and concludes that they were formed subaërially as gravel-fans by rivers charged with a maximum load of sediment, and therefore incapable of performing any appreciable amount of erosion. An examination of many of the fragments at Abberley and some at Church Hill reveals the presence of scratches, which occur in such a manner that the author believes they existed on the fragments before they were transported, and discusses the evidence for their production by ice or soil-cap movement, deciding in favour of the former.

A short description of the Upper Carboniferous deposits of India follows, and it is pointed out that they differ markedly from the deposits of Britain. Amongst other things the separation of different pebbles by considerable interspace of matrix, and the bending of stratification-planes round a pebble as though the pebble had dropped from above, are noted, and it is maintained that floating ice alone will account for these pebbles being dropped into the Indian deposits. Finally, it is remarked that the so-called Upper Carboniferous deposits of India and the Permian deposits of the Midlands of Britain may be practically contemporaneous, as maintained by the late Mr. H. F. Blanford, indicating a possible simultaneous existence of glaciers in England, India, and Australia.

CORRESPONDENCE.

NORWEGIAN ROCKS IN THE ENGLISH BOULDER-CLAYS.

Sir,—Anyone familiar with the Boulder-clays of our East Coast—or, I may add, with the methods of working customary among field-geologists—must have read with astonishment Sir Henry Howorth's confident suggestion that the records of "so-called Norwegian boulders" are due to material brought by ships as ballast. In the first place, he clearly has no idea of the immense profusion of these boulders, hundreds of which may be observed in as many yards on some parts of the Holderness beach. This is in places where the Basement Clay is exposed in the cliffs and to the south of such places, *i.e.* in the direction of movement of the beach. If, however, Sir H. Howorth can find an adequate explanation of this in the statistics of ship-wrecks, he still has to meet the fact that these boulders are found not only on the beach but in the clay. Five years ago I examined and described specimens of the Laurvig augite-syenite collected by Mr. Lamplugh from the Basement Clay of Dimlington and Bridlington Quay. This was merely that my friend and myself might be perfectly satisfied of the identification of this rock-type. The fact that such rocks occur as boulders in the clay had long been a matter of common knowledge, and half an hour's work at the cliffs will always produce specimens of this augite-syenite and of the equally characteristic rhomb-porphyry, the two most striking rocks among the beach material. Surely it would be "more in accordance with scientific laws of evidence" to ascertain the facts of the case, either personally or from the records, before propounding an artificial explanation of them.

If further evidence be needed, I may add that I have recently sliced and examined typical specimens of the two unique Scandinavian rocks mentioned above, which were collected at Cambridge by Professor Hughes.

St. John's College, Cambridge,
June 2nd, 1894.

Alfred Harker.

UNIFORMITY IN GEOLOGY AND THE ORIGIN OF THE DRIFT.

Sir,—Sir Henry H. Howorth opens a rather strangely reasoned paper in your last month's issue with the statement that signs are accumulating everywhere that geologists are now harking back to the views of the old catastrophists, and giving up the uniformitarian views so ably placed on record by Lyell and later workers. Where these signs are to be seen I am at a loss to discover. Certainly not in the Nottingham Address of Mr. J. J. Harris Teall to the geological section of the British Association, nor yet in the text-books and original papers written during the last few years. No doubt popular magazine writers will to some extent regard Sir Henry H. Howorth's writings as being one of the signs of the times, and will be ready to put his ideas before their readers as "recent advances." Every supporter of uniformitarian principles admits that floods and earthquakes have always occurred. Nor am I aware that any exact limit has been fixed to their magnitude. At least I never heard it argued that the eruption of Krakatoa, for example, was the greatest outburst that has ever occurred, or that there will never be a greater. It only asks us to seek to explain the facts by slow and well-known causes that may be seen in everyday action rather than by extreme or violent means. For instance, the great majority of geologists consider that the distribution of the drifts can be best accounted for on the assumption that large portions of the northern continents were covered by immense ice-fields. Judging from the present distribution of glaciers and ice-fields, etc., Sir Henry H. Howorth thinks this view extreme and not sufficiently uniformitarian, and pins his faith on floods and dancing mountain ranges. The time has gone by for a general discussion on this point. If a particular deposit can only be explained on the assumption that there was a deluge, we must believe that there was a deluge. It would be unscientific to settle upon the agent first and then point to all sorts of deposits as being produced by it.

But, to return to the paper, my intention was also to refer to two letters which appeared in "Nature," and which Sir Henry H. Howorth quotes. One was from the pen of Professor Bonney. In it he asks whether the fact that there is a deep submarine channel along the coast of Norway does not render it improbable that the ice-sheet could have crossed it and reached Great Britain. Professor Bonney very wisely does not say that it could not, for he would be a rash man who would say what the snowfall was upon the mountains, and how far the ice would have to move from them before it melted, and the law of supply and wasting was satisfied. However, on the strength of the fact that the question has been asked, we learn that "Prof. Bonney has added a new and striking" objection, "based upon the difficulty an ice-sheet would have in traversing the hollow trough."

Another letter, also published in "Nature," and written by Prof. Hughes, is also referred to. In this letter Prof. Hughes calls attention to the fact that on such coasts as that of Norfolk great care should be taken, when collecting rock-specimens from the drift, that the boulders are really from the drift, and not ballast thrown overboard or spread along the coast by the wreck of a vessel. When I read the letter I thought it was addressed as a warning to some careless student, but we now hear from Sir Henry H. Howorth that it is an expression of opinion on the part of Prof. Hughes that the officers of the Geological Survey, and other experienced field geologists, who have visited the coast have not been alive to such possibilities.

I should like to notice the rest of the paper, but to do so would require too much space, Sir Henry H. Howorth having treated the drifts as a hotch-potch of mud, sand, and gravel, instead of a series of deposits formed at different times and under different circumstances.

R. M. Deeley.

JURASSIC SPECIES OF CHEILOSTOMATA.

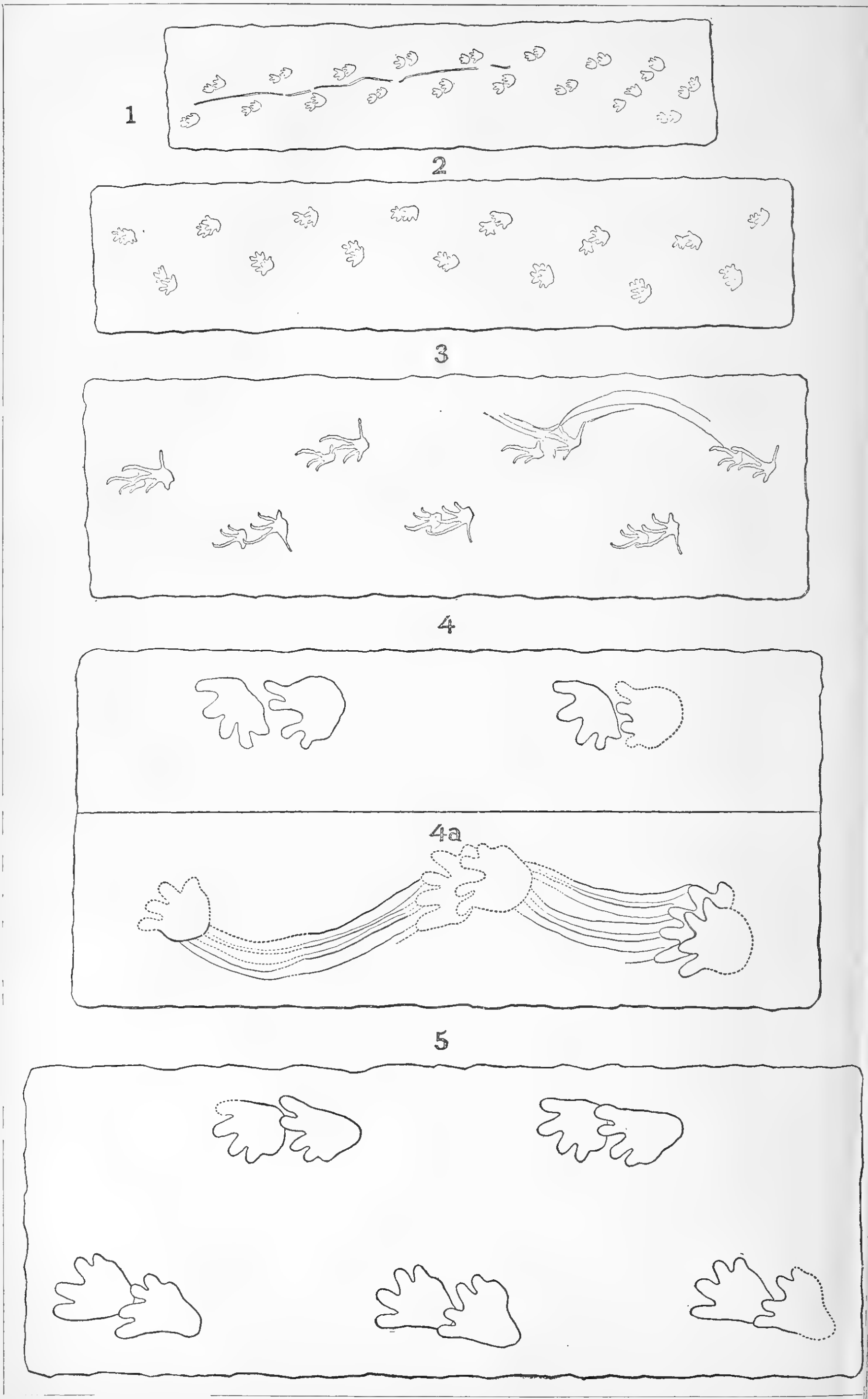
Sir,—My attention has been drawn to Mr. Edwin A. Walford's articles "On some Bryozoa from the Inferior Oolite of Shipton Gorge," and "On Cheilostomatous Bryozoa from the Middle Lias," both of which were published in the Quarterly Journal of the Geological Society, Vol. L., February, 1894, pp. 72–82.

I regret that I have omitted to make a reference to Mr. Walford's papers in an article published by me, "On some Jurassic species of Cheilostomata" in the Geological Magazine for February, 1894, pp. 61–64; but at that time Mr. Walford's papers were unpublished save for the abstracts which had appeared in April and June, 1893, during my absence in East Africa.

J. W. Gregory.

Errata.—Sir H. H. Howorth begs us to correct the following errata in his article in the June Number of this Magazine :—

On p. 260, line 41 from top, for "Hampshire" read *Sussex.*
On p. 262, line 8 from top, for "Micael" read *Michel.*
On p. 262, line 31 from top, delete the words "among them."



Footprints from Kansas Coal-measures. One-twelfth natural size.

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ORIGINAL ARTICLES.

I.—Footprints of Vertebrates in the Coal-measures of Kansas.

By Prof. O. C. Marsh, M.A., Ph.D., LL.D., F.G.S.;
of Yale College, New Haven, U.S.

(PLATE XI.)

THE Museum of Yale University contains a small collection of footprints of much interest, which were found in 1873, in the Middle Coal-measures, near Osage, in South-eastern Kansas. A careful re-examination of these footprints has been recently made by the writer, and the main results are given in the present paper.

The impressions are well preserved in a calcareous shale, which separates readily into thin slabs, each representing a surface of the beach at the time the footprints were made upon it. A few shells in the shale are sufficient to prove that the formation is marine. Trails of annelids, and perhaps of other invertebrates, are seen on some of the surfaces. The footprints of vertebrate animals, however, are of paramount importance, and the large number and variety of these here recorded on a single surface, if they could be rightly interpreted, would form an interesting chapter of land vertebrate life in the Carboniferous period, about which so little is at present known.

On Plate XI., accompanying the present article, five distinct series of footprints are shown, each one-twelfth natural size. All were found on essentially the same surface, and at one locality. The five different animals they represent were thus contemporaries, and indicate a wealth of air-breathing vertebrate life at this period, hitherto unsuspected.

With these impressions were still others, made either by animals nearly allied, or by the same animals under different circumstances. These need not be further noticed in this connection, but they serve to emphasize the diversity of life at this point. The typical series are briefly described below.

Nanopus caudatus. Pl. XI. Fig. 1.

The first series represented on Plate XI. Fig. 1 indicates the smallest animal that here left a distinct series of footsteps, and the only one in which an imprint made by the tail was preserved. This small quadruped had evidently but three functional toes on the fore feet, and four on those behind. The fore feet were considerably smaller than the hind feet. The impressions made by the latter are nearly all separate from the anterior footprints, although at times slightly overlapping them.

The nature of the animal indicated by these impressions can at present be a matter of conjecture only, but the probabilities are in favour of its reference to the Amphibians rather than to the true *Reptilia.* As it is evidently distinct from anything hitherto described, the above name is proposed for it.

Limnopus vagus. Pl. XI. Fig. 2.

In Fig. 2, Plate XI., a second series of footprints is represented, somewhat larger than those above described, and evidently made by a very different animal. The front feet had four functional toes, while those behind had five, all well developed. The impressions of the hind feet, as a rule, overlap those of the corresponding fore feet. No indications of a tail can be detected. In length of stride, and in the distance between the footsteps of the right and left sides, the present series is proportionately about the same as those above described, although the animals differed much in size. They were probably both Amphibians, and may have been nearly allied.

Dromopus agilis. Pl. XI. Fig. 3.

The third series of footprints shown on Plate XI. Fig. 3 is of special interest, and indicates an animal very distinct from the two already described.

A striking feature in the fore and hind feet of this animal was the long, slender digits, terminated by sharp claws. Another point of interest, as recorded in the footprints, is that the animal in walking swung the hind feet outward, and so near the ground that the ends of the longer toes sometimes made trails in the mud, marking accurately the sweep of the foot. This would seem to indicate a comparatively short hind leg, rather than the long slender one which the footmarks themselves naturally suggest.

The animal that made these interesting footprints was probably a Lacertilian rather than an Amphibian, but there is also a possibility that it was a primitive Dinosaur.

Allopus littoralis. Pl. XI. Figs. 4, 4*a*.

Besides the footprints above described, which pertain to animals of comparatively small size, there are several other series in this collection made by very large animals, which were probably all Labyrinthodonts. These tracks were made on the same beach, and at about the same time, as the small footprints, but not all under the same circumstances. The largest animal thus represented appears to have walked on one part of the beach that was quite firm, leaving very shallow footprints, and again to have traversed another part, quite near the first, but slightly covered with water, or at all events so soft that deep impressions were made by the feet, while the toes of the hind feet also left deep trails as they swung outward at each step. On Plate XI. Figs 4 and 4*a* these two kinds of footprints are represented. They show the stride of the animal, and, as put together, also denote the width between the footprints of the two sides, so that the series can be compared with the others on the same plate.

These tracks show that the animal had five toes in the fore feet and four behind. The hind feet show a distinct impression of a sole. There is no imprint of a tail, even where the mud appears to have been deep.

Baropus lentus. Pl. XI. Fig. 5.

The most abundant of the large footprints are represented by several series, which are remarkably uniform in stride and in width between the right and left rows. One of these series is represented on Plate XI. Fig. 5, and this is typical of the others. The animal that made these footprints evidently had four functional toes in front and the same number behind. On the inner side of each foot, however, there was a projection, which, in the hind feet, was quite prominent and characteristic, but can hardly be interpreted as the imprint of the first digit. Nearly all these footprints show a distinct impression of a sole. This is usually faint in the tracks of the fore feet, but strongly marked in those behind.

It is hardly necessary at this time to attempt a detailed comparison of the footprints above described with those already on record. The present specimens all have well-marked characters, and, being from a single horizon and locality, have a value of their own as throwing light on the land vertebrate life, during the deposition of the true Coal-measures. If, in themselves, they add but little to what is already known, they at least offer encouragement to investigators in an interesting field not yet systematically explored. The publications of Logan, Lyell, King, Lea, Dawson, and others have already made known discoveries of importance in this country, and others have been recorded in the Old World.

So far as at present known, land vertebrate life began in the Carboniferous age, no footprints or other remains of this kind having been detected below the sub-Carboniferous. That such remains will eventually be found in the Devonian, there can be no reasonable doubt, and perhaps even in the Silurian, if the land surfaces then existing can be explored.

EXPLANATION OF PLATE XI.

Fig. 1.—Series of footprints of *Nanopus caudatus*, Marsh; showing, also, impression made by the tail.
,, 2.—Series of footprints of *Limnopus vagus*, Marsh.
,, 3.—Series of footprints of *Dromopus agilis*, Marsh; showing trails made by the toes.
,, 4.—Two pairs of footprints of *Allopus littoralis*, Marsh; right side.
,, 4*a*.—Footprints of same; showing trails made by the toes; left side.
,, 5.—Series of footprints of *Baropus lentus*, Marsh.

All the figures are one-twelfth natural size.

II.—Pleistocene Climatic Changes.[1]

By Warren Upham, F.G.S.A.

THE most interesting and difficult climatic problem presented in all the geologic record is that of its latest period, immediately preceding the present, to discover the causes, first, of the accumulation, and later, of the rapid final melting of its vast sheets of land-ice. The fossil floras of Greenland and Spitzbergen indicate that those far northern latitudes enjoyed a temperate climate in the Miocene period; and, from the absence of glacial drift through the great series of Tertiary and Mesozoic formations, we infer that climates as mild as those of the present day had prevailed during long eras before the Ice-age. With suddenness, geologically speaking, there came during the Quaternary era a very exceptional and unique period of great refrigeration of the climate of northern regions, overwhelming the Siberian herds of Mammoths, and covering the surface of the northern half of North America and of North-Western Europe with snow and ice which increased to thousands of feet in depth. The conditions that seem requisite for the formation of these ice-sheets are long-continued rather than excessive cold and an abundant supply of moisture by storms, giving plentiful precipitation of snow during more of the year than now, so as to include in the time of snow accumulation not only the present winter but also the autumn and spring months. The summers, too, were probably cooler than now, for their heat was not sufficient to melt away the accumulated snow, which gradually increased in thickness from year to year, its lower part being changed to ice. When large portions of continents became thus ice-covered, the storms sweeping over them would be so rapidly cooled that the greater part of their snowfall would take place upon the borders of the ice-sheet, within probably fifty to two hundred miles from its margin; but the snowfall during the advance of the ice was probably in excess of the amount of evaporation and melting over the whole of the ice-covered areas.

Upon British America and in the northern part of the United States the directions of the glacial striæ and transportation of the drift show that there were two general ice-sheets—one reaching from New England, Nova Scotia, Newfoundland, and Labrador west to the Rocky Mountains, and north to the Arctic Ocean, having its greatest thickness over the Laurentide Highlands and James Bay, with outflow thence to the east, south, west, and north; and the other west of the Rocky Mountains, covering British Columbia, attaining a maximum thickness of about one mile, and outflowing south into the United States, west into the Pacific Ocean, and northward into the upper part of the Yukon Basin. These ice-sheets, named by Dr. George M. Dawson the Laurentide and Cordilleran, are shown, by the characters of the drift deposits along the eastern

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[1] Presented at the World's Congress on Geology, auxiliary with the Columbian Exposition in Chicago, August 26th, 1893.

side of the Rocky Mountains, to have become confluent at their time of maximum thickness and extent. The Cordilleran outflow, pouring eastward through passes of these mountains, and in the Peace River region probably overtopping the highest summits, which there are only about 6000 feet above the sea, pushed across a narrow belt adjoining the mountains, to a maximum distance of nearly 100 miles, and there (on land about 2500 feet above the sea) was merged with the Laurentide ice, the two united currents thence passing in part to the south and in part to the north from the interior tract, where the confluent ice was thickest. When the Glacial period reached its culmination, nearly all the northern half of this continent, excepting Alaska, was thus enveloped by a continuous sheet of land-ice which stretched from the Atlantic to the Pacific, and from the Ohio and Missouri Rivers to the Arctic Archipelago, having an approximate area of 4,000,000 square miles.

Almost half as large an area was ice-covered in Europe, with the basins of the Irish, North, Baltic, and White Seas, the principal centre of outflow being the plateau and mountains of Scandinavia, whence the ice moved west and north into the Atlantic, southward over Northern Germany, and eastward over a large part of Russia. Smaller ice-sheets were formed upon Scotland and Ireland, and these became confluent with each other and with the Scandinavian ice which outflowed to the borders of Great Britain. Glaciers also were far more extensive than now in the Alps, Pyrenees, Caucasus, and Himalayas; but Northern Asia seems to have had no general ice-sheet. The most anomalous feature in this strange accumulation of ice was its absence from the greater portions of Siberia and Alaska, while so heavily massed in the same and more southern latitudes of British America, the Northern United States, the British Isles, and North-Western Europe.

Both the growth and the decline of the ice-sheets were attended by considerable fluctuations of the ice-border, which appear to have been due to secular changes of moderate amount in the average climatic conditions of temperature and precipitation of snow and rain. Comparatively few records, however, of the glacial fluctuations during the time of general advance and culmination are preserved, since the drift deposits of those stages are mostly covered, unless they suffered glacial erosion and were thus wholly lost, beneath the deposits of later drift which tell the vicissitudes of the general retreat and departure of the ice.

Evidence of important glacial recession and re-advance in North America, separated by centuries or probably thousands of years, has been obtained only in the great interior expanse of the Mississippi basin. Mr. Frank Leverett[1] has reported there, in Southern Illinois, Indiana, and Ohio, sections showing an old surface of Till, deeply buried by the Till of another ice advance, which extended far south of the retreatal moraines and on some areas formed the extreme glacial boundary. The soil and the oxidized and leached

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[1] Proceedings of the Boston Society of Natural History, vol. xxiv. pp. 455–459, January 1st, 1890.

subsoil of the buried Till have been examined carefully by Mr. Leverett, who finds that the large proportion of glacially eroded limestone detritus which characterizes both these Tills had been wholly dissolved away from the buried subsoil, before its envelopment by the ensuing ice advance, to a depth of several feet, equalling or exceeding the depth of such leaching in the Till subsoil at the present surface. He therefore concludes that an interval of time at least approximately equal to the duration of the post-Glacial epoch had elapsed between the retreat and re-advance of the ice in that district close to the limits of the Drift. Further, very impressive testimony of this long interval is afforded in the valleys of the Ohio river and its tributaries by the great amount of erosion of the early stratified drift gravel and sand which had taken place, cutting the valleys from the highest terraces to the present river-beds or deeper, before the formation of the retreatal moraines and the accompanying low valley-drift deposits. The climatic changes, and the resulting two advances of the ice-border, which are thus recorded, probably belonged to the later part of the time of general growth of the ice-sheet. The extent of the intervening retreat appears to have been 100 to 250 miles in portions of the Mississippi basin; but it was doubtless much less, as perhaps only a few miles, or may have been mainly wanting, in New York, Pennsylvania, New Jersey, and New England, for there no observations of similar significance have been reported.

During the general recession of the ice-sheet abundant deposition of Loess took place in the Mississippi and Missouri basins. The observations of Prof. R. D. Salisbury, Mr. W. J. McGee, and the present writer show, respectively, that the Loess was being laid down contemporaneously with the retreat of the ice (1) in Southern Illinois and Indiana, on the borders of the Drift; (2) in North-Eastern Iowa, between the driftless area of Wisconsin and the retreatal moraines; and (3) in North-Western Iowa, adjacent to and accompanying the accumulation of the outermost moraine and the late drift which it encloses.

Beginning with this first or Altamont moraine, I have traced a series of twelve approximately parallel moraine belts, succeeding one another from south to north, in North Central Iowa, Minnesota, North Dakota, and Manitoba, of which a Map for the State of Minnesota is presented in Wright's "Ice-Age in North America" (page 546). A still larger number of retreatal moraines, up to fifteen or twenty, has been found by Mr. Leverett in the country north of the Ohio river; and Prof. T. C. Chamberlin has mapped the course of the principal outer moraines from the Atlantic coast across a distance of 1500 miles to North Dakota.[1]

Contemporaneous with the formation of the most northern five moraines explored in Minnesota, the glacial lake Agassiz was held in the basin of the Red River of the North and of Lake Winnipeg by the barrier of the receding ice-sheet; but these moraines, each

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[1] United States Geol. Survey, Third Ann. Rep. for 1881–82, pp. 291–402, with 10 plates.

comprising portions which rise in hills 150 to 200 feet high, all belong to the southern third or half of the entire extent of Lake Agassiz, and probably also to the first third or half of its entire duration. When the forest-covered and almost uninhabited country northward shall be fully explored, probably the number of moraines ascertained to have been formed during the existence of this glacial lake will be at least doubled. Growing from south to north as the barrier of the continental glacier retreated, Lake Agassiz attained a length of about 700 miles, and an area of not less than 110,000 square miles, exceeding the combined areas of the great lakes outflowing by the St. Lawrence; and its depth above Lake Winnipeg was about 600 feet.

If now the question be asked how many thousand years ago did the recession of the ice-sheet take place, producing Lake Agassiz, and at halts or slight stages of re-advance forming the moraines, a reply is furnished by the computations of Prof. N. H. Winchell,[1] that approximately 8000 years have elapsed during the erosion of the post-Glacial gorge of the Mississippi from Fort Snelling to the Falls of St. Anthony; of Dr. Andrews,[2] that the erosion of the shores of Lake Michigan, and the resulting accumulation of dune sand drifted to the southern end of that lake, cannot have occupied more than 7500 years; of Prof. G. Frederick Wright,[3] that streams tributary to Lake Erie have taken a similar length of time to cut their valleys and the gorges below their water-falls; of Mr. G. K. Gilbert,[4] that the gorge below Niagara Falls has required only 7000 years, more or less; and of Prof. B. K. Emerson,[5] on the rate of deposition of modified drift in the Connecticut Valley at Northampton, Massachusetts, from which he believes that not more than 10,000 years have elapsed since the Glacial period. An equally small estimate is also indicated by the studies of Gilbert[6] and Russell[7] for the time since the last great rise of the Quaternary Lakes Bonneville and Lahontan, lying in Utah and Nevada, within the arid Great Basin of interior drainage, which are believed to have been contemporaneous with the great extension of land-ice upon the northern part of the North American continent. These measures of time, surprisingly short, whether we compare them on the one hand with the period of authentic human history, or on the other with the long record of geology, carry us back to the date when the ice-sheet

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[1] Geology of Minnesota, Fifth Annual Report, for 1876; and Final Report, vol. ii. 1888, pp. 313–341. Quart. Journ. Geol. Soc. vol. xxxiv. 1878, pp. 886–901.

[2] Trans. Chicago Academy of Sciences, vol. ii. James C. Southall's Epoch of the Mammoth and the Apparition of Man upon the Earth, 1878, chapters xxii. and xxiii.

[3] Amer. Journ. Science, iii. vol. xxi. pp. 120–123, February, 1881; The Ice-Age in North America, 1889, chapter xx.

[4] Proc. Amer. Assoc. for Advancement of Science, vol. xxxv. for 1886, p. 222. "The History of the Niagara River," Sixth Ann. Rep. of Commissioners of the State Reservation at Niagara, for 1889, pp. 61–84.

[5] Amer. Journ. Science, iii. vol. xxxiv. pp. 404–5, November, 1887.

[6] United States Geol. Survey, Second Annual Report, for 1880–81, p. 188; Monograph I. Lake Bonneville, 1890, chapter vi.

[7] United States Geol. Survey, Monograph XI. Geological History of Lake Lahontan, 1885, p. 273.

was melting away from the basins of the Upper Mississippi, of the northern Red River, and of the Laurentian lakes.

The entire departure of the North American ice-sheet, therefore, probably occupied only two or three thousand years; and half of this time may measure the duration of Lake Agassiz, with the accumulation of the numerous adjacent moraines whose courses intersect the lake area, and with the formation of its beaches marking about thirty successive stages in the concurrent subsidence of the lake surface and rise of the earth's crust, which amounted together to 700 feet on the latitude of the north part of Duck Mountain and the middle of Lake Winnipeg. But even these short estimates may be too long. The shores of Lake Michigan, similar with those of Lake Agassiz, in the Drift of which they are formed, in their north and south trends and in the adjoining depths of water, have suffered an amount of erosion by the lake waves during post-Glacial time which very far exceeds the total erosion that was effected upon the shores of Lake Agassiz during all its stages, the proportion between them being surely not less than ten to one; and Lake Michigan has a similarly greater amount of beach deposits, which upon a large area about its south end are raised by the wind in conspicuous dunes. This contrast, indeed, suggests that the duration of Lake Agassiz, and the recession of the ice-sheet from its area and from the greater part of the area of Hudson Bay, may have been included within less than one thousand years.[1]

Having thus reviewed the Glacial period, we come to inquire—What were the causes of its grand climatic changes, leading first to the accumulation, and then to the rapid departure, of the ice-sheets? Upon their areas warm or at least temperate climates had prevailed during long foregoing geologic ages, and again at the present time they have mostly mild and temperate conditions. The Pleistocene continental glaciers of North America, Europe, and Patagonia have disappeared; and the later and principal part of their melting was very rapid, as is known by various features of the contemporaneous glacial and modified drift deposits and by the beaches and deltas of temporary lakes that were formed by the barrier of the receding glaciers. Can the conditions and causes be found which amassed the thick and vastly extended sheets of land-ice, and whose cessation suddenly permitted the ice to be quickly melted away?

Two principal theories of the causes of the Ice-age seek to answer these inquiries. The one which we will first consider is the astronomic theory of Croll, Geikie, and Ball. In accordance with Dr. Croll's theory, Glacial periods would be expected to recur with geologic frequency, whenever the earth's orbit attained a stage of maximum eccentricity, during the very long Tertiary and Mesozoic eras, which together were probably a hundred times as long as the Quaternary era in which the Ice-age occurred. But we have no evidence of any Tertiary or Mesozoic period of general glaciation in circumpolar and temperate regions, although high mountain groups or ranges are

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[1] Geol. and Nat. Hist. Survey of Canada, Annual Report, new series, vol. iv. for 1888–89, pp. 50, 51 E.

known to have had local glaciers. Not until we go back to the Permian period, closing the Palæozoic era, are numerous and widely distributed proofs of very ancient glaciation encountered. Boulder-bearing deposits, sometimes closely resembling Till and including striated stones, while the underlying rock also occasionally bears glacial grooves and striæ, are found in the Carboniferous or more frequently the Permian series in Britain, France, and Germany, Natal, India, and South-Eastern Australia. In Natal the striated glacier floor is in latitude 30° south, and in India only 20° north, of the Equator. During all the earth's history previous to the Ice-age, which constitutes its latest completed chapter, no other such distinct evidences of general or interrupted and alternating glaciation have been found; and just then, in close relationship with extensive and repeated oscillations of the land, and with widely distant glacial deposits and striation, we find a most remarkable epoch of mountain-building, surpassing any other time between the close of the Archæan era and the Quaternary. Mr. Alfred Russel Wallace therefore concludes that eccentricity of the earth's orbit, though tending to produce a Glacial period, is insufficient without the concurrence of high uplifts of the areas glaciated. He thinks that the last time of increased eccentricity, 240,000 to 80,000 years ago, was coincident with great altitude of North-Western Europe, North America, and Patagonia, which consequently became covered by ice-sheets; but that such previous times of eccentricity, not being favoured by geographic conditions, were not attended by glaciation. The recentness of the Ice-age, however, which has now become generally recognised and accepted by glacialists, seems to demonstrate that eccentricity was not the primary cause of glaciation, and to bring doubt that it has exerted any determining influence in producing unusual severity of cold either during the Pleistocene or any former period.

The alternative theory, which is accepted in this discussion as an explanation of the climatic conditions bringing on and carrying off the ice-sheets, has been thought out and formulated by Dana,[1] Le Conte,[2] Wright,[3] and the present writer[4] in America, and by Jamieson[5] in Scotland. On account of its referring the cold and snowy climate of the time of ice accumulation to high uplifts of the glaciated

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[1] James D. Dana, Presidential Address, Proc. Amer. Assoc. for Adv. of Science, vol. ix. for 1855, pp. 23–29; Trans. Conn. Acad. of Arts and Sciences, vol. ii. 1870; many papers in the Amer. Journ. of Science; and the several editions of his Manual of Geology.

[2] Joseph Le Conte, Bulletin Geol. Soc. of America, vol. ii. 1891, pp. 323–330; Elements of Geology, third edition, 1891, p. 589.

[3] G. Frederick Wright, The Ice-Age in North America, 1889, chapter xix.; Man and the Glacial Period, 1892, chapter ix.; Amer. Journ. of Science, third series, vol. xlvii. pp. 184–187, March, 1894.

[4] Warren Upham, Appendix of the Ice-Age in North America, pp. 573–595; Amer. Journ. of Science, iii. vol. xlvi. pp. 114–121, August, 1893; Bulletin Geol. Soc. of America, vol. v. 1894, pp. 87–100; GEOL. MAG. Dec. III. Vol. VII. pp. 492–497, November, 1890.

[5] Quart. Journ. Geol. Soc. vol. xviii. 1862, p. 180; vol. xxi. 1865, p. 178; GEOL. MAG. Dec. II. Vol. IX. pp. 400–407 and pp. 457–466, Sept. and Oct. 1882; Dec. III. Vol. IV. pp. 344–348, August, 1887; and Dec. III. Vol. VIII. pp. 387–392, September, 1891.

regions, this may be properly named the epeirogenic theory of the Ice-age.[1] Condensed into a single paragraph, it shows in the fjords and submarine continuations of river valleys a proof that the drift-bearing areas immediately before the accumulation of the ice-sheets had been gradually elevated thousands of feet, until finally the cool plateau climate at the culmination of the uplift brought on the Glacial period; in the low condition of the lands, when the Drift was left by the retreat of the ice, it sees that these areas had sunk beneath their ice-weight, until mostly they stood somewhat below their present level; and in the post-Glacial uplift of the marine Champlain deposits, overlying coastal portions of the Glacial drift, it sees an effort of the earth to regain a state of simple flotation of the crust on the heavier mobile interior which is capable of flow whether it be solid or molten.

The epeirogenic movements of the countries which became glaciated were only a portion of widespread oscillations of continental areas during the closing part of Tertiary time and the ensuing much shorter Quaternary area. Not only were the northern half of North America and the north-western part of Europe uplifted 1000 to 3000 feet or more, but probably all the western side of Europe and Africa shared in this movement, of which we have the most convincing proof in the submerged channel of the Congo, about four hundred miles south of the Equator. From soundings for the selection of a route for a submarine cable to connect commercial stations on the African coast, Mr. J. Y. Buchanan[2] found this channel to extend eighty miles into the ocean to a depth of more than 6000 feet. The last twenty miles of the Congo have a depth of from 900 to 1450 feet. At the mouth of the river its width is three miles and its depth 2000 feet. Thirty-five miles off shore the width of the submerged channel or cañon is six miles, with a depth of about 3450 feet, its bottom being nearly 3000 feet below the sea-bed on each side. Fifty miles from the mouth of the river the sounding to the submarine continental slope is nearly 3000 feet, while the bottom of the old channel lies at 6000 feet. This very remarkable continuation of the Congo Valley far beneath the sea-level is like those of the Hudson and St. Lawrence rivers, and like numerous submerged valleys on the coast of California; but the Congo reaches to a greater depth than those of North America, and even exceeds the Sogne fjord, the longest and deepest in Norway, which has a maximum sounding of 4080 feet. Another deep submarine valley, called the "Bottomless Pit," having soundings of 2700 feet, is described by Buchanan on the African coast 350 miles north of the Equator, and he states that a similar valley exists in the southern part of the Bay of Biscay. These observations show that within very late geologic time probably almost the entire

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[1] The terms *epeirogeny* and *epeirogenic* ("continent-producing," from the Greek *epeiros*, a mainland or continent) are proposed by Mr. G. K. Gilbert in his U.S. Geol. Survey Monograph, Lake Bonneville (1890), to designate the broad movements of uplift and subsidence which affect the whole or large portions of continental areas or of the oceanic basins.

[2] Scottish Geographical Magazine, vol. iii. 1887, pp. 217–238.

Atlantic side of the eastern continent has been greatly uplifted, attaining as high an altitude as that which Sir A. C. Ramsay and James Geikie conjectured as a possible cause of the frost-riven limestone-agglomerates of Gibraltar.[1]

Wherever great movements of land elevation have taken place in high latitudes, either north or south, which received abundant precipitation of moisture, ice-sheets were formed; and the weight of these ice-sheets, as was first pointed out by Jamieson, seems to have been a chief cause, and often probably the only cause, of the subsidence of these lands and the disappearance of their ice. Though the still high surface of the greater part of an ice-sheet would not be affected by the temperate climate of the country depressed to its present level or slightly lower, the warm summers along the ice-border would cause it to be rapidly melted, and by the extension of this process inward all the ice-sheet would disappear. When the progress of the marginal melting in the Mississippi basin had given generally steep gradients to the ice-front, its more powerful currents formed the retreatal moraines and the many lake basins of the unevenly laid later drift which are so strongly contrasted with the smooth and attenuated outer portion of the drift-sheet beyond the moraines.

What were the original sources of the energy displayed in the earth-movements of uplift preceding glaciation, and why this has been so extensively developed during the Quaternary era, are very difficult questions which it is not the purpose of this paper to consider, since I have attempted elsewhere to answer them, in an appendix of Wright's "Ice-Age in North America." It may be properly noted, however, that the explanations mentioned are entirely consistent with Dana's teaching that the great continental and oceanic areas have been mainly permanent from very early geologic times.

The chief objection urged against this explanation of the causes of the Glacial period and its sudden end consists in an approximate identity of level with that of to-day having been held by some drift-bearing areas at a time very shortly preceding their glaciation. This is clearly known to have been true of portions of Great Britain and of New England. In respect to this objection, it must be acknowledged that the pre-Glacial high elevation which these areas experienced was geologically very short. With the steep gradients of the Hudson, of the streams which formed the now submerged channels on the Californian coast, and of the Congo, these rivers, if allowed a long time for erosion, must have formed even longer and broader valleys than the yet very impressive troughs, continuing to depths of 2000 to 6000 feet beneath the sea-level, which are now found on these submarine continental slopes. But the duration of the epeirogenic uplift of these areas on the border of the glaciation for the Hudson, beyond it for the Californian rivers, and near the Equator in Western Africa, can scarcely be compared in its brevity with the prolonged high altitude held

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[1] Quart. Journ. Geol. Soc. vol. xxxiv. 1878, pp. 505-541.

during late Tertiary and early Quaternary time by the Scandinavian peninsula, and by all the northern coasts of North America from Maine and Puget Sound to the great Arctic Archipelago and Greenland. The abundant long and branching fjords of these northern regions, and the wide and deep channels dividing the many large and small islands north of this continent, attest a very long time of high elevation there. At the time of culmination of the long-continued and slowly increasing uplifts at the north, they seem to have extended during a short epoch far to the south, coincident with the formation of ice-sheets in high latitudes. But when these lands became depressed, and the ice burden of the glaciated countries was removed, they, in some instances, as in Great Britain and New England, returned very nearly to their original levels, beautifully illustrating the natural condition of equilibrium of the earth's crust before referred to, which Dutton has named *isostasy*, that when not subjected to special and exceptional stresses it acts as if floating on a heavier plastic or molten interior.

The wane and departure of both the North American and European ice-sheets have been marked by many stages of halt and oscillation, whereby the flora, including forest trees, and less frequently traces of the fauna, of the temperate areas adjoining the melting and mainly receding ice were covered by its drift at the times of temporary re-advance of the ice-border. No better illustration of conditions favourable for the burial of forest beds in the Drift can be imagined than those of the Malaspina glacier or ice-sheet, between Mount St. Elias and the ocean, explored by Russell in 1890 and 1891, and found to be covered on its attenuated border with drift which supports luxuriant growing forests. Let a century of exceptional snowfall cause a thickening and re-advance of that ice-sheet, and sections of its drift exposed after the glacial recession will show a thick forest bed of chiefly or wholly temperate species. Such re-advances of the continental ice-sheets, interrupting their retreat, are known by well-marked recessional moraines in both North America and Europe. Near the drift boundary in the Mississippi basin some of these glacial fluctuations have involved long stages of time, measured by years or centuries, with important though minor changes in altitude, as shown by the excellent analytic studies of Chamberlin, Salisbury, McGee, and Leverett; but farther north, as in the large region of the glacial lake Agassiz, the withdrawal of the ice-sheet and formation of successive moraines marking slight halts and re-advances due to secular changes in temperature, humidity, and snowfall, were demonstrably very rapid, the whole duration of this glacial lake being probably only about 1000 years. The vicissitudes of the general glacial retreat seem to me to have been due thus chiefly to variations of snowfall, some long terms of years having much snow and prevailingly cool temperature, therefore allowing considerable glacial re-advance, while for the greater part other series of years favoured rapid melting and retreat.

Under this view we may, I think, account for all the observations which have been held in America and Europe as proofs of inter-

Glacial epochs, without assuming that there was either any far re-advance of the ice-border or any epeirogenic movements attending the glacial retreat of such magnitude as to induce the fluctuations of which the forest beds and marginal moraines bear witness. Though the whole history of the growth, culmination, and departure of the ice-sheets is indeed very complex and long, as measured by our familiar historical time units, it was yet, in my opinion, geologically very brief if compared with all preceding geologic periods and epochs. Instead of being subdivided by long intervals of temperate or warm climate, the Ice-age seems to me to have been essentially continuous and single, with important fluctuations, but not of epochal significance, both during its advance and decline.

III.—NOTES ON RUSSIAN GEOLOGY.

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(*Continued from the July Number*, p. 312.)

III. THE BLACK EARTH.

Prof. Krasnov states that the decomposition of the roots of plants gives rise to the humus, but attaches much more importance to the effect of climatic conditions. Thus, he remarks, "that it is impossible not to note that the Tchernozem occupies a band stretching from S.W. to N.E., that is, the position where the influence of a temperate and moist climate ends, and the region of dry S.E. winds begins. In the N. and N.W. of Russia the woods predominate, unless destroyed by man, or prevented by the marshy nature of the country. Where Black Earth begins, the woods end, and little by little steppe assumes sway, first as half steppe (that is to say, the alternation of wood and broad black earth plains), and finally to the S. as true steppe, where the view is, in most cases, unimpeded even by a single bush."

Prof. Dokoutchaieff has recently discussed the whole of this question ("The Russian Steppes": a pamphlet written for the World's Columbian Exhibition at Chicago, 1893). He shows that in the N. of the Poltava government the outlines of the steppe and forest boundaries are clearly marked out, and that it is yet possible to trace the positions formerly occupied by extensive forests, by means of the special character of the soil to which they have given rise.

He has also shown that there is a transitional structure in the Black Earth itself. In some of the Eastern governments (Tambov, Penza, Simbirsk, and Samara in part) a maximum humus percentage of 12 per cent. is attained, whilst to the N.W. and S.E. of these the quantity of humus diminishes.

Accordingly he concludes that to the N.W. the superabundance of moisture, and to the S.E. the dryness, prevent the formation of humus, and that it is in the transitional climatic band that the most favourable conditions for its production exist. I am not aware that any chemical research has been carried out on Black Earth soils hailing from districts south of the Poltava government. Such a research could not fail to be of great interest, when compared with the results already obtained by students of the problems of Central Russian agriculture.

Prof. Krasnov holds the same views, and claims that they are materially confirmed by the fact that in Turkestan, the Crimea, the Caucasus, and America the transition districts between the dry steppe and moist forest-land, under climatic influences resembling those of South Russia, possess soil structures similar to the Black Earth, and present the same phases in their alternation. In addition the flora can be readily paralleled with those of the steppe itself.

The original virgin steppe is fast disappearing before the advance of cultivation. Nevertheless, here and there a few traces of its original characters are preserved. The typical forms are *Stipa pennata*, *Stipa capillata*, *Campanula Sibirica*, *Falcaria Rivini*, and *Gypsophila paniculata*. At a point in the south of the Poltava government, *Amygdalus nana* and *Prunus chamœcerasus* form low-growing but impenetrable bushes, so that it is evident that the present conditions are but a poor indication of the wealth of vegetation which once covered these plains (Dokoutchaieff, *loc. cit.*). The cultivation above-mentioned has, no doubt, wielded an enormous influence in the production of those serious changes which are causing such anxiety to Russian agriculturists. The virgin steppe easily sucked up the atmospheric moisture which fell upon its surface, whereas on the ploughed land the rain-water collects in the form of minor torrents, sweeps away the rich earth, carrying it down into the river valleys and alluvial flats. The result is very noticeable along the banks of the Dnieper during the summer-time, a distinctly-marked Black Earth forming a conspicuous object in the low cliffs which skirt the river for many miles. In addition, the Black Earth is much more liable to redistribution by æolian action, every breath of wind tending to carry away a small cloud of dust with it. This may be easily proved by direct observation, the traveller who crosses the steppes having his face blackened on the side which is windward, whereas the other remains perfectly clean.

This movement has only one result, viz. that the Black Earth is moved from one steppe to another, excepting where it meets with some obstacle, or is carried outside the plain region altogether. Far more destructive has been the forest denudation in the higher reaches of the river, the flooded waters, having lost the check which formerly kept them in bounds, carrying away the rich soil without offering any compensating advantage. This destruction, due to human agency, is in strong contrast to the gradual and natural advance of trees into the steppe area, an advance which is in close connection with the denudation of that area.

It has been pointed out by students of forestry in Russia that the woods on the steppe are of two classes: 1st, Conifers, represented mostly by firs; and 2nd, the leafy (deciduous) trees, principally oak, ash, birch, and hornbeam. The Conifers generally form forests, often of considerable extent, which occupy the alluvial plains of the great rivers, growing exclusively on sands and other fluviatile deposits. The woods which form such conspicuous backgrounds to the views obtainable from Kieff and Sviati-Gori, over the valleys of the Dnieper and Donetz respectively, are of this nature.

Nevertheless, at the latter locality, occurs an exception which appears to be of the greatest interest. D. J. Litwinoff (Moscow Bull. Sept. 1891) has called attention to the fact that on the chalk escarpment, which forms so prominent a feature at Sviati-Gori, and at other points along the Donetz, is one of the very few occurrences of *Pinus silvestris* known in S. Russia. Accompanying it is a great variety of flowers, all of which have a distinct Alpine character. The whole evidence seems to prove that these plants were already living here at far earlier geological epochs, and that this small remnant had been preserved during all the vicissitudes and changes of Pleistocene history.

On the other hand, the deciduous leaved trees cling to the sides of the balkas and smaller streams, such as the Kalmiuss, and also clothe the sides of the high right banks of the rivers already referred to. Professor Krasnov points out "that the forests appear to avoid the level steppes open to the influences of the winds. There are, however, numerous exceptions. High watersheds, cut into deep ravines, and balkas are generally wooded; thence the vegetation extends down the water-courses, in a band which comes closer to the stream as the latter reaches more level regions, less cut into by ravines and fissures. As researches have shown in the Poltava government, the grey wood-soil follows the same law of extension. This law has received but slight attention on the part of students of soils." Professor Dokoutchaieff also lays stress on the fact that as fissures are formed, going over into ravines or valleys of rivers, woods hasten to occupy them, and thus are gradually invading S. Russia.

Professor Kostitch on his side argues along the lines adopted by Professor Whitney for the United States. He holds that the law of the extension of forests depends upon the structure of the watersheds. The rains carry away the fine particles, leaving a coarse-grained undersoil. The relations of coarse and fine-grained soils to the absorption of rain-water are very different. In the former case the water quickly descends into the deeper parts, and is retained there for a long time, before it evaporates. On the contrary, the fine-grained soil holds all the moisture at the surface, and allows it with difficulty to penetrate. The lower-lying substratum, even after strong rains, remains dry, while the upper is turned to mud. From such a surface the moisture, under the influence of dry winds, soon evaporates.

On these foundations Professor Kostitch builds his wood-extension theory. He believes that in the steppes the only places where trees would succeed are those where a coarse-grained soil exists, in which the deeply descending roots could find sufficient moisture for their growth.

Professor Krasnov considers that although this view has a true basis, it is too wide a conclusion, being founded merely on a study of the Nijni-Novgorod government, and that the watersheds of the country are very far from possessing the coarse-grained soil that Professor Kostitch expects. Also the woods do not themselves always follow the watersheds, but, on the contrary, are very frequently quite absent at such points.

Mr. Rodway, reviewing the American aspect of the case, introduces another agency. With him water becomes a most important agent in the distribution of trees, and he adduces examples of the results of inundations in this respect. Trees are not found in treeless regions, because water has never transported them thither, and they never were there, because no trace of their existence can be found.

The general result thus stated may be freely admitted, but at the same time it is very obvious, in Russia at any rate, that there is some special difficulty as regards tree-growth on the steppe. The precautions taken in cultivating trees in gardens and on the steppe is a case in point. The grass has to be carefully removed, and a little trench dug round the plant, to enable it to obtain the necessary water-supply. Whether it be that the grass itself absorbs the moisture, or that the soil is too fine for free percolation, is a question an answer to which it is not easy to obtain. Small trees have to be planted very thickly to prevent wind drying up the moisture.

Professor Dokoutchaieff has given expression to the following views: "The low-level districts of the Poltava government are devoid of woods, at the same time being rich in salts. The higher parts are, however, wooded, and the ground has but few salty constituents." In his opinion absence of tree-life and presence of salts are in close connection.

Streams, draining the upper parts of the government, carry down the salts in solution, depositing these in marshes or giving rise to salt-springs, when the lowlands are reached. As salt is a deadly enemy of tree-life, and as the lowlands being strongly alkalized do not admit of forest-growth, steppes are produced in such localities. Especially is this the case in the lowest parts, where the largest amount of salt is concentrated. These statements are practically the application of Lesquereux's views to the South Russian area.

As far as my own experience goes, I must agree with Professor Krasnov, that this theory appears untenable when applied to the South Russian Black Earth region as a whole, though it may be of great importance in its relation to individual districts, and especially to that area which lies immediately south of the distinct glacial boundary. Owing to the great extent of the Russian empire, and the broad regions over which its various deposits are spread out, there is a natural danger of the formation of separate schools of thought, each basing itself on the peculiarities existing in special districts, and raising local features to the rank of far-reaching generalities. Only after prolonged and friendly discussion will it be possible to establish those wider principles which must form the foundations for true progress in the subjects under discussion.

The facts on which such wider conceptions are based come out forcibly when the conditions in Russia and N. America are compared. Both possessed an ice-sheet, or, at any rate, an abnormal glacier, occupying similar geographical positions. In both, the northern portions are rich in forest, lake, and marsh; whilst further south spread the broad prairie or the rolling steppe. Not only so, the similarity extends even to the consideration of soil and flora. Only the other day, a short account of North Dakota appeared in one of the newspapers, special stress being laid on the richness of the black soil which there exists. Parallelism of character has been accompanied by parallelism of theory, and turn by turn, climate, nomads, fine-grained silt, and presence of salts, have been used to account for the absence of tree-life.

Prof. Krasnov arrives at the conclusion that in Russia the process of dessication has gone further than in America; for, in the latter, as Lesquereux has shown, near the Gulf of Sandousk, on the Mississippi, may yet be seen the marshy prairie covered with small lakes. These views are founded on the supposition that the melting of the ice-sheet must have saturated the soil with water. Lesquereux, indeed, concluded that the prairie lands must have once been occupied by an unbroken chain of lakes and marshes; gradually the area has been drained, though traces are still left of the former predominance of more lacustrine conditions.

In Russia, the lakes still exist on a small scale in the Kharkov and Poltava governments; but these, it appears, are rapidly disappearing, having been far more numerous even within the memory of men still living. The shores of one visited by me at the village of Kvianovka, near Voroshba, were crowded with the shells of large *Limneæ* and *Paludinæ*, which had evidently been left behind on the lowering of the water-level. That the change has been of recent date is shown by the fact that the strip bordering this sheet of water is in a very marshy condition.

In these districts, too, corn often ripens without having received a drop of rain during the spring, whilst it is stated that the flora is rather that of the marsh than of the steppe. In the south, further removed from the original termination of the ice-sheet, the advent of showers at this season is one of the things most anxiously looked for by the agriculturist, and the flora is of a truer steppe character.

This interesting question of the floral distribution is also discussed by Professor Krasnov, who says: "The watersheds of the Donetz-Dnieper and Donetz-Don are very rich in species; along the Dnieper and Volga the number is at least 20 per cent. less. Without regard to climate, the rarest species are found on the highest ground of the district; these are partly steppe and partly Caucasian forms, characteristic of moist mountain meadow-lands near the terminations of glaciers. The districts of Constantinograd and Loubny, in the Poltava government, and those of Volchansk, Starobielsk, and Sviatoia Gora, in the Kharkov government, some of the highest districts in the south, are specially rich in these types. The steppe soil itself also changes its character according to the position, that on higher ground being the richer in humus."

In Russia, then, we have three distinct regions distributed in regular sequence from north to south, or more strictly lying in broad curves bending from N.E. to S.W., and running parallel to the line given by Murchison as the limit of distribution of glacial boulders.

To the north and west of this boundary division lies the great forest region, now much denuded by man; but still, especially in Lithuania, attaining magnificent proportions. Immediately to the south of this line lies the band, which shows a combination of forest, small lake, and patches of steppe. This latter passes directly but gradually into the true steppe region.

Prof. Krasnov, after a comparison of the American and Russian literature on this subject, concludes that the Black Earth region has gone through three distinct stages:—

1st. The stage of marsh formation, presumably the immediate result of the melting of the ice-sheet. During this period there would be a decided predominance of lakes and morasses, and a low-lying marshy flora would be conspicuous. Trees and steppe-grasses then only occupied the highest points.

2nd. The stage of drainage, connected with poverty of the subsoil waters. This stage has been passed through by the greater part of the steppes and prairies. In their northern portions there is still evidence of those water-holding depressions which on this hypothesis must formerly have existed, and even such traces are fast disappearing. These changes are accompanied by the immigration of a flora more suitable to a dry climate, and by the formation of Black Earth.

3rd. The wood stage, which is, as regards the south, as yet in its infancy. As the steppe is denuded, so the woods, or more commonly isolated trees in the first instance, advance along the valleys of the streams, and occupy the ravines. My former paper on Loess really dealt with the first, and part of the second above-mentioned stages. It is noteworthy that but little is said about this great deposit in the paper to which reference has been made above, although the general sequence of events suggested by me has been to a large extent borne out by Prof. Krasnov's results.

The zoological studies carried out by Professor Nehring have still further strengthened the position here being maintained. Since 1874 a series of papers have been written by him (see, for instance, Sitz. Ber. der Gesell. Naturforsch. Freunde, Berlin, 1888–89–90, p. 164) in which he has endeavoured to establish the existence of steppe-characters in Central Europe during Pleistocene time. Here again a triple division has been observed, each zone differing as regards the animal remains contained in it.

In the lowest, immediately succeeding true glacial deposits, occur the bones of animals, now living chiefly in tundra regions and higher latitudes, such as the Elk and Lemming. Besides these, the Reindeer, Arctic Fox, and Arctic Hare have been noticed. Not only so, but fresh-water mollusca are very abundant, species of *Limnea*, *Paludina*, and *Pisidium*, being especially noticeable.

In the second, or zone of Loess proper, a typical steppe fauna commences to make its appearance, the Horse, Jerboa, and Marmot being especially characteristic. On the other hand the remains of Mammoth and Rhinoceros are found in close conjunction with these in Germany.

In Russia the smaller rodents persist at the present day, though these are now fast disappearing before advancing civilization. The steppe-rat still holds its own to a great extent, but when we consider that over forty thousand were destroyed in one year (and that in one district only, Stila, south of Ekaterinoslav governments), it will be readily understood that their extinction as such is but a question of time. In the Upper beds of the German Loess at Thiele, in Brunswick, the steppe rodents practically disappear, the Mammoth, Rhinoceros, Horse, Hyæna, and Lion alone carrying on the faunal history. The latter two animals never appear to have established themselves in the S. Russian area, but the first three are of typical occurrence. In the last zone forest-living animals commenced to appear, but it is to be feared have been unable to obtain a strong footing, thanks to the hunting propensities of mankind.

It is interesting to note that man seems at the present day to be engaged in a deadly struggle with what we should otherwise regard as a natural tendency, for whilst the forests, if left alone, would probably become successful invaders, they are ruthlessly cut down in the hour of victory.

In Germany, then, as in Russia, a steppe-region probably succeeded the period of lake and tundra, but the forests had long played an important part in the former ere the southward advance of the vegetation commenced in the latter country. Already in the time of Tacitus they were spread over the face of the country, forming a mighty fortress, behind whose defences Arminius could well defy the all-powerful Roman hosts.

In England the climatic conditions are so totally different that steppe-characters might well not have existed. Nevertheless, even here, as has been suggested by Mr. Clement Reid in "Natural Science," there is some evidence of the erstwhile presence of such plains over which the Saiga Antelope may have roamed at will.

The greater extension of the forests in former times is, of course, a matter of common knowledge; for we learn at the time of Cæsar's landing, Londinium was in the midst of the Middlesex forests, traces of which are still abundant, *e.g.* Epping Forest, Highgate and Hadley woods.

It therefore would appear that like conditions succeeded each other all over the North of Europe, but that our own island is ahead of both Eastern Germany and Southern Russia as regards historical development; probably due to its greater nearness to the edge of the continental plateau, and consequent more rapid transition to an insular climate.

Before summarising the views set forth in the present paper, it may be of interest to call attention to the humus-bearing Loess which lies at the base of the main deposit. Prof. Armachevsky

(Geological Outlines of the Tchernigov Government, p. 129) remarks: "Of special interest is undoubtedly the Loess, which contains a marked percentage of humus, and which may be described as *humus-bearing Loess.* This structure is always met with in the *lower* horizons of the Loess, and may sometimes attain a thickness of seven feet. It is distinguished from ordinary Loess by its grey-brown, chestnut-brown, or dirty grey colour, and is at the same time more compact and clayey; otherwise its characters are those of the true Loess. Two analyses gave 2·04 and 3·03 per cent. of humus respectively."

This interesting condition is one to which attention should very specially be directed, seeing that it alone can furnish evidence as to the actual condition of the open country lying to the south of the glacier. There is not at present sufficient evidence to show that steppe lands, as such, were then already marked geographical features; and there are some conditions, such as the existence of isolated tree-islands in the midst of the plains, which rather tend to prove the greater extension of woods at that time, and their partial destruction by the flooded Loess-bearing waters. With this brief statement I must leave this complex subject.

In this paper I have endeavoured to show, first, that the three main propositions submitted by me in my previous note on the Loess are fully confirmed, not merely by the change in character of the strata in a vertical direction, but also by the variations they display when traced horizontally from north to south.

Not only do we find a gradual transition from beds containing fresh-water shells to those which bear only evidence of a steppe fauna and flora, but we have similarly the existence of marshes and lakes (though disappearing) in the north of Little Russia; whilst in the southern parts broad steppe and grassy plains alone prevail.

These views are further strengthened by a consideration of the faunal changes which have taken place in South Russia. Here the Mammoth and Rhinoceros seem more abundant in the lower beds, and appear to be more rapidly replaced by the smaller steppe forms than is the case in Germany. Perhaps it may be that in the latter country less continental conditions may have prevailed, and possibly it may never have attained to the perfection of steppe conditions developed further east.

As regards the flora, there remain here and there some traces of the older vegetation, but in general the glacial and Caucasian types have practically disappeared, marshy forms now predominating in the northern, and steppe-forms in the southern governments of Little Russia.

The suggestion, then, is, that the position of the Loess has been originally determined by the manner and conditions of its origin, but from the time that the glacial melting ceased to have effect it was subject to the action of denuding influence, the wind becoming a principal factor when the main outlines of steppe-life were established.

Secondly, the Black Earth is merely a special closing feature in the sequence of a long history, a last page in a many-chaptered volume. Its position and character are, in the main, determined by that of the Loess, and it is merely that deposit rich in humus, resulting from the decomposition, through long ages, of many generations of grasses and steppe plants. Not only has it not resulted from changes of a complex, sudden, and variable character, but it is actually being produced at the present day, a layer several inches thick covering some of the ancient Tartar tumuli so frequent on the Russian steppe.

Further, there is no proof of the former existence of trees on these areas; in fact there is actual evidence forthcoming against such a view, both in the pages of history and in the facts of agricultural development. The winds that sweep the steppes, and carry far and wide the loose powdery soil, are directly opposed to the growth of wood or forest on these plains. The Russo-German colonist finds it necessary, when attempting to start a plantation, to grow the trees close together, so that the outer ring may protect the inner ones from the blast.

Circumstances have been mentioned which tend to show the necessity of overcoming special obstacles ere tree-life can be established, and also proving that it is only invading the steppe-lands along lines where denudation influences are active. The variations in richness of humus may be largely due to climate, and the alteration in thickness to the action of the wind; but in any case the Black Earth would appear to be a typical surface formation, resulting from the direct chemical combination of organic materials with the soil constituents.

IV.—JURASSIC AMMONITES: ON THE GENUS *CYMBITES* (NEUMAYR).[1]

By S. S. BUCKMAN, F.G.S.

THIS paper deals with the species which are considered to belong to the genus *Cymbites*, and the reason for placing *Paroniceras*, Bonarelli, as a synonym. A few notes are added concerning *Agassiceras*, which is also affected; and a description of the little-known species *Agassiceras Colesi* (J. Buckm.) is given.

Genus, CYMBITES, Neumayr, 1878.

(Type, CYMBITES GLOBOSUS, Zieten, sp.)

1875. *Agassiceras*, Hyatt, New Genera Amm.; Proc. Boston N. H. Soc. vol. 17, p. 225 (*pars*).
1878. *Cymbites*, Neumayr, Unverm. auftret. Ceph.; k.k. geol. Reichsanstalt. Bd. 28, Heft 1, p. 64 [28], footnote.
1884. *Agassiceras*, Zittel, Palæont. Bd. i. Abth. 2, Lief. iii. p. 455.
1884. *Cymbites*, Zittel, *op. cit.* p. 456.
1887. *Agassiceras*, Haug, Polymorphidæ; Neues Jahrbuch für Mineralogie, etc. Bd. ii. p. 94 (*pars*).
1889. *Agassiceras*, Hyatt, Genesis Arietidæ; Smithsonian Contrib. Knowledge, 673, p. 194 (*pars*).
1893. *Paroniceras*, Bonarelli, Sul Toarciano, etc.; Boll. d. Soc. geol. italiana, vol. xii. fasc. 2, p. 202 (10).

Also *Phylloceras*, Blake, and Wright, *pars*. *Harpoceras*, *pars*, Meneghini et auct. *Pœcilomorphus*, Bonarelli, *Pelecoceras*, Haug, etc.

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[1] See the author's previous paper, GEOL. MAG. July, No. 361, p. 298.

CYMBITES GLOBOSUS (Zieten).

1830. *Ammonites globosus*, Zieten, Verst. Würt. pl. 28, fig. 2.
1849. *Ammonites globosus*, Quenstedt, Ceph. pl. 15, fig. 8.
1853. *Ammonites globosus*, Oppel, Mittl. Lias Schwäbens. pl. 3, fig. 7.
1864. *Ammonites lævigatus*, Dumortier (*non* Sowerby), Bass. Rhône, pl. 18, figs. 5 and 6.
1885. *Ammonites globosus*, Quenstedt, Schwäbischen Ammon. (pl. 22, figs. 45, 46 ?),[1] pl. 42, fig. 29 only.
1889. *Agassiceras lævigatum*, Hyatt, Genesis Arietidæ; Smithsonian Contrib. Knowledge, 673, pl. vii. fig. 13 only.

(But not *Cymbites globosus*, Geyer, Ceph. Hierlatz; k.k. geol. Reichsanstalt, Bd. xii. No. 4, pl. iii. fig. 26, 1886.)

An involute, smooth, globose shell, always very small. There is a tendency to enlarge the umbilicus in the last whorl, and to produce an evolute shell. The septa are exceedingly simple for an Ammonite, one two-pointed lobe on the periphery, and two simple lobes on the side.

There is but little difference apparently between the forms figured from the *angulatus*-zone (Dumortier) and those from the *margaritatus*-zone (Quenstedt). Some of the figures quoted in the above synonymy are rather more widely centred than others; and this, together with the length of time above-noticed, makes it doubtful if they are all the same species. As, however, the figures are small it is not safe to pass a definite opinion on the subject one way or the other. Enlarged figures of the forms from each horizon, all to the same scale, are required. Further, it is necessary that the inner whorls of species on the same horizons which might be mistaken for them should be similarly figured.

This species is quoted from the *angulatus*-, *Bucklandi*-,[2] *obtusus*-,[2] *oxynotus*-, and *margaritatus*-zones. I can call to mind no other Ammonite with anything like this range.

CYMBITES LÆVIGATUS (Sowerby).

1829. *Ammonites lævigatus*, Sowerby (*non* Reinecke), M. Conch. pl. 570, fig. 3.
1849. *Ammonites Davidsoni*, d'Orbigny, Prodrome i. p. 225, No. 38.
1856. *Ammonites lævigatus*, Oppel, Juraf. p. 81.
1875. *Agassiceras lævigatum*, Hyatt. Two new genera Ammonites; Proc. Boston Nat. Hist. Soc. vol. 17, p. 226.
1887. *Agassiceras lævigatum*, Haug, Polymorphidæ; N. Jahrbuch für Mineral, etc. Bd. ii. p. 94.
1889. *Agassiceras lævigatum*, Hyatt, Genesis Arietidæ; Smithsonian Contrib. Knowledge, 673, pl. viii. fig. 12 (9, 11 ?).

This species is thinner and more evolute than *C. globosus*; and it may be regarded as a development of that form having characteristics which are due to the earlier inheritance of the adult features of that one. Hyatt's figure 12 is typical; but his figs. 9, 11, are developments of this species to the subcostate stage. They are possibly connecting links; thus his fig. 9 might lead to *Agassiceras*, and his fig. 11 to something like *planicosta*.

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[1] Probably young forms of *oxynotus*.
[2] These records may refer to *Cymbites lævigatus* (Sow.).

Sowerby was not the first to use the name *lævigatus* for an Ammonite; and, therefore, d'Orbigny placed the name *Davidsoni* instead of *lævigatus*. Oppel, however, says: "As Reinecke's *lævigatus* is a poorly-described, ill-defined species, and Lamarck's *lævigatus* is a synonym of *A. Lewesiensis*, I make use of Sowerby's name" (Juraf. p. 82). It is wise to follow this example, because there may reasonably be some doubt whether d'Orbigny meant by *Davidsoni*, which he placed in the Middle Lias, the same species as Sowerby's *lævigatus*, which is a well-known Lower Lias form. Further, Dumortier has applied d'Orbigny's name *Davidsoni* to a species which is not Sowerby's *lævigatus*.

Cymbites lævigatus is a well-known fossil at Lyme Regis; but curiously it found no place in Wright's Monograph. Oppel gives the horizon as just over *Am. Bucklandi* at Lyme Regis. Hyatt says that it occurs there with *obtusus*.

CYMBITES BERARDI (Dumortier).

1867. *Ammonites Berardi*, Dumortier, Bassin Rhône ii. pl. 21, figs. 5–7.

If this be not the young form of a larger Ammonite, then it must be regarded as an evolute development of *C. globosus*, which has acquired slight costæ, but has not lost its thickness. It looks not unlike a much larger edition of the inner whorls of *planicosta*; and it may be a species connecting *globosus* with *planicosta*.

From what Dumortier says, it occurs in the *Turneri*-zone.

CYMBITES OBESUS (Reynès).

1879. *Ammonites obesus*, Reynès, Monog. Amm. pl. xxvi. figs. 10 and 11.
1887. *Agassiceras obesum*, Haug, Polymorph.; N. Jahrbuch für Mineral, Bd. ii. p. 96.

This form is the further development—more evolute and showing a faint keel—of a form like the striate *globosus* (Hyatt's *lævigatus*, pl. viii. fig. 13); and it leads to the next species.

Bucklandi-zone (Reynès).

CYMBITES DAVIDSONI (Dumortier).

1867. *Ammonites Davidsoni*, Dumortier, Bassin Rhône ii. pl. 21, figs. 1 and 4.
1887. *Agassiceras Davidsoni*, Haug, Polymorphidæ; N. Jahrbuch für Mineral, etc., Bd. ii. p. 96.

This is a subcarinate form which seems to be merely a compressed development of *obesus* occurring on a higher horizon. The compression causes a difference in the whorl-shape—in *obesum* the whorl is depressed, in this species it is compressed.

Turneri-zone (Dumortier, interpreted).

CYMBITES, sp.

1885. *Ammonites*, cf. *globosus*, Quenstedt, Amm. Schwäb. Jura, pl. 42, fig. 39 only.

A somewhat evolute, densisept form which shows a small subcarina. The subcarina, which is a nascent feature in this series, is of interest in connection with *Cymbites sternalis* (see later).

Lias δ, Quenstedt. (*Margaritatus*- or *spinatus*-zones.)

CYMBITES STERNALIS (von Buch).

1843. *Ammonites sternalis*, d'Orbigny, Ceph. Jurass. Pal. franç. pl. 111.
1885. *Ammonites sternalis*, Quenstedt, Amm. Schwäbischen Jura, pl. 50, figs. 6 and 7.
1893. *Paroniceras sternale*, Bonarelli, sul Toarciano, etc., p. 202 (10).

Von Buch's work is not at present accessible, so that my remarks must be considered to refer to the above-quoted figures. D'Orbigny's figures appear to indicate that the carina was phyletically nascent in this species—a carinate periphery being, in this case, a developmental advance upon one uncarinate.

Upper Lias. Zone ?

CYMBITES SUBCARINATUS (Young and Bird).

1822. *Nautilus subcarinatus*, Young and Bird, Geology of Yorkshire Coast, pl. xii. fig. 7. Also 1828, ed. 2, pl. xii. fig. 9.
1829. *Ammonites subcarinatus*, Phillips, Geology of Yorkshire, pl. xiii. fig. 3. (The figure is really not identifiable.)
1862. *Ammonites subcarinatus*, Oppel, Pal. Mitth. pl. 44, figs. 1 and 2.
1876. *Phylloceras subcarinatum*, Blake, Yorkshire Lias, p. 297.
1884. *Phylloceras subcarinatum*, Wright, Lias Ammonites Pal. Soc. pl. 81, figs. 1–3.
1893. *Pœcilomorphus subcarinatus*, Bonarelli, Osserv. sul Toarciano; Boll. Soc. geol. italiana, vol. xii. fasc. 2, p. 5.

The subcarinate periphery of *sternalis* has developed into the bisulcate-carinate periphery of *subcarinatus*; the striæ have become ribs, and the small umbilicus has become larger; these are all progressive developmental features seen in analogous series.

This species appears to be well distributed, but not common. It occurs in Yorkshire, in the Midlands, and in the South of England. At Shepton Beauchamp, in Somerset, I found it *in situ*, just at the top of the beds, with *Harpoceras falciferum*—in fact just at the place where *Harpoceras falciferum* and *Hildoceras bifrons* came into contact.

The position of the two species, *sternalis* and *subcarinatus*, has always seemed to be a puzzle to palæontologists,[1] yet their relationship to the *globosus* series appears obvious from their septation and general characters. They differ only in their peripheral aspects; but this is merely a matter of development. When an Ammonite-periphery departs from the arched shape, it becomes either elevated or depressed medianly. In the former case its full phases of development are, in consecutive order, fastigate,[2] subcarinate, carinate, carinate-bisulcate. These changes can only become of generic value when the phyletic series splits into two stocks—one of which retains, say, the arched periphery, the other acquires a carinate periphery.

Now *Cymbites* is, in my opinion, the radical of all *Ammonaceæ*; and, unlike Hyatt, who goes to *planorbis* for his radical, I consider that *globosus*-like Triassic species—perchance *Nannites*—are the parents of our Lower-Lias Ammonites. From *Cymbites* the various Ammonite-stocks have been cast off at different times. Thus

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[1] "Forms very doubtful as to their position."—Neumayr, Unverm. Ceph. p. 67.

[2] *Fastigatus*, rising evenly, like the roof of a house; sloping.

Arnioceras is an example of a derivative from *Cymbites*, acquiring a carina while *Cymbites* itself remained uncarinate: here the carina becomes of generic importance. But in the cases of *sternalis* and *subcarinatus* there does not seem to be any breaking up of the stock — simply developmental change in *Cymbites* as a whole. In this case a generic name for *sternalis* otherwise than that of *Cymbites* does not appear to be needed; and Bonarelli's *Paroniceras* seems not to be required. That author places *subcarinatus* again in another genus—*Pœcilomorphus*; but this is unnecessary for the same reason. Further, the type species of *Pœcilomorphus* is the *Am. cycloides*, d'Orbigny, which possesses sigmoidal costæ, whereas those of *subcarinatus* are nearly direct.

Blake and Wright placed *subcarinatus* as a *Phylloceras*, but this was a decidedly unfortunate position, which the septa at once negative. No wonder that Bonarelli in quoting this adds ! after it.

As to the position in a family arrangement, the inclusion of *Cymbites* in the *Arietidæ* appears most convenient. The lower forms are decidedly goniatitic in appearance, and the suture-line throughout is of an Arietan character; further, *Cymbites* is the radical stock of several series of *Arietidæ*, though it seems also to be the radical of the *Polymorphidæ*,[1] *Deroceratidæ*,[2] etc. Biologically considered, however, the *Arietidæ* are the lowest of the *Ammonaceæ*.

Hyatt did not include *sternalis* and *subcarinatus* in his magnificent Monograph on the *Arietidæ*;[3] but he placed *lævigatus* in his genus *Agassiceras*; in fact, *Agassiceras* has priority of *Cymbites*. If it were to be insisted that *Agassiceras* should be the generic name for the *globosus*-group, then *Cymbites* would be lost, and a new name would have to be found for *Scipionianus* and allied forms. A reasonable way out of the difficulty seems to be the present use of *Cymbites*, and the employment of *Agassiceras* as a generic name with *Scipionianus* as the type-species. To that genus[4] would belong *Gaudryi* (Reynès) *Sauzeanus* (d'Orbigny)—removed from *Coroniceras*, where it was placed by Hyatt—and *Colesi* (J. Buckman), a species which has been altogether overlooked. The only difficulty in the matter is the possibility of *Oxynotoceras oxynotum* being derived directly from *Agassiceras*, in which case the name *Agassiceras* would be rightly employed for the *globosus*-series, and *Oxynotoceras* for the *Scipionianus*-series, and *Cymbites* would have to go.

The present is a suitable opportunity to give a description of *Agassiceras Colesi*.

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[1] Through *Polymorphites polymorphus* (Quenstedt).

[2] Through *Microceras planicostatum* (Sowerby). The *Stephanoceratidæ* are descended from the *Deroceratidæ*. The *Amaltheidæ* and *Oppelidæ* are not traceable to any of the *Cymbites*-forms directly, but they give ontogenetic evidence of a somewhat similar phase in phyletic development.

[3] Smithson. Contrib. Knowledge, 673.

[4] To that series *latum* ("*Coroniceras latum*," Hyatt) should probably be added as the form connecting *Agassiceras* with *Coroniceras*. The readiest generic distinction between *Coroniceras* and *Agassiceras* will be found in the greater degeneration of the septa in the latter, *Coroniceras* proper being distinguished by long lobes.

AGASSICERAS COLESI (J. Buckman).

1845. *Ammonites Colesi*, J. Buckman, Murchison's Geology of Cheltenham, second edition, p. 89, pl. 12, fig. 2.

Discoidal, much compressed, strongly carinate. Whorls in youth evidently gibbous, rather strongly and widely costate, gradually becoming flatter-sided, and ornamented with direct, slightly inclining costæ, which have a strong forward projection on the periphery, where they are very obscure. The costæ, which are slightly swollen at the edge of the inner margin, and again a little more swollen at the bend on the outer area, become practically obsolete towards the end of the whorl (specimen 89 mm. diameter). Periphery fastigate divided by a strong carina. Inner margin well-defined on last whorl, upright. Inclusion one-third.

This species is a dwarf development of the evolute form of *Scipionianum.*[1] It does not seem to show the unispinous stage of that species but exhibits only a costate stage, and even further decline at any early age, namely, obsolescence of the costæ. In fact degeneration of ornament is noticeable, while the form is small as compared to *Scipionianum.*

The absence of tubercles and the small size it has attained when the ribs become almost obsolete distinguish this form from *Scipionianum.* The original type-specimen, which was badly figured, of reduced size, in my father's work, is now in my cabinet. It came from the Lias of a railway cutting at Swindon, near Cheltenham, and seems to be a rare form. Unfortunately exposures of Lias in the neighbourhood, or in fact in the Vale of Gloucester, are few and far between now.

P.S.—Since the above went to press I have received a pamphlet, "Ueber Ammonoideen mit anormaler Wohnkammer," by Dr. J. F. Pompeckj (Vereins f. Vaterl. Naterkunde in Württ. 1894). This may be consulted in reference to *Cymbites*, pp. 238–240; and it reminds me that I have overlooked

CYMBITES CENTRIGLOBUS (Oppel).

Pal. Mith. p. 140, 1862, the type of which is, no doubt, the third reference given under *C. globosus* (above). From that place may be removed, to be added here, the second reference, and probably

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[1] Included by authors under the name *Scipionianus*, evolute and involute forms may be distinguished—the former in Reynès and Wright's figures, the latter in d'Orbigny's. Certainly Reynès calls his "*Ammonites Scipionis*," but this is only short for *Scipionianus*, d'Orbigny, whose authority he gives. Hyatt, however, distinguishes *Agassiceras Scipionianum* and *Ag. Scipionis* as two species. His "*Ag. Scipionis*" seems to be divisible into three: 1st, *Scipionis* (Reynès), which he quotes—an evolute form of *Scipionianus*, as alluded to above; 2nd, *Scipionianus olifex* (Quenstedt, Amm. Schwäb. Jura, pl. 17, figs. 7–10), which he also gives in his synonomy—this seems to be a costate retrogression of *Scipionianum*, and therefore a cousin of *Colesi*, from which it differs in being more involute, more closely costate to a larger size, and it probably deserves distinction as *Agassiceras olifex*; 3rd, a form of which an outline sketch is given in pl. 13, fig. 8 (Genesis *Arietidæ*)—a much more involute fossil than *olifex*, apparently very retrogressive, deserving a distinct name.

the fifth, and also Quenstedt, Jura, pl. 21, fig. 8. This is the *Margaritatus*-zone form. Oppel considers that Zicters's species is the *Obtusus*-zone form. The difference between them seems to be chiefly one of coiling, difficult to appreciate except in the handling of specimens.

At page 289 Pompeckj states in reference to *Cymbites* and an opinion of mine that Ammonites with "normal" body-chambers ("concentrically umbilicate") cannot be the descendants of those with abnormal body-chambers ("excentrically umbilicate," S. S. B.). In making this assertion he has overlooked *Dactylioceras* and *Stephanoceras*, both examples of the earlier inheritance of "excentric umbilication"—the result of ancestral "abnormal" body-chambers—producing "concentric umbilication." After all, the so-called abnormality is a very normal feature of phyletic development; and the incorrectness of Pompeckj's statement I hope to prove at another opportunity.

V.—TWENTY YEARS' WORK AT THE YOUNGER RED ROCKS.[1]

By the Rev. A. IRVING, D.Sc., B.A., F.G.S.

HAVING made my first acquaintance with that puzzling series of strata which bridges over the vast interval of geologic time between the Carboniferous and the Jurassic in the Nottingham district during a residence of eight years in the good old town (see Proc. Geol. Assoc. vol. iv.; also Quart. Journ. Geol. Soc., November, 1875), the meeting at Nottingham seems a fitting occasion for summarizing the results of further work in connection with those rocks, as opportunities have offered, during the last twenty years. Those investigations have extended to other parts of the Midlands, the Severn country, to Central Germany, the Eastern Alps, and to Devonshire.

As Reporter to the Sub-Committee of the *International Geological Congress* for the "Permian and Trias," I had unusual facilities for correlating the results of my own work in the field with those of other workers. For this reference may be made to the Report issued by the Congress.

In a paper on the "Classification of the European Rocks known as Permian and Trias" (GEOL. MAG. Dec. II. Vol. IX. 1882), I discussed more at length the results obtained down to that date, with the aid of the German literature of the subject, my own observations in the German and English areas, and the assistance of Prof. Jules Marcou. These results may be briefly stated as tending to establish for the European area generally the definite existence of two independent systems, the one (the Permian or Dyas) marking the close of the Palæozoic history of the European area, with which it is connected by its fauna and flora; the other (the Trias) forming the base of the Secondary series of rock-formations. I was, therefore, compelled to abandon the view as to the continuity of the

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[1] A paper read at the Nottingham Meeting of the British Association in 1893 (Section C).

whole series implied in the name "poikilitic," which I had (from a too limited sphere of observation) previously adopted for the North Midlands, as Prof. Phillips had done for the Severn country in his work on the Geology of Oxford, etc. Observations made in the Alps and information obtained from the writings of Gümbel and other Continental geologists, were communicated to this section at the Southampton meeting in 1882, and published in fuller form the same year (Geol. Mag. November, 1882). In that paper it is shown that the Alpine Trias admits of direct correlation with the Trias of Germany by means of fossil-contents (the horizons of the Muschelkalk being very definitely determined by many characteristic fossils common to both areas), while the Permian or Dyas (the Trias in part of von Hauer) is closely tied on to the true Trias by the transition series of Gümbel (plant-remains in the sandstones at Neumarkt near Bozen, fauna of the Bellerophon Limestone). The importance *of further investigation of the true stratigraphical relation of the Dyas and Trias of Germany,* and (as involved in this question) *the true position of the Bunterschiefer of Murchison, were thus brought into prominence.* This investigation (with the assistance of Prof. Geinitz, Prof. Ritter von Hauer, Prof. Liebe, and other German geologists) I was able to make in the summer of 1883. The results were given to the world in two papers, one "On the Dyas and Trias of Central Europe, and the true Divisional-line of those two Systems" (Quart. Journ. Geol. Soc. August, 1884); the other on "The Permian-Trias Question" (Geol. Mag. July, 1884). Those two papers were received with expressions of the highest appreciation by so great an authority as Prof. Marcou, and my results were confirmed by the work of Geinitz and Dittmarsch in the following year (*Nova Acta Acad. Leopoldinæ,* 1885)—"On the limits of the Zechstein Formation and of the Dyas in General," by H. B. Geinitz. The contention that the so-called Bunterschiefer was an uppermost member of the Trias, was thus refuted all along the line; and a stratigraphical break between the Dyas and Trias in the German area was thus established on physical as well as on palæontological evidence sufficiently strong to carry conviction to the mind of Prof. Hull, who had previously given his adherence to the view implied in the Permian Trias of Murchison.

The chief results down to 1884 would thus appear to be:—

1. The more complete establishment of the Permian or Dyas as an integral and independent system, though subordinated on palæontological grounds to the Carboniferous, to which it is in some localities (*e.g.* in the Warwickshire area) conformable, though more often unconformable, as in Notts, in the North-Eastern area (where the Rothliegendes is almost, if not entirely, absent), in Thüringen, in Saxony (Zwickau and other places in the basin of the Erzgebirge). This differentiation has been further confirmed by the later work of Mr. De Rance in the Midlands, even for the Warwickshire area.

2. The existence of a great difference in the relation of the Permian and Trias to the adjacent palæozoic and archæan land, the coarser detritus of the Permian breccias (both in the German and

English areas) being traceable to the older rocks of the region as their source, in the valleys and creeks and fjords of which it was deposited; while the materials of the coarser sediments of the Trias (Bunter) are of a more varied nature, including, and in some localities almost entirely made up of, well-rolled detritus (often containing fossils of Silurian age) derived from a wider area, and in some cases transported from a considerable distance. The striking contrast between the German Dyas and Trias, based on physical facts alone, taken along with the stratigraphical hiatus which exists between them, and the complete concordancy of the whole succession of the strata which constitute the German Trias, harmonizes fully with the palæontological evidence which has been worked out so thoroughly by Geinitz and others on the Continent, and by King in this country.

The Devon Area.

With the results indicated above pretty well established and the knowledge gained at first-hand of the German Rothliegendes and its English representatives, it is not surprising that on my first examination of the Red Rocks of the Devon Coast Section in 1887 I was unable to accept the mapping of them as wholly of Triassic age, or the interpretation of that magnificent coast section from Seaton to Torquay, which had been published by Mr. Ussher in the Quart. Journ. Geol. Soc. The attempt on my part to carve out a Permian system in the paper published in the Quart. Journ. Geol. Soc. in 1888 was officially ignored; but when, after some delay (mainly on official grounds), Prof. Edward Hull was able to verify my main contention from field-observations, a very energetic attempt was made to explain it all away (see discussion of the Papers by Prof. E. Hull and A. Irving in Quart. Journ. Geol. Soc. for 1892). Further work in the field in the year 1892 (see Quart. Journ. Geol. Soc. for February, 1893) led to the definition of the base of the Keuper along the Otter Valley, as it had been previously recognised in the Valley of the Sid. The surrender by Prof. Hull of the only point of importance on which we had differed,[1] on going over the ground together the year before, cleared the issues of the controversy, and made a complete and direct correlation of the Devon Red Rock Series (from stratigraphical and lithological evidence) with those of the Midland and Severn country, and with those of Central Germany, not only possible but easy.

In my 1892 paper I dwelt upon the importance of the evidence furnished by the contemporaneous volcanic rocks in the breccia-sandstone series of Devon (just as they occur in the Permians of the Solway Basin and of Central Germany), and on the other hand the entire absence of them from the undoubted Trias of Devon (as they are absent from the Trias of the two regions just mentioned). The value of this comparative evidence was generally admitted in the discussion of that paper at the Geological Society. I felt, however,

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[1] That is to say, the age of the great red marl series below the Budleigh Salterton Pebble-bed. (See Q.J.G.S. vol. xlix. p. 83.)

that clear and unmistakable proof of the *contemporaneity* of the intrusive rocks with the breccias was wanting; and it remained, therefore, a somewhat moot point whether the breccias were not on the whole younger than the volcanic outbursts of the district, the fragments of which are abundant in the breccias. Since this meeting began, however, Mr. Ussher has kindly informed me of observations made by himself of the volcanic rocks overlying portions of the breccia-series, which we may, therefore, without much hesitation, correlate with the pre-porphyritic stage of the Rothliegendes of Central Germany. We may thence conclude that the very oldest Permian rocks of Europe are represented in the Devon region.

Prof. Hull has in his paper of 1892 (see Quart. Journ. Geol Soc. vol. xlviii.) dwelt upon the great unconformity of the breccias with the Devonian Limestone, as seen in the cliffs above Babbacombe Bay, where the detrital materials appear to fill an ancient (pre-Permian) fjord or valley of the older Devonian land: to this I should like to add an instance of unconformity, exhibited in a very fine section at Saltern Cove, near Paignton, where the breccias with intervening bands of coarse sandstone are seen resting nearly horizontally upon the planed-off edges of the stratified slates and grits of Lower Devonian age. We have, therefore, in the neighbourhood of Torquay clear evidence of even a greater break in the stratigraphical sequence between the lowest portion of the Permian and the older rocks than that which exists at Zwickau and other places in that part of Saxony between the unconformable Coal-measures and Naumann's "pre-porphyritic stage" of the Rothliegendes; or that which exists (as seen in the Kimberley section) between the unconformable Upper Permians (Magnesian Limestone and Marl Slate) and the highly inclined Coal-measures.

Subjoined are two section-diagrams illustrating this unconformity in the Devon and Notts areas:—

The frank recognition of the presence of a system of rocks of Permian age in Devonshire by Sir A. Geikie in his Presidential Address to the Geological Society of London in 1892, and the re-mapping of the Devon Red Rocks (nearly according to the boundary-lines indicated in my two later papers) on the new edition of the one-inch Map of the Geological Survey, which is exhibited at this meeting of the British Association, is a result, not only gratifying to myself, but one on which I think we may congratulate the Director-General and his colleagues. The older mapping of the Devon area by De la Beche is now officially superseded by the introduction of the Devon Permians (*cf.* the writer's remarks, in Q.J.G.S. vol. xlix. p. 83).

Physical History of the Series.

I have written so much in my various papers on the physical relations of these rocks to one another, and to the older formations, that it would be out of place on the present occasion to do much more than refer to those papers.

The land-shore- and bay-origin of the great detrital Permian deposits (the breccia-sandstone series), claimed by the German writers for their area, is found to be equally true for the West Midlands and for Devonshire; but my work has led me (as my papers show) to recognise *terrestrial* deposits in them to a greater extent than our German confrères have done.

To a geologist familiar with the Permian of Notts, there is little difficulty in recognising the great red-marl series of Devon west of the Aylesbeare line of hills, as replacing homotaxially the marine Magnesian Limestone of the northern area; since in Notts the two are bound together by the closest of all ties—interstratification. And the marls of the two areas are identical in character. That they are the finer washings-out from the coarser detritus, and the sediments thrown down along with the chemically-precipitated peroxide of iron (to which they owe their prevalent colour) in shallow enclosed basins, is to me the most probable theory as to their origin; and there would appear to be no serious objection to the view which regards them as the "Continental" equivalents of marine Magnesian Limestone of the North of England and the marine Zechstein of Germany, with both of which such marls are intimately associated.

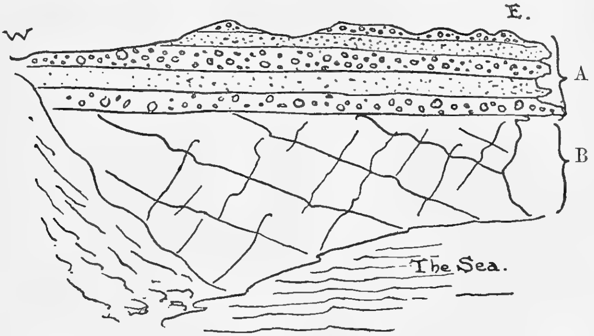

Fig. 1.—Coast-section at Saltern Cove (Tor Bay), Devon, showing unconformity of Permian breccia-sandstones with the Lower Devonian.

A Breccias and thin beds of irony sandstone.
B Lower Devonian slates with bands of quartzite, intersected by quartz veins.

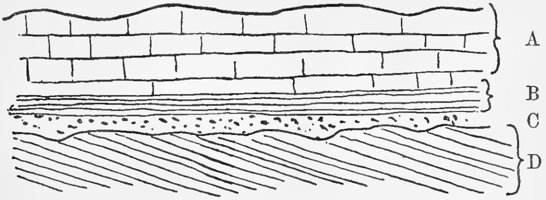

Fig. 2.—Railway section at Kimberley, Notts, showing unconformity of Upper Permian (Magnesian Limestone and Marl Slate) with the Coal-measures.

A Magnesian Limestone. B Marl Slate. C Breccia. D Coal-measures.

As to the coarser detrital material of the Bunter, which clearly gives us a record of conditions very different from the lacustrine conditions under which the Keuper marls were deposited, I have never been able to see how a riverine origin for these coarse and irregular deposits can be reconciled either with their structure, their composition, or their geographical distribution. There are plenty of sections in and around Nottingham (Castle Rock, Church Cemetery, Sneinton, and other places) where these structural characters may be studied. More recent work has but confirmed the view I put forward twenty years ago as to the rocks of the Pebbly Sandstone type (such as we have in Notts) consisting of Triassic *sandbanks* deposited in narrow *tidal* seas; and more extended observation of the great pebble-beds of the Warwickshire and the Budleigh Salterton type, compels me to regard them as the "chesil-banks," which formed the shore-equivalents of the sandbanks.

VI.—ON SOME LIFE ZONES IN THE LOWER PALÆOZOIC ROCKS OF THE BRITISH AREAS, AS DEFINED MAINLY BY RESEARCHES DURING THE PAST 30 YEARS.

By HENRY HICKS, M.D., F.R.S., F.G.S.

IT not unfrequently happens in these days of superabundant scientific periodical literature that articles appear in which the authors, usually unwittingly, and generally from want of leisure, fail to give an adequate idea of the work of authors anterior to periods with which the writers are more specially acquainted. The injustice thus perpetrated can best be prevented by giving occasionally a brief resumé of work done in certain formations and in special areas during a given period. The present time seems to me appropriate for giving such a resumé in the GEOLOGICAL MAGAZINE. The first Number of the GEOLOGICAL MAGAZINE was published exactly 30 years ago (July, 1864), and in articles in the first Number by two eminent palæontologists (Prof. R. Jones, the then Editor, and Mr. J. W. Salter) we have clear and definite statements relating to the advances which had been made, and to the prevailing influences affecting geological thought at that time. The writings of Edward Forbes, Darwin, and Huxley were then producing a marked effect, and workers were led to search more carefully than had ever been done before for causes which may have tended to influence the distribution of life in the past, and many of the methods of research now in use are the outcome of the advances then made. It was undoubtedly a period marked by great changes in *methods* of research, but, fortunately, facts which had been well established and the means by which they had been obtained were not forgotten. The general effect was well described by Prof. Rupert Jones in the following passage in the Editorial Article, Vol. I. p. 3, entitled "The Past and Present Aspects of Geology": "It is now rightly considered legitimate to call in the agency of forces which, though not seen in operation in nature, may be evoked in the laboratory; and we thus seem to be in a fair way of obtaining an insight into the causes of some of the most obscure physical phenomena. These attempts to enlarge the legitimate field of geological investigation may, therefore, be considered to have been attended with results beneficial to Science; and instead of the single line of research of a century ago, we have now a perfect labyrinth, each path being an avenue of thought paved with its fundamental ideas and supported and lined by the facts that have been accumulated by Geologists during the last fifty years.

"The present epoch in the history of Geology may also be said to be characterized to some extent by scepticism as to the exact truth of at least one of the fundamental principles to which we have alluded, namely, the contemporaneity of strata which contain the same or similar fossils, and which are geographically far apart. The late Professor Edward Forbes was the first to cast doubt on the general belief, and his opinions have been recently reiterated in a more or less modified form by several other geologists. Moreover, there is a general tone of wholesome scepticism respecting other matters, noticeable in recent geological works; especially as regards the simplicity of several phenomena, which are thus apparently being shown to be much more complex than has been supposed, whilst some few others are being proved to be more simple."

In the same Number, page 5, Mr. Salter, who two years previously had discovered *Paradoxides Davidis* at St. David's, and to whom in the meantime I had submitted material enough to enable him to announce at the meeting of the British Association of that year that the work had "already brought to light more than thirty (new) species of fossils, most of them Trilobites" (Geol. Mag. Vol. I. p. 289), and who was then about describing the fossils obtained by Mr. W. Vicary of Exeter from the Budleigh Salterton Pebble Beds, in his article "On some Points in Ancient Physical Geography, illustrated by Fossils from a Pebble-bed at Budleigh Salterton, Devonshire," said: "A sea-side walk, with a hammer in the pocket, may discover a new world by accident; for, as Darwin, Lyell, and Ramsay have told us, the unrepresented past times have been *far greater* than those of which we have a geological record, and fragments of the missing pages may turn up at any time. It is hard to realize this, no doubt . . . . . yet every now and then we alight upon new geological kingdoms; and still oftener on new provinces of old and well-established ones. An obscure, but novel, group of organic remains comes to light in some well-worked district, for which we have as yet no fixed geological place. Then the bed containing it is found to have a more extended range; it begins to be recognised by a local name; and, after undergoing the usual ordeal of doubt and disbelief attached to a new-comer, and being variously assigned as a local variation of some better-known *stratum*, it settles at length into its rightful position, and secures its hold of the public. And when this is done, we find it is no stranger after all—that some twenty or thirty feet of shales, for instance, packed in with the base of our Lias, are really the representative of some great Alpine Limestones, which range from the Tyrol to the sources of the

Ganges, and which are only not as important as the Dudley Limestone because they have been as yet less studied and described."

It is sometimes stated that the work of correlation by the study of the distribution of organisms in the strata received about this time a severe check, not only because of the views already referred to, but also owing to the doctrine of colonies, as propounded by M. Barrande, and that this was especially the case with the Lower Palæozoic rocks. Mr. Salter's remarks show clearly that he, at least, was not unduly influenced by the wave of thought just then affecting the geological mind; and there is abundant evidence in the many papers published about this time and subsequently on the Lower Palæozoic rocks of Wales to show that though the prevailing views were given due consideration they did not in the least prevent the facts obtained being always fairly stated and supported.

In regard to Life Zones, which it has been stated were then particularly neglected as being objects of distrust, I need only say that so far as the Welsh rocks were concerned from the very commencement of our work in 1863, the Life Zones were clearly indicated, the range of each species was given, and the organisms supposed to be most typical of the zones and most useful for purposes of comparison were always carefully mentioned. As evidence bearing on this point I need only quote the following passage from my paper, "On some undescribed Fossils from the Menevian Group," in the Quart. Journ. Geol. Soc. May, 1872, pp. 180, 181: "During my researches at St. David's I have, from time to time, endeavoured to note the range of the genera and species as they were discovered; and the results have been given in the several tables published in the Journal of the Geological Society and in the British Association Reports. I have not, however, been able to obtain much evidence by this means to support the theory of colonies propounded by the eminent palæontologist, M. Barrande; but several very interesting facts have been noted, which it might be well again to refer to. The Brachiopods here, as in other formations, have a greater range than any of the other fossils, the same species extending in some cases through the whole Cambrian series. The sponges come next; for *Protospongia fenestrata* occurs in the Longmynd group, in the Menevian group, and again in the Upper Lingula flags, to the base of the Tremadoc rocks, where it was found by me a few years since when examining these rocks in North Wales. These, therefore, continued to live on during the deposition of from 8,000 to 10,000 feet of strata. None of the other Menevian species have any considerable range; and but very few of the genera pass beyond the Menevian boundary. Out of ten genera of Trilobites, one only, the little *Agnostus*, passes upwards; and not one species out of the whole number, in all twenty-nine. Indeed, the range of all the species is very limited; and each one seems to mark a special zone, where it flourished for a time and then disappeared, perhaps to be followed by others of the same type but never to re-appear. The Crustacea are, therefore, in these earliest rocks, the surest indices of the age of the strata, and the best guides in defining the several zones; for the more perfect the forms and the higher the development, the less likely are they to have a great range."

Though Trilobites were found by us to be of greatest value in defining and correlating the zones in the Cambrian rocks, in succeeding sediments Graptolites and other organisms have proved of equal value. Sometimes it so happens that the forms which appear to be the most typical of an horizon in one area are entirely absent from another geographically not far distant; but in such a case, unless it can be shown that the physical conditions must have varied sufficiently to have affected the whole fauna, there are usually evidences of a sufficient number of the associated organisms present to enable the zone to be easily defined.

In working out zones it is necessary, therefore, to register with care all the forms which occur with the so-called zonal fossils, and also the evidences in the strata of the physical conditions prevailing when the sediments were accumulating.

(*To be continued.*)

VII.—THE PRIMITIVE BOULDERS OF THE YORKSHIRE COAST AND THEIR LESSONS. A REPLY TO TWO CRITICS.

By Sir HENRY H. HOWORTH, K.C.I.E., M.P., F.R.S., F.G.S.

I CANNOT sufficiently welcome the two letters devoted to myself in the July Number of the GEOLOGICAL MAGAZINE; and I only hope Mr. Harker and Mr. Deeley will continue to face the issues between us, and not be content, as others have been, with fulminating more or less testy protests, and then retiring from the field.

Mr. Deeley objects to my statement that the tendency of the most philosophical writers on geology is to go back from the scholastic formula of Uniformity enunciated by Lyell and Ramsay to more inductive reasoning. With the writings of Suess and Lapparent, of Spencer and of Prestwich, before me, all of them veterans of the first class, I cannot either understand or appreciate Mr. Deeley's protest. Perhaps he means that the geological world is limited to English official geologists; most of them scholars of Jukes and of Ramsay, who naturally echo their masters' views. He will not expect me to agree with this delusion.

Turning from this wide issue to the narrower one of ice-sheets, I must again emphatically say that English geology is making itself ridiculous in the eyes of men trained as mathematicians and physicists by some of its professors habitually appealing to causes and to dynamical forces whose competence has not been proved or even shown to be consistent with the laws of matter. That ice moves as a plastic body has been abundantly proved by experiment. That moving thus it can travel over hundreds of miles of level country, or up and down great hollows like the Baltic and the North Sea, without an adequate *vis a tergo*, is incomprehensible to me. That such a *vis a tergo* can only, in the case of such ice-sheets, be obtained by postulating a considerable slope to the ice surface is equally plain and equally admitted. How this slope is to be obtained, however, no one has yet explained, nor can I see how it could exist without burying every available land surface in Scandinavia, in the Laurentian Highlands, etc., etc., under deep ice. If the land surfaces were so buried it is impossible to understand whence the boulders could be derived, for they only come from exposed rocks, and to explain how it is that the higher parts of the Dovrefelds, etc., are not ice-marked. These are merely samples of the many difficulties which many inquirers have raised, and which I have tried to condense and focus in my recent books. These books, not having been written by an official geologist, and therefore lacking official inspiration, have probably not been read by my critics. Perhaps they will favour the readers of the GEOLOGICAL MAGAZINE with some adequate reply to them now.

But I must not content myself with *a priori* arguments, unanswerable though they may be. I want to ask my two critics how an ice-sheet in the North Sea is consistent with the splintered and pinnacled Lofoden Islands?—a question Matthew Williams long ago asked, and which has been strongly urged in a long letter I have received on the subject from Professor Bonney; or with the facts so eloquently put forward by Pettersen, the most competent observer who has written on the geology of North Norway, and who has shown that the inland ice of Northern Scandinavia did not even reach the string of islands lining its western coasts, much less invade and cross the North Sea. It is no use adopting the attitude of the ostrich towards facts like these. The ostrich is a very poor geologist, although some people think that he can thrive on boulders and gravel.

Again, if a Scandinavian ice-sheet reached Great Britain, how is it there are no boulders here from the western coasts of Norway at all? How is it that the few boulders which have been recognised as Scandinavian by Scandinavian geologists, who know their own rocks well, come not from Western Norway, but from the famous "Viken"—whence the Vikings got their name, and whence they sailed; and that in order to reach Northern England on the back or under the foot of an ice-sheet, that ice-sheet must not only have meandered like a serpent and ignored the lines of least resistance, without any assignable cause, but have cut right through and across the main ice-sheet which was presumably being shed in sporadic fashion by the great Dovrefelds? The whole position is so grotesque, when brought face to face with elementary facts, that I can only explain the logic of its champions on the supposition that the ice they appeal to is not frozen water but composed of brain dust.

One of my critics thinks he disposes of me by the statement that the so-called glacial beds of East Yorkshire are not heterogeneous masses of mixed mud, sand, clay, and gravel, but are assorted and sifted. Of course they are, and that is why these beds have nothing to do with glaciers or with ice in any form. Every moraine and every ice deposit known to myself, except in some very local cases, is a heterogeneous mass, and is not assorted in this way; and human ingenuity has hitherto been baffled in trying to show how a great moving mass of very nearly rigid ice can sift sands and gravels and tough clays apart from each other and deposit them successively in the way these beds are laid down. Of course, if we go to the moon for our cheese instead of to some farm, where we can examine the process of making it step by step, we can postulate anything as to the process, but the result must be moonshine and nothing but moonshine!

Lastly, as to the provénance of the Yorkshire boulders: here, unfortunately, we differ absolutely about the facts. I have spent months on the coasts of Yorkshire and East Anglia, and have examined hundreds of boulders there, but I am bound to say I have never had the luck to find an unmistakable Scandinavian one.

There are vast numbers of boulders from the sandstones and the limestones of the Carboniferous series, and a large number from the basaltic and other dykes which cross and permeate those beds. Mr. Lamplugh, who has collected and tabulated hundreds of the boulders, says that those from the Carboniferous beds, including the dykes, form about ninety per cent. of the whole. I do not know anyone who has brought these boulders from Scandinavia. Nor do I know anyone who has ventured to suggest that the Oolitic, Liassic, and Cretaceous pebbles (which I have collected in considerable numbers) have come across the sea either. These latter everybody known to me attributes to the local beds. As to the Carboniferous boulders and their parentage, Mr. Lamplugh says: "With the definite and well-known trail of the Shap granite and Brockram erratics to guide us, we need feel no uncertainty as to the quarter whence the Carboniferous rocks have been derived. It is clearly the elevated region lying to the north-westward, 80 or 100 miles away, which has been the main contributor, and the route must in most, if not all cases, have been down Teesdale, and thence south-eastward along the coast."

Let us put aside all these admittedly English boulders, therefore, and limit ourselves to the primitive stones, which in the various collections made by Mr. Lamplugh formed respectively 3·4; 2; 5·7; 2; 3; 4; and 1 per cent. only of the whole.

It was these primitive boulders only which were sent for examination to Mr. Harker. Of them he says, "that the bulk of the specimens selected and submitted to him, of granitic, gneissic, and other crystalline rocks, might have been derived, so far as their individual character is concerned, either from Scandinavia or from the Scottish Highlands." This is assuredly a very important admission; made by Mr. Harker, not when engaged in a polemic with a man of Gath like myself, but when calmly summing up the evidence in the Transactions of the Geological Society of the West Riding of Yorkshire, new series, vol. xi.

Among the boulders just named are some of Shap granite, which are unmistakable, and others which are apparently derived from the altered beds in contact with the Shap granite and from the Cheviots. Notwithstanding this concurrent evidence about the British derivation of the immense proportion of the boulders, Mr. Harker proceeds to argue, apparently on purely fantastic grounds, that the primitive boulders which *may have* come from Scotland really came from Scandinavia. He says that "the movements of the ice and the consequent directions of transport render this conclusion probable." This is assuredly putting aside empirical methods in favour of *a priori* and fantastic ones with a vengeance. Let us translate the argument into a syllogism: "Because more than nine-tenths of the Yorkshire boulders, including a great many primitive ones, are known to have come from the north-west, *therefore it is probable that the stones of doubtful origin found among the other tenth came from the north-east.*" Could he or I put an inconsequent argument more clearly?

There still remain a few boulders—*a very few*—which, so far as our present evidence goes, were apparently derived from Viken, in Norway; but even here Mr. Harker speaks with a dogmatism which is unusual in science. When we remember how long it took to discover the rock *in situ* from which the picrite boulders in Anglesea were derived, it is a very unsafe thing to assert dogmatically that a particular kind of crystalline rock *does not occur* in any part of Cumberland or Scotland, and must have come from Norway. I have the authority of one petrologist, quite as distinguished and more experienced than Mr. Harker, who is as sceptical as I can be about these *ex cathedra* judgments. It is noteworthy, by the way, as Mr. Harker admits, that while boulders of augite porphyry like that found at Laurveg have occurred on the Yorkshire coast, none have occurred there of the elæolite syenites which are associated with the augites in Norway.

But granting that some of these stones may have come from Norway—

A distinguished Norwegian geologist, belonging to the Geological Survey of that country, who wrote a paper in the Quart. Journ. Geol. Soc. on the East Anglian boulders, tells us that out of the many he saw only two seemed to him to be of Norwegian origin.

But let us turn to Mr. Harker himself. In his appendix to Mr. Lamplugh's second and third papers he only mentions two as similar to the augite syenites of Southern Norway; to these he adds two more in a subsequent paper. He also mentions two boulders of saussurite gabbro whose provénance seems to be equally established as from the same district; and this is all. If this be all, Mr. Harker has assuredly been making a voyage to one of Swift's regions of cloudland when he speaks of hundreds of Scandinavian boulders as having been found in as many yards of the Yorkshire coast. As a matter of fact, those he has described amount to six, all told; and to explain these six boulders he would fill up the North Sea with ice and then make it travel by a labyrinthine path which might have puzzled the Minotaur himself. I prefer to think that his six boulders, if really Norwegian, were brought by another agency, and very probably by some ship—either by a Viking, whose countrymen used stones for anchors; or as ballast, as Mr. Hughes has seen other primitive boulders scattered on the coast of Norfolk. What I object to most emphatically is the continual manufacture of these gigantic postulates on the most fragile evidence by men whose work and gifts give them a wide audience.

REVIEWS.

I.—A MANUAL OF THE GEOLOGY OF INDIA. Chiefly Compiled from the Observations of the Geological Survey. Stratigraphical and Structural Geology. Second Edition, revised and largely re-written by R. D. OLDHAM, A.R.S.M., Superintendent, Geological Survey of India. Published by Order of the Government of India. 8vo. pages i.–xxiii. and 1–543. With several Plates and Woodcuts, and large Geological Map. Calcutta and London, 1893.

THE first edition of the "Manual of the Geology of India," published in 1879, consisted of two thick Parts or volumes, and a large map, by H. B. Medlicott, Superintendent, and W. T. Blanford, Deputy Superintendent, of the Geological Survey of India. This was followed in 1881 by Part III., on the "Economic Geology," by V. Ball, Officiating Deputy Superintendent; and in 1887 by Part IV., "Mineralogy," by F. R. Mallet, Superintendent of the Geological Survey of India.

The Parts I. and II. above-mentioned were carefully reviewed in the GEOLOGICAL MAGAZINE, Decade II. Vol. VII. 1880, pp. 79–85 and 127–134. The important conclusions arrived at by Messrs. Medlicott and Blanford, from the geological researches made and recorded by themselves and their colleagues in the Survey, were noticed in detail in the review alluded to above, and were shown in classified tables taken from the "Manual," especially as to the successional formations, severally in "peninsular" and "extra-peninsular" India, with their approximate thicknesses, characteristics, geographical range, local types, and foreign equivalents, as far as then known.

The labours of the Survey since that time (1879) have been continuous and successful in many directions, as its rich and well-conducted "Palæontologia Indica" (many volumes in Series 4, 9, 10, 12, 13, and 14; with an Index, 1892, to the whole issue), and its "Memoirs" (vols. xviii. to xxiv.), fully prove.

In the title-page of this new Number of the "Records" (the "Manual of the Geology of India—stratigraphical and structural—second edition, revised and largely re-written, pp. 543, with numerous tables and geological maps. Royal 8vo. half-calf, 1893. 16*s*."), unfortunately, the names of the original authors have been omitted,—apparently by inadvertence, we must suppose, for one of them is mentioned at page x. as having assisted in the preparation of this second edition. This omission is greatly to be regretted.

In a prefatory note the Director of the Survey explains why this new edition was unavoidably delayed, and why he "accepted Mr. R. D. Oldham's offer to prepare a fresh issue" of the book "accordant with our progressive Survey of the Empire."

In this new edition, instead of describing the geological features and conditions of separate districts on a geographical plan, the new arrangement takes the formations of the two (peninsular and extra-peninsular) regions together in their chronological order. Thus the two tables at pages 82 and 83 of the Geol. Mag. 1880, have to be taken together. Some corrected determinations of the true age of certain groups of strata allow of this new plan being adopted with advantage. For those parts of the country where the Survey has not been able to add any particulars, the text "has been allowed to stand practically as in the original publication"; but revised and condensed. Some alterations, on account of advancing knowledge, have been made where necessary. "In the Table of Contents, the portions in which the First Edition has been taken as the basis of the text are distinguished by a different type from that which refers to portions which are new or have been entirely re-written." Judging from the appearance of the new among the old headings, the proportion of the new to the old matter is about 9 to 22.

The first paragraph in Chapter I. is certainly re-written, but is rather longer than at page ii. in the first edition. The rest of the chapter confines itself mainly to the Physical Geography, without so much introductory and general classificatory matter as was given in 1879. Chapter II. shows that the metamorphic and crystalline rocks are now better known. The non-fossiliferous older sedimentary rocks are still referred to some "Transition" series or systems (Chap. III.)

The "older palæozoic" (Vindhyan, or Cambro-Silurian, for the upper, and Cuddapah for the lower) systems, both in the peninsular and the extra-peninsular areas, and including indications of Devonian in Thibet, and Silurian in Burma, are dealt with in Chapters IV. and V. The Carboniferous and Triassic rocks of extra-peninsular India (the Salt-Range, Kuling, Simla, Kashmir, etc.), with possible glacial beds, come into successional order here (Chap. VI.). The important Gondwána system succeeds (Chapters VII. and VIII.); with the Coal-beds of Damuda, Ráníganj, etc., with their interesting fossil flora, fishes, and reptiles. The correlation of these formations with others in Australia and South Africa is carefully reproduced. The Lower Gondwána comprises stages from Carboniferous to Trias; and the Upper Gondwána is Jurassic. The marine Jurassic strata of Cutch, Western Rájputaná, Spiti, Hazára, etc., are found in Chap. IX.; and the marine Cretaceous beds of the Peninsula, in Chap. X. The affinities of the latter with extra-Indian Cretaceous formations is of considerable interest; so also the relation of the great Trappean formation of the Deccan to the same series and to the Eocene volcanic rocks of the Himálaya, somewhat condensed from the first edition. The extra-peninsular Cretaceous rocks are briefly treated, with some new notes, in Chap. XII.

The Tertiary strata of the Peninsula (Chap. XIII.), and of the Himálaya (Chap. XIV.), have been carefully re-arranged, with new information on some points. The great and extensive Nummulitic Limestone (Eocene) comes into this part of the series (the reference "Nummulites, cretaceous, in Balúchistán, 291," in the Index is a mistake; no *Nummulites* are really present). The extraordinary fossil Mammalian Fauna of the Sewalik strata, and their associated land and fresh-water shells, appear in their place as belonging to the Upper Tertiary in Chap. XIV. The Laterite, the Pleistocene, and Recent deposits, and the features and composition of the great Indo-Gangetic plain, follow with some additional knowledge in Chapters XV., XVI., and XVII. Chap. XVIII., on the Origin and Age of the Himálayas, and Chap. XIX., on the Geological History of peninsular India, are newly arranged and freshly written.

Besides some 27 woodcuts, in the text (mostly new), there are 16 plates (not numbered) of fossils, "phototyped" from either some re-arranged figures of the former plates, or specimens different from, but more or less similar to, those figured in the previous plates,—also a fine view, from a photograph, of the snow-capped Simvo (22,300 feet high) in the Himálaya,—a map of the Hill-ranges of India, modified from the former map,—a map and plans of the Volcanoes of Burma and Bay of Bengal,—a map of the Indo-Gangetic Alluvium,—a plate of sections of the Himálayas and Sub-Himálayas; also a good map of the Himálayas,—and a new geological map of India, dated 1891. Moreover, a useful "Geographical Index of Indian localities" fills 30 pages.

This book cannot but prove useful to those who wish to enquire into the structure and physical history of India and adjoining territories. Some notion of the characteristic fossils can be got from the figures; but they are far inferior to the plates in the first edition; and so indeed is the printing and general finish of the volume. The Index is faulty; many points are poorly treated; for instance, Baluchistán does not take a place in the alphabet, but appears incidentally, once with a wrong page, and once with a palæontological mistake (noticed above); and Nagpur is omitted altogether, though an important centre of geological facts both physically and historically.

When the next edition is required (it may be soon, with advantage), better paper and type, a more exact style of printing scientific and technical words, some improvement in other editorial points, and a more considerate title-page will make it compare more favourably with the first edition, and greatly enhance its value. T. R. J.

II.—An Index to the Genera and Species of the Foraminifera. By Charles Davies Sherborn. Part I. A to Non. Smithsonian Miscellaneous Collections, 856. 8vo. City of Washington. 1893.

AMONG the many minute organisms in the sea are those which influence the features of the sea-bottom, by either local or widespread accumulation of what we may call shell-matter. Sometimes this occurs to such an extent as to modify the fairway of ships;

and in past times it formed shoals and banks of extensive sea-beds, which have remained more or less consolidated as recognizable limestones among the various strata constituting the accessible parts of the Earth's crust. These microzoa are chiefly Foraminifera, of which we have heard and read much since the Expedition for the arrangement of the Atlantic Cable was reported in the Newspapers, and the subsequent scientific exploration of the "Challenger" was explained in various ways. For a century and more, however, before that period, scientists had known much of both the deep-sea life and the shore-life of organisms similar to what the deep-dredging brought up. Naturalists had already devoted labour and thought to the elucidation of these interesting objects; and descriptions with illustrations, often good, though rarely perfect, had accumulated in memoirs and books on the several kinds, genera, and species, of the Foraminifera. These little creatures were easily mistaken one for another, within certain limits of form and structure; hence names for them multiplied without clear distinctions, just as different observers in many cases took up really similar individuals and treated them with their own notions and new names. Especially this occurred with fossil forms, which offered a fascinating study, but required a previous knowledge of the results of former observations. To meet this difficulty, bibliographic lists had been appended to some of the best memoirs on the Foraminifera; but a far more exact catalogue of the authors and their works was supplied in 1888 by Mr. C. D. Sherborn; and was duly noticed in the GEOLOGICAL MAGAZINE for January, 1889, pp. 34, 35. Feeling that still more was required to enable workers to see through this crowd of writers and manifold confusion of creatures, one and the same often bearing several different names, Mr. Sherborn continued to devote time and labour to an exhaustive bibliography, not only of the writers, but of every generic and specific name applied to the Foraminifera, recent and fossil. In 1889 the Smithsonian Institution, at Washington, D.C., U.S.A., generously undertook the publication of this enormous catalogue, or "Index to the Genera and Species of Foraminifera"; and the first half of this grand work, containing 10,000 names (from *A* to *Non.*), in 240 pages 8vo., dated "November, 1893," has been printed and published in a form befitting the liberality of that excellent and highly useful scientific Institution. Thanks to Mr. Sherborn's enthusiastic and painstaking labour, and his well-tried experience in bibliographic work, we can now congratulate Rhizopodists on having at hand a trustworthy guide through the nomenclatorial labyrinth which has grown up, from about 1565 (when the Italian naturalists were beginning to notice the abundant microzoa on their shores and in their strata) down to 1889.

Thus both former and present students of the Foraminifera will have the credit due to them fairly apportioned by priority; and many useful notes, falling in their right places in the Index, will aid future workers in solving doubts and difficulties. These wonderfully elegant, or quaintly shelled, microzoa are carefully studied in many countries; and of late years much has been added to our knowledge of their intimate structure by MM. Munier-Chalmas, Schlumberger, and others, in Paris and elsewhere; and quite lately J. J. Lister, of Cambridge, has communicated new and very important information about living forms to the Royal Society of London. The fossil species and varieties are always being presented in memoirs from one part of Europe or another, and occasionally from other regions. England is not behindhand in this study;—and of this fact, F. Chapman's elucidation of the Foraminifera in the Chalk of Taplow,—in the several Gault zones of Folkestone,—and quite lately in the Bargate-stone of Surrey, is sufficient evidence. T. R. J.

REPORTS AND PROCEEDINGS.

Geological Society of London.

June 20th, 1894.—Dr. Henry Woodward, F.R.S., President, in the Chair. The following communications were read:—

1. "On Deep Borings at Culford and Winkfield, with notes on those at Ware and Cheshunt." By W. Whitaker, Esq., B.A., F.R.S., F.G.S., and A. J. Jukes-Browne, Esq., B.A., F.G.S.

The four borings are described in detail, so far as the specimens examined would permit; these were few in the case of Culford, but many from the other borings. The following is an abstract of the formations traversed in each:—

	Culford.	Winkfield.	Ware.	Cheshunt.
	ft.	ft.	ft.	ft.
Surface Beds	6	—	17	14½
London Clay	—	136	—	30
Reading and Thanet Beds	—	78	—	46½
Upper Chalk	383	329	? 183	? 273
Middle Chalk		177	227	? 237
Lower Chalk	143	219	173	183
Upper Greensand	—	31	40	44
Gault	73	264	166½	153½
Lower Greensand	32½	9	—	—
Palæozoic Rocks	19¾	—	35	29½
	657¼	1243	841½	1011

The interest of the Culford boring centres in its striking the Palæozoic floor at the small depth of 637½ feet; but the age of the slaty rocks cannot be determined. Although only 20 miles east of Ely, no Jurassic rocks exist, and the Lower Cretaceous series is only about 32 feet thick, the beds differing greatly from those of Cambridgeshire, but resembling those of the same age in the Richmond boring.

The Winkfield boring (3½ miles W.S.W. of Windsor) is remarkable for having been successful in obtaining water from the Lower Greensand, and for the great depth (1243 feet) to which it was carried for this purpose, the Gault being unusually thick.

The boring at Ware is now for the first time described in detail, and former accounts are corrected from specimens preserved by the New River Company. By this means, and with the assistance of Mr. W. Hill, the authors are able to give a fairly complete account of the rocks and to determine the limits of the divisions of the Upper Cretaceous series. They deny the existence of Lower Greensand at this locality.

Of the boring at Cheshunt a more complete account is now given, based on information and specimens supplied by Mr. J. Francis, the Engineer of the New River Company.

The paper concludes with a tabular view of all the borings in the East of England, showing the level below Ordnance datum at which the Palæozoic floor occurs in each.

2. "The Bargate Beds of Surrey, and their Microscopic Contents." By Frederick Chapman, Esq,, F.R.M.S. (Communicated by Prof. T. Rupert Jones, F.R.S., F.G.S.)

This is an attempt to correlate the Bargate Beds of Guildford and its vicinity with the members of the Lower Greensand as known elsewhere in the S.E. of England.

(1) The strata at Littleton quarry, near Guildford, are described in detail; the *remanié* fossils, Oolite ironstone, and other material derived from older rocks are noticed; the abundant occurrence of Ostracoda and Foraminifera in a particular clay-band is noted, and the method adopted for getting them free from the matrix is described. The residuary minerals left from the washed sand of this clay-band, and comprising zircon, rutile, tourmaline, kyanite, quartz, felspar, and glauconite, have been carefully studied and described for the author by Dr. W. F. Hume, F.G.S., who states that the minerals present are of the same size as those from the Bagshot Sands and three times as large as those from the Chalk-marl of the Isle of Wight. The constitution of the compact Bargate Stone, with its sponge-spicules and silicified shell-structures, is described in detail; and a rare Corallina and numerous arenaceous Foraminifera are noticed.

(2) The Bargate Series is well shown, along the lane crossing the hill below St. Martha's Chapel at Chilworth, with its pebbly beds, clay-seams, limestone, and sponge-beds. Dr. Hinde's descriptive notes on the sponge-spicules are given. Some detrital fragments of fossiliferous Oolitic rock described as of Jurassic age occur in these Neocomian strata, and are comparable with some of the material obtained from the deep boring at Richmond, Surrey, and probably derived from the old Jurassic ridge to which Godwin-Austen formerly made reference. The author has found evidence in this neighbourhood of the Folkestone Sands lying unconformably on the Bargate Beds.

The clay-beds noticed by Dr. Fitton at Holloway Hill, Godalming, the author refers to the Bargate series. South of Dorking, also, Mr. Chapman found sand and clay of this series on the Horsham Road.

The Ostracoda and Foraminifera found abundantly in some of the Bargate Beds in Surrey are then described in detail. Of the former there are 20 species and varieties, 7 of which are new; 9 have been previously described from Cretaceous strata, whilst 4 are Jurassic forms. Of the Foraminifera there are 139 species and varieties. Of these, 11 are described for the first time. There are besides

107 which have hitherto been unrecorded from beds of Neocomian age. The following 10 species and varieties have been known previously only from recent deposits, viz. :—*Haplophragmium foliaceum,* Brady; *Virgulina subdepressa,* Brady; *Ehrenbergina pupa* (d'Orb.); *Polymorphina sororia,* Reuss, var. *cuspidata,* Brady; *P. oblonga,* Will.; *P. regina,* Brady, Parker, and Jones; *Discorbina Bertheloti* (d'Orb.); *D. concinna,* Brady; *D. Vilardeboana* (d'Orb.); and *D. araucana* (d'Orb.). The large number of forms new to the Neocomian fauna is undoubtedly due to the fact that the deposits of the Bargate series belong almost exclusively to the "Laminarian" and "Coralline" zones. Taking into consideration the facts that 23 per cent. of the forms recorded are almost peculiarly Neocomian types, that these added to known Cretaceous and Tertiary species amount to 122, or 87 per cent. (the latter additions probably being due to the circumstance that the Neocomian strata have not been so extensively examined in regard to their rhizopodal fauna as might have been desired), it is extremely probable that the microzoic fauna of the Bargate series is almost entirely, though not quite (since we have a few Jurassic species present), indigenous to the deposit.

In conclusion, the author states his indebtedness to Prof. T. Rupert Jones, F.R.S., and Prof. J. W. Judd, F.R.S.; to Dr. W. F. Hume, F.G.S., Dr. G. J. Hinde, V.P.G.S., Dr. J. W. Gregory, F.G.S., and Graf Solms-Laubach; and to George Murray, Esq., F.L.S.,—for valuable aid during the preparation of the present work.

3. "On Deposits from Snowdrifts, with Special Reference to the Origin of the Loess and the Preservation of Mammoth-remains." By Charles Davison, Esq., M.A., F.G.S.

When the temperature is several degrees below freezing-point, snow recently fallen is fine and powdery, and is easily drifted by the wind. If a fall of snow has been preceded by dry frosty weather, the interstitial ice in the frozen ground is evaporated, and the dust so formed may be drifted with the snow and deposited in the same places. The snowdrifts as a rule are soon hardened by the action of the sun or wind, and the dust is thus imprisoned in the snow. As the snow decays, by melting and evaporation, a coating of dust is extruded on the surface of the drifts, and, increasing continually in thickness as the snow wastes away, is finally left upon the ground as a layer of mud, which coalesces with that of previous years. The deposit so formed is fine in texture, unstratified, and, as experiments show, mica-flakes included in it are inclined at all angles to the horizon.

The author describes several such deposits both in this country and in the Arctic regions; and suggests (1) that the Loess is such a deposit from snowdrifts, chiefly formed when the climate was much colder, but still very slowly growing; (2) that Mammoths suffocated in snowdrifts are subsequently embedded, and their remains preserved, in the deposits from them; and (3) that the ground-ice formation of Alaska, etc., is the remains of heavy snowdrifts when the coating of earth attained a thickness greater than that which the summer heat can effectually penetrate.

4. "Additions to the Fauna of the *Olenellus*-zone of the North-west Highlands." By B. N. Peach, Esq., F.R.S., F.G.S. (Communicated by permission of the Director-General Geological Survey.)

New material obtained by the Officers of the Geological Survey has been placed in the author's hands, and as a result he is enabled to add information concerning the species of *Olenellus* previously described by him (*O. Lapworthi*); he also describes a new variety of this species, three new species of the genus, a new subgenus of *Olenellus*, and a form provisionally referred to *Bathynotus*.

A study of the remains described in the paper make it probable that the dispersal of the Olenellids was from the Old World towards the New.

5. "Questions relating to the Formation of Coal-Seams, including a New Theory of them; suggested by Field and other Observations made during the past decade on both sides of the Atlantic." By W. S. Gresley, Esq., F.G.S.

A number of new facts are described, and the bearing of these and of previously recorded facts upon the origin of coal is discussed, special reference being made to the Pittsburgh Coal. The author lays stress on the stratification of coal, the sharp line of demarcation between coal and underclays, the character of the plants in the underclays and their asserted root-nature, the existence of partings in such seams as the Pittsburgh Coal, which partings sometimes contain *Anthracosia*, and really separate the coal into distinct seams. He describes the occurrence of "rods" of vegetable origin whose exact nature is not known, which, with ferns, he suggests contributed largely to the formation of some coals. He maintains that the evidence points to the formation of coal on the floor of an expanse of water, by vegetable matter sinking down from floating "islands" of vegetation, which may have been of very large size, and enumerates cases of such "islands" or "rafts" of vegetation which have been described as existing in modern times.

6. "Observations regarding the Occurrence of Anthracite generally, with a New Theory as to its Origin." By W. S. Gresley, Esq., F.G.S.

After discussing Dr. J. J. Stevenson's theory of the origin of anthracite, the author describes the nature and mode of occurrence of the anthracites of Pennsylvania, and gives his reasons for concluding that the de-bituminization of coal was not produced by dynamic metamorphism during mountain-building but rather by previously applied hydrothermal action.

7. "The Igneous Rocks of the Neighbourhood of Builth." By Henry Woods, Esq., M.A., F.G.S.

In south-west Radnorshire (just north of Builth) there is an area of Ordovician and associated igneous rocks, surrounded on all sides, except the north-west, by Silurian beds; this is shown on Sheet 56 S.W. and S.E. of the Geological Survey map, and was described by Murchison. In this paper the author gives a map of the southern half of this area, and a description of the igneous rocks—andesites, andesitic ash, rhyolites, diabase-porphyrite, and diabase. The diabase-porphyrite is intrusive in the andesite, and the diabase in the Llandeilo Shales. The andesitic ash rests on the andesite, and is overlain by the Llandeilo Shales. The author concludes that the andesites, andesitic ash, rhyolites, and diabase-porphyrite are of Lower Llandeilo age; and that the diabases are post-Llandeilo and pre-Llandovery.

8. "On the Relations of some of the Older Fragmental Rocks in North-west Caernarvonshire." By Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S., and Miss Catherine A. Raisin, B.Sc.

In a recent paper on "The Felsites and Conglomerates between Bethesda and Llanllyfni, North Wales," it is argued that, in the well-known sections on either side of Llyn Padarn, a great unconformity separates the rocks into two totally distinct groups.

The authors of the present communication discuss at the outset the great physical difficulties involved in this hypothesis.

They further affirm, in the course of a description of the sections, which are most clear and afford the best evidence:—

(1) That the strike in both the supposed rock-groups is similar.

(2) That the same is true of the dips.

(3) That very marked identity of lithological characters may be found in rocks on either side of the alleged unconformity, specimens occasionally being practically indistinguishable.

(4) That in no case which has been examined can any valid evidence be found in favour of the alleged unconformity, and that in the one which is supposed to be the most satisfactory proof of it the facts are wholly opposed to this notion.

CORRESPONDENCE.

ON THE ALLEGED CONVERSION OF CHLORITE INTO BIOTITE.

Sir,—The discussion between Dr. Callaway and myself, on the above subject, has reached a stage beyond which I do not think it can be profitably carried.

My great difficulty in this controversy has been to know where to have my adversary. Hunting Dr. Callaway's theories, from paper to paper over the leaves of the Geological Magazine, takes my memory back to certain sporting episodes in my life connected with the Indian Gazelle. These graceful but restless little creatures are constantly on the move, and object, in a provoking way, to stand still to be shot at. I hope I may be pardoned for saying that Dr. Callaway's theories display a similar unsteadiness under fire.

I understood the author, in his first paper,[1] to be stating a case of dynamo-metamorphism, and treated the matter from that point of view. Dr. Callaway replied plaintively that "for the past four or five years, I have been insisting that, in the Malvern crystallines, biotite has been produced out of chlorite by 'contact-action';"[2] and on the following page he added, "I think it probable that there is not a scrap of biotite in the crystallines of the Malverns which has been produced except by 'contact-action.'"

On reading these statements, which seemed precise and definite, I tried another shot. Alas! the bullet flew wide of the mark. The

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[1] Geol. Mag. December, 1893, p. 535.

[2] *Ibid.* May, 1894, p. 217.

author writes[1]: "I never said that chlorite is changed into biotite by contact-action *only*. . . . . Chlorite is changed into biotite by contact action *plus* dynamic action."

I will only say in conclusion, that I do not see that the illustrations which Dr. Callaway has given in his July paper strengthen his case. If I understand him, he seems to think (to put the argument shortly) that because chlorite abounds where signs of shearing exist that the hydrous chlorite has been produced by shearing; and secondly, because he has observed cores of mica in the chlorite, that the mica has been produced out of the chlorite by contact-action. "The uniform appearance of mica," he writes, "where the shearing is great and where the granite veins are numerous, while it is nowhere seen where shearing and veins are absent, appear to demonstrate that these are the true causes of the generation of the mica."

I think all the probabilities of the case are opposed to this view. As I said in my last paper, all petrologists are ready to admit that dark mica is a very common product of the contact-action of granite intrusion in diorite; and I think that the subsequent more or less complete conversion of this contact mica into chlorite by aqueous agents that have found ready access to the rock along the lines of crushing and shearing is what one would naturally expect. That there should be cores of mica left in the secondary hydrous chlorite is in accordance with the petrologist's experience in his studies of the conversion of olivine into serpentine and of augite into hornblende. Dr. Callaway's theory involves the supposition that the production of hydrous chlorite should precede the gneiss of the mica; and that portions of the hydrous chlorite should escape unsinged from the burning fiery furnace of contact metamorphism that converted their fellows into anhydrous mica. These, and other difficulties enlarged on in my last paper, have not been met.

C. A. McMahon.

[This correspondence is now concluded.—Edit. Geol. Mag.]

CATALOGUE OF THE MESOZOIC PLANTS IN THE DEPARTMENT OF GEOLOGY, BRITISH MUSEUM (NATURAL HISTORY). THE WEALDEN FLORA, PART I. 1894.—A CORRECTION.

Sir,—In adopting the generic name *Nathorstia* for a new type of Wealden fern ("Wealden Flora," p. 145), I was not aware that the late Prof. Heer had previously made use of the same genus.

My thanks are due to Prof. Nathorst of Stockholm for calling my attention to Heer's genus *Nathorstia*, which was instituted in 1880 for the reception of certain fragments of Marattiaceous ferns from the Cretaceous strata of Pattorfik, Greenland (Flor. foss. Arct. vol. vi. 1882. Nachträge zur foss. flor. Grönlands, p. 5, pls. i. and ii.). I propose, therefore, to substitute the generic name *Leckenbya* for the fern described in the Catalogue as *Nathorstia valdensis*.

Cambridge, *July*, 1894. A. C. Seward.

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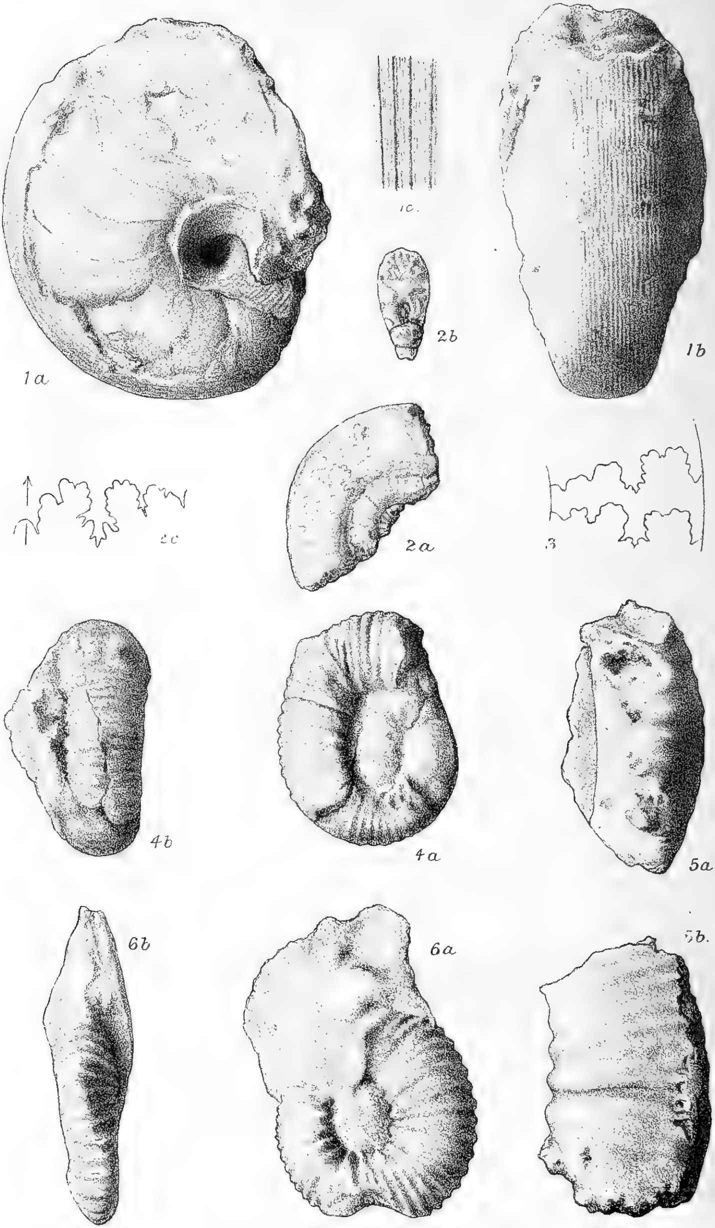
[1] Geol. Mag. July, 1894, p. 320.

Geol. Mag. 1894.

Decade IV. Vol. I. Pl. XII.



E. C & G. M. Woodward del. et lith.

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Western Australian Cephalopoda.

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

No. IX.—SEPTEMBER, 1894.

ORIGINAL ARTICLES.

I.—On a Collection of Jurassic Cephalopoda from Western Australia—Obtained by Harry Page Woodward, F.G.S., Government Geologist—with Descriptions of the Species.

By G. C. Crick, A.R.S.M., F.G.S.,
of the British Museum (Natural History).

(PLATE XII.)

THE Collection of Western Australian Cephalopoda which has been handed to me for examination consists of twelve specimens, viz. two Belemnites, one Nautilus, and nine Ammonites. One Ammonite was obtained from Cape Riche, E. of Albany; all the other specimens were collected near Champion Bay. They are chiefly internal casts, and on the whole are badly preserved: the Nautilus is in a fair state of preservation; but the Ammonites are very imperfect; the suture-line can be satisfactorily made out in only one specimen, hence the generic determinations must be regarded as only approximate. There may be some difference of opinion as to the desirability of founding species upon such poorly preserved fossils, but as several distinct forms can be made out, it seems desirable to assign names to them for convenience of reference, and it is hoped that the figures which supplement the descriptions will enable the species to be easily recognised.

The British Museum (Natural History) Collection contains two Ammonites (Nos. C. 4708 and C. 4709) from "the Greenough, Champion Bay, Australia," which were presented by Captain Elliot to the Museum of Practical Geology, Jermyn Street, and subsequently transferred from that Museum to the National Collection.

I desire to express my thanks to Dr. Henry Woodward, F.R.S., for valuable suggestions; and to the Rev. H. H. Winwood, M.A., F.G.S., for the loan of the Western Australian Cephalopoda which were figured and described by the late Mr. Chas. Moore, now in the Bath Museum. My thanks are also due to Mr. W. Rupert Jones for directing my attention to some Western Australian fossils which are preserved in the Museum of the Geological Society of London.

BELEMNOIDEA.

Belemnites (Agricola), Lister.

Belemnites, sp.

The collection contains only two fragments referable to this genus. The one is 42 mm. in length, much abraded, and partly obscured by matrix. The fragment appears to have been originally nearly cylindrical, but its dorsal surface has been considerably abraded, whilst its ventral surface and portions of the sides are obscured by matrix. A little below the middle of the specimen, its dorso-ventral diameter is 13·5 mm. and its transverse diameter 14·0 mm. One end is obliquely abraded and shows the presence of a ventral groove, from which a fissure passes inwards to the apical line, which is here nearer the ventral than the dorsal surface. The extent of the groove cannot be seen, as the ventral surface is obscured by matrix.

The other fragment is 15·5 mm. long and is divided longitudinally so as to present a median section; at the larger end the dorso-ventral diameter is 8·5 mm., its transverse about 8·0 mm., whilst at the smaller end the dorso-ventral diameter is 6·5 mm. and the transverse about 8·0 mm.

These fragments are probably referable to the species which Clarke[1] and Moore[2] identified from W. Australia as *Belemnites canaliculatus*, Schlotheim.[3] Moore's figured specimen is in the Bath Museum.

Locality.—Champion Bay, Western Australia.

NAUTILOIDEA.

Nautilus, Breynius.

Several Mesozoic Nautili have been recorded from Australia, viz. *Nautilus sinuatus* ?, J. Sowerby,[4] *Nautilus semistriatus*, d'Orbigny,[5] and a probably new species[6]—all from Western Australia; and *Nautilus Hendersoni*, R. Etheridge, *fil.*,[7] from Queensland.

The present collection contains only one specimen of *Nautilus*; this appears to belong to a new species, and is here described as *N. perornatus.*

Nautilus perornatus, sp. nov. (Pl. XII. Figs. 1*a*, *b*, *c*.)

1870. *Nautilus semistriatus*, C. Moore, "Australian Mesozoic Geology and Palæontology," Quart. Journ. Geol. Soc. vol. xxvi. pp. 230–232. (Not of d'Orbigny.)

Sp. char.—Shell moderately inflated, rapidly enlarging; greatest thickness near the umbilical margin; sides somewhat flattened, sloping towards the periphery;

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[1] Quart. Journ. Geol. Soc. vol. xxiii. (1867), p. 9.

[2] *Ibid.* vol. xxvi. (1870), pp. 227, 230, and 232, pl. xvi. fig. 7.

[3] Petrefactenkunde, 1820, p. 49.

[4] J. Sowerby, Min. Con. vol. ii. p. 213, pl. cxciv. 1818; W. B. Clarke, Quart. Journ. Geol. Soc. vol. xxiii. (1867), p. 8.

[5] A. d'Orbigny, Pal. Franç. Terr. Jur. vol. i. 1842, p. 149, pl. xxvi.; C. Moore, Quart. Journ. Geol. Soc. vol. xxvi. (1870), pp. 230–232.

[6] W. B. Clarke, Quart. Journ. Geol. Soc. vol. xxiii. (1867), p. 9.

[7] R. Etheridge, *fil.*, in Jack and Etheridge, Geology and Palæontology of Queensland and New Guinea, 1892, p. 502.

periphery broad, flattened, its width about one-half that of the lateral area, its margins subangular. Umbilicus of moderate size, deep, with steep sides, exposing a portion of the inner whorls; margin rounded. Siphuncle not seen. Chambers rather deep, about two-fifths of the corresponding height (breadth) of the whorl in depth at the periphery; suture-line forming a sigmoidal curve on the side, its direction on the periphery not seen. Test covered with numerous subregular longitudinal ridges, about one-twelfth of an inch apart where the height of the whorl is three inches, and one-tenth of an inch apart where the whorl reaches five inches in height; between each pair of ridges lie five or six very fine thread-like wavy longitudinal lines.

Dimensions:—

Diameter of shell		8½ inches	(216 mm.)
Height of outer whorl		5 ,,	(127 ,,)
Height of outer whorl above preceding whorl	about	3½ ,,	(89 ,,)
Thickness of outer whorl	about	4½ ,,	(114·5 ,,)
Width of umbilicus		¾ ,,	(19 ,,)
Depth of chamber at periphery where whorl has a height of 4½ inches		1⅝ ,,	(41·5 ,,)

Remarks.—This species is represented by only one example, which consists of the septate portion of the shell and the base of the body-chamber. One side is much abraded, but the periphery and the other side are well preserved, portions of the shell remaining on the umbilical and peripheral regions and on parts of the lateral area, sufficient to show that the ornamentation of the test extended over the whole of the sides; the greater part of the lateral area is denuded of the test, and shows the course of the suture-lines. The position of the siphuncle is not seen.

The collection of Western Australian fossils in the Bath Museum contains a *Nautilus*, which, though much worn, has a small fragment of the test preserved near the extremity of the shell and close to the periphery (hence probably assigned by Moore to *N. semistriatus*, d'Orb.), that enables the writer to identify it with the present species. The dimensions of the specimen are as follows:—

Diameter of shell		120 mm.
Height of outer whorl		77 ,,
Height of outer whorl above preceding whorl		51 ,,
Thickness of outer whorl (shell crushed on one side)	about	68 ,,
Width of umbilicus (obscured by matrix)	about	14 ,,
Depth of chamber where shell has a diameter of 95 mm.		21 ,,

This specimen does not show the position of the siphuncle.

Affinities and differences.—The species of Mesozoic Nautili which have hitherto been identified from Australia are *Nautilus sinuatus*?[1] and *Nautilus semistriatus*,[2] both from Western Australia. *Nautilus subsinuatus*, d'Orbigny[3] (=*Nautilus sinuatus*, J. Sowerby[4]) is distinguished from the present species by its more compressed form and the narrower and deeper lateral sinus of its suture-line. In *Nautilus semistriatus*, d'Orbigny,[5] the longitudinal ornaments do not

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[1] W. B. Clarke, "On Marine Fossiliferous Secondary Formations in Australia," Quart. Journ. Geol. Soc. vol. xxiii. (1867), p. 8.

[2] C. Moore, "Australian Mesozoic Geology and Palæontology," *ibid.* vol. xxvi. (1870), pp. 230–232.

[3] Prod. de Paléont. Stratigr. vol. i. (1850), p. 260.

[4] Min. Con. vol. ii. p. 213, pl. cxciv. 1818. This name was preoccupied by Fichtel and Moll in 1803, and hence altered by d'Orbigny to *subsinuatus*.

[5] Pal. Franç. Terr. Jur. vol. i. 1842, p. 149, pl. xxvi.

cover the entire surface of the test as in the Australian species, but are confined to the peripheral and umbilical regions. The present species is closely allied to *Nautilus ornatus*, Foord and G. C. Crick,[1] from the Inferior Oolite of Sherborne and Dundry, but it is at once distinguished by the character of its ornaments. From *Nautilus intermedius*, J. Sowerby,[2] and *N. striatus*, J. Sowerby,[3] the Australian form is distinguished by the ornamentation of the shell; it is also less inflated than *N. striatus*. The sculpture of the present species bears a marked resemblance to Dumortier's figures[4] of the test of *Nautilus rugosus*, Buvignier[5]; but the Australian shell lacks the transverse lines, which Buvignier notes in the young of his species, and which Dumortier figures on a specimen 140 mm. in diameter. *N. rugosus* is, moreover, a much more compressed shell. According to Dumortier it is not very rare in the zone of *Ammonites armatus*. *Nautilus Jourdani*, Dumortier,[6] from the Upper Lias of England and France, differs from the Australian species by its sculpture and the angular margin of its umbilicus.

Locality.—Champion Bay, Western Australia.

AMMONOIDEA.

AMMONITES (DORSETENSIA, S. S. Buckman).

Ammonites (*Dorsetensia*) *Clarkei*, sp. nov. (Pl. XII. Figs. 2*a*, *b*, *c*.)

? 1870. *Ammonites radians*, C. Moore, "Australian Mesozoic Geology and Palæontology," Quart. Journ. Geol. Soc. vol. xxvi. pp. 230 and 232, pl. xv. fig. 2.

Sp. char.—Shell discoidal, compressed, evolute; greatest thickness at about the middle of the lateral area, nearly three-fourths of the height (breadth) of the whorl. Number of whorls unknown; inclusion small; umbilicus large, open, shallow. Whorl subquadrate in section, higher than wide, very slightly indented by the preceding whorl. Periphery sloping on either side from a small well-marked solid carina; in the cast the peripheral area is flattened, having a depressed band or rudimentary sulcus on each side of the carina; the inner whorls have a flattened peripheral area with a clearly marked sulcus on either side of the carina. Sides feebly convex; inner area imperfectly defined, slightly convex, sloping towards the umbilicus. Chambers moderately deep, in depth at the periphery nearly two-thirds of the height (breadth) of the whorl. Suture-line not very complicated; peripheral (siphonal) lobe narrow, fairly deep, with nearly parallel sides, divided by a rather low median saddle; first (superior) lateral lobe somewhat deeper than the peripheral (siphonal), trifid; second (inferior) lateral lobe small, trifid, scarcely one-half the size of the first lateral; a small auxiliary lobe; external (siphonal) saddle broad, divided by a small secondary lobe into two unequal parts, the smaller of which is towards the peripheral (siphonal) lobe; lateral saddle much smaller than the external

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[1] Ann. Mag. Nat. Hist. [6], vol. v. p. 273, fig. 7. When the specimen here represented was figured the locality was not known, but Mr. Etheridge, F.R.S., in whose collection the specimen was originally, tells the writer that the "D" written in ink upon the specimen means "Dundry."

[2] Min. Con. vol. ii. p. 53, pl. cxxv. 1816.

[3] *Ibid.* p. 183, pl. clxxxii. 1817.

[4] Études paléontologiques sur les dépôts jurassiques du Bassin du Rhône, pt. 3, p. 54, pl. viii. ff. 3, 4; f. 3 especially.

[5] Statistique géologique, minéralogique, minérallurgique, et paléontologique du Départment de la Meuse, 1852, Atlas, p. 46, pl. xxxi. ff. 23–25.

[6] Études paléontologiques sur les dépôts jurassiques du Bassin du Rhône, pt. 4, p. 44, pl. vii. ff. 1–5.

(peripheral). Test ornamented with ventrally-projected, subarcuate ribs, which (in the cast) are inconspicuous on the inner third of the whorl. The inner whorls are marked by forwardly inclined ribs, which (in the cast) are not very conspicuous on the inner area, though they appear occasionally to have crossed this area.

Dimensions:—

Diameter of shell (estimated) about	60	mm.
Height of outer whorl	19	,,
Thickness of outer whorl	13·5	,,
Width of umbilicus (estimated) about	26	,,

Remarks.—This species is represented by a single specimen consisting of portions of three whorls of a shell about 60 mm. in diameter. The whole is septate and only a small portion of the test is preserved. The extreme length of the specimen along the periphery is 71 mm. At the central point the dimensions of the whorls are as follows:—

Height (breadth) of outer whorl	16·5	mm.
Thickness of outer whorl	11·5	,,
Height (breadth) of preceding whorl (as seen in a lateral aspect)	7·0	,,
Thickness of preceding whorl	7·5	,,
Height (breadth) of next inner whorl (as seen in a lateral aspect)	3·0	,,
Thickness of next inner whorl	4·5	,,

Thus the combined height (breadth) of the three adjacent whorls is seen to be 26·5 mm.

The specimen figured by Moore under the name *Ammonites radians* most probably belongs to the present species. It has a diameter of about 60 mm., but, for the sake of comparison with the example just mentioned, the following measurements were taken at a point where the shell has a radius of 28 mm.:—

Height (breadth) of outer whorl	17	mm.
Thickness of outer whorl	10·5	,,
Umbilicus of outer whorl	21	,,
Height (breadth) of preceding whorl (as seen in a lateral aspect)	7	,,
Thickness of preceding whorl	indeterminable	
Umbilicus of preceding whorl	9	mm.
Height (breadth) of 2nd inner whorl (as seen in a lateral aspect)	2·5	,,
Thickness of 2nd inner whorl	indeterminable	
Umbilicus of 2nd inner whorl	4	mm.
Height (breadth) of 3rd inner whorl	1	,,

It will thus be seen that at this point the combined height of the outer and two earlier whorls is the same as in the previous specimen, and that the relative proportion of the height of the whorls is almost identical with that in the incomplete specimen previously referred to. At the point where the septa are best seen, Moore's specimen is somewhat abraded, so that the true form of the suture-line is not displayed (see Pl. XII. Fig. 3).

Affinities and differences.—This species at once suggests a comparison with *Grammoceras*, Hyatt, and *Dumortieria*, Haug; both the character of the ornamentation and the general form of the suture-line suggest the division *Grammoceras* rather than *Dumortieria.* Mr. S. S. Buckman has, however, very kindly examined this specimen, and, in a letter to the writer, says: "It would be advisable to ascribe it to *Dorsetensia.* . . . . Its costation indicates either *Grammoceras* or one of the *Sonninina*; its septation—the tridactyloid character of the superior lateral lobe is decidedly against *Grammoceras* and in favour of the *Sonninineæ*."

The species of *Dorsetensia* which seems to come nearest to the Australian fossil is *D. Edouardiana* (d'Orbigny),[1] but the latter can be at once distinguished by the form of its suture-line.

The present species comes very near *Grammoceras toarcense* (d'Orbigny)[2] and *Grammoceras striatulum* (J. de C. Sowerby),[3] two forms which have great resemblances, but which are regarded as distinct species by Oppel, Dumortier, and Buckman. The inner whorls of the Australian fossil possess a square peripheral area with a rudimentary sulcus on each side of the carina, and in this respect the specimen more nearly resembles middle-aged examples of *Grammoceras toarcense* (d'Orbigny) as described by Buckman, *Gram. striatulum* having an acute peripheral area at all ages. The ribbing, too, is like that of *toarcense*, but the whorls have no well-defined inner margin, and in this character the specimen resembles *Grammoceras striatulum* (J. de C. Sowerby). The suture-line is more ornamented than in *Grammoceras toarcense*, and approaches that of *Grammoceras Doertense* (Denckmann); but in the latter species[4] the first (superior) lateral lobe is not so deep, and the *lateral saddle* is neither so broad nor so rounded as in the Australian specimen.

The character of the suture-line distinguishes this present species from "*Harpoceras*" *pseudoradiosum*,[5] and "*Harpoc.*" *subundulatum*,[6] Branco, whilst the disposition of the inner part of the suture-line of the Australian specimen separates it at once from such forms as *Dumortieria grammoceroides*,[7] Haug, and *D. Levesquei*[8] (d'Orbigny), with which it has certain external resemblances.

Of the Ammonites which have been recorded from Australia, two only, viz. *A. Moorei*, Lycett,[9] or *A. Aalensis*, Zieten, var. *Moorei*, Lycett,[10] and *A. radians*, Schlotheim,[11] have any resemblance to the

[1] Pal. Franç. Terr. Jur. vol. i. 1842, p. 392, pl. cxxx. ff. 3, 4 (5?); S. S. Buckman, Inf. Ool. Amm. (Mon. Pal. Soc.), pt. vi. 1892, p. 304, pl. xlix. f. 4, and pl. lii. ff. 8–24.

[2] Pal. Franç. Terr. Jur. vol. i. 1842, p. 222, pl. lvii. D'Orbigny wrote the name as *Thouarsensis*, which spelling has been adopted by most authors except E. Deslongchamps, who wrote *Ammonites toarcensis*. Mr. S. S. Buckman [Inf. Ool. Amm. (Mon. Pal. Soc.), pt. iv. 1890, p. 172] adopts the spelling *toarcensis*, "since the name is taken from Thouars, a town in Deux Sèvres, of which the correct Latin name is Toarcium."

[3] Min. Conch. vol. v. p. 23, pl. ccccxxi. f. 1.

[4] See Denckmann, "Ueber die geognostischen Verhältnisse Umgegend von Dörnten nördlich Goslar," Abhandlungen zur geologischen Specialkarte von Preussen und den Thüringischen Staaten, vol. viii. pt. 2, 1887, pl. viii. f. 4; pl. x. f. 9; and S. S. Buckman, Inf. Ool. Amm. (Mon. Pal. Soc.), pt. iv. 1890, pl. xxix. f. 3.

[5] W. Branco, "Der untere Dogger Deutsch-Lothringens," Abhandlungen zur geologischen Specialkarte von Elsass-Lothringen, vol. ii. (i.), p. 77, pl. ii. ff. 1–4.

[6] W. Branco, *ibid.* p. 84, pl. iii. ff. 3, 4, 5; pl. iv. f. 1.

[7] E. Haug, "Polymorphidæ," Neues Jahrbuch, 1887, vol. ii. pl. v. f. 5, and woodcut 6*c*, p. 137; and S. S. Buckman, Inf. Ool. Amm. (Mon. Pal. Soc.), pt. vi. 1892, p. 262, pls. xlvi. and xlvii.

[8] D'Orbigny, Pal. Franç. Terr. Jur. vol. i. 1842, p. 230, pl. lx.

[9] W. B. Clarke, Quart. Journ. Geol. Soc. vol. xxiii. (1867), p. 9.

[10] C. Moore, *ibid.* vol. xxvi. (1870), pp. 230, 232, pl. xv. f. 1.

[11] W. B. Clarke, *ibid.* vol. xxiii. (1867), p. 8; C. Moore, *ibid.* vol. xxvi. (1870), pp. 230, 232, pl. xv. f. 2.

present species. Both have been recorded from Western Australia. *Ammonites Moorei*, Lycett,[1] differs both as regards sculpture and the form of the suture-line; in fact it belongs to *Dumortieria*. As we have already remarked, the present species is most probably the same as that which Moore figured under the name *A. radians*, Schlotheim (*Nautilus radians*, Reinecke); a name which has been given to various species of Ammonites, as Mr. Buckman[2] has pointed out; the present specimen certainly does not agree with Reinecke's figure of "*Nautilus radians*."[3] We therefore suggest for the Australian species the trivial name *Clarkei*.

According to Mr. Buckman all the species of *Dorsetensia* are found in the *Humphriesianus*-zone, with the exception of two forms, which occur in the *Sauzei*-zone.

Locality.—Champion Bay, Western Australia.

AMMONITES (STEPHANOCERAS, W. WAAGEN).

Ammonites (*Stephanoceras*) *Australe*, sp. nov. (Pl. XII. Figs. 4*a*, *b*.)

? 1870. *Ammonites macrocephalus*, C. Moore, "Australian Mesozoic Geology and Palæontology," Quart. Journ. Geol. Soc. vol. xxvi. pp. 227, 232, pl. xv. f. 5.

Sp. char.—Shell (cast) discoidal, somewhat inflated, not very rapidly increasing; greatest thickness at about the middle of the lateral area, about two-fifths of the diameter of the shell; height (breadth) of outer whorl rather more than one-third of the diameter of the shell. Number of whorls and amount of inclusion unknown; umbilicus wide, fully one-third of the diameter of the shell in width. Whorl somewhat depressed, elliptical in section, a little thicker than high, slightly indented by the preceding whorl; periphery convex, a little flattened; sides convex, inner area rounded, imperfectly defined. Each whorl bears about twenty-five short umbilical ribs, each of which commences at the suture, extends with a slight forward inclination over the inner third of the lateral area, and terminates in a well-marked radially elongated tubercle. Each tubercle gives rise to two subangular (in the cast) ribs, which pass uninterruptedly over the periphery. Single ribs are occasionally interpolated between the pairs. There are about sixty peripheral ribs to a whorl, and on the periphery the interspaces are wider than the ribs. Suture-line unknown. Length of body-chamber unknown and aperture not seen.

Dimensions:—

Diameter of shell	62	mm.
Width of umbilicus *	24 −	,,
Height of outer whorl	20	,,
Thickness of outer whorl †	24 +	,,

* Too large, owing to distortion of specimen.
† Probably too small, owing to crushed condition of whorl.

Remarks.—This species is represented by only one example, which consists of the greater part of the outer whorl, somewhat damaged and distorted, and much obscured by the matrix on one side. The mouth-border is not preserved, and there is no trace of the suture-line.

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[1] Lycett, The Cotteswold Hills, 1857, p. 122, pl. i. fig. 2. (The suture-line represented in fig. 2*a* does not, according to Mr. S. S. Buckman, belong to this species. Mr. Buckman gives the suture-line of Lycett's figured specimen in his Inf. Ool. Amm. (Mon. Pal. Soc.), pt. v. 1891, pl. xliv. f. 9.)

[2] S. S. Buckman, Inf. Ool. Amm. (Mon. Pal. Soc.), pt. iv. 1890, p. 188.

[3] Maris protogæi Nautilos et Argonautos, etc., figs. 39, 40.

The specimen from Western Australia figured by Moore as *Am. macrocephalus* is preserved in the Bath Museum. It has a diameter of 81 mm., but is so obscured by matrix that the other dimensions cannot be made out, except perhaps the thickness, which at the right-hand portion of the specimen as represented in Moore's figure is 31 mm. The very pronounced tubercle on the whorls gives rise to two well-marked ribs, and there is occasionally an intermediate rib. From the characters of the fossil, so far as they can be made out, the specimen would seem to be referable to the present species.

Affinities and differences.—Although resembling *Ammonites* (*Sphæroceras*?) *Woodwardi*, the present species differs in having a rather finer sculpture, less prominent primary (umbilical) ribs, and a somewhat larger umbilicus.

Unfortunately the suture-line of the Australian form is not available for comparison with other well-known species; but the present species is evidently closely allied to "*Ammonites*" *Braikenridgii*, J. Sowerby (Min. Con. vol. ii. p. 187, pl. clxxxiv.). An example of this species from the Inferior Oolite of Sherborne, Dorset (Brit. Mus. No. 98239), in its external characters, agrees remarkably well with the Australian fossil. It has the following dimensions: diameter of shell, 57 mm.; width of umbilicus, 26 mm.; height of outer whorl, 17 mm.; thickness of outer whorl, 22 mm.; with 27 umbilical, and 60 peripheral, ribs to a whorl. The present species has finer ornaments and shorter umbilical ribs than d'Orbigny's figure of *Amm. Braikenridgii* (Pal. Franç. Terr. Jur. vol. i. 1842, pl. cxxxv. ff. 3, 4); and coarser, less numerous ribs, much shorter umbilical ribs, and less inflated whorls than d'Orbigny's *Amm. linguiferus* (Pal. Franç. Terr. Jur. vol. i. 1842, pl. cxxxvi.); whilst the presence of a tubercle at the point of bifurcation of each umbilical rib at once distinguishes the Australian form from such species as *Amm. biplex*, J. Sowerby (Min. Con. vol. iii. p. 168, pl. ccxciii. ff. 1, 2).

Locality.—Champion Bay, Western Australia.

Ammonites (*Stephanoceras*), sp. (Pl. XII. Figs. 5*a*, *b*.)

Since this species is represented merely by a fragment it is not possible to give a complete diagnosis, but the following characters may be noted:—

Shell (cast) inflated; greatest thickness at the margin of the umbilicus. Umbilicus rather wide. Whorl (at the base of the body-chamber) obtusely cordate or almost lunate in section, nearly twice as wide as high; indented to about one-fourth of its height by the preceding whorl; periphery broadly convex and continuous with the sides; inner area sloping steeply towards the umbilicus and forming an acute angle with the convex surface of the shell. Suture-line imperfectly known. Whorl ornamented with a number of umbilical transversely-compressed tubercles, situated upon the prominent margin of the umbilicus; each tubercle giving rise to three ribs which, in crossing the convex surface of the cast, form a broad shallow sinus having its concavity directed backward. The tubercles are not continued over the inner area of the whorl.

Remarks.—The fragment representing this species is a natural cast in a ferruginous matrix of a portion of the body-chamber and of the adjoining chamber, the form of part of the penultimate septum being seen at the posterior extremity of the specimen. One side of the cast is fairly well preserved; the other is much crushed and worn. The impressed zone, seen on the inner part of the whorl, shows that the ribs of the preceding whorl crossed the periphery without interruption. That the umbilicus was wide is indicated by the direction of the tuberculated margin of the fragment; this margin has five tubercles in a length of 38 mm. The maximum length of the specimen along the periphery is 80 mm. and its radius of curvature is 67 mm. Seventeen transverse ribs can be counted on the periphery; the interspaces are of about the same width as the ribs. The chamber adjoining the body-chamber was shallow, but, as this chamber is frequently much shallower than the rest, it may not represent the average depth of the chambers. The height of the whorl is 33 mm., the height above the preceding whorl being 27 mm.; the width was probably about 60 mm.

Affinities and differences.—The species represented by this fragment appears to be a close ally of *Ammonites sublævis*, J. Sowerby,[1] from the Oxford Clay and Kellaway Rock, having a particularly close resemblance to the middle-aged shell of this species from the British Callovian. But, judging from the fragment, the Australian fossil had a larger umbilicus and less numerous umbilical tubercles, and whilst in Sowerby's species the ribs arise usually in pairs from the margin of the umbilicus, in the Australian specimen each umbilical tubercle gives rise to three ribs.

The whorls of *Ammonites coronatus*, as figured by d'Orbigny,[2] have a much coarser ornamentation, a broader and flatter external area, and a narrower inner area than the Australian form; whilst *Ammonites Atherstoni*, Sharpe,[3] from South Africa, as represented by a specimen in the British Museum (No. 46534), has a smaller umbilicus, smaller umbilical tubercles, and very distinct, forwardly-directed ribs on the inner area of the whorls, *i.e.* on the sides of the umbilicus.

Ammonites Schenki, Oppel,[4] from the Jurassic of the Himalaya, has a smaller umbilicus, much more prominent umbilical tubercles, and less numerous peripheral ribs.

In sculpture the Australian form resembles *Olcostephanus latissimus*, Neumayr and Uhlig,[5] but it is a less tumid shell, and, so far as can be ascertained, has a different suture-line, its suture-line more nearly resembling that of *Ammonites Sutherlandiæ*, J. de C. Sowerby,[6] from the Calcareous grit, but the character of the ornaments at once distinguishes these two forms. The adult of the latter species is smooth, and the ribs on the inner whorls have a different direction from those of the Australian form.

Locality.—Champion Bay, Western Australia.

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[1] Min. Con. vol. i. p. 117, pl. liv.

[2] Pal. Franç. Terr. Jur. vol. i. 1842, p. 465, pl. clxviii.

[3] Trans. Geol. Soc. [2], vol. vii. 1847, p. 196, pl. xxiii. f. 1.

[4] Pal. Mittheil. vol. ii. pl. 81, ff. 4*a–c*.

[5] Palæontogr. vol. xxvii. (1881), p. 158, pl. xxviii.

[6] Min. Con. vol. vi. p. 121, pl. dlxiii.

(*To be continued.*)

II.—NOTES ON THE PLEISTOCENE OF THE NORTH-WEST TERRITORIES OF CANADA, NORTH-WEST AND WEST OF HUDSON BAY.[1]

By J. BURR TYRRELL, M.A., B.Sc., F.G.S.

IN the extreme northernmost part of Canada, lying between North Latitudes 56° and 68° and West Longitudes 88° and 112°, is an area of about 400,000 square miles, which had up to the past two years remained geologically unexplored.

In 1892 the Director of the Geological Survey of Canada sent the writer to explore the country north of Churchill River, and south-west of Lake Athabasca; in 1893 the exploration was continued northward, along the north shore of Athabasca Lake, travelling from the east end of Lake Athabasca across the country in canoes to the west end of Chesterfield Inlet, and thence continuing in canoes along the shores of Hudson Bay almost to Churchill, from which place an overland journey was made to Winnipeg, Manitoba.

The south-western half of the country traversed in these two summers is more or less thickly covered with coniferous forest, while the north-eastern half is devoid of trees, and is generally covered with stunted grasses or lichens.

North of Churchill River the country is underlain by red and grey Laurentian granites and gneisses, with a fairly persistent strike in a south-westerly direction.

South of Lake Athabasca and Black River these Laurentian rocks are overlain by horizontal red sandstones and conglomerates, occasionally cut by trap dykes, which probably represent the Kewenawan sandstones of Lake Superior, and are therefore of Cambrian age, though no fossils were found in them. Athabasca, Black, Wollaston, and Cree Lakes lie along the line of contact of these sandstones and the underlying Archæan rocks.

The north shore of Lake Athabasca is composed of Laurentian gneiss, and Huronian quartzite, conglomerates, and schists, which in one place were found to be associated with a large deposit of hæmatite. The country crossed from Lake Athabasca to Doobaunt Lake is underlain by Laurentian gneiss, which, however, is often hidden by extensive deposits of Boulder-clay.

In one locality a small outline of unaltered fossiliferous Ordovician limestone was found, very similar in character to the white limestone of the Winnipeg Basin.

On Doobaunt Lake the Kewenawan sandstones and conglomerates were again discovered, and the country lying between this lake and the head of Chesterfield Inlet was found to be largely underlain by these rocks. The north side of Chesterfield Inlet is generally red and grey Laurentian gneiss, while the greater part of the shore of Hudson Bay for 150 miles south of the Inlet is composed of green Huronian schists cut by many quartz veins, and sprinkled through with particles of copper pyrites.

The whole of this region shows abundant evidence of having been comparatively recently covered with a mantle of ice, and even

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[1] Published by permission of the Director of the Geological Survey of Canada.

to the present time Doobaunt Lake, the largest of the many hitherto unexplored lakes through which we passed, lying in North Latitude 63° and West Longitude 102°, and with an elevation of about 500 feet above the sea, seems to be always more or less completely covered with ice, for during the ten days which we spent on it—from August 7th to August 17th—we were obliged to travel in a narrow lane of water between the solid ice covering the main body of the lake and the shore, and in two places this channel was blocked by the ice resting against the beach.

In general physical features the "Barren Lands" often closely resemble the great plains west of Manitoba along the line of the Canadian Pacific Railway, being undulating grass-covered country, underlain by Till more or less thickly studded with boulders; but a hard granite knoll projecting here and there serves to remind one that the Till is not here resting on soft cretaceous shales and sandstones, and at once accounts for the much greater abundance of boulders.

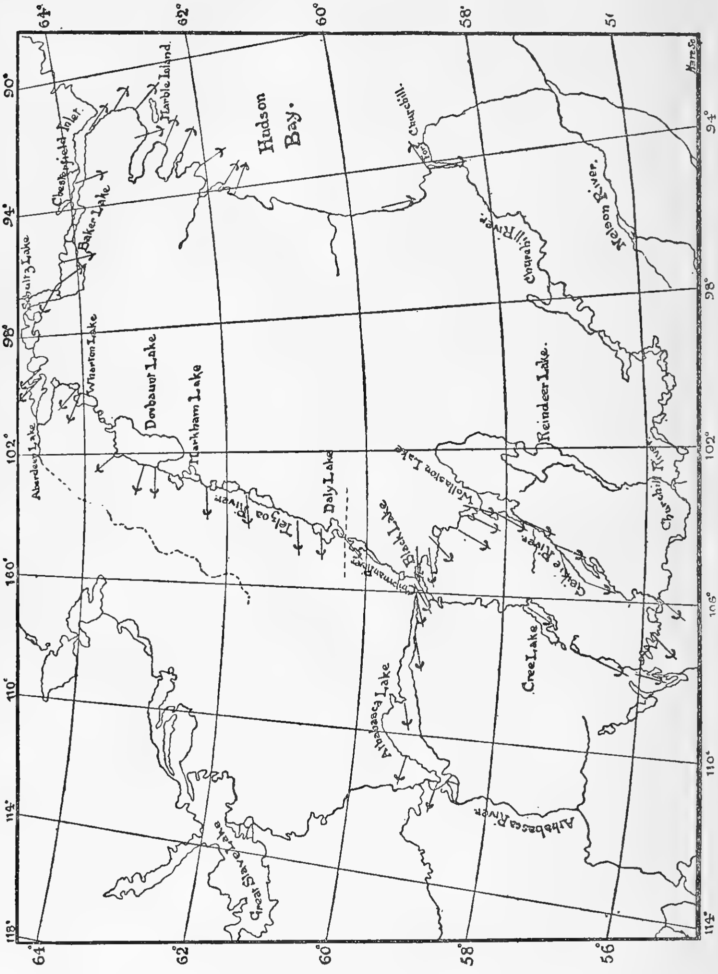
In some places the surface is composed entirely of large subangular boulders, without any matrix of sand or clay, while the shores of Chesterfield Inlet, and part of the north-west coast of Hudson Bay, are bold and rocky.

A particularly noticeable feature of the "Barren Lands" is the absence of valleys for the rivers. The Telzoa River, probably the largest stream in all that country, is, through the greater part of its course from Daly Lake to the head of Chesterfield Inlet, merely a succession of lakes of larger or smaller size, lying in original depressions in the Till or rock, connected by stretches of rapid water flowing in one or more shallow, tortuous, and often ill-defined channels frequently choked with boulders. Although the long winter and the ever-frozen ground would prevent very rapid erosion, it is evident that this river has been but a short time cutting out its channel.

Throughout the whole region the rock has everywhere been strongly glaciated, leaving the exposed portions rounded and often polished and striated. Most of the prominent knolls show clearly the direction of glaciation by the rounded stoss and broken lee sides, but in cases where two or three different glaciers have scored records on the small rocky knolls, all sides may be well smoothed, rounded, and scored.

The accompanying map shows the general directions in which the glacial grooves and striæ are trending, deduced from several hundred observations. As is there shown, the direction of glacial movement on the upper Churchill River is south or a little west of south, or parallel to the long axis of the lake; on Chipman River and the head of Telzoa River south-west; on Doobaunt Lake and the river in its vicinity west. Some of these last striations are crossed by an earlier set of striæ coming from the north.

On Telzoa River, between Doobaunt and Baker Lakes, the direction of striation is north-westward, the course being clearly shown by the stoss and lee surfaces, boulder trains, and the crescentic cross-fractures in the grooves. At the west end of Baker Lake the north-westerly striation is crossed by what appears to be a local glaciation from the north, but this southward moving glacier soon obliterated all traces of the north-westerly one, and then the trend of the glaciation is found to be down Chesterfield Inlet, which is a rocky fiord with a depth varying from twenty-five to forty fathoms. The north-west coast of Hudson Bay, for 150 miles south of Chesterfield Inlet, is bold and rocky, and the hard Huronian rocks of which it is chiefly composed everywhere show well-defined glacial markings which have a general direction about S. 50° E. or directly out into the bay. Near the mouth of Egg River a boss of



Map of the North-West Territories of Canada, explored by J. B. Tyrrell in 1892 and 1893. The arrows indicate the general direction in which the glacial grooves and striæ are trending.

coarse red granite on the shore is polished and scored with glacial markings trending southward. At Fort Churchill the low granite knolls, and the high bare rounded hills of green feldspathic quartzite, are scored by three sets of striæ, the two most recent of which are very distinct, while the earliest, wherever seen, is rather obscure. This latter trends N. 80° E. (or S. 70° W.?), and is not improbably merely an early variation of the next, which trends N. 55° E. This set of grooves and striæ is very strongly marked on all the southern and south-western slopes, against which the glacier pressed heavily on its way down the valley of the Churchill River to Hudson Bay, but the eastern sides of the hills show comparatively few traces of this glaciation.

Crescentric cross-fractures are common in the grooves, and these all lie with their concave sides towards the north-east, or towards the point of the compass to which the glacier moved. The most recent set of striæ is found on the summits and northern sides of the hills, and points southward, the striæ being found to vary from S. 5° W. to S. 10° E.

From the above record of striæ it will be seen that one of the great gathering grounds for the snow of the Glacial period in North America was a comparatively short distance west of the northern portion of Hudson Bay, and from that centre or gathering ground the ice flowed not only towards the Arctic Ocean and Hudson Bay, but it extended a long distance westward towards the Mackenzie River, and southward towards the great plains, while Hudson Bay was probably then to a great extent open water. From it the moisture would be derived which fell as snow near its western shore.

The older geology of the country is known over such a small portion of the total area that it is impossible to draw any definite conclusions from the direction of transportation of boulders; but on the west shore of Hudson Bay the boulders were such as would be derived from the Laurentian, Huronian, and Kewenawan rocks to the west, and there were no signs of the limestones, etc., from the islands in the Arctic Ocean or Hudson Bay. On the Telzoa River the boulders showed no evidence of having been derived from the west coast of Hudson Bay.

Drumlins or ridges of Till are almost everywhere found in the less rocky areas. Eskers are also common, either rising in high narrow elongated hills, or running as long sandy ridges, keeping their courses, which are parallel to the glacial striæ, over hills and through valleys and lakes quite regardless of the surface contour of the country. In the more southern districts these are wooded with large white spruce, which rise conspicuously above the stunted black spruce on the surrounding low land.

After the ice receded from the lower country the land was about 400 feet below its present level. On the lower side of a long portage a short distance below Doobaunt Lake the first well-defined raised beach and terrace was seen, and from that point all the way down the river to Hudson Bay old strand lines could be seen on the sides of all the prominent hills.

A white quartzite hill on the east side of Wharton Lake has three distinct gravel terraces or shore-lines on its southern side at heights of 60, 105, and 130 feet above the water. At the east end of Aberdeen Lake scarps, gravel, terraces, and ridges extend up the side of some hills of Kewenawan conglomerate to the height of 290 feet, the total series here having the following heights in feet above the water in the lake: 290, 220, 180, 150, 105, 90, and 60. On the side of a quartzite hill at the east end of Schultz is a well-marked gravel beach which the aneroid showed to have a height of 260 feet above that lake, probably the same as the 220 feet beach on Aberdeen Lake.

Similar raised beaches are found in favourable localities all along the shore of Hudson Bay.

These beaches indicate a gradual, though probably intermittent, rise of the land towards, or after the close of, the Glacial period; and some, even among the oldest of them, look as new as if they had been formed but yesterday, but it would seem that at Fort Churchill, and probably along the rest of the coast, the land and sea have reached conditions of comparative equilibrium. Some evidence on this point was collected near Fort Churchill, and especially at Sloop's Cove, a little bay on the north side of the river, where the ships of the Hudson Bay Company used occasionally to winter about the middle of last century. This spot was visited on the 29th of October and the 2nd of November of last year. The ice was in it then up to the level of an average spring tide, which had occurred two days before our first visit.

The cove is forty paces wide and one hundred paces long, and on each side are smooth well-glaciated hills of green quartzite rising to about 25 feet above the ice. At the back is a grass-covered bar of sand and gravel, joining the two disconnected hills of rock, and separating the cove from a wide flat that is flooded at spring-tide. The height of the summit of this beach was seven feet and a half above the level of the ice, or about the level of extreme extraordinary high tides. On the smooth glaciated surface of the rock many names and dates have been cut, some of which are given below, with their heights above the level of the ice:—

Furnace and Discovery, 1741	3 ft. 3 in.
J. Horner, 1746	6 ft.
James Walker, May 25th, 1753	7 ft.
Guilford Long, May 27th, 1753	7 ft.

and many others.

The "Furnace" and "Discovery," two small ships sent to discover a North-west passage, spent the winter of 1741–42 in Sloop's Cove, and left for the north as soon as the ice broke up in the spring of the latter year. Probably the names were cut in the almost vertical face of the rock by some one of the crew on whose hands the long days of waiting in winter hung very heavily. They are almost as high as a man would naturally reach if he were seated on a box or keg on the ice at the foot of the rock. The dates May 25th and May 27th opposite the names of James Walker and Guilford Long would show that these names were cut when the ice was still solid in the cove, for the ice does not break up in the river at Churchill until the middle of June. These names were apparently cut by men standing on the ice when it was about two feet higher than it was last November, or when it was covered with two feet of snow. Nine large iron rings had been set in the rock at heights varying from two feet and a half to seven feet above the ice, just where they would be convenient to tie a small ship to at present, for the cove could not be entered, except at high tide. One other ring is fifteen feet above the ice.

All these signs of the winter occupation of this cove a century and a half ago are such as might be made at the present time, and are quite inconsistent with the theory that the rise of the land which took place in post-Glacial times is still going on at a comparatively rapid rate.

III.—On some Life Zones in the Lower Palæozoic Rocks of the British Areas, as defined mainly by Researches during the Past 30 Years.

By Henry Hicks, M.D., F.R.S., F.G.S.

(*Continued from the August Number, page* 371.)

Lower Cambrian.

Up to the year 1867 the only traces of organisms that had been found in the beds then classed as Cambrian by the Geological Survey (now Lower and part of Middle Cambrian of most authors) were tracks and burrows of Annelids; and the doubtful Trilobite *Palæopyge* found by Mr. Salter in the Longmynd rocks of Shropshire.[1] In "Siluria," fourth edition, 1867, p. 30, Sir R. Murchison refers to them as follows: "These, then, are the only signs of former life we have yet become acquainted with after the most assiduous researches in the Cambrian deposits of such vast dimensions, which are often, I repeat, less altered than much younger rocks replete with organic remains"; but, in the Appendix, p. 550, he says, "At the meeting of the Geological Society on June 19th, 1867, Mr. J. W. Salter read an account of the discovery of a minute *Lingulella* in the red Cambrian rocks of St. David's, which there underlies the 'primordial Silurian' (*mihi*). According to my view (and I am entitled to judge by acquaintance with both districts) the rock in which the fossil was found may be paralleled in age with the uppermost or red portion of my original 'Cambrian' of the Longmynd." This fossil was found by me in the red beds, below the *Paradoxides aurora* zone, which were then supposed to mark the Lower boundary of the Menevian Group, and in the paper communicated to the Geological Society, in which the account of its discovery is given, are the following remarks by Mr. Salter:[2] "Fossils in the red Cambrian rocks are so rare, that no apology seems due for introducing a single small specimen, lately gathered, after great

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[1] Quart. Journ. Geol. Soc. vol. xii. (1856), and vol. xiv. p. 199.

[2] *Ibid.* vol. xxiii. p. 339.

research, by one of the authors of this paper. The search has been systematically pursued since 1862, when the first fossil of the Menevian Group was described by Mr. Salter from this neighbourhood; and the labour has chiefly fallen upon Mr. Hicks, who resides at St. David's. He has, literally, not left a stone unturned to find the true place of *Oldhamia*, and, if possible, of the mythical *Palæopyge* in these old red rocks. He has been rewarded, during the search, by many additions to the Menevian fossils, found at successively lower and lower horizons in the grey rocks which form the passage from the Lower to the Upper Cambrians. But, until quite lately, not a vestige had occurred to him in the actual red rocks themselves." I give these quotations as they clearly state what was then known in regard to the evidences of life in the so-called unaltered Cambrians as marked then and now on the Geological Survey Maps. The boundary line it appears was first adopted by Sir A. Ramsay when mapping the rocks in Pembrokeshire; for in the Geological Survey Memoirs, vol. iii., he says: "In 1841 the Geological Survey began to map the Silurian rocks at Haverfordwest, in Pembrokeshire, and Sir Henry de la Beche was unable in that neighbourhood to detect any base for the Silurian strata. In the same year, at St. David's, I traced a provisional line between the black and the purple slates, and this was afterwards adopted as the line between the Silurian and Cambrian strata." It was well known that the Cambrian as so defined contained in Pembrokeshire a great thickness of strata, with somewhat marked lithological characters; therefore it was but natural when the equivalent rocks in Merionethshire and Carnarvonshire were mapped in 1846 and 1848 that the Surveyors adopted the same name for these deposits, as "stratigraphically they occupy the same position, and lithologically they resemble each other."[1]

After the *Lingulella* was found by me in the red rocks, in 1867, I determined to search the underlying rocks systematically, and with much care, in the hope of finding still lower zones of fossils; and in the following year, 1868, I was able to announce at the meeting of the British Association that I had discovered several zones of fossils in the Cambrian, the lowest being 1200 feet below the red beds in which the previously described *Lingulella* had been found. The fossils, it was stated, occur usually at intervals in the strata; "scores, and sometimes hundreds, of feet of strata apparently intervening" between each zone. It was on this occasion also that I proposed that the "Menevian Group" should henceforth be included in Prof. Sedgwick's "Lower Cambrian" (the Cambrian of the Survey), owing to the much greater likeness between the fauna of the Menevian Group and the newly discovered fauna of the underlying beds, than between that of the former and the overlying Lingula Flags. The fossils found in these beds were subsequently described by me in the Quart. Journ. Geol. Soc. for 1871[2];

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[1] Survey Memoirs, vol. iii. second edition, p. 8.

[2] "Descriptions of New Species of Fossils from the Longmynd Rocks of St. David's."

and for many years afterwards they remained the only organisms known in the Lower Cambrian rocks of Britain.

In the year 1881 I decided to divide the Lower Cambrian into three groups[1] under the names from below upwards of Caerfai, Solva, Menevian. I pointed out that it had a "natural base made up of massive conglomerates and sandstones," and that "its upper boundary is well defined by an important palæontological break," and that it is "clearly divisible at St. David's, where it has chiefly been explored of late years into three groups."

In speaking of the Caerfai Group I said that "beds of the same age are also found in the Harlech Mountains. The great slate quarries of Llanberis, Bethesda, and other places in Carnarvonshire are also on this horizon. Though the basal beds are not exposed in the Longmynd area, it is probable also that some belonging to this group occur there. There is a strong general resemblance between the beds of this group in each of the areas, but as they were at first shore deposits around a subsiding land-area, some differences in appearance and in thickness must necessarily occur."

In the year 1887 Dr. Woodward[2] described a *Conocoryphe* (*C. viola*), specimens of which had been found in the Upper Green Slates of the Penrhyn Quarries by Prof. Dobbie, and Messrs. R. E. Jones and R. Lloyd (two quarrymen employed in the Penrhyn Quarry, Bethesda, Carnarvonshire). This very important discovery of fossils in the undoubted Cambrian of the Geological Survey in North Wales, was hailed with delight by those who had been working in the Cambrian rocks in other areas, and it was hoped that additional fossils which would enable the horizon to be definitely fixed would soon be discovered. Up to the present, however, only one or two additional forms have been found in the quarry, and the horizon has mainly to be fixed by stratigraphical evidence. The *Conocoryphe* is undoubtedly of the type restricted to zones low down in the Cambrian; and, in my opinion, until further evidence is obtained, it may fairly be placed at as low an horizon as the base of the Solva Group of St. David's.

The stratigraphical sequence here, I described briefly as follows in the Report of an Excursion of the Geologists' Association to Penrhyn Slate Quarry and Nant Ffrancon in 1883 (vol. viii. No. 4):—"In traversing this section from west to east, along the sides of Nant Ffrancon, the following general order of the rocks seemed tolerably clear:—

1. The purple and green slates of the quarry (Llanberis).
2. A thick series of grits and flaggy sandstones (Harlech).
3. Dark flaggy beds (Menevian).
4. Flags and sandstones with *Cruziana* (Lingula flags).
5. Dark flags (Tremadoc?).
6. Black slates and flags with pisolitic iron ore and grit at base (Arenig).

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[1] "The Classification of the Eozoic and Lower Palæozoic Rocks of the British Isles," Popular Science Review, 1881, and Proc. Geol. Assoc. vol. viii. No. 5, 1881.

[2] Q.J.G.S., vol. xliv. p. 74.

In 1888, after another visit, Mr. J. Evans, F.G.S., a former Manager of the Penrhyn Slate Quarry, kindly furnished me with a careful statement of the succession made out in the tunnels, and in working the quarry, and the following table is mainly compiled from the details supplied to me by him. By its side I place also a detailed statement of the succession at St. David's:—

Nant Ffrancon, and Penrhyn Slate Quarry, Carnarvonshire.	St. David's, Pembrokeshire.	FEET	
14 Dark slates and flags (Menevian ?).	14 Dark flags and black slates (Menevian) . . . . . (*Paradoxides*, etc.)	750	
13 Grits and sandstones (Bronllwyd).	13 Grey, purple, red, and greenish sandstones, flags, and slates. (*Paradoxides*, etc.)	1800	SOLVA GROUP.
12 Green slates. (*Conocoryphe viola*, etc.)	12 Grits, sandstones, and greenish flags . . . . (*Plutonia, Paradoxides Harknessii, Conocoryphe Lyellii, Micrordiscus*, etc.)	150	
11 Purple slates.			
10 Purplish blue slates.			
9 Hard grits.			
8 Purplish blue slates.			
7 Grits.	7–11 Red and purple sandstones, flags, and slates	1000	CAERFAI GROUP.
6 Red slates.	6 Red slates and flags . . . . (*Olenellus* fauna.)	50	
5 Purplish blue stripy slate.	5 Purplish flaggy sandstones . .	20	
4 Dyke (basic rock).	4 Dykes of basic rocks cut across the Lower Cambrian rocks at this and at various other horizons		
3 Green hard slates.	3 Greenish flaggy sandstones . . (*Olenellus* fauna.)	440	
2 Conglomerates (with large pebbles).	2 Conglomerates . . . . . . (Many very large pebbles.)	60–150	
1 Pre-Cambrian rocks (felstones, etc.)	1 Pre-Cambrian rocks . . . . (Granite, felstones, volcanic ash, etc., etc.)		

As there are several faults in the quarry between Nos. 3 and 10, it is quite possible that some of the beds have been repeated.

It will be seen that there is a general resemblance in the succession in the two areas. At first, as the sea encroached on the pre-Cambrian land, the deposits would accumulate mainly in minor troughs separated by the higher plateaux and mountain ridges, and important differences in the thicknesses of the lowest Cambrian strata would necessarily occur even within limited areas. As depression went on oceanic conditions would prevail, and the sediments would become more alike over extensive areas. In a paper which I published in 1875,[1] I endeavoured to show the direction of encroachments of the sea, and of the migrations of the lowest Palæozoic faunas over the European areas, and in 1876[2] I entered more fully into this question in a discussion of the deposits as then known in

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[1] Quart. Journ. Geol. Soc. vol. xxxi. p. 552.

[2] "Some Considerations on the Probable Conditions under which the Palæozoic Rocks were Deposited over the Northern Hemisphere." GEOL. MAG. Dec. II. Vol. III. (April, May, and June, 1876).

the Northern Hemisphere. In this paper, page 157, I stated that "on both sides of the Atlantic they (the pre-Cambrian rocks) are to be seen at various places from the latitude of 30° to the Arctic regions, and it seems reasonable to suppose that these portions indicate parts only of what were probably two great continents extending over these areas, separated from one another by an intermediate ocean, narrower considerably than the present Atlantic, but still occupying part of that basin. When these continents commenced to subside, the parts facing the Atlantic were the first to become submerged."[1]

The great thicknesses found in some areas show that there must have been much loose material on the pre-Cambrian land ready to be washed off as each part became depressed, and an examination of the sediments shows very clearly that much of the material came from the volcanic rocks and cones of the pre-Cambrian period.[2] Angular fragments of volcanic rocks occur so frequently, mixed up with other sediments in the Lower Cambrian rocks, that it seems clear that such loose materials remained on the higher ridges and plateaux after adjoining areas had been depressed to a considerable depth; and the incoming of these materials along with other rough sediments, usually at fairly definite horizons, mark frequently the vertical limits of certain organisms in these areas.

At the meeting of the International Geological Congress in London in 1888, Mr. C. Walcott, of the United States Geological Survey, made the very important announcement that he had recently discovered in a very complete section of the Cambrian rocks at Manuel's Brook, Newfoundland, that the *Olenellus* fauna occurred below the *Paradoxides* fauna, and not above, as had up to that time been supposed to be the case in America. In Sweden and in some other areas in the N. of Europe it had been previously shown by Doctors Linnarsson, Brögger, Holm, and Schmidt that the *Olenellus* fauna was the oldest; but until Mr. Walcott showed that the order of succession was similar in America, it had not been taken as of general application. Mr. Walcott now proposed also that the Cambrian should be divided into three parts, viz. the *Lower*, characterized by the *Olenellus*, the *Middle* by the *Paradoxides*, and the *Upper* by the *Olenus* fauna, and this classification has since been very generally adopted. Previously in Wales we had divided the Cambrian into two main parts, viz. a *Lower* containing the *Paradoxides* and earlier faunas, and an *Upper* the *Olenus* fauna. I had, however, as already shown, subdivided in 1881 the then Lower Cambrian into three groups, viz. Caerfai, Solva, and Menevian; and in the year 1892[3] I was able to show that the *Olenellus* fauna at St. David's was confined to the Caerfai Group. Here the *Paradoxides*

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[1] Mr. C. Walcott has recently worked out with much care the evidences of the early conditions prevailing during the same periods on the American continent ("The Fauna of the Lower Cambrian or *Olenellus* Zone," 1890, and "Bulletin of the United States Geological Survey," No. 81, 1891).

[2] See "Pre-Cambrian Volcanoes and Glaciers," GEOL. MAG. Dec. II. Vol. VII. (November, 1880).

[3] GEOL. MAG. Dec. III. Vol. IX. p. 22.

fauna extends through a great thickness of strata, as I shall be able to show when I refer more particularly to the Middle Cambrian. Almost immediately after Mr. Walcott's announcement was made, Prof. C. Lapworth published a highly interesting account of the discovery by him in Shropshire of the *Olenellus* fauna, and he there states that "the presence of traces of the *Olenellus* fauna in the West of England" was known to him for some time, the first recognisable fragments having been detected by him "on the flanks of Caer Caradoc in 1885, but they were too imperfect for description." Better material had by this time been obtained, and he was now able to give the provisional name of *Olenellus Callavei* to one of the forms, and to add several other fossils known to be characteristic of the *Olenellus* zone. He further says[1] that "this Lower Cambrian or *Olenellus* formation of the Shropshire area consists of two main members, viz. the basal quartzite of Lawrence Hill and Caer Caradoc, and an overlying green sandstone, the Comley Sandstone (Hollybush Sandstone of Dr. Callaway). This formation follows unconformably upon the so-called Uriconian rocks of the district, and occurs in many localities, as at Lilleshall, the Wrekin, Caer Caradoc, Cardington, etc."

In the Geological Magazine for December, 1891, Prof. Lapworth published a full description of *Olenellus Callavei*, with figures; and stated that in Shropshire, as elsewhere, "we find the Cambrian divisible into three sections—an Upper Cambrian above, marked by the presence of the genus *Olenus* (Olenidian); a Middle Cambrian group with *Paradoxides* (Menevian or Paradoxidian); and finally a Lower Cambrian (*Olenellus* zone) or basal group (possibly of somewhat different systematic importance), distinguished by the presence of *Olenellus*." At the meeting of the British Association in 1891, Sir A. Geikie announced the discovery of *Olenellus* by the Geological Surveyors in the North-West of Scotland, and since then additional species of that genus have been obtained by them as well as some of the usually associated organisms. This important discovery of typical Lower Cambrian fossils overlying Torridon Sandstone proved that the latter must be of higher antiquity, hence of pre-Cambrian age. Up to the present time the usually overlying *Paradoxides* and *Olenus* zones have not been found in Scotland. It seems pretty evident that the Cambrian rocks must be comparatively thin in the North-West of Scotland; in this respect simulating the succession in Scandinavia rather than that in Wales.

There can be no doubt that the genera *Olenellus*, *Paradoxides*, and *Olenus* in the areas where they have been found to succeed each other in conformable sediments do mark very definite periods in the world's history; but such arbitrary lines are not natural, and we must expect to find from time to time that the limit assigned to a genus will have to be extended as new areas are being explored. Where a genus, which has been sufficiently abundant to characterize a main zone, disappears suddenly, there is usually some indication in the deposits of at least a slight physical change. At St. David's

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[1] Geol. Mag. Dec. III. Vol. V. p. 485, and "Nature," vol. xxix. p. 213.

this is particularly marked, for immediately below the lowest *Paradoxides* zone a fine conglomerate containing angular fragments of volcanic material occurs, and this I have taken as the boundary line between the Caerfai (*Olenellus* beds) and the overlying Solva (*Plutonian* and *Paradoxides* beds). Again, at the top of the Menevian, and separating it from the overlying Lingula flags (*Olenus* beds), massive grits succeed black slates, and in these grits we again meet with volcanic materials. Were it not for these changes I doubt not the genera would have a greater vertical range, and at certain horizons also intermediate forms would be found. In naming groups of strata after a genus there is, of course, the danger that the prevailing genus in one area may not be so in another, and may indeed be entirely absent, though the beds may be of exactly the same age. Still, as already stated, other associated fossils are usually equally characteristic of the zone, therefore there is not, as a rule, much difficulty in defining the horizon even when the stratigraphical evidence is incomplete. In Wales there are many exposures of Lower Cambrian rocks which would be likely to yield fossils to a careful search, and I feel confident that, ere long, they will yield a much richer fauna than has hitherto been obtained from them.

(*To be continued.*)

IV.—THE MOST RECENT CHANGES OF LEVEL AND THEIR TEACHING. THE RAPID COLLAPSE OF SOME DISTRICTS AT THE CLOSE OF THE MAMMOTH AGE.

By Sir HENRY H. HOWORTH, K.C.I.E., M.P., F.R.S., F.G.S.

IN some recent papers published in the GEOLOGICAL MAGAZINE, I have endeavoured to show that at the close of the Mammoth age there was a very considerable dislocation of the earth's crust, and that a consequence of it was the upheaval of some of the highest masses of land on the earth, including the massive mountains of Asia and the American Cordillera. I now propose to show that (as is *à priori* probable) there was a concurrent collapse or sinking of the ground over large areas, which, as in the corresponding upheaval, was very rapid, if not sudden.

We will begin with our own latitudes. There cannot be any doubt that in the Mammoth age England was joined to the Continent. This, I presume, is accepted by everybody. We cannot account for the presence here of the Pleistocene and existing Mammals by any other postulate than the existence of a land-bridge when the Mammoth and the Tichorhine Rhinoceros were living on both sides of what is now the Channel.

This is plain. Where was this bridge? Was it a continuous stretch of land entirely occupying the English Channel, as has been generally supposed, and as has in consequence been figured on many maps; or was it a much more partial one, forming an isthmus. In my view there can be little doubt it was the latter. In the great headland at Selsea, Godwin-Austen has described large portions of the skeleton of a Mammoth as found mixed with marine shells in the same bed. I can only explain this by supposing that the English Channel in the Mammoth age was open at least as far as the longitude of Selsea; and as these shells contained a number of Lusitanian species, it means that the English Channel was then open to the west and south-west, whence these shells must have come. This is confirmed by the further fact that, so far as I know, no Mammoth remains have ever been dredged in the Channel west from this point, except close inshore in Torbay, etc. How much further eastward than Selsea the open water extended I do not know. A Mammoth tooth has been dredged on the oyster banks off Calais, and another in the channel separating the Vorn sandbank from its neighbour. This last is the furthest west in the open channel that I know of any such remains having been found under the sea, and the two banks perhaps mark the western edge of the land. When we approach *the eastern* entrance to the Channel we begin to find ample evidence of the land-bridge we have been talking about. Between Dunkirk and Cromer we can draw a line which passes through an area where the whole sea-bottom was once strewn with Mammoth bones and teeth. The majority of them have been cleared away by the dredgers. Most of them have been broken and destroyed; but the Owles Collection in the British Museum is a splendid trophy, "*spolia opima*," from this cemetery, as the fishermen call it. We can put our dredges upon the actual land-surface which then existed and bring up in them the remains of the animals which lived on it, fresh, unweathered, and sometimes even articulated, as is the case with specimens I have by me, and many specimens in the Owles Collection, and in the collections at Norwich, etc. The sharp edges of the muscular attachments in all these bones and teeth show they were never exposed to the weather nor rolled by the sea, and that they must have remained where the animals fell from the time they fell until now. That these bones are the *débris* of carcases floated by the rivers I do not for a moment believe. Rivers do not float carcases out to sea in this way, and if they did, these carcases are quite out of the way of any possible river-current of any known rivers. When occasionally animals are drowned in rivers they are speedily pulled under by the carnivorous fish, etc. The vast cemetery of Mammoths and other animals existing between Norfolk and Dunkirk has all the appearance of a stretch of land which suddenly sank, and was thus submerged, with all its living inhabitants.

What the northern boundary of this isthmus was we cannot positively say. If it be permissible to borrow an argument from ornithology, we may fix it at a line joining the mouth of the Elbe and Norfolk; for it is here that the famous migrating line of birds is placed, and the ornithologists tell us they can only explain it by supposing that this was the former limit of land and sea. Here, then, we have the rude outline of the bridge over which Mammoth and Rhinoceros, Bison and Irish Elk, with their contemporary Palæolithic Man, travelled from the Continent to Britain. This same isthmus would also separate the cold waters of the North Sea, whose temperature is attested by the so-called glacial shells found on the north-eastern coast of England, and the eastern coast of Scotland, from the warmer waters of what is now the English Channel, whose temperature is similarly attested by the shells found at Selsea.

S. V. Wood, jun., speaking of the Selsea beds, says "they contain a marine fauna quite unlike that of any post-Glacial marine beds in England and Scotland, and consisting of species, all of which are living. Nearly all the shells live on the south coast, but a few do not now reach us, but have their northern limit on the Lusitanian coast; so that the English Channel at some post-Glacial time (? post-Glacial, H. H. H.) was subjected to an influx of Lusitanian water, which afterwards ceased when the Lusitanian shells disappeared."

The disappearance of the Lusitanian shells can be explained, most rationally as it seems to me, by the breakdown of the isthmus in question, which would allow the cold waters of the North Sea to circulate into the Channel, and thus lower the temperature of its waters.

In the collapse of this land-bridge we have some evidence of the considerable subsidence which took place at the close of the Mammoth age. If we travel westward it is almost certain that the separation of the Isle of Wight from the mainland took place at the same time, for the remains of the Mammoth and its companions have been found there as on the mainland.

Further west the evidence is more definite. Round the coasts of Dorsetshire, Devonshire, Cornwall, and Somerset, there have been found large remains of submerged forests, and both in Torbay and Bideford Bay, on the two sides of the great western English promontory, there have occurred Mammoth's teeth, apparently derived from these beds. These clearly point to a considerable submergence of land in the west country after the Mammoth time, and, as the teeth and bones are unweathered, it would seem to follow that it was immediately after the destruction of the Mammoth that the submergence took place. A similar conclusion was arrived at by Dr. Falconer and the explorers of the Gower Caves, who concluded that it was impossible for herds of great herbivorous animals to live in a district like that in which the Gower Caves are situated, unless its condition was very different, and that the facts point to the submergence of a considerable extent of champagne country at the close of the Mammoth era in the district now occupied by the Bristol Channel.

If we now turn to the Irish Sea we shall have reason to come to the same conclusion. In the middle of the Irish Sea is the Isle of Man. In the Isle of Man have occurred remains of the great Irish Deer in the marls underlying the peat bogs. Similar remains have occurred in Great Britain, and of course in Ireland, and they mean that a land-bridge must have existed connecting the three areas. That this land-bridge existed in the Mammoth age we cannot positively say, since no Mammoth remains have hitherto occurred, I believe, in the Isle of Man, and there is some doubt as to whether the Irish Deer did not survive the Mammoth period in Ireland. But the probabilities are very greatly in favour of this bridge having existed at the time when the Channel bridge was broken.

The exact position of this land-bridge we cannot absolutely ascertain at present, but we have some guide. The peculiar fauna of Ireland points to its having been united to Great Britain, not in the south but in the north. The birds of Ireland are especially noteworthy in this respect, and ornithologists in fact treat Ireland as a province of Scotland. The same conclusion is pointed at by the scarcity of the remains of the Mammoth in Ireland, and the absence of the Tichorhine Rhinoceros there, the identity of the Irish Hare and the Scotch Blue Hare, etc.; and it would seem, therefore, almost certain that this bridge was situated in the north of the Irish Channel, while the south of the same sea was occupied as now by water; and we have some evidence that the Molluscan fauna of Moel Tryfaen and of the Lancashire and Macclesfield beds, and also of the Irish Pleistocene beds, is of a more temperate character than that of the beds of the same age in the west of Scotland, pointing to a separation between the waters of the Irish Sea and those bathing Western Scotland having once existed.

That some changes of level have taken place, however, in the southern part of the Irish Sea, involving a considerable subsidence, we know, from the buried forests, etc., in Cardigan Bay, while the junction of Anglesea to the mainland in the Mammoth age seems attested by the well-known molar tooth discovered by Mr. Owen Stanley in a submerged peat bog.

If we turn to the other side of England, evidence of a similar kind is forthcoming. We have remains of submerged forests off the coast of East Anglia and Yorkshire which cannot be explained by any other theory than a widespread submergence; the same conclusion follows from the semi-fossil *littoral* shells which have been dredged in the North Sea, and which show that there must have been shallow water where there is now deep.

Let us now cross over the North Sea. The coasts of Denmark are girdled with traces of submerged forests, so are the southern shores of the Baltic. Similar traces have been found in the Sounds separating Sweden and Denmark. Here we seem to be on traces of a comparatively recent change of level, since at least one polished stone axe has been dredged in the Cattegat. But even better evidence of such a submergence is the comparatively recent existence of the *Bos primigenius,* and perhaps the Bison, on both sides of the Sounds and its absence in Central and Northern Sweden, in Finland, etc. Its remains have been found in the turbary deposits of Scania, while they abound in Mecklenburg, and there is no way in which we can account for this animal occurring in both areas except by a land-bridge.

If we now turn to the plains of Holland and North Germany, we shall have evidence of another kind. The Drift deposits lie there in some places to a vast depth, and it has been remarked, that if they were removed, a very large area would be under the level of the sea; this, too, where there are no traces of marine beds below the Drift, but every evidence of continuous land conditions. This old land-surface, with its living occupants, points unmistakably to the general level having been considerably higher very recently.

Let us now turn to another district. I have already in previous articles discussed the more recent history of the Arctic border lands of North-Eastern Europe and Asia, and have shown that while in the Mammoth age the Bear Islands were united to the mainland, there was also a land-bridge between Asia and America by which the animals could pass to and fro. In either case this was followed by a great collapse along the whole sea-board, by which a large strip of land was submerged. The evidence of this is twofold, namely, the occurrence of large numbers of bones between the Bear Islands and the mainland, where they have been dredged; and secondly, the occurrence of marine shells far inland in the valleys of the Petchora, the Obi, and the Yenessei, showing quite a recent elevation. In some cases these marine beds overlie the Mammoth beds and thus enable us to fix the fact that the last upheaval has been more recent than the last submergence in those latitudes. If we turn to the eastern coast of Asia, and examine the fauna and flora of the Island of Saghalien and the Northern Island of Japan, separated from the Southern Island by that great zoological "divide" Blackeston's Line, we shall be constrained to the conclusion that these two islands, forming so integral a part of the Palæarctic region, can only very recently have been separated from the mainland, and that we have here, as in the broken bridge of Bering Straits, fresh evidence of a great and recent collapse of the land.

If we turn to America, we shall find some of the most experienced geologists in agreement as to there having been a very recent much higher continental elevation there. This is shown by the submerged valleys. Thus Prof. J. W. Spencer calls attention to the fact that the original rocky floor of the Mississippi valley is buried to a depth of 170 feet at La Closse, 1000 miles from the Gulf of Mexico; while at New Orleans the boring of 630 feet below the sea-level does not penetrate the Southern Drift, nor even reach to its highest members; this, as he says, points to the fact that the country drained by the upper waters of the Mississippi must have stood many hundred feet higher than it does now relatively to the region at its mouth, while that same region has also been greatly elevated. "Passing," he says, "from the buried channels of the Mississippi to its continuation, now submerged beneath the waves of the Gulf of Mexico, we find evidence indicating such a stupendous continental elevation as to be almost incredible were it not supported by collateral evidence upon both the Pacific and Atlantic coasts. The surroundings off the coast of the delta of the Mississippi indicate the outer margin of the continental plateau as submerged to a depth of 3600 feet, indented by an embayment of another hundred fathoms in depth, at the head of which there is a valley, a few miles wide, bounded by a plateau from 900 to 1200 feet above its floor. This valley is now submerged to a depth of over 3000 feet, and is the representative of the channel of the ancient Mississippi River, towards which it heads."

On the Pacific coast, in the region of Cape Mendocino, Professor George Davidson has identified three valleys, now submerged, from 2400 to 3120 feet, and several of inferior depth. These measurements are those of the valleys where they break through the marginal plateaux of the continent at about six miles from the present shore, where it is submerged to the depth of a hundred fathoms. Similar deep fiords exist on the Atlantic sea-board; that of the Hudson River is traceable to the margin of the continental plateau, requiring a depth of 2844 feet; similarly the Delaware River valley is continued by another fiord, the floor of which is now covered to a depth of 1200 feet, its continuation seaward not having been ascertained; so with the St. Lawrence and the Saguenay. Similar evidence of former elevation, according to Mr. Spencer, is also shown by the great depths of the American lakes. Turning elsewhere, Professor Le Conte has shown that the islands south of Santa Barbara and Los Angeles on the Pacific coast of the United States, which are separated from the mainland, and from each other, by channels from 20 to 30 miles wide, and 600 to 1000 feet deep, were still a part of the mainland during the late Pliocene and early Quaternary periods. Mr. Upham calls attention to the submerged valleys in California, and right away to Alaska, as pointing the same lesson. Travelling elsewhere again, it is impossible to doubt, if we examine the biological evidence, that the Island of Ceylon has been quite recently united to the peninsula of India; so with the islands in the Gulf of Bengal. In a recent number of "Nature" we have an account of the discoveries of the remains of an Elephant in a little island in that gulf, showing that it also must have been very recently joined to the mainland. We cannot explain the problem of the fauna of Sumatra, except by supposing that it has been very recently indeed separated from the Malay peninsula. Nor do I know anyone who doubts, since the researches of Wallace, that the Eastern Archipelago has been the scene of a very recent dislocation and subsidence. The same kind of evidence compels us to postulate the very recent sinking of the channel between Tasmania and Australia; the fauna of the two areas being so conspicuously alike, while that of the former is marked by the presence of more than one living animal now extinct in Australia, but existing there in Pleistocene times. I might continue this examination farther, and easily enlarge the number of cases, proving unmistakably that at the close of the Mammoth age there was a great subsidence of the earth's crust in many latitudes.

I have argued in previous papers that it is equally clear that some very important mountain chains were very rapidly, if not suddenly, elevated at the same period, so that the subsidence here postulated would only be the complement of elevation elsewhere.

I do not know that the facts of such a subsidence would be seriously contested provided it were granted that it were slow and continuous, but this slowness and continuity I cannot concede. I do not find evidence anywhere that is satisfactory that the earth, since it became solid, has behaved like a great mass of dough, swelling here and subsiding there by continuous movements; on the contrary, it seems to me that wherever we have evidence of such movements, and surely it is ample enough, that evidence points to its having been by jumps and starts, involving great fractures and dislocations, reversals and breaches of continuity. Just as I ventured to argue that the upheaval of the Ural Mountains, of the Altai, and of the American Cordillera was rapid, if not sudden, and marked by every sign of cataclysmic change, so also do I hold the corresponding subsidences to have been rapid, if not sudden. Evidence on such a point is not always easy to find, but in some cases it seems to me to be patent and conclusive, and I would quote them as samples of the rest. Take the Channel Bridge, to which I have already referred, or the sea-bottom between the Bear Islands and Siberia, or the submerged forests occurring on many coasts. How is it possible to understand, if the remains of these old land-surfaces were submerged by slow and gradual sinking, that the sea with its sharp chisels and hammers did not break down and wear away to powder every Mammoth tooth and bone, and every tree trunk. Instead of this, as I can testify from many examples in many places, especially in regard to the bones and teeth referred to, every slight ridge and muscular attachment is beautifully preserved, and there is no sign whatever of weathering. The bones are as sharp as the day they were deposited, not in one place only, but over wide areas. We cannot escape the conclusion that the land-surfaces on which they lie, which are entirely out of the reach of any river portage, were rapidly submerged, and thus protected from the gnawing tooth with which the ocean between high and low water-mark grinds hard rocks as well as soft ones into gravel, sand, and mud. The same argument applies to the submerged forests and beds of soft and easily eroded clay in which the trees are often rooted. Here, also, I cannot understand how such beds could have survived the battering of shingle and tide if they had been gradually submerged, as some have argued. This is not my view only, but has been held by much better men than myself, Godwin-Austen, Murchison, and others.

To quote one of them, Murchison, "it cannot surely be maintained," he says, "that by the ordinary action of the sea and a gradual depression of the lands now sunk beneath the Irish Channel, England and Ireland were separated since the gigantic Elk (*Cervus magaceros*) inhabited our lands. Nor by such gradual agency only can we even account for the formation of the great channel which now separates England from France. My firm belief, indeed, is that these separations were effected in the first instance by powerful breaks of continuity, caused by much grander earthquakes than any of which history affords a record, due to expansive internal forces, which gave rise to great upheavals and subsidences in the crust of the earth. In more remote periods, or those of older geological date, these forces have, we well know, produced still more intense disruptions, and have even abruptly thrown enormous masses of hard pebbly sediment under the rocks out of whose detritus they have been derived" (J.R.G.S. vol. clxv.–vii. p. 33).

The burden of the parable which I have been trying to preach in this paper is that the catastrophe which involved the destruction of the Mammoth and some of its companions involved not only the upheaval of some important mountain chains, but the corresponding subsidence of large areas in different parts of the world, both movements having been sudden and cataclysmic. This conclusion explains two facts which need explanation. In the first place it affords a good and ample cause for the diluvian movement which I have so often postulated, and which was deemed necessary by geologists of as great distinction, acuteness, and experience as any now living, and whose wisdom time will presently vindicate. It also explains that form of the Glacial theory which an increasing number of geologists are supporting, namely, the existence at a recent geological date, not of portentous ice-caps and ice-sheets caused by goodness knows what, and completely at issue with the laws of mechanics and the deductions of astronomy, but of much larger glaciers where glaciers still exist, and of the recent existence of glaciers where glaciers no longer exist. This result, some of us think, was due to changes within the earth itself, and not to astronomical causes. Geographical reasons suffice to create a climate at this moment at Yakutsk far exceeding in severity any climate at places on the same latitude which purely astronomical causes could induce. I believe that geographical changes of a similar kind would suffice to build up the great glaciers of Pleistocene times. If the British Isles were upheaved, so that a large part of the Irish Sea and of the German Ocean were above the sea-level it seems not improbable that the mountains of Scotland and of Wales would nurse glaciers of their own. If this elevation extended, as some very acute French geologists have urged, to Switzerland, the glaciers of the Alps would be correspondingly enlarged; so with Scandinavia. If the United States and the country to the north stood in Pleistocene times several thousand feet higher than they do now, it would invariably follow that the Laurentian highlands and the mountains of British Columbia would nurse, as the evidence shows they nursed, large glaciers also. If Tasmania were joined to Australia by the process of the general upheaval of the land in those regions, there is no difficulty in understanding how the mountains of Western Tasmania and of Victoria should also have had glaciers of their own. Thus the postulate we stand upon explains the facts as we read them. Of course it explains them on the supposition that Sedgwick, and Conybeare, and Murchison, and d'Archiac, and many other heroes of our science were not children at their work, but acute and experienced philosophers, when they argued that catastrophe is an indispensable factor in unravelling the riddle of the earth. It also involves a breach with those modern teachers of our science who, while professing to be shocked at the very sound of the word cataclysm, do not scruple to raise up continents and to sink them again, in order to explain a few rounded pebbles on the isolated flank of a hill, and make ice travel by some properties unknown to experience over hundreds of miles of level country, scraping the rock as it marches, and yet carrying under its gentle slipper several hundred feet thick of soft clay and sand, and sometimes delicate and fragile shells. I do not understand, and feel bound to protest against, the continual appeal of the modern school of geology to causes which have not been verified; and it seems to me like trying to turn the flank of the north wind by an appeal to the east wind, when a geologist, in order to save a mere scholastic formula, such as Uniformity, ignores the laws and conditions of science.

V.—SOME PHYSICAL QUESTIONS CONNECTED WITH THEORIES OF THE ORIGIN OF MOUNTAIN RANGES.

By T. MELLARD READE, C.E., F.G.S., F.R.I.B.A.

MR. A. VAUGHAN has honoured with a criticism[1] my exposition of the physical principles upon which my Theory of the Origin of Mountain Ranges is founded, which appeared in this MAGAZINE last May.[2]

Had it not been that much of what I have written seems to have been misapprehended, I should probably have refrained from comment and left the two papers to speak for themselves.

If Mr. Vaughan will refer to my "Origin of Mountain Ranges," which has been before the scientific public for eight years, he will see that chap. xi., while dealing with "the Hypothesis that Mountain Ranges are ridges thrown up by the Compression induced in the rigid Crust of the Globe by a Shrinkage of the heated Nucleus," was written to show that the ideas then prevailing on the effects of secular contraction were inaccurate, and in this chapter the conception of the existence of a level-of-no-strain was first developed. Further, to quote my own words, I say: "If the above reasoning be valid, it is plain that whatever compression may take place in the crust of the globe must be confined to a very slight depth below the surface; *to such a thin stratum*, in fact, that the ordinary denudation constantly going on would probably obliterate most of the resultant corrugations."[3]

In the contrast I have drawn from time to time between my expansion theory, and the older one of secular contraction, I have studiously given the latter theory the benefit of maximum figures in order to prove up to the hilt that the expansion theory gives the most effective explanation of geological facts as we find them. I join issue with Mr. Vaughan, however, in his calculation of the amount of material which the compression of the outer shell, according to my figures, would give for mountain-making. It would not exceed on the most favourable conditions one twenty-third of the amount he states (p. 316). Also as a practical result such surplus material could not possibly be all used for mountain-making, much

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[1] GEOLOGICAL MAGAZINE, July, 1894, pp. 312–320.

[2] *Ibid.* pp. 203–214.

[3] Origin of Mountain Ranges, p. 125.

less be concentrated in one spot; some of it would go to thicken the earth's crust.

Mr. Vaughan calls in question the principle adopted by me of ascertaining the radial contraction of the earth under the conditions assumed by me. The method, of course, is only a rough one, but when we are dealing with quantities which cannot be established with great accuracy the rough method is the safest. I take the direct linear radial contraction across the contracting shells, and multiply that by three. A little consideration will show why the linear contraction across the shells is not a true index of the earth's contraction as a whole. The shells are stretching themselves over a nucleus that remains of a nearly constant diameter, therefore they are thinning themselves by *stretching*, as well as by radial contraction. To put it in other words: A voluminal contraction is a contraction of a given volume along three axes at right angles to one another—this will be expressed roughly by a figure three times the linear contraction. When, however, a shell of rock contracts over an unshrinking sphere below, contraction along two of these axes being impossible, the whole effect is concentrated on the third and becomes a linear contraction—roughly, three times the linear contraction proper for the rock; of course being accompanied by tensile stresses and deformation of shape.

Having had considerable difficulty in following Mr. Vaughan's reasoning respecting his own theory, I may possibly have misapprehended it as he has mine in the cases just dealt with.

To put it shortly, his may be called a *tensile* theory. Before such a theory could be established it would be necessary to show that the tensile strengths of the materials of the earth are sufficient to stand the stresses this theory puts upon them. It appears to be part of Mr. Vaughan's theory that the outer crust has not been able to withstand the tensile stress put upon it by shrinkage through loss of heat, and is consequently full of fractures. How then could the underlayers by shrinking exert such a huge pressure on the interior as to actually compress the materials of the earth into a smaller volume? Is the tensile strength of any of these underlayers equal to that of steel? We know that 30 tons to the square inch is about the breaking strength of steel. It would be interesting if Mr. Vaughan or some other mathematician would work out the decrease of volume which would result from a given contraction of a shell of steel, say 30 miles thick, acting on a sphere of the size and composition of our earth.[1] A theory is of little use without a quantitative basis. When this is worked out it may be found unnecessary to calculate the amount of compression of the interior which a local shrinkage of a given segment of the sphere would be competent to produce, if, indeed, it would produce any, which I very much doubt.

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[1] If we look upon this shell as a spherical boiler of steel 30 miles thick and of the diameter of the Earth, dependent only upon its tensile strength, a pressure of steam of half a ton to the square inch would burst it. It is questionable if such a shell of steel could by shrinkage exert an effective pressure of one quarter of a ton per square inch on the materials of the interior of the Globe.

NOTICES OF MEMOIRS.

I.—British Association for the Advancement of Science. Sixty-fourth Annual Meeting, held at Oxford, August 9th to 14th, 1894.

List of Papers read in Section (C), Geology.

L. Fletcher, M.A., F.R.S., F.G.S., President.

The President's Address.

Prof. A. H. Green.—Some Points of Special Interest in the Geology of the Neighbourhood of Oxford.

E. A. Walford.—Report of the Committee on the Stonesfield "Slate."

E. A. Walford.—On the Terraced Hill Slopes of North Oxfordshire.

Prof. W. Boyd-Dawkins.—The Probable Range of the Coal-measures under the Newer Rocks of Oxfordshire and the Adjoining Counties.

Prof. W. Boyd-Dawkins.—On a Deposit of Iron Ore in the Boring at Shakespeare's Cliff, Dover.

J. Logan-Lobley.—On the Cause of Earthquakes.

Dr. Tempest Anderson.—On certain Volcanic Subsidences in the North of Iceland.

Joint Discussion with Section H, on the Plateau Gravels, opened by Mr. Whitaker and Prof. T. Rupert Jones.

Sir Archibald Geikie.—On some Traces of Two Rivers of Tertiary Time in the Inner Hebrides.

H. A. Miers.—On a New Method of Measuring Crystals, and its Application to the Measurement of the Octahedral Angles of Potash-Alum and Ammonia-Alum.

Prof. T. G. Bonney.—A Comparison of the Pebbles in the Trias of Budleigh Salterton and of Cannock Chase.

Howard Fox.—On a Soda-felspar Rock at Dinas Head, North Coast of Cornwall.

O. W. Jeffs.—Report of the Committee on Geological Photographs.

Prof. T. R. Jones.—Report of the Committee on Palæozoic Phyllopoda.

M. Laurie.—Report of the Committee on the Eurypterid-bearing Deposits of the Pentlands.

Dr. R. H. Traquair.—Preliminary Note on a New Fossil Fish from the Upper Old Red Sandstone of Elginshire.

Dr. H. Hicks.—The Homes and Migrations of the Earliest Known Forms of Animal Life, as Indicated by Recent Researches.

Montagu Browne.—On some Vertebrate Remains from the Rhætic of Britain (Third Contribution).

Osmund W. Jeffs.—On some Forms of Saurian Footprints from the Cheshire Trias.

P. F. Kendall.—Report of the Committee on Erratic Blocks.

Dugald Bell.—Report of the Committee on the High-level Shell-bearing Deposits of Clava, etc.

Dr. H. Hicks.—On some Lacustrine Deposits of the Glacial Period in Middlesex.

Prof. J. F. Blake.—Sporadic Glaciation in the Harlech Mountains.

Prof. T. G. Bonney.—On the Probable Temperature of the Glacial Period.

E. P. Culverwell.—An Examination of Croll's and Ball's Theory of Ice Ages and Genial Ages.

Prof. J. F. Blake.—On the Mechanics of an Ice Sheet.

Rev. E. Jones.—Report of the Committee on the Elbolton Cave.

Rev. E. Jones.—Report of the Committee on the Calf Hole Cave.

Prof. W. Boyd-Dawkins.—On the Permian Strata of the North of the Isle of Man.

Prof. W. Boyd-Dawkins.—The Carboniferous Limestone, Triassic Sandstone, and Salt-bearing Marls of the North of the Isle of Man.

Sir Henry Howorth.—Strictures on the Current Method of Geological Classification and Nomenclature, with Proposals for its Revision.

Montgomerie Bell.—The Pleistocene Gravel at Wolvercote, Oxford.

R. Bruce Foote.—Prehistoric Man in the Old Alluvium of the Sabar Mati River in Guzerat.

Prof. W. A. Herdman.—Report of Committee on the Marine Zoology of the Irish Sea.

C. Davison.—Report of the Committee on Earth Tremors.

Dr. H. J. Johnston-Lavis.—Report of the Committee on the Volcanic Phenomena of Vesuvius.

Prof. W. J. Sollas.—Report of the Committee on the Investigation of a Coral Reef.

Prof. W. Hennessy.—On the Shape of the Banks of Small Channels in Tidal Estuaries.

C. E. de Rance.—Report of the Committee on Underground Waters.

W. W. Watts.—On a Keuper Sandstone cemented by Barium Sulphate, from the Peakstones Rock, Alton, Staffordshire.

Titles of Papers bearing on Geology, read in other Sections:—

J. W. Thomas.—On the Chemistry of Coal Formation.

T. Johnson.—Chalk-forming and Chalk-destroying Algæ.

Prof. Osborn.—On Certain Principles of Progressively Adaptive Variation observed in Fossil Species.

W. P. Pycraft.—The wing of *Archæopteryx* viewed in the light of that of some Modern Birds.

Dr. Scott.—The Structure of Fossil Plants in its bearing on Modern Botanical Questions.

A. C. Seward.—A Contribution to the Geological History of Cycads.

H. Stopes.—The Evolution of Stone Implements.

II.—On the Geology of the Plateau Implements in Kent.

By Professor T. Rupert Jones, F.R.S., F.G.S.[1]

THIS subject having been fully treated of by Prof. J. Prestwich, the requisite references to his various memoirs elucidating the general geology of the local drift-deposits, the geological stages of their formation, and the peculiar flint-implements of the plateau are given. He has shown that certain superficial soils on the North Downs between Sevenoaks and Rochester contain numerous rudely worked flints, discovered by Mr. B. Harrison; and that these were derived from a gravel, of very great antiquity, originally formed on

[1] Read before Sections C and H, British Association, Oxford.

the side of the old Wealden Hill-range or mountain, which once rose about 3000 feet above where Crowborough and other hills in Sussex now are. Man existed at the time of these gravels, and used the flints for tools. These gravels and the implements left in them were removed by natural agencies, such as rain, rivers, sea, frost, and ice, and distributed by torrential streams on the Chalk slopes (now part of the North Downs) at a lower level on the flanks of the range.

These rude old flint implements have an ochreous colouring, due to ferruginous gravel, whence they came; and are now found on the plateau, sometimes with limited patches of some of the ochreous flint gravel, together with Tertiary pebbles, less-worn flints, and fragments of Lower Greensand, on the red "clay-with-flints" covering the Chalk. It is shown how desirable systematic excavations, to prove the extent and thickness of the implementiferous soil, would be.

Prof. Prestwich's history of the origin of the ancient Wealden Dome, Island, and Hill-ranges, and of the gradual destruction of those uplands, in the course of untold ages, with the resulting formation and removal of successive geological groups of strata, such as the Thanet Sands, Woolwich and Reading Beds, London Clay, Lenham Beds, and the old ferruginous gravel with its rude implements above mentioned, are noticed in detail.

The Diestian or Lenham Beds were found in the Early Pliocene period; and the denudation of Holmesdale probably began directly afterwards, at about the time of the Red or the Chillesford Crag in Late Pliocene, or in post-Pliocene times; and the old ferruginous gravel had not only been formed, but washed away to a lower level before that time.

The ultimate denudation of the valley cutting off the Chalk from the Weald being subsequent to the formation and removal of that gravel, the latter must have been pre-Glacial in age.

REVIEWS.

I.—(1) LES PREUVES DE L'EXISTENCE D'ORGANISMES DANS LE TERRAIN PRÉ-CAMBRIEN, PREMIÈRE NOTE SUR LES RADIOLAIRES PRÉ-CAMBRIENS. Par M. L. CAYEUX. Bulletin de la Société Géologique de France, 3e s., tome xxii. pp. 197–228, pl. xi., année 1894.

(2) SUR LA PRÉSENCE DE RESTES DE FORAMINIFÈRES DANS LES TERRAINS PRÉ-CAMBRIENS DE BRETAGNE. Note de M. L. CAYEUX, présentée par M. FOUQUÉ. Comptes Rendus de l'Académie des Sciences. Tome cxviii. No. 25 (18 Juin, 1894), pp. 1433–1435.

(1) Proofs of the existence of Radiolarians in Pre-Cambrian rocks. By M. L. Cayeux.
(2) Remains of Foraminifera in the Pre-Cambrian of Brittany. By M. L. Cayeux.

ABOUT two years since Dr. Charles Barrois announced, in a brief note to the "Comptes Rendus," the discovery of Radiolaria in Pre-Cambrian rocks of the horizon of the mineral schists and phyllites of St. Lô, in the north of Brittany. The further description of these, probably the oldest fossils known, was intrusted to M. L. Cayeux, who has had considerable experience in the study of Radiolaria and other microscopic organisms in the Cretaceous rocks; and the first of the above papers contains the results of a careful investigation into the nature of these bodies from an examination of numerous sections of the rocks in which they are preserved.

From the geological sections of the country drawn up by Dr. Barrois no doubt can be felt as to the horizon of the fossiliferous beds, which are bands of phtanite from half-an-inch to over three feet in thickness, interstratified with the schists. The phtanites are now principally of crystalline silica, and a certain amount of carbonaceous material is also present in them.

The bodies described as Radiolaria are irregularly distributed in the phtanites, sometimes occurring singly, at others great numbers are closely associated together, so as occasionally to be in actual contact. They are exceedingly small in size—the figured forms range from ·001 mm. to ·022 mm. in diameter—and to observe their structures it is needful to use much higher object-glasses than those required for other fossil and recent Radiolaria. By far the larger number are simply spherical in form, some are ellipsoidal, and there are many varieties of the inflated or cyrtoidal bell-shaped forms. One or more radial spines occur in several forms, and in two or three an inner concentric shell connected by rays with the outer test has been detected. Most of the forms figured have holes or perforations in the outer test, thus showing a lattice-like structure. This is considered by the author to be present in all, though not always recognisable.

The author has figured 45 different forms of these minute bodies, and the greater number are assigned to different known Radiolarian genera, 19 in all; a few forms cannot be placed in any described genus, but all are comprised in four of the great subordinal divisions of Haeckel, viz., Sphæroidea, Prunoidea, Discoidea, and Cyrtoidea. The author thus confidently asserts the close relationship of these Pre-Cambrian forms to existing and other fossil Radiolaria.

It will readily be conceded that, at a first glance, the forms which the author has had figured on the accompanying plate by an artist unacquainted with these organisms (and therefore unbiassed) present a strong *primâ facie* resemblance to known Radiolaria. Certain objections have, however, been made to placing them in this group by some who have had the opportunity of seeing sections of the rock containing them, and the author has very fairly and candidly stated these objections and replied to them in the paper. It should, perhaps, be mentioned that the figures now given have been taken from specimens lately obtained by the author, which show their characters more distinctly than in those which came under the notice of the objectors.

One objection is based on the extremely small size of the Pre-Cambrian bodies as compared with the dimensions of undoubted Radiolaria. This difference is very striking under the microscope, and it may be expressed by the fact that the average diameter of the

44 figured forms of which the dimensions are given is ·0115 mm; whilst the average diameter of 44 of the Palæozoic Radiolaria figured by Dr. Rüst (taking the 44 species first described) is ·2 mm.; thus it would require the combined diameters of 17 of the Pre-Cambrian bodies to reach the average diameter of one of the Palæozoic Radiolaria. The author considers that the small dimensions of the ancient forms may possibly arise from different biological conditions, and, that as size does not enter into the diagnosis of recent Radiolaria, the objection is not valid in the present case. It may, however, be noted that there is no important difference in the size of existing Radiolaria and that of fossil forms as far down as the Silurian and Ordovician rocks, and there is, therefore, no ground for anticipating that still earlier forms would be more diminutive than those of Ordovician and later times. Other objections are based on the fact that it is only in some of these bodies that perforations can be discovered, whilst it is also stated that they are too regularly spherical to be Radiolaria, and further that the bodies are not organic but are produced by the juxtaposition of small rounded granules, and that the interstices between these give the appearance of perforations. The author considers that such an interpretation is inconsistent with the law of optics, and that the perforations are really pores in the siliceous test.

Dr. Rüst, judging from the section supplied to him by the author, considered that the small rounded bodies more nearly resembled the detached chambers of Foraminifera than Radiolaria, thus allowing the organic character of the forms present; but this view does not account for the larger perforations in the test of some, and further will not apply to those which are bell-shaped. The author has, however, since the publication of the first paper, communicated a note to the "Comptes Rendus," in which he asserts the Foraminiferal character of some of the bodies in the Pre-Cambrian phtanites associated together with the forms described as Radiolaria. Of these Foraminifera, both simple and compound forms are present, but the simple specimens are hardly to be distinguished from those Radiolaria in which the pores are obliterated. The compound forms consist of a variable number—ranging from 2 to 7—of spherical or ovoid chambers of different sizes aggregated together. In some cases the chambers are furnished with one or more short blunted spines. The walls are very finely perforate, and they are therefore included in the perforate group of Carpenter. In size they correspond with the Radiolarian bodies; the largest of the chambers hardly reaching the diameter of 10 micromillimetres (=·01 mm. or about $\frac{1}{2500}$ of an inch), and thus the objection made to the Radiolarian bodies on account of the disparity in size in comparison with recent forms will equally apply to these Foraminifera.

The importance of determining the real character of the minute bodies in these Pre-Cambrian rocks will be generally recognised, and we cordially trust the author will persevere in his researches until he meets with evidence sufficient to convince those who now feel some hesitation in accepting his conclusions about them.

G. J. H.

II.—1. Western Australia in 1893. By Francis Hart. Illustrated by Maps of the Colony and numerous Photograveures and Sketches. Published by authority of the Government of Western Australia (1893). London: 8vo. pp. 276. Issued in 1894.

2. Western Australian Year-Book for 1892–93 (seventh year of issue). By Malcolm A. C. Fraser, Registrar-General. By authority, pp. i.–viii. and 1–276, with a Map of the Colony. (Perth, 1893.)

3. Mining Hand-Book to the Colony of Western Australia, written expressly for Prospectors and Strangers to the Colony who are interested in Mining. By Harry P. Woodward, F.G.S., F.R.G.S., F.I.Inst., Government Geologist. By authority of the Commissioner of Crown Lands. 8vo. pp. 126, illustrated with numerous Maps, etc. (Perth, 1894.)

4. Geological Sketch-Map of Western Australia, 1894. Scale of Nature 1 : 3,000,000. By Harry P. Woodward, F.G.S., F.R.G.S., F.I.Inst., Government Geologist, Perth. Size of Map 2 feet × 3 feet. (Published by George Phillip and Son, 32, Fleet Street, London, E.C.)

WE have frequently called attention to this rapidly-advancing colony in the pages of the Geological Magazine, and many of its fossils have been described and figured in its pages.[1]

This year has been more than usually prolific in publications issued by authority of the Government of Western Australia, and none need henceforth complain of being kept in ignorance of the wonderful discoveries as to its mineral resources, which have so astonished the world during the past few years.

Mr. Hart's Handbook is now in its second edition, and is what it professes to be, an excellent compilation from official and other reliable sources, of all matters of interest, whether political, mining, or agricultural, relating to the colony of Western Australia.

In extent of territory it greatly exceeds all the other Australian colonies; and only a short time since it was seriously proposed to subdivide it, but for the present it remains intact, with a length of 1400 miles from north to south, 1000 from east to west, and a coast-line of more than 3000 miles. Nevertheless, with all its natural advantages of climate and geographical extent, it has until the present the smallest population of any colony on that continent; but the author believes that population by means of emigration can only be obtained in competition with other countries, by offering some stronger attraction to the emigrant, as did the great gold discoveries in Victoria in 1851. Such a magnetic attraction is now

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[1] Geol. Mag. Dec. III. Vol. III. 1886, pp. 1–7, Pl. I.; Geol. Mag. 1889, p. 432. *Ibid.* 1890, pp. 97, 98–106, Pls. IV. and V.; pp. 145–155, Pls. VI. and VII.; pp. 193–204, Pls. VIII. and VIII.a; pp. 481–492, Pls. XIII. and XIV. *Ibid.* 1892, pp. 132, 133; pp. 433–437, Pl. XII.; pp. 468, 469, 542–544, Pl. XIV. *Ibid.* 1893, p. 288; pp. 412, 413. *Ibid.* 1894, pp. 385–393 *et seq.*, Pls. XII. and XIII.

being exerted by Western Australia, whose gold-fields seem likely to surpass in richness those of any other part of the world.

It remains to be seen whether the thirst for growing rich rapidly, will influence a larger body of adventurers to try their fortunes in this colony than have already been drawn to her shores; certainly opportunities are not lacking to those who can seize upon them at the right moment.

It is quite evident that Western Australia will always rank as a mining colony. The report of gold recorded by the Customs in 1892 amounted to 59,548 ounces, which at £3 16*s.* per ounce would realize £226,283; being an increase of £111,101 over the year 1891. This gold was obtained as follows, viz.:—

	£	*s.*	*d.*
Customs-returns of gold from near Albany	901	13	8
,, ,, from Yilgarn...	79,694	7	4
,, ,, ,, Cossack...	48,992	12	9
,, ,, ,, Wyndham	2,683	9	7
,, ,, ,, Derby	680	15	4
,, ,, ,, Ashburton	2	13	2
,, ,, ,, Murchison	27,110	12	0
,, ,, ,, Kimberley	773	7	3
,, ,, ,, Champion Bay ...	65,444	0	0
	£226,283	11	1

Much gold, however, was obtained which was never declared to the Customs.

No better sign of vitality in this colony, which has quite lately obtained its Constitution, can be instanced than the fact of its providing a sum of £71,482 for public works and buildings; this includes the erection of many school-houses and the expenditure of £2000 for the building of a Museum in Perth.

In his summary of the Geology, Mines, and Minerals of the colony, the author (Mr. Francis Hart) has, by an error, described Mr. H. Y. L. Brown, F.G.S., as the "*late* Government Geologist of S. Australia, and *now employed* by the N. S. Wales Government" (p. 57), and he repeats this error at p. 69. We are happy to state that Mr. H. Y. L. Brown, F.G.S., is *not late*, but is still, *the* Government Geologist for S. Australia; long may he continue to occupy that post to the advantage of the colony of South Australia!

2. This is the seventh annual issue of the "Western Australian Year-Book," 1892–93, by Malcolm A. C. Fraser, Registrar-General. A most useful book, which gives in a brief summary the discovery of Western Australia, its colonization and early settlement, its constitution and government. Much valuable information is also collected bearing upon its mineral, pastoral, agricultural, and forest resources, its population, health, and climate.

The forests, from which timber for export is obtained, are situated within the parallels of South latitude 31° to 35° and extend over an area of about 30,000 square miles, or equal to the whole territory of Scotland. Over this vast extent of wooded country a species of *Eucalyptus* (the Jarrah) prevails, which for the durability of its timber is unsurpassed by any kind of tree in any portion of the globe.

This tract is within a moderate distance of the coast, thus rendering its productions easily accessible for shipment to foreign ports.

Stems of these giant trees have been measured 80 feet to the first branch, with a circumference of 32 feet at 5 feet from the ground, while the maximum height of the Jarrah is certainly not over estimated at 400 feet.

The entire acreage of the colony is estimated at 624,588,800 acres; of this area not more that 161,459 acres were under cultivation in 1892. This is not surprising when we find the population in this vast area, at its highest, recorded at 60,000,[1] the larger proportion of whom is engaged in mining, in the timber trade, and upon the construction of railways in the colony, or living in towns and occupied in commerce.

The Constitution under which Western Australia is now governed was granted on the 15th August, 1890, and the present Ministry assumed office on the 29th December, 1890, so that, for a "four-year-old" government that of Sir John Forrest deserves the highest praise for the work it has accomplished in so brief a period of its existence.

3. "The Mining Hand-Book," by Harry P. Woodward, F.G.S., the Government Geologist, deserves notice as a most laudable effort to supply the requirements and answer the questions of a vast number of people who "*want to know*," and insist upon having official information, on the geography, geology, and mineral resources of the colony generally. The author tells us he has not written it as a scientific treatise, but has tried, as far as possible, to give the information required in as simple a form as possible, so as to bring it within the understanding of persons who have had no scientific training. After a general description of the physical and geographical features of the colony, its water-supply, timber, etc., Mr. Woodward deals with the geognosy of each district in detail, commencing with the Kimberley District in the north; then the North-Western District, followed by the Gascoyne District, which is succeeded by the Victoria; the South-Western District, the Plantagenet and the Eastern District.

The author then proceeds briefly to sketch the geology. He points out that the earlier notion regarding this continent, which assumed it to possess only a very limited number of formations, was erroneous, and that every formation known in other parts of the world is represented here, from the most ancient Archæan rocks with Cambrian, Silurian, Devonian, and Carboniferous, attested by the evidence of the fossils they contain, which have been figured and described by Mr. Wilfrid Hudleston, F.R.S. (see Quart. Journ. Geol. Soc. 1883, vol. xxxix. p. 582, pl. xxiii.), by Dr. G. J. Hinde, V.P.G.S., Dr. H. Woodward, P.G.S., Mr. A. H. Foord, F.G.S., and Mr. R. B. Newton, F.G.S., in the pages of this Magazine from 1886 to 1894, whilst the Jurassic, Cretaceous, and Tertiary formations have also been certified by their organic remains, described

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[1] Sir Malcolm Fraser, on 15 August, 1894, gives it at 71,000 on 31 March last, and 86,000 on 30 June, 1894, an increase due to the steady influx of mining prospectors now taking place, especially in the south.

by the late Mr. Charles Moore, F.G.S., by Dr. J. W. Gregory, F.G.S., and Mr. G. C. Crick, F.G.S.

The author describes briefly the aspect of mineral veins, and gives four illustrations of their appearance. He then devotes two pages and two diagrams in order to explain why, in certain areas, spring water may be obtained by boring, whilst in others it is hopeless to expect to obtain an artesian supply of water. The area occupied by each formation is then briefly noticed.

This is followed (pp. 34–55) by a short description of the minerals of commercial value which have been found, or are likely to be met with, in the colony, and the common tests by which such minerals may be recognised.

The metallic minerals are first described, and then the non-metallic; and under each is given their occurrence and uses. To this follows the account of the gold-fields of the colony (pp. 56–78). The return given by the Customs of the export of gold in the last seven years shows a value of £952,182, rising from £1,207 in 1886 to £421,385 in 1893.

This return is only the amount *declared* at the Customs, and is far below the actual export, which cannot be correctly ascertained. Most old miners are silent as to their actual gains.

The author then gives a description of other mineral deposits, as Copper-Lead, Copper, Tin, Coal, Iron and Antimony, Zinc, Manganese Graphite, etc. Much general information follows as to the means of reaching the various gold-fields, and the necessary outfit; licenses to mine; means of shipping; a glossary of terms in use by miners, etc.

No one need complain of the quantity of information contained in this little work of 126 pages, which is certain to prove of great service to the many whom it is intended to assist.

4. It must require a man as courageous as the "Bold Buccleuch" to undertake the post of Government Geologist for Western Australia, and to map an area of 976,000 square miles, being about nine times the size of the United Kingdom. We can well understand Mr. H. P. Woodward when he writes that since 1887 (a period of seven years) he has spent most of his time in travelling about this vast territory, and in examining and reporting upon the mineral resources of the colony generally.

Prior to Mr. Woodward's appointment in 1887, small portions of the colony had been examined between the years 1847 and 1851, by Dr. F. von Sommer; and prior to 1860, by Messrs. A. C. and F. T. Gregory (who published a geological map, in London, of a part of the colony in 1860). Mr. Hy. Y. Lyell Brown, F.G.S., made a geological examination of a part of the colony in 1870–71, mapping a strip of country from the Murchison River to the south coast. In 1882 Mr. E. T. Hardman reported on the Kimberley District, and indicated the existence of extensive gold areas in the north-west, which have since yielded a considerable amount of the precious metal.

The Map which the Government Geologist has just completed, and which has been carefully engraved and reproduced in chromolithography by Messrs. George Philip and Son, embodies not only the work of those earlier geologists, to whose labours we have briefly referred above, but gives a vast amount of information derived from careful geological field-work, which Mr. Woodward has accomplished during numerous expeditions, extending over the past seven years.

The largest additional areas coloured geologically extend from north of Pilbarra (lat. 20° South) to the Murchison; and the great area enclosing the Wyndham and Kimberley gold-fields in the extreme north-eastern territory, and the region about Albany, and towards Eucla in the south.

Taking the whole area of the colony at 976,000 square miles, about one-half of this has now been *provisionally* surveyed and geologically coloured on the Map. The major part of this explored area extends along the coast, and may be said to comprise a belt about 250 to 300 miles broad, reaching from Condon, north of Pilbarra, down to Cape Howe in the south, a stretch of country rather over 1000 miles in length. A second and minor area is that of the Kimberley Division in the extreme north-east of the colony, also geologically coloured on the present Map, embracing an area of probably not less than 67,000 square miles. The former and major area may be roughly divided into a broad belt 100 miles in width, and 600 in length, of volcanic rocks (granite and basalt), flanked on the west by a band, 50 to 100 miles broad, of crystalline schists and granite, and on the east by a belt of metamorphic rocks, clay slates, quartzites, etc., in which the principal gold-fields are situated. These highly altered rocks also extend for some 300 miles along the coast to the east of Albany, being covered inland by sands, limestones, and clays of Tertiary age, which stretch for 600 miles eastwards to Eucla, and 200 miles inland to the northward towards the Dundas and Coolgardie gold-fields.

At Fly Brook, and on the Collie River, Coal-beds, believed to be of Carboniferous age (but possibly younger), occur; and again on the Irwin, and probably on the Murchison also.

From here rocks of Carboniferous age, usually fossiliferous, extend in a northerly direction, about 50 miles from the coast, in a belt 20 miles wide, and covering a still larger area to the north-east, and again making their appearance on the south side of the Kimberley gold-field, and outcropping along the edge of the basalt flow, between Mt. Elder and the Antrim Plateau. Notwithstanding the larger area over which these formations are known to extend, very few beds of the series are exposed, being but little disturbed or faulted, and lying nearly always in a horizontal position.

In the Ashburton, Pilbarra, and Kimberley Districts, Cambrian, Silurian, and Devonian rocks occur, especially in the higher ranges.

The Stirling range, to the north of Albany, is probably also of Silurian age. Chalky limestones with flints forming the Lower Cretaceous beds occur at Gingin, 50 miles to the north of Fremantle, and extend for 600 miles, more or less, uninterruptedly to Onslow, on the Ashburton River. To the Cretaceous age is also attributed the overlying ferruginous sandstones, conglomerates, and clays, which not only form the flat-topped coast range, but stretch away far into the interior, forming the large table-lands, and capping the ranges to the eastward. This formation is probably an extension westwards of "the great desert sandstone" formation of the Eastern Colonies. No fossils have been found in these rocks, but as they rest conformably upon true Cretaceous rocks, both here and in South Australia, they have been classed with them; but it is quite possible they may be of *much later age.* These Cretaceous rocks are underlain by strata of Jurassic age to the north of Champion Bay, from which fossils have been obtained and described by the late Mr. Charles Moore, F.G.S., and also by Mr. G. C. Crick, F.G.S. (in this present number of the GEOLOGICAL MAGAZINE).

Although highly important to the agriculturist, the Tertiary deposits of the colony do not appear, geologically speaking, to be of considerable interest. The largest area, coloured as Cainozoic, is that of the Eucla division. The Coralline limestones form the lower beds of the coast, and are well seen at Shark's Bay and on the islands adjacent. These limestones contain many fossils, and are said to be of Eocene age. The sand-plains (of Pliocene age) are a characteristic feature of Western Australia, extending in places from one end of the colony to the other. The great sand-plains of the interior are not unfrequently 20 to 30 miles across, but as they usually contain a good deal of clay and iron which cement the grains of sand together, and there being a fair rainfall, they are covered with a hardy vegetation, and during the two spring months they are perfectly gorgeous with flowers, and form good summer grazing-grounds. These sands result mostly from the disintegration of the great desert sandstone, which forms the table-land of much of the interior of Australia.

Add to these the Shelly Limestones of the coast; the Estuarine and River-valley deposits; the Raised beaches; the ancient River-gravels and Lake-basins; and we have a very fair notion of the nature of the later deposits of this colony. In addition to the coal-fields, which are indicated by black oblique lines, the author shows on the map by similar means, in various colours, the tin-fields; the lead, copper, and last, but by no means least, the vast extent of the gold-fields of this wonderful colony, which has lain dormant so long waiting for the master-mind which should develop it, or, rather, which should re-act upon other minds, and so stimulate its fellow-men to go forth to colonize this hitherto all but *terra incognita,* where fortune awaits the man of enterprise. With such a Map to aid one; with such guide-books to direct one's steps; with so admirable an Agent-General here in London as Sir Malcolm Fraser to assist one; with so energetic a Premier as Sir John Forrest out in Perth; and so able a Government Geologist as Mr. Harry Page Woodward, to advise them on the spot, what need the emigrant fear who embarks for Western Australia? The climate is the finest in the world, and the death-rate the lowest.

III.—PROCEEDINGS OF THE MALACOLOGICAL SOCIETY OF LONDON. Vol. I., October, 1893—June, 1894. 8vo. pp. 138, 10 Plates. (London: Dulau & Co.)

THE first three numbers of the Proceedings of this vigorous young Society, whose President is Dr. Henry Woodward, F.R.S., lie before us, and if they be any earnest of the future of the Society, which may be said to show its hand in them, they indicate that, if cheiromancy be worth anything, assuredly the Society's "line of life" will be long. The object of this new bond between malacologists, we learn, is "to facilitate the study of the Mollusca and Brachiopoda, both recent and fossil," and we are pleased to note that the palæontological side of the subject is fairly represented by some most valuable and important papers by Mr. G. F. Harris and Mr. R. B. Newton, who in three out of their four contributions write conjointly. Their "Revision of British Eocene Scaphopoda" and "Revision of British Eocene Cephalopoda" are memoirs that will long be of great value, even in these days of rapidly increasing knowledge. In the latter paper Edwards' anomalous genus *Belemnosis* is neatly disposed of; for, acting on a hint received from Mr. F. A. Bather, the authors are able to show that it was founded on a rolled specimen of *Spirulirostra.* Their paper on some little known Pulmonate Mollusca from the Oligocene and Eocene formations of England, is, we think, less happy; the authors having given living force to certain MS. names, some of which, considering the very fragmentary nature of the specimens, had better have been left in obscurity; nor do they seem yet to have realized that *Planorbis* has long been known to be a sinistral, not a dextral, genus. It is to be hoped that further contributions from these and other palæontologists may be found in future numbers of the Society's Proceedings.

IV.—CREATURES OF OTHER DAYS. By Rev. H. N. HUTCHINSON, B.A., F.G.S. With numerous Illustrations by J. Smidt and others (24 plates and full-page illustrations, and 79 illustrations in the text). Pages xv. and 270, 8vo. Chapman & Hall, London, 1894.

MR. HUTCHINSON'S former book, "On Extinct Monsters," noticed in the GEOL. MAG. for January, 1893, was a praiseworthy and successful attempt to give a good popular account of many of the more noteworthy denizens of this world existing before the advent of Man, and now known only by their fossilized bones, teeth, and scales. Some of these relics, formerly gazed at with ignorant wonder, and often referred to as evidences of prehistoric giants drowned by the Noachian Deluge, had gradually during the last century been pieced together into intelligible forms, though strange even to those who knew something of the various modifications of the animals now existing. Limited groups of such reconstructed skeletons have been frequently used in Manuals and Text-books of Geology, and were occasionally invested with imaginary integuments. These creatures in some instances were, as far as circumstances permitted, even represented by solid models, such as Mr. B. Waterhouse Hawkins made of the little *Dendrerpeton* and of the gigantic forms still visible in the gardens of the Crystal Palace.

The advancing science of palæontology, realizing more and more of the fossil remains of vertebrate animals, as discoveries have been made of late years, especially in the North-west Territories of the United States, has rehabilitated many of the former creatures of all the continental lands, whether they had been washed out to sea, drowned in lakes, swamped in bogs, or left in rifts and caverns of the solid rocks. Several of these were boldly figured in their living aspects, and vividly described for the general reader, in Mr. Hutchinson's former volume, and its second edition, including some very old and interesting forms, quaint indeed, and strange among their modern successors and representatives. Not excepting even those who know by close study something of the numerous links of the wonderful chain of life, all must be astonished at the manifold and ever-varying representatives of the corporeal types that present themselves once more when the dry bones seem to live again in the studio or museum, taking their relative places among, or near to, the several kinds of existing animals. Doubtless many links, still missing, will be supplied by either personal or national well-directed research.

How many such fossils have been found and cared for by societies and persons at home and abroad, the several large Museums about the world plainly show. Not least, the Natural-History Branch of the British Museum; and of this Mr. Hutchinson has especially availed himself in enlarging his menagerie of extinct animals in the very presentable volume before us.

Our friends in the United States have obtained vast collections of teeth, bones, and skeletons, not merely with expense and trouble, but often with personal danger to explorer and collector in the North-western Territories. The talented and hard-working palæontologists have described and figured the remarkable animals restored from these bones; and, years ago, they had life-sized models made of some, by the late Mr. B. Waterhouse Hawkins, for the Central Park of New York. In preparing, for the Educational Department, these bodily restorations of early and long-past creatures, which exact knowledge proves to have had near relationship with existing forms, and in themselves to be "manifestations of the present and all-pervading plan," Mr. Hawkins must have been highly "gratified in advancing the means of educational progress in America" (Geol Mag. December, 1879). An ignorant Mayor of New York City, however, being told that the restorations represented *extinct* creatures, said that, if the Creator had ordained their extinction, they should be extinct; and this great magistrate of a great city had the models extinguished by sledge-hammer and burial. But still God's creatures survive in appreciable fossils, and by books and illustrations, to the advantage of science, and hence, in many ways, to the welfare of intellectual communities; and fanatical ignorance has only damaged the credit of its votaries. Figures of the restored *Hadrosaurus* and *Dryptosaurus* (*Lælaps*) are reproduced in Chap. vii. in two plates from the Central Park Reports for 1869–70; that of *Hadrosaurus* is also given at page 488 of J. La Conte's "Elements of Geology," 1886.

Still more strongly may it be said of Mr. Hutchinson's work (in presenting to the general public so many exemplifications of animal variety resulting from the fixed and inexplicable laws of life in successive ages, long before Man's appearance on Earth), that he not only opens up for many, unthought-of scenes with strange actors, but strengthens the intellectual growth of the rising generation; for, the more that is known of the Earth and its history, the broader and better is popular knowledge in general, and the more exact and aptly useful is professional knowledge.

The accepted series of Geological Formations characteristic of the several periods, when Invertebrates, Fishes, Reptiles, Mammals, and Man have been successively abundant or dominant, is given in the Appendix i. A classification of Vertebrate Animals, in Appendix ii., shows how the many kinds, both existing and extinct, fall into order, according to their known structure, and form correlative groups, linking fishes, at the lowest end of the scale, to Man at the highest. With these plans or synopses of nature before him, the reader can better grasp the meaning of the author's arrangement of his subject, and the details given in his twelve chapters.

The markings left on mud-flats and other soft surfaces by various burrowing, trailing, crawling, and walking animals are referred to as "footprints on the sands of time," in Chap. i.; those made by four-footed animals being chiefly noticed. The Fishes, as the lowest of the back-boned animals, come in Chap. ii., with notes as to their evidence of the "law of progress." As in all the other chapters, the author makes careful allusion to those who have collected, recorded, and elucidated the fossils.

The Batrachian and other Amphibia of the present day are the tropical Cœcilians, Illyrian Proteus, American Siren, Axolotl, and Menobranchus, Javanese Menopoma, European Newts, and world-wide Frogs and Toads. Of these the Frog group is represented in the Tertiary formations only; but, as Chap. iii. fully shows, there were very numerous creatures more or less allied to such Salamanders as *Menopoma* and its allies in foregone periods of the Earth's history, when the Carboniferous, Permian, and Triassic beds were being formed. Of these the *Archægosaurus* and *Labyrinthodon* are frequently mentioned. Their sculptured skull-bones and dermal plates, their teeth with internal labyrinthic structure, and their peculiar skeletal bones, are very characteristic, sometimes giving a salamandroid, and sometimes an elongate fish-like shape. The different size of the well-known Triassic prints of the fore and hind feet at first suggested a somewhat frog-like, shambling body (Owen); and as such it appeared in various text-books in 1850–60. During that period it had taken the more toad-like position in the model by Mr. B. W. Hawkins,[1] alluded to at pages 57 and 144. Prof. Owen's outline of the creature was grossly exaggerated into an awkward sprawling attitude in some manuals of geology about 1865. We have still to be thankful for Owen's suggestive sketch of such an animal as could have left the Cheirotherian foot-prints; especially since nothing in Chapters iii. and iv. explains their incongruous appearance. The *Actinodon*, however, in Plate III. makes some approach to the conditions required. A special point of interest with regard to these old fossils is that they supply links between fish and reptile. Ireland and Bohemia have more especially supplied several well-preserved Labyrinthodont Amphibia, chiefly from the Coal-measures.

The great Ichthyosaurian tyrants of the Triassic, Jurassic, and Cretaceous seas had relationship to both fishes and lizards; and Chapter iv., headed "Anomalous Reptiles," treats of some extinct creatures allied to the Amphibia and the Sauria or "Reptiles proper,"—such as the *Dicynodon*, *Oudenodon*, *Tapinocephalus*, *Galæsaurus*, and especially the great *Pareiasaurus*, all from the Karoo formation of South Africa. Moreover, some of these peculiar South-African reptiles possess indications of having affinity to the mammals succeeding them.

The earliest Lizard (or true Reptile) known is the Permian *Proterosaurus*; the Triassic *Rhynchosaurus* and *Telerpeton* come next. The wonderful *Elginia mirabilis*, with its diabolically horned and prickly skull, coming (like the last-mentioned) from the Trias of Scotland, is said to be related to both labyrinthodonts and lizards.

The Crocodiles come next in order of animal structure; and Chap. v. gives a sketch of their history. The earliest were in the Trias (the first formation in the Mesozoic, or middle-life, period); and animals of the same type have survived (that is, have been successively represented) until now, "with comparatively little change either in structure or habits," being "one of Nature's persistent types"; but the sharks, nautiloid and nuculoid molluscs, some brachiopods, bivalved crustaceans, and rhizopods have held on for a much longer time,—even from the Silurian period. The land and water conditions formerly existing in the European area favourable for crocodilian life, and the remarkably abundant co-existence of crocodile, gavial, and alligator in what is now part of the British area, have been fully described with the poetry of simple truth by the late Professor Owen, and quoted by Mr. Hutchinson at pages 115 and 116.

In Chapters vi. and vii. are described several of the extinct Reptiles which have usually a long neck, big body, strong hind legs, and powerful tail, but always short front legs and relatively small head. From the dreadful aspect which our *Iguanodon*, *Hylæosaurus*, and *Megalosaurus* were supposed to have had, these creatures were named Dinosaurs (or Deinosaurs=terrible-lizards). Of late years their forms have been better understood; and, indeed, there have been many newly discovered examples showing "the

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[1] Mr. Hawkins's sketch of the Crystal Palace Models was published in the "Journal of the Society of Arts," No. 78, 1854.

definite shapes and proportions of some of the great and long-unknown reptilian masters of the world, whether dignified in their monstrous bulk and unused power, as Herbivores, or domineering as the Carnivorous tyrants of their day" (GEOL. MAG. 1869, p. 566).

Hypsilophodon, Compsognathus, and *Hallopus* are the smallest —the first about four feet long, and the last "about the size of a fowl," and probably light enough to hop about. The larger forms, such as *Iguanodon* in Europe, and *Claosaurus* and others in America, reached about thirty feet in length and fifteen in erect height. These animals, (like Crocodiles) adapted for both swimming and walking, have left their tracks on former mud-flats and sand-banks, as in Sussex and Connecticut. In the latter district they are mingled with possible bird-tracks and probable labyrinthodont footprints.

Beginning with the Trias, they ended their career in the early part of the Cretaceous period; and they brought with them certain structural peculiarities, which became more developed and specialized in Birds. The *Pterodactyle* (flying reptile) and *Archæopteryx* (reptilian bird) present other such evidences of progressive stages among life-forms.

The "Ancient Birds" have Chap. viii. to themselves, bringing the reader through the Cretaceous period, with its toothed birds, to a few centuries and less ago when the Moa, Dodo, Solitaire, and Great Auk have succumbed to destructive Man.

Chapter ix. begins a new era of the history of the "Creatures of Other Days," with animals of the Tapir and Elephant types; those belonging to the Horse, Whale, and Wombat occupy Chapters x. and xi.; and some extinct South-American creatures, and the Californian Ox, end the series in Chapter xii.

The most advanced and highest Mammals are doubtlessly shown in Plates i. and xii., though the latter is placed in the Dinosaur chapter; for Richard Owen, Huxley, Marsh, Cope, von Zittel, and Gaudry, are here pourtrayed as representative palæontologists. The other numerous illustrations have also been carefully prepared, and in many cases are artistically good.

Certainly verbal errors (by author or printer) are not absent; and there are obscurely elliptical phrases, such as "the genus must have been as large as an ostricht" (p. 161). The author's own "kind friends" will probably have drawn his attention to some such weaknesses, and to points on which differences of opinion are held. We need only say that the book is clearly and pleasantly written; it is full of desirable information well considered and conveniently arranged. T. R. J.

CORRESPONDENCE.

DYNAMICAL METAMORPHISM.

SIR,—In connection with my friend Mr. Harker's remarks on experimental dynamic metamorphism, some of your readers may be interested to try for themselves one of the simplest cases. Apparatus—a teaspoon, a lamp, a sheet of paper, and a few crystals of Biniodide of Mercury. Heat the scarlet crystals in the teaspoon over the lamp; they become pale yellow. Place them on the paper, and rub them with the thumb-nail, and they become scarlet again. They are now reduced to a red powder colouring the paper. Pass the paper to and fro over the lamp, the scarlet instantly turns yellow. Attempt to rub the powder off by passing the paper over the carpet, the paper instantly turns red again.

Miller explains the change from yellow to red as follows:—"Warrington has shown that this change of colour depends upon a change in the molecular constitution of the salt, in consequence of which the rhomboidal crystals are converted into octahedra with a square base." This alone would be sufficiently perplexing, but the changes seem capable of being produced over and over again, and we have simply to alternate thermal and dynamic metamorphic processes to produce the yellow biniodide and the scarlet biniodide of mercury at pleasure. If these things may be done in the drawing-room, what may not thermal and dynamic metamorphism, alone or combined, effect in the laboratory of nature?

One more possible case. In using the soldering iron (which iron is always copper) a very moderate temperature is essential to keep the solder on the face of the clean copper, a temperature far below that requisite to melt copper with tin to produce one of the copper-tin alloys; yet occasionally the soldering iron will show streaks of yellow gun-metal. An amateur in his attempts at soldering is apt to press the soldering iron heavily on his work, and it seems possible that the alloy indicated on the iron may arise from insufficient heat being reinforced by equally insufficient pressure; the two combined being, however, sufficient to produce an alloy of copper and tin. If this be so we have in the soldering iron a case of thermal and dynamic metamorphism in combination, just as in the biniodide of mercury we have thermal and dynamic metamorphism in alternation.

A friend employed on the Manchester Ship Canal once sent me a specimen of red sandstone from a slickenside. At the plane of contact and pressure the red colour is entirely discharged, and the stone apparently porcellanized. The depth to which the metamorphic action extends is so very slight, sometimes less than $\frac{1}{8}$th of an inch, that the metamorphosis would seem due to pressure rather than heat, as it is difficult to understand how pure thermal action could be restricted to such a mere film.

Torquay, 16*th June*, 1894. A. R. Hunt.

SHELLS FROM PORTLAND RUBBLE DRIFT.

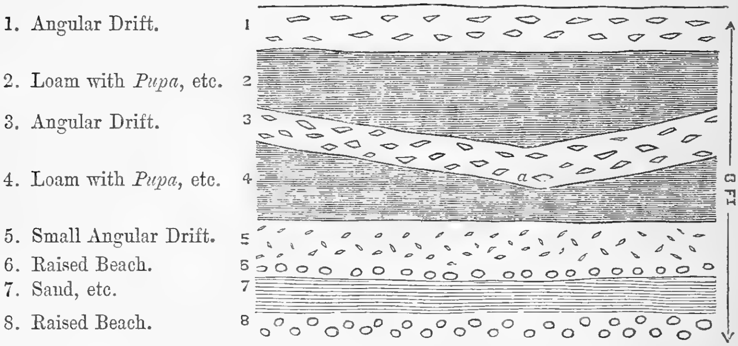
Sir,—I had the pleasure of several hours work in June last at the Rubble Drift at Portland, both at Chesilton and at the Bill.

I was not able to obtain any recent shells from the Chesilton Rubble; but I would remark on the enormous angular and sub-angular blocks of Portland oolite that occur in this section at various horizons, the whole of the material being unsorted, and therefore having been accumulated by more or less rapid aggregation of material in a comparatively brief space of time.

At Portland Bill, in the loam or loess between strata of angular *débris* from the Middle Purbecks, I found an interesting collection of land and fresh-water shells. Mr. Edgar A. Smith, of the British Museum (Natural History), has kindly determined the species for me. They are:—

Succinea oblonga (Drap.)	41 specimens.	*Pupa muscorum* (Linn.)	56 specimens.
Limnæa peregra (Linn.)	4 ,,	*Cyclostoma elegans* ...	1 ,,
Helix hispida (Linn.) ...	1 ,,	*Pisidium*, sp.	1 ,,
Helix pulchella	5 ,,		

These shells are entire, but very brittle. A great many broke to pieces in the process of washing out, and reduced my spoils. The *Cyclostoma* was dug out of a large block of fallen loam by my wife, but in such a position as left no doubt of its genuineness. Fifteen of the *P. muscorum* are immature specimens; two of them have only two whorls. Professor Prestwich has hitherto only found the operculum of *Cyclostoma* at the Battery, Folkstone, and *H. hispida* and *H. pulchella* at the same place. *Pisidium* does not occur in his lists of Rubble Drift Shells as given in the Raised Beach paper (Quart. Journ. Geol. Soc. 1892, vol. xlviii.), and of the above list only *S. oblonga, L. peregra,* and *P. muscorum* are named from Portland Bill. I also found four specimens of *Littorina litorea* in the Rubble Drift, one at a height of 4½ feet above the raised beach, from which they have probably been derived. A large piece of mammalian bone also occurred at the bottom of the second seam of angular Rubble Drift, at (*a*), and which is only slightly adherent to the tongue. I give a rough sketch of the section.



Section of the Rubble-Drift, Portland.

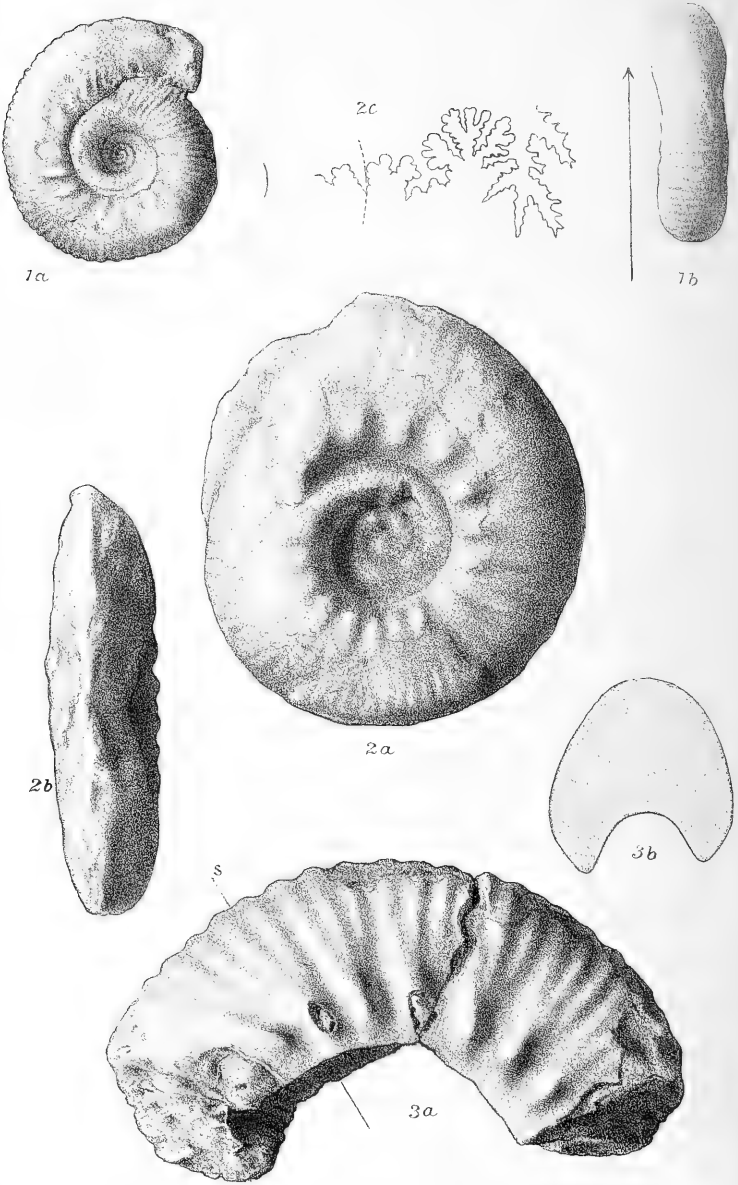
Shoreham Vicarage, Kent. R. Ashington Bullen.

Geological Survey of India.—We are glad to announce that Major C. L. Griesbach, C.I.E., F.G.S., has been appointed (July 17th) Director of the Geological Survey of India, after about twenty years service, *vice* Dr. Wm. King, F.G.S., retired.

Errata:

Geol. Mag. August Number, pp. 337 and 339, for *Nanopus* read *Nasopus*.—O. C. Marsh.

Ibid. p. 364, line 19 from bottom, for *Trias* read Permian.—A. Irving.



E. C. & G. M. Woodward del. et lith. West, Newman & Co. imp.

Western Australian Cephalopoda.

THE

GEOLOGICAL MAGAZINE.

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No. X.—OCTOBER, 1894.

ORIGINAL ARTICLES.

I.—On a Collection of Jurassic Cephalopoda from Western Australia—Obtained by Harry Page Woodward, F.G.S., Government Geologist—with Descriptions of the Species.

By G. C. Crick, A.R.S.M., F.G.S.,
of the British Museum (Natural History).

(PLATE XIII.)

(*Continued from the September Number*, p. 393.)

Ammonites (Sphæroceras, Bayle).

Ammonites (*Sphæroceras* ?) *Woodwardi*,[1] sp. nov. (Pl. XII. Figs. 6*a* and *b*.)

Sp. char.—Shell (cast) discoidal, somewhat inflated, rather rapidly increasing. Whorls somewhat inflated, very convex on the periphery, less convex on the sides, rounded near the umbilicus. Umbilicus moderately wide, occupying nearly one-third of the diameter of the shell. Number of whorls and amount of inclusion unknown. Height of outer whorl rather more than one-third of the diameter of the shell. Each whorl ornamented with about 20 short, thick, umbilical ribs, each of which commences at the suture, extends radially or with a very slight forward inclination over one-fourth of the width of the lateral area, and terminates in a radially-elongated tubercle. Each tubercle gives rise to three, or more rarely to two, subangular ribs (in the cast), which pass uninterruptedly over the periphery. There are about 48 of these ribs to a whorl; at the periphery, the interspaces are twice the width of the ribs. Length of body-chamber unknown. Margin of the aperture prominent, provided on each side with an apophysis. Septa and suture-line unknown. Test not preserved.

Dimensions:—

Diameter of the shell	60	mm.
Width of umbilicus	20	,,
Height of last whorl	22	,,
Thickness of last whorl	16+	,,

Since the fossil has been somewhat distorted, these dimensions must be considered only as approximate; the height of the outer whorl has probably been somewhat increased, whilst the thickness of the whorl has been considerably reduced.

Remarks.—The only example representing this species is a rather crushed natural cast of the greater portion of the outer whorl, much abraded on one side. The inner whorls are not visible, and unfortunately there is no trace of the suture-line. A portion of the mouth-border is preserved, and there are remains of the prominent base of one of the lateral apophyses.

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[1] Not *Ammonites Woodwardi*, H. G. Seeley, Ann. Mag. Nat. Hist. [3], vol. xvi. 1865, p. 236, pl. xi. f. 3, which probably belongs to the section *Hoplites*, Neumayr.

Affinities and differences.—In its general form and ornamentation this species closely resembles *Ammonites Sauzei*, d'Orbigny (Pal. Franç. Terr. Jur. vol. i. 1842, p. 407, pl. cxxxix.). A specimen of the latter from the Inferior Oolite of Sherborne, Dorset (Brit. Mus. No. C. 3230), 61 mm. in diameter, gives the following measurements: Width of umbilicus, 19 mm.; height of outer whorl, 24 mm.; thickness of outer whorl, 30 mm. Allowing for the compression of the Australian specimen, d'Orbigny's species was probably a more inflated shell with somewhat coarser ornaments and fewer umbilical ribs (14–15).

In its sculpture *Ammonites Bainii*,[1] Sharpe, from Sunday River, S. Africa, somewhat resembles the present species, but it has much more inflated whorls, and a narrower and deeper umbilicus.

From such forms as *Ammonites biplex*,[2] J. Sowerby, the present species is at once distinguished by the presence of a tubercle at the point of bifurcation of each umbilical rib.

In proposing for the Australian form the specific name *Woodwardi*, the writer has great pleasure in associating with the fossil the name of Mr. H. P. Woodward, Government Geologist, Western Australia.

Locality.—Champion Bay, Western Australia.

Ammonites (*Sphæroceras*) *semiornatus*, sp. nov. (Pl. XIII. Figs. 1*a*, *b*.)

1870. *Ammonites Brocchii*, C. Moore, Quart. Journ. Geol. Soc. vol. xxvi. pl. xv. f. 4.

Sp. char.—Shell discoidal, somewhat inflated; greatest thickness at a point distant from the umbilicus about one-third of the width of the lateral area, about one-third of the diameter; height of outer whorl about one-third of the diameter of the shell. Whorls six; inclusion two-thirds, diminishing considerably in the outer whorl, so that at the commencement of the outer whorl the inclusion is not one-half; umbilicus wide, rather deep, exposing the inner area of the whorls. Suture-line imperfectly seen, and depth of chambers unknown. Whorl lunate in section at base of body-chamber, and about as wide as high, becoming at the anterior part of the body-chamber more elliptical in section, and rather higher than wide; periphery convex, forming a continuous curve with the sides; inner area sloping towards the umbilicus, feebly convex. Each whorl ornamented with about twenty-two primary ribs, slightly curved and forwardly inclined, extending from the suture over about one-third of the width of the lateral area; each then dividing into three, or more rarely into two, less prominent ribs which cross the periphery without interruption, the number of these peripheral ribs being about sixty-nine to a whorl. Up to the point where the diameter of the umbilicus is 8 mm. the inner area of the whorls (as seen within the umbilicus) is quite smooth.

Dimensions:—

Diameter of shell	61	mm.
Width of umbilicus	22·5	,,
Height of outer whorl	20	,,
Thickness of outer whorl	17·5	,,

The specimen from which the above measurements were taken has a maximum diameter of 64 mm., but at this diameter the other dimensions cannot be so accurately determined. The anterior portion of the body-chamber appears to be slightly crushed, so that the thickness of the outer whorl as given above is probably too small.

Remarks.—The description given above is based upon a single

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[1] Trans. Geol. Soc. [2], vol. vii. 1847, p. 197, pl. xxiii. f. 2. Pavlow (Bull. Soc. Imp. Nat. Moscow, N.S. vol. v. 1892, p. 493) places this species in a division (*Astieria*) of Neumayr's genus *Olcostephanus*.

[2] Min. Con. vol. iii. p. 168, pl. ccxciii. 1821.

specimen 64 mm. in diameter. It is a natural cast, and bears only fragments of the test; its outer whorl appears to have been occupied by the body-chamber, traces of the septa being seen at the commencement of this whorl.

Having examined the specimen figured by Moore as *Ammonites Brocchii,*[1] I believe it is to be referred to the present species. Its dimensions are as follows:—

Diameter of shell		92 mm.
Width of umbilicus		33 ,,
Height of outer whorl	about	33 ,,

The thickness of the outer whorl at a diameter of 72 mm. is 36 mm.; beyond this point the specimen is much crushed. The shell is somewhat distorted, so that the width of the umbilicus is probably exaggerated. Its suture-line cannot be made out, but around the umbilicus can be seen the compressed, forwardly-inclined, short primary ribs, each giving rise to three or four prominent ribs, which pass without interruption over the peripheral area.

To the present species may also probably be referred a specimen (No. C. 4709) in the British Museum (Nat. Hist.), from "the Greenough, Champion Bay, Australia." It is part of a specimen 127 mm. in diameter; the inner whorls up to a diameter of 25 mm. are fairly well preserved, the innermost being perfectly smooth; about half of the outer whorl is present and in fair condition, and shows the compressed umbilical tubercles or short prominent primary ribs, each branching into three less prominent, but well-marked, ribs, which cross the periphery without interruption. On the anterior half of the outer whorl the primary ribs are more forwardly-inclined than on the posterior half. A projection on the lateral area at the anterior extremity of the specimen may be a portion of the prominent mouth-border. The sculpture of the posterior part of the outer whorl greatly resembles that of the large specimen from Cape Riche, which I have referred to *Ammonites* (*Perisphinctes*) *Championensis* (see p. 436), but the latter appears to have been a more inflated shell.

Affinities and differences.—J. Sowerby's type-specimens of *Ammonites Brocchii*[2] are much more inflated than the present species, whilst the type-specimen of *Ammonites Brodiæi*[3] of the same author has more distinct and somewhat larger primary ribs and very prominent tubercles at the points of subdivision of the primary ribs. *Ammonites contractus*[4] of J. de C. Sowerby is a much more inflated shell with a smaller umbilicus. D'Orbigny's figure of *Ammonites linguiferus*[5] represents a more inflated shell, with more numerous ribs and more prominent lateral tubercles; and *Ammonites dimorphus*[6] of the same author has fewer whorls, a differently-formed umbilicus, and its whorls bear constrictions at nearly regular intervals.

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[1] Quart. Journ. Geol. Soc. vol. xxvi. (1870), pl. xv. f. 4.
[2] Min. Con. vol. ii. p. 233, pl. 202, both figs. [Brit. Mus. No. 43906].
[3] Min. Con. vol. iv. p. 71, pl. 351 [Brit. Mus. No. 43905].
[4] Min. Con. vol. v. p. 162, pl. 500, f. 2.
[5] Pal. Franç. Terr. Jur. vol. i. pl. 136.
[6] Pal. Franç. Terr. Jur. vol. i. pl. 141.

Compared with *Ammonites Gervillii*, J. Sowerby,[1] [*Ammonites Brongniartii* (*pars*), A. d'Orbigny,[2]] the Australian fossil is less inflated and differently ornamented, whilst the greater inclusion of its whorls, its narrower umbilicus, and the smoothness of its inner whorls distinguish it from *Ammonites polymerus*, W. Waagen[3] [*Ammonites Brongniartii* (*pars*) d'Orbigny].[4]

The British Museum Collection contains examples of an apparently undescribed species from the Inferior Oolite of Dundry, Somerset, which resemble the present species most closely; they have, however, a somewhat larger umbilicus, finer ornaments, and their inner whorls (as seen within, the umbilicus) are distinctly ribbed, even where the umbilicus has a diameter of only 2·5 mm.

Locality.—Champion Bay, Western Australia.

AMMONITES (PERISPHINCTES, W. Waagen).

Ammonites (*Perisphinctes*) *Championensis*, sp. nov. (Pl. XIII. Figs. 2 *a*, *b*, and *c*.)

Sp. char.—Shell (cast) discoidal, with somewhat inflated whorls; greatest thickness near the margin of the umbilicus, exact thickness unknown; outer whorl about two-fifths of the diameter of the shell in height. Number of whorls not seen; inclusion (in the outer whorl) about three-fifths; umbilicus not very deep, wide, about one-third of the diameter of the shell in width. Whorl somewhat oval or almost lunate in section, probably wider than high; indented to about two-fifths of its height by the preceding whorl; periphery probably narrowly convex; sides convex; inner area steep, almost perpendicular, slightly convex. Chambers shallow. Suture-line rather complex, incompletely known; outer saddle only partly known; the first lateral lobe deep, narrow, trifid; the first lateral saddle much broader than the first lateral lobe, divided into four principal branches, that forming the most anterior portion of the suture-line being again divided by a secondary lobe into two branches, the outer of which is again subdivided by a small lobe; the second lateral lobe scarcely one-half the size of the first lateral lobe, indistinctly trifid, the median portion being very short; the second lateral saddle small, divided by a small lobe into two unequal branches, the inner of which is again subdivided by a minute lobe; between the second lateral saddle and the suture of the shell three auxiliary lobes and saddles. Each whorl ornamented with about nineteen or twenty compressed, not very elevated, short ribs, or radially elongated tubercles, each giving rise to three or four rounded, slightly elevated ribs, thirty-eight of which can be counted in half a whorl, the interspaces being of about the same width as the ribs.

Dimensions:—

Diameter of the shell	about	115	mm.
Width of umbilicus		39	,,
Height of outer whorl	about	45	,,
Thickness of outer whorl		(?)	,,

The thickness of the outer whorl cannot be ascertained, since only one side of the specimen is preserved.

Remarks.—The above diagnosis has been drawn up chiefly from a natural cast about 115 mm. in diameter, consisting of one side of the outer whorl fairly well preserved, bearing fragments of the test and exhibiting the greater part of the suture-line; the inner whorls are not preserved. The collection, however, includes another speci-

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[1] Min. Con. vol. ii. p. 189, pl. clxxxiv. A, fig. 3.

[2] Pal. Franç. Terr. Jur. i. p. 403, pl. 137, ff. 3, 4 (*non* ff. 1, 2, 5).

[3] Ueber die Zone des *Ammonites Sowerbyi*, Benecke's Geogn.-paläont. Beiträge, vol. i. p. 605.

[4] Pal. Franç. Terr. Jur. i. p. 403, pl. 137, ff. 1, 2 (*non* ff. 3, 4).

men, probably referable to this species, which exhibits a portion of the suture-line that supplements in a certain degree the suture-line of the example selected as the type. The collection also contains, from "Cape Riche, about 50 miles E. of Albany," a large specimen 160 mm. in diameter, which is probably a more mature example of this species. It consists of the outer whorl only. Although its suture-line cannot be made out, its general form resembles that of the present species so closely that it is referred to this species.

The present species appears to be represented in the British Museum Collection by a crushed and distorted portion of the outer whorl of an example from "the Greenough, Champion Bay," about 110 mm. in diameter (No. C. 4708). It bears fragments of the test.

Probably to this species may also be referred an example in the collection of Western Australian fossils in the Bath Museum. It is labelled "*Ammonites macrocephalus*"; but is not the specimen figured by Moore. It has the following dimensions: Diameter of shell, 109 mm.; width of umbilicus, 37 mm.; height of outer whorl above preceding whorl, 27 mm.; thickness of outer whorl, 40 mm.; width (as seen within the umbilicus) of the penultimate whorl at the greatest diameter of the shell, 12 mm. The body-chamber commences where the shell has a diameter of 88 mm., and therefore occupies nearly a whorl.

Affinities and differences.—This species greatly resembles *Ammonites Cautleyi*,[1] Oppel, from the Jurassic rocks of Laptel, in Gnari-Khorsum, Thibet; but Oppel's species possesses constrictions and is a more compressed shell. Unfortunately the suture-line is not available in Oppel's species for comparison. Compared with *Ammonites albineus*,[2] Oppel, from the Oxfordian of Würtemberg, the Australian species is more robust and has a different suture-line. In Oppel's species, moreover, the ribs which cross the periphery disappear at a diameter of 75 mm., but they are quite distinct in the Australian specimen at a diameter of 110 mm. The present species differs from *Ammonites polymorphus*,[3] d'Orbigny, from the Inferior Oolite, in having more inflated whorls, larger and fewer tubercles around the umbilicus, and ribs which are uninterrupted on the peripheral area. Although somewhat resembling *Perisphinctes obtusicosta*[4] and *Perisph. paramorphus*,[5] Waagen, from the Callovian of Cutch, the Australian species has much finer ornaments and a very different suture-line.

The general arrangement of the suture-line is not unlike that of *Olcostephanus Brancoi*,[6] Neumayr and Uhlig, but the lattter is a more inflated and more coarsely ornamented species. The ornamentation of the present form agrees somewhat closely with that of *Olcostephanus Keyserlingi*,[7] Neumayr and Uhlig, but the suture-line of

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[1] Pal. Mittheil. p. 279, pl. lxxviii. figs. 1*a*, *b*; 2*a*, *b*.

[2] *Ibid.* p. 161, pl. l. figs. 3*a*, *b*.

[3] Pal. Franç. Terr. Jur. vol. i. 1842, p. 379, pl. cxxiv.

[4] Pal. Indica, Jurassic Fauna of Cutch, vol. i. (Cephalopoda), p. 146, pl. xxxviii. figs. 1*a*, *b*; 2; 3*a*, *b*.

[5] *Ibid.* p. 162, pl. xlvi. figs. 1*a*, *b*; 2*a*, *b*; pl. xlvii. fig. 3.

[6] Palæontographica, vol. xxvii. p. 156, pl. xxvi. fig. 1.

[7] *Ibid.* p. 155, pl. xxvii. figs. 1–3.

the latter differs considerably from that of the Australian species. *Ammonites polyptychus*,[1] Keyserling, resembles the Australian species in its external form, but is distinguished by its dichotomous ribs and the form of its suture-line. *Ammonites arbustigerus*,[2] d'Orbigny, occurring in the Bathonian of France, is a closely allied species; but the Australian form is distinguished by the greater prominence of its short umbilical ribs, by its finer sculpture, and by its suture-line. The sculpture of the shell and the form of the suture-line distinguish the present species from the form figured by d'Orbigny as *Ammonites planula*[3] from the Bathonian of France.

Localities.—Champion Bay; Cape Riche, E. of Albany, Western Australia.

Ammonites (*Perisphinctes*) *robiginosus*, sp. nov. (Pl. XIII. Figs. 3 *a* and *b*.)

Although a complete diagnosis of the species cannot be given the following characters may be noted :—

Shell (cast) discoidal, rather widely umbilicated; its greatest thickness at a short distance from the inner edge of the whorl, about two-sevenths of the diameter of the shell; height of outer whorl about equal to its thickness. Umbilicus wide, probably about three-sevenths of the diameter of the shell in width. Whorl obtusely cordate in section, about as wide as high; indented to about one-fourth of its height by the preceding whorl; periphery rather broadly convex; sides somewhat flattened, sloping away from the periphery; inner area sloping towards the umbilicus. The cast is ornamented with a number of primary umbilical ribs, or very compressed, elongated tubercles, having a decided forward inclination; each primary rib divides into three secondary rounded ribs, which cross the periphery without interruption, and are separated by interspaces of rather more than their own width.

Remarks.—This species is represented by a portion of the outer whorl of an example of about 160 or 170 mm. in diameter. It is a natural cast in a ferruginous matrix; one side is fairly well preserved; the other is crushed and much weathered. It exhibits no trace of the suture-line. Its extreme length measured along the median line of the periphery is about 200 mm., the radius of curvature of the periphery being about 86 mm. In a length of 173 mm. along the periphery there are 21 peripherial ribs, which are connected with 7 primary ribs. The latter are about 12 mm. apart, whilst the secondary ribs have a thickness of about 3 mm., the interspaces being a little wider than the ribs.

Affinities and differences.—The present species is very nearly related to *Ammonites Wagneri*, Oppel,[4] from the Bathonian of France, but the primary ribs of the Australian fossil are straighter, more prominent, and trifurcate more regularly. Compared with d'Orbigny's figures[5] of *Ammonites Panderi*, Eichwald, the present

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[1] Petschora-Land, 1846, p. 327, pl. xxi. figs. 1–3; pl. xxii. fig. 9.

[2] Pal. Franç. Terr. Jur. vol. i. 1842, p. 414, pl. cxliii.

[3] Pal. Franç. Terr. Jur. vol. i. 1842, p. 416, pl. cxliv. According to Oppel (Juraformation, p. 477), d'Orbigny's figure does not represent Hehl's *Amm. planula*; he, therefore, alters the name of d'Orbigny's species to *Wagneri*.

[4] A. Oppel, Die Juraformation, 1856–58, p. 477 [*Ammonites planula*, d'Orbigny, Pal. Franç. Terr. Jur. vol. i. p. 416, pl. cxliv. (*non* Hehl)].

[5] D'Orbigny, in Murchison, de Verneuil and de Keyserling, Géologie de la Russie d'Europe et des montagnes de l'Oural, vol. ii. 1845, p. 430, pl. xxxiii. figs. 1–5 (figs. 1, 2 especially).

species has the primary ribs proportionately nearer together, and the secondary ribs proportionately finer. Its primary and secondary ribs are straighter than in *Ammonites uralensis*, d'Orbigny,[1] and cross the periphery without interruption.

Locality.—Champion Bay, Western Australia.

Of the fossils referred to in the foregoing descriptions the *Belemnites*, *Nautilus*, and *Ammonites* (*Dorsetensia*) are preserved in a yellowish limestone, the *Ammonites* (*Stephanoceras*) sp. and *Ammonites* (*Perisphinctes*) *robiginosus* in a highly ferruginous matrix, and the rest in a red or red and yellow limestone, but the specimens are not accompanied by any notes on the sequence of the beds from which they were obtained. The Mesozoic rocks, however, in the portion of Western Australia whence the fossils were derived, have been described by Mr. H. Y. L. Brown in his "Report on a Geological Exploration of that portion of the Colony of Western Australia lying southward of the Murchison River and westward of Esperance Bay." Referring to the rocks of the "Mesozoic or Secondary Epoch—Oolitic Period," Mr. Brown says: "The character of the strata belonging to this period may be described as follows: Beds of highly ferruginous clay, stone, or shale, sandstones, grits, conglomerates, clays, and limestone, placed in horizontal layers upon the older rocks, which originally they must have almost entirely covered, but have since been cut into and denuded to a great extent from off them, in such manner as to leave tablelands, isolated table hills, and peaks with steep escarpments and slopes. Their average elevation is about 600 feet above sea-level. The surface of this formation is generally coated with a deposit of sand, arising from the weathering of the sandstones, the larger areas being known by the name of sand plains. There are two principal areas occupied by this formation. The first, which varies in width from 10 to 30 miles, extends from the neighbourhood of Gingin and Yatheroo to the Murchison, and probably a long distance farther northward, in a line more or less parallel to the coast. Proceeding eastward it thins out, and only exists there as outliers and cappings on the hills. Its average thickness, where best developed, is some 400 feet. The second area commences near Cape Riche, and stretches in a north-east direction beyond the Phillips River, thinning out eastward to mere cappings on the hills.

"The uppermost beds in the first-named area are generally more ferruginous than the lower, and consist of highly ferruginous concretionary claystone, shale, and grit.

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"The great denudation which has operated since the close of this period has removed a great portion of the rocks, leaving the remainder as undulating plateaux and flat-topped hills, at the bases of which the older rocks outcrop. As a rule these strata are horizontal, although in some cases a slight undulating dip is perceptible. The interstratified beds of white, yellow, and sometimes ferruginous

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[1] D'Orbigny, *ibid.* p. 429, pl. xxxii. figs. 6–10.

limestone, attaining the thickness of 30 feet, which occur chiefly in the neighbourhood of Champion Bay, do not seem to be persistent, but are found as it were in patches, which gradually thin out. As the limestone composing them is made up of shells, which in some cases have consolidated into a solid rock, in others have retained their original form, it seems most probable that the accumulation of shells in hollows, in the ancient sea-beds, is the cause of their now being found in isolated areas. The most common fossils found includes species belonging to the [families] *Ammonitidæ, Belemnitidæ, Ostreidæ, Pectinidæ, Trigonidæ, Rhynchonellidæ,* etc. These fossils are generally found in the limestone, whole masses of rock being composed of them; they are also found in the hard ferruginous shale and sandstone, in which case they have been converted into oxide of iron. In a paper published in the Proceedings of the Geological Society, the author, Mr. C. Moore, considers the fossils from these beds to represent the fossil fauna of the Lias and Lower Oolitic formations of England.

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"The second principal area of this formation, which embraces the country extending from near Cape Riche to beyond the Phillips River, consists of a series of horizontal sandstones, grits, and conglomerates, capped generally by the usual ferruginous claystones, the whole thinning out on to the granite along its northern boundary at a level of from 600 to 700 feet above the sea, and forming level plains and table hills, with steep escarpments, along the Gairdner, Fitzgerald, Hamersley, Phillips, and Jerdicart Rivers. To the southward and eastward the formation, which attains a thickness of some three or four hundred feet, rests on the slaty rocks of the Mount Barren and Jerdicart country. In lithological and stratigraphical character and position, they are almost precisely similar to the same formation in the more northern parts of the colony. White marly saliferous sandstones, ferruginous grits and claystones, conglomerate, reddish sandstones, etc., are the principal rocks met with. Perfect specimens of fossil sponges are frequent in some of the caves which occur along the escarpments, hanging from the roof and sides, where the rock has weathered away; worn casts are also abundant. Mainbenup, near Esperance Bay, is the farthest point eastward where I have observed the formation. At Cape Riche beds of white and mottled sandstone, overlying granite, form low but steep cliffs along the shore of the bay."

The present collection of Cephalopoda confirms the view expressed by Clarke[1] and by Moore[2] as to the existence of rocks of Lower Oolite age in Western Australia. Possibly the highly ferruginous rocks may represent a somewhat higher portion of the Oolite, but the evidence of the present collection is by no means conclusive. No species of Middle Liassic age has been recognised in the collection.

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[1] Quart. Journ. Geol. Soc. vol. xxiii. (1867), p. 9.

[2] *Ibid.* vol. xxvi. (1870), p. 230.

The species here described do not appear to be in any way related to the forms which have been recorded[1] from New Guinea.

It may be observed in conclusion that an excellent Geological Sketch-map of Western Australia by the Government Geologist, Mr. Harry Page Woodward, F.G.S., has recently been issued.

EXPLANATION OF PLATES XII. AND XIII.

[All the figures are drawn one-half the natural size unless otherwise stated.]

PLATE XII.

FIG. 1. *Nautilus perornatus*, sp. nov.: *a*, lateral view, showing portions of the test, and the course of the suture-lines; *b*, peripheral view; *c*, portion of the test on the periphery. *a* and *b* are drawn one-fourth nat. size, *c* is drawn nat. size.

FIG. 2. *Ammonites* (*Dorsetensia*) *Clarkei*, sp. nov.: *a*, lateral view; *b*, front view; *c*, suture-line.

FIG. 3. Suture-line traced from the specimen figured by Moore (Quart. Journ. Geol. Soc. vol. xxvi. (1870), pl. xv. fig. 2) under the name of *Ammonites radians*; nat. size.

FIG. 4. *Ammonites* (*Stephanoceras*) *Australis*, sp. nov.: *a*, lateral view; *b*, peripheral view.

FIG. 5. *Ammonites* (*Stephanoceras*), sp.: *a*, lateral view; *b*, peripheral view.

FIG. 6. *Ammonites* (*Sphæroceras*?) *Woodwardi*, sp. nov.: *a*, lateral view; *b*, peripheral view.

PLATE XIII.

FIG. 1. *Ammonites* (*Sphæroceras*) *semiornatus*, sp. nov.: *a*, lateral view; *b*, peripheral view.

FIG. 2. *Ammonites* (*Perisphinctes*) *Championensis*, sp. nov.: *a*, lateral view; *b*, front view; *c*, portion of the suture-line. The right-hand portion of the first lateral lobe may not be quite correct, the fossil being badly-preserved at this part.

FIG. 3. *Ammonites* (*Perisphinctes*) *robiginosus*, sp. nov.: *a*, lateral view of fragment devoid of septa; *b*, section of whorl at S.

All the specimens are from near Champion Bay, Western Australia.

II.—ON SOME LIFE ZONES IN THE LOWER PALÆOZOIC ROCKS OF THE BRITISH AREAS, AS DEFINED MAINLY BY RESEARCHES DURING THE PAST 30 YEARS.

By HENRY HICKS, M.D., F.R.S., F.G.S.

(*Continued from the September Number, page* 405.)

Middle Cambrian.

FROM the foregoing remarks it will be seen that the Middle Cambrian, as at present defined, is characterized by having numerous Life Zones in which, usually, species of the genus *Paradoxides*, or of some closely allied forms, may be considered the dominant organisms. Up to the present the genus *Olenellus*, so typical of the Lower Cambrian rocks, has not been found in direct association with *Paradoxides*, but some of the associated genera are equally characteristic both of the Lower and of the Middle Cambrian.[2] The *Olenellus* fauna, as a whole, seems to have dis-

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[1] R. Etheridge, *fil.*, Records Geol. Surv. New South Wales, vol. i. pt. 3, 1889 (1890), pp. 172–179, pl. xxix.

[2] Mr. G. F. Matthew, who has worked out the zones in the Cambrian rocks of New Brunswick, Canada, with much care and success, has recently described a new

appeared from the areas as depression went on, and though, as I have already stated, there are some signs of a slight physical change at the close of the Lower Cambrian, I believe that the main cause why there should be no greater admixture of organisms, which evidently were suitable to live under like conditions, was that the fauna which first appeared, and which, to a certain extent, would cling to the shores and occupy shallow basins, would pass on to fresh areas as the depression increased.[1] The tendency to migrate along certain lines, and to follow like conditions, would undoubtedly have a powerful influence with the organisms even at this early period in the world's history, and many of the apparent difficulties which crop up when an attempt is made to trace the order of development will be brushed aside as Palæontology and Biology join hand in hand more closely in these investigations. To my mind no portion of the geological record can be more intensely interesting to biologists than that which contains the history of these earliest known organisms, as we have to deal only with marine faunas with a comparatively limited number of types which, of necessity, would be far less liable to be affected by disturbing influences than land faunas. When working out the Life History in the Cambrian rocks at St. David's, I kept constantly in mind the possibility of adding evidence in favour of the theory of evolution, and as this could only be hoped for by the adoption of a minute subdivision of the main Life Zones, I gave a section in my first paper, published in the Proceedings of the Liverpool Geological Society in 1863, showing five sub-zones in a thickness of 214 feet, with names of all the genera and species found in each. At this time the upper portion only of the Menevian (then called Lower Lingula Flags) had yielded any fossils. Lower zones were afterwards found and worked out on the same principle, and in the year 1872 I was able to state that[2] "the additions made to the fauna of the Cambrian rocks by these researches include no less than fifty-two new species, belonging to twenty-three genera. The following table shows to what orders these belong, and in what proportion they occur in these early rocks :—

Trilobites	10	genera	including	31	species
Bivalve Crustaceans	4	,,	,,	4	,,
Brachiopods	4	,,	,,	6	,,
Pteropods	3	,,	,,	6	,,
Sponges	1	genus	,,	4	,,
Cystideans	1	,,	,,	1	,,

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genus, *Protolenus*, which, he says, is there the characteristic fossil of the *Olenellus* zone ("Pre-*Paradoxides* beds"). With it is associated the genus *Ellipsocephalus*, which occurs in Europe in the *Paradoxides* beds, as well as in those containing *Olenellus* (see Canadian Record of Science, October, 1892).

[1] Mr. C. D. Walcott, in his most instructive monograph "The Fauna of the Lower Cambrian or *Olenellus* Zone," says, at p. 594, "The cause of the abrupt change from the *Olenellus* to the *Paradoxides* fauna is not yet fully recognised. While a considerable portion of the genera pass up, very few of the species are known to do so, and in none of the sections has there been found a commingling of the characteristic species of the Lower and Middle Cambrian."

[2] Quart. Journ. Geol. Soc. vol. xxviii. p. 173.

If we now add to these the Annelids which had been previously discovered in these rocks, we have at least seven orders represented in this fauna, the earliest at present known. These same groups are also more or less present and tend to characterize these early deposits wherever found; but no country has, up to the present time, produced a more varied fauna or a greater richness in types than England. Scandinavia has a larger number of species, but not so many groups." I then give a table showing the number of "forms discovered in the Lowest or *Paradoxides* Zone in different parts of the world," from which "it will be observed that England has produced eight of these groups, whilst none of the other countries has yielded more than five. It is, however, most interesting to note the similarity of types in regions so far apart, and the close resemblance of the faunas." The researches which have been carried on in the Cambrian rocks since that time, though they have added greatly to the number of forms, especially in America, owing to the labours of Mr. Ford, Mr. G. F. Matthew, Mr. C. D. Walcott, and others, have mainly strengthened the evidence in regard to the similarity of types. The still earlier faunas since made out in Scandinavia, Russia, and America also show that the following conclusions given in my paper were, in the main, fully warranted: "The fact also that Trilobites had attained their maximum size at this period, and that forms were present representative of almost every stage of development, from the little *Agnostus* with two rings to the thorax, and *Microdiscus* with four, to *Erinnys* with twenty-four, and blind genera along with those having the largest eyes, leads to the conclusion that, for these several stages to have taken place, numerous previous faunas must have had an existence, and, moreover, that even at this time, in the history of our globe, an enormous period had already elapsed since life first dawned upon it." In so minute a subdivision as I at first adopted it was scarcely to be expected that the zones would be of equal value; but the plan nevertheless often furnished information of much interest. For instance, in one section at what appeared to be a new horizon a form of *Paradoxides* was found which seemed to differ materially from the *Paradoxides* (*P. Hicksii*) in the next zone, and I was only able to satisfy myself that it was a young specimen of that species by finding others showing intermediate stages in association with fully grown specimens. Five main zones characterized by new species of *Paradoxides* were made out, and in each of these new species of the more important associated forms also occurred. Though five species of *Paradoxides* only were made out at St. David's, three species of the very closely allied genera *Plutonia* and *Anopolenus* were also discovered. *Plutonia*, characterized mainly by its spinous ornamentation and wide ribs, a Trilobite of gigantic size, equalling, if not exceeding, the largest *Paradoxides*, must have been a formidable-looking Crustacean in these early seas. Hitherto, it has only been found at the base of the Middle Cambrian at St. David's, and one species only has been discovered. The largest *Paradoxides* (*P. Davidis*), on the other hand, occurs in the highest beds. In my paper in the Quart. Journ. Geol. Soc. in 1872, after giving a minute description of the strata from the base of the Cambrian to the Lingula Flags and the evidences of the physical conditions under which they had been deposited, I added the following remarks: "These successive changes, producing such varied conditions of deposit, must have had much to do with causing barrenness in parts of the strata, and with the appearance, on the other hand, of successive zones of animal life. The continuation of the same genera through a great thickness of shore or shallow-water deposits, as is the case in the Longmynd (now called Caerfai and Solva Groups) and Lingula Flags and the rapid dying out and shorter range of the genera in finer beds or deep sea-deposits, like the bulk of the Menevian Group, are interesting facts, and deserving of consideration when we seek for natural laws to account for the conditions presented to us at these early periods." Though a considerable number of the St. David's species have been found in North Wales in beds almost identical in character with those at St. David's, two species only of *Paradoxides*, viz. *P. Hicksii* and *P. Davidis*, have as yet been determined. They hold there exactly the same position in relation to one another as they do at St. David's, and I have no doubt a careful examination of the underlying beds will show that the Lower Zones occur there also. Soon after we had discovered the majority of the forms at St. David's, Mr. D. Homfray was asked by Mr. Salter to examine the slaty beds which flanked the Harlech Mountains, and in a joint paper by Mr. Salter and myself to the Geological Society[1] Mr. Salter gives the general results in the following words: "Having faith in the continuity of the band, I had begged Mr. David Homfray, of Portmadoc, to employ his first leisure in examining the same horizon in the Ffestiniog country, a locality which had hitherto been neglected. He met with his usual good success; and found, not merely the same genera, but many species which we had discovered at St. David's. I think hardly any of the forms are distinct. There are *Anopolenus, Conocoryphe, Microdiscus, Holocephalus,* together with *Theca* and *Agnostus,* all, or nearly all, of the same species as those described in our paper. There is also a new genus of Trilobites which we have called *Erinnys,* distinguished by the great number of the body-rings, and this is also found both in North and South Wales. This identity of forms between localities so widely separated and on the same horizon gives us great reason to believe that the fauna is a marked and persistent one over large areas." In 1891 (Geol. Mag. p. 533) Prof. Lapworth announced the discovery by Mr. T. T. Groom of a *Paradoxides* occurring with *Ptychoparia, Obolella, Protospongia,* etc., at Nevis Castle and Comley, Shropshire. In a paper in 1875 in which I attempted to correlate the main zones which we had found in Wales with those which had at that time been made out in various areas on the Continent of Europe[2] I said that the "Western areas have a larger number of

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[1] Quart. Journ. Geol. Soc., November, 1865.

[2] "The Physical conditions under which the Cambrian and Lower Silurian rocks were probably deposited over the European areas" (Q.J.G.S. vol. xxxi. p. 552).

orders, a greater number of genera, and, in the genera, show a greater number of varieties or stages of progression, than we find in any of the more Eastern areas. Many of these steps or species are wanting in the Eastern areas, and it is probable that they never reached so far, just as it is evident that many intermediate forms did not reach the Western areas. Many forms, as they fulfilled their mission, were lost on the way, and it is only the stronger and more marked varieties, which we now look upon as species, that were able to pass on. Minor changes may also have taken place even in very limited areas; but it is evident that the more marked species were tolerably persistent and became more generally distributed." It is a remarkable fact that all the evidence which has been accumulated of late years tends to prove that there is a very close resemblance between the succession of the sediments, and in the forms characterizing the faunas of the Cambrian rocks on both sides of the Atlantic Ocean. This seems to me to show, as I mentioned in my paper in 1875, that the earliest homes of these faunas in this portion of the northern hemisphere must have been in some intermediate basin, whence migration took place towards each continent, and it would also account for the larger number of species as we approach towards this basin and for the diminished number in the more distant areas. How far animal life had progressed, and how many types were then in existence, it is impossible to say, for those only which were suitable to the conditions then prevailing in any given area would migrate to that part. The Zones of Life, as we at present know them, are therefore mainly records of the periods of dispersion of certain forms from areas previously occupied by them. This is why our chronological sequence of organisms is not more often in accordance with what the theory of evolution may seem to demand. Generally the evidence of a gradual progression from lower to higher forms is clear enough; but the actual stages are not often found, owing to the probability that none of the areas at present known to us retained the forms sufficiently long, or supplied all the influences necessary, to produce very marked changes in the animal forms.

Upper Cambrian.

In the very excellent summary of the researches carried on in Wales given by Mr. R. Etheridge, in the Memoirs of the Geological Survey, vol. iii. (1881),[1] it is stated that M. Barrande, who paid a visit to this country in 1851 "for the express purpose of comparing his rich materials with our published and unpublished types," then recognised the "Lingula Flag" of Sedgwick as the exact equivalent of his primordial stratum" (Étage C). At this time the Middle Cambrian or *Paradoxides* fauna was entirely unknown in Britain, therefore the Upper Cambrian or *Olenus* fauna only could in any way be used for comparison. To M. Barrande, therefore, must be given the credit of first recognising the presence of this portion of the "Primordial zone" in Britain.

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[1] See also the Presidential Address to the Geological Society 1881.

Soon after M. Barrande's conclusions had been announced, "Mr. Salter was directed by Sir H. de la Beche to re-examine a portion of the Lingula Flag series, with special regard to the fossil succession, and found that the group was divisible into three distinct zones, two in the Lower, and one in the Upper division." As characteristic of the Lower series, he mentions *Agnostus princeps, Olenus cataractes*, and *Lingulella Davisii*, of the next overlying series, *Olenus micrurus, Hymenocaris vermicauda*, and *Lingullela Davisii* in great abundance; of the highest, *Olenus alatus, O. scarabæoides, Agnostus princeps*, several species of *Conocoryphe, Orthis lenticularis*, and *Dictyonema ?sociale.* In 1860 Mr. Salter again visited North Wales, and with "the hearty and eager assistance of Messrs. Homfray and Ash," and the services of the Chief Collector of the Survey, Mr. R. Gibbs, was not only able to add to the number of forms, but also to trace the three divisions into several new areas. In 1867 Mr. T. Belt, in a paper on "Some New Trilobites from the Upper Cambrian Rocks of North Wales,"[1] subdivides the lowest series given by Mr. Salter, and points out that there are two horizons marked by distinct species of *Olenus, Olenus gibbosus* being characteristic of the lowest, and *Olenus cataractes* of the higher beds. In another paper, "On the Lingula Flags or Ffestiniog Group of the Dolgelly district,"[2] he gives the results of researches carried on by him during the previous three years in conjunction with Messrs. Ezekiel Williamson and J. E. Barlow, and says that "recent discoveries have shown that the group includes at least six zones of animal life, each distinct and separate." To the three divisions previously marked out by Mr. Salter he gives the local names of Maentwrog, Ffestiniog, and Dolgelly, and says that they "are both lithologically and palæontologically distinct. None of the Crustaceans pass from one group to another, and peculiar genera are found in each." Professor Phillips had previously discovered several species of *Olenus* in black shales on the western flanks of the Malvern Hills, and these beds Mr. Belt correlates with his Upper Dolgelly beds. Other fossils had been discovered in these rocks, near Malvern, by Dr. Harvey B. Holl, Dr. Grindrod, the Rev. W. S. Symons, and others. In the year 1877 Dr. C. Callaway published a paper,[3] in which he gives an account of a most interesting discovery by him of Upper Cambrian rocks in South Shropshire. The "Shineton shales," he there states, appear to him from the fossils to be of Tremadoc age; but he says that one new species of *Olenus* (*O. Salteri*) "is probably representative of our Lingula Flags," and also that the majority of the "species have an older facies than the Tremadoc; but the abundant occurrence of an Upper Tremadoc form, and of another Asaphid, points in an opposite direction." He then states "that the facts of the case so far as the fossils are concerned will be best satisfied by referring the beds to the age of the Lower Tremadoc," but suggests the probability of the "Shineton shales forming beds of passage between the

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[1] Geol. Mag. Vol. IV. p. 294.
[2] *Ibid.* p. 493.
[3] Quart. Journ. Geol. Soc. vol. xxxiii. p. 652.

Lingula Flags and the Lower Tremadoc." In the year 1882[1] Professor Lapworth gave an account of the discovery by him in the "Stockingford shales," near Birmingham, of "many of the most typical Upper Cambrian Brachiopoda and Trilobites," a list of which he gives as follows: *Acrotreta socialis, Obolella Salteri, Lingulella ferruginea, Kutorgina cingulata, Agnostus pisiformis, Lingulella Nicholsoni.*

In a paper in 1885[2] by Mr. J. E. Marr and Mr. T. Roberts is given an account of the discovery by them of fossils characteristic of the "Lingula Flags" in some "black iron-stained slates" which are "well seen near Leweston, Trefgarn Bridge, and Spittal Cross, in North Pembrokeshire. The species mentioned are *Agnostus pisiformis*, var. *socialis*, and *Olenus spinulosus.*

The "Tremadoc Slates" of Sedgwick were divided by Mr. Salter, in 1857, into a Lower and Upper series. The fauna was stated by him to be essentially Middle Cambrian (now Upper Cambrian), but showing a tendency to include some few types characteristic of higher horizons. "The species, however, are all distinct, even from those of the Arenig Group, and those of the Upper are distinct from those of the Lower Tremadoc."[3] In the report by Mr. Salter and myself to the British Association in 1866, we announced the discovery of Tremadoc beds, "or what we regard as such," near St. David's, for "lying as they do upon the true Lingula Flags, and under the Arenig or Skiddaw Slates, they can hardly be anything but Tremadoc beds." A list is given of the fossils which had then been discovered by us, but many additional forms were subsequently added to it. These were discovered during our continued researches, carried on with occasional very valuable assistance from Messrs. Homfray, Lightbody, Hopkinson, and Kershaw. The fossils, comprising a rich and exceedingly interesting fauna (in which the earliest lamellibranchs, encrinites, and star-fish up to that time discovered in Britain occurred), were described by me in the Quarterly Journal of the Geological Society for February 1873, and at page 42 I stated that "the palæontological evidence goes to prove that they (the Tremadoc rocks) are closely allied to, if not identical with, the lower portion of the Tremadoc rocks of North Wales," and that the "conditions under which these rocks at St. David's were deposited seem to have been intermediate between those of the shoal and shallow water of the Lingula Flag period and those of the deep sea which must have prevailed when the fine muddy deposits of the overlying Arenig slates were being thrown down. This intermediate condition must have been particularly favourable to the existence of life, and was doubtless one of the causes of the appearance at this time of such a varied and important group of organisms."

The boundary-line between the Tremadoc rocks at St. David's

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[1] GEOL. MAG. Dec. II. Vol. IX. p. 565.

[2] Quart. Journ. Geol. Soc. vol. xli. p. 476.

[3] "Catalogue of the Collection of Cambrian and Silurian Fossils contained in the Geological Museum of the University of Cambridge," 1873, p. 15.

and the overlying Arenig rocks was then mainly adopted owing to the discovery by us of very rich Graptolite zones in the overlying slates, and to the recognition by Mr. J. Hopkinson of over 20 species belonging to genera characteristic of the Quebec Group of Canada.[1]

In the Quart. Journ. Geol. Soc. for 1880, p. 237, there is an important communication from Prof. T. McKenny Hughes, in which it is stated that beds in Anglesey which had hitherto been "referred to the Caradoc are Tremadoc; that they are succeeded by Arenig." In these beds he found *Orthis Carausii*, and *Neseuretus Ramseyensis*, a characteristic Tremadoc form, and he states that "they exactly resemble specimens from the Tremadoc of Ramsey Island (St. David's) in the character of the rock and mode of preservation of the fossils."

Although I have had to limit my summary to that portion of the Lower Palæozoic rocks now usually classified under the name Cambrian, I think it must be granted that the researches carried on in these rocks during the past thirty years have been most fruitful in important results. During this period the doctrine of evolution has exerted a powerful influence on geological thought; and no one who can call to mind the state of our knowledge before that time can possibly deny that the influence has been for good. Of necessity, those who were working on the earliest known faunas kept this doctrine continually in view, and I believe there are few at the present time who will not admit that evidence in its favour has constantly increased in strength as the gaps in the succession were being filled up.

III.—RESTORATION OF THE ANTILLEAN CONTINENT.[2]

By J. W. SPENCER, Ph.D., M.A., B.A.Sc., F.G.S.

THERE have been many suggestions respecting a continental connection of the West Indies, but this is the first attempt made to restore the Antillean lands. It is based upon the slowly

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[1] These, with many additional forms obtained by us from the Arenig rocks of St. David's, were afterwards described by Messrs. Hopkinson and Lapworth in the Quart. Journ. Geol. Soc. vol. xxxi. p. 632 (1875), and in the discussion of that paper Mr. Hopkinson said "that the dendroid forms are only known to occur in abundance in Britain in the Arenig rocks of St. David's, and that there are intermediate forms connecting British and American species which occur in rocks of more ancient date." He further remarked that he "did not consider the dendroid forms valuable for determining zones, species very nearly allied to those of the Arenig rocks being met with even in the Lower Ludlow rocks of Shropshire; but the Rhabdophora occur only in small zones, and wherever they are found they seem to hold an equivalent position. They are consequently valuable for stratigraphical purposes." In the same paper they give a Table "in which every species (obtained in the vicinity of St. David's) is referred to its exact position in the vertical series," and in page 639 they say: "Perhaps the most patent result of these researches is the circumstance that they clearly demonstrate that the Hydroida of these ancient rocks, so long shunned or misinterpreted by the systematist, are rapidly emerging from the obscurity which has enveloped them, and will perhaps soon stand side by side with the better understood Brachiopoda and Crustacea, as unerring exponents of the true geological age of the most widely separated rocks in which they are found."

[2] Abstract of a paper read before the Geol. Soc. of America, August 14th, 1894.

accumulating evidence of great systems of submerged valleys, or fjords extending from the commonly buried lower reaches of all the great rivers, upon the terrestrial deformation involved in the changes of level over large regions and upon the distribution of the characteristic forms of life. The present investigations confirm and amplify the history of the coastal plain of the northern continent.

The forms of the valleys of the southern Appalachian mountains and of the coastal plain were illustrated, showing that their characteristics are mostly due to the insidious action of rains and rills, producing different results according to the slope or elevation of the base-level of erosion. This study was introduced in order to compare the drowned *cañons* with the land valleys.

The gentle but varying amount of epeirogenic deformation has permitted of correlations which would have been prevented had the sharp orogenic disturbances of recent times prevailed over very wide areas.

The submarine valleys or fjords have been correlated into systems with their tributaries, and in all cases they connect with the partly buried land valleys. The continent is bordered by a sub-coastal plain from 100 to 300 miles wide, which is characterized by plateaux or terraces now submerged to even 3000 or 5000 feet, with the oceanic bed beyond depressed to 12,000 feet or more. Crossing these plateaux, the *cañons* reach to depths of thousands of feet, and terminate in embayments into margins of the continental shelves. The Gulf Stream occupies portions of three distinct valleys, exclusive of its tributaries, which have been only slightly modified on the cols between them. The drainage of the West Indian continent was almost entirely to the west, there being only two or three long valleys upon the eastern side of the Windward mass. The fjords reach to the bottoms of the Gulf of Mexico and Carribean Sea, whose beds are shown to have been recent land plains (except the Sea of Honduras, in part). The valleys of the existing rivers, often deeply buried near their mouths, are in magnitude proportional to their fjords beyond.

The analogy between the land valleys and the drowned *cañons* is so complete that the unqualified conclusion is reached that the fjords are evidences of atmospheric erosion to their depths (with perhaps one or two exceptions), or in other words there was an elevation of the region, as high as the fjords are deep, less the reduction by differential deformation, which is more or less determinable. Thus it appears that there has been a post-erosion subsidence to an amount from 8,000 to 12,000 feet, carrying down the Antillean plains to form the present sea-basins, and the high lands to form the islands.

The general Miocene depression of the whole region left only small islands, and during this submergence portions of the region appear to have sunk to abyssmal depths.

The Pliocene period was characterized by the connection of the two Americas by way of the West Indian bridge, part of which was a high plateau as is Mexico and the Great Basin to-day. This was the first period of the formation of the great *cañons*, and the modern topographic features. But at the close of the Pliocene period there was a submergence of from 100 to 1300 feet below the present altitudes, with the deposition of from 100 to 260 feet of (Matanzas) limestones. During this epoch the connections with the Pacific Ocean were shallow.

The earlier Pleistocene days were characterized by a re-elevation of the continent with great erosion and the clearing out and extension of the older Pliocene valleys. The continental development was nearly the same as in the earlier Pliocene continental epoch.

In Mid-Pleistocene times the continent was again depressed, so that the West Indian islands were reduced to a much smaller size than at present, but not so small as during the subsidence at the close of the Pliocene days. These later deposits were mostly loams and gravels. Some minor oscillations are recorded in the terraces.

Again there was a slight elevation of from 100 to 300 feet as shown in the *cañons* which form the outlets of many harbours. Then followed the depressions that gave rise to the latest terraces, which have been recently elevated, as also the modern coral reefs. Some portions of the region seem to be sinking very slowly and others rising.

In the Miocene period there was free communication between the Atlantic and Pacific Oceans. This was cut off by the Pliocene continental elevation, but slightly reopened in the later Pliocene submergence. Again the Atlantic waters were driven back in the earlier part of the Pleistocene period, after which the later depression freely admitted the Atlantic waters, with probably a shallow connection with the Pacific Ocean for a short time. Since the Mid-Pleistocene epoch the gentle undulations have made no changes in the sea connections, but have only varied the breadth of the now slightly submerged coastal plains.

The physical changes appear to explain the occurrence of the greater number of the marine fauna of the Antillean region. In this abstract the Sea of Honduras has not been explained, but it may have been a basin from earlier times than the date of the Gulf and Caribbean basins. The physical history is in accord with the distribution of mammals. The late Miocene fauna of Florida could not have reached the islands, and in that region there is no known Pliocene fauna to be considered even on the adjacent parts of the northern continent. At the close of the Pliocene period the lands were reduced to a few very small islets, and the coastal plain of the continent was submerged. Then followed the continental rise with a rich Pleistocene fauna in Florida, and some forms are known in the islands, but their life was again cut off by the next subsidence, since which time the modern types of mammalian life of Florida have not been able to reach the islands. In short, the physical history seems to explain the disappearance of many mammals from the region, for with a continental change of altitude of from 8000 to

12,000 feet, and the general drowning of the Antillean continent, the animals became extinct alike on the continental margin and the islands.

The key to the physical evolution of the continent seems to be locked up in the West Indies, yet it appears simple. Where the studies will lead, it cannot be predicted. These are fundamental questions in terrestrial movements and continent-making; changes of ocean currents and climates; the production of glacial conditions, and the distribution of the inhabitants.

IV.—ON A SERIES OF SAURIAN FOOTPRINTS FROM THE CHESHIRE TRIAS (WITH A NOTE ON *CHEIROTHERIUM*).[1]

By OSMUND W. JEFFS.

EVERY geologist is familiar with the name of Storeton Quarry, which may fitly be termed the "home of the *Cheirotherium*," celebrated as being the scene of the earliest discovery in England of the fossil footprints, first described by Messrs. John Cunningham and James Yates in 1839.

Fifty years' study of these footprints has left their origin, so far as exact identification with any known animal is concerned, a matter of as much mystery as when Sir Richard Owen gave attention to the subject in his classical work on "Palæontology." All the evidence, in fact, which we have accumulated since that time has only brought us to a negative position, and taught us that the explanation first suggested by Owen, and thereafter copied into nearly all our popular geological text-books, is not entirely correct.

The forms described have all been obtained from the "footprint bed" at the Storeton quarries (with the exception, named below, of two specimens from Oxton Heath). This "footprint bed" is a thin stratum of sandstone, with seams of white clay, together some three or four feet in thickness, which is exposed at several points along the quarry excavations, where it may be traced for some distance. The geological structure of the quarries is fully described by Mr. G. H. Morton, F.G.S., in "The Geology of the Country Around Liverpool" (second edition).

I first refer to the well-known impressions to which the name of *Cheirotherium* was originally given by Dr. Kaup, under the idea that the tracks were of mammalian character. In the event of their being afterwards proved to be Saurian, the alternative name of *Chierosaurus* was proposed. The latter term, being the more correct—all the indications pointing to a reptilian origin of the footprints—has been adopted by the British Museum authorities (see "Catalogue of the Fossil Reptilia and Amphibia in the British Museum"), but it does not seem to have found its way into general geological literature, or into our local museums. In a paper read before the Liverpool Geological Association in June last, I described several specimens of this genus, among which were the following:—

1. Slab (No. 130) showing right-hand, hind and fore feet of

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[1] Read at the British Association (Section C), Oxford, August 11th, 1894.

C. Stortonensis. Pentadactylate digits. Length of pes 7½ inches; length of manus 3 inches. All the digits are perfect. The two feet are close together, being less than 1 inch apart. The toes are narrow and tapering, the first showing the characteristic turning inwards, like a thumb. In all the true *Cheirotherium* impressions the digits radiate from a centre like those in an outspread human hand.

2. Slab containing the natural mould of the impression of a medium-sized footprint; pes about 8 inches in length. These moulds or hollows in which the animal impressed its foot into the sand are far more uncommon than might be imagined, and this is the only perfect specimen I have been able to obtain. Its preservation is evidently due to the sandy matrix. Most of the "moulds" occur in the soft clay which is intercalated in the footprint bed.

3. Genus indet.—Slab (No. 134) showing hind and fore feet of a smaller species, with narrow toes. Length of pes 3 inches; length of manus 1½ inches. The toes in this species all curve inwards, and are not separated, nor do they radiate as in *Cheirotherium.*

4. Slab (No. 142) showing rain-pittings and a remarkable median impression running in a straight line, which may be attributed to the track made by the point of a tail trailing on the ground.

Of impressions made by smaller species of Reptilia, the Keuper, both at Storeton and Oxton, presents several examples. With the exception of *Rhynchosaurus* itself, very little is known of these creatures; for, although a great number of bones have been found in the Triassic strata, not only of Europe but of America and South Africa, it is still a matter of difficulty to correlate the footprints with any known species of animals.

The difficulty in deciphering these small footprints is increased by the fact that several kinds of impressions are often found together on the same slab, in addition to the frequent superposition of one impression upon another, as the animals walked across the expanse of sand in various directions.

Among the specimens exhibited are examples of five species, all of which are probably the prints of small reptiles. The forms marked *b*, *c*. and *d* have not been previously recorded from Storeton.

5. (*a*) *Rhynchosaurus.*—Four well-defined digits, with occasional vestiges of a fifth digit, much shorter that the others, possessing short claws and curved inwards. There is sometimes the mark of a projecting spur at the back of the foot. Length of foot 1½ inches. The middle toe often extends beyond the others. It is difficult to distinguish between the fore and hind feet, and the impressions follow so closely that the successive tracks of the animal's march are not clearly defined. All the toes curve slightly in the same direction. These impressions frequently occur on slabs exhibiting the tracks of *Cheirotherium,* often being superposed on the actual imprint of the larger saurian.

6. (*b*) Genus indet.—Tracks of a smaller animal, ⅔ of an inch in length, with a more stubby foot, and very distinct claws on the digits; the first digit very short, often indicated by a mere point

where the claw has penetrated the sand; four distinct toes, probably had a rudimentary fifth. The digits do not display the same parallelism as in the specimens attributed to *Rhynchosaurus*.

7. (*c*) Genus indet.—A minute form, ½ an inch long, showing four digits, tapering to a point; no vestige of claws.

8. (*d*) Genus indet.—Three rather broad digits, with claws (? webbed). Not well defined; may be same as (*b*).

9. (*e*) Genus indet.—An oval impression, with concave terminated digits, four or five in number, and a hinder projecting spur (? Chelonian). Toes webbed.

10. Two slabs from Oxton Heath (found by Dr. Ricketts) covered with impressions of (*a*) *Rhynchosaurus*, and probably of those included under (*b*).

11. A large slab found *in situ* from the South quarry, Storeton, at Easter, 1894, by Mr. Norman Jeffs. Shows specimens of several varieties—the slender-toed *Rhynchosaurus*; the minute form (*c*), several tracks; the stubby form (*b*); and both the fore and hind foot of a similar species to No. 134, resembling the *Cheirotherium*, but of smaller size, and differentiated from that species by having the digits all pointing in the same direction.

Note on *Cheirotherium*.

The larger footprints known as belonging to the *Cheirotherium* have long been attributed, on the authority of Sir R. Owen, to one or other genera of Labyrinthodonts.

In a paper contributed to the Transactions of the Liverpool Geological Association, in 1889, by Mr. James Hornell, the author records an interesting series of investigations on Labyrinthodonts, chiefly from a biological point of view, and though he apparently accepts Owen's correlation—since he terms it "successful" (p. 67)—he shows very clearly that the *Cheirotherium* impressions do not coincide with the normal type of *Labyrinthodon*. For the "hand-footed kind, where the hind limbs by reason of their greatly increased size depart from the central type," Mr. Hornell proposes a separate classification in a sub-order. But it may be pertinently asked whether there exists any evidence from the skeletons of Labyrinthodonts, now so numerously discovered in the Coal-measures, Permian and Triassic strata, of this special type of *Labyrinthodon*?

Since Owen correlated the *Labyrinthodon* with the *Batrachia*, a great mass of evidence has come to light, through the researches of Burmeister and Fritsch in Germany; Professors Huxley, Seeley, and Miall in England; and Professors Cope and Marsh in America. It is now accepted that the *Labyrinthodon* was more akin to the Salamander or Newt than to the Frog. Indeed, the skeletons which have been obtained entire from the petroleum shales of Germany show none of the supposed frog-like affinities. The *Labyrinthodon* was, in fact, a primeval Salamander, the species varying in size from small creatures, 8 inches in length, to huge animals of eight or nine feet.

It is but fair to state that Owen recognised the footprints of

Cheirotherium as resembling those of a Salamander,[1] although he, at the same time, attributed them to a supposed Batrachian. In his restoration of *Mastodonsaurus*, from Coton End, Warwick, Owen judged by the simple relics—chiefly of the teeth, parts of the skull, an ilium and humerus—he found there; but our present knowledge of the structure of these animals (which has been most minutely and elaborately investigated by a Committee of the British Association, reported upon by Professor Miall) is founded upon material which did not exist when Owen wrote his treatise in 1842. Even now our knowledge of the limbs of Triassic species of Labyrinthodonts is imperfect, and thus an important link in the chain of evidence required to enable us to correlate the footprints is wanting. Nor are we helped much by studying the limbs of the Carboniferous species of these Amphibians; for, on the authority of Professor Miall, the corresponding parts of the fore and hind limbs of *Labyrinthodon* are very similar in form, and present no uncommon difference of size. This feature, it is very evident, does not agree with the fossil footprints of *Cheirotherium*; and the more we study the known forms of true Labyrinthodonts, the more we are driven to the conclusion that whatever was the mysterious animal by which the larger footprints at Storeton were made, it cannot be referred to any *known* species of Labyrinthodont.

V.—The Aptychus.

By Ernest H. L. Schwarz, A.R.C.S.

The discovery of an Ammonite (*Oppelia subradiata*, Sow., from Dundry, now in the British Museum) with the Aptychus *in situ* closing the orifice, would seem sufficient to set all doubts at rest as to the true nature of that body, viz. that of an operculum.[2] Many of the writers on the continent, however, have not seen that specimen, which unfortunately is unique, and are inclined to attribute to the Aptychus other offices, because:—

1. It usually occupies a very definite position within the living chamber of the shell, lying in the middle of the outer edge, with its umboes pointing forward, and its rough surface outwards.

2. The complicated internal structure of the middle layer of the calcareous Aptychi proves them to have been formed beneath the epidermis, and were not therefore homologous with the opercula of other Mollusca, which are dermal in origin.

3. The Aptychus very seldom, either in shape or size, corresponds with the aperture of the Ammonite shell to which it was supposed to belong.

These objections are valid enough if they went to support any

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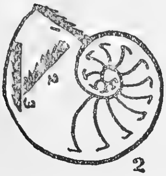
[1] ". . . . in having the shorter toe of the hind foot projecting at a right angle to the line of the mid-toe." Miall considers this feature common to other orders of reptiles.

[2] See article by Dr. S. P. Woodward, F.G.S., "On an Ammonite with an Operculum in situ," "The Geologist," 1860, Vol. III. p. 328 (with a woodcut); also Dr. H. Woodward, F.R.S., Geol. Mag. 1885, p. 346, and "Student," vol. iv. p. 1, pl. i. fig. 12.

solid opposition explanation; but none can compete with the teaching of the Dundry specimen, and the objections can be very well answered, as I propose to do in the sequel.

Taking the objections in order:—

1. Of the many suggestions which have been offered as to the internal nature of the Aptychus, such as the shell of dwarf males residing in the mantle space, like those of some cirrhipedes, or the gizzard teeth, etc., three have gained greater prominence than the rest. The first of these is that put forward by Valenciennes, and recently elaborated by Steinmann,[1] namely, that the Aptychus was a structure attached to the funnel, and working like the shells of bivalves by means of ligaments situate along the hinge-line, thus strengthening that organ, and enabling it to eject the water with greater force; this, then, indicating a higher degree of organism in the funnel than that exhibited by the Nautilus, led Steinmann to the conclusion that the Ammonites were Dibranchiata, though, of course, he brings other reasons to bear on the subject; and from the general acceptance of Steinmann's conclusion, I suppose the idea of the Aptychus being a funnel-cartilage has many followers. A second theory is that put forward by Keferstein, Waagen, and von Zittel,[2] namely, that the Aptychus was the covering of the nidamental gland, the view being supported by the fact that those glands are usually thrown into ridges, similar to those of the Aptychus, in many recent Cephalopoda. The third is that of von Jhering,[3] where, relying upon the fact that the recent sepia has a nuchal cartilage situated at the back of the head, almost identical in shape with some Aptychi, he concludes, therefore, that the function of the Aptychus was to give attachment to the mantle; and, believing that the Aptychus, as it usually occurs in the living-chamber, retains the position it occupied in life, he concludes that the back of the Ammonite was turned outward, and the funnel internal (endogastric). Although Zittel, in his Palæontology, says that this view seems to have convinced nobody, yet it receives countenance from Haug's contention[4] that some Ammonites must have been endogastric, because the bay in the outline of the aperture, which was supposed to lodge the siphon, is internal in some genera.



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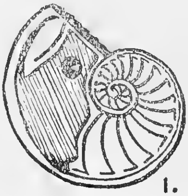

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Fig. 1. Shows the Ammonite animal in the shell in the living resting position.
Fig. 2. Shows three stages of the position of the Apytchus after the animal has died.

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[1] Steinmann, Berich. naturforsch. Gesell., Freiberg, vol. iv. pt. 3, 1889.

[2] Von Zittel, Handbuch der Palæontologie: Cephalopoda.

[3] Neues Jahrbuch, 1881, pt. i. p. 80.

[4] Gattung *Harpoceras*, Neues Jahrbuch, 1885, pt. iii. p. 596.

However, if we consider what would happen to an Ammonite when it had died and sunk in the ooze at the sea-bottom, we see that, supposing the animal exogastric like the living Nautilus, and the Aptychus functioning as a lid, the latter would necessarily have to take up its position in the place inside the chamber where we usually find it. For, being exogastric, the outer part of the animal would be occupied by the mantle space underlying the funnel; while on the inner side, the great muscles of the arms and head would present an impediment to anything entering the shell; so that, when the mud began to push in, the outer border of the operculum would be forced in first, and the whole thing would be turned on its axis, throwing the rough side downwards and outwards; and eventually, when the entire animal was decomposed, it would sink to the under surface of the body-chamber with its umboes looking forward, as we usually find it. Hence there is nothing in the fact that the Aptychus is usually found internal in fossils to preclude its having once acted as an operculum.

2. Though the horny Aptychus of *Goniatites*, *Arietites*, etc., might have been dermal in origin, the calcareous varieties most certainly cannot have been formed simply from the surface. But we never find rough bodies, such as the Aptychi belonging to the group *Imbricati* for instance, internal, unless they are suspended freely in a cavity, as the otoliths of fishes, or give support to other hard parts as in the vertebrate skull; and this, coupled with the apparent external uses of the Aptychus, drives one to the conclusion that, though primarily internal, it must have reached the surface by degeneration of tissues external to it. What these tissues were, it is impossible to say with certainty. Perhaps it was preformed in cartilage, for that tissue, as von Jhering has shown, sometimes becomes separated into square cells by means of fibres running through it; or more probably, the mass of muscle which constituted the hood, or conjoined tentacles, became surcharged beneath the sarcolemma with calcium carbonate, as happens in the case of man and hibernating carnivores, where it gives rise to gout; and the enclosed muscle bundle then decaying, left the cavity of the cell empty, or filled with secondary liquids, etc. Possibly, also, as suggested by the last simile, the Aptychus may have been formed at special resting periods during the life-history of the animal, for the organ has no means of growing when once it is fully formed; and to this cause may be due the small size of the Aptychus in some species, as compared with the normal aperture; that is, the lid, once formed, was retained for a long time without increment, though the animal itself went on growing as usual. In other cases it would become thrown off when the animal resumed active habits.

Although the structure of the Aptychus has many times been figured, especially in Meneghini and Bornemann's classical paper,[1] yet preparations that I have made show a feature that seems to have escaped the notice of other observers, namely, that the cells of the middle layer communicate one with another, and that their

[1] Atti. Soc. Toscan. di Sci. nat. 1876, vol. ii.

cavities open on to the outer surface by means of trumpet-shaped apertures (Fig. 3). This shows that there was something in the cells that required taking to the surface, and the suggestion of degenerate muscle supplies a clue to the meaning. The muscle would decompose slowly, having only a limited communication with the exterior, and gases would naturally force their way through the substance; but as the calcite of the Aptychus is peculiarly compact, it would have to make definite conduits for itself. This gas would probably be poisonous or evil smelling, so that, when the animal was resting during the elaboration of eggs, and the Aptychus applied to the opening, a natural defence would be secured against other predacious Mollusca, worms, and especially boring algæ, which usually manage to secure a foot-hold on resting shells, and which, as far as I have seen, the Aptychus is free from, though the pearly shells which contain them nearly always show abundant evidence of their ravages.

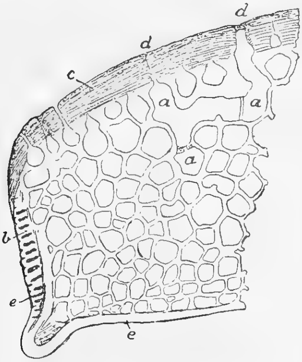

Fig. 3. Section of *Aptychus lævis*, von Meyer, cut at right angles to the hinge-line in about the centre. *a*, *a*, *a*, communicating cells of the middle layer opening by two orifices on the exterior *d*, *d*; *b*, *b*, ligament pits? of the hinge-line; *c*, secondary outer layer of calcareous material; *e*, *e*, inner layer.

It is in this connection that I think we should look for the reason why the Aptychus is so frequently preserved, while no trace of the Ammonite shell is discoverable in the same beds. Fuchs[1] advanced the explanation that the shells consist of aragonite, and the Aptychus of calcite; but this difference would not sufficiently account for the phenomenon where the action of solvent waters went on for a great length of time. Also, although Sorby[2] and others quote the specific gravity of the Nautilus shell as 2·9 (aragonite), I have tried it with every possible care, both in the specific-gravity bottle, and the Joly-spring balance, and have found it 2·68 (calcite); the structure and properties of the Ammonite shell are so exactly similar to that of the recent Nautilus, that what obtains for the one holds good for

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[1] Sitz. ber. d. k. Ak. d. Wiss., Math.-nat. cl. Bd. lxxvi. 1877, p. 329; also, Verhandl. d. k.k. geol. Reichsanst., Wien, 1879, no. 9, p. 186.

[2] Presidential Address, Geol. Soc., 1879, p. 30.

the other. But if the Aptychus contained gas when immersed in water it would be surrounded by a film of it, and thus would be rendered practically impervious to the water containing carbon dioxide in solution; while on the other hand, the shell tends to split repeatedly parallel to the surface, and thus draws the water into the cracks by capillary attraction, thereby exposing an enormous surface to the solvent action.

The outer layer of the Aptychus grows by simple deposition of calcite on the exterior, obscuring often the original outer ornamentation; thus in *Aptychus lævis*, von Meyer, the surface is perfectly smooth, with fine punctures all over it; but on cutting a section of it radially from the umbo (Fig. 4), the primary ridges are clearly seen, which would put it into the group *Imbricati.* Where this deposit on the outer surface is thick, as in the region near the umboes, the tubes communicating with the cavities of the cells of the middle layer are proportionately long. No trace of communications through the internal layer has been observed.

The hinge-line of the two valves shows narrow, deep cells filled in with a black material; von Meyer[1] has described them as ligament pits, though in my preparations they do not show any opening on to the exterior; the outer boundary however, may be secondary in origin, but the specimens I have cut certainly did not owe their adherence to ligament, but to the tissues underlying the two halves during life.

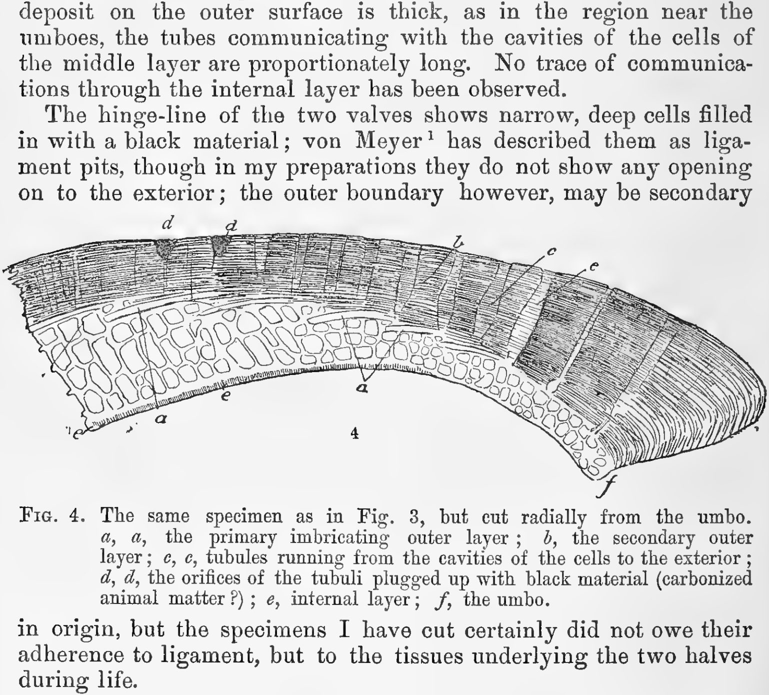

Fig. 4. The same specimen as in Fig. 3, but cut radially from the umbo. *a*, *a*, the primary imbricating outer layer; *b*, the secondary outer layer; *c*, *c*, tubules running from the cavities of the cells to the exterior; *d*, *d*, the orifices of the tubuli plugged up with black material (carbonized animal matter?); *e*, internal layer; *f*, the umbo.

In the group of *Aptychi nigrescentes* the inner layer is represented by a brilliant black coaly material, usually considered to be carbonized horny matter; but there is no reason why it should not be the decayed remnant of a derivative of muscle-tissue, viz. ligament.

Whatever be the nature of the tissues forming the Aptychus, the presence of tubuli reaching from the cavities of the cells to the exterior is absolutely opposed to the functional internal nature of the shell.

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[1] Nova Acta Ac. Leop. Car. Nat. Cur., Bd. xv. No. 2, 1831; mentions a "starkstinkende Geruch" when the Aptychus is dissolved in acid.

3. In reference to the size of the Aptychus, it seems natural that it should not exactly fit the aperture of the shell, for if it did the animal would have to be continually opening the lid to obtain fresh water; while if there were abundant space between the operculum and the shell-wall, the animal could breathe continuously in a contracted condition, and the presence of "*stries creuses*" in the test of many Ammonites (produced by the tightening of the muscular walls, so that they were thrown up into little ridges which left their imprint on the inner shell) seems to necessitate the power of doing so. While, again, if the Aptychus were poisonous, as I have suggested, and not merely a passive protection, there would be no necessity for the orifice to be closely shut. At any rate, then, there seems abundant evidence that the Aptychus could perform useful functions as an operculum without having to fit the aperture exactly.

In conclusion, I have shown that the theories against the Aptychus being an operculum can be met with equally plausible ones in favour of that view; and the fact that the Aptychus is known in one specimen to have officiated in that capacity, ought to throw suspicion on the other theories.

NOTICES OF MEMOIRS.

ABSTRACTS OF PAPERS READ BEFORE THE BRITISH ASSOCIATION AT OXFORD, AUGUST 9–14, 1894.

I.—THE PROBABLE RANGE OF THE COAL-MEASURES UNDER THE NEWER ROCKS OF OXFORDSHIRE AND THE ADJOINING COUNTIES.

By Professor BOYD-DAWKINS, F.R.S.

THE principle laid down by Godwin-Austen and Prestwich that the master or tectonic folds in the pre-Carboniferous and Carboniferous rocks are lines of weakness along which the newer rocks have been folded in later times, has been recently applied by Bertrand to the district of northern France. In the present communication the author proposes to see how far it can be used in the search after the buried Coal-fields of the counties of Oxford, Buckingham, Berks, and Wilts.

From the relation existing between the tectonic anticlines and synclines in the districts of South Wales, Gloucester, and the West of England, where they can be studied at the surface in the Palæozoic rocks, most important conclusions may be drawn as to the Coal-fields buried under the newer rocks in southern England. They are as follows:—

1. The Mid-Devon syncline, traceable eastwards until it cuts the sea-line near Bognor.

2. The North Devon anticline, which runs eastwards through the Vale of Wardour, past Salisbury, and along the anticline of the Weald from Petersfield to Dungeness.

3. The Mid-Somerset syncline, which sweeps eastward through the Vale of Bridgewater and Glastonbury, through the Chalk downs between Heytesbury and Hindon, to Haslemere. From this point

it is continued to the east through Tunbridge Wells and Tenterden to the sea to the south of Hythe.

These three folds have no bearing on the range of the Coal-fields in the drainage area of the Thames. The fourth, or Pembroke-Mendip anticline, and the fifth, or South Welsh syncline, are the two great tectonic folds which remain for consideration.

The Pembroke-Mendip anticlinal range, highly faulted and folded, is traceable westwards into South Ireland, and eastwards through Pembroke and the peninsula of Gower, to the south of Cardiff, through Weston-super-Mare and the Mendip Hills. Throughout this area it forms the southern margin of the Coal-fields. Near Frome it plunges beneath the Oolites. It is, however, clearly marked by the Upper Greensand anticline of the Vale of Pewsey, and by the Upper Greensand inliers of Ham and Kingsclere. Thence it passes along the line to the high downs past Basingstoke and Farnham to Peasemarsh, south of Guildford, where it is seen in an inlier of Weald clay. It is carried still further to the east by similiar inliers south of Westerham, and at Wateringbury and Maidstone. From Maidstone it sweeps to the south-east, through Otham and Ashford, arriving at the coast close to Hythe. In the eastern portion of its course it has, in my opinion, been the chief factor causing the south-eastern trend of the North Downs in the district of Maidstone. It forms also the southern boundary of the south-eastern Coal-field discovered in the boring at Dover, and of the Coal-fields of northern France and Belgium.

The South Welsh syncline, only two miles wide at St. Bride's Bay, in the anthracite district of Pembroke, widens out into the Coal-field of South Wales, twenty miles in width. As it approaches the upper estuary of the Severn it is represented by the outlying Coal-field of the Forest of Dean, and the three partially or wholly covered fields to the north of the Mendip Hills, distributed through an area measuring forty-five miles from north to south. The wedge-like syncline with its more or less connected Coal-fields continues to widen eastwards, its northern boundary being probably represented by a line drawn from the northern rim of the South Welsh Coal-field to the north of the Forest of Dean, and continued due east beneath the Secondary and Tertiary rocks to some point between Walton-on-the-Naze and the mouth of the Blackwater. It passes through Gloucester, Rissington in the valley of the Windrush, Blenheim, Kirtlington, Quainton, Luton, Bishop's Stortford, Dunmow, Braintree, and Colchester. The width of this great tectonic syncline between Colchester and Dover is about fifty miles, and it occupies nearly the whole of the London Tertiary basin, which, it must be noted, is of the same wedge shape, widening to the east.

The boring recently described by Mr. Whitaker at Culford, near Bury St. Edmunds, in which a slate rock, probably of Silurian or pre-Silurian age, was struck at a depth of 637 feet 6 inches from the surface, shows that in all probability that area is an anticlinal area. About forty-two miles to the south, in the deep boring at Harwich, the Yoredale shales come in. Both these points are, be it remarked, to the north of the line in question. Both indicate a Palæozoic area in Suffolk and northern Essex older than the Coal-measures, and similar to that on the same meridian in South Wales and Gloucestershire which lies to the north of the western Coal-fields. We have, therefore, not merely a well-defined Pembroke-Mendip anticlinal forming the southern boundary of the Coal-fields both in the west and in the east, as proved by the south-eastern Coal-field at Dover, but also evidence of the continuation of the South Welsh pre-Carboniferous barrier of Hull, which forms the northern boundary of the visible Coal-fields due eastwards into Suffolk. It may, therefore, be reasonably inferred that similar Coal-fields, isolated from each other by tracts of older rocks, are to be found in the South Welsh syncline, where it lies buried beneath the Secondary and Tertiary strata. In other words, we may conclude that there are Coal-fields in North Wilts, in the counties of Berks, Oxford, and Buckingham, and the Tertiary basin of the Thames within the limits laid down above, and in a direction indicated in 1871 by the Coal Commissioners.

One such Coal-field, indeed, has already been discovered in a deep boring at Burford, near Whitney, in the valley of the Windrush. The discovery, however, has unfortunately not been followed up, and we do not know whether it is of wide east and west range, similar to that of South Wales, or of Bethune and Namur, or whether it is small and unimportant, like some of the smaller Coal-basins north of the Mendip Hills. It offers a sure basis for other deep borings, which might have the same industrial effect on Oxfordshire as those which have extended the range of the buried Coal-measures in northern France, ninety miles to the west of Charleroi, and converted a purely agricultural into a great manufacturing district. There is no practical difficulty arising from the depth at which the Coal-measures may be expected to occur in this region. At Burford they were struck at 1184 feet from the surface, and at Dover at 1113 feet below high-water mark.

The borings in the area of the London Tertiaries prove that the Palæozoic rocks are not buried to a greater depth than about 1200 feet below sea-level, and in Hertfordshire to as little as 796 feet. The most important collieries in England are carried on at depths ranging from 1500 to more than 3000 feet. The new light thrown upon the question of the buried Coal-fields by recent discoveries places it in a very different position from that which it occupied in 1871, when Godwin-Austen, Prestwich, and Hull gave their evidence before the Royal Commission.

The boring at Dover, revealing the existence of a valuable Coal-field, now offers a fixed point for further discovery in south-eastern England. That at Burford offers a similar basis for the proving of the Oxfordshire Coal-field. The many other wells and borings made in the area of London, and as far north as Bury St. Edmunds, also afford important information as to the northern boundary of the productive South Welsh syncline. The development of our mineral wealth is of such vast importance that it would be quite worth the while of the Government to undertake a series of experimental borings, which would indicate the exact position of the buried Coal-fields. In the present state of the mining laws it is a task not likely to be undertaken by the private adventurer. It might, however, be carried out by the County Councils, or by a combination of land-owners, either with or without a compulsory rate, as the property would be benefited by the discovery of new fields. It is one of those objects of public utility which are especially worthy of the support of the British Association at this time and in this place.

II.—STONESFIELD SLATE. REPORT OF THE COMMITTEE, CONSISTING OF MR. H. B. WOODWARD (Chairman), MR. E. A. WALFORD (Secretary), Professor A. H. GREEN, Dr. H. WOODWARD, and Mr. J. WINDOES, appointed to open further sections in the neighbourhood of Stonesfield in order to show the relationship of the Stonesfield Slate to the underlying and overlying strata. (Drawn up by Mr. EDWIN A. WALFORD, Secretary.)

THE basement beds of the Great Oolite in the Midlands and in the south-west counties of England have been hitherto supposed to be well defined; for in all the records of the many writers on this geologic subdivision, to the Stonesfield Slate has been assigned the line of separation from the Fuller's Earth or Inferior Oolite, or, where the Stonesfield Slate is absent, as in the extreme west, to the Minchinhampton beds has been assigned the same position. Undue prominence has been given to so inconstant a set of beds as the Slate, as much from the ease with which fossils for its study have been collected as from the varied character of the fauna and flora found in it. From the days when the finding of the mammalian remains in the Slate called the attention of geologists prominently to it, every text-book of geology has found a place for it at the bottom of the Great Oolite limestones. Though, however, text-books and papers have defined the lower boundary of the Great Oolite so clearly, the officers of the Geological Survey in their work in the neighbourhood of Stonesfield found the lines so difficult to define that it became necessary, where the Slate had disappeared, to adopt an intermediate colouring, a kind of no-man's-land. Since then an argillaceous stratum, "the Rift bed," has been recognised as the lowest of the Great Oolite beds in the Banbury and Hook Norton area.

The endeavour of the work, for which the British Association made a money grant in 1893, has been to ascertain the thickness and composition of the beds underlying the Slate, for hitherto no account of these beds has been obtainable, Prof. Ed. Hull's record[1] of 70 feet being the only assumed thickness of the Great Oolite, and to this he adds 30 feet for the Inferior Oolite. Though their thickness seems to be over-estimated, no correction or account of a series of rocks so important has since then been made. Nearer Chipping Norton, however, Mr. J. Windoes, Mr. W. H. Hudleston,[2]

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[1] Report Brit. Assoc. p. 82 (sections), 1860.

[2] W. H. Hudleston, Proc. Geol. Assoc. vol. v. No. 7.

and your Secretary[1] have worked at some of the debatable beds above the Clypeus grit, one of the highest of the Cotswold divisions of the Inferior Oolite. To the bulk of these beds has been given the name of the "Chipping Norton Limestone" by Mr. Hudleston, and though the beds have not been reached in the section, they may be seen in the lane sections and near the spring on the banks of the Evenlode, south of Stonesfield. Your Secretary in 1892–93 sank a shaft near Ditchley, Oxon, to find out the true position of the Slate beds there; but of this an account will be published elsewhere.

The progress of the work, so far, at Stocky Bank, Stonesfield, has consisted in scarping the bank for 33 feet, and in continuing the section by carrying a shaft of 20 feet in depth through the lower bank. The purpose of the work has been so far successfully carried out by showing the existence of 30 feet of rock with some thin clay courses below the Slate. These limestones and clays (see accompanying section) are of Great Oolite type. To reach the Clypeus grit will need an extension of time and work.

Your Secretary has, by the discovery of numerous species of corals on the ploughed fields on the bank top, been able to define the Coral bed (Rift bed)[2] so prominent a feature in the near section at Ashford bridge. Seventeen feet below the coral bed a course of Slate is met with, almost thinned out at that point, and only from 5 to 7 inches in thickness; the total thickness of it and the associated beds (10, 12, 13 of the section) being about 5 feet. The usual fossils, *Trigonia impressa*, etc., occur. In the lower limestones, 15 and 17, are greenish clay inclusions.

The great mass of buff limestone below the slate is almost unfossiliferous, and neither its mineralogical character nor its few fossils give sure evidence of its relationship to neighbouring beds.

Prominent in the lower half of the section is the breaking up of the calcareous series by small clay beds, and of these No. 23, with its dark compact clays, is in part made up of oyster-shell fragments. It contains numerous compressed shells, *Perna quadrata, Nucula*, etc., but washings of the beds yield hardly any microzoa. The limestone above the clay yields well-known Great Oolite shells, *Mytilus Sowerbyanus, Rhychonella concinna*, and *Ostrea Sowerbyi*. The shelly limestone below the clay is in part an Oyster lumachelle, and passes into a blue-hearted limestone with *Perna quadrata*, large *Cyprinæ, Corbula*, and *Macrodon*. Here, again, both petrological facies and fauna are dissimilar to any of our known Oxfordshire Oolitic rocks and, like each of the succeeding lower beds, should be classed as Great Oolite; one of the latter, a hard, very oolitic freestone, has also as distinctive a character.

In conclusion, it should be stated that though, when Prof. Ed. Hull reported to your Association at its Oxford meeting, thirty-four years ago (1860), the presence of seventy feet of Great Oolite limestone under the Stonesfield Slate, it seemed to be an over-

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[1] E. A. Walford, "On the Relation of the so-called Northampton Sand of North Oxon to Clypeus Grit," Q.J.G.S., vol. xxxix. p. 235.

[2] E. A. Walford, Q.J.G.S. vol. xxxix. p. 230.

estimate, yet the result of the present investigation has been to prove the presence of an important and overlooked section of the Great Oolite, and to entitle place for it in future accounts of that subdivision. That Prof. A. H. Green doubted the existence of so great a series of beds as those quoted by Prof. Hull is proved by the absence of any account of them in his excellent memoir "On the Geology of the Country round Banbury, Woodstock, Bicester, and Buckingham," published in 1864.

Mr. James Windoes, Mr. Wilfrid Hudleston, Mr. H. B. Woodward, and your Secretary have also worked in later years at the determination of the equivalent of these lower Bathonian beds in the neighbourhood of Chipping Norton.

To his Grace the Duke of Marlborough, to the Right Hon. Lord Dillon, to Mr. John Barrett of Stonesfield, and to Mr. S. Shilson of Charlbury, the thanks of your Committee are due for aid in this and other relative work.

The probable extension of a lower division of the Great Oolite, great enough to entitle it to a place as a sub-formation, below the limit reached by us makes a continuance of the work a necessity for the right understanding of the Lower Jurassic rocks of Great Britain.

SECTION AT THE S.W. END OF COVERT, STOCKY BANK, STONESFIELD, OXON, 1894.

		Ft.	in.
1.	Humus with limestone fragments containing *Nerinæa*, *Cryptocænia Prattii*, E and H, *Cryptocænia* sp., *Isastræa microphylla*, Tomes, *Isastræa limitata*, Lamx., *Isastræa* near to *limitata*, Lamx., *Thamnastræa Lyelli*, E. and H., and *Epismilia* sp. "Rift Bed"	0	9
2.	Grey Marls with *Ostrea*, *Placunopsis*, and *Rhynchonella concinna*	4	0
3.	Fawn-coloured Sands and Marls—Oyster bed	2	0
4.	Grey shelly compact Limestone, weathering cream-coloured	6	0
5.	Hard grey Marls with *Rhynchonella concinna*	0	9
6.	Shelly Limestone	0	6
7.	Marl	0	2
8.	Limestone	1	3
9.	Marls with Oysters, etc.	2	6
10.	Limestone, shelly Oolitic and cream-coloured "Roof" of Slate	1	8
11.	Stonesfield Slate, "Top hard," compact, grey crystalline	5 in. to	7 in.
12.	Soft fissile Sandstone "Pendle"	9 in. to	1 ft.
13.	Limestone, coarsely fissile and Oolitic, with clay inclusions, concretions, black carbonaceous markings, and fragments of *Rhynchonella* and *Trigonia impressa*	2	0
14.	Marl, brown fissile and sandy	0	3
15.	Shelly Limestone, laminated and banded with clay inclusions in the upper part; fawn coloured with Oysters	2	3
16.	Soft fissile Sandstone with carbonaceous markings	0	5
17.	Limestone, compact, close-grained, fawn coloured, with carbonaceous markings and clay inclusions	7	6
18.	Limestone, close-grained, buff coloured	5	6
19.	Clay	1	6
20.	Limestone, compact, buff coloured	2	8
21.	Marl	0	4
22.	Limestone, white, shelly, and crystalline, with *Mytilus Sowerbyanus Rhynchonella concinna*, and *Ostrea Sowerbyi*	1	3
23.	Black Clay, crowded with *Placunopsis* in places, with *Perna*, *Nucula*, and *Ostrea*	1	7
24.	Shelly earthy Limestone, made up mainly of Oyster fragments, and passing into a brown, blue-hearted Limestone crowded with shells, *Perna quadrata*, large *Cyprina*, *Corbula*, and *Macrodon*	2	0

		Ft.	in.
25.	Black Clay	0	11
26.	Hard Oolitic Freestone, blue-hearted, made up of whitish Oolites in blue or brown base	2	0
27.	Rubble	0	3
28.	White fine-grained Limestone, with few shells	1	2

III.—ON SOME LACUSTRINE DEPOSITS OF THE GLACIAL PERIOD IN MIDDLESEX. By HENRY HICKS, M.D., F.R.S., F.G.S.

IN this paper the author refers to some deposits, consisting of stratified gravels, sands, and clay, varying in thickness from a few feet to over 20 feet, which are spread out over the plateaux of Hendon, Finchley, and Whetstone. They are frequently covered over by the chalky Boulder-clay with northern erratics; but seldom themselves contain other materials than those which could have been derived from the Tertiary or Cretaceous series in the south-east of England. No marine fossils of contemporaneous age have been found in these deposits, but remains of land animals occur occasionally in and under them. The author has found that their geographical distribution is much greater than has usually been supposed, and he has been led to the conclusion that they must have been deposited in a lake, in the Glacial period, whose waters attained to a height of nearly 400 feet above present O. D. This lake, he believes, occupied a considerable area in the south-east of England, and spread for some distance south of the Thames, but was dammed up on the east and west. As the lake became gradually reduced in size, lakelets were formed in the Thames Valley, and most of the stratified deposits now found there, except those in the immediate proximity of the present Thames and its tributaries, date back to that period. Man, however, lived in the valley before any of these deposits were thrown down, hence it is that the flint implements and the mammalian remains usually occur under or in the lower parts of the deposits.

IV.—ON THE TERRACED HILL SLOPES OF NORTH OXFORDSHIRE. By EDWIN A. WALFORD, F.G.S.

THE green slopes of many of the minor vales of North Oxfordshire are scored with parallel terraces or terraced banks, frequently of such regularity in depth of step and slope as to present to the mind any other origin for their formation than that of the every-day work of natural forces. They have been described as camps, entrenchments, and amphitheatres, and those of other districts Mr. Gomme has described, and has cited the many theories of their origin.

Mr. Walford first drew attention to the Oxfordshire and Warwickshire terraced fields in 1886,[1] and dealt at greater length with the subject in 1890.[2]

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[1] E. A. Walford, "Edge Hill: the Battle and Battlefield," p. 24 (Banbury, 1886).

[2] E. A. Walford, "On some Terraced Hill Slopes in the Midlands," Journ. Northampton Nat. Hist. Soc., January, 1890.

He gives as causes of formation—

1. The downward creep of the surface and sub-surface soil.

2. The occurrence of the terraces upon one precise geologic line, the micaceous marls of the Middle Lias which come in below the Red Rock bed. The marls are porous and non-cohesive. On the slippery slopes the soil must creep. The rain and rain-wash loosen the light soil below and about the roots of the herbage and urge its movement downward. Terraces from an incipient stage, like an ordinary grass ridge, to minor and major terraced banks of varying regularity of form can be traced. Below these marls are depths of compact blue clay (the zone of *Ammonites margaritatus* if in near contact with the marls). A little below the point where the marls and clays meet is the line of water outflow. Along the line there is constant removal of marl by chemical and mechanical solution. The effect is the loosening and sliding of the land downwards and outwards. This pressure is aided by the weight of the overlying mass of rock, sometimes twenty-five feet in thickness.

3. Free passage of water through the rock and marl is necessary, for the Upper Lias clays have on the Oxfordshire terraced hills either been wholly stripped from the hill top or pushed back by atmospheric denudation. Regularly terraced slopes are not found on clay-covered hills; the appearance of terraces is coincident with the wearing away of the clay "roof."

The amphitheatre form of terraced land is always a valley head. The outflow of the stream—the valley-maker—marks ordinarily the base of the amphitheatre. More frequently the terraces of the valley head are small in slip and their curvature is broken. Such an instance is Kenhill, near Shennington. An instance of greater regularity of curvature and greater depth of step is the Beargarden, Banbury.

From the Edge Hill escarpment a fork of the Horton vale runs alongside Adsum Plantation, and makes what is known as Adsum Hollow. The terraces sweep in regular curves along the high banks of the stream, and where it joins the main vale to the north of Horley the steps are so prominent as to give the name of Steps Meadow to the ground. Gredenton Hill, on the Burton Darrett range, is very regularly and beautifully terraced on three sides.

The author does not attempt description of the Chalk hills or the lynchets of Dorsetshire. The sandy marls of the Dorsetshire Inferior Oolite have a composition approaching that of the micaceous marls of the Midlands, and reasons like those brought forward will no doubt prove their similar mode of formation.

REVIEWS.

I.—PALÆOSPONGIOLOGIE; von HERMANN RAUFF. Erster Theil. 5te und 6te Lieferung. Mit 17 Tafeln und 27 Abbildungen im Text. Palæontographica. Band xl. Stuttgart, 1894, pp. 233–346.

THE previously issued (1–4) parts of Dr. Rauff's elaborate Monograph on Fossil Sponges, which dealt with the general history, structure, and classification of the group, have already been noticed in the GEOLOGICAL MAGAZINE.[1] The present issue begins the special portions of the work which treats of the characters and relations of the different genera and species, taking them in the order of their geological appearance. In these two parts the sponges from the Cambrian rocks, and a considerable number of those from the Silurian, are described in great detail, and in most cases both the sponges themselves and their minute and often intricate skeletal structures are figured either in the text or in the beautifully-executed plates, with striking fidelity. The majority of the forms are not new to science, but it may be said of many of them, hitherto only superficially described, that their characters are now made known for the first time. In several respects the sponges from the older rocks present greater difficulties to the student than those from the Mesozoic formations, for they are often less perfectly preserved, and the structures in some differ markedly from those of a later age; but these obstacles have been successfully overcome by the author, who has worked out the construction of their skeletons with much skill and patience.

From Cambrian strata but a small number of species are known, and these as a rule only by imperfect fragments. The Hexactinellid genus *Protospongia* is the most widely distributed form, but it is principally represented by detached spicules and small fragments of the mesh, which, as regards preservation, fall far short of those discovered by Dawson in the Ordovician strata of Métis. Lithistid sponges from the Upper Cambrian of the Mingan Islands are better preserved, at all events in the case of the remarkable *Archæoscyphia Minganensis*, Bill., sp., whose affinities to this group, which had been disputed by Bornemann, are confirmed by the author; another form, first described by Billings, is the *Nipterella paradoxica*. Dr. Rauff very properly excludes from the group a number of peculiar bodies from the Cambrian of New Brunswick, which Mr. G. F. Matthew had placed under sponges, apparently because they would not fit in with any other class of organisms, and also the doubtful *Leptomitus Zitteli*, Walcott, and a few others.

Coming now to the Silurian (in which the Ordovician is included by the author), we meet with a very considerable increase in genera and species both of Hexactinellid and Lithistid sponges. The Hexactinellids all belong to the Lyssakine division, and are referred to the following genera: *Protospongia*, *Dictyophytra* (=*Dictyophyton*, Hall), *Cyathophycus*, *Palæosaccus*, *Acanthodictya*, *Plectoderma*, and *Teganium*, n.g.

An interesting new form of this group, from the Wenlock Limestone of Dudley, is described under the name *Oncosella catinum*, n.g. et sp. Only one specimen of it is as yet known, and it is remarkable to find that it retains its form fairly complete and uncompressed, although its original siliceous skeleton has been altogether replaced by calcite. Yet other Hexactinellid genera of somewhat less regular build are *Pattersoñia*, Miller (=*Strobilospongia*, Beecher), *Brachiospongia*, and *Amphispongia*. Dr. Rauff does not hesitate to rank this

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[1] Dec. III. Vol. X. 1893, p. 524.

latter genus as a genuine Lyssakine Hexactinellid, in spite of its peculiar features. Of not infrequent occurrence, both in Silurian and in Carboniferous rocks, are the bundles of spicular rods which anchor the Hexactinellid sponges to the sea-floor; they have been variously named according to the different opinions held about them; thus M'Coy and Portlock considered them as annelid tubes, and placed them under *Serpula*; subsequently M'Coy placed them in a distinct genus, *Pyritonema*. For similar spicular bundles in the Carboniferous rocks associated with normal Hexactinellid spicules, von Zittel used the generic term *Hyalostelia*. It is quite possible that these bundles may have belonged to different species and genera of sponges, and Dr. Rauff proposes to employ M'Coy's name for Silurian, and von Zittel's for Carboniferous specimens. But until it can be proved that the later ones belonged to another genus than the earlier forms, these similar objects cannot rightly be placed under two genera, and only one of these two names can therefore be retained.

The Ordovician and Silurian Lithistida probably were more numerous and important at this epoch than the Hexactinellida. One of the principal families is that of the Astylospongidæ, which, with the Hindiadæ, is included by the author in the tribe Eutaxicladinidæ. In this group the arrangement of the spicules and their mode of attachment to each other to form the skeleton are of a very complicated character; theoretically, according to the scheme of the author, where the rays of the spicule are simple, they are so grouped as to form the outlines of a series of rhombohedra. But as one or more of the rays may be in duplicate, the regularity of the theoretical plan is but seldom apparent in actual sections of these sponges. From an examination of a large number of American and European specimens of the Astylospongidæ the author has discovered that the European examples and those from Waldron in Indiana are characterized by smaller spicules and a closer skeletal network than exist in the forms from Tennessee and Canada, and though it is acknowledged that these latter belong to the same respective genera as the former Dr. Rauff proposes to distinguish them by employing a different generic term; so that, for instance, the Tennessee specimens are placed under *Astylomanon*, and the corresponding European forms remain under *Astylospongia*. We doubt very much the advisability of this proceeding, in view of the author's admission that the Tenesseean and Canadian Astylospongidæ belong to the same genera as the European. On the other hand, we quite agree with the author in dividing up the forms hitherto placed under *Astylospongia*, retaining this name for the typical *A. præmorsa*, Goldfuss, sp., which has a definite cloacal depression, and proposing two new genera, *Caryospongia* and *Carpospongia*, for the specimens, in which there is a different arrangement of the canal system.

The structure of the skeleton in the genus *Hindia*, which is made the type of a new family, is stated to be in near relationship to that of the Astylospongidæ. Both the American and European examples are referred to a single species.

In the Appendix the author supplies some omissions in the catalogue of the literature previously published, and continues it down to the end of 1893, thus placing the students of fossil sponges under additional obligations. G. J. H.

II.—PAPERS AND NOTES ON THE GLACIAL GEOLOGY OF GREAT BRITAIN AND IRELAND. By the late HENRY CARVILL LEWIS, M.A., F.G.S.; Professor of Mineralogy in the Academy of Natural Sciences, Philadelphia, and Professor of Geology in Haverford College, U.S.A. Edited from his unpublished MSS., with an Introduction by HENRY W. CROSSKEY, LL.D., F.G.S. (London and New York: Longmans, Green, and Co. 1894.)

SCIENTIFIC ideas which engage attention show a remarkable parallelism to the history of characteristic species in a geological formation. Sooner or later, after their first appearance, they attain an extraordinary development, displacing the other ideas or species which had previously been familiar; then become less important, and eventually settle down side by side with the older types of life or thought, which often come back again, to share the field with the interloper, which has found its true position.

The studies of the elder Agassiz among the glaciers of the Alps, gave an impetus to observation of the nature of glaciers and the work they do, which took nearly thirty years to develop. And subsequently the observations of the late Sir Andrew Ramsay, and the exposition of Sir Archibald Geikie, led to an endeavour to discover the extent to which the surface of the earth has been shaped by land-ice, which has now reached its full expression. On a recent occasion we drew attention to the way in which Sir William Dawson, preserving the old traditionary iceberg theory of the origin of glacial drift, had endeavoured to apply it in explanation of the glacial phenomena of North America, assigning a subordinate place to the moraines produced by terrestrial glaciation. We have now the converse story in the record of observations made by the late Professor Carvill Lewis, on the Glacial Geology of the British Islands. Everyone who knew Mr. Lewis will recognise that no more brilliant exponent of the glacial theory has been heard in the present generation; and whatever may be the place which his contribution to glacial geology eventually occupies in the history of science, it arrests attention by the boldness of conception which directs it, and by the breadth of observation of fact, which endeavours to apply to this country the mode of interpretation which he had already used in concert with other geologists in the United States.

The work was, unfortunately, little more than begun, and the memorial volume which we now notice includes but eighty pages of completed papers, and consists largely of the contents of notebooks, which are rather a diary of observations of glacial phenomena as they were seen than a digest, or interpretation. The late Dr. Crosskey has, however, in his introduction, endeavoured to indicate the main points which these extensive and original observations suggest as worthy of examination. Mrs. Lewis contributes a short historical account of her husband's work. Professor Lewis believed that the division of the drift into Lower Boulder-clay, Middle Glacial sands, and Upper Boulder-clay, has yet to be established; and thought it probable that the Upper and Lower Boulder-clays in Lancashire may be the same deposit. Science is always in danger from hasty generalization of local phenomena; and those who are familiar with the Eastern Counties sections of the Upper Boulder-clay have probably always held that the three-fold division of the drift is essentially local, and that there has never been any demonstration of its universality.

Professor Lewis called attention to the fresh-water origin of many deposits regarded as glacial, pointing out that when the courses of rivers were dammed by advancing or retreating ice, morainic lakes would be formed, in which icebergs would float; and as a necessary corollary he concluded that areas free from glaciation existed in between the glaciers. He endeavoured to define these glaciated areas by tracing their terminal moraines, and maintained that every glacier could be defined by this evidence in the time of its maximum development. A glacier may form a terminal moraine, but if the history of the glacier be a story first of augmentation and then of diminution, the retreat of the glacial moraine may give rise to appearances which are not quite in harmony with the theoretical position of the parent ice. There can be no doubt that enormous masses of Boulder-clay have been denuded since the Glacial period, and the residue of the boulders is only to be found in post-Glacial deposits. And one of the problems of the future, as of the past, is to discover the relation of the snow waters upon the surface of the land to the erosion of the Boulder-clay. For it is always towards the river basins that the clayey matter disappears, and the Boulder-clay passes into a hill gravel which shows some evidence of water-action. For a long time a submergence in the middle of the Glacial period had been looked upon as practically demonstrated, but of this submergence Professor Lewis found at first no evidence, or only such evidence as would imply a submergence of 100 feet on the east coast, and 150 feet on the west coast of England.

The shell beds in the Boulder-clay which occur at great elevations were regarded as having been pushed up bodily out of the Irish Sea into the positions in which they are found.

The fossiliferous deposits at a height of 400 to 450 feet, he supposed to be transported by glaciers which formed an ice-dam, helping to enclose an extra morainic lake; and in the same way the beds at Moel Tryfaen are regarded as examples of glacial transport. There is some appearance of Professor Lewis having arrived at the conclusion that there was a second and older Glacial epoch on the evidence furnished by the sections at Frankley Hill and California, near Birmingham, between the 500 feet and 900 feet levels, where he found great abundance of Welsh felsites and slates. Since the first Glacial epoch he believed great erosion to have occurred before the second Glacial period. He remarks that the Lower Till at California, if not made by a glacier, was made by water close to the end of a glacier. Hence the whole question of subdivision of the Glacial period is practically left in the position in which Professor Lewis found it, and the criticism is the history of his own increase of knowledge.

The hypothesis of moraines, defining extra morainic lakes, in the middle and east of England, which Professor Lewis introduced, appears to rest essentially on the further hypothesis that the seas were filled with glacial ice, which prevented the escape of fresh water from off the land. Yet we are not aware of any evidence that the Cromer Boulder-clay was deposited in fresh water, as Professor Lewis supposes. Marine shells, especially *Cyprina* and *Tellina*, abound in the Cromer Boulder-clay, though they are mostly broken, and contemporary marine shells occur as far south as Ely, and this may be taken as evidence of water transport; but in view of the southward extension of the Boulder-clay in the Eastern Counties, it is difficult to find in it proof of a fresh-water origin.

The hypothesis of extra morainic lakes in which icebergs moved, does not appear to differ substantially from the older hypothesis of iceberg deposition of Boulder-clay as held by Phillips, Sedgwick, and many early observers, and the difference between Professor Lewis and them is rather of degree than of kind in interpretation of the facts.

The notebooks of Professor Lewis are a record of observation, never intended for publication, which will lead to useful work, in following up the indications given of facts observed at points, which are all carefully shown upon his maps. About 80 pages of these notes are given to Ireland; and the English notes are grouped geographically, dealing with Durham and Northumberland, Yorkshire; Lancashire, Cheshire, and the Midland district; the valley of the Severn; the east of England; the south of England, Wales; together with many notes on illustrative subjects. No small part of these notebooks is occupied with references to the literature of the subject, and the author's notes on localities described by previous observers.

The volume is illustrated with several maps showing the distribution of glaciers in North America and the British Islands; and about 80 woodcuts, which are mostly diagrammatic records of sections. There is an appendix by Mr. Percy Kendall, giving observations on the Manchester Ship Canal, on Lancashire and Cheshire glacial phenomena, and other subjects which he examined in company with Professor Lewis. Mrs. Lewis throughout has contributed notes in elucidation of her husband's work. The volume is excellently printed; but is, unfortunately, without an index.

III.—THE SEISMOLOGICAL JOURNAL OF JAPAN, Vol. III. 1894 (corresponding to Transactions of the Seismological Society): Edited by Prof. J. Milne, F.R.S. pp. 106, Five Plates.

Contents: (1) F. Omori: The Eruption of Azuma-san, pp. 1–22. (2) J. Milne: Seismic, Magnetic, and Electric Phenomena, pp. 23–33. (3) E. von Rebeur-Paschwitz: Description of an Apparatus for recording by Photography the Motions of Horizontal Pendulums, pp. 35–54. (4) J. Milne: A Note on Horizontal Pendulums, pp. 55–60. (5) H. Darwin: A Bifilar Pendulum, pp. 61–63. (6) J. Milne: A Note on Earth Pulsations and Mine Gas, pp. 65–69. (7) F. Omori: On After-Shocks, pp. 71–80. (8) E. J. Pereira: Record of Yokohama Earthquakes, 1890–1894, pp. 81–86. (9) J. Milne: Velocities of the Earth Waves, pp. 87–89. (10) M. Daubrée: La Cause des Tremblements de Terre, pp. 91–106.

The increasing attention paid to the study of earth-pulsations is strikingly shown in this new volume. Five out of the ten papers are indeed more or less connected with the subject. Prof. Milne (4) describes a modification of his conical pendulum, one of the least expensive instruments used for their investigation. Dr. von Rebeur-Paschwitz (3), who has done so much excellent work with the horizontal pendulum, gives many practical details of the greatest service to those engaged, or about to engage, in this fascinating study.

In the other papers, Mr. F. Omori (1) describes the eruption of Azuma-san in 1893, and proves that the conical holes surrounding the crater were produced by falling stones. Professor Milne (2) concludes that we do not yet possess any certain evidence of a physical connection between earthquakes and electric and magnetic phenomena. Mr. Pereira continues his useful list of Yokohama shocks.

Mr. F. Omori (7) discusses the relative frequency of the after-shocks of the great earthquakes of Kumamoto in 1889, Mino-Owari in 1891, and Kagoshima in 1893. Every strong earthquake is invariably followed by a few weaker shocks; a destructive earthquake may be succeeded by even hundreds or thousands. For instance, during the two years after the Mino-Owari earthquake, as many as 3364 after-shocks were recorded at the Gifu meteorological station. Of these, 11 were violent, 97 strong, 1809 weak, 1039 slight, and the remaining 408 merely sounds. Ten of the violent shocks occurred during the first four months, the strong shocks all within the first thirteen months, and the weak ones all within the first twenty months. Towards the end only slight shocks and sounds were observed. Curves are drawn showing how the after-shocks gradually became less frequent. Roughly rectangular hyperbolas, they at the same time exhibit several maxima and minima, corresponding to periodic fluctuations in seismic frequency. Mr. Omori reckons that after a lapse of about ten years, the residual effect of the Mino-Owari earthquake will be so far reduced that there will be only one weak shock a month.

Lastly, M. Daubrée (10), noting the usual classification of earthquakes into volcanic (due primarily to the action of steam) and non-volcanic (connected with fractures in the earth's crust), and referring to the frequent occurrence of after-shocks, endeavours to trace both classes to the same origin. "Les tremblements de terre des régions dépourvues de volcans," he concludes, "paraissent dus aux effets d'un sorte d'éruption volcanique qui ne peut aboutir jusqu'à la surface, et semblent dépendre, aussi bien que ceux des régions volcaniques, d'une cause unique: la vapeur d'eau, animée de la puissance énorme qu'elle acquiert dans les profondeurs de la croûte terrestre."

C. Davison.

IV.—Zur Paläozoischen Flora der Arktischen Zone, enthaltend die auf Spitzbergen, auf der Bären-Insel, und auf Novaja Zemlja von den Schwedischen Expeditionen entdeckten Paläozoischen Pflanzen. Von A. G. Nathorst. Mit 16 Tafeln. Kongl. Svenska Vetenskaps-Akademiens Handlingar. Bandet 26, No. 4, pp. 80. (Stockholm, 1894.)

On the Palæozoic Flora of the Arctic Zone, comprising the Palæozoic Plants Discovered by the Swedish Expeditions on Spitzbergen, Bear Island, and Novaya Zemlya. By Dr. A. G. Nathorst.

THE occurrence in Spitzbergen of plant remains of Palæozoic age was first made known by Roberts in 1838; several subsequent Swedish geological expeditions also obtained them, both from Spitzbergen and from Bear Island, and the collections were described by the late Professor Heer. The last Swedish expedition, in 1882, under the leadership of Nathorst and de Geer, discovered Carboniferous plants in several new localities in Spitzbergen, and also for the first time they found plant remains in the Devonian rocks of Liefde Bay. They further ascertained that the true position of the Carboniferous plant-bearing strata of Roberts' valley, which had been described as above the marine Permo-Carboniferous formation, was beneath this series, its apparent position being due to an inversion of the beds. The present Memoir contains descriptions and figures not only of the newly-discovered plants, but of those previously collected and worked out by Heer, the originals of which, now preserved in the Stockholm Museum, have been revised by Dr. Nathorst, with the result that many are shown to belong to quite other groups than those in which Heer had placed them.

Taking first the plants from the Devonian or Old Red Sandstone rocks of the Liefde Bay series of Spitzbergen, it appears that they occur on two horizons—a lower, in which only fragmentary remains of a form resembling the *Psilophyton* of Dawson have been found; and a higher containing remains of *Lepidodendron*, *Bergeria*, and *Bothrodendron*, and also the leaves of a probable Gymnosperm, named *Psygmophyllum Williamsoni.* The plants are too fragmentary to be compared with the Devonian of other regions, but they show a relationship to the succeeding Lower Carboniferous flora.

The stratigraphical relations of the beds yielding the Carboniferous plants on Spitzbergen have not yet been satisfactorily determined. It is certain that they are below the marine Permo-Carboniferous series, but hitherto the existence of the Carboniferous Limestone has not definitely been made out, though it is possible that it may be represented by the *Cyathophyllum*-limestone. The new forms from the Carboniferous include species of *Sphenopteris*, *Cardiopteris*, and *Lepidodendron.* The forms described by Heer as *Cordaites* and as leaves of *Rhynchogonium* are considered by Nathorst to be unusually large stems of fern fronds. A comparison of these Carboniferous plants with those from other areas shows a very close resemblance with the flora of the Culm and that of the Bergkalk on the continent, and equally so with that of the Calciferous Sandstone in Scotland, so that it may justly be considered a Culm flora. It has no special relation with the Old Red Sandstone flora, and therefore Heer's name of the "Ursa-Stufe" is not applicable to it. One of the remarkable features of this flora is the large size of the Ferns, *Lepidodendra* and *Stigmaria*, which show that the climate of the Lower Carboniferous epoch in Lat. 78½° N. must have been equally as favourable to plant life as that of the European continent at the same period.

Coming now to the Palæozoic flora of Bear Island, Dr. Nathorst modifies very materially Heer's determinations of the plants collected by Nordenskiöld and Malmgren. Thus, for instance, he doubts the occurrence of genuine *Calamites*, many of the specimens referred to this genus really belonging to *Knorria*, and one is provisionally placed as a new genus and species, *Pseudobornia ursina*. Several species of *Bothrodendron* are also present; one of these is identical with *B.* (*Cyclostigma*) *Kiltorkense*, Haughton, from the Old Red of Ireland. Many specimens placed under *Knorria* prove to be fragments of *Bothrodendron*. There is, further, no ground for supposing that *Lepidodendron Veltheimianum* occurs on Bear Island. The flora of this island is very distinct from that of the Lower Carboniferous of Spitzbergen, for with the exception of *Stigmaria ficoides* all the species are different; and it is equally as distinct from the Devonian flora of Spitzbergen. The author considers that it is intermediate between the Devonian and the Lower Carboniferous, and that the name *Ursa flora* may be retained for it.

Very little remains to be said respecting the fragmentary plants discovered by Nordenskiöld on Novaya Zemlya. The shales containing them are above the Permo-Carboniferous deposits, but the horizon they represent has not been determined. The plants were rightly referred by Heer to *Cordaites*, but on revision only two of the species described by him can be maintained. G. J. H.

V.—ÉTUDE SUR LES VARIATIONS DU SPIRIFER VERNEUILI. PAR J. GOSSELET. Mémoires de la Société Géologique du Nord. Tome IV. Mém. I. pp. 61, Pls. I–VII. (Lille, 1894.)

A STUDY OF THE VARIATIONS OF *SPIRIFER VERNEUILI*. By Prof. JULES GOSSELET.

THE well-known and very widely-distributed Upper Devonian Brachiopod, *Spirifer Verneuili*, Murch. (=*S. disjuncta*, Sow.), is one of the commonest fossils of the Frasnien series in the North of France and Belgium. It is said to occur in the Eifélien and the *Stringocephalus* beds of the Middle Devonian, but the author considers that it makes its first appearance in the upper portion of the Givétien limestones. It reaches its greatest development in the Frasnien series and in the next higher Famennien series it is also very abundant. Here it comes into competition with *Cyrtia Murchisoniana*, and apparently gains the mastery; but in the higher beds of the series it becomes less common, and finally it disappears before the end of the Devonian. The forms of this species are extremely variable, and Professor Gosselet gives in this Memoir the results of the study of numerous specimens, more particularly of those occurring in the Schistes de Barvaux, where it is especially numerous and well preserved. Detailed measurements of a large series of forms show important variations in nearly every feature of the shell, and the only constant character is the simple form of the ribs on the lateral or winged portions. The extreme variations are connected by a crowd of intermediate forms, and in the course of development the same individual may pass from one variation to another. There can, therefore, be no question of varieties in a zoological sense, and the author arranges the various modifications into groups of forms, six in number, taking as a basis the proportion of the width of the shell to the length of the smaller valve.

The author considers that *S. Verneuili* finally dies out without giving rise to another species; for though there are no extreme differences between it and such forms as *S. attenuatus* and *S. Mosquensis*, there are yet no intermediate forms known to indicate that it may be the ancestor of these latter. Discussing the question of the name properly belonging to the species, that of Murchison is adopted as, on the whole, having the best claim to priority.

To all interested in the question of Brachiopodal development the carefully worked out details in this Memoir, and its abundant illustrations, should prove highly valuable. G. J. H.

CORRESPONDENCE.

ORIGIN OF THE YOUNGER RED ROCKS.

Sir,—In his very interesting paper "On the Younger Red Rocks," my friend Dr. Irving professes himself to be more than ever convinced that the pebbly sandstones of the Bunter—such as those in Notts—consist of Triassic *sandbanks* deposited in narrow *tidal* seas, and "the great pebble beds of the Warwickshire and Budleigh Salterton type" are "the 'Chesil banks' which formed the shore equivalents of the sandbanks."

This is a matter on which I thirst for knowledge. Will he then kindly inform me: (1) What instances of marine conglomerates are known in which length, breadth, and thickness are simultaneously great? As a rule, the zone on which ordinary shingle is deposited extends but a few feet vertically above high-water mark, and not many below it. These conditions must somewhat restrict its breadth, and still more its thickness. Banks of the "Chesil" type can attain a greater thickness (though I should be glad to hear of one which came near or exceeded 100 feet), but they are comparatively narrow. (Mr. H. B. Woodward states that the Chesil Bank at Portland is 200 yards wide and 42 feet high.) But, according to Mr. Ussher and other authorities, the length and breadth of the area occupied by the Budleigh Salterton pebble bed is measured by miles, and its thickness varies from 50 to nearly 100 feet. The pebble beds in the Midland Bunter must have extended over a large part of Staffordshire (interruptions being mainly due to faulting or denudation), and they have trespassed on the neighbouring counties. Their thickness sometimes come near, if it does not exceed, 300 feet, and very commonly is over 100 feet.

(2) How he explains the fact that the Triassic pebble beds present such a close resemblance to the *nagelfluh* of the Alps, and to the great gravel beds of later date which overspread the lowlands on both sides of that chain, while it is difficult to find a parallel for them among beds undoubtedly marine. I asked these questions in 1890, but failed to obtain an answer, so I am obliged to repeat them.

T. G. Bonney.

THE SOUTHERN DRIFT.

Sir,—In this month's number of the Journal of the Anthropological Institute, p. 45, there is a statement of so misleading a character that I cannot pass it over without comment. In speaking of the Hill Gravels of Berkshire, Mr. O. A. Shrubsole says: "this extensive deposit is composed of the Southern Drift of Phillips and Prestwich." Anyone reading this would suppose, as he gives precedence to the late Prof. Phillips, to whom I have not referred in my paper on the Southern Drift, that I had failed to make acknowledgment to him as the discoverer thereof. Such an impression I am anxious at once to remove. I was at a loss to conceive what foundation Mr. Shrubsole had for this statement. On turning to Phillips' "Geology of Oxford and the Valley of the Thames, 1871," I find at p. 460 the following paragraphs. After speaking of the "operation of a great flood, a deluge, coming from the north, north-west, and north-east," bringing down spoil of the Midland Counties into the Valley of the Thames at Maidenhead and at Kensington, Prof. Phillips says: "Looking at the distribution of foreign drift in the country under review, we find evidence of abundant currents from the north, which brought plenty of gravels on the western side, but no Boulder-clay; and plenty of Boulder-clay with some gravels on the eastern side; while in the middle space there are traces of currents from the south transporting *flints and Sarsen-stones*." A diagram accompanies this description showing flints and *Sarsen-stones* from the Chalk hills, apparently of Kent, striking in between the north-west and north-east drifts. He then goes on to say how this might have been effected by the agency of ice. This is all that Professor Phillips says of the composition of this drift. He does not even mention the term "southern" in the text; but in the index attached to the word "drift" are the words "northern" and "southern," used, I presume, merely as antithesis. No definition of age nor superposition is attempted; and, be it observed, surrounded as the Thames basin is on all sides by Chalk ranges, flints and *Sarsen-stones* are of themselves no sufficient evidence of direction of their source.

Long before I had formulated my ideas respecting the Southern Drift, I often had the opportunity of discussing with my old friend and predecessor, Professor Phillips, the Drift beds of the neighbourhood of Oxford and the Thames Valley. Beyond the fact of the occurrence of flints in the Thames Valley, he was not aware of the widespread distribution of *chert* from the Lower Greensand on the higher hills of the Thames district, on which I mainly based my hypothesis of the Southern Drift. In fact, at that time, no one had recognised this chert *débris*, or if it had been noticed the fragments were spoken of as *Sarsen-stones.*

So far back as 1847, in "The Ground Beneath Us," after speaking of the flint gravel of the Thames Valley, I say: "It must have been from some distant spot that the materials of this gravel had been derived. . . . . The nearest place . . . . is in the range of hills passing by Croydon and Epsom, a distance of six to ten miles southward from Clapham." Again, "Whatever may have been the cause of this exceptional phenomenon the great and preponderating mass of flint *débris* from the Chalk hills, and of *sandstone* and *chert* from the Greensand hills of Surrey, leaves no reasonable doubt that the main bulk of the gravel of Clapham and of London has been derived and transported from the *Surrey downs* and *Sussex hills.*"

Mr. Shrubsole sees a difficulty in the existence of a Wealden dome, which he considers open to question. But how, without higher ground than any in the Thames Valley, could *débris* from the Lower Greensands have drifted over the ground to the northward of it?

These remarks are not intended to convey any disparagement of Professor Phillips' excellent work, which I have often had occasion to study with advantage. JOSEPH PRESTWICH.

BOULDERS OF ELÆOLITE-SYENITE IN EAST YORKSHIRE.

SIR,—The absence of the well-known elæolite-syenite (laurdalite of Brögger) from the Norwegian boulders hitherto identified in Holderness has more than once been mentioned, and is cited by Sir Henry Howorth in your August Number as in some way supporting his theory that the boulders were brought artificially as ballast. Why laurdalite should be less suitable for ballast than laurvikite does not appear. The non-recognition of the former is, of course, easily explained by its resemblance to the latter, which occupies a much larger area in the Christiania basin, and is correspondingly more plentiful among the boulders. Nevertheless it is satisfactory to be able to record the occurrence of the Norwegian elæolite-syenite on the Holderness coast. Visiting Dimlington a few months ago, I selected from the profusion of syenitic boulders on the beach eight which seemed worthy of closer study. These and the slices cut from them are now before me. Two contain abundant elæolite, and are identical in every respect with specimens of laurdalite from its original home; one or two others have accessory elæolite and sodalite.

Since these boulders were collected on the beach, the facts mentioned do not appeal to those who find comfort in the ballast theory. Indeed, it is not easy to see how Sir Henry Howorth can be met at all. Passing over his travesty of my argument, which I suppose is not to be taken seriously, I find nothing in his article that does not evade the point. He first suggested that the records of Norwegian boulders on our East coast were due to observers having been deceived by material artificially transported. Thereupon I pointed out the well-known fact that such boulders are found imbedded in the Holderness clays, as well as on the beach. Of this he takes no explicit notice, but proceeds to shift his ground and throw doubt on the identification of the rocks in question. If Sir Henry will submit some of the disputed boulders to his eminent but anonymous petrological friend, the testimony of the latter will no doubt receive due weight; meanwhile, though a hundred witnesses may depose that they have *not* seen Scandinavian boulders in Yorkshire, the jury will listen rather to the evidence of one or two who *have* seen and investigated the matter.

St. John's College, Cambridge.
August 18*th*, 1894.

Alfred Harker.

GLACIAL GEOLOGY.

Sir,—In your issue for August last Sir Henry H. Howorth, replying to a short letter in which I criticized an article of his you had printed, remarks: "I hope Mr. Harker and Mr. Deeley will continue to face the issues between us, and not be content, as others have been, with fulminating more or less testy protests, and then retiring from the field." It is clear that your correspondent here refers to a discussion which took place in the pages of "Nature" between himself and Dr. Alfred Russell Wallace. In that discussion Sir Henry H. Howorth, to discredit his opponent's views, denied the correctness of a statement made by Dr. Wallace. In reply, Dr. Wallace showed that Sir Henry H. Howorth had, in his "Glacial Nightmare," taken the same view as Dr. Wallace; and as Sir Henry H. Howorth would not admit that he had played fast and loose with his facts, Dr. Wallace very properly refused to further discuss the matter with him. Is it proper to call this retiring from the field with more or less testy protests? In my letter I charged Sir Henry H. Howorth with having misrepresented the teaching of two letters, one written by Prof. Bonney and the other by Prof. Hughes. In his reply we have no word of explanation or apology for this, or even reference to it; but instead an attack, delivered quite beside the mark, intended to throw discredit upon me. He also sneers at "English official geologists" as a body, so I can, at any rate, congratulate myself upon being in excellent company.

In face of the discussions which have already taken place—discussions in which it has been pointed out that, as far as is known, ice in bulk is plastic (that it has no *yield-point* in the sense that steel or even clay has, and that, therefore, so long as there is an upper slope to the ice the ice must move)—it would be useless to try to make the matter clearer in a letter. However, I will quote again from Sir Henry H. Howorth by way of illustration. He requires an "adequate *vis a tergo*," and says: "That such a *vis a tergo* can only, in the case of such ice-sheets, be obtained by postulating a considerable slope to the ice surface is equally plain and equally admitted." Will Sir Henry H. Howorth kindly express the necessary slope to produce motion in degrees, and give the *yield-point* of ice by which this slope is controlled?

I would have answered Sir Henry H. Howorth before, but have been for a short tour in Switzerland with Mr. G. Fletcher, F.G.S. Shortly we hope to be able to put together some notes we then made on the structure of glacier ice. During our stay I was able to examine many of the larger glaciers, and also to reach the summit of Mont Blanc and compare true *névé* with true glacier ice.

R. M. DEELEY.

CHANGES IN OLD LAND-SURFACES AND COAST-LINES IN THE GLACIAL PERIOD.

SIR,—For some time past I have been attempting to represent, by coloured diagrams, the gradual changes of the level of the land above the sea, and the relative altitude of the Hills in the British Islands in Pleistocene times, and up to the present period. It was, in my opinion, a great and prolonged denudation which took place during the first Glacial epoch, and after the maximum of glaciation was reached, a period of land submergence was also effected, and then commenced a gradual emergence, in which a wearing away in depressed areas progressed by action of the sea, leaving high-level drifts on the surface of Chalk and other rock formations; but the channels which now divide the French and English coasts, and the Isle of Wight from the mainland of Hampshire, had not been cut, and did not prevent the migration of the terrestrial inhabitants, the temperature reverting to a condition similar to that now prevailing. The inter-Glacial period, which we now designate as Palæolithic and Prehistoric, ensued. It was a mild climate which then prevailed, and continued for about 15,000 years duration, when there existed a fauna composed of Elephants, Rhinoceroses, Hippopotami, Bison, Musk-Ox, Irish Deer, Elks, Red Deer, Beavers, Wild Boars, Bears, Cave Lions, Hyænas, and other Carnivora. These creatures ranged through vast forests of Oaks, Elms, Yews, Fir Trees, with peat-mosses separating Arctic plants beneath from a flora of warmer times above.

At this time a race of men appeared whose intelligence was sufficient to enable them to provide for their wants and to engrave figures of animals and make weapons of stone and bone. We find their relics in caves and under the shelter of rocks, which have resisted destruction during the subsequent submergence to which they were exposed, and which must have continued for a period of about 15,000 years.

An ice-sheet covered the land, whilst it was submerged, to the depth of many hundred feet, and of this we have records in Scandinavia, in Canada, and also on Snowdon.

A question here arises, whether the vast thickness and weight of such an incumbent mass of ice, was not the true cause of the submergence. A change in the centre of gravity of the globe's surface will explain this. The subsidence of the land may well be referred to, as it is by Professor Prestwich, as that of the cause of the Traditional Deluge. This Glacial epoch seems gradually to have ceased and then again commenced a gradual elevation of the surface of the land above the sea, its outline becoming changed and modified accordingly, as its submarine rock-formations would have been subject to it, until its condition eventually became such as we now see it, with marine channels separating the British Islands, the Isle of Wight, and others from the Continent of Europe.

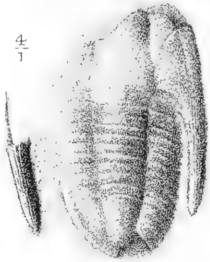
75, Kensington Gardens Square, LAMBART BRICKENDEN.

MISCELLANEOUS.

MANUAL OF THE GEOLOGY OF INDIA.—In the GEOLOGICAL MAGAZINE for August (*ante*, p. 375) attention was called to the omission of the names of Messrs. H. B. Medlicott and W. T. Blanford, the authors of the Manual of the Geology of India, from the title-page of the new edition. We are gratified to learn that, the circumstance having been brought to the notice of the Government of India, orders have been given by the Government for a new title-page, with the names inserted to be substituted for that first issued.

INTERNATIONAL GEOLOGICAL CONGRESS, ZURICH.—At the instance of Captain Marshall Hall, the Geological Congress at Zurich decided upon appointing an International Committee to report upon existing glaciers. As soon as the constitution of this committee is completed we hope to give details of the work it is to be charged with and its members.

THE GEOLOGY OF SOUTH SHROPSHIRE.—Fifty-nine pages of the August Number of the Proceedings of the Geologists' Association are devoted to an admirable description of "The Geology of South Shropshire," by Prof. C. Lapworth, LL.D., F.R.S., and W. W. Watts, M.A., F.G.S., illustrated by twenty-three woodcuts and two plates. On this historic ground so many eminent geologists have laboured and so much has been published, that it is no small boon to Associates to be able to obtain, in so small a space, so excellent an epitome of this interesting and important British area. The illustrations embrace a good Map and a large number of sections, a capital table of the Lower Palæozoic rocks of Shropshire, with the subdivisions proposed by various authors from 1830 to 1894, viz.: Sedgwick, Murchison, the Geological Survey, Barrande, Lyell, Geikie, Barrois, Bigot, de Lapparent, Lapworth, Callaway, Hicks, Nicholson, etc. The Geologists' Association are to be congratulated upon securing for their Proceedings so valuable a contribution, which is also descriptive of the area that has formed the object of their long excursion this summer, from July 29th to August 4th.



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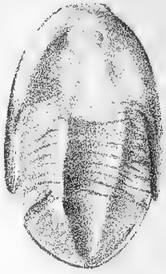

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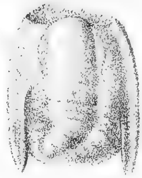

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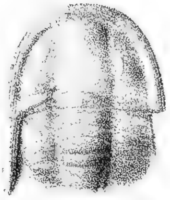

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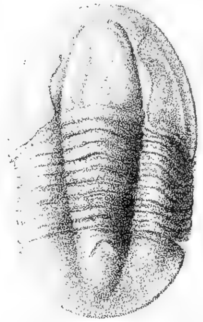

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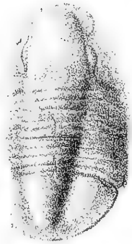

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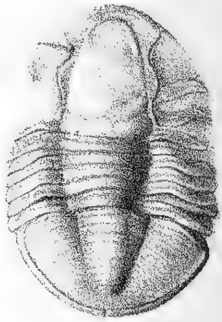

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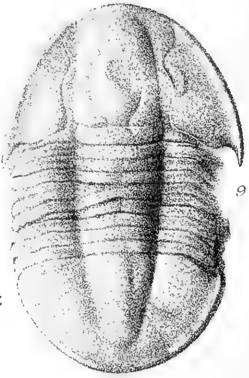

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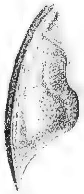

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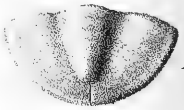

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E. C. & G. M. Woodward del. et lith.

West, Newman imp.

Carboniferous Trilobites.
from Stonyhurst.

THE GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE IV. VOL. I.

No. XI.—NOVEMBER, 1894.

ORIGINAL ARTICLES.

I.—NOTE ON A COLLECTION OF CARBONIFEROUS TRILOBITES FROM THE BANKS OF THE HODDER, NEAR STONYHURST, LANCASHIRE.

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

(PLATE XIV.)

EARLY in 1893, the Rev. G. C. H. Pollen, S.J., of Stonyhurst College, was so kind as to send up to me for examination a collection of Carboniferous fossils, obtained by himself with the assistance of Mr. William van Waterschoot van der Gracht, Jur. Stud., who during his residence at Stonyhurst paid much attention to the geology of the neighbourhood.

The collection proved to be an extremely interesting one, and Mr. Pollen most kindly requested me to keep a selection of the specimens for the Museum, only returning him a named duplicate collection for Stonyhurst. Subsequently Mr. van der Gracht sent me all the specimens he had himself collected, so that I was able to study a very fair series of the fossils from these beds.

The specimens sent up were carefully examined by Mr. R. B. Newton, F.G.S., and were found to comprise as follows:—Fragments of Vertebrata (possibly phalangeal bones of a small reptile?), also a part of jaw of a small Fish? (not determined).

		Recorded horizon.
MOLLUSCA—CEPHALOPODA—		
	Discites (*Nautilus*) *sulcatus*, J. de C. Sby.	(Carboniferous L.).
	Orthoceras læve ? Fleming	(,, ,,).
	,, *cylindraceum* ? Fleming	(,, ,,).
	,, *pyramidale* ? Fleming	(Yoredale series).
LAMELLIBRANCHIATA—	*Entolium* (*Pecten*), sp. nov.	(? ,, ,,).
BRACHIOPODA—	*Athyris lamellosa* ? Leveille	(,, ,,).
	Chonetes, sp. ?	(? ,, ,,).
	Productus, sp. (spines of)	(? ,, ,,).
POLYZOA ?—	"*Palæocoryne*" (very doubtful)	(Carb. L. shales).
TRILOBITA—	*Phillipsia van-der-Grachtii*, H. Woodw.	(,, ,,).
	,, *Polleni*, H. Woodw.	(,, ,,).
ECHINODERMATA—	Numerous ossiculæ of arms of Crinoids	(,, ,,).

My first impression, and that also I find which was entertained by Mr. Pollen, was that we were dealing with beds of the age of the Yoredale series, and this view was confirmed by a reference to the Geological Survey map, upon which the beds along this part of the Hodder are so coloured.

In the Centenary Record of Stonyhurst College, published in 1894, by the Rev. John Gerard, S.J., I am quoted, at p. 278, as having stated that the Trilobites obtained by Mr. Pollen from the banks of the Hodder "represent *probably* the *highest zone* in the

Carboniferous series from which this ancient group of Crustacea has yet been obtained." At that time, also, I had *provisionally referred* these specimens to *Phillipsia Eichwaldi*, Fischer, sp., and to *Ph. Colei*, M'Coy; but in the question of the geological horizon at which they occur I had not then enjoyed the advantage of Mr. Tiddeman's opinion, nor had I visited the spot and examined the beds *in situ.* I should therefore wish to modify the remarks I then made, both as regards the species of the Trilobites, which I now consider to be distinct, and also as to the exact bed they occur in, which, in deference to Mr. Tiddeman's judgment, I am led to consider must be placed lower down in the series.

As I was very desirous to ascertain what the geological horizon of these Trilobites really was, I decided to pay a visit to the locality, and, being most cordially invited by the Rector, the Rev. Herman Walmesley, S.J., and by Mr. Pollen, I started for Stonyhurst on the 10th of September, where my friend Mr. R. H. Tiddeman, M.A., F.G.S., of the Geological Survey, most kindly met me, and spent a day and a half going over the ground most carefully with Mr. Pollen, Mr. P. Stapleton, and myself.

Mr. Tiddeman pointed out to me that, in his opinion, we were dealing with the shales and limestones overlying the Clitheroe Limestones, and that our Trilobites came from near the top of this series.

TABLE OF THE CARBONIFEROUS ROCKS IN CRAVEN.[1]

Southern or Bowland Type.	Feet.		Feet.	Northern or Yoredale Type.
Coal-measures (Ingleton)	1500	The great Craven faults.	...	Coal-measures Incomplete near the faults in this area.
Millstone Grits	3900		...	Millstone Grits
Bowland Shales	300—1000		400—900	Yoredale Series
Pendleside[2] Grits (inconstant)	0—250			
Pendleside[3] Limestone (with Knoll-Reefs)	0—400		400—800	The Carboniferous Limestone (with conglomerates at base)
Shales, with Limestones (Trilobites occur here on R. Hodder)	2500			
Clitheroe Limestones (with Knoll-Reefs)	×3250 No base.			

"These beds," said Mr. Tiddeman, "were marked as 'Yoredale Beds' in the earlier edition of the Survey Map, but after the

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[1] Proceedings Yorkshire Geological and Polytechnic Society, 1890, vol. xi. pt. 3.

[2] [3] Both these sets of beds are considered to be absent on the Hodder.

intervening country between this and Wensleydale (=Yoredale) had been mapped in detail, the name was removed from the index in the later edition of 1891.

"It was not found practicable where, as in this case, the inconstant Pendleside Limestone and Pendleside Grits (see Table *supra*) were absent, to draw any definite boundary between the 'Bowland Shales' above and the 'Shales-with-Limestones' below, and both were coloured the light-blue shale colour."

In his paper referred to Mr. Tiddeman writes:—"Until the area of which we now speak was carefully surveyed it was assumed that there was a rapid transition of type in the Carboniferous rocks between Clitheroe and the big fells north of Settle and Malham; but as to the cause of such a rapid change no explanation was forthcoming. Even Prof. Phillips, who knew the country perhaps best of any among the old pioneers of Geology, often expressed himself to me as quite unable to account for it. If there is one thing more clearly brought out than another by the mapping in detail of this ground, it is this, that there is absolutely no transition from one type to the other. The two types run unchanged in their respective areas and with complete discordance with each other, quite up to a common boundary where the differences are rather accentuated than smoothed down. They might be Jews and Samaritans, agreeing in nothing save a common boundary to their territories and a determination to have nothing to do with one another.

"The line of demarcation is given by the Craven faults, and more particularly by that which runs by the south end of Malham Tarn, and that which passes between Malham Cove and Malham."

"The rocks on both sides of these faults seem to have been formed on slowly subsiding areas, but the Bowland area appears to have been subsiding more quickly and to a greater extent than the area occupied by the Yoredale type. It represents the downthrow side of the faults. The other side of the faults, of course, is relatively an upthrow" (see Table *supra*, York. Geol. Soc. Proc. 1890, vol. xi. pt. 3).

The subjoined brief note of the locality was drawn up for me by Mr. Pollen a year ago, and I now reproduce it in his own words, with the section of the beds which he also caused to be made for me with the kind assistance of Mr. van der Gracht.

Mr. Pollen writes:—"The River Hodder makes a straight run of about half a mile, in a direction E. by S., having Hodder School ('Hodder Place,' on the Ordnance Maps) on the right bank. Beneath this house the bank is very steep and high, but there is a broad shelf at the bottom on which are built the bathing-cots of Stonyhurst. The rock all along here is limestone, very crystalline and with much chert, alternating with clay-shales. The total thickness of the 'Yoredale series'[1] here is certainly over 500 feet, but the

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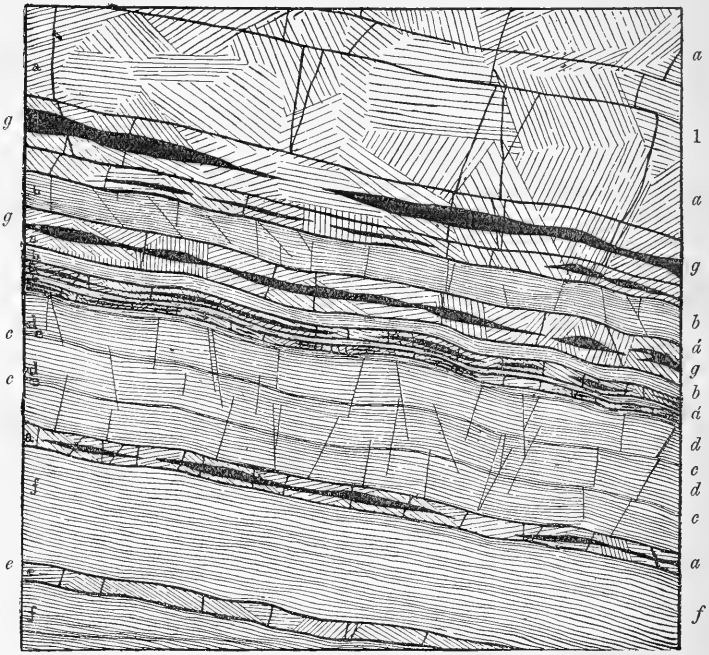
[1] I retain the term "Yoredale series" here in copying Mr. Pollen's note, although we may follow Mr. Tiddeman in considering them to be lower down in the series than was supposed twenty years ago, when the country was originally mapped by the Geological Survey.

strata are so contorted that it is difficult, or impossible, to measure them accurately. Above are the grits and sandstones of Longridge Fell. The dip of the strata is here 20° W., but hardly 100 yards of the river-bank can be found without irregularities, faults, or curves in the beds.

"At the bathing-cots the limestone predominates, but very few fossils have been found in it, with the exception of the coral *Lonsdaleia*; but a little lower down the river the shales occur in thicker beds, and in several places, at least, are rich in fossils. The section is drawn from the highest of these broad bands of shale, where there is a cutting about 15 feet vertical, perpendicular to the



Section, about 15 feet in vertical height, not far below the Bathing-cots, on the River Hodder, Stonyhurst.

Reduced from a drawing to scale, by Wm. van Waterschoot van der Gracht, Esq.

a 1 *a*. Limestone forming roof of section, about 9 feet in thickness here; *g*, *g*. lenticular masses of chert forming irregular bands or nodules in the limestone; *b*, *b*. dark carbonaceous finely laminated shales (varying in thickness) separated by *á*, *á*, bands of limestone of variable thickness, some only a few inches; *d*, *d*. shales with Trilobites, etc., subdivided by *c*, *c*. thin seams of mixed limestone and clay in rectangular blocks; *f*, *f*. shales with "*Palæocoryne*," etc., separated by *e*. band of limestone, under which specimens of "*Palæocoryne*" were found.

Almost all the fossils enumerated were found in the upper thick band of shale *b*, under the beds 1, *a*, *g*.

It is estimated that the total thickness of beds observed here along the River Hodder exceeds 500 feet. Above are grits and fine sandstones (Longridge Fell).

dip of the strata (see section). There is a roof of about 9 feet of limestone, then some thin bands of limestone and shale, and below these several thick layers of soft shales, separated by thin seams of limestone about 2–3 inches thick. In the upper of these broad bands of shale most of the fossils have been found, with the exception of '*Palæocoryne*,'[1] which occurs somewhat lower down.

"The jointing of the shales is very clean cut, the horizontal lines being usually parallel, though the surfaces of the joints are not. There are also transverse joints likewise parallel. The cleavage is parallel to the surface of the stratum, and very greatly developed for 2 or 3 feet from the exposed parts.

"In the sketch may be seen two thin bands (*c*, *c*) at about 8 inches apart, traversing and dividing the layers of shale (*d*, *d*). These bands, about ¼ inch thick, are harder, from the presence of more lime, and are broken up into almost square blocks measuring ¾ inch each way. Most of the Trilobites were found about 1 inch above each of these bands, the other organisms, the Crinoidal ossicles and most of the shells in the same line or a little higher up. The rest of the shale is almost free from fossils, and is covered with minute flakes of mica. Altogether the shales are too brittle to allow us to get out large slabs. It is easy to see that the Trilobites, especially the smaller specimens, must have lived in groups together. The largest specimens are often 4 or 5 inches apart from the others. We cannot pretend to have fully examined the beds lower down, but until now no ferns, or traces of terrestrial life, have been found in strata nearer than 40 or 50 feet below this horizon."

Genus PHILLIPSIA, *Portlock*, 1843.

General form oval; glabella with nearly parallel sides, marked by either two or three short lateral furrows; the posterior angles, forming the basal lobes, always separated by a circular furrow from the rest of the glabella; eyes large, reniform, delicately faceted; cervical furrow deep; free-cheek separated from the glabella by the axial suture, which forms an acute angle with the circular border of the cheek in front of the glabella; whilst the facial suture cuts obliquely across the posterior margin just behind the eye, leaving a small pointed portion fixed to the glabella by the neck-lobe; angles of cheeks more or less produced, margin of head incurved, forming a striated and punctated rim. Thoracic segments nine in number, the axis distinctly marked off from the side-lobes or pleuræ by the axal furrows; the abdomen or pygidium usually with a rounded border, the axis composed of from 12 to 18 coalesced segments.

1. *Phillipsia van-der-Grachtii*, sp. nov. Pl. XIV. Figs. 1–6.

This is a small, but very interesting form of Trilobite. The characters best observed are, the extremely long cheek-spines, more

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[1] This form may prove to belong to quite another group of organisms. It is at present under examination by Dr. Hinde, who has kindly consented to study it microscopically.

than one-third the entire length of the animal; the presence of a tubercle on the axis of the neck-lobe of the glabella, and the rounded form of the pygidium. The border of the head-shield is semicircular, with a broad rounded margin; the glabella is somewhat expanded in front, and the facial suture curves away from the glabella outwards before it intersects the frontal margin. The eyes are rather large, but are only faintly shown in Figs. 4 and 5, not being well preserved in the soft shale. The axis of the thorax is broad, being rather more than a third of the whole breadth of the body, and is separated by a distinct and straight furrow from the pleuræ on either side. The body-segments, which are nine in number, are straight and smooth, and have rounded extremities to their pleuræ. The outline of the pygidium is rounded, with a smooth and narrow margin; the axis narrows rapidly to its extremity and appears to consist of about eight coalesced segments, but these are only faintly indicated. The extremity of the axis reaches nearly to the outer edge of the border of the pygidium. The two nearly entire specimens figured (Figs. 1 and 3) are each of them 12 millimetres in length.

Compared with *Phillipsia Eichwaldi,*[1] the species it most nearly resembles, *Ph. van-der-Grachtii* agrees with it in the possession of long cheek-spines, and in the presence of a median tubercle on the axis of the neck-lobe of the glabella. It differs from it in the absence of any furrows on the glabella. The segments of the cephalothorax agree with those of *Ph. Eichwaldi,* but the pygidium differs greatly in outline, and also in the number of coalesced segments. The margin of the pygidium in *Ph. Eichwaldi* is broad and smooth, and ornamented with fine parallel lines or striæ, but in *Ph. van-der-Grachtii* the border is narrow and much more rounded in outline. The axis of *Ph. Eichwaldi* shows distinct evidence of the coalescence of 16 segments, whilst *Ph. van-der-Grachtii* does not show more than 8 coalesced segments.[2] *Ph. Eichwaldi* measures 25 mm. in length, or double the size of *Ph. van-der-Grachtii.*

The only other species besides *Ph. Eichwaldi* which might be compared with *Ph. van-der-Grachtii* are *Ph. Leeii* and *Ph. minor,* from the Culm-measures of Waddon Barton, near Chudleigh, Devonshire, but the cheek-spines are not so long, and the pygidium is more pointed and consists of about 14 coalesced segments.

I have much pleasure in dedicating this species to Mr. William van Waterschoot-van-der-Gracht, an old student at Stonyhurst, who, as already mentioned, accompanied the Rev. G. C. H. Pollen in his geological rambles along the banks of the Hodder, and also collected many of the specimens here referred to.

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[1] See Mon. Pal. Soc. Carb. Trilob., 1883, p. 22, pl. iv.

[2] It is probable that this interesting little species may hereafter prove to be an *immature form* of some larger Trilobite, at present unknown, from these beds. Meantime it seems more convenient to treat it as distinct, and to describe it as we have done. Numbers of this little form have been found on a slab in close proximity to one another.

2. *Phillipsia Polleni*, sp. nov. Pl. XIV. Figs. 7–12.

This species is considerably larger than the preceding one; the head is about one-third broader than long; the central portion of the glabella is smooth and rounded, gradually becoming narrower towards the front and being broadest at the neck-furrow. The facial suture runs in an undulating line between the glabella and the genal portion (free-cheek) of the head. The eyes, as a rule, are not well preserved, and in some specimens they might (as in the preceding one) be supposed to be wholly absent; but a careful study of numerous specimens shows that this is due, not to their absence, but to their imperfect state of preservation, the facets of the eye being clearly seen in Figs. 9 and 11. This condition of the eyes, due to compression, is also observable in the Trilobites from the Culm of Devonshire (see Mon. Pal. Soc. Carb. Trilobites, 1884, pl. x. p. 66). The contour of the head-shield is semicircular, the posterior genal angles are slightly produced, forming a short spine to each cheek (as seen in Figs. 8, 9, and 11). There are no furrows visible on the glabella. The neck-lobe is well developed and is broader than the free-segments which follow it; the pleural portion is less distinctly marked. The free-segments of the cephalothorax are nine in number; the axis is very slightly raised, and is nearly one-third broader anteriorly than the pleural portions, but diminishes in breadth gradually towards the pygidium; the extremities of the pleuræ are slightly pointed and recurved; the pygidium is one-third broader than long; the border is slightly raised, the axis being rounded off at some little distance short of the posterior border. The number of coalesced segments observable in Figs. 9 and 12 is about seven, but in Fig. 10 it apparently exceeds that number.

Compared with *Phillipsia Colei*, from the Carboniferous of Ireland, which is no doubt its nearest allied species (see Mon. Pal. Soc. Carb. Trilobites, 1883, p. 16, pl. ii.), *Ph. Polleni*, differs from it in the form of the glabella, and also in having the cheek-spines more pronounced, and in the absence of furrows on the glabella. The extremities of the pleuræ are rather more pointed in *Ph. Colei.* In the pygidium the border of the shield is not so wide in *Ph. Polleni,* and the axis is more rounded at the extremity and does not reach so near to the outer edge of the border as it does in *Ph. Colei,* in which the margin of the pygidium is also more corrugated. *Ph. Colei* is the only Carboniferous species which closely approximates to *Ph. Polleni*; but the differences just pointed out may easily suffice to distinguish them from one another. I venture to dedicate this form to the Rev. G. C. H. Pollen, S.J., of Stonyhurst College, to whom I am indebted for my knowledge of these Trilobites, and whose careful geological investigations brought about their discovery.

Both Trilobites belong to the Carboniferous Formation; but as to their *exact* geological horizon in the series it seems at present most unwise to speak dogmatically, owing to the difficult nature of the ground to be examined and the almost certainty of the recurrence of the same beds brought in again by faults and folds. The absence of palæontological horizons to fix the position of other beds above and below, is also greatly felt. I have no doubt, however, that if Mr. Pollen is able to give the necessary time to the task, he will unravel the succession, so far as it affects the banks of the Hodder. For larger areas we may look with confidence to Mr. Tiddeman and the officers of the Geological Survey, to whom we already owe so much, for light and guidance.

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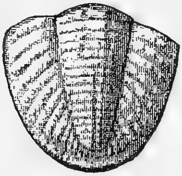
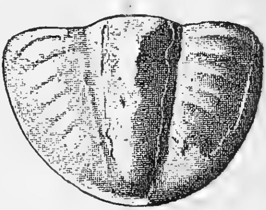




1.

Fig. 1.—Pygidium of *Phillipsia Derbiensis*, Martin (× 3 times nat. size), in red Carboniferous Limestone; R. Hodder.

Fig. 2.—Pygidium of *Phillipsia gemmulifera*, Phillips, sp. (× 3 times nat. size), in dark greyish Carboniferous Limestones; R. Hodder.

Postscript.—In addition to the numerous remains of Trilobites from the carbonaceous shales of the Hodder bank, Mr. Pollen has sent me up two small pygidia (see Woodcut) obtained by him, Fig. 1 from a dark reddish pebble, Fig. 2 from a dark greyish pebble of crystalline limestone, obtained out of the river-bed itself. As these pebbles have undoubtedly come from points much higher up stream, and have undergone rounding, the exact position of the parent rock is not at present known.

Fig. 1.—The larger abdominal shield, or pygidium, in the red matrix measures 10 millimetres in length, by 13 mm. broad, and is composed of 13 coalesced segments, very indistinctly seen, being partly decorticated; the axis of the tail is roundly elevated, about 4 mm. broad at the proximal border, where it articulates with the cephalothorax and tapers down to an obtuse point close to the posterior border; the pleuræ composing the margin are indicated by distinct lateral furrows on the pygidium, around the margin of which there is a narrow smooth border 1 mm. broad. The surface is not ornamented by any tubercles or punctæ. I refer this form to *Phillipsia Derbiensis*, Martin (see H. Woodward's Mon. Carb. Trilobites; Pal. Soc. Mon. 1883, p. 12, pl. i. figs. 2a, 6, and 9) (see Woodcut, *supra*, Fig. 1). There is a minute *Goniatite* imbedded in the same pebble.

Fig. 2.—The second and smaller tail, preserved in a pebble of glistening crinoidal limestone, is 8 mm. in length and the same in breadth; it is composed of 14 coalesced segments, the ridge of each segment being ornamented by a single row of very minute tubercles; there is a very narrow smooth margin around the border of the tail-shield; the axis is about 3 mm. broad where it articulates with the cephalothorax; it diminishes posteriorly, and it terminates

bluntly within the margin of the shield (see Woodcut, *supra*, Fig. 2). I have no doubt in referring this specimen to *Phillipsia gemmulifera*, Phillips, sp. (See H. Woodward's Mon. Carb. Trilobites, Pal. Soc. Mon. 1883, p. 17, pl. iii. figs. 1–6.)

EXPLANATION OF PLATE XIV.

Figs. 1–6. *Phillipsia van-der-Grachtii*, H. Woodw.

Fig. 1. Specimen showing part of head with long cheek-spines and entire body-segments and pygidium. One eye seen on right side of head. × $\frac{4}{1}$.
Fig. 2. A fairly well-preserved head-shield with long cheek-spines. × $\frac{4}{1}$.
Fig. 3. A nearly complete example viewed from the under side; the test is, however, removed. It gives the general proportions fairly well. × $\frac{3}{1}$.
Fig. 4. A specimen with the head and body-segments preserved, wanting the last two, and the pygidium also, with one long cheek-spine only preserved; eyes faintly seen. × $\frac{4}{1}$.
Fig. 5. Small specimen showing imperfect head-shield with eyes and cheek-spines, body-segments displaced and pygidium squeezed over them. × $\frac{4}{1}$.
Fig. 6. Imperfect specimen, showing head-shield and cheek-spines, eyes not preserved; body-segments obscure. × $\frac{2}{1}$.

Figs. 7–12. *Phillipsia Polleni*, H. Woodw.

Fig. 7. Specimen showing glabella, body-segments, and pygidium, but wanting left margin and both cheeks. × $\frac{2}{1}$.
Fig. 8. An entire but poorly preserved specimen, giving, however, valuable details of head, facial sutures, body-segments, and pygidium. × $\frac{2}{1}$.
Fig. 9. Specimen nearly entire, the pleuræ injured on right side, showing eyes and facial sutures and angles of head-shield.
Fig. 10. A less perfect specimen, but with the test preserved. The pygidium is perfect, and has a larger number of coalesced segments composing it than the others. Possibly distinct?
Fig. 11. A detached free-cheek showing eye well preserved.
Fig. 12. A detached pygidium.

All the specimens are from the thin, laminated, black carbonaceous shales. Carboniferous formation: banks of the Hodder near the Bathing-cots below Hodder House; Stonyhurst. The "types" preserved in the British Museum (Nat. Hist.).

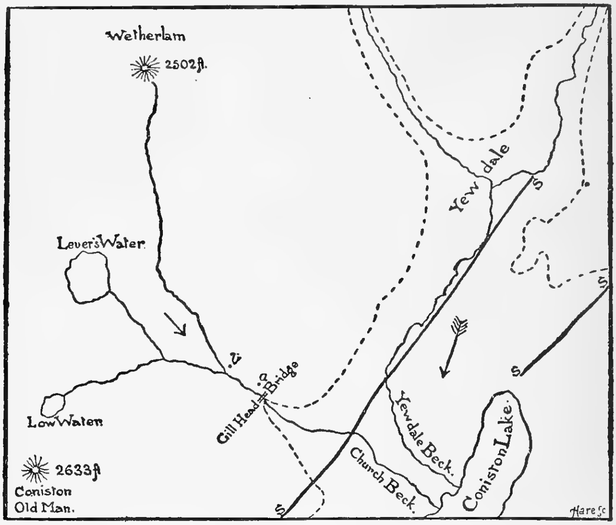
II.—Physiographical Studies in Lakeland.

By J. E. Marr, M.A., F.R.S., Sec.G.S.

1. Church Beck, Coniston.

When working amongst the rocks of Lakeland, one is often confronted with problems connected with the superficial features of the country, and as some of these are of more than local interest I propose to notice them from time to time.

Church Beck, flowing in a south-easterly direction from the eastern slopes of the Old Man range, passes through Coniston Valley to discharge its waters into the head of Coniston Lake, not far from the point of entrance of the more important Yewdale Beck, which flows through the wide valley of Yewdale in a southerly direction. Church Beck, on the other hand, flows through an upland valley, and is joined by the union of Low Water, Lever's Water, and the Red Dell Becks. Walking up its banks from Coniston Village, one presently comes upon an exposure of the Skelgill graptolitic shales at a height of about 225 feet above sea-level. Above this, one rapidly mounts the hill, and passing a considerable waterfall, reaches Gill Head Bridge at a height of about 540 feet. Above this is an alluvial flat extending to the Coniston copper works at the junction of the Red Dell Beck with that formed by the union of Lever's Water and Low Water Becks. The bottom of this alluvial valley is occupied by stratified deposits, formed by the washings of the copper works, which will, of course, not be confused with the much older deposits about to be described.



Explanation of Map of Church Beck, Coniston.
SS, Outcrop of Skelgill beds (shifted by fault above head of Coniston Lake).
a, Position of gravels with fragments of Skelgill beds.
b, Position of contorted loam, etc., on Boulder-clay.
The dotted line on map marks the 500-feet contour line.
The plain arrow indicates the direction of the Local Glacier.
The feathered arrow indicates the direction of the Yewdale Glacier.

Close to Gill Head Bridge, by the side of the road on the left bank of the stream, is a section in gravel and loam (a similar gravel occurs by the side of the road at a lower level and nearer Coniston Village at a height of 400 feet).

These deposits are well stratified, and rest on glaciated rocks with striæ pointing down the Church Beck Valley, and no doubt formed by a glacier coming down from the Old Man Range. Amongst other stones, they contain a number of fragments of the Skelgill graptolite-bearing beds, occurring *in situ* about 350 feet lower down the valley. It is of interest to inquire how these fragments got into this position.

The top of the gravel forms an indistinct terrace, at a height of about 575 feet, which may be seen on either side of the valley; but it does not run continuously round it, for the stratified deposits abut against and overlie Boulder-clay near the top of the alluvial plain, just below the Copper Works, and by the side of the above-mentioned road. Here an interesting section is seen of extremely fine laminated loam, resting upon the Boulder-clay, which, however, contains seams of a similar loam. This appears to be the section drawn in Mackintosh's "Scenery of England and Wales," p. 393, though all the details shown there are not now visible.

These stratified deposits are of such a nature that they would be unhesitatingly referred to "mid-Glacial gravels" by some writers; but on this view the presence of the fragments of Skelgill Shale will be difficult to explain. It is true that the Skelgill Beds occur at a level higher than that of the gravel both to the north-east and south-west of Church Beck, but they certainly cannot have been brought by ice from the south-west, for the movement of the ice was generally from the north, nor could they have come from the north-east, for the only place where they occur there at a higher level than that of the gravel, is on the opposite side of the Yewdale Valley, down which the main mass of ice moved in a general southerly direction. The local distribution of the gravel is an objection to their having been brought by floating ice in a glacial sea. If they had been so brought, we should expect to find similar deposits widely spread on the low ground about Coniston Lake, but they do not occur there. How, then, did they reach their present position? The most plausible explanation that I can give is as follows:—

It has been seen that the local ice from the Old Man Range once came down the valley below Gill Head Bridge, as shown by the rock striations. This glacier had certainly receded above that bridge when the stratified deposits were formed. But the more important mass of ice coming down Yewdale would extend across the mouth of the Church Beck Valley, blocking it up, and converting it into a glacier-dammed lake. Into this lake the coarse sediments would be washed off the hillsides to form the gravel terrace. The presence of fine loam higher up the valley, and the absence of the terrace just above, suggests that at this time the local glacier was about the head of the lake, and the muddy waters from it were discharged into the lake to form the impalpable laminated loam. The contortion of the loam, and the inclusion of patches of loam in the Boulder-clay, point to slight oscillations in the glacier, which at one time retreated from the lake shore, at another advanced a short way into the lake. The main Yewdale glacier would shed its bergs into the lake, as does the Aletsch glacier into the Märjelen See, and fragments of the Skelgill Beds carried in the ice could in this way be floated up and incorporated in the gravels. This certainly seems the most natural explanation of the phenomena exhibited in this valley. The accompanying map, when looked at in connection with a general map of the district, will show how favourable were the circumstances for the blocking up of the valley by ice.[1] The 400 foot gravel appears to belong to a lower terrace, formed when the Yewdale glacier had shrunk.

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[1] The top of the terrace does not coincide with any *col*. The surplus water from the lake probably disappeared through rents in the glacier.

I should not have noticed this case were it not for the tendency of some writers to assign all stratified deposits connected with Glacial beds to a mid-Glacial period. The stratified deposits of Lakeland and its neighbourhood are very numerous, but their modes of production are very diverse, and after many years of work in the district I have seen no proofs of an extensive mid-Glacial submergence there; everything points to the contrary.

III.—NOTES ON THE OSTEOLOGY OF *ANCODUS* (*HYOPOTAMUS*).

By Prof. W. B. SCOTT, F.G.S.
Professor of Geology in the E. M. Museum of Geology, Princeton, New Jersey, U.S.A.

IT might well appear that the labours of Kowalevsky and Filhol had so completely determined the structure of this genus, that nothing of importance remained to add to their results; but this is very far from being the case. The European material, found principally at Hempstead and at Ronzon, near Puy in France, is so scattered that its proper association is a matter of great difficulty, and errors are unavoidable.

Mr. J. B. Hatcher, Assistant in Geology, and one of the Curators of this Museum, has during the past two summers been engaged in collecting from the Oligocene beds of South Dakota, and among many other treasures has obtained several all but complete skeletons of *Ancodus*, belonging to the species which Osborn and Wortman have lately named *A.* (*Hyopotamus*) *brachyrhynchus.* This material proves to be of great interest and importance, and will be fully described in an illustrated monograph which is soon to appear. The object of the present preliminary notice is to call attention to some of the more striking characteristics of this curious animal.

The American species of *Ancodus* present certain constant differences from the European members of the genus. (1) The muzzle is not drawn out into such an extraordinary rostrum; (2) The skull has greater vertical height, though this difference may be due in part to the crushing which the Ronzon specimens have undergone; (3) The coronoid process of the lower jaw is much more prominent and more decidedly recurved.

The structure of the cranium is very similar to that found in the peculiar American genus, *Oreodon*, the proportions of the cranial bones being nearly identical; but while in *Ancodus* the facial region is remarkably elongate, in *Oreodon* it is extremely short, the teeth forming a continuous series without diastemata.

The vertebral column is also oreodont in character, and the odontoid process of the axis, as in that family, is neither conical nor spout-like, but half way between the two. The ribs are long and broader and more flattened than in the oreodonts, and the sternum is similar to that of the latter family. The scapula, humerus, ulna, and radius differ from those of the oreodonts only in detail; thus the ulna is less reduced and has a shorter and remarkably heavy olecranon.

The manus is pentadactyl, with a large, well-developed pollex.

In 1884 I showed that *Oreodon* possessed a pollex, the first artiodactyl in which this structure had been observed; later I found it in the Uinta (Upper Eocene) form *Protoreodon. Ancodus* is thus the third genus known to possess it, and is doubtless an indication that the Eocene artiodactyls will be generally found to have five digits in the manus. In this genus the pollex is larger relatively than in either of the others, and must have been of some functional value.

The femur and tibia differ from those of *Oreodon* only in their much greater size and massiveness; they are longer and heavier in proportion to the fore-limb than in that genus, but the shape and character of these bones are similar. The fibula is complete, but the shaft is much reduced and the distal portion is shifted more beneath the tibia than is common among artiodactyls of such antiquity.

The tarsus is oreodont in type, with some curious specializations, which are more elaborated in the American species than in those figured by Kowalevsky and Filhol. The astragalus and calcaneum are interlocked in a remarkably complex and perfect way, which, however, can hardly be rendered intelligible without the aid of figures. As in the oreodont, and indeed most artiodactyls, the ecto- and mesocuneiforms are ankylosed into a single piece. The entocuneiform is very unusually large and heavy, and to its distal end is attached a good-sized nodule representing a rudiment of the first metatarsal. The artiodactyl hallux was first demonstrated by Osborn and Wortman, who found it in the foot upon which they established the genus *Artionyx,* but which I have shown to be referable to *Agriochœrus,* Leidy, a most remarkable artiodactyl with claws instead of hoofs. Marsh has lately published the statement that a rudiment of the hallux is preserved in *Protoreodon* (*Eomeryx*).

The phalanges of *Ancodus brachyrhynchus,* and especially the unguals, are quite different from those of the European species and approximate more to the oreodont type.

The general resemblance of *Oreodon* and *Ancodus* has been commented on by many writers, but we are now for the first time in a position to determine just what that resemblance is, and we find it to extend to all parts of the structure. When the Upper Eocene genus *Protoreodon* is taken into account the similarity is found to be all the greater, for the latter has the oreodont peculiarities less markedly developed and still retains the pentaselenodont type of dentition. *Agriochœrus* is also clearly related to the oreodonts, but represents a very aberrant line. We may infer with considerable confidence that *Oreodon, Ancodus,* and *Agriochœrus* belong to three divergent branches of the same stock. It is true that the former is an exclusively American genus, while *Ancodus* very probably originated in the Old World, reaching North America by migration in early Oligocene times. Doubtless, however, we shall eventually find a Middle Eocene form, common to both hemispheres, which will prove to be the ancestral type required.

IV.—Chloritic Marl and Warminster Greensand.

By C. J. A. Meyer, F.G.S., and A. J. Jukes-Browne, F.G.S.

In the year 1878 there was a short controversy between us respecting these beds in the pages of this Magazine. Since that date we have both enlarged our knowledge of the beds at the junction of Chalk and Greensand, and recently we have had an opportunity of meeting at Seaton in Devon, and of examining the Whitecliff and Beer Head sections together. The result of this and of friendly discussion is that we have both modified our views and have come to an agreement on the most important points about which we differed in 1878. Under these circumstances we think it will save trouble and facilitate future enquiry if we jointly express our present views on the subject so far as we are in agreement.

1. *Chloritic Marl.*—As far as we can ascertain, this name was first applied to certain beds at the junction of the Chalk and Greensand in the Isle of Wight.[1] It was subsequently adopted by Prof. E. Forbes, for a bed which occupied a similar position in Dorset, and has since been used for any bed lying at the base of the Chalk Marl and containing fossils and green grains.

It does not follow, however, that the basal part of the Chalk Marl is everywhere of exactly the same age; there may have been continuous deposition over one part of the sea-floor, while a neighbouring part was swept by a strong current. We think this was the case, because in some localities there is a complete passage upwards from Greensand to Chalk, while in others there is a clearly marked break and plane of erosion between them. Where there is a passage the beds with phosphate nodules are probably on the same stratigraphical horizon; but wherever a break occurs the basement of the Chalk may belong to a higher horizon.

In the Isle of Wight, in N.E. Dorset, and South Wilts there is either complete passage or very slight signs of erosion; there is always soft greensand below the bed with phosphatic nodules, and the latter always contains the sponge *Stauronema Carteri.*

In the western part of Dorset there is always a break between Greensand and Chalk: the top bed of the Greensand is generally a hard calcareous sandstone; the nodule bed at the base of the Chalk does not contain *Stauronema,* but yields *Scaphites æqualis* in abundance, whereas in the Isle of Wight *Scaphites* only occurs in the Chalk Marl about 20 feet above the base.[2] Consequently we consider that the *Scaphites* bed of Dorset belongs to a higher stratigraphical horizon than the *Stauronema* bed of the Isle of Wight.

Now if the name Chloritic Marl is to be retained—and it seems to die hard—we think it should be restricted to the horizon or

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[1] Ibbetson, "Notes on the Strata of the Isle of Wight." London, 1849. 8vo.

[2] It has been recorded from the Chloritic Marl, but we believe that this is a mistake; at any rate, the find has never been confirmed.

"hemera" of *Stauronema Carteri*, and that the name should cease to be applied to the *Scaphites* bed of Dorset and Somerset, or to any bed in Devonshire. We are now of opinion that the bed which lithologically resembles Chloritic Marl at Beer Head, namely, No. 13 of the succession described by one of us in 1874,[1] is really the representative of the zone of *Belemnitella plena*, for it contains that fossil and passes up into the basement bed of the Middle Chalk.

2. *Warminster Beds.*—As one of us pointed out in 1878,[2] the fossils of the Warminster fauna were always collected from the surface of a field near Chute Farm; but there is now an exposure of the Greensand which contains these fossils in a small pit at the neighbouring farm called Rye Hill (Ray Hill on the old Ordnance Map). This Greensand is seen to pass up into a glauconitic marl containing scattered phosphatic nodules, and in this nodule-bed at another exposure *Stauronema Carteri* occurs, the bed gradually passing up into Chalk Marl. Hence it is clear that the home of the Warminster fauna is entirely below the Chloritic Marl, if that be defined as the horizon of *Stauronema Carteri*.

It is, moreover, important to note that the fossiliferous greensand does not contain brown phosphatic nodules, only a few pale yellow calcareous concretions; consequently fossils in brown phosphate purporting to come from the "Warminster Greensand" must really have come from the overlying Chloritic Marl, and should therefore be excluded from the list of Warminster Greensand fossils. We find that many such phosphatic fossils occur in the collections of different museums, and this fact has no doubt tended to increase the confusion between the Warminster bed and the Chloritic Marl.

On the other hand, in the Isle of Wight the bed of soft greensand which lies below the nodule-beds, and which has by some been included in the Chloritic Marl, contains *Terebratella pectita*, *Catopygus columbarius*, and other Warminster species, which do not occur in the *Stauronema* beds above.

It is true that in Devonshire (Beer Head, etc.) a Warminster fauna is present in beds which appear to be wholly above the Upper Greensand; this, however, is probably due in part to the survival of shallow-water species in the neighbourhood of a coast-line, for *Pecten asper* and other Warminster fossils are there associated with *Holaster subglobosus* and *Ammonites Mantelli*, which are essentially Chalk Marl species.

We think, therefore, that the Warminster Greensand and its equivalents should be regarded as the summit of the Upper Greensand, and the *Stauronema* bed or Chloritic Marl as the lowest horizon which can be included in the Chalk, this horizon being sometimes absent through non-deposition.

These views will entail a complete revision of the lists of Chloritic Marl fossils, as well as of the Warminster greensand fossils.

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[1] Quart. Journ. Geol. Soc. vol. xxx. p. 369.

[2] GEOL. MAG. Dec. II. Vol. V. pp. 547–551, December, 1878.

V.—Mr. Harker and Mr. Deeley on the Scandinavian Ice-Sheet.

By Sir Henry H. Howorth, K.C.I.E., M.P., F.R.S., F.G.S.

MR. DEELEY tells your readers that he has recently been to the summit of Mont Blanc, and has been studying the difference between *névé* and glacier ice. This is interesting; but we thought that a great many people had done the same thing during the last hundred years, and we thought that one of them, Forbes, had studied the famous Mountain and the phenomenon in question to good effect, not in a casual visit to the Alps, but in the course of many years of patient labour. Among other things we also thought he had shown that in a viscous body like ice, the slope of the upper surface necessary to make it begin to move is the same as the slope which would be required to induce motion in the ice if its bed were inclined at an angle. He further collected considerable evidence to show what the least angle is upon which ice will begin to move. This is the slope, *the least slope,* available. It is nothing less than astounding to me that anyone should venture to postulate a Scandinavian ice-sheet in the North Sea until he had considered this necessary factor, and how it would operate.

The Scandinavian ice-sheet was, I believe, the invention of Croll, who, sitting in his arm-chair and endowed with a brilliant imagination, imposed upon sober science this extraordinary postulate. He did not dream of testing it by an examination of the coasts of Norway, or even of Britain, but put it forward apparently as a magnificent deduction. All deductions untested by experiment are dangerous. Thus it came about that the great monster which is said to have come from Norway, goodness knows by what mechanical process, speedily dissolved away on the application of inductive methods. *Of course* it still maintained its hold upon that section of geologists who dogmatise in print a great deal about the Glacial period before they have ever seen a glacier at work at all; but I am speaking of those who have studied the problem inductively. First Mr. James Geikie, a disciple of Croll, was obliged to confess that this ice-sheet, which is actually said to have *advanced* as far as the hundred-fathom line in the Atlantic, and there presented a cliff of ice like the Antarctic continent, never can have reached the Faroes, which had an ice-sheet of their own. Next Messrs. Peach and Horne were constrained to admit that no traces of it of any kind occur in the Orkneys, or in Eastern Scotland. They still maintained its presence in the Shetlands; however, this was upon evidence which is somewhat extraordinary. I do not mean the evidence as to the direction of the striation, which was so roughly handled by Mr. Milne-Home, but I mean the evidence they adduce that the boulders found on the islands are apparently all local ones, and that, contrary to the deposits of glaciers, they diminish in number as we recede from the matrix whence they were derived.

If we cross the North Sea we have the converging evidence of Bonney and Matthew Williams in the Lofodens, of Pettersen in Central Norway, and, may I add, of Kjerulf, whose splendid map of the distribution of striæ and boulders in South Norway is most instructive, all of them plainly showing that such an ice-sheet is an impossibility unless we are to ignore the facts, for the Norwegian ice is shown not to have even extended to the islands on its coast. All this, and a great deal more, I have called attention to at very great length elsewhere; and I am bound to say I felt surprised that Mr. Harker, whose laurels have been won as a petrologist, should have ventured into the very intricate and difficult region of glacial geology without ascertaining what the best men (I mean the men I quote) had already done, and should not have felt some hesitation in basing so stupendous a postulate as a North Sea ice-sheet upon the occurrence at Dimlington of some stones like the rocks found in Viken.

Mr. Harker complains that I have travestied his argument by converting it into a simple syllogism. That argument is in print, and any of your readers is at liberty to construct a more attractive syllogism if he can. The fact is, some arguments look like travesties when thus analysed. Apart from this, Mr. Harker would oblige me by re-stating what he actually meant when, in view of the postulate admitted by him and Mr. Lamplugh, that more than nine-tenths of the Yorkshire boulders came from the north-west, he adduced as *a priori* probable that the other tenth came from the north-east, or rather the east.

He misunderstood me if he supposed I questioned his identification of the rocks in question. As a petrographer he is my master, and a very accomplished master; when he wanders away into glacial geology he has not the same vantage. When I said that in my rambles in East Anglia, and on the coasts of Durham and Yorkshire, I had not myself met with these so-called Scandinavian stones, I meant not that such stones do not occur there, but that they are distributed very locally, which they are. In referring to another petrologist it was for the purpose of saying that we must be very certain that we have exhausted every possibility of these stones having come from the Cheviots, or some other British site, before we take the course of going to the Cattegat for them; and that, inasmuch as the vast mass of the boulders found with them came from the north-west, it is, *primâ facie*, probable that they also may have come from some buried or undiscovered dyke or outflow in Britain, more especially as the Laurvig rock is itself so very local in Norway. Assuredly this is a reasonable position to take.

Supposing, however, they come from the Cattegat—the next question is, how did they come? That was, and remains, the really interesting question between us. I argued (in view of the facts already mentioned) that a Scandinavian ice-sheet is an impossibility. At all events, if it be possible, the facts collected by some of the most experienced geologists, Norwegian and English, have to be explained. Mr. Harker has ignored them all, and inasmuch as it was he who was mainly responsible for this correspondence, I think it would be welcome to us all if he were to suggest some answer to them.

If an ice-sheet crossing the North Sea is not possible as the porter of these stones, how are we to account for them? Icebergs seem to me to be as difficult to explain on many grounds as an ice-sheet. *Inter alia*, I presume the postulated ice must have collected the Carboniferous stones from Durham, and the stones from the Cheviots, where we have no evidence of continuous submergence. I therefore suggested the possibility of these local deposits of northern stones on the seaboard, all of which, so far as I have seen, *are rounded and water-worn*, and not one of them has the flattened parallel sides of undoubted glacier stones, being possibly ballast, which finds its way into many strange places.

This very year I heard, at Southwold, a most circumstantial account of two cargoes of stones from wrecks which had been scattered on the beach—one of them, a steamer from Guernsey with Guernsey rocks, wrecked near Aldborough, and the other a cargo of paving-stones from Scotland. Mr. Hulke writes to say that he remembers a cargo of Elephants' tusks being similarly shipwrecked in the Channel. I further pointed out that the Norse pirates, whose ships were being continually wrecked on the Yorkshire and East Anglian coasts, curiously enough chiefly came from Laurvig and its neighbourhood, and not only must have carried ballast, but also used stones for anchors. This explanation does explain simply, completely, and absolutely the local character of the finds, and the occurrence of the stones on the strand. It is on the strand the great bulk of them occur. Mr. Harker says, however, that some also occur *in situ* in the cliffs. He does not say he has found any himself. If he has, and the question is very important, its importance has certainly been overlooked in his former papers, which I quoted. The question is not a simple one to decide, and we should all be grateful for precise and definite details, and not *obiter dicta.*

It is very difficult sometimes on these coasts (and I confess to having been myself misled the other day at Cove Hithe) to distinguish between boulders actually in the clay originally and those driven into the face of the cliff by the high tides. The safest test is to examine pits in the Boulder-clay some distance from the sea. Has this been done? Any details as to the exact facts of the finds other than on the strand would be very useful.

The issue is too interesting and too important to be left in doubt, and now that the question has been raised in this way it ought to be properly sifted, and by no one better than by Mr. Harker and Mr. Lamplugh. The stones in question deserve to be more systematically collected, and their external appearance as well as their internal structure described, and the provénance of each properly marked. Such a collection ought to be found in Jermyn Street, the best of Geological Museums, but, unfortunately, the Yorkshire boulders are badly represented there. I could only find two small specimens of the rhomb porphyr. I am bound to add that from my own superficial examination, the Yorkshire stones seem to differ both in colour and in the shape and size and mode of occurrence of the imbedded felspar crystals from specimens of rhomb porphyry from Laurvig in the Natural History Museum.

Now for two personal matters:—Mr. Deeley says I have misquoted two letters of Professors Bonney and Hughes. The letters were private letters, written to myself, and are on my table. How anyone but myself and the writers can know what they contain I know not. All I know is that Prof. Bonney, in regard to the Lofodens, and Prof. Hughes, in regard to the shipwrecked stones on the East coast, absolutely confirm my statements of fact. The inferences are my own.

Secondly, Mr. Deeley says I sneer at official geologists. In my case to do so would be like parricide and fratricide. I have learnt a great deal of what I know from them, and have received unbounded courtesy from them. What I do object to, and shall continue to protest against, is the notion that geologists, official or otherwise, any more than any other scientific men, have a right to publish and discuss great issues *until they have read what other people have written about them.* It does further seem preposterous to me that a number of men should be told off to map so-called glacial deposits, and to write memoirs—*not* on the facts, but on a glacial explanation of the facts—who have never studied the mechanics of ice in the laboratory, and, what is more strange, have never seen a glacier at all.

Lastly, I suppose no other science but long-suffering geology would tolerate the absurdity—may I say the impertinence?—of a public advertisement from a casual visitor to Switzerland, that, having gone to Mont Blanc in the year of grace 1894, he proposed to settle the great question of the different action of *névé* and ice. Why, the question is a century old, and there was a whole library written upon it before either Mr. Deeley or myself was born!

VI.—The Yumuri Valley of Cuba—A Rock-Basin.

By J. W. Spencer, M.A., Ph.D., B.A.Sc., F.G.S.

NEAR the city of Matanzas, in Cuba, there is a beautiful valley called the Yumuri, of which the good people of the region are justly proud. Its interest to the geologist is unsurpassed in the island. At its entrance there is the most complete section of Tertiary rocks observed by me in Cuba. This valley is a record of the great erosion of the land during most of the Pliocene period, at the close of which it was partly refilled. The valley was re-excavated during the earlier days of the Pleistocene period, and suffered other changes, but it is the closing of the valley into a rock-basin in almost modern days of which I write.

Upon the northern side of the ridges, of which Pan de Matanzas is the highest point (1277 feet above tide), there are the remains of a former plain, which extended five or six miles to near the sea-shore, with an elevation of about 450 feet. Out of this plateau the Yumuri Valley has been excavated with a breadth of about three miles, and length of five or six miles, with a further rugged extension of one of the tributary valleys ~~to~~ the foot of Pan de Matanzas, as shown on Map (Fig. 1). The floor of the basin rises from near tide-level to considerable elevations in its upper part, where there are low ridges produced by the unequal washings of the tropical rains. The floor of the lower part of the basin has been silted up so as to be level, and it is bounded by steep wave-washed banks indicating its former lacustrine character. The floor of the basin is underlaid by Cretaceous sands, decaying serpentine rock, or Tertiary limestone, which have been very extensively removed so as to expose the other and older named beds. The original valley was excavated out of the upturned beds of Miocene and Eocene limestones. During the following submergence, at the close of the Pliocene period, the valley does not appear to have been completely filled with the later calcareous rocks (Matanzas limestone of the author [1]), which contain, mostly, living organisms. During the long epoch of the earlier Pleistocene elevation and erosion, the Yumuri Valley was again excavated, and in some parts enlarged, so that only fragments of the Matanzas limestones are found on the sides of the valley. The south-eastern end of the basin is about three miles wide, and is divided by a hill into two lobes. The basin is cut off from the bay (or rather fjord) of Matanzas (with an increasing depth of from 1000 to 1500 feet) by a barrier ridge, whose base is about a mile wide, and whose height is from 250 to over 450 feet above tide (see Fig. 3). The Miocene and Eocene strata dip at from 20° to 30° S. 20° E., whilst the overlying Matanzas marls dip at 10° or 12° N. 20° E.; and these last are succeeded by modern coral-reefs on the seaward side of the ridge. The outlet of the broad valley is a *cañon* with vertical walls (below and sloping above) rising 250 feet above the water, and with a breadth of only 300 feet, like many other

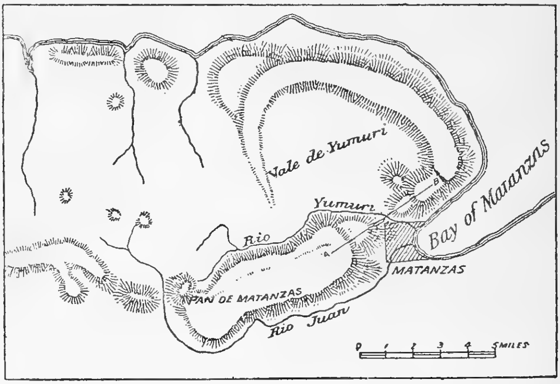

Fig 1.

Fig. 1. Map of the Yumuri Valley, A B, position of section shown in Fig. 3.

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[1] Described in a paper read before the Brooklyn Meeting of Am. Assoc. Ad. Sc. as an advanced notice of an unfinished paper.

recent *cañons* along the streams in Cuba. After seriously considering the untenable hypothesis of the origin of the basin as due to solution, I found that the explanation of the basin with modern insignificant outlet was due to recent dislocation, as was shown in the fault exposed in the longitudinal section of the *cañon*. The Matanzas limestones have a thickness of about 150 feet; the Miocene 790 feet; and the Eocene above the fault 760 feet, but after making allowance for the dislocation along the fault, the total thickness of the Eocene may reach to 1200 or 1500 feet in the section along the side of the valley beyond the limit of Figure 2. The vertical elevation produced by the fault varies from 250 to nearly 400 feet, as shown in Figure 3. The valley had formerly extended in two lobes round an island to the Matanzas Bay, but with the elevation of the ridge to the named height the basin was produced. The plain of uplift has been preserved and exposed in the fault, shown at the inner end of the *cañon*, or on the side of the barrier-ridge facing the basin. The plain of the fault dips 60° with the adjacent strata crushed, the only structure of the kind seen in the whole section.

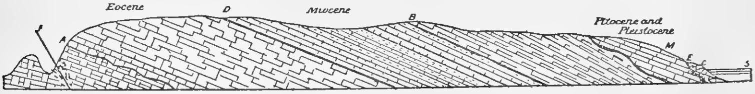

Fig 2

FIG. 2. Longitudinal section through the *cañon* of the Yumuri, at right angles to the strike; S, sea-level; C, raised coral-reefs; M, Matanzas limestones; B, slight unconformity between Miocene limestones and Miocene sands; D, base of Miocene; A, undulations in Eocene limestones; F, fault whose dip is 60°, general dip of strata varies from 20° to 30°.

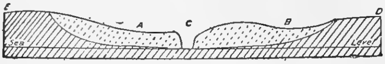

Fig 3.

FIG. 3. Section across the end of Yumuri Valley (same as section A B, Fig. 1). Broken shading represents the barrier raised in front of the valley; A and B, the former extensions of the two lobes of the valley; and C, the site of the *cañon*. The broken shaded section is about three miles long, and the maximum height about 450 feet.

The discovery of the fault settled the origin of the basin, and the occurrence of late Pliocene beds in the uplifted mass brings down the date of the dislocation, after the erosion of the valley, into the later part of the Pleistocene period, or later, as would be suggested by the newness of the walls of the *cañon*.

After the earlier Pliocene elevation, there was a subsidence somewhat below the present altitude of the land, when the Zapata (mid-Pleistocene) formation was deposited.[1] At other places in Cuba these accumulations obstructed the drainage of the earlier Pleistocene valleys, and caused streams to cut across the last made

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[1] This formation was described at the same time as the Matanzas.

limestones, as the land rose from the Zapata subsidence, although it has subsequently been slightly depressed again. These *cañons* are all alike, and date only from the elevation following the mid-Pleistocene deposits constituting the Zapata and gravels, and perhaps marls, of about the same date as the Columbia formation of the American coastal plain.[1]

There are other basins in Cuba where subterranean passages carry off the drainage, and those amongst the mountains are more striking than the numerous lime-sinks of Florida. But the Yumuri basin would have defied explanation had its outlet followed some other course than across the faulted ridge (which had barred the ancient drainage), and not exposed the dislocation. Some of the harbours along the extended coast may be found to be of the same origin as the Yumuri basin, and some of the valleys, such as that of Trinidad on the southern side of the island, have been more or less affected by late faulting.

VII.—A REPLY TO SIR H. HOWORTH'S PAPER ON "RECENT CHANGES OF LEVEL."

By MARK STIRRUP, F.G.S.

IN a paper published in the GEOLOGICAL MAGAZINE, September, 1894, Sir Henry Howorth expatiates on recent changes of the relative level of land and sea in support of his views on the Mammoth age and his diluvial catastrophe, in which there seems to me some very extraordinary confusion in the matter of geological chronology and sequence of events. The first paragraph reads as follows:—"In some recent papers published in the GEOLOGICAL MAGAZINE, I have endeavoured to show that at the *close* of the Mammoth age there was a very considerable dislocation of the Earth's crust, and that a consequence of it was the upheaval of some of the highest masses of land on the earth, including the massive mountains of Asia and the American Cordillera. I now propose to show that (as is *a priori* probable) there was a concurrent collapse or sinking of the ground over large areas, which, as in the corresponding upheaval, was *very rapid*, if not *sudden*" (the italics are mine). The suggested relationship of these various events and their alleged catastrophic character, induces me to again enter this ever-expanding field of controversy.

In support of his thesis Sir Henry first refers to the subsidences which resulted in the separation of England from the Continent, and consequent extinction of the Mammoth.

Assuming that the course of things was as stated, when it is further suggested that this event was *contemporaneous* with great dislocation of the Earth's crust, resulting in stupendous upheavals of mountain ranges in Asia and America, he attempts more than can well be proved. Sir Henry proceeds, in the development of his argument, to the evidence offered by the remains of submerged forests which exist at various points around our coasts, and attributes their

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[1] The Lafayette Formation, by W. J. McGee, 12th Report U.S. Geol. Survey.

occurrence to a widespread submergence, which extended to continental shores. He assigns the date of this event to a time immediately after the destruction of the Mammoth.

The evidence, I take it, of these submerged forests is far from corresponding with the interpretation thus given; for not only are they of different ages, but, instead of supporting any argument for a sudden or rapid sinking of the land, they seem clearly to indicate a *progressive* subsidence, marked by the distinct beds of peat, clay, sand, or gravel by which they are often accompanied. The changes of the level of the land which these submarine forests indicate no one would attempt to dispute; but to affirm their contemporaneous growth, or attempt to synchronize them with the end of the Mammoth period for the purpose of sustaining some fancied theory, is scarcely permissible or scientific.

That the peat and forest beds took a long time for their accumulation and growth might be proved from many of the instances cited by Sir Henry, having regard to the thickness of the deposits and the character of the plant remains, which, in some instances, indicate climatic changes of considerable duration.

That some of these sunken forests are of an age far more recent than that of the Mammoth, is shown by the prehistoric and Roman remains that have been occasionally extracted from them.

The difficulty attending the examination of submerged forests prevents researches which might prove of great interest with regard to their history, therefore those claim special attention which have been exposed to the light of day, such as those due to the dock excavations at Hull and Grimsby. A concise account of the sections is given in the memoir of the Geology of Holderness, by Mr. Clement Reid. Dr. Foster, writes Mr. Reid, thus describes the beds exposed in the Albert Docks at Hull:—"In the cuttings at the east end the upper stratum is silt, ... and immediately under the silt, the trunks, roots, and branches of Oak trees, together with a peat soil of two feet in thickness, beneath that a strong clay soil, and under this an extensive bed of blue sand, etc."

"At a depth of 40 feet below the level of the adjoining land, trees (chiefly Oak) are found in all positions; those which are upright and still *in situ* having been broken off within three feet of the roots. One Oak tree, of noble dimensions, is perfectly straight, its trunk being 45 feet long, and in the thickest part measuring 12½ feet in circumference; it is tolerably sound, but blackened in colour."

"The trees . . . . would require at least 300 years to attain the dimensions given."

A section taken during the excavation for the Alexandra Docks, two miles lower down the Humber, exposes the "Submerged Forest" at upwards of 20 feet below the level of mean tide. Messrs. Wood and Rome (Quart. Journ. Geol. Soc. vol. xxiv. p. 146) state that "the borings at Grimsby Docks disclosed the forest-bed at still greater depths than at Hull, varying at from 35 to 52 feet below high water . . . . In some parts there were two forest surfaces, divided by a bed of leafy clay from 5 to 15 feet thick."

Examples, such as those that I have cited, might readily be drawn from other localities, showing periods of repose and gradual growth rather than a sudden or rapid sinking of the land; and proving the utter fallacy of the doctrine which these sunken forests are presumed to support,—of a sudden or rapid sinking of the ground at that vague and mysterious date, the close of the Mammoth period.

After a quest over Europe and Asia in search of evidence for great uplifts of land and their complementary depressions, Sir Henry turns his attention to America, and in the ancient channels, now submerged beneath the sea, of rivers like the Mississippi, the Hudson, and the St. Lawrence, he finds so-called examples of the great catastrophe for which he is pleading.

He quotes extracts from papers by Professor J. W. Spencer and other well-known American geologists with regard to stupendous continental elevations and great subsidences. These enormous changes of level are facts well recognised by geologists; but the point is—Do any of the writers whose views are cited claim these earth movements to have taken place at the special geological period required by Sir Henry's postulate, or do they even assert those changes of level to have been either sudden or catastrophic.

The authors quoted would, I believe, be the first to repudiate the extraordinary inferences which Sir Henry seeks to draw from the facts. For instance, I will take the paragraph in which Sir Henry Howorth cites Prof. Spencer's remarks on the submerged valleys of the Mississippi and the St. Lawrence. Prof. Spencer says, in reference to the Mississippi:—"This valley is now submerged to a depth of over 3000 feet, and is the representative of the channel of the ancient Mississippi river, towards which it heads."

This quotation, and others of like character, are brought forward by Sir Henry as supporting his argument of a sudden and cataclysmic subsidence. Bearing this in mind, remark what Professor Spencer says in relation to this same submergence, quoted from the same paper as that from which Sir Henry has drawn his facts. "The length of time required to excavate the channels of these great rivers commenced as far back as the *Palæozoic* days. However, the culmination of that of the Mississippi was not until in the later Tertiary, before the Pleistocene period. As the St. Lawrence, now submerged to a depth of over 1200 feet for a distance of 800 miles, is mostly cut out of rocks of the Palæozoic group, except a belt of the Triassic, its antiquity must be very great. The culmination was also probably in the later Tertiary era, like that of the Mississippi, and the channels on the Californian coast, for there are submerged Tertiary rocks off the coasts of Massachusetts and Newfoundland at elevations much higher than the beds of the old channels." Prof. Spencer, moreover, does not argue that these submerged valleys or depressions in the Earth's surface are wholly due to terrestrial crust movements, but that they one and all have been made by the long-continued excavating power of rivers and streams.

Such is the testimony of Prof. Spencer on these submerged valleys or fjords, which is distinctly opposed to Sir Henry's interpretation of the history of these phenomena as sudden and cataclysmic. Sir Henry goes on to produce evidence of his postulated concurrent elevations of mountain chains, which, as he says, were very rapidly, if not suddenly, elevated at the same period, viz. the close of the Mammoth age.

Again, he observes:—"Just as I ventured to argue that the upheaval of the Ural Mountains, of the Altai, and of the American Cordillera was rapid, if not sudden, and marked by every sign of cataclysmic change, so also do I hold the corresponding subsidences to have been rapid, if not sudden." No ambiguity of expression here; Sir Henry seems to outdo his "old masters" in his appeal to catastrophism to explain his difficulties. He, however, naively says, "Evidence on such a point is not always easy to find"; just so, because the facts are all the other way. Mountain ranges were not formed in a day, but are the result of long-continued upward movements, of periods of repose, and also of depression.

It may be asked, what would be the effect of such sudden and violent terrestrial disturbances on the organic life of the globe? Undoubtedly great climatic changes would be induced, unfavourable and destructive to any unfortunate animal or plant that might be then existing; as no time would be given to the organism to adapt itself to its altered environment. Where are the signs and evidences of such destruction of life?

But to return to our mountain-uplifts—the very structure of mountain ranges, their various strata of different geological ages, their successive lines of cliff and other evidences of long erosion, all requiring time for their production, prove that their movements, as with subsidences, have, as a rule, been very slow and intermittent.

There was undoubtedly a very pronounced upward movement of a large area of North America at the close of the Tertiary period, to which American Geologists, with great show of probability, ascribe that severe climatic change which resulted in what is known as the "Glacial age"; but, if this continental uplift be the *cause* of the Glacial age, it does not square with Sir Henry's postulate as to the geological date of the changes of level which resulted, as Sir Henry assumes, in the destruction of the Mammoth at the *close* of that period.

It will be needless, I think, to pursue this subject farther, or to attempt to lighten "the burden of the parable which Sir Henry has been trying to preach" (I would rather say paradox). His recent pleadings in favour of his pet postulate of the "Mammoth and the Flood" appear to me as unreliable and unconvincing as those of his many previous contributions to the pages of the Geological Magazine on the same subject.

VIII.—Problems connected with a Cooling Earth.

By Arthur Vaughan, B.A., B.Sc.

In the Geological Magazine for June and July of this year, I stated a new theory to account for the inequalities of the earth's surface, and, at the same time, offered a criticism of Mr.

Reade's theory, as epitomised by him in the May Number of the same Journal. In a short reply, contributed by Mr. Reade to the September Number, he shows so clearly that he has totally misunderstood the physical reasoning upon which my theory is based, that some rejoinder is absolutely demanded.

In criticising my theory, he asks: "How then could the underlayers, by shrinking, exert such a huge pressure on the interior as to actually *compress the materials of the earth into a smaller volume*?" and, a few lines further on, he proposes that we should "work out *the decrease of volume* which would result from a given contraction of a shell of steel, 30 miles thick, acting on a sphere of the size and composition of our earth."

Did I rely upon actual decrease of volume due to pressure, my theory would, of course, be absurdly untenable; but my reasoning is based upon the *transference* of material from beneath a surface of great pressure to below a surface upon which the pressure is much less. This I have so frequently reiterated in my paper that I could quote from almost any page; perhaps the following extract, taken from my first paper, will suffice: "The underlying material will be, so to speak, squeezed out, and this will cause a real transfer from under the sinking area to beneath the surrounding regions."

To my criticism of his own theory Mr. Reade has not replied, but he has, however, objected to my attempt to show that the reasoning he employs is hardly sufficient to disprove the old contraction theory. Mr. Reade takes exception to a calculation, based upon his own figures, as to the elevation which could be produced from an outer shell too large, by a certain amount, for the interior sphere. I took a special case, and supposed the outer shell to be drawn out over the interior sphere, somewhat in the shape of a balloon, so as to produce over a certain large area a vast hollow cone-shaped elevation. I cannot understand how the very simple calculation necessary can be called in question, and I can only suppose that Mr. Reade has assumed that any elevation must be solid. If, however, we accept the theory of elevation by the folding due to lateral pressure, it is very difficult to see how all vacuities could be avoided, and yet the known dips of anticlines produced. It is, consequently, necessary in considering any elevation, which is not actually a maximum, to assume that elevation to be hollow.

The last point raised by Mr. Reade is one of much greater interest, and it directly introduces the main object of this paper. Stated in its simplest form, the physical problem is:—What would be the behaviour of a contracting shell closely fitted round a sphere unalterable in volume? (This is, in reality, the same as supposing such a shell to surround a less rapidly contracting interior.) Here we can easily distinguish two cases.

First, the shell may be contracting unequally at points whose distance from the centre is the same. This is the actual problem in the case of the earth, as I have shown in a former paper; and the results I believe to follow may be briefly recapitulated.

Any contracting area must attempt to become smaller, and this object could be attained in two ways; either by splitting, that is, by overcoming the forces of cohesion between separate particles, or by moving bodily inwards, so as to become flatter and therefore smaller. The resistance to this last-named effect will arise from the pressure of the interior sphere, and in the case we are considering, of an unequally contracting shell, the effect will be to subject the interior sphere to pressure at all points, but to much greater pressure under the more rapidly contracting areas than under those whose contraction is less. The result seems clear, that the interior sphere will become deformed; material being transferred from under the areas of great pressure to beneath those of less, with the after effects I have stated in a former paper. The mechanism by which the solid interior sphere would thus become deformed can be illustrated by the consideration of two layers of closely touching spherical balls. If we suppose pressure to be applied over any area of the upper layer, the lower layer of balls beneath that area will be pushed asunder, and those which lie on the borders of the area of pressure will wedge themselves between the layers of balls surrounding the area, and thus produce a vertical elevation around the area of pressure.

Secondly, suppose an ideal case, that the shell contracts equally at all points equally distant from the centre. It follows that the pressure exerted upon the interior sphere will now be the same at all points of its surface, and, consequently, no transfer of material from areas of high to areas of low pressure can take place. The only relief to the forces of contraction can now be found in rupture or deformation.

Either of two effects may ensue. In the first place, the shell may, in contracting, split and each separate portion then contract normally, so that its contraction in any direction is linear. It is to be remarked that any want of homogeneity, or, in other words, any slight differences in contractibility, which may exist among the materials of which the shell is made, will aid in producing this effect. Secondly, the shell may stretch without splitting. This is a case of great interest as being the one usually assumed in problems dealing with the contraction of the earth's crust.

This assumption amounts to supposing any shell to contract by splitting, and then the separate portions to be pressed together again by the pressure of the overlying mass; much as if a very heavy roller had been pushed over their surface.

Now this second process will obviously evolve heat by the mutual rubbing of particle over particle; so that each shell must be regarded as an origin of heat, of which no account is taken in using the ordinary differential equation of conduction. The general effect will be to increase the time from first consolidation.

For, let us suppose the two processes to take place perfectly independently. First, let us suppose the shells to contract by splitting, so that no portion is in any way deformed, but decreases in volume, always remaining similar to itself. If, then, we further assume the conduction of heat to be unaffected by the vacuities so formed, that is to say, if we suppose the heat to be uniformly conducted through the mass, and not to flow mainly along the separation surfaces (as is the case in the flow of electricity through a solid cylinder), we shall have the conditions which are assumed in the equation employed for solution.

Now let us imagine all the separate pieces of each shell rolled together; the further any shell is from the centre the greater will be the volume per unit area to be filled up, and, consequently, the greater the amount of heat evolved by viscous friction. Hence the difference between the temperatures of two consecutive shells, at any time, will be, in reality, less than that, had the first process alone come into play. Thus it would really take longer to establish any given temperature gradient; which amounts to saying that the time from consolidation would be increased. To make allowance for this new factor we should require some data as to the heat evolved by viscous friction in the rolling out of sheets of rock material.

TIME FROM CONSOLIDATION.

Since physicists and geologists differ considerably in the number of years which they would allow for the world's age, it is a matter of great interest to see whether the numerical results arrived at by physicists should not be considerably increased.

I need scarcely remark that, in what follows, I am in no way concerned with the effect which any of the alterations suggested below may have upon the position of the theoretical level of no-strain; for I have already expressed my belief that the main elevations and depressions of the earth's surface have been caused by differential contraction.

In the determination of the time from first solidification, heat is supposed lost solely by conduction from within outwards, and no mechanical deformation or change of physical state is accounted for. Now, as I have shown above, heat must be generated in that settling together, which is considered to be the probable outcome of contraction, and this extra heat will, as I have shown, tend to increase the time from consolidation. So far there is a correction to be applied on account of the insufficiency of the equation employed to express all that actually takes place, for this equation takes account only of heat actually conducted from point to point, and does not recognise any heat originated within the cooling mass.

Again, the final result arrived at is, that the time varies as the square of the temperature of solidification directly, and as the coefficient of thermometric conductivity inversely. The temperature of solidification is assumed as 7000° F., and the coefficient of conductivity as 400. Both these quantities are supposed constant throughout the mass considered, and hence must be taken to have their average values throughout that mass.

But when the Earth was molten, the pressure at any point within a few hundred miles of the surface, was practically that due to the weight of the overlying mass; hence it follows that the molten rock would solidify at a very much higher temperature than at the surface. The average value assumed must represent the temperature at a great depth; in fact, the constant multiplier of the integral, which occurs in the equation connecting temperature, depth, and time, is found by assuming that the temperature of solidification is the average value which it has at a very great depth. It is, then, quite beside the question to employ the temperature of solidification of slag or other molten rock at the surface, for we really require to know at what temperature the rock would solidify under a pressure of, say, a hundred miles of rock. At the surface molten slag solidifies at about 3000° F.; it seems then, that the assumption of 7000° F. for use in the problem under consideration, leans very much on the side of under-estimation.

Again, the conductivity or, in other words, the number which represents the amount of heat which escapes through a given thickness of rock in a given time is assumed as 400°, a number obtained by experiments on rocks at the surface. But the greater the temperature, the greater must be the instability of the mean centre of oscillation for each molecule, and this instability must increase until the fusion point is reached, when the molecules have free motion over each other. Hence, the hotter the rock, the more heat will be absorbed in molecular action, and, consequently, the less will be the heat conducted through in any given time; or, in other words, it seems probable that the conductivity must diminish as we reach a greater depth beneath the surface. It follows, that the average value of the conductivity must be much less than its surface value. But any decrease in this value increases the time in the same ratio. A further cause acting in the direction of increasing the time has already been pointed out, though probably of no great weight and not worthy of consideration, beside the corrections suggested above. This consists in the conduction being diminished when heat has to traverse rocks stratified or laminated transversely to the flow of heat. Since the rocks near the surface have their separation planes, as a general rule, inclined at a low angle, the stratified rocks of the crust must conserve the heat passing through by conduction; though this will be, to a small extent, counteracted by the existence of vertical joints which allow a more rapid loss by a kind of surface creep.

In fine, the geologist and biologist have a right to demand of the physicist first, that all losses of heat, other than those considered in his calculations, should be shown to have a negligible effect on the result; and, secondly, that the numerical data he assumes should be at least greater than the probability, not less. Results obtained by the substitution of values, formed on considerations of phenomena taking place under atmospheric pressure, and, as in the case of the determination of conductivity, at low temperatures, can lead to nothing but misconception. There seems no reason why the estimate of 100 million years should not be increased to 1000 million, which would almost allow as much time as the evolutionist desires.

NOTICES OF MEMOIRS.

ABSTRACTS OF PAPERS READ BEFORE THE BRITISH ASSOCIATION AT OXFORD, AUGUST 9–14, 1894.

I.—ON A KEUPER SANDSTONE CEMENTED BY BARIUM SULPHATE FROM THE PEAKSTONES ROCK, ALTON, STAFFORDSHIRE. By W. W. WATTS, M.A., F.G.S.

PROFESSOR F. CLOWES[1] has described a sandstone from the Himlack Stone, near Nottingham, in which the grains were cemented with crystalline barytes, the amount of this material varying from 28 to 50 per cent. in different specimens. This rock occurred at the base of the Keuper sandstone of that locality. A somewhat similar rock, occurring at about the same horizon, is described by Mr. A. Strahan,[2] from Beeston Castle in Cheshire, and the same author refers to the frequent occurrence of barytes in the Keuper breccias.

Bearing these facts in mind, the writer visited a curious isolated stack of rock, called the "Peakstones Rock," near the village of Alton in Staffordshire, which is figured in Professor Hull's Memoir on "The Triassic and Permian Rocks of the Midland Counties of England." This stack is made of the Lower beds of Keuper sandstone, but its outer portion has lost whatever cement it may once have contained. It is, however, situated at the end of a spur which projects into a valley, and exposes a good deal of bare rock. This rock contains what at first look like several veins of barytes two or three inches thick, striking along the spur and straight through the place occupied by the Peakstones Rock. On examination of specimens the veins are seen to be planes in the sandstone cemented by barytes. The specific gravity of the rock is 3·09, and, as the grains are chiefly subangular fragments of quartz and felspar, it must contain about 28 per cent. of barytes. This almost insoluble cement has undoubtedly given rise to the spur above alluded to, and almost as certainly has caused the survival of the Peakstones Rock. This is, however, so much exposed to the weather on all sides, and both to mechanical and chemical disintegration, that if any cement is still left it must be in the inner part of the mass, which cannot be reached by ordinary means. Another specimen from west of Kent Green, near Congleton, containing barytes, and with a structure very like that described by Mr. Strahan, was also referred to.

II.—SPORADIC GLACIATION IN THE HARLECH MOUNTAINS. By the Rev. J. F. BLAKE, M.A., F.G.S.

THE author drew a distinction between two results of glaciation—the one, negative, in which the rocks are rounded and striated, and all or nearly all the débris removed; the other, positive, in which the rocks are covered by a thick deposit of drift with

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[1] Rep. Brit. Assoc. 1885, p. 1038; 1889, p. 594; 1893, p. 732; and Proc. Roy. Soc. vol. xlvi. pp. 363–369.

[2] Mem. Geol. Survey. Exp. Quarter Sheet, 80, S.W. p. 7.

boulders. In the Harlech Mountains district areas showing these opposite results lie side by side. Most of the glaciation is of the negative kind, but the areas drained by the Crawewellt and the Ysgethin are covered by glacial cones of dejection. This difference is accounted for in the first instance by the local drainage being opposite to the general drainage, and in the second by the small size of the gathering ground for the ice. From these results it was argued: 1. That drift deposits are, as a rule, left beyond the area of ice-flow. 2. That no submergence could possibly have taken place here since the Glacial period, or the features above noted would have been obliterated.

III.—ON THE MECHANICS OF AN ICE-SHEET.—By the Rev. J. F. BLAKE, M.A., F.G.S.

THE author attempted to explain how an ice-sheet can carry boulders up a slope, and leave them at a height of 1,000 feet or more above sea-level. The sides of the channel are, in the first instance, supposed to be parallel, so that the mass of ice may be represented in a diagram by its longitudinal section. Taking, for simplicity, the shape of the surface moved over to be represented by two straight lines, one corresponding to the slope down from the mountains, the other the slope up from the sea-bottom to the final destination of the boulders, and, taking the surface of the ice as flat, the ice-sheet is represented by a triangle. This is supposed to settle down in such a way that, though the level of the end is higher, the centre of gravity of the whole is lower. This fall of the centre of gravity is the effective cause of the motion of the ice-sheet, the resistance to be overcome being that of the ice to change its shape. If the ice-sheet be supposed divided into strips parallel to the slope from the mountains, these will be like a series of overlapping glaciers, and under the influence of the pressure will swell out at the bottom, and thus push the further end of the whole mass a little way up the counter-slope. Continual additions of snow at the end where the ice-sheet commences, or elsewhere on its surface, will be cumulative in their effects, and thus the further end of the ice-sheet will ultimately ascend as required. Again divide the triangle into strips by lines parallel to the counter-slope. The lower of these strips will be pressed together, and any point on the base will be carried on in the direction of the whole motion at a greater rate than the higher layers, and thus the stones, etc., on the sea-bottom will be pushed up to their final resting-place, and anomalies of distribution might thus be accounted for by the previous dispersal of the boulders. It was then shown that differences in shape of the ice-sheet and its spreading out at the further end will make little difference in the argument, and under certain conditions will aid the motion.

The author then discussed the question of the glacial erosion of lakelets, and indicated the conditions under which this is possible, particularly referring to the difference between an ice-sheet such as that dealt with in the paper and an ordinary glacier.

IV.—ON THE DEPOSIT OF IRON ORE IN THE BORING AT SHAKESPEARE CLIFF, DOVER. By Professor BOYD-DAWKINS, F.R.S.

THE general results of the boring at Dover were laid before the British Association at Cardiff in 1892, so far as relates to the discovery of the South-eastern Coal-field. In the present communication the author treats of a bed of ironstone, which is likely to be of great importance in the new industries which will spring up sooner or later in Kent in consequence of the discovery of Coal in workable quantities.

The strata penetrated in the boring are as follows:—

		Feet.
UPPER CRETACEOUS	Lower Gray Chalk and Chalk marl	130
	Glauconitic marl	8
	Gault	121
NEOCOMIAN	Folkestone Beds	64
	Sandgate Beds	77
	Hythe Beds	87
	Atherfield Clays	18
OOLITIC	Portlandian	32
	Kimmeridgian	73
	Corallian	159
	Oxfordian Callovian	188
	Bathonian	156
Coal-measures with twelve seams of Coal 23 feet 5 inches thick		1068½

The ironstone occurs in the Kimmeridgian part of the section, and as shown in the following details:—

PORTLANDIAN BEDS:—	Feet.
Gray marl with oolitic grains of ferric oxide	2
Hard gray limestone	1
Brown calcareous sandstone	2
Gray shelly limestone with oolitic grains of ferric oxide	1
Dark-gray marl	2
Hard blue limestone with *Littorina*	1
Brown oolitic ironstone	12
Gray limestone	4
Dark bituminous clay	8
Flaggy sandstone	2
Gray sandy clay	4
Arenaceous limestone with *Cidaris*	7
Dark bituminous shale	27
Gray nodular limestone	2
Coralline Oolite with the usual fossils, *Pecten vagans*, etc.	27

The ironstone presents very singular physical characters. It is composed of small dark-brown shining grains of hydrated oxide of iron like millet seed, embedded in a crystalline base partly of calcium carbonate, and partly of iron carbonate. These grains are oolitic in structure, and are probably the result of the same chemical change by which the calcareous beds of the Inferior Oolite in Lincolnshire have been converted into iron ores. They occur, it will be noted, in several strata above the main bed, 12 feet in thickness in the above section.

This bed of iron ore is identical with that described by Blake and Hudleston at Abbotsbury in Dorset, where it occurs between the Kimmeridge clay above and the Corallian rocks below.

It is also physically identical with the valuable iron ore worked for many years at Westbury in Wiltshire, where it is met with at a lower horizon, being there separated from the Corallian limestones by 4 feet of marls and sands.

This stratum, although probably of purely local origin, is to be looked for in the beds above the Corallian throughout the whole of Southern England, from Dorset eastwards. Its discovery at Dover is only second in importance to that of the South-eastern Coal-field. It will have to be taken into account in the future development of the Coal-fields in Southern England.

V.—THE VOLCANIC PHENOMENA OF VESUVIUS AND ITS NEIGHBOURHOOD. REPORT OF THE COMMITTEE, CONSISTING OF Mr. H. BAUERMAN, Mr. F. W. RUDLER, Mr. J. J. H. TEALL, and Prof. H. J. JOHNSTON-LAVIS. (Drawn up by Prof. H. J. JOHNSTON-LAVIS.)

SINCE the last report lava has continued to pour forth from the top of the new lava-cone in the Atrio del Cavallo, sometimes in small quantities, at others in considerable abundance. On no occasion, however, did the lava issue beyond the limits that it had reached in the years 1891–92. In fact, the whole of that eastern part of the Atrio known as the Val d'Inferno has not been invaded at all by the new lava during or since its issue in the spring of 1891. The consequence of this has been that it has continued to pile itself up around the line of fissure by which it issued, and still further add to the dimensions of the great lava-cone that it had built up in the Atrio. So great has this cone become that it constitutes a prominent feature in the outline of the volcano as seen from Naples. The eminence of Somma is separated from Vesuvius by the depression of the Atrio. This notch, so to speak, in the general outline was terminated below by an almost horizontal line, which is now replaced by an obtuse cone, so that many people speak of three summits to the Vesuvian volcano. This is rather an exaggeration, for although the new lava-cone is of very considerable dimensions, for the time occupied in its growth, yet it cannot compare with that of the cone of Vesuvius on one side or the ridge of Somma on the other.

The whole of this new cone is entirely built up of lava, by far the greater part being of the *pahoehoe* or corded type; only now and then, during marked activity, has there been produced any lava with a rugged scoriaceous surface. The occasion was therefore a very valuable one to determine the slope of such a lava-cone. This was done only normally to the line of fissure by which the lava issued, and which makes the cone terminate in an elongated ridge rather than in a point. Practically all these clinometric observations, which were taken with great care, gave angles varying from 13° to 15°.

Comparing this angle with that of such mountains as Etna or Mauna Loa we must consider that both are composite cones, and have experienced many disturbing influences, such as the formation of parasitic eruptive outlets, from which lava streams have issued far away from the summit, and have thus diminished the general slope of the volcano. Those mountains are usually considered to have an average slope of 10°. The Hawaiian lavas are, as is well known, exceptionally fluid, and we could hardly expect cones of greater slope than 10°. At Etna the lavas have always been more viscous from their lower temperature and the compound or false viscosity given to them by the large number of porphyritic crystals already existing in the magma at the time of emission, just as earth mixed with water may produce a viscous mud. These new lavas of Vesuvius, as is the case with all those that issue high up on the volcano and in small quantities, were very viscous owing to their low temperature and advanced crystallisation, so that soon after the material poured out it was prevented from flowing by slight further cooling. We may take, therefore, this average slope of 14° as the best and most correct estimate for a lava of this nature.

This recent outflow exhibits most of the varieties of surface to be met with in the type of lava above mentioned, such as corded shapes of different kinds, irregular globular surfaces, sheets, and plates either in position or reared on end, and tunnels of every variety, frequently with continuations as walled canals. A magnificent lava hump was formed right under the escarpment of Somma. The origin of these humps is still obscure. They are common on most large flows of corded lava of Vesuvius, but, unfortunately, I have never been present at their formation, nor do I know of anyone who has.

The points of issue of the lava occurred at various spots along a line corresponding with the strike of the radial dyke to which it owes its origin, so that the new lava has as a summit an irregular ridge running nearly north and south. Of course the actual highest point is nearly always that where the last lava issued. Generally more than one spot along this line gave out lava at the same time. The fluid rock flowed sometimes on one side, sometimes on the other, so that the general public at Naples were only from time to time treated to a glimpse of Nature's fireworks, and when the lava flowed in the opposite direction it was often announced that it had altogether stopped.

During the last year several new conical spiracles were formed, but none of them comparable in perfection of form to those described in the last two reports, or exhibiting equally interesting features.

No very interesting minerals were produced as sublimates. In fact, only two species are worthy of mention. On one occasion a small quantity of tenorite was formed in one of the spiracles. Soon after the lava had entirely stopped flowing in February, sublimates of potash-bearing halite were very abundant around the vents, in beautiful fern-like skeletons, in which a number of feathery branches radiated at right angles from a stem representing usually about three edges of a cube, and were themselves so many edges of smaller cubes. Sometimes this halite was gray, from minute hæmatite crystals being deposited with the salt, which likewise was in some cases greenish from copper impurities. Most, however, were of a beautiful snow white. One small cavity in particular, about the size of a man's body, was clothed with the most glistening white lining, and from the roof and walls showers of crystals fell from time to time. These were not visibly red-hot in bright diffused daylight, but looking towards the shaded inner extremity of the cavity, a bright red incandescence was visible. In a short time, with suitable apparatus, I collected over two kilogrammes of this material absolutely free from mechanical impurities.

Along many of the cracks of the lava beautiful glassy crusts of halite, more or less impure, were formed, and often showed a dull red heat in daylight. These crusts on being removed become rapidly opaque and milky in hue, and audibly cracked into starch-like columns, due to the rapid contraction on cooling—producing, in fact, a miniature basaltic structure.

About February 5th, 1894, the lava was issuing in very small quantity, and by the 7th showed no trace of movement. Yet even in May cracks in the lava near its point of exit were incandescent some distance in, and the saline incrustations mentioned above were in full perfection.

Coincident with the arrest of the lateral outflow, the lava rose in the chimney, and the red reflection from the top of Vesuvius that had been absent for so long, with rare exceptions, was again almost daily visible. The level of the lava in the main chimney soon rose to the bottom of the new crater that had been forming, and increasing in size during the time the lateral issue of lava had been going on, and commenced the filling up of that cavity by the formation of a cone of eruption, so that almost coincident with the arrest of the leakage of lava laterally the central activity changed from the crater- and dust-forming stage to the lava cake- and cone-forming stage.

I made a careful examination of the summit of Vesuvius about the middle of May. The crater in an east and west direction was about 150 m. in diameter, and its depth, then decreasing, was about the same. The walls were remarkably steep, in some places even vertical or overhanging. The bottom could be seen with difficulty owing to the crumbling nature of the edges. The walls are nearly all covered by sublimates or dust that has adhered and crusted them over, so that several dykes, both solid and hollow, can no longer be distinguished. This is especially the case with the one formed during the 1891 outburst. The details of the great rift of the 1880–81 and subsequent eruptions on the east side of the great cone were still easily discernible. On the south side, and a little to the east, a wall of rock stands out from the side of the crater and is directed nearly towards the centre. It is capped by a pinnacle of rock, and is really the old dyke of the 1885 eruption.

Just to the east of that wall, and partly owing to its existence, the slope of the inside of the crater is less in that direction. Here the guides had made a little path for a few metres down. On examining carefully the condition of things from its lower termination, which so far aided little the view of what was going on at the crater-bottom, I found that by extending it down a slope, and then cutting a ledge farther round to the east at a suitable point, a bracket-like platform some metres square could be reached, which is about half way down the crater. Later the path was further widened by me and made more commodious, and now gives easy access to the platform, from which one can look right into the vent of the volcano and watch with ease the boiling up of the lava and the ejection of the great blobs and cakes that are rapidly filling up the crater. Unfortunately, owing to the well-like shape of the crater, the shadows due to the vapour column spreading out overhead, and the dark colour of the rocks, instantaneous photography could not be utilised to record this interesting and everchanging scene.

As is usual at some period after an eruption, feathery gypsum is a common product in the cavities of the old scoriæ, and is associated at the fumaroles with a little sulphur (an exceedingly rare mineral at Vesuvius), with abundance of molysite and kermesite.

In the Campi Phlegræi little of novelty has come to light. A tunnel and a deep shaft which is being constructed in Naples to complete the drainage works have brought several interesting sections to light, but not of sufficient completeness to be yet worth recording.

VI.—ON CERTAIN VOLCANIC SUBSIDENCES IN THE NORTH OF ICELAND.

By TEMPEST ANDERSON, M.D., B.Sc., F.G.S.

PERHAPS the most striking features in Icelandic scenery are the *giás* (pronounced "geow"), or fissures and chasms, which are so frequently met with in all the districts in which recent volcanic activity manifests itself. They are usually, and in most cases rightly, ascribed to the lower stratum of a molten lava stream, having obtained an outlet after the surface has consolidated into a crust of greater or less thickness.

Giás of this class are, so far as the author has been able to observe, confined within the limits of a single lava stream, and do not affect previously formed rocks. Usually there is a large giá roughly parallel with each side of the original lava stream, and the space between these has subsided considerably. Any giás in this subsided portion are much smaller, and obviously of secondary importance. Examples of this are to be found in the well-known Almanagiá, at Thingvalla, which has a throw of about 100 feet, while the sides of the smaller giás which enclose the Logberg in the subsided portion are practically on the same level.

There are also several such subsidences near Lón and Ásbergi, in the north of Iceland. The main subsidence at Ásbergi is a little more complicated, though evidently due to the same causes. Here a large roughly triangular area has subsided, the throw at the apex being probably nearly 300 feet, but a space in the middle has remained at its original height, so that a depression has been produced like a great V, the portions both between and outside the legs having remained standing. In the case of Thingvalla it appears not unlikely that the lava which flowed down into the lake solidified on coming in contact with the water, and formed a wall sufficiently strong to hold up the lava plain till it formed a firm crust, and that the giving way of this and the escape of the molten lower layers into the deeper parts of the lake caused the subsidence.

Similarly the lava which escaped from Ásbergi may have been that which now occupies the low ground near the estuary of the Jokulsá, in the direction of Lón.

On the east and south-east of Lake Myvatu a very extensive eruption, or series of eruptions, has taken place from a chain of craters locally called Gardr Borgir ("the castles of Gardr," which is the name of a farm). The lava flow has occupied nearly all the bed of Lake Myvatu, and flowed down the valley of the Laxá to its mouth at Laxamyri. All this stream of lava is very remarkable for the number and size of the spiracles with which it is studded, and a regular gradation of sizes exists, between spiracles the size of a haycock and cones some of which cannot be less than 200 feet high. These cones and craters, which constitute such a striking feature of Lake Myvatu, may probably be nothing more than spiracles formed by the escape of steam generated by the conflict of the hot lava with the water of the lake. The barrier which holds up the water of the present lake consists of this lava, and caves exist in it which are obviously channels by which molten lava has escaped. These and deeper-seated ones would be those by which the lava escaped and left the depression occupied by the present lake. Between the craters of eruption and the lake no spiracles were noticed, but there is a very remarkable series of rocks—the Dimmuborgir—masses of lava of fantastic shape, 30 or 40 feet high, which have remained standing while the intervening portions have subsided. They present slickenside marks where the subsiding portions have scratched the masses that have remained standing, and tide-marks where the crust has halted in its descent; also in many places bulgings, where the lava has been scarcely stiff enough to stand, and others where it has actually formed stalactitic masses.

So much for actual lava subsidences.

The special object of this paper is to draw attention to a subsidence on the slopes of Leirnukr, a volcano several miles north of this spot, where a large strip of land, perhaps 200 yards wide, and one mile or more long, has been let down to a varying depth, averaging perhaps 60 to 80 feet.

The faults bounding it, like nearly all the fissures in this district, run north and south; and the east face, which is most perfect, cuts right through a thick stream of old columnar lava and through a large boss of tuff, round and over which the lava has bedded itself, and also through the tuff rocks at each side of the lava stream. It would appear worthy of consideration whether this great depression, which thus affects all the crust of the volcano impartially, may not have been caused by the falling in of one of the steam cavities which may be presumed to exist under volcanoes after the lavas have been expelled by the steam pressure.

This would accord with the observation that sedimentary rocks near volcanoes often dip towards those volcanoes. Mr. Goodchild has informed the author that the sedimentary rocks round Arthur's

Seat are much thicker the nearer they are to that old volcano, as if the ground had slowly sunk while they were being deposited.

Near Lón the author was shown a small giá, said to have been formed during an earthquake in February, 1885. The crack was of a freshness corresponding to such a date, and was only a few inches wide, and so short that it could not be determined whether it extended beyond one bed of lava. It certainly was not an example of the escape of liquid lava from below a crust, nor of a subsidence over a steam cavity, and its chief interest in this connection is as showing that at least three separate sets of causes are at work in producing the giás of Iceland.

VII.—ON A NEW METHOD OF MEASURING CRYSTALS, AND ITS APPLICATION TO THE MEASUREMENT OF THE OCTAHEDRON ANGLE OF POTASH ALUM AND AMMONIA ALUM. By H. A. MIERS, M.A., F.G.S.

THE two fundamental laws of Crystallography—namely (1) the constancy of the angle in crystals of the same substance, and (2) the law of simple rational indices—seem to be violated by those crystals which are liable to irregular variations in their angles, or those which have the simple faces replaced by complicated "vicinal" planes.

Both these anomalies are exhibited by potash and ammonia alum. Brilliant and apparently perfect octahedra of these salts show large variations in the octahedron angle; other crystals show low vicinal planes in place of the octahedron faces.

If it be true, as is supposed, that the octahedron angle varies in different crystals, it would be interesting to ascertain whether progressive variations can be traced during the growth of a single crystal, and whether some or all of the octahedron faces change their direction in space if the crystal be held fixed during growth.

In order to solve this problem a new goniometer has been constructed, in which the crystal is fixed at the lower end of a vertical axis, so that it can be immersed in a liquid during measurement.

This device is in reality an inversion of the ordinary goniometer with horizontal disc; the liquid is contained in a rectangular glass trough with parallel-plate sides; one side is placed rigidly perpendicular to the fixed collimator, and the other is perpendicular to the telescope, which is set at 90° to the collimator. The trough is supported on a table which can be raised and lowered, so that the crystal can be placed at any required depth in the liquid. If the liquid used be its own concentrated solution the crystal can be measured during growth, and the changes of angle, if any, can be observed at different stages.

In order that it may be held rigidly, the crystal is mounted, when small, in a platinum clip, which it envelops as it grows larger.

The results derived from the measurement of a large number of alum crystals are as follow:—

(1) The faces of the regular octahedron are never developed upon alum growing from aqueous solution.

(2) The reflecting planes (which are often very perfect) are those of a very flat triangular pyramid (triakis octahedron), which overlies each octahedron face.

(3) The three faces of this triangular pyramid may be very unequal in size.

(4) The triakis octahedron which replaces one octahedron face may be different from that which replaces another octahedron face upon the same crystal.

(5) During the growth of the crystal the reflecting planes change their mutual inclinations; the triakis octahedron becomes in general more acute, *i.e.* deviates further from the octahedron which it replaces as the crystal grows.

(6) This change takes place not continuously, but *per saltum*, each reflecting plane becoming replaced by another which is inclined at a small angle (generally about three minutes) to it.

(7) During growth the faces are always those of triakis octahedra; if, owing to rise of temperature, re-solution begins to take place, faces of icositetrahedra are developed.

Conclusions:—The above observations prove that the growth of an alum crystal expresses an ever-changing condition of equilibrium between the crystal and the mother liquor. It does not take place by the deposition of parallel-plane layers; new faces are constantly developed: since these succeed one another *per saltum* they doubtless obey the law of rational indices, though not that of *simple* rational indices.

From the mutual inclinations of these vicinal faces it is possible to calculate with absolute accuracy the angle of the faces to which they symmetrically approximate. This angle is found to be that of the regular octahedron, 70° $31\frac{3}{4}'$. The octahedron angle of alum is not, therefore, as appeared from the observations of Pfaff and Brauns, subject to any variation.

The angle at which a given vicinal plane is inclined to the octahedron is independent of the area of the plane, and of the temperature of the solution, and of the barometric pressure: it appears to be conditioned by the concentration of the solution at the surface of the plane.

In confirmation of this view it is found that the upper and lower portions of an octahedron face which stands vertical are often replaced by two different triangular pyramids; also that the three faces of one such pyramid are, at a given moment, not necessarily equally inclined to the octahedron face which it replaces.

When, as is often the case, one of the three vicinal planes is large, and the other two are too small to give a visible reflection, the face appears to be a single reflecting plane. It is this which has been mistaken for the octahedron face in previous observations.

Similar phenomena of growth are exhibited by crystals of other substances belonging to different systems. The conditions of equilibrium between the crystal and the solution are such that vicinal planes appear in place of simple forms; these vary with the concentration of the solution, and give rise to variations in the measured angles, which are only apparently anomalous. Their true position can be determined on a crystal of cubic symmetry (such as alum) whose theoretical angles are known.

A further study of the faces developed during the growth of crystals will, it is hoped, lead to a better understanding of the reasons why a simple face like the octahedron should not be a surface of equilibrium, and of the relation between the vicinal planes and the structure of the crystal.

REVIEWS.

I.—Memoirs of the Geological Survey of the United Kingdom. The Jurassic Rocks of Britain. Vol. IV. The Lower Oolitic Rocks of England (Yorkshire excepted). By Horace B. Woodward, F.G.S. 8vo. pp. xiv. and 628, with 2 Plates and 137 Woodcuts. (London: Kegan Paul, Trench, Trübner & Co., Limited, 1894.) Price 10*s*.

THIS is, practically, a third instalment of the important work now in course of publication by the Geological Survey, of which the previous volumes have already been noticed in the Geological Magazine. Vol. iv. contains an account of the Lower Oolites (Inferior Oolite and Great Oolite) throughout their long outcrop from the English Channel to the Humber.

In his preface Sir A. Geikie observes that much assistance has been derived by Mr. Woodward in the preparation of the present volume from the previous Memoirs of the Survey, especially those dealing with the Oolitic rocks by Professors Hull, Green, and Judd, and more recently by Messrs. Ussher and Jukes-Browne. The Director-General also does justice to the work of other observers in this field, commencing with William Smith, whose original labours are commemorated in the names given by him to many of the subdivisions of the Oolites.

The author, in fact, has largely availed himself of the assistance to be derived from previous publications, both official and non-official; and he likewise acknowledges the help which he has from time to time received from the personal communications of those interested in the Jurassic geology of this country, It is of course obvious that with such a work as Judd's Geology of Rutland in hand, the path of the surveyor in the East Midlands must have been made comparatively easy.

After some introductory remarks by Mr. Woodward, dealing with the Oolitic rocks as a whole, we have some petrological notes from Mr. Teall; nor is the subject of *Girvanella*-tubes forgotten in connection with the possible origin of Pisolite. Two plates of sections of Oolitic limestones and ironstones illustrate this portion of the work.

The Inferior Oolite Series (*Bajocian*). Chapters ii. to vii. inclusive, are devoted to this series, which, in its course throughout England, is justly described as exhibiting almost every variety of stratified rock. The base, Mr. Woodward considers, is not always well-defined. From Dorsetshire to the Vale of Moreton there occurs a group of sandy passage-beds which he thinks are most conveniently designated by the term "Midford Sand," comprising the zones of *Am. opalinus* and *Am. Jurensis,* between which the division of Lias and Oolites is taken. The discussions on these points between the author on one side and Messrs. Buckman and Hudleston on the other, are familiar to the readers of the Quart. Journ. Geol. Society. East of the Vale of Moreton the base of the Inferior Oolite is less connected by passage-beds with the Lias, and, as we pass across Central England into Lincolnshire, the Northampton Sand and its equivalents form a base which is clearly separated from the Upper Lias. Such also, we would observe, appears to be the case generally in Yorkshire, except at Blue Wyke, where these same passage-beds, more perfectly developed, perhaps, than elsewhere in England, are seen to connect the Upper Lias with the Dogger. We must not forget, either, that even in the South-West of England, where there is an overlap of the *Parkinsoni*-zone, as is frequently the case, no passage-beds intervene between the Ragstones and the beds on which they rest.

In the south-west also the upper limits of the Inferior Oolite are more easily defined, as the contrast between its uppermost limestones and the Lower Fuller's Earth is strong, and the line readily drawn. But when we reach North Oxfordshire, without any typical Fuller's Earth as a guide, whilst the Inferior Oolite itself is changing and putting on higher beds, often of an extremely sandy character, the upper limit has not always been easy to define. The result has been an indefinite mapping of the area. Thus Mr. Woodward writes (p. 148): "It is clear that the mass of the sandy strata previously grouped as belonging partly to the Great Oolite and partly to the Inferior Oolite belongs to the latter series. . . . . There is no more complicated tract among the Oolitic rocks of England than this region of the Inferior Oolite between Chipping Norton, Charlbury, and Banbury. We enter a region of changing sedimentation, which to some extent corresponds with the change in the general strike of the beds." Further eastwards the upper limits are not always clear in the absence of the Lincolnshire Limestone; although, in section, the Lower Estuarine may generally be distinguished from the Upper Estuarine.

The zonal divisions and varying developments of the Inferior Oolite are points of great consequence, and it may also be added of great interest, to the student of Jurassic geology. Hence their differentiation and correlation constitute by no means the least important part of this work. For convenience of description Mr. Woodward follows a grouping already indicated by Mr. Hudleston, and refers to the fossils of the Inferior Oolite under the following principal zones:—

Upper Division	*Am. Parkinsoni.*	Lower Division	*Am. Murchisonæ.*
	Am. Humphriesianus.		*Am. opalinus.*

These zones, as is well known, are best developed in the Dorset area, where an essentially Cephalopod facies prevails; and in that district it is possible to subdivide them, as Mr. Buckman has lately done, into sub-zones or hemeræ. In the far more bulky deposits of the Cotteswolds such precision is scarcely possible; whilst in the Inferior Oolite of Lincolnshire, where as a rule a thoroughly non-Cephalopod facies prevails, any subdivisions which may be attempted in the limestones must be based on the general character of the fauna rather than on Ammonites which are seldom in evidence.

The varying development of the Inferior Oolite, in its local details, is well worked out in Chapters iii. to vii., as this protean formation is followed from the thin but highly fossiliferous ironshot oolites of Dorset and part of Somerset, through the thick false-bedded oolites and ragstones of the Cotteswolds, into the sandy limestones of North Oxfordshire. In this region the Inferior Oolite begins to suffer an eclipse even on the outcrop, whilst on the dip generally we know that it thins out to nothing beneath the overlying Bathonian, the highest beds in most cases being widely transgressive over all the others. The typical developments in the counties of Northampton and Lincoln, which belong to the northern or Yorkshire province of the Inferior Oolite, are partly foreshadowed in North Oxfordshire, as, for instance, at Otley Hill, where, beneath 3 feet of Ragstones representing the Upper Division, occur 4 feet of hard, sandy and ferruginous limestones which are regarded as in part the equivalents of the Northampton Beds.

The Northampton Sand itself, "where fully developed, represents the upper part of the zone of *Am. Jurensis,* the zone of *Am. opalinus,* and portions of the zone of *Am. Murchisonæ.*" The exact horizon of the overlying Lower Estuarine Beds is not quite clear. Judging from the fauna there is good reason to suppose that the lower and larger portion of the Lincolnshire Limestone is on or about the horizon of the Oolite Marl. It is probable, however, that higher beds succeed, and we cannot agree with the author in his suggestion that the Great Ponton Beds may be merely a repetition of these in the Little Ponton cutting. A study of the fauna is clearly in favour of the view that the Great Ponton Beds are high in the series, many of the fossils being Bathonian in character, whilst in the more northern cutting some of the most characteristic fossils of the Oolite Marl may be noted. As we proceed towards the Humber the representative of the Northampton Sand has had the Yorkshire term "Dogger" applied to it, whilst the Lincolnshire Limestone has been divided into an upper series (the Hibaldstow beds) and a lower series (the Kirton Beds), though, so far as is known at present, there is no marked palæontological distinction.

THE GREAT OOLITE SERIES (*Bathonian*) presents a marked contrast to the preceding one in the comparative constancy of its Ammonite species, which, moreover, are by no means numerous. The following grouping is adopted.

	Cornbrash. Zone of *Am. macrocephalus.*	
Zone of *Am. arbustigerus*	Forest Marble and Bradford Clay	Great Oolite Clay
	Great Oolite and	Great Oolite Limestone
	Stonesfield Slate	Upper Estuarine Series
	Fuller's Earth	

Under this arrangement the Fuller's Earth, or "Fullonian," is regarded as a member of the Great Oolite Series, and, indeed, Mr. Woodward considers that its upper portion is intimately connected with the Stonesfield Slate where that phase of the Great Oolite is developed. He also confirms Mr. Etheridge's numerical estimate as to the preponderance of Bathonian species throughout the Fuller's Earth.

None of the subdivisions of the Great Oolite can be regarded as being constant, and excepting in the Stonesfield Slate its Lower Division contains few, if any, distinctive fossils. Practically there is no zonal grouping, and the fossils for the most part range throughout. Lycett, it will be remembered, drew attention to this circumstance, and was thus disposed to minimize the value of the Great Oolite subdivisions. Indeed, he went so far as to suggest that the Forest Marble and Bradford Clay might be omitted altogether without detriment to science. Doubtless, as marking time in a palæontological sense, there is much truth in this, and we have always thought that far too much importance was attached to these subdivisions in the south-west of England. However, as local developments, they are worthy of note by a Geological Surveyor, and all the more since Mr. Woodward has shown that the Great Oolite of Bath and Bradford does not pass into the Forest Marble of Dorset. As originally held by William Smith, there seems to be evidence in part of the Dorset area of the mass of the Great Oolite having been eroded. This, at any rate, is Mr. Woodward's view, though it is just possible that the Great Oolite Limestone may have originally been a lenticular deposit, such as the Lincolnshire Limestone was described by Judd and Sharp.

On the whole Mr. Woodward concludes that the Forest Marble or Bradfordian has some claims to be regarded as a subdivision of the Great Oolite Series altogether independent of the Great Oolite itself. And yet he (pp. 271, 272) elsewhere speaks of the difficulty of separating the Forest Marble and Great Oolite, there being no band that can be relied upon as a constant horizon in the series. This uncertainty is exhibited in the difference of opinion as to the position of the "Kemble Beds," which were mapped by Prof. Hull as part of the Forest Marble, though Mr. Woodward endorses the view of the late Prof. Buckman that they should be regarded as a portion of the Great Oolite. Thus, the general section of the Great Oolite (by Prof. Buckman) adopted for the Cotteswold district is as follows:—

UPPER DIVISION.	Ft.	in.
Yellowish Oolite [=Kemble Beds]	45	0
Marl, etc., with *Lima cardiiformis* and *Terebratula maxillata*	4	0
Hard Limestone with *Purpuroidea*, *Pachyrisma*, etc.	6	0
White Limestone	30	0
LOWER DIVISION.		
Rough Freestone or Ragstone	25	0
Stonesfield Slate	15	0
	125	0

The Kemble Beds are not seen in the Minchinhampton Quarries, the highest beds there visible he regards as belonging to the "White Limestone."

Although palæontological evidence is not a certain guide for fixing horizons in the Great Oolite, it is probable that in North Oxfordshire the Great Oolite Series, as it is observed to rest on the Chipping Norton Limestone, does not present precisely the same basement beds throughout. About Chipping Norton itself there seems to be a definite line and a thorough physical break at the base of the Great Oolite, and this is further evidenced by the occurrence of the "rift bed," where a clay with Bathonian fossils fills up cracks in the limestone of Inferior Oolite age. In this district also the equivalents of the Stonesfield Slate may be observed to occur, as, for instance, in the famous cutting at Langton Bridge. This section seems to corroborate Mr. Walford's recent discoveries at Stonesfield, which go to prove that the Stonesfield Slate is not the actual base of the Great Oolite in that area, as some sort of limestone, with clay seams, presenting on the whole the aspect of the Great Oolite, is found to occur beneath the slate bed.

Reverting once more to the Forest Marble, with its locally developed Bradford Clay, the author considers that, in spite of the varying nature of its particular character, when taken as a whole, it forms a fairly well-marked division, extending from the coast of Dorset to the neighbourhood of Buckingham. For this division the name "Bradfordian" is adopted.

It is admitted, however, that shelly limestones of similar character occur apparently on different horizons in the Great Oolite Series of Northampton, Rutland, and Lincoln. Here the divisions were originally made out by Prof. Judd and the late Samuel Sharp, and are as follows:—

Great Oolite Clay. Great Oolite Limestone. Upper Estuarine Series.

Amongst the fossils of the Upper Estuarine Mr. Woodward, we observe, includes *Paludina.* Without doubt this genus might very well be expected to occur in Bathonian Estuarine Beds, since *Paludina scotica* abounds in the Loch Staffin Group ("*infra* Oxfordian"). Yet there had been no previous mention of *Paludina* in Sharp's lists, so that it would be interesting to know on what authority this genus is quoted. As the Bathonian Beds are traced towards the Humber, the evidence favours the view that there is but one stratigraphical division, representing the Upper Estuarine Series, the Great Oolite Limestone, and the Great Oolite Clay.

The Cornbrash naturally terminates the series of Lower Oolitic Rocks, although the author observes that there is no palæontological break in the South of England or elsewhere between the Cornbrash and the Oxfordian Series; since in the Kellaways Rock we find, more or less abundantly, some of the characteristic fossils of the Cornbrash. As a proof of the solidarity of the Bathonian Series we would point out that *Am. discus,* figured on page 432 as a Cornbrash fossil, is also quoted from beds as low down as the Stonesfield Slate.

This serves to show that the Cornbrash is rightly regarded as a member of the Lower Oolites, whilst its palæontological connection with the Kellaways Rock is perhaps not quite so strong as the author would have us believe. The strong Cephalopod facies which accompanies the incoming of Oxfordian Beds—regarding the Kellaways Rock as the base of these—makes the palæontological distinction almost as remarkable as that indicated by the lithology. In common with the rest of the Lower Oolites, this most persistent band of calcareous rock becomes of less importance in the north of Lincolnshire and finally disappears before the Humber is reached.

The remaining chapters of the volume treat of Scenery and Agriculture, of Economic Products, and of Springs and Water Supply. Apart from the importance of the Northamptonshire iron-ore, we cannot forget that the Lower Oolites have furnished some of the most celebrated of our building-stones; whilst we must also bear in mind that the Thames is largely indebted for its waters to the peculiar configuration of these rocks in the Cotteswolds. The curious facts connected with the distribution of saline waters in the Jurassic Rocks generally have not escaped Mr. Woodward's observation; more especially noteworthy being the Forest Marble touched in the Swindon borehole, which contained water carrying 2,131 grains of saline matter per gallon.

A full catalogue of fossils from the Lower Oolitic Rocks of England completes the volume. Mr. Woodward is to be congratulated on this exhaustive work, in the preparation of which an immense amount of literature has been consulted, and the whole put together in the light of a personal experience in the field extending over several years. The volume will be invaluable to those who desire to become acquainted with the Lower Oolitic Rocks of this country. But while we consider that the author has done his duty thoroughly, it is difficult to say much in praise of the illustrations. Some of the figures of fossils are characteristic, but the sections are often indistinctly printed, whilst the reference numbers are frequently illegible. We would recommend those who are responsible for bringing out the Survey Memoirs to inspect a recent Number of the Proceedings of the Geologists' Association, where a section at Finedon Hill, in Northamptonshire (from a photograph), disposes of pretty nearly the whole of the Lower Oolites, as developed in that district, within a vertical space of 46 feet. The distinctness of the numbering in this case is a satisfactory feature which the Queen's printers would do well to imitate.

II.—ON THE OCCURRENCE OF CHIPPED (?) FLINTS IN THE UPPER MIOCENE OF BURMA. By Dr. FRITZ NOETLING, F.G.S., Palæontologist, Geological Survey of India. With a Plate. (In The Records of the Geological Survey of India, vol. xxvii. part 3, 1894, pages 101–103.)

IN the Tertiaries near Yenangyoung, where Dr. Noetling has lately been mapping the Oil-field of that district in Burma, he distinguishes three distinct groups of strata, which, in descending order, are—

3. Group C. Hard and soft sand-rocks, alternating with light-brown clays. Silicified wood common, and remains of land and fresh-water animals. Thickness not less than 4620 feet.

2. Group B. Brown and red sandstones and light-brown clays, containing numerous crystals of selenite, and locally countless numbers of *Batissa Crawfordi*, Noetl.; terminating in a bed of ferruginous conglomerate with numerous remains of terrestrial animals, among which *Hippotherium* [*Hipparion*] *antelopinum*, Cautley and Falconer, and *Rhinoceros Perimensis* preponderate. *Chipped flints locally not rare.* Thickness 1105 feet.

1. Group A. Blue clays, alternating with grey sandstones, which contain locally large quantities of petroleum. Fossils are scarce, but chiefly marine, with rolled fragments of bones and some teeth of land animals. Thickness not less than 1000 feet.

The author points out that this series exhibits a gradation from a littoral marine formation to fresh-water deposits; that the vertebrate remains belong to a fauna nearly identical with that of the Sewaliks; "that Group C (probably inclusive of Group B) must be of Upper Miocene, if not Pliocene, age"; and that the ferruginous conglomerate, containing the chipped flints, is therefore either lowest (earliest) Pliocene, or uppermost (latest) Miocene.

The well-known ossiferous Sewalik strata are regarded as Lower Pliocene by Lydekker; but Upper Miocene by Gaudry, Boyd-Dawkins, and others.

There were about a dozen specimens of worked flints found in the ferruginous conglomerate by Dr. Noetling, whose attention was drawn to them by one in particular, 45 millemètres long and 20 wide (illustrated by figs. 1, 1*a*, 1*b*), which was partly imbedded in the rock close to a fine lower molar of *Hippotherium* (fig. 6); four of the other flint specimens are shown in figs. 2, 3, 4, 5, in various aspects. These latter are more or less triangular flakes, about 25 millemètres long; and some specimens which seem to be ordinary ridge-flakes, as much as 40 mm. in length.

It is not clear why Dr. Noetling inserted a note of interrogation after the word "chipped" in the title of his paper. The specimen (fig. 1), which he terms "a rectangular flake," has been very definitely dressed; and the other smaller flakes have evidently been struck off larger flints, and probably manipulated so as to have a point and one or more sharp edges. The bettermost specimen (fig. 1) is ridged on each face, rounded at one end, truncate at the other, and has its edges almost parallel and sharp. One ridge-face retains a narrow strip of its original flat surface; and the other is sharply defined by nearly symmetrical flakings sloping up from the edges and meeting in a line along the middle. One edge of the implement is somewhat concave, either by irregular flaking, or subsequent breakage, on the face (fig. 1*a*) retaining a strip of the former plane surface.

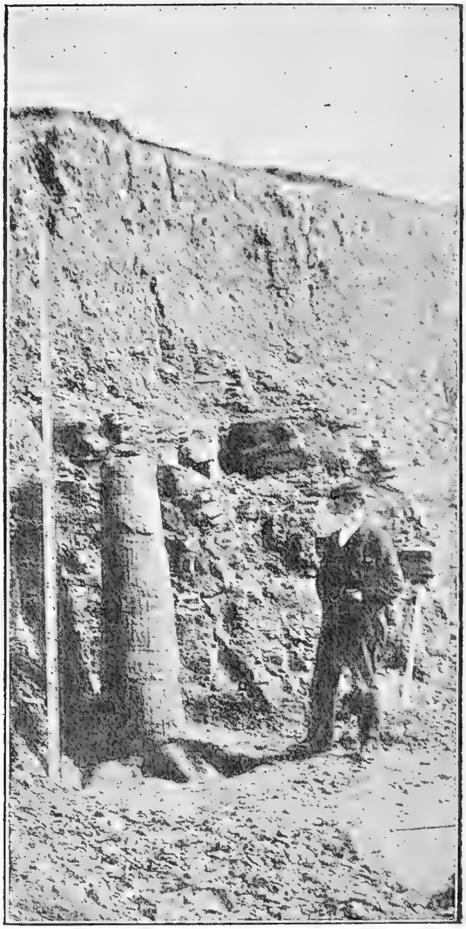
It is apparent, therefore, that worked flints have been found by an experienced Geological Surveyor in India in a stratum of either Upper Miocene or Lower Pliocene age. In the title of his paper Dr. Noetling refers it to the "Upper Miocene."

In 1863 the Abbé L. Bourgeois, with the Abbé Delaunay and M. Bouvet, found some worked flints at the outcrop of some freshwater beds of the lower part of the Calcaire de Beauce, above the bank of the stream of Thenay, near Pontlevoy (Loir-et-Cher), France; and in 1869, to certify their position, MM. Bourgeois and Delaunay had a pit dug on the top of the hill, at about a hundred mètres within the edge of the plateau above the valley, and believed that they discovered several well-characterized flint instruments, at a depth of six mètres, in the same marly beds of the Beauce Limestone that crop out on the hill-side below. See Bulletin Soc. Géol. France, ser. 2, vol. xx. 1863, pp. 535–542; vol. xxvi. 1869, pp. 901–902; vol. xxvii. 1870, pp. 519–520 (M. Raulin). Some geologists and archæologists have not accepted M. Bourgeois' interpretation of the facts, and others have ignored it; but there still remains the possibility of this Miocene occurrence of man-worked flints. This is strengthened by the finding of such relics in the Miocene of Burma; nor need we hesitate to allow that Man, as well as such Miocene animals as the *Hippotherium* (*Hipparion*), could, within a limited period, spread over the Asiatico-European continent, so as to constitute a real contemporaneity, and not merely a homotaxis, of the fossiliferous strata in that far-back stage of Geological History. T. Rupert Jones.

CORRESPONDENCE.

AN ERECT TREE IN THE COAL-MEASURES.

Sir,—My brother-in-law, Mr. J. C. Brierley, of Rochdale, has sent me some photographs of a recent discovery there, which I think you might like to record in the Geological Magazine. My friend Mr. Platt, of Rochdale, may possibly describe it at greater length. It is that of a very perfect internal cast of an erect *Sigillarian* trunk rooted in the ground and rising to the unusual height of more than six feet, with a circumference at the base of about the same, and of four feet at its present summit. As now exposed there are three main roots from the trunk, each of which bifurcates. Near the base of the trunk the bark has been preserved in a carbonized form. The tree stands in a bed of Carboniferous shale in the Lower Coal-measures, which forms an insular mass in the bottom of the valley of the Roach and is topped by Boulder-clay. Apart from other interesting circumstances, the trunk is clearly *in situ*, and it affords good evidence of the very rapid accumulation under certain conditions of some of the primary rocks. It cannot be doubted that the shales which enclose it must have been deposited very rapidly, or else the trunk itself would have weathered away. It is also a proof that whatever deposited the Boulder-clay in the valley of the Roach, it could not have been an instrument of very active erosion, or such masses of soft shale as this, enclosing a perpendicular tree-trunk, would have been swept away. (See illustration on page 528.) Henry H. Howorth.



View of an erect stem of *Sigillaria*, Coal-measures, Valley of the Roach, Rochdale (from a photograph);
In illustration of Sir Henry Howorth's letter (*ante*, p. 527).

OBITUARY.

WILLIAM TOPLEY, F.R.S., F.G..S.

We regret to record the death, on the 30th September, of William Topley, F.R.S., who was so long connected with the Geological Survey. In our next Number we shall publish a short Memoir of him, accompanied by a portrait.

THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE IV. VOL. I.

No. XII.—DECEMBER, 1894.

A RETROSPECT OF MORE THAN THIRTY YEARS.

IT is now more than thirty years ago since, with my friend Professor T. Rupert Jones, F.R.S., we commenced to Edit the GEOLOGICAL MAGAZINE, Messrs. Longmans & Co. being our publishers.

Out of the long list of distinguished Supporters and Contributors to the GEOLOGICAL MAGAZINE published in 1864, I rejoice that twenty-four ORIGINAL NAMES still remain, after more than thirty years, namely:—The Duke of Argyll; the Earl of Ducie; Sir Archibald Geikie; the Right Hon. Thomas Huxley; Sir John Evans; Prof. Prestwich; Prof. T. G. Bonney; Prof. Wiltshire; Prof. Boyd-Dawkins; Prof. Alphonse Milne-Edwards; Prof. Dr. A. Fritsch; Prof. A. von Koenen; Prof. E. Hull; Prof. H. G. Seeley; Mr. R. Etheridge; Mr. William Carruthers; Mr. William Whitaker; Rev. O. Fisher; Mr. James Carter; Mr. James Powrie; Mr. R. H. Valpy; Mr. G. C. Churchill; Mr. R. F. Tomes; and Mr. E. C. H. Day.

To my regret Prof. Rupert Jones retired from the Editorship in June, 1865. After that date, aided by Prof. John Morris (since deceased), and by my colleagues, Mr. R. Etheridge, Mr. Wilfrid Hudleston, and Dr. G. J. Hinde, the MAGAZINE has enjoyed an uninterrupted existence and a well-earned position as a scientific journal.

Messrs. Longmans relinquished the publication in 1865, but it was at once taken up by Messrs. Trübner & Co., who successfully maintained its issue for 25 years, until 1890, when their business was absorbed into that of Messrs. Kegan Paul, Trench, Trübner, and Company (Limited). Now, after a further term of four years, Messrs. Kegan Paul & Co. have kindly allowed me to take the GEOLOGICAL MAGAZINE into my own hands. I embrace the opportunity, therefore, to express to them my sincere thanks for the uniform kindness and courtesy with which they have treated the Editor during the period of their administration, and especially at this epoch in the history of the MAGAZINE.

After the issue of the present Number of the GEOLOGICAL MAGAZINE, Messrs. Dulau and Company, 37, Soho Square, W., have consented to act as my publishers, and I trust to obtain the continued support of my geological friends who have heretofore aided me, both by their contributions and subscriptions, for so many years past.

HENRY WOODWARD.

129, BEAUFORT STREET, CHELSEA, S.W.

ORIGINAL ARTICLES.

I.—CONTRIBUTIONS TO OUR KNOWLEDGE OF THE GENUS *CYCLUS*, FROM THE CARBONIFEROUS FORMATION OF VARIOUS BRITISH LOCALITIES.

By HENRY WOODWARD, LL.D., F.R.S., Pres.Geol.Soc.,
of the British Museum (Natural History).

(PLATE XV.)

THE curious little shield-like Crustaceans, known under the generic name of *Cyclus*, were first noticed by de Koninck in 1841, and have been subsequently figured and described by various authors, but their exact systematic position has never been clearly understood owing to the absence of appendages or other indications by which their affinities might be satisfactorily ascertained.

In 1868 I gave a description, with figures, of two species:[1] one of which, the *Cyclus radialis*, had been previously noticed by de Koninck[2] and Phillips[3]; the other, *C. Rankini*, was then first made known.

In 1870, under the title of "Contributions to British Fossil Crustacea,"[4] I redescribed the above-named species, and added *Cyclus bilobatus*, *C. torosus*, *C. Jonesianus*, *C. Wrightii*, *C. Harknessi*, *C.* (*Halicyne*) *laxus*,[5] *C.* (*Halicyne*) *agnotus*.[5]

The next record of the genus is to be found in the fifth part of my Monograph of British Fossil Crustacea[6] of the order Merostomata, which records and figures the then known seven British species of *Cyclus*, but adds no new forms.

In 1883 Mr. B. N. Peach, F.R.S., L. and E., F.G.S., published an account of *Cyclus testudo*, from the Carboniferous series of Langholm,[7] to which reference will again be made later on.

In 1893 I noticed a new British species of *Cyclus*,[8] discovered by Mr. George Scott in the "Gannister seam" of the Lower Coal-measures, Old Clough Colliery, Bacup, Lancashire, which I named *Cyclus Scotti*.

In the same year Mr. F. R. Cowper Reed, B.A., F.G.S., of Trinity College, Cambridge, gave a description of what he deemed to be probably a new species of *Cyclus*,[9] from the Carboniferous Limestone of Settle, Yorkshire, near to, but not identical with, *C. Harknessi*, which he named *C. Woodwardi*.

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[1] British Association Reports, Norwich, 1868, 4th Report on Fossil Crustacea, pp. 72–75, pl. ii. figs. 1 and 2.

[2] L. G. de Koninck, Descript. des Animaux Foss. Terr. Carb. de Belg. Liége, 1842, p. 591, pl. lii.

[3] J. Phillips, Geol. Yorksh. vol. ii. p. 240, t. xxii. fig. 25, 1829.

[4] GEOL MAG. 1870, Vol. VII. Pl. XXIII. Figs. 1–7, pp. 554–560.

[5], [5], These last-named species are not British, and had been previously described by Prof. Hermann von Meyer, in the Palæontographica, 1847, vol. i. p. 134, under the genus *Halicyne*. They are from the Muschelkalk of Rottweil in Germany. Goldfuss originally figured *Halicyne* as *Olenus serotinus* (Petrefactenkunde), afterwards von Münster referred it to *Limulus* (Beiträge, 1841, Bd. i. t. v. f. 1).

[6] Palæontographical Society, 1878, vol. xxxii. pp. 248–255, pl. xxxii. figs. 42–49.

[7] See Trans. Roy. Soc. Edinburgh, 1883, vol. xxx. pl. xxviii. figs. 9–9*d*, p. 227.

[8] See GEOL. MAG. 1893, Decade III. Vol. X. (Woodcuts A, B), p. 28.

[9] *Ibid.* pp. 64–66 (with a Woodcut).

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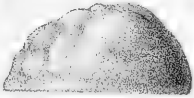

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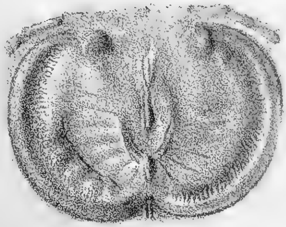

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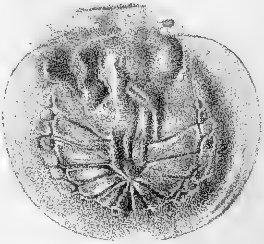

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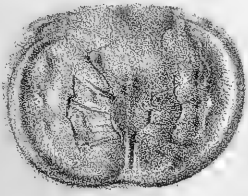

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E.C.&G.M. Woodward del. et lith.

West Newman imp.

Cyclus: Carboniferous.

Having, through the kindness of Prof. John Young, M.D., F.R.S.E. (Regius Professor of Natural History in the University of Glasgow), and Mr. John Young, LL.D., F.G.S., of the Hunterian Museum of the University of Glasgow, been allowed to examine and figure another of the late Dr. Rankin's specimens from Carluke—now preserved in the Museum of the University (Plate XV. Fig. 8)—and being also in possession of a long series of specimens obtained by the late Mr. Henry Johnson, C.E., F.G.S., of Dudley,[1] from the "Pennystone ironstone," over the thick coal of the Staffordshire Coal-field, at Coseley, near Dudley, I am desirous once more to call attention to these very singular little Arthropods.

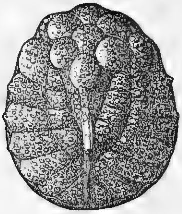

FIG. 1.—*Cyclus Woodwardi*, Reed. The original specimen is in the Woodwardian Museum, Cambridge, and was obtained from the Carboniferous Limestone, Settle, Yorkshire. Magnified $\frac{3}{1}$ nat. size.

By far the most important contribution to the genus *Cyclus* recently published is to be found in the paper by Peach, entitled "Further Researches among the Crustacea and Arachnida of the Scottish Border."[2] These specimens, writes Peach, "occur chiefly as flat discs, or dome-shaped masses of radiating calculi which have coalesced into a polygonal mosaic of calcareous plates. They vary from 3 mm. to 10 mm. in diameter." . . . . "Being embedded in shale they are more or less flattened, and apparently much in the same condition as the *Cyclus Rankini* described by Woodward as having been obtained from the Carboniferous (shales) of Carluke." They are considered by the author to belong to one species, which is, he thinks, different from any yet described. "A few of the specimens exhibit the dorsal shield, which is plain or slightly embossed; while others only show the dorsal aspect of the borders, the rest of the upper surface being broken away, exposing the ventral or sternal arches, which radiate much as in *Cyclus Rankini*." . . . . "From the fact that several of the Survey specimens exhibit limbs, the radiating lines of the sternum are most probably the divisions between the coxæ, so that I am inclined to differ from Woodward and to look upon the opposite end to what he does as being the anterior." Then follows the specific description of *Cyclus testudo*, Peach, from the Calciferous Sandstone series, Langholm.

In October, 1886, I became aware, from a study of Mr. Henry Johnson's collection of *Cyclus*, obtained from the clay-ironstone

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[1] Purchased by the British Museum in 1886.

[2] Trans. Roy. Soc. Edinburgh, 1883, vol. xxx. p. 511, pl. xxviii. figs. 9 and 9*a*, *b*, *c*, *d*.

nodules of the Coal-measures, Coseley, Staffordshire, that the form which I had described in 1868 as *Cyclus Rankini,* from Carluke, and which differed in so very remarkable a manner from all the other carapaces referred to that genus from the Carboniferous Limestone, was really the *underside* of a *Cyclus* from which the shield or carapace had been removed. Unfortunately at that time I had not seen Mr. B. N. Peach's paper, nor was I aware that he had written upon the genus, until my paper on *Cyclus Scotti,* in 1893, was in print, when I added a note apologising for having overlooked it.[1]

To Mr. Peach, therefore, belongs the merit of having been the first to explain (in 1883) the true nature of the peculiar structure observed in *C. Rankini.* But the interpretation put upon the genus by Mr. Peach remains to be considered. And here let me express my thanks to Sir A. Geikie, the Director-General, for granting me permission to study the original specimens of *Cyclus,* described by Mr. Peach, which Mr. J. G. Goodchild, in charge of the Survey Collection in Edinburgh, has most kindly forwarded to me.

An examination of these specimens at once reveals the extreme difficulties which Mr. Peach encountered in endeavouring to decipher these very obscure little organisms, most of which have had the details of their structure almost entirely obliterated by deposits of globular or orbicular calcite.[2]

I was fortunate also in obtaining twenty specimens of *Cyclus testudo* from Eskdale, early in the present year, from Mr. T. Stock; and, although most of these were similarly obscured by calcite-deposits, I have obtained some good results, which I will presently refer to.

The best preserved specimens which Mr. Peach had the good fortune to secure, not only show traces of an upper dorsal shield, but also evidence of the ventral surface with its sterna and radiating apodemata, as figured by me, in 1868, in *C. Rankini* from Carluke, and also in our present Plate XV. Fig. 8. Thus the enigmatical *Cyclus Rankini*—as Peach points out, and as the specimens here figured conclusively prove—is in reality the sternal surface of a *Cyclus,* the dorsal shield of which may, or may not, be known.

So far, we are in general agreement; but when Mr. Peach proceeds to suggest that I have mistaken the *anterior* for the *posterior* end of these carapaces, I am at once at issue with him, and can only conclude that the "globular calcite" has obstructed his clearer vision. Nor is it necessary to institute any very lengthy comparisons with other forms in order to ascertain, as in the famous Skye-terrier controversy, "which is his head and which is his tail." We are, fortunately, not dependent upon the Langholm specimens alone for settling this fundamental point, for in the numerous and beautifully preserved examples from Mr. Henry Johnson's collection we have evidence enough to establish our position beyond a doubt.

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[1] See Geol. Mag. 1893, Dec. III. Vol. X. footnote, p. 29.

[2] See note, p. 482, on globular calcite, on a new species of *Eurypterus* from Eskdale, by H. Woodward, Geol. Mag. 1887, Dec. III. Vol. IV. pp. 481–484, Pl. XIII.

Without maintaining that the pair of large rounded prominences, observable in most of the specimens near the anterior border, are eyes, there is evidence both in Figs. 7 and 8, Pl. XV., of the presence of much smaller, and probably stalked, eyes near the front of the head. The evidence of antennæ-like organs, *in situ*, attached to the part which I designate as *the front* of the shield (represented on Plate XV. Figs. 4, 5, and faintly on Fig. 6), seems to me conclusive that this *front*, or *upper border*, as figured by me, is indubitably the head.

Mr. Peach mentions that where the dorsal shield, in his *Cyclus testudo*, "has been broken away, so as to expose the interior of the sternal portion to view, six triangular plates on each side, divided from each other by deep sulci, are seen to converge upon an oval sternum." These plates, he considers, "are the coxæ of limbs."

In discussing the question of the anterior and posterior ends of *Cyclus*, as raised by Peach, the following points must be taken into consideration:—

1. The large pair of jointed appendages at one end, when taken in conjunction with the entire absence of any prolongation of the body beyond the circular shield at either end, suggests that this is the head, and that these appendages represent a pair of swimming antennæ (ant. 2), similar to those of the Phyllopoda.

2. This is further strengthened by the arrangement of the radiating ventral plates at the opposite end of the body, which Peach suggests are enlarged coxæ. If the homology be the true one, which seems probable, then a comparison either with Arachnida or Crustacea, results in the same conclusion, for, in any of these Arthropods, where the limbs converge towards the mouth, or towards the sternum, we find them tending to meet in the middle ventral line, *behind* these structures, and *not in front*, as would be the case in *Cyclus* if Peach's view as to the anterior end of the body were the right one.

3. The *Eye*.—A (paired) small appendage, having somewhat the form of a stalked eye, but showing no facets, is present near the anterior margin of the shell (see Pl. XV. Figs. 7, 8).

Appendages.—The first visible appendages consist of one large jointed pair, extending outwards from the anterior end of the carapace. They suggest, from their position and development, the second pair of antennæ of the *Nauplius*-stage of the Phyllopoda, or of the adult *Cladocera*. No special mouth-parts are visible.

The remaining appendages, which possibly represent both the jaw-parts and anterior thoracic limbs of the higher Crustacea, appear to be 6–7 in number, each of which was provided with a greatly-developed basal joint radiating outwards from the mid-line, and probably had a wide attachment, which may account for their remaining *in situ*. The enlarged joints of the legs pressed against one another, and covered the ventral surface of the body everywhere, save in the centre, which was occupied by a V-shaped plate, towards the pointed extremity of which all the basal joints of the limbs converge. Distally each limb presents two small plates. The rest of the limb is lost in most specimens.

One specimen, however (discovered amongst those obtained by Mr. Stock from Eskdale), besides exhibiting a number of fragments of appendages, scattered irregularly over the surface of the matrix, shows one of the middle limbs in position, still attached to a shield of *Cyclus testudo*. This limb is a typical biramous appendage, such as we find in the lower Crustacea, and persisting as the swimmerets in the Decapoda; that type of limb, in fact, which is generally believed to have been the most primitive form, and which is only a slight modification of the typical Phyllopod limb. The numerous broken fragments of appendages scattered over the surface of the matrix appear to have been of the same kind. We may, therefore, conclude it is most probable that the oral and post-oral appendages of *Cyclus* were all of the same type, *i.e.* simple swimming-legs.

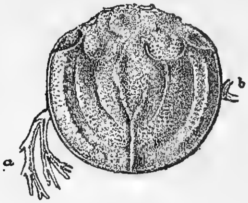

Fig. 2.—*Cyclus testudo*, Peach; Langholm. Enlarged 4 times natural size.
a. One of the biramous swimming-feet which remains attached *in situ*.[1]
b. Base of another appendage, broken off close to the edge of the shield.

The V-shaped median plate between the bases of the appendages must either be the coalesced sternites, or an enormously developed labrum. Against the first view we have the fact that this structure is apparently continued without a break up to the anterior margin of the ventral surface, thus giving no place for the mouth.

If, as the presence of the large antennæ and the swimming-legs prove, *Cyclus* is a Crustacean, then we should naturally expect to find a labrum; and as there is no other median-lobe-like development of the ventral integument, we must, I think, conclude that the structure represents an enormously developed labrum, and that the mouth opened at the posterior extremity of that structure —an exaggeration of what is met with in the Cladocera, where the mouth opens well back in the shell under cover of a great labrum. This would be further strengthened by the convergence of the bases of the limbs towards its posterior border, a condition similar to that met with in *Limulus* (and supposed by Bernard to have been the primitive condition of the jaw-parts of all Crustacea), these bases serving probably, as in *Limulus*, as masticatory organs.

Affinities.—The presence of antennæ and biramous swimming-legs prove undoubtedly that *Cyclus* was a Crustacean. The large size of the former and the homogeneous nature of the rest of the appendages (all biramous swimming-legs, with possibly masticatory

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[1] The branching of the two rami may be due to rod-like deposits of lime in a paddle-shaped fin, two such structures being attached to each limb, representing the endopodite and exopodite. A slight indication of this is visible in the specimen.

bases), taken in connection with the large, slightly-bivalved carapace, suggest that it is an Entomostracan and probably one of the Phyllopoda, with a broad cephalic carapace like that possessed by *Apus* and by *Daphnia*; with large swimming second antennæ like the latter, and possibly with a pair of stalked eyes. *Cyclus*, however, differs from the Cladocera in being flattened dorso-ventrally, and from the lowest Crustacea in not apparently possessing any true jaw-parts—the head, with the labrum and mouth, being bent further back than in the living Entomostraca. These differences may either indicate very lowly characters or very much specialized ones. Two views suggest themselves:—

(1) That these animals were small, free-swimming Phyllopods, with expanded cephalic shield, swimming second antennæ, and biramous limbs, the bases of which served as masticatory organs, no true jaws having yet been developed; the backward position of the mouth may have been brought about in order to allow as many appendages as possible to serve as jaws, as is seen in *Limulus*. Or, possibly, the beast could attach itself like a living *Daphnia* by a cement gland on the dorsal side of the head, in which case it might be an advantage to have the mouth as near the freer end as possible and close to the swimming-legs, which were, by their movements, producing the foot-currents.

(2) The other view is that these animals were ecto-parasitic Phyllopods, although they had not lost their power of free-movement, yet had become specialized in the form of their body, which is flattened ventrally and only slightly convex above, the whole animal being expanded horizontally, unlike most other Phyllopods. This view might account for the two large round structures seen on the ventral surface (Pl. XV. Fig. 8), situated one on either side of the body, and close to the anterior margin of the shell. These might possibly represent a pair of ventral suckers, such as are seen in the modern fish-lice; these structures, whatever they may be, are evidently enormously developed, and possess great muscles, which produce prominent modifications of the dorsal shield, where they are attached (Pl. XV. Figs. 3–5). The great labrum might possibly represent the suctorial tube of *Argulus*, under cover of which are concealed the reduced mandibles, etc.

Some of the specimens show curious oblique scars on the coxæ of the legs, which may indicate the points of attachment of spines or setæ to enable the parasite to stick to its fishy host.

The following notes refer to the specimens figured on Plate XV.

1.—CYCLUS JONESIANUS, H. Woodward. Pl. XV. Figs. 1*a*, 1*b*. × 3 times natural size.

Cyclus Jonesianus, H. Woodw., 1870. GEOL. MAG. Vol VII. pp. 557–558, Woodcut, Figs. 1 and 2.

Cyclus Jonesianus, H. Woodw., 1878. Mon. Pal. Soc. vol. xxxii. Fossil Merostomata, part v. p. 254, pl. xxxii. figs. 46*a*, *b*.

I was at first inclined to the opinion that the specimen of *Cyclus* lent to me by my friend Dr. John Young of Glasgow (see Pl. XV. Figs. 1*a*, 1*b*), was a new species; but after having carefully compared it with that already figured in this MAGAZINE (1870, Woodcut, p. 558), from the collection of Mr. Joseph Wright of Belfast, and obtained by him from the Carboniferous Limestone of Little Island, Cork, and, making allowance for some slight variation between the two specimens, due to their different state of preservation, I am compelled to conclude that they are both referable to the same species, namely, *C. Jonesianus.*

Dr. Young's specimen measures 8 millimètres in length, 7 mm. in breadth, and 4mm. in height. The carapace, which is finely granulated all over its surface, is divided along the anterior border into five rounded lobes of nearly equal size, forming a semicircle, reaching almost to the margin of the shield. The middle area of the carapace, enclosed by these five encircling lobes, is divided down the centre by the dorsal line, thus forming a pair of oblong, somewhat pentagonal lobes, separated only by the median line; behind these, again, is a lesser unpaired subtriangular lobe, with its base directed forwards and having a raised rounded boss in its centre. The hinder and greater half of the carapace is occupied by two large lobes, forming together a semicircle, but divided down the mesial line by the well-marked dorsal ridge which extends to the posterior border. The upper and more central part of each lobe is marked by a slight semicircular furrow dividing faintly this inner and more elevated portion of the shield from the lower and outer encircling border. The two minute depressions observed in Mr. Wright's specimen, one on either side of the dorsal ridge, at the vertex of the shield, are not visible in Dr. Young's specimen, being probably covered by a shelly layer, which had been removed in Mr. Wright's Irish example.

Formation.—Carboniferous Limestone.

Localities.—Little Island, Cork; and Trearne, Beith, Ayrshire.

2.—CYCLUS RADIALIS, Phillips, sp. Pl. XV. Fig. 2. × 4 times natural size.

Agnostus radialis, Phillips, 1836. Geol. Yorks. vol. ii. t. xxii. fig. 25.

Cyclus radialis, H. Woodw. and J. W. Salter, 1865. Cat. and Chart Foss. Crustacea, p. 15, fig. 14.

Cyclus radialis, H. Woodw., 1868. Brit. Assoc. Rept. p. 75, pl. ii. fig. i.

Cyclus radialis, H. Woodw., 1870. GEOL. MAG. Vol. VII. Pl. XXIII. Figs. 2 and 2*a*, p. 557.

Dr. John Young, F.G.S., of the Hunterian Museum, Glasgow University, very kindly submitted the small specimen to me, which is drawn (Pl. XV. Fig. 2), as probably a new species; but, after comparing it, I am of opinion that it should be referred to Phillips's *Cyclus radialis.* The specimen, which is imperfect around the border, is from the Carboniferous Limestone of Beith, Ayrshire, and is attached to a portion of a frond of *Ptilopora* or *Fenestella.*

The carapace measures 6 millimètres long, by 5 mm. broad. As it is less perfect than the type it is needless to give a fresh description of it here.

Formation.—Carboniferous Limestone.

Localities.—Little Island, Cork; Bolland and Settle, Yorkshire; Trearne, Beith, Ayrshire; Visé, Belgium.

3.—CYCLUS SCOTTI, H. Woodw. Pl. XV. Fig. 3. × twice nat. size.

Cyclus Scotti, H. Woodw., 1893. GEOL. MAG. Dec. III. Vol. X. p. 28 (Woodcuts A, B).

Notwithstanding the difference in the size between Mr. Scott's specimen from the Coal-measures of Bacup and Fig. 3, from Mr.

Henry Johnson's collection from Coseley, near Dudley, I am inclined to refer them both to the same species.

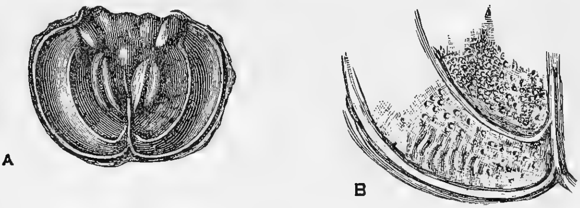

Fig. 3.—*Cyclus Scotti*, H. Woodw., Lower Coal-measures, Bacup, Lancashire.
A. Dorsal aspect of carapace (nat. size).
B. A portion of the left posterior border, magnified to show ornamentation.
[See Geol. Mag. 1893, Dec. III. Vol. X. p. 28, for full description.]
Length of Bacup specimen 20 millimètres long and 25 mm. broad.
,, of Coseley ,, 10 millimètres ,, and 13 mm. ,,

The most striking feature about this specimen is the very strongly accentuated raised circular lines which give quite a character to this form, and also the very steep acclivity to the outer margin of the shield, save at the anterior border, which is marked by indistinctly preserved oval prominences.

As this species was so recently described (1893) in this Magazine, it may be sufficient to point out that in our Plate XV. Fig. 3 the anterior border does not show the two inner oval prominences noticeable in *C. Scotti* (see Woodcut above), and which are very distinctly marked in *Cyclus* (*Halicyne*) *agnotus*, H. von Meyer, sp., from the Muschelkalk of Rottweil, Germany (see Geol. Mag. 1870, Vol. VII. Pl. XXIII. Fig. 8), a form that, in some respects, comes near to our Coseley *Cyclus*. The ornamentation on the surface of the carapace has a similar finely granulated appearance in both specimens, and the encircling ridges in both are very strongly marked.

Formation.—Pennystone Ironstone of the Coal-measures.

Localities.—Coseley, near Dudley, Staffordshire, and Bacup, Lancashire.

4. Cyclus Johnsoni, H. Woodw., sp. nov. Pl. XV. Figs. 4, 5, 6, 7.

I have ventured to place the four examples (Figs. 4–7) and some others not figured, all from the "Pennystone" ironstone of the Coal-measures, Coseley, near Dudley, in one species. Fig. 4 exposes the outer dorsal surface; Figs. 5, 6, 7 (which, like the preceding Fig. 4, are all drawn twice the natural size) show the dorsal shield more or less removed, especially over the central part, revealing the fact of the similarity of all three species *on the underside* to *C. Rankini* (Pl. XV. Fig. 8). The following are the measurements of the four figured examples:—

Fig. 4.	Length, 14 mm.	... ...	Breadth, 16 mm.
Fig. 5.	,, 14 ,,	... ...	,, 18 ,,
Fig. 6.	,, 12 ,,	... ...	,, 16 ,,
Fig. 7.	,, 13 ,,	... ...	,, 15 ,,

Spec. char.—Carapace rounded, width somewhat greater than length, broader and flatter in front, narrower behind, and with a shallow rounded indentation at the centre; having a broad and well-marked flattened rim, followed by a corresponding shallow depression around the lateral and posterior borders; front border tumid, with two (or more?) raised rounded or ovoid prominences; carapace with a median dorsal ridge reaching from the posterior border rather more than half way up the centre of the shield, then bifurcating so as to embrace a triangular space, which widens out to the anterior border; carapace with moderately raised and roundly swelling side-lobes (not strongly ridged as in *C. Scotti*) and with a pair of smaller oblong faintly raised lobes next the median ridge.

Appendages.—These consist of a pair of rather stout antennæ (probably the second pair of antennæ), showing about four joints on each side, the rest having been broken off. These are seen on Figs. 4 and 5, and faintly on Fig. 6.

Eyes.—Fig. 7 shows traces of two small eyes occupying the same relative position as the one seen more distinctly in Fig. 8 (*C. Rankini*), and which appears to be pedunculated.

The under-surface of the animal is partly exposed in Figs. 5, 6, and 7 by the accidental removal of a part of the dorsal surface of the carapace which remained adhering to the other half of the clay-ironstone nodule when it was split open.

In each of these examples, the converging bases of 6–7 pairs of gnathopodites are seen uniting mesially behind the V-shaped oral area (already referred to on p. 533) the median ridge behind which may indicate the posterior prolongation of the straight alimentary canal.

In all these specimens, the bases of the limbs have a very close agreement with *C. Rankini* (Pl. XV. Fig. 8). In Fig. 5 there is a slight indication of the base of an appendage on the central posterior border, which may have been part of a tail-spine; but it has not been observed in the others. Wherever the surface is preserved there is a fine granular ornamentation observable, more especially in the hollow formed within the broad flattened rim that surrounds the greater part of the shield. Fig. 7 is distinctly *more rounded* in outline than the others, and may possibly belong to another species.

I have dedicated this form to the memory of the finder, the late Mr. Henry Johnson, F.G.S., to whose labours as a geologist in the Dudley area we are so largely indebted for our knowledge of the fossil fauna and flora both of the Coal-measures and the Wenlock Limestone.

I must not omit to record my thanks to my son, Mr. Martin Fountain Woodward, of the Biological Laboratory in the Royal College of Science, for much valuable aid in the examination of these minute specimens, and to my daughters for their excellent figures in illustration of this and so many other papers which have appeared in this Magazine.

EXPLANATION OF PLATE XV.

FIG. 1*a*, *b*. *Cyclus Jonesianus*, H. Woodw. (1870). × 3 times nat. size. Fig. 1*b*. Lateral view. Carboniferous L. Trearne, Beith, Ayrshire. Coll. Dr. John Young, F.G.S., Glasgow.

FIG. 2. *Cyclus radialis*, Phillips, sp. (1836). × 4 times nat. size. Dorsal view. Carb. L. Trearne, Beith, Ayrshire. Coll. Dr. John Young, F.G.S., Glasgow.

FIG. 3. *Cyclus Scotti*, H. Woodw. (1893). × twice nat. size. Dorsal view. Clay-ironstone nodule, Coal-measures, Coseley, near Dudley, Staffordshire.

FIGS. 4, 5, 6, 7. *Cyclus Johnsoni*, H. Woodw. (1894). × twice nat. size. In Pennystone-ironstone nodules, Coal-measures, Coseley, near Dudley.

FIG. 4. Dorsal view, showing (2) antenna on right side and surface of shield.

FIG. 5. Dorsal view, showing parts of a pair of antennæ (imperfect), and trace of tail-spine. Dorsal shield partly decorticated, showing converging bases of limbs and labrum?

FIG. 6. Dorsal view of shield, partly decorticated, showing under-surface and traces of bases of antennæ.

FIG. 7. Dorsal view, decorticated, showing bases of limbs and traces of small eyes (pedunculated?).

FIGS. 3–7 are from the late Mr. Henry Johnson's Collection, now in the Geological Department Collection of the British Museum (Nat. Hist.), Cromwell Road, London, S.W.

FIG. 8. *Cyclus Rankini*, H. Woodw. (1868). × three times nat. size. Dorsal aspect of shield showing 6–7 paired bases of limbs converging upon labrum; each limb giving rise to a biramous swimming or other appendage (see Woodcut in text, p. 534). A small eye (pedunculated?) is seen in front on the right side and traces of an antenna?; also impression for muscles of sucker-attachment? Coal-measures, Carluke, Lanarkshire. Hunterian Museum Coll. University of Glasgow.

II.—PHYSIOGRAPHICAL STUDIES IN LAKELAND.

By J. E. MARR, M.A., F.R.S., Sec.G.S.

2. SWINDALE.[1]

TO the west of the London and North-Western Railway, after it has surmounted the incline of Shap Fells, lies the valley of the River Lowther, which eventually flows into the Eamont, which in turn drains into the Eden. The Lowther, flowing in a general northerly direction, receives the drainage of three important streams, coming from the south-west. The first of these flows through the valley of Wet Sleddale, just north of the Fells, which exhibit the exposures of the Shap Granite. It is lettered W.S. in Fig. 1. The second, Swindale (S. Fig. 1), the subject of this paper, joins the Lowther stream at Rossgill Hamlet, about two miles north of Shap Village, whilst the third, Haweswater Beck (H.B. Fig. 1), flows out of Haweswater (H. Fig. 1) and joins the Lowther at Bampton.

Proceeding up Swindale from Rossgill, we follow the road over Rossgill Moor, a barren tract of country occupied by Skiddaw Slates, to Swindale Foot, near which the Borrowdale Volcanic Group appears, and causes the fine cliff scenery which marks the upper part of Swindale. The road proceeds at the foot of these cliffs to Swindale Head, a farm about four miles from Rossgill, and a little below the semicircular line of cliff, which has been a prominent

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[1] For No. 1, "Church Beck, Coniston," see GEOL. MAG. November, p. 489.

object during our walk, and which here appears to close up the valley: of this more anon.

On the side of the stream, opposite Swindale Head Farm, a prominent cliff known as the Knott (K. Fig. 2) rises up from the valley; its top is well ice-worn, but the lower part of the cliff, protected from the ice flowing down the valley, is rough and angular. To the south of the farm we come across a fine moraine, which has once blocked the drainage and formed a lake, now converted into a marsh, called Dod Bottom. This moraine is here seen to have plastered the south side of the Knott (*i.e.* the side facing the direction from which the ice came), so that, but for the appearance of two ice-worn knobs of rock at the top, anyone coming down the valley might suppose that the Knott was entirely composed of moraine-matter. Just south of the Knott is a large boulder, known as the Simon Stone. So much for one of the prettiest exhibitions of glacial action to be found in the district; let us now return to the structure of the valley, apparently hemmed in by cliffs at its head. The great cliffs south of Swindale Head are reft down the middle by a narrow gulley (having the far from euphonious name of Hobgrumble Gill), down which a small stream pours from the hill known as Howes, of which these cliffs form the north face. The main stream, however, enters the valley from its east side, descending the cliffs in a series of waterfalls, which, notwithstanding the volume of water, have done very little work in the way of cutting a valley. This part of the stream is called "The Forces" (F. Fig. 2). Climbing to the top of it we enter a desolate part of the valley, up which we walk for about a mile in a southerly direction, after which it turns sharply to the left and proceeds for nearly two miles

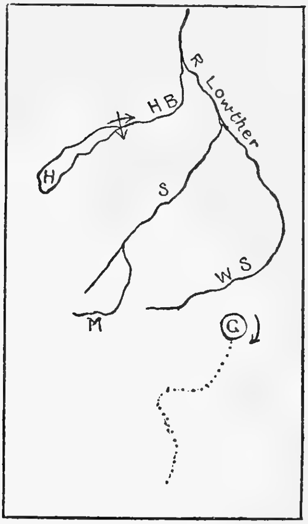

Fig. 1.

towards the south-west to its head, at the pass separating it from Long Sleddale. This upper part of the valley is known as Mosedale. It is a very different valley from that of Swindale proper, being dreary in the extreme, and having its floor largely choked up with peat. The col separating it from Long Sleddale is 1661 feet above sea-level, that which divides it from Wet Sleddale about 1540 feet. An inspection of the map suggests at once that Mosedale may once have formed the upper part of Wet Sleddale (see Fig. 2), of which it is a direct continuation, whilst the course which the stream now takes to reach Swindale proper is decidedly remarkable.

If we walk up the Mosedale Valley, about as far as Mosedale Cottage, and look back at the col separating this valley from Wet Sleddale (F.C. Fig. 2), a remarkable appearance is seen: the col is perfectly flat-topped for a considerable distance, like part of an alluvial plain. My colleague, Mr. Harker, remarked to me, when we were in this valley, "that is the most curious watershed I ever saw." As the appearance might have been deceptive, I visited the valley again this year, and made a close examination of this watershed. Reaching the summit, it is found to be perfectly level for some scores of yards across. It has a covering of four or five feet of peat, which rests on a clayey mass containing numerous stones. On the Mosedale side this superficial accumulation extends to within about thirty feet of Mosedale Beck, though it may actually fill a narrower channel much nearer to the level of the Beck. On the Wet Sleddale side the ground sinks gradually as a peat-covered slope for about half-a-mile, and the nature of the slope indicates that it is composed of drift beneath the peat. The point where rock first appears below this tract in the Wet Sleddale Valley is at a lower level than that part of Mosedale Beck adjoining the col.

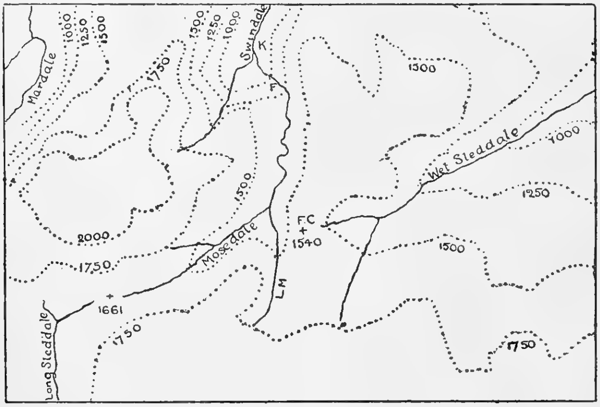

Fig. 2.

It seems impossible to avoid the conclusion that the material underlying this flat-topped watershed was deposited by water, though at first sight the difficulty of getting a sheet of water other than the sea at a point now forming the watershed between two valleys appears great. Furthermore, the distribution of the superficial deposits leads one to infer that if they were entirely removed, we should find the Mosedale Valley practically continuous with that of Wet Sleddale. How, then, is the nature of this col to be accounted for?

Its extreme flatness forbids the idea that it is a dry delta brought down during violent floods by the Little Mosedale stream (L.M. Fig. 2), which seems the easiest explanation. Moreover, the material beneath the peat is not of the character which we should expect on this supposition. The mixture of stones and very fine clay suggests deposit in still water, combined with the agency of ice, but the occurrence of a tract of still water in a position now occupied by a col between two valleys necessitates the existence of two barriers, one between Mosedale and Swindale proper, the other in Wet Sleddale below the peat-covered slope. If the Mosedale Valley were, as it appears to have been, at one time a continuation of Wet Sleddale, an ordinary barrier of rock (possibly somewhat rotten, as is often the case on the ridges of this district) would intervene between it and Swindale, but no such barrier can have existed lower down Wet Sleddale, and the only possible barrier in this direction which would produce the required effects is one of *ice.* A mass of ice crossing the Wet Sleddale Valley in its lower part would pond back the waters of the upper part of the valley (including what is now Mosedale) and convert it into a lake. The water of this lake would escape over the lowest point, which was probably situated in Mosedale a little below the present col between it and Wet Sleddale; this col must have been more than 1540 feet high (the height of the flat-topped col), and must have been less than 1661 feet (the height of that between Mosedale and Long Sleddale). The water thus switched off into Swindale would cut out the portion of the valley now running north and south between the alluvial col and the Forces. As the stream, at the point where the ridge between Mosedale and Swindale is supposed to have existed, is about 1300 feet high, an erosion of less than 200 feet is required, which could be readily performed during the period which has elapsed since the existence of the ice-dam. Granting the formation of this ice-dammed lake, we have all the requisites for the formation of the flat-topped watershed of superficial detritus. The fine clay would be derived from melting icebergs, as would also some of the stones with which it is mixed, whilst others would be brought into the lake by the Little Mosedale stream to form a subaqueous delta, which would eventually extend right across the lake and cut it in two, thus entirely separating what is now Mosedale from Wet Sleddale, and diverting its waters into Swindale. If the large volume of water which now runs over the Forces has been thus diverted in that direction, comparatively recently, this will account for the insignificant groove which those waters have cut out, whereas, if Mosedale had always been part of Swindale, it would be difficult to account for this, and for the great difference in height between the upland Mosedale and the lowland Swindale Valley.

But how could a barrier of ice move across Wet Sleddale in a direction at right angles to the trend of the valley, which points towards the centre of the Lake District? Such a barrier must have originated either to the south (on the Shap Fells) or to the north. It can hardly have been from the south, for the highest point of Shap Fells is only 1852 feet above sea-level; that is, less than 300 feet above the top of the required ice-barrier, and less than two miles to the south of it. There are, however, further reasons for believing that the ice did not come from the south but from the north, and that the ice-barrier which blocked Wet Sleddale was the western part of the Scotch ice, which occupied the Eden Valley, and carried boulders of Criffel granite over Stainmoor, or ice from the north end of the Lake District pushed south by this Scotch ice. As the existence of this ice mass in the Shap area is a matter of some importance, I propose to consider the evidence for it in detail.

In the Fifth Appendix to the late Prof. Carvill Lewis' valuable "Glacial Geology of Great Britain and Ireland," Mr. Kendall refers to the transport of boulders of Shap granite over Stainmoor, and also to the north towards Penrith, and to the south *viâ* Hest Bank and Lancaster, and observes: "This remarkable distribution appears to me to point very clearly to the action of land-ice, and the dispersal in these directions may be accounted for partly by the fact that Shap Fell was the ice-shed (which is indicated by the striæ) as it is now the watershed; and, so far as its Yorkshire distribution is concerned, by the action of the land-ice from Criffel, which was driven up the Solway Frith and the Vale of Eden during the period of maximum glaciation by the congested state of the northern part of the Irish Sea." Agreeing, as I do, with most of Mr. Kendall's conclusions, he will perhaps forgive me if I differ from him on one point, namely, "that Shap Fell was the ice-shed." If this were the case, we should hardly find, as we do find, boulders of granite extending due east along the present line of watershed (occurring at a height of 1200 feet on Orton Scar). Moreover, a series of striæ curves round the east side of the Shap granite right across the watershed (see Goodchild, Q.J.G.S. vol. xxx. map opposite p. 98; also see arrow to east of Shap granite, G. Fig. 1). The direction of the southerly train of boulders from the Shap granite is described by Mr. Dakyns in the Proceedings of the Yorkshire Geological and Polytechnic Society for 1878, and more fully by Mr. Strahan in the Geological Survey Memoir relating to the country around Kendal, Sedbergh, Bowness, and Tebay (1888 edition). From the description given in this memoir the direction of the train of boulders south of the Shap granite represented by the dotted line in Fig. 1 is taken.

At the foot of Haweswater, I have observed *roches moutonnées* striated in two directions, a faint set running W.S.W.–E.N.E. (that is, in the general direction of the Haweswater Valley), crossed by a more pronounced set running N.N.W.–S.S.E. (see arrow at foot of Haweswater, Fig. 1).

These various phenomena are best explained by supposing that the Lake District ice at first extended far to the eastward, producing the faint scratches at Haweswater, and the eastward distribution of Shap boulders over Stainmoor, and that as the Lake District ice shrank, the ice from the northward (either South Scottish ice, or ice from the northern part of the Lake District diverted southward by the Scotch ice) extended southward, curving round the high ground on the east side of the Lake District, forming the prominent striæ at the foot of Haweswater, *blocking up the Wet Sleddale Valley*, and carrying the southerly train of Shap boulders to Kendal and Lancaster. (The replacement of a mass of ice from the heart of the Lake District by one coming from the northward is also maintained by Mr. Dakyns, for different reasons, in the paper referred to above.)

But to return to the flat-topped watershed: Could it not have been formed during a period of submergence? If an arm of the sea extended up Wet Sleddale and Mosedale, might not the condition of things above described have been produced? The deposit no doubt might, but how is the Mosedale drainage to be deflected from Wet Sleddale to Swindale by this? However, the main objection is the local nature of the deposit; no sign of marine deposit is to be detected in the lowland valley of Swindale, which would be admirably adapted for receiving and preserving sea-sediment, nor do the neighbouring valleys give any proofs of an incursion of the sea, for I hold that the observations of Tiddeman, Goodchild, Dakyns, and Strahan have abundantly proved that the distribution of boulders in this district is not the result of marine action, but of land-ice. It is incumbent upon anyone who maintains that these boulders have been carried by floating ice, to account not only for the carrying of the Brockram blocks of the Eden Valley over Stainmoor, as described by Mr. Goodchild, but also the entire absence of Shap granite boulders in the Lune Gorge below Tebay, as described by Mr. Strahan.

To sum up:—1. The physiography of Mosedale suggests that it once formed part of Wet Sleddale and not, as now, of Swindale.

2. Mosedale is separated from Wet Sleddale by a flat-topped watershed, which gives evidence of having been formed by the deposition of superficial materials under water, and the distribution of this superficial material leads one to suppose that if it were removed we should find that Mosedale again formed practically a continuation of Wet Sleddale.

3. The presence of water other than the sea requires a dam across the Wet Sleddale Valley, below the point to which the superficial accumulation extends.

4. The only dam that can have existed here is a temporary one, such as would be formed by ice.

5. The distribution of the striæ and of the Shap granite boulders, points to a mass of ice coming from the north down the low ground on

the west side of the Eden valley, and abutting against the high ground of the east side of the Lake District. This ice would (according to the striæ and the distribution of the boulders) have taken the exact direction required in order to form the temporary dam.

6. Unless the above explanations be proved erroneous, it is unphilosophical to advocate a great submergence to account for the phenomena, a submergence to which other phenomena seen in the neighbourhood are in direct opposition.

III.—Notes on the Geology of Western Australia.

By Harry P. Woodward, F.G.S., F.R.G.S., Government Geologist, Perth.

As Western Australia is attracting considerable notice on account of the recent rich gold discoveries, a short paper upon its geological formations may be of interest.

Regarded as a whole, Western Australia is not an interesting field for geological research, at any rate from a stratigraphical or palæontological point of view, for, with the exception of one or two districts in the north, all the rock-outcrops are either granites, crystalline schists, or volcanic dykes.

Physical Features.

Although surrounded on three sides by the ocean, the coast-line is comparatively short, being only about 3,500 miles to the superficial area of 976,000 square miles. It is low and uninteresting on the whole, being destitute of bold headlands; the shore is either flat and little above the sea-level, or when cliffs do occur, they rarely exceed an elevation of 100 feet. These cliffs appear mostly where the escarpment of the table-land, which extends into the interior, has been cut off abruptly by the sea. That the coast has been elevated in recent times is proved by numerous raised beaches—low shelly limestone-cliffs, containing remains of existing species of mollusca, etc., and by large deposits of dead marine shells in the estuaries of the rivers upon the south-west coast. Upon the southern portion of the coast there is very little rise and fall of tide, but to the northward of North-west Cape it is considerable (being 46 feet in King's Sound), the constant alteration of sea-level playing an important part as a denuding agent along the coast and inlets.

The interior is most accurately described as a low, gradually-rising table-land with no bold ranges, the highest hills in the colony not exceeding 4,000 feet above the sea-level. There are no navigable rivers, and with the exception of a few in the South-west (which are always running) they are only immense storm-water channels.

The so-called lakes of the interior are large salt-marshes or clay-flats, being, in fact, the upper courses of the rivers where there is but little rainfall, and the country is so level that the water spreads out over the flats, where, except in very wet seasons, it evaporates, leaving a deposit of mud and salt behind.

There are no active volcanoes, but large lava-flows exist, and extinct craters are said to have been met with.

GEOLOGICAL FEATURES.[1]

In describing the geological features it will be necessary to divide the country into six sections: namely, the North, North-west, West, South-west, South, and Central.

The North or Kimberley section embraces all the country to the northward of Roebuck Bay and eastward to the northern territory of South Australia. It consists mostly of broken country and is very interesting geologically, as many good sections of the Palæozoic rocks are exposed in the river gorges. Near the coast the Upper Carboniferous series is largely developed, whilst the Devonian, Silurian, Cambrian, and Archæan rocks are met with further inland. Moreover, associated with these older rocks there occur rich deposits of gold at the heads of the Ord and Fitzroy rivers, whilst to the eastward, on the border of the colony, one of the largest known basaltic lava-flows is met with.

Along the North-west coast the country is also much broken, but here the crystalline and granitic rocks outcrop directly from the alluvium with occasional bold hills and ridges of trap-rock, and it is amongst these that the gold deposits of Pilbarra are found. Further to the southward there is a table-land composed partly of Dolomite and partly of Basalt, but these formations are of no great thickness as the clay slates are exposed in the Ashburton valley, where some important discoveries of gold have been made.

The Western section stretches south from North-west Cape to Champion Bay, and consists of low cliffs formed of later Tertiary strata. Inland, in the northern part, a sandy plain extends for some 20 or 30 miles, as far as a narrow ridge of Mesozoic hills running north and south, and is followed to the eastward by a belt of Lower Carboniferous rocks which immediately overlie the crystalline schists. South of the Murchison River, near Northampton and Geraldton, a fine series of Mesozoic rocks is exposed in the broken table-land near the coast. These formations rest unconformably upon the crystalline rocks, with their rich copper and lead-lodes.

The South-western coast consists of low-lying sand-plains of recent origin, with many salt estuaries, lakes, and swamps, which extend inland for a distance of from 10 to 20 miles. Rising abruptly upon the eastern side of these plains is the Darling Range, composed of crystalline rocks, which attain a general elevation of about 1000 feet above the sea-level. The surface of this range and the country for about 50 miles to the eastward of it, is mostly covered by deposits of indurated nodular ferruginous clay-stones called "ironstone gravel." This deposit is often of considerable thickness, and, particularly upon the high ridges, is often cemented together into blocks of conglomerate called "ironstone."

In the river flat of the Collie, on the east side of the range, about 30 miles from the coast, Coal-measures have lately been discovered, and a fine series of seams has been proved to exist by boring. Nevertheless, no outcrop of this formation is visible at the surface,

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[1] See a Notice of Geological Map and recent publications on Western Australia, in GEOL. MAG. September Number, pp. 420–425.

for the whole is covered by sand. From Cape Naturaliste to Cape Leeuwin is a low ridge of crystalline rocks, but between this and the Darling Range the low swampy and sandy flats still continue to the south coast. Beneath this flat a large series of Mesozoic Coal-seams have been discovered by boring, but no Coal of commercial value has yet been found.

The South coast consists of a series of rough granite headlands, with low sandy and swampy country behind them, and this extends inland for a distance of about 30 miles, when the crystalline rocks again outcrop. This type of country extends eastward as far as the Great Australian Bight, where a bold escarpment of limestone, about 200 feet in height, presents a vertical face to the sea, sometimes rising abruptly from it and sometimes being separated by low sandy plains and raised beaches.

The Central or interior section, as far as known, consists of a sandy table-land, broken by numerous lake basins, around which the granitic and crystalline rocks outcrop, and it is in these areas of depression that the rich gold-fields of Coolgardie, the Murchison, Yilgarn, and Dundas are situated. The sand-plains are supposed to belong to the Mesozoic age and to be the western extension of the "Great Desert Sandstone" formation of the Central and Eastern colonies.

It will be seen from the following summary that the principal geological formations are represented, although (if we except the Palæozoic formations) only to a small extent.

CAINOZOIC.

The *Recent* deposits are represented in the Lake-beds, River-Valleys, Estuaries, Sand-Dunes, Raised-Beaches, and Shell-Marls.

The *Pliocene* in the Pindan plains of Kimberley, ferruginous sandstones, and variegated clays, with plant-remains on the Gascoyne River and North-west coast; and the gravels and conglomerates of the Darling Range.

The *Eocene* in the Coralline limestones of Shark's Bay; clays, sandstones, grits, and conglomerates of Champion Bay; limestones with flints of the Bight.

MESOZOIC.

The *Cretaceous* formation is met with near the coast, 50 miles north of Perth; it extends northward to the Murchison River, and occurs also in the Kennedy Range upon the Gascoyne River, and between Capes Naturaliste and Leeuwin. It consists of beds of chalky limestone, with flints, sandstones, conglomerates, and clays. The sandstone of the table-land in the interior is also supposed to be of this age.

The *Jurassic* formation underlies the Cretaceous in the Champion Bay district, where a series of Oolitic limestones, clays, sandstones, ferruginous sandstones, grits, and conglomerates occur, which contain the characteristic fossils.[1]

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[1] See GEOL. MAG. for Sept. and Oct. 1894, pp. 385 and 433, Pls. XII. and XIII.

PALÆOZOIC.

The *Carboniferous* formation is largely developed in the Kimberley district, forming flat-topped hills and ranges which consist mostly of shale with quartzite cappings; there are also a few limestone beds. A small patch of the Upper Carboniferous formation has been discovered upon the Collie River, consisting of shales, sandstones, fireclays, with coal-seams. It is probably one of a series of small basins lying to the eastward of the range, but as the whole surface is covered by recent formations, this remains to be proved. The Lower Carboniferous outcrops upon the Irwin River, where there are a series of shales, fireclays, sandstones, and limestones, with coal-seams. This formation extends north in a narrow strip to the Lyons River.

The *Devonian* formation has only been certainly proved to exist in the Kimberley district, where there is an almost horizontally bedded series of sandstones, grits, conglomerates, shales, and limestones, which contain fossils; but on both sides of the Ashburton River there is a great extent of magnesian limestone, which probably also belongs to this age.

The *Silurian* rocks have only been identified in the Kimberley district, but they are probably represented in other parts of the colony by clay-slates and quartzites, as in the Stirling Range.

The *Cambrian* formation has also been proved to exist in the Kimberley district, where it contains the gold-bearing lodes.

AZOIC, OR ARCHÆAN.

The *Archæan* and *Crystalline* rocks are more largely developed in this colony than in any other portion of the world, outcropping as they do in all parts of the country, and, where they are overlain by more modern formations, these latter are rarely of any great thickness. This series is highly contorted, being folded into a number of parallel anticlinal and synclinal folds, striking north and south, and often presenting the appearance of a highly inclined dip, which is either nearly vertical, or trending slightly to the eastward. These rocks are much broken and faulted by numerous diorite and granite dykes; they contain many quartz-veins and iron lodes, and it is in this group of rocks that the principal auriferous deposits exist.

This great series of rocks may be subdivided into three sections, which, as a rule, run in parallel belts north and south, with a slight trend to the north-west in the northern part of the colony.

The first, or western, belt extends from the Murchison River to the south coast, but is very little exposed, except in the Northampton district, and a little south of the Irwin River, where it is rich in copper, lead, and zinc ores. It underlies the sandy coastal plains, outcropping here and there at the base of the Darling Range, forming a small range between the Capes Naturaliste and Leeuwin, and characterised throughout by lead, copper, and zinc lodes. The rocks of this belt are, for the most part, comparatively soft, consisting of clay-slates (often kaolinised), quartzites, and schists, with dykes of diorite and granite, and veins of quartz and pyrites, containing lead, copper, zinc, iron, and ferruginous graphite.

The second belt extends northward from the south coast (forming the bold escarpment at the edge of the great plateau called the Darling Range) as far as the Murchison River. It then follows this river in a narrow belt in a north-easterly direction for about 200 miles, where it suddenly spreads out to the east and north-west from the Robinson Range to the Lyons River, disappearing beneath the magnesian limestones to the northward.

In this belt the rocks are mostly hard and crystalline, consisting principally of gneiss and schist, with dykes of diorite, granite, and felstone, and veins of quartz. The latter (as well as the diorite) often contains large quantities of pyrites, most of which yield a little gold. Tin is also being worked at the Green Bushes Tin-field, the ore being derived from the disintegration of quartz-porphyry dykes, in which it is associated with tourmaline and titanic iron. Besides iron and manganese, large deposits of kaolin of a very fine quality occur, as well as veins containing mica and asbestos; but these latter are too much weathered at their outcrop to be of any value.

Near Bridge town a very large deposit of graphite has lately been opened up: it exists in the form of a bed between talcose schists about 20 feet in thickness.

The third or great granite belt lies about 100 miles east from the west coast, and is about 100 miles in width, extending from the south coast to the Murchison River. It consists of a series of bold bare outcrops of gneiss or granite often 100 feet in height and covering several hundred acres in extent, rising from loamy flats. The rocks mostly outcrop in the depressions of the table-land, the higher portions of which are covered by sand-plains. This belt is absolutely destitute of mineral veins, and it is due to this barrier that the rich gold-fields to the eastward remained so long unprospected. These outcrops are made use of for the conservation of water in this dry portion of the colony, as they shed water like a house-roof, whilst around them there are many natural dams or basins filled with sand, which are either being cleaned out or wells are being sunk in them. The rocks of this belt consist entirely of gneiss and granite, much fissured and faulted, and traversed by numerous dykes of granite and diorite, whilst the main masses generally enclose fragments and masses of schistose and gneissic rock.

The fourth or first auriferous belt is situated immediately to the eastward of the granite belt, and is about 20 miles in width. It starts from the south coast at the Phillips River, extending northward in a narrow belt by the Ravensthorpe Range, Parker's Range, Southern Cross, Golden Valley, Mt. Jackson, Mt. Kenneth, Mt. Magnet, Austin's Lake to the Cue. Thence it takes a slight bend to the north-east to Nannine and the Star of the East, where it strikes more to the north, and skirting round the heads of the Murchison and Gascoyne Rivers, it turns north-west and follows down the Ashburton Valley to its junction with the Henry, finally disappearing beneath the Palæozoic formation. The rocks of this belt consist mostly of hornblende, mica, or talc schists, of which the hornblende schist so closely resembles diorite that it is impossible to distinguish it in a broken specimen.

The rocks of this belt are a good deal broken and faulted by granite and diorite dykes and quartz lodes containing gold, iron, and copper. There are also some large magnesia lode-masses rich in fine gold, which will probably prove to be serpentine at a depth. Many of the lodes also contain large quantities of chlorite.

The fifth or second granite belt is about the same width, and similar in every way to the first mentioned. It extends from the south coast, following the line of the first auriferous belt north, and, like it, dipping under the Palæozoic table-land of the Fortescue. Only a small portion makes its appearance on the northern side on the Yule River near Pilbarra upon the north-west coast.

The sixth or second auriferous belt lies next, and at present its width is unknown, but it is certainly of considerable width in places, and has proved wherever prospected to be extremely rich in gold. It extends north from the Dundas Hills (where this formation first outcrops from below the sand-plains) by Wagemulla, Coolgardie, the Three Pinnacles, Ullaring, Lake Carey, and following about the same line as the other belts, and turning with them to the north-west by the Nullagine, Marble Bar, Pilbarra, Egina, and Mallina upon the north-west coast.

The rocks of this belt are generally very similar to those of the first auriferous belt, but the formation and lodes are a great deal more faulted and broken; however, to make up for this they are the richest that have ever been discovered.

The hornblende rocks of this colony are very remarkable in character, being met with most abundantly from north to south. They vary immensely in colour, structure, and external character, some at first glance having the appearance of clay-slate, but on being fractured they exhibit a structure similar to diorite, whilst others again only contain green crystals of hornblende disseminated through a quartz matrix or have a jade-like appearance, which latter variety are continually being mistaken for copper, nickel, or silver. With these rocks are associated the principal mineral deposits of the colony: gold, tin, copper, antimony, lead, zinc, manganese, and iron.

IGNEOUS.

Volcanic.—No active volcanoes are known to exist in this colony, but as many volcanic (*Obsidian*) bombs have been discovered in the far north and in the interior, and large basaltic flows exist, extinct volcanic craters may occur, as has been stated. On the north-west coast, south of the Nullagine, and on the Fortescue River there are several lava-flows, but the largest development takes place in the Kimberley district, where a flow stretches from the east side of the head of the Ord River far into the northern territory of South Australia. At Bunbury, and one or two points on the coast around the south-west corner of the colony, columnar basalt occurs.

Plutonic.—Dykes of granite and diorite are found all over the colony. The surfaces of these rocks are often split up and weathered into rounded masses, having a water-worn appearance, owing to the angles and edges being first disintegrated, and then exfoliated, which eventually causes the mass to assume a rounded shape. Amygdaloids are met with in great variety in the north-west, where they form huge rugged hill masses, upon which nothing will grow. Both the matrix and the enclosures vary much in different places, the latter being most commonly agates and calcite.

IV.—On some Variolitic Rocks on Carrock Fell.

By Alfred Harker, F.G.S., Fellow of St. John's College, Cambridge.

THE district of Carrock Fell, in Cumberland, is one rich in varieties of intrusive igneous rocks. Those on Carrock Fell itself, while probably belonging to one period of igneous activity, fall under three or four heads, which can be arranged in chronological sequence, as follows:—

(i.) A large intrusion of gabbro generally laccolitic in character.

(ii.) A granophyre, also forming laccolitic bodies, but with associated dykes and veins which traverse the gabbro.

(iii.) A diabase or gabbro, not essentially different from the first intrusion, but injected later and under somewhat changed conditions.

(iv.) A large number of dykes and veins of intermediate to basic composition.

These last are found traversing all the other rocks, and therefore, if we are justified in grouping them all together, they represent the latest intrusions in the neighbourhood. They vary from straight dykes two or three feet wide to narrow and rather tortuous veins not more than an inch in width.

I have recently presented to the Geological Society an account of the larger intrusive masses of Carrock Fell,[1] and I originally intended to include also the minor dykes and veins alluded to. This purpose I abandoned in view of the multiplicity and variety of rocks which they include, but some of the specimens examined seem worthy of a brief notice.

The only account yet published of any of these minor intrusions is a description by Mr. T. T. Groom,[2] of a one-inch vein traversing the gabbro near the head of Furthergill Sike. This is a tachylite with some remarkable spherulitic structures, and is of distinctly basic composition, having 53·63 per cent. of silica and 20·00 of iron-oxides,[3] with a specific gravity of 2·99 (central zone 2·95). I have examined my friend's specimens, but have nothing to add to his description. Veins having a very similar appearance are numerous

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[1] Part I., dealing with the gabbro, is published in Q.J.G.S. vol. l. (1894), pp. 311–336.

[2] Q.J.G.S., vol. xlv. (1889), pp. 298–304.

[3] Analysis by Mr. R. H. Adie (Groom, *l.c.*). The iron is estimated as ferric oxide, but is probably present in the ferrous state, which would explain the high total of 103·76 per cent.

about the summit of Carrick Fell. They have a dark compact appearance, with a colour varying from greenish-gray to brownish-gray. There is often a strong banding parallel to the walls of the vein, while a certain crumpling of the brittle rock has sometimes given rise to a kind of cross-jointing resembling a rough cleavage-structure.

A slice was prepared from one of these veins, about 50 yards east of the summit, the specific gravity of the rock being 2·846. The slice [1754] is considerably obscured by secondary changes. Where the structure is most regular, it shows dull round or ovoid spots, averaging 0·01 inch in diameter, set rather close together with clearer interspaces of a light brownish-green tint. This green substance might be taken at first glance for an altered glass; but when examined with polarised light it is seen to be doubly refracting, and the manner in which dark rays sweep across it, when the stage is rotated between crossed nicols, indicates a radiate arrangement of some birefringent mineral. In the thinnest parts of the slice it can be resolved into radiating bundles of very slender felspar-fibres, which seem to be impregnated and stained with chloritic matter. A common radiate arrangement extends over areas large enough to enclose several of the round spots mentioned, and is often sufficiently complete to give a rather imperfect black cross, but the areas which behave in this way interlock irregularly with one another. The round spots in some places seem to have a very obscure radial structure in themselves, giving sometimes a vague black cross, but in general they merely become darker and lighter when rotated, behaving with the adjacent interstitial matter, as if they shared in the larger radiate structure. In one part of the slide are little prisms, mostly untwinned, of oligoclase with a fluxional disposition.

Another rock examined comes from a four-inch vein a little west of the summit, and has a specific gravity of 2·806. In this [1755] the little round spots are wanting, and it is seen at a glance that the rock consists essentially of slender felspar-needles, about 0·03 inch long, grouped in sheaf-like bundles, which interlace with one another. A higher magnification shows that these little needles are themselves built up of very fine parallel fibres. As before, there are a few scattered felspars of larger size. The greenish material is here collected into definite patches, and may probably be taken to represent a destroyed pyroxenic mineral.

Specimens showing similar features come from the face of the cliff called the Scurth, at a spot about 450 yards W.S.W. of Stone Ends Farm. A slice from one of these [1552] shows very beautifully the sheaf-like grouping of the felspar-fibres which make up the great bulk of the rock. The central part of each sheaf is composed of parallel fibres, or may be compact enough to be regarded as a little felspar-crystal, but spreads out at its extremities into a fan-like bundle of fibres. Individual fibres give sensibly straight extinction, and in one or two little prisms sufficiently developed to show albite-lamellation, the largest extinction-angle measured from the twin-line is 5°. These observations agree precisely with Michel Lévy's results for oligoclase of composition $Ab_3\ An_1$. The green mineral in this rock forms distinct slender rods and skeleton-crystals about 0·03 inch long, with occasionally a stouter crystal or pseudomorph. Most of it seems to be hornblende, but some is a feebly polarising chloritoid substance: possibly both represent an altered pyroxene. The specific gravity of this rock is 2·663.

Another specimen, richer in the green mineral [1757], gave 2·763, and yielded 59·8 per cent. of silica.[1] Oligoclase of composition $Ab_3\ An_1$ has a specific gravity 2·659 (Tschermak) or less (Goldschmidt), and contains 61·9 per cent. of silica: the higher density and lower acidity of our rock is sufficiently accounted for by the considerable quantity of a ferro-magnesian mineral which it contains. A similar mineral occurs more richly in a six-inch dyke traversing the gabbro of Iron Crags [1881], and this rock has a specific gravity of 2·906. Here, however, the little felspar-fibres have lost their radiate arrangement.

Readers familiar with British and foreign "variolites" will recognise in the preceding short descriptions features characteristic of those curious rocks, or perhaps more accurately features often found in intimate association with the more typical variolitic structures. But while such structures have usually been described in distinctly basic rocks, we have them here reproduced in rocks of intermediate chemical composition. Other veins and dykes in the neighbourhood are of thoroughly basic rocks, and if, as seems probable, the whole group had a common origin, we have here another problem in the differentiation of rock-magmas in this very interesting district.

V.—ON THE APPLICATION OF THE SAND-BLAST FOR THE DEVELOPMENT OF TRILOBITES.

By H. M. BERNARD, M.A., Cantab., F.L.S., F.Z.S.

MY endeavours to establish a genetic relationship between the Annelida and the Phyllopod Crustacean Apus[2] led me, very naturally, to the study of the Trilobites. Specimens were kindly lent me by Dr. Woodward, F.R.S., Prof. Judd, F.R.S., and by Prof. G. B. Howes, it being my privilege at the time to be working in the Huxley Research Laboratory, which is under his direction.

Picking at the fossil with a steel point taught me, what every worker soon finds out for himself, that the limbs which, under such a dorsal shield, would probably have been thin-walled structures, could not be differentiated from the matrix by any such method. Was there, then, no mechanical method of revealing the undersurface? At first I thought, among other things, of a stream of water, mixed with emery powder, forced through a rose; this idea

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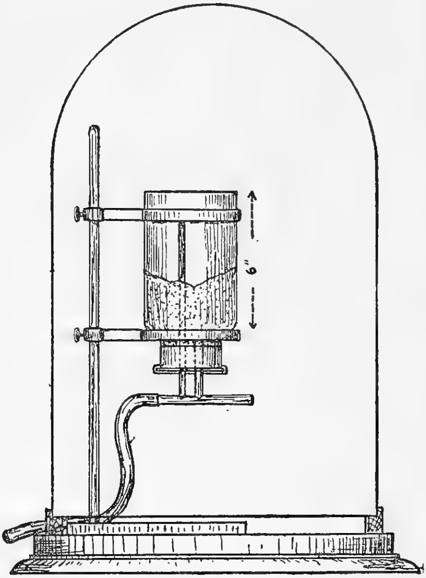
[1] This was kindly determined for me in the laboratory of the Yorkshire College of Science under the direction of Dr. J. B. Cohen.

[2] "The Apodidæ," Nature Series, 1892, and the Systematic Position of the Trilobites, Quart. Journ. Geol. Soc. August, 1894, Vol. L. pp. 411–432.

led, very naturally, to the sand-blast. A visit to the "London Sand-blast Works" (58A, Gray's Inn Road) gave some promise. The proprietor was kind enough to express interest in the idea, and showed me blocks of granite which had been treated with the sand-blast, and in which the harder elements stood out in good relief. A very short application of one of the sand-blasts belonging to the Works to the under-surface of a Trilobite from the soft Wenlock cleared away a large portion of the matrix, and revealed a small area of the under-surface of the carapace completely cleaned. In this specimen there was no trace of any under membrane having been cut through, and the carapace was probably the last remnant of a cast skin.

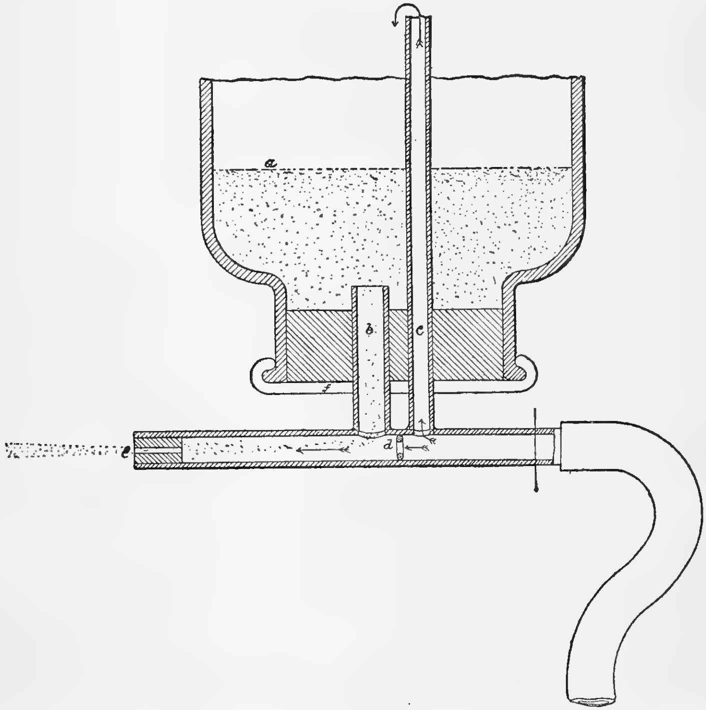
I then applied to Mr. W. I. Last, the keeper of the Machinery Division of the South Kensington Museum, for advice and assistance. He suggested several methods by which a constant stream of sand might be obtained, very kindly allowing me to make use of the air pressure (about 5lbs to the square inch) by means of which the beautiful series of model engines in his charge are kept in motion or set working by the visitor on pressing a button. I take this opportunity of thanking Mr. Last very sincerely for the friendly assistance he rendered, for whatever is of value in this paper, viz. the description of the apparatus, is entirely due to him.



Reproduction of drawing (on greatly reduced scale) to show Sand-blast Apparatus for developing fossils, invented by W. I. Last, Esq. (Keeper of the Machinery Division), Science and Art Museum, South Kensington.

The sand was first thrown up from the bottom of a deep funnel by the air current rising in its base, always falling back again to be again shot up. Under these circumstances it was not easy to manipulate the fossil, and the cutting action was not sufficient.

The sand was then allowed to run out through the funnel, which was connected by a short india-rubber tube with the nozzle of a blow-pipe apparatus. The air was forced through a small aperture just behind the feed, which, in this case, was sand instead of gas, and further, the aperture of the nozzle itself was narrowed by inserting a short piece of fine bore india-rubber tubing. The sand was shot out by this arrangement, with much greater velocity, but yet not with the highest possible, under the available pressure.



Enlarged section of part of Apparatus for developing fossils by means of the Sand-blast. Apparatus invented by W. I. Last, Esq. (Keeper of the Machinery Division), Science and Art Museum, South Kensington.

"The action, being partly due to induced currents, the amount of inert air carried along considerably reduced the velocity of the combined jet." Various other difficulties also had to be contended with—the dispersal of the sand, the clouds of fine dust, and, again, the manipulation of the fossil.

The final method planned and carried out by Mr. Last was the most ingenious: in order to get still more force, the sand was confined in a large bottle, but instead of being drawn into the air stream as before, it was forced in by the air pressure within the bottle. This happy device brought the whole available force of the air upon the sand, and its cutting action was much increased. Mr. Last has kindly furnished me with a couple of sketches explaining the apparatus as it was used. In the section, *a* represents the level of the sand, nearly run out; *b*, the feed-pipe; *c*, the tube carrying the air above the sand; at *d* is a wire ring which, by contracting the air passage between the two vertical pipes, secures a slight excess of pressure within the bottle. Without this excess of pressure the sand was not fed into the jet in sufficient quantity; *e* is the nozzle, formed by a piece of fine bore india-rubber tubing; *f* is the wire clip to keep the cork from being blown out.

A considerably larger bottle might have been used with advantage. The one figured only lasted about five minutes; although it was easily filled, yet, when there was much matrix to be cut away, it would have been more convenient had it lasted 15 to 20 minutes.

The fossil was embedded in paraffin, for convenience of manipulation and for the ready protection of exposed parts, the under-surface alone being exposed. It was then fixed in position by screw clips in front of the nozzle of the sand-blast, and the whole covered with a large glass shade, to prevent the dispersal of the sand. The shade stood on feet so as to allow the air to escape. Parts which at any moment required protection were covered with the paraffin by means of a hot knife or needle. Various other methods of protection were tried, such as collodion, india-rubber solution (this applied by a fine brush), strips of gum-paper, small cardboard screens, but none of them helped much.

Although I devoted many hours to the process, I was too busy with other things to be able in any way to exhaust the method; on the contrary, I did but make a beginning, and cannot, therefore, pretend to give a final judgment on its merits. At the same time, my experience of it, as far as it went, may not be without interest.

The differential action is not so great as I expected it would be, still it undoubtedly exists. Many times structures appeared which looked very like fragments of limbs. These I did not care to try to save. I was looking for a series of segmentally arranged processes which ought to appear in more or less regular rows on each side, hence single fragments were of little use to me. The interesting question unfortunately remains to be solved: "Had such rows of limbs come into view, would the sand-blast have differentiated them, or would it have cut them away together with the matrix?" My experience, as far as it goes, makes me believe that this would depend entirely upon the hardness of the matrix. In one partly rolled specimen (such specimens, inasmuch as they must have been complete animals when they rolled up, are the most hopeful to experiment with), I found with a pocket lens, a regular row of dots close under the lateral edge of the head-shield. I worked away the matrix, commencing near the middle line and working slowly outwards towards these points so as if possible to reveal the limbs along their lengths. As I suspected, the points were the tips of structures which were almost certainly limbs, but the matrix was so hard, that no differential action was possible, and further, the faint ridge of darker material which represented the limb first revealed was too thin to protect with paraffin.

On the other hand, if the matrix is not very hard, the sand-blast would almost certainly differentiate fine structures, provided, of course, they were not exposed too long to the action of the sand. My final plan, therefore, was to work away till I discovered by means of the sand-blast the existence of a serial row of limbs in a specimen, and then to blast away the matrix on all sides of these limbs, even through the dorsal surface, always stopping as soon as they showed as ridges, and then to work in some other way to clear the limbs further. Unfortunately, I never found such a specimen, and believe that it would be very difficult to find. The rolled-up or partly rolled-up specimens get filled with a substance too hard for the sand-blast to yield any result, while the limbs of the open specimens were probably flattened down against the dorsal carapace into a tangled mass. I did not, however, give up hope that, if I could work long enough at it and had sufficient material, the sand-blast would reveal something worth finding, if not a complete series of limbs. As above stated, many mysterious fragments and membranes appeared which kept me for a few days or hours in a state of tension. For instance, a fragment of the ventral membrane was very clearly shown in one specimen (figured in the paper above quoted).

The absence of nearly all tangible result from my own researches need deter no one from repeating the attempt. It must be remembered that a very large portion of the time I devoted to it was given to getting an apparatus which would work, and then when this was overcome by the mechanical skill and kindly assistance of my friend Mr. Last, other and more pressing duties called me away, so that on the whole I did not apply the method to more than six specimens in all. From every one of them I think I learned something, and I firmly believe that if anyone with more leisure and sufficient material would repeat the attempt, he would sooner or later certainly be rewarded. We have not by any means exhausted all that could be learned from a study of the inner surface of the dorsal shell, which the sand-blast is well able to clear out. In these cases, it is well to take care that the carapace is firmly bound together by strips of gum-paper, or by embedding in paraffin, otherwise it is very likely to fall to pieces as soon as the matrix is removed.

It may be said, in conclusion, that when the matrix is soft as compared with the fossil—and this would apply to all fossils—the sand-blast cleans the objects very beautifully, and for this alone, as an accessory method of investigation, it might be of great use to palæontologists. It is only with great regret that I have felt myself compelled, on account of other duties, to drop this method of investigation, and I hope that some one with sufficient leisure and opportunity will be tempted to carry it on.

NOTICES OF MEMOIRS.

ABSTRACTS OF PAPERS READ BEFORE THE BRITISH ASSOCIATION AT OXFORD, AUGUST 9–14, 1894.

I.—THE CARBONIFEROUS LIMESTONE, TRIASSIC SANDSTONE, AND SALT-BEARING MARLS OF THE NORTH OF THE ISLE OF MAN. By Professor BOYD-DAWKINS, F.R.S.

THE Ordovician slates, quartzites, and conglomerates, and the associated volcanic rocks of the "massif" of the island gradually pass underneath the sand, shingle, and clay of the Boulder-clay series in going northward along the coast towards Kirk Michael, until they disappear altogether from the cliffs and the shore. They stand up conspicuously along the ancient shore-line extending from Kirk Michael to Ballaugh, Sulby, and Ramsey, commanding the low, sandy, and marshy region which forms the northern portion of the island, contrasting in its flatness with the lofty rolling Ordovician hills behind, culminating in Startfell, Snaefell, and North Barule. This contrast is obviously the result of a difference in the physical character of the rocks in the two districts. The problem as to which rocks underlie the glacial strata in the former, which had occupied the author's mind for many years, is now partially solved by the three borings which have been made under his advice by Messrs. Craine in 1891–94 in search of the Coal-measures of the Whitehaven field, at the Point of Ayre, at Blue Point, and at Shen Moar. The boring at Shen Moar revealed the existence of the Carboniferous Limestone at a depth of 167 feet 6 inches below the drift. The next bore-hole, at Blue Point, about 40,050 feet to the north-east of that at Shen Moar, revealed the presence of more than 60 feet of Red Sandstone buried 171 feet beneath the drift. The Red Sandstone in this section is, in his opinion, identical with the St. Bees sandstone, or lowest member of the Triassic formation in the district of the Lakes. This is greatly strengthened by the discovery in the third boring at the Point of Ayre, to the east of the lighthouse, of the Triassic marls with salt, at a distance of a little under five miles from Blue Point. The diamond drill was used from a depth of 452 feet to the bottom. The total thickness of the salt-beds amounts to 33 feet 6 inches, and the bore-hole happened also to intersect a brine run 2 feet 6 inches in depth. If this section be compared with that published by Mr. Dickenson of the saliferous marls of Duncrue, near Carrickfergus, it will be found to be practically identical. The same series of salt-bearing marls is also worked at Barrow-in-Furness and at Preesal, near Fleetwood. The salt-beds in each of these cases are variable in thickness, and those in the Isle of Man are thinner than in the other localities. It must, however, be remembered that the Manx boring has not been put down to a sufficient depth to test the true thickness of the salt-field. The discovery is of great theoretical importance, because it links on the deposit at Barrow with that of Carrickfergus, and shows the

Irish Sea was an area in which the salt-bearing Triassic marls were deposited. It points towards the truth of Mr. Dickenson's suggestion that the Cheshire salt-field was formerly continuous with that of Ireland. These marls have since been broken up, faulted, and denuded away in many places. It is an open question how far those of the Isle of Man are now continuous under the sea eastwards to Barrow and Fleetwood, and to the north-west in the direction of Carrickfergus.

All these rocks are buried under a great thickness of boulder sand, gravel, and clay, amounting at the Point of Ayre to 298 feet. To this also must be added the height of the drift hills close by, formed of the same materials, which would give the total thickness as not less than 450 feet in the extreme north. The rocky floor on which it rests dips rapidly to the north-east towards the deeper part of the Irish Sea.

The discovery of this salt-field is likely to add a new industry to the resources of the Isle of Man.

II.—FOSSIL PHYLLOPODA OF THE PALÆOZOIC ROCKS. ELEVENTH REPORT OF THE COMMITTEE, CONSISTING OF Professor T. WILTSHIRE (Chairman), Dr. H. WOODWARD, and Professor T. RUPERT JONES (Secretary). Drawn up by Professor T. Rupert Jones, F.R.S., F.G.S.

1. A NEW species of Beecher's phyllocaridal genus *Elymocaris*, from the collection of Dr. G. J. Hinde, F.G.S., has been figured and described in the GEOLOGICAL MAGAZINE for July, 1894, p. 292, Pl. IX. Fig. 7. It was found at Arkona, Ontario, Canada, in the Hamilton group of the Middle Devonian series.

Its nearest known ally is *Elymocaris capsella* (Hall and Clarke), from the Hamilton group of New York State, Palæont. New York, vol. vii. 1888, p. 181, pl. xxxi. fig. 4. It differs, however, in details of outline, ornament, and ocular spot. The new species is named *E. Hindei*, after its discoverer.

2. Two imperfect sets of abdominal segments, impressed on a piece of Moffat Shale (from Garpel Linn), have been noticed in association with a carapace of *Discinocaris Browniana*, and therefore probably belonging to individuals of either that genus and species, or of *Aptychopsis*, or possibly *Peltocaris*, which also occur in the Moffat Shales. The two above-mentioned specimens are figured and described in the GEOLOGICAL MAGAZINE for July, 1894, p. 291, Pl. IX. Figs. 4*a*, 4*b*. Fig 3 shows the associated carapace. They belong to the Carlisle Museum.

We have noticed similar abdominal segments, but differing somewhat in size, associated with *Hymenocaris* in the Tremadoc slates, and with *Ceratiocaris* in the Upper Silurian beds. As such body-rings belong to various groups of these low-class Crustacea, it is not extraordinary that the above-mentioned genera should each possess the same kind of structure in the abdominal region.

3. A good-sized *Discinocaris Browniana* and the moiety of a rather large *Aptychopsis Wilsoni*, preserved in the Carlisle Museum,

have also been described and figured in the GEOLOGICAL MAGAZINE for July, 1894, p. 292, Pl. IX. Figs. 5 and 6. They are typical of the Moffat Shales.

4. It may be remarked that the figured interior of the bipartite carapace of *Macrocaris Gorbyi*, Miller, referred to in our Tenth Report, at page 468, Report British Association for 1893, appears (if looked at upside down) very much to resemble some of the bivalved *Aptychopses* figured in the Monograph of Palæozoic Phyllopoda, Pal. Soc., 1892, pl. xv., but with a more acutely sagittate outline, and without the definitely concentric umbonal striæ.

If the carapace in the drawing (fig. 43) exposes its *interior*, it seems to lie unconformably with respect to the body-rings, for they appear to be covered by the carapace upside down. If it normally covered the body it would show its *exterior*.

Is it possible that after death, the attachments of the body and carapace having been loosened, the carapace turned quite over, and the parts of the animal floated into a position reverse to what they held in life? Or have we here two valves and an imperfect body of an *Aptychopsis* which during decay were washed into a *reversed* position—that is, with the abdomen projecting from the anterior region, as is not unusual with some fossil *Ceratiocaridæ*?

5. By favour of Dr. Wheelton Hind, F.G.S., we have very lately seen, from Mr. George Wild's collection, some pyritous specimens of what seems to be a very small *Estheria* in shale from the roof of the Bullion Coal, Lower Coal-measures, lately worked at Trawden, near Colne, in North-east Lancashire.

6. A specimen of *Estheria Dawsoni*, Jones (GEOL. MAG., 1870, p. 220, Pl. IX. Fig. 15; *ibid.*, 1876, p. 576; *ibid.*, 1878, p. 101, Pl. III. Fig. 2), has been obtained from the vicinity of Five-Islands, Nova Scotia, by Mr. H. Fletcher, of the Geological Survey of Canada. Like a former specimen it may be from the Horton series; and has been sent by Sir W. Dawson, F.R.S., of Montreal, for our examination.

III.—ON THE PERMIAN STRATA OF THE NORTH OF THE ISLE OF MAN.

By Professor BOYD-DAWKINS, F.R.S.

THE main features of the geology of the island are identical with those of Cumberland and Westmoreland. The Ordovician strata form the "massif" in both areas, and constitute the sea-worn floor upon which the Carboniferous rocks rest unconformably. The Red Sandstone series of Peel, 1368 feet in thickness, occupies but a very limited area, extending from the Creg Malin, along the sea-front, in a line of picturesque cliffs, about one and a half mile to the north-east, and extending inland about 1700 feet. The rocks may be divided into two distinct groups. First, the Peel Sandstone series, or Roth-todt-liegende, which presents a thickness of 913 feet, and the calcareous conglomerates and breccias of the Stack series, 455 feet thick, representing the Magnesian limestone of the Permians. These rocks are faulted into the Ordovician slates, and neither their true base nor their upper boundary is visible. The pebbles of Carboniferous Limestone in the conglomerates point to a post-Carboniferous age, and the physical characters of both divisions are identical with those of the Permian rocks of the North of England, and more particularly with those of the Lake District, of the Vale of Eden and Barrow Mouth, described by Sedgwick, Harkness, Binney, Eccles, and Nicholson. It is clear that north-eastern Ireland, the northern part of the Isle of Man, and the area of the Lake District, including the Vale of Eden, were parts of the same Permian marine basin, in which, as it approached southern Lancashire, the waters gradually were more highly charged with mud, the calcareous element being conspicuous in the one, and being replaced in the other by thick accumulations of marl.

REVIEWS.

I.—NANNO, A NEW CEPHALOPODAN TYPE. By J. M. CLARKE. (The American Geologist, vol. xiv. pp. 205–208, pl. vi. October, 1894.)

THE author's description of this Cephalopodan type is based upon "seven specimens obtained from the Trenton shales of Minneapolis and from the Galena shales at Chatfield, Minnesota." All the specimens represent only one species, for which the name *Nanno aulema* is proposed. The species has the appearance of a short, stout, fusiform *Endoceras*, tapering rather rapidly to a somewhat acute point. The siphuncular tube (sipho) is marginal, and occupies nearly one-half of the diameter of the shell. "The septa are gently and regularly concave over most of their surface, but abruptly deflected immediately above the sipho." The conical posterior portion is aseptate; it is formed by the inflation of the siphuncular tube, which is covered by a thin layer of the test. As in the genus *Endoceras*, the siphuncular tubes (siphones) are sometimes found detached from the rest of the shell; they have then the appearance of small *Belemnites*, whose posterior extremity is somewhat inflated; the cylindrical portion bears oblique impressions as in *Endoceras*, but these are interrupted on that side of the tube which was in contact with the shell-wall. The siphuncular tubes are "completely solid in the apical portion for usually about one-half the length of the præseptal cone, but in some examples the solidification extends for the entire length of the cone and into the cylindrical part of the tube. The cavity of the sipho above this filling is a narrowly conical chamber, whose walls gradually become thinner from the apex upward, their upper edge appearing to be rounded off and finished."

"The substance of the siphonal cone and walls is invariably very compact, radially crystalline calcite." "Cross-sections of the cone in both directions indicate * * that this is composed of at least two invaginated and consolidated sheaths," similar to those found in *Piloceras*, *Vaginoceras*, and *Endoceras*, but the author did not observe any traces of a tube connecting the apices of these sheaths, such as has been described in *Piloceras* and *Endoceras*.

"All the specimens indicate that the shells were of small size. . . . . The most complete example has a length of 58 mm.; the apical cone measures 15 mm.; the entire diameter of the shell is 18 mm. at its widest part and 16 mm. at or near the aperture."

The author regards this Cephalopodan type as most nearly related to the genus *Piloceras*, but the figures accompanying the paper so closely resemble those illustrating Dr. Gerhard Holm's paper, "Ueber die Anfangskammer von *Endoceras belemnitiforme*" (Pal. Abhandl., Dames and Kayser, vol. iii. (1), 1885, pl. i.), that it would have been interesting if the author had pointed out the characters by which his "new Cephalopodan type" differs generically from Holm's *Endoceras belemnitiforme*. We think the two species are certainly referable to the same genus, and if Holm's species be a true *Endoceras*, *Nanno* becomes a synonym. It is, however, interesting to find that a structure very similar to that described by Holm has now been observed in American specimens. G. C. CRICK.

II.—THE MAMMALIA OF THE DEEP-RIVER BEDS. By W. B. SCOTT. (Trans. Amer. Phil. Soc., Vol. XVII., pp. 55–185, Plates 1–6. Philadelphia, 1894.)

IN this paper the author describes in detail a collection of Mammalian remains from the Deep-River Beds of Montana, a series of deposits occurring in a Tertiary lake basin, originally discovered by Grinnell and Dall in 1875. The beds consist of an upper and a lower division, from both of which collections have been made. The upper division is considered to form the lowest horizon of the Loup Fork Beds, which are referred by the author to the Upper Miocene. The lower portion is regarded as being on the horizon of the uppermost John Day. The former is tentatively correlated with the Miocene of Steinheim and Sansan, the latter with that of St. Gerand-le-Puy, while the White-River Beds are considered to be approximately equivalent to the deposits of Ronzon, and should therefore be referred to the Oligocene.

One of the most interesting forms from the lower division is *Cynodesmus thoöides*, a dog-like animal, represented in the collection by a beautifully preserved skull, the upper portion of which is broken away, exposing a natural cast of the brain case. The surface of the cerebral hemispheres is much less convoluted than in any recent member of the Canidæ, and the cerebellum is only very slightly overlapped by the hemispheres. The author considers that this animal is probably on the direct line of descent of *Canis*, connecting the latter with *Daphænus* of the White-River Beds, hence it is possible that the Canidæ must be added to the list of families that originated in the New World.

Of the Equidæ, *Desmathippus*, a most important form connecting *Miohippus* with *Protohippus*, is fully described. The teeth are low-crowned, with the valleys partly filled with cement, and, in the feet, the lateral digits are fairly well developed.

Of the genus *Anchitherium* (in the restricted sense employed by the author, *i.e.* excluding *Miohippus* and *Mesohippus*), one species, *A. equinum,* occurs. This form fairly closely resembles the European species, *A. aurelianense,* but in some respects is of a more modernised type. The affinities of the genus are discussed at length and cogent reasons given for considering that it is quite off the direct line of descent of *Equus,* being probably an abortive side branch derived from *Miohippus,* or some allied form. If this be true the European representatives of the genus must have reached the Old World by migration.

The Rhinoceridæ are represented in the lower beds by some undeterminable fragments only, but in the upper the remains of a species of *Aphelops* are found. The author points out an interesting series of parallelisms in development between the hornless Rhinoceroses of America and their horned congeners of the Old World; the common ancestors of the two groups are probably to be found among the Aceratheria of the Oligocene.

Of the Artiodactyla, several species of Oreodonts referred to the genera *Mesoreodon, Merychyus, Merycochoerus,* and *Cyclopidius,* are described. *Mesoreodon chelonyx* is peculiar from the fact that it possesses an ossified thyroid cartilage, a character unique among mammals. It is suggested that this structure, like the greatly expanded basihyal in the howling Monkeys, was connected with great power of voice. The same species is further remarkable for the presence of a small ossified clavicle and of a distinct metacromial process on the scapula.

A small species of *Blastomeryx, B. antelopinus,* is described and its affinities considered. It appears to be an Old World type, nearly related to *Palæomeryx,* and may possibly be an ancestral form of *Antilocapra,* the American Prong-horn Antelope, which it must have closely resembled in outward form, the horns, however, being unbranched.

The Camelidæ are represented in the lower beds by *Poëbrotherium,* and in the upper by *Protolabis* and *Procamelus.* In the axis vertebra of *Protolabis* the odontoid process is intermediate in structure between the peg-like form occurring in *Poëbrotherium* and the spout-like condition found in *Procamelus* and the recent Camels, this latter form having been acquired among the Camels by precisely the same series of modifications as in the Equidæ, in which series *Miohippus,* in this respect, represents *Protolabis.*

Finally, in the upper beds remains of a Mastodon, *M. proavus,* Cope, are found; this is the earliest occurrence of the genus in America.

REPORTS AND PROCEEDINGS.

GEOLOGICAL SOCIETY OF LONDON.

November 7th, 1894.—Dr. Henry Woodward, F.R.S., President, in the Chair.

Sir John Lubbock exhibited specimens of fossiliferous limestone from the valley of Lauterbrunnen, at Mürren. He pointed out that the specimens contain *Nummulites Ramondi, Orbitoides dispansus,* etc.

as determined by Prof. T. Rupert Jones. The find was perhaps the more interesting because the specimens were obtained from a quarry by the road-side in the village of Mürren, and actually between the two principal hotels.

Mr. Etheridge referred to the position of the Orbitoidal limestones on the slope of the Mürrenberg, and stated that Prof. Rupert Jones had examined and named the Foraminifera, etc., contained in the several specimens collected by Sir John Lubbock and himself at Mürren.

The following communications were read:—

1. "Notes on some recent sections in the Malvern Hills." By Prof. A. H. Green, M.A., F.R.S., F.G.S.

The sections described occur on the east side of the Herefordshire Beacon, and for convenience are named the Warren House Rocks. They are bedded, and have a general north-and-south strike. The great bulk of the rocks are hard, close-grained, and splintery, and are largely altered, and in many cases thickly veined with calcite. Details of their structure are given; and the author states that he is inclined to regard them as a group of bedded acid lavas and tuffs, crossed by three bands of dolerite. What little balance of evidence there is seems to be in favour of the intrusive character of the dolerites. No true limestones have been found, and the only very calcareous rock seen is regarded as a rock belonging to the volcanic group which has been largely calcified.

Somewhat similar rocks are found on the southern part of Raggedstone Hill, and a shattered felstone occurs forming an isolated boss south of Chase End Hill.

Several hypotheses present themselves as to the relationship between the Warren House Rocks and the crystalline schists. The former may be distinct from the latter, in which case the absence of mechanical deformation would indicate that they are younger. If we consider that the Malvern Schists have been formed out of volcanic rocks by dynamic metamorphism, the Ragged-stone Hill Rocks may be a portion of the volcanic complex which has undergone only partial transformation, whilst the Warren House Rocks have altogether escaped metamorphism, the crystalline schists representing its final stages.

2. "The Denbighshire Series of South Denbighshire." By Philip Lake, Esq., M.A., F.G.S.

The area to which this paper chiefly refers is the south-western quarter of the Llangollen basin of Silurian rocks. The beds are here very little disturbed, and the sequence is readily made out. The following subdivisions are recognized (in descending order):—

Leintwardinensis Slates; with *Monograptus Leintwardinensis.*
Upper gritty beds; with no fossils known.
Nantglyn Flags; with *M. colonus, Cardiola*, etc.
Moel Ferna Slates; with *M. priodon, M. Flemingii.*
Pen-y-glog Grit.
Pen-y-glog Slate; with *M. personatus, M. priodon, Retiolites Geinitzianus*, etc.

Farther east the fossiliferous beds of Dinas Brân appear to lie considerably above the *Leintwardinensis* Slates.

On comparison with other areas it is found that this succession is almost identical with that in the Long Mountain, in North Denbighshire, and in the Lake District. It is also inferred that the *Leintwardinensis* Slates represent the Leintwardine Flags of Herefordshire, and that the Dinas Brân beds correspond with a part of the Upper Ludlow.

3. "On some Points in the Geology of the Harlech Area." By the Rev. J. F. Blake, M.A., F.G.S.

In testing the conclusions arrived at in regard to the Llanberis and Penrhyn area by an examination of that of Harlech, two questions are raised concerning the latter:—(1) Can a succession be traced below the Purple Slates similar to that which the author has described as occurring in Caernarvonshire? and (2) Where is the most natural break in the series, and does it show an unconformity?

With reference to the first question, the author gives his reasons for concluding that, as far as the succession is seen in the Harlech area, it is similar to that of Caernarvonshire. A group of Purple Slates is described which so closely resemble the Llanberis and Penrhyn Slates, that he considers that he is justified in definitely correlating them with those slates. Below these are slaty greywackes, which, if not identical with those of Caernarvonshire, bear a greater resemblance to them than any other part of the series does. No older beds are seen. Above the Purple Slates are the Harlech Grits proper.

In discussing the second question, the author describes conglomeratic beds occurring some distance above the base of these Harlech Grits; but at Pont Llyn-y-Crom the junction between them and the underlying Purple Slates shows features recalling what is seen at Bronllwyd. He discusses the possible existence of an unconformity at the base of these grits, and concludes that on the whole the phenomena point, though not very strongly, to an unconformity of no great importance.

The concluding part of the paper is occupied with a consideration of the question of classification of the Cambrian strata and those in juxtaposition with them.

CORRESPONDENCE.

SIR H. HOWORTH ON THE HOLDERNESS BOULDERS.

Sir,—The title and some of the paragraphs of Sir Henry Howorth's latest contribution have been penned under a singular misapprehension. I have written not a word "on the Scandinavian Ice-sheet," nor offered any opinion as to the mode of transport of those very damaging boulders. I have, indeed, my own views on these questions, but have kept them to myself with the modesty which your correspondent recommends. This reserve I propose to maintain, despite Sir Henry's somewhat inconsistent challenge to me to enter the lists against "the best men" among Glacial geologists—meaning, as he rather quaintly explains, the men he quotes.

The sole statement of mine with which we are concerned is that certain boulders extracted by Mr. Lamplugh and myself from the Holderness Boulder-clays are of Norwegian origin. Extricating from Sir Henry's communication what is germane to this question, I note first that the ballast theory has taken a more definite shape. It may have occurred to the writer that there is no port on the Holderness coast, and that the number of vessels from Christiania cast away there is limited. For whatever reason, Sir Henry now carries us back to the age of the Vikings, who, it appears, ballasted their ships with little pieces of rhombenporphyr, and used small pebbles of laurvikite for anchors; and he, apparently, would have us believe that the stones now on the strand have lain there undisturbed for many centuries! To anyone who has watched the movement of this beach, which no artificial works have been able to hold, or who reflects that in the days of the Vikings the Holderness coast-line must certainly have been several miles to seaward of its present site, this idea will come with all the force of novelty.

But, besides the pirates from Viken, Sir Henry has two other strings to his bow. One is the idea that we have mistaken boulders driven into the face of the cliff by high tides for boulders belonging to the clay. Sir Henry is rather fertile in suggesting foolish blunders that somebody else may have made, and I do not see how he is to be convinced on this point except by personally examining the cliffs that he writes about, which is perhaps too much to expect from so busy an author. But, since he inquires whether boulders of the rocks in question have been found inland, I venture to remind him of such a find made at Cambridge by an observer in whose caution he has, I am sure, full confidence. It was recorded by me in your July Number, and still awaits Sir Henry's attention. In the northern counties, where so many thousands of boulders have been critically examined, there is no record of the types in question except from the eastern coast-line.

This last significant fact will afford exercise for Sir Henry's ingenuity with reference to his remaining alternative, viz. that these rock-types may occur *in situ* somewhere in Britain, apparently in Durham, the Cheviots, or the Lake District. Assuredly this suggestion cannot have been submitted to the writer's petrological adviser. Recalling that the disputed boulders, of at least four distinct types, have all been matched in one district of Norway, and that the British areas indicated, which are as thoroughly known as any part of this country, have yielded nothing remotely resembling any one of those types, we may fairly ask for some surer ground for this very original hypothesis than the exigencies of Sir Henry Howorth's glacial theories.

St. John's College, Cambridge.
August 18*th*, 1894.

Alfred Harker.

NEW LOCALITIES FOR THE MINERALS *BROOKITE, NATROLITE,* AND *BARYTES.*

Sir,—I have recently discovered a new locality for *Brookite* and *Natrolite* in Caernarvonshire (the old locality is near Tremadoc). The Gimblet rock, Pwllheli, consists of a compact ophitic dolerite containing labradorite, large brilliant crystals of augite, and magnetite. Fissures traverse the rock in all directions, and are filled with quartz and calcite. Small bright crystals of *Brookite* are imbedded in the dolerite and project into the fissures; they are in many cases surrounded and covered by calcite, but are revealed on removal of the latter by hydrochloric acid. The largest crystals have a diameter of one quarter of an inch, and are tabular in habit: the large faces are striated in the direction of the vertical axis.

The mineral *Natrolite* occurs in geode-like cavities in the dolerite, and is intimately associated with calcite and quartz. The radiating spherical groups of *Natrolite* are white in colour, and from one quarter to half an inch in diameter.

Last August I had occasion to visit Dosthill, near Tamworth, and am able to add a new mineral to the list of those hitherto known as occurring in Warwickshire. The mineral is *Barytes*, and occurs in veins an inch in diameter in the Cambrian shales. The crystals have a beautiful reddish colour due to enclosed ferric oxide.

122, Linwood Road, Handsworth, Birmingham.
Nov. 3rd, 1894.

W. J. Harrison, Jun.

GLACIAL GEOLOGY.

Sir,—Although I scarcely think that Sir H. H. Howorth's letter, published in your November Number, calls for any remark from me, I cannot refrain from noticing a few of his arguments, as they reflect strongly upon his controversial methods.

It is an *impertinence,* it would seem, for me to say anything about Switzerland and its glaciers, or to look at them, seeing that others have already been there, and that a whole library was written upon the subject before I was born! Indeed, it was an unjustifiable public advertisement to say that I had ever been there or had even seen a glacier! At the same time he regards it as *preposterous* that "those who have never studied the mechanics of ice in a laboratory, and, what is more strange, have never seen a glacier at all," should write upon the subject. There is clearly no way out of the difficulty; I must do something preposterous or be impertinent, if I am legitimately to interest myself in glacial matters!

His answer to the demand I made for a statement of the angle of slope at which a glacier ceases to flow is equally characteristic. We learn that Forbes "collected considerable evidence to show what the least angle is upon which ice will begin to move. This is the slope, *the least slope,* available." In other words it is "as much again as half."

We also learn that although the Antarctic continental ice may move into deep water, and present a vertical wall of ice to the ocean 450 miles long and more than 150 feet high, to imagine that continental Arctic ice can do the same thing required "the invention of Croll, who, sitting in his arm-chair, and endowed with a brilliant imagination, imposed upon sober science the extraordinary postulate"; and the sober, simple, scientific explanation of every difficulty, imagined or real, is that the upheaval of "the highest masses of land on the earth, including the massive mountains of Asia and the American Cordillera," was "very rapid, if not sudden," and that "the breaking up of the earth's crust at the time, of which the evidence seems to be overwhelming, necessarily caused great waves of translation to traverse wide continental areas." His own words, "no science but long-suffering geology would tolerate the absurdity," seem more to the point here.

There need be no loss of temper or heated argument on the subject. Neither dogmatic assertion nor the weight of authority will ultimately prevail. In the eyes of many it may be impertinent of me to have opinions on this or any other subject; but all, it seems to me, have a right to add their mite in the hope that it will assist in the elucidation of the truth. Of one thing I am sure, and that is, that although we have been preceded by Forbes, Agassiz, Bishop Rendu, Ramsay, and Tyndall, and a host of others who have ceased to work in this world, there still remains very much to be done.

10, Charnwood Street, Derby. R. M. Deeley.

THE "SOUTHERN DRIFT."

Sir,—I am sorry that in my paper there should have been any statement which Prof. Prestwich or anyone else could consider misleading. In mentioning the name of Prof. Phillips, as well as that of Prof. Prestwich, in connection with the Southern Drift, my only object was to afford information to those unacquainted with the literature of the subject. I suppose I put Phillips first because the date of the work referred to (1871) was earlier than the quoted paper of Prof. Prestwich.[1] But no one who is at all acquainted with Geology, or even with contemporary history, can suppose that the slight reference in Phillips's work bears any sort of comparison to the full and exhaustive work of Prof. Prestwich, who has done more than any other geologist to create an interest in the once despised "superficial deposits." Nor is it any disparagement of Prof. Phillips's reputation as a geologist that his treatment of these deposits in the Thames district should be necessarily imperfect, and to some extent based on information supplied by others. It is evident that he knew of a hill-gravel formed by "currents from the south transporting flints and sarsen-stones"; but the passage quoted by Prof. Prestwich contains all that he has said on the subject in the work referred to. He has also figured neolithic forms as "Implements from the drift."

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[1] Prof. Prestwich writes:—"This is a mistake. Prof. Prestwich's first paper on this subject was published in 1847. Besides, flint, gravel, and sarsen-stones *alone* do not prove a drift from the south. It might as well have been from the west or north-west."—J. P.

I hope, therefore, that Prof. Prestwich will accept my assurance that I had no intention of suggesting that he was in any way indebted to Phillips. I regret also that my reference to the Weald is not sufficiently clear; I said: "It is open to question whether the Weald ever had the character of a mountain-region." The question which I was considering was whether stones are ever worn by the action of torrents so as to produce a groove in one side, and I placed the remarks quoted above in a footnote. Of course the Weald must at some time have been a region of comparative elevation; but considering the nature of the materials of which it was composed, and that denudation must have gone on during the period of gradual elevation, it appeared to me permissible to doubt whether it was ever a mountain-region in the sense in which, for instance, the district of Snowdon is a mountain-region; that is to say, a region giving birth to numerous torrents.

But in any case the argument in my paper would not be affected; and I have certainly no wish to raise a controversy on a matter in regard to which Prof. Prestwich knows far more than I do.

THORNDALE, CRAVEN ROAD, READING. O. A. SHRUBSOLE.

MOUNTAIN-MAKING BY TENSION.

SIR,—Mr. Vaughan "having stated a new theory to account for the inequalities of the Earth's Surface," and this theory being dependant upon the tensile strength of the Earth's crust, I suggested that he should favour us with some proof that the outer shell of the Earth is sufficiently strong to do the work demanded of it. He observed in his first paper,[1] "It obviously follows that the outer shell exerts a squeezing force upon the interior, and by compressing the mass into a smaller volume increases its density." In my communication to this MAGAZINE[2] I pointed out that no tensile stress that the Earth's crust could stand would be sufficient to compress the materials of the interior of the Earth, stating in effect that if the outer shell is assumed to be 30 miles thick, and of the tensile strength of steel, it could not exert a pressure of half a ton per square inch upon the interior without fracturing.

Mr. Vaughan now says that he does not rely upon decrease of volume due to pressure, but "upon the *transference* of material from beneath a surface of great pressure to below a surface upon which the pressure is much less." This is not very different to what I understood of his theory from his first paper, and my calculation was given merely to show what an exaggerated view Mr. Vaughan held of the compressive powers of a contracting crust. Mr. Vaughan's theory, so far as I can understand it, appears to be this:—Mountain Ranges are produced by the differential tensile stresses of a shrinking crust causing a local flattening of the Earth's curvature, and thus compelling a flow of material from where the crust is strong enough to prevent, to where it is weak enough to permit of, bulging. Now, on the assumption that a shell of steel 30 miles thick represents the tensile strength of the contracting crust—an exceedingly liberal

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[1] GEOL. MAG. 1894, p. 264.

[2] *Ibid.* p. 414.

estimate—the maximum effect, leaving out of account internal friction, would be equal to raising a column of rock 1000 feet above the normal of the Earth's surface; but, when we come to consider a local contraction of the crust, we have an exceedingly complex problem to deal with. Each section of the spherical shell, such as we have assumed, would initially possess tensile strength sufficient to put the same pressure per square inch upon the interior of the sphere that the whole shell would; but, as the area became flattened by contraction, its power of compression would become proportionally less. Taking this into consideration, together with internal friction, in small areas the elevatory effect by transference of material would become infinitesimal.

If this reasoning be true, and I believe it to be so, Mountain-Making by Tension is an impossibility. It will not account for either the shape, height, bulk, or linear direction of Mountain Ranges as we know them, much less the compression and folding most of them have undergone. We are thus thrown back upon some theory of compression would we account for mountain-structure as seen in Nature.

Before concluding, I would point out that, in addition to these quantitative deficiencies, Mr. Vaughan's theory seems to involve a mechanical contradiction. If the tensile strength of the contracting crust were great enough to do the required work, a strong enough anchorage would be needed at the boundaries; whereas by the hypothesis this is the weak part, otherwise it could not be elevated by material forced to flow under it from below the contracting area. It seems to me very like the case of a man trying to lift himself up by pulling at the chair he is sitting upon.

PARK CORNER, BLUNDELL SANDS, LIVERPOOL. T. MELLARD READE.

OBITUARY.

WILLIAM TOPLEY, F.R.S., F.G.S.

BORN MARCH 13TH, 1841. DIED SEPTEMBER 30TH, 1894.

(With a Portrait.)

WILLIAM TOPLEY was born at Greenwich, on March 13th, 1841; and after gaining his early education at local schools, he received, during the years 1858–61, the valuable scientific and practical training of the Royal School of Mines.

In 1862 he was appointed an Assistant Geologist on the Geological Survey, when Murchison was Director-General, and Ramsay was Local Director for Great Britain. He then commenced field-work under the guidance of Dr. (now Professor) Le Neve Foster, who, with others, was engaged in the Survey of the Wealden area. There he was initiated into the methods of geological mapping among the changeful Hastings Beds, at Mayfield and other places between Burwash and Lindfield, to the south of Ashdown Forest. There, too, in course of time, he gained a detailed knowledge of the Cretaceous and Neocomian formations, and his interest was aroused in questions of Physical Geology, to which for many years he gave particular attention.

Yours Truly
Wm. Finley

In conjunction with his colleague Dr. Foster he made a study of the superficial deposits over a large part of the Wealden area, and more especially of the gravels of the Medway valley; and together they elaborated in 1865 the well-known paper in which they brought their knowledge to bear on the vexed subject of the Denudation of the Weald. In this essay they gave numerous facts and new arguments to prove, what had in general terms been taught by Ramsay, that the main features of the ground were sculptured by the agency of rain and rivers.

On the completion of the Geological Survey of the Wealden area, the preparation of the descriptive Memoir devolved upon Mr. Topley. Other colleagues, Mr. F. Drew, Mr. C. Gould, and Dr. Foster, who had mapped large portions of the region, had resigned their official positions; but Mr. Topley had had numerous opportunities of becoming generally acquainted with the entire district. How carefully his Memoir was written, and how exhaustively (so far as our knowledge then existed), is known to every geologist. The book, which was published in 1875, at once became the standard work of reference; for, apart from its original information, it gave evidence, as did all his writings, of a thorough study of the publications of other observers, and a full acknowledgment of all they had done.

Meanwhile Mr. Topley had been instructed to proceed to the Coal-field of Northumberland and Durham, and much of his literary labour connected with the Memoir had to be performed in that northern region in the winter time, or at other seasons when field-work was impracticable. In 1868, after six years' service, he had been advanced to the rank of Geologist on the Geological Survey—promotion in those earlier days being far more rapid than at the present time.

When, in 1872, the Committee of the Sub-Wealden Exploration commenced their active operations near Battle, Mr. Topley was, of course, specially interested. He was one of the first to be consulted, and, later on, he was expressly sent by the Geological Survey to the locality, to examine and report upon the cores brought up by the boring-apparatus. He was thereby enabled to record, in his Memoir on the Geology of the Weald, particulars of the strata and their fossils to a depth of over 1000 feet. The classification of the strata given in that work was subsequently modified, and Mr. Topley from time to time contributed many reports and other articles on the subject (see Appendix).

A considerable portion of Mr. Topley's sojourn in the north was spent at Rothbury, near Morpeth, and at Alnwick, where his studies were directed mainly to the Carboniferous rocks and to the Glacial Drifts. The nature of that great sheet of basalt known as the Whin Sill, also engaged his attention and that of his friend and former colleague, Prof. Lebour, and the result of their observations was to prove its intrusive character.

The subject of Denudation never ceased to interest Mr. Topley, and when, during the early years of the GEOLOGICAL MAGAZINE, many warm discussions took place concerning the origin of escarpments and other features, he joined in the fray on behalf of subaërial agents. In confirmation of views that had been expressed with regard to other regions, he pointed out how in East Yorkshire anticlines, by their fissured summits, had been readily acted upon by inland agents of erosion, whereas, in certain cases, synclines had better withstood the assaults of rain and rivers.

In 1880 Mr. Topley was called upon to abandon his field-work in Northumberland in order to superintend the publication of Maps and Memoirs at the Geological Survey Office in Jermyn Street. This post, which for many reasons was congenial to him, he continued to occupy; and on the retirement of Mr. Edward Best in 1893, Mr. Topley was entrusted with the entire charge of the office. Throughout this period in London the multifarious duties of the department gave but little opportunity for continuous scientific work: ever busy, he was seldom able to do more than the routine work of the office, but his wide knowledge and experience were always at the service of his colleagues and of others who frequently sought advice and information.

Eager at all times to promote the progress of Geology, Mr. Topley took a leading part in the work of that most useful compendium of geological literature, the Geological Record; and here his extensive acquaintance with bibliography was of great service. Finally, in 1887, he undertook the post of Editor, at a time when the Record was in a somewhat troubled condition, owing to delays in publication. These had arisen, despite every effort made by the untiring and disinterested exertions of the original Editor, Mr. Whitaker. In labour which is arduous, by no means uniformly interesting, which brings but little credit, and is wholly unremunerative, it is far from easy to gain and retain steady-working contributors. Men may come to aid the work; but too often they go after dissipating a small amount of energy in recording titles and making short abstracts of papers. Two volumes, dealing with the literature of 1880–84, were brought out in 1888 and 1889; but, even with the effective help rendered by Mr. C. D. Sherborn, the Geological Record had ultimately to be abandoned.

Mr. Topley joined the British Association at the Meeting held in Brighton in 1872, and was at once made one of the Secretaries of Section C (Geology); and from 1872 to 1888 he served this office during no less than fifteen meetings. He was for several years Secretary of a committee appointed by the Association to report upon the Coast Erosion of England and Wales. He was also for some years a member of the Councils of the Geological Society and of the Geologists' Association. In 1885 he was elected President of the latter body, and during his term of office he prepared the interesting account of "The Life and Work of Professor John Morris," which he read in 1886 in place of an Anniversary Address. The long excursion of the Association for the same year was made to the Ardennes on the frontier between Belgium and France; and this, their second foreign excursion, was one of singular interest and success. It was organized with the aid of M. Dupont, but the arrangements and direction of the excursion fell largely upon the President, Mr. Topley. In the following year, aided by Professor Lebour, the President conducted the Association to many of the scenes of his former labours in Northumberland. On other occasions he led the Members to some of his old haunts in the Wealden area, and to several localities in and around London.

When the International Geological Congress arranged for a meeting in London in 1888, Mr. Topley (who had attended previous gatherings) was chosen as one of the Secretaries, and then, not only during the meeting, but for a long while before and afterwards, his energies were severely taxed with the many duties he had to perform. One feature of this London meeting was the promptitude with which the printed agenda and reports of proceedings were issued day by day—work that was only accomplished by dint of burning much midnight oil.

In 1885 Mr. Topley had prepared an elaborate Report on the National Geological Surveys of Europe; and he was much interested in the question of an international scheme of colouring for geological maps. He had, in 1881, been appointed to superintend the publication of the British section of the Geological Map of Europe, promised by the International Geological Congress; and in 1888 (conjointly with Mr. J. G. Goodchild) he prepared the excellent little Geological Map of Europe which accompanies the second volume of Prof. Prestwich's Geology.

Thus were his services in constant demand. At one time Agricultural Geology occupied a large share of his attention, and he had gathered together much material bearing on the subject, with the view of publishing a work on Soils in their relation to Geology. Several essays dealing with these matters were printed, and perhaps the most important outcome of his studies in the South-east of England was his paper dealing with the connection between the Parish Boundaries and the great physical features which are dependant on the geological structure. The subject was first brought before the Brighton meeting of the British Association in 1872, and it there attracted very considerable attention. The author showed how the ancient divisions of the land were made according to the water-supply, the soil, and situation; portions of down-land being taken to pasture sheep, the productive tracts for agriculture, and portions of forest-land, whether wood or open glade, for swine and as pasture for cattle.

In later years the subjects of Applied Geology occupied the greater part of Mr. Topley's leisure hours. He had given a good deal of attention to the mode of occurrence of Phosphates; he wrote a report on the geological distribution of Gold and Silver; discussed the schemes for the construction of a Channel Tunnel; and wrote concerning the discovery of Coal in Kent.

The subject of Water Supply, however, more than any other engaged his mind, and it was one on which he was recognised as a leading authority. The needs of Hastings, Tunbridge Wells, Croydon, Birmingham, as well as of London, and many other centres, large and small, were investigated and reported on by him; and during the sittings of the late Royal Commission on Metropolitan Water Supply he gave most important evidence, besides officially doing much work for the Commission in the preparation of maps and sections for the Report.

Sanitary Science was another branch of the subject to which he had applied his knowledge. He assisted Sir George Buchanan, in 1867, in a Report on the Distribution of Phthisis as affected by dampness of Soil; and in 1890 he was appointed chairman of Section III. of the Sanitary Institute, at the Congress held at Brighton. He then delivered an address on Geology in its relation to Hygiene, as illustrated by the Geology of Sussex.

To the study of Petroleum in its geological aspects he had latterly devoted much time, and he had in view the preparation of a treatise on that subject.

Mr. Topley's published Papers and Memoirs amount to eighty-two in number; his Survey Maps to twenty-one sheets, with three vertical and five horizontal sections, illustrating the Northumberland Coal-field and the Wealden area.

His knowledge, however, was by no means restricted to matters of professional concern. In his early days in the Weald, as Professor Le Neve Foster informs the writer, Mr. Topley was fond of Botany, and the two friends collected many specimens for determination at their field-quarters. At that time, too, he was a great reader of the works of Carlyle. Poetry, again, and the Fine Arts were subjects in which at all times he was greatly interested, and with which he possessed more than an average acquaintance.

Since 1875 Mr. Topley had been Examiner in Geology to the Durham University at the Newcastle College of Science; he also succeeded the late Mr. Bristow as Examiner in Geology to the Science and Art Department.

He was elected a Fellow of the Geological Society in 1862; an Associate of the Institute of Civil Engineers in 1874; and a Fellow of the Royal Society in 1888.

Full of energy until within about three weeks of his death, he had attended the Zurich meeting of the International Geological Congress. There, as an acknowledgment of his services, and a testimony to his wide acquaintance with the subject, the chairmanship of the Committee on Bibliography was offered to him; but this he declined on the ground of insufficient acquaintance with spoken French. Leaving Switzerland he subsequently paid a short visit to Algiers, when serious illness overtook him. He had barely time to reach his home at Croydon, ere he was prostrated, and he finally succumbed to an attack of gastritis on September 30th, 1894.

The record of his life is one of constant and unremitting labour. Yet he was ever cheery, and what was perhaps most noteworthy, however much he was occupied, he was always willing, and without any trace of impatience, to be interrupted.

It is sad to feel that he has left unaccomplished several tasks which he had planned, and which he was peculiarly well fitted to perform; but, nevertheless, he leaves behind him a substantial record of good work done. It is far sadder to think of the loss of a most kindly, amiable nature—of a true friend, whose readiness in helping others too often stood in the way of the fulfilment of his own desires. H. B. Woodward.

REV. HUGH MITCHELL, M.A., LL.D.

Born June 22nd, 1822. Died November 10th, 1894.

Hugh Mitchell was born on 22nd June, 1822, at Aberdeen, where his father held a situation in an ironwork. The son, after attending a private English school, proceeded to the City Grammar School, and afterwards went through the curriculum of Marischal College and University. He was always a diligent student, and graduated Master of Arts in 1841.

Of all the classes he attended none pleased him more than that of Natural Science, then admirably taught by Mr. John Shier, LL.D., a much abler man than the aged Professor for whom he acted as substitute. Hugh gained the second prize, and also distinguished himself highly in the chemical class. In company with the writer of this notice, he subsequently roamed the country for miles round Aberdeen, making Natural History collections. Geology and Mineralogy were his heart's love.

Having studied for the Christian ministry, he was ordained in 1848 to the Free Church of Craig, near the southern shore of the South Esk, in Forfarshire, and not far from Montrose. Many of his congregation were Ferryden fishermen, whom he spiritually benefited and whose affection he retained for the 46 years that he continued in the active discharge of his pastoral duty. He took much interest in the condition of the children, and for more than fifteen years was Chairman of the Craig School Board. Whenever leisure was obtainable, he employed it in prosecuting his scientific researches, but was careful that they should not encroach on his proper duty. Only one slight failure in this respect is remembered. The "Dundee Advertiser" in a long and appreciative notice of Dr. Mitchell, to which the writer has been much indebted in preparing this obituary notice, puts it on record. We give the details, feeling assured that the one solitary lapse will be condoned, if not even regarded with positive favour, by readers of the Geological Magazine. Mr. Mitchell had walked some miles in July, 1857, to baptise a child in a part of Forfarshire, some distance from his ordinary sphere of labour. On arriving, he found that the father had not returned from his work, so, not to lose time, the minister asked the mother to lend him a hammer, and took his way with it to a quarry. He had previously found ichthyic fragments in Canterland Den, but here, at Farnell, on splitting a slab, he laid bare a small, beautifully distinct, and almost perfect fish. He dropped the hammer, forgot all about the baptism (which he performed, with an apology, a fortnight later), and hied him homeward with his treasure. Sir Philip Egerton named it after him, *Acanthodes Mitchelli.* At the same place, the minister afterwards found two more fishes, which were named by Sir Philip, *Climatius scutiger* and *Diplacanthus* (*Ischnacanthus*) *gracilis.* The three species were exhibited in Aberdeen in 1859, in illustration of a paper read by Mr. Mitchell before the British Association at its Meeting in that city. They were afterwards figured in the Tenth Decade of the Geological Survey of England. Another fish called after him is *Pteraspis Mitchelli*, by his old friend James Powrie, F.G.S., of Reswallie, near Forfar, also like himself an ardent collector of Devonian Fishes and Crustacea. Both Sir Roderick Murchison and Sir Charles Lyell sought him out in his country "Manse," and examined his extensive palæontological and mineralogical collections.

In 1874 his *alma mater*, the University of Aberdeen, conferred on him the degree of LL.D.

Last year, being aged and infirm, he obtained a colleague to relieve him of his ministerial duties, and returned to his native city. He desired before his departure to dispose of his collection, and it was ultimately arranged that it should be sent to the British Museum (Natural History), Cromwell Road, London, which was accordingly done. The names of Dr. Mitchell's Old Red Sandstone fish specimens, now in the Geological Department of the British Museum, take up about 6½ pages of the Manuscript Catalogue.

On the forenoon of Saturday, 10th November, 1894, Dr. Mitchell peacefully passed away in his 73rd year, leaving a widow and many sympathising friends to mourn his loss. Robert Hunter.

RICHARD MEADE.

Richard Meade, who was so well known in connection with the Mining Record Office, was born in Dublin, in 1827, and died on the 12th September, 1894, after a few hours' illness. He entered the public service in 1841, in the Drawing Office of the old Houses of Parliament, as an assistant to Dr. Reid, who then had charge of the ventilating arrangements of the Houses of Parliament. Here he received instruction in drawing, and was trained as a Surveyor. In 1853, when Sir Charles Barry assumed the control of the ventilating arrangements, Mr. Meade was transferred to the Mining Record Office in the Museum of Practical Geology, as Assistant Keeper of Mining Records, under the late Mr. Robert Hunt, F.R.S.

Here, in the preparation of the volumes of "Mineral Statistics," he acquired that mastery over facts and figures connected with British mining which enabled him, in 1882, to publish his book entitled "The Coal and Iron Industries of the United Kingdom," an elaborate work,[1] the result of five years' labour, which was recognized as a standard work of reference on the subject.

On the abolition of the Mining Record Office, in 1883, Mr. Meade was transferred to the Home Office, and was appointed Clerk of Mineral Statistics, a position which he held till 1889, when ill-health necessitated his retirement from the service.

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[1] Noticed in the Geological Magazine for 1883, p. 324.

INDEX.

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