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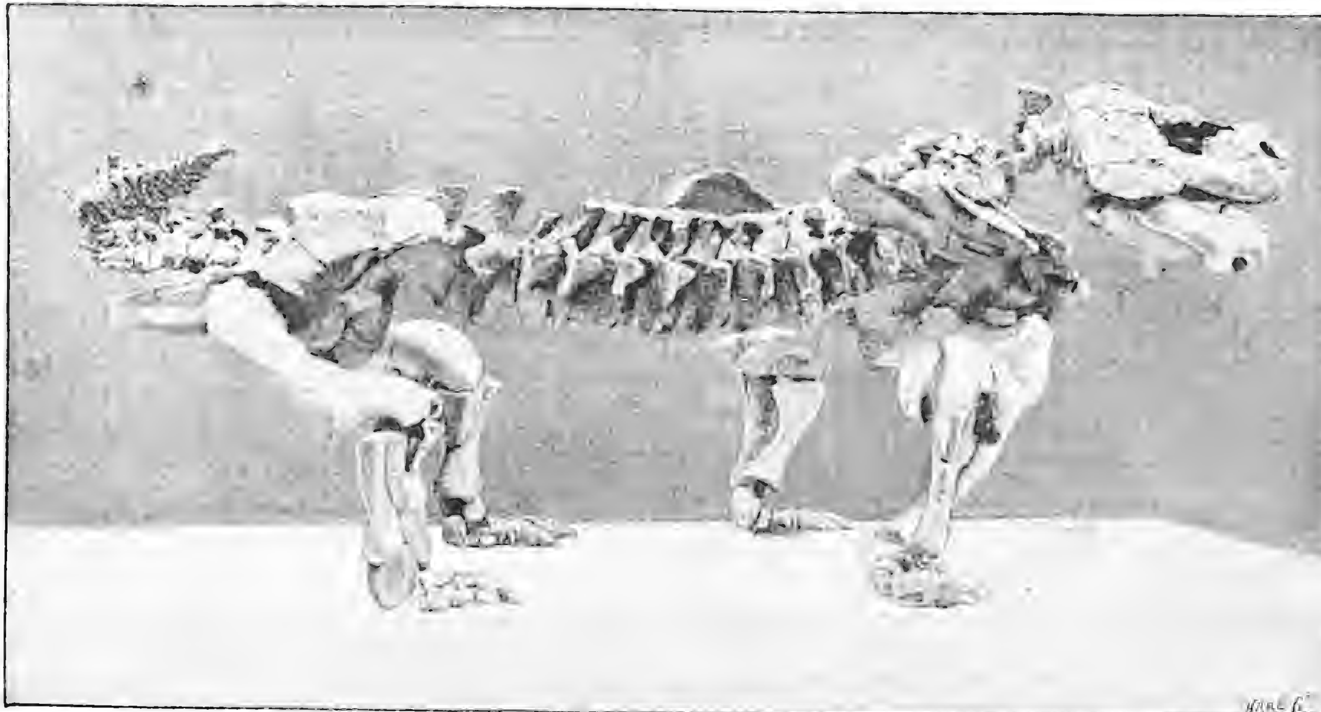

Skeleton of *Pareiasaurus Baini*, Seeley.

Karoo Formation (Trias), Bad, near Tamboer Fontein, Cape Colony.

The original preserved in the British Museum (Natural History). Length of skeleton 7 feet 9 inches.

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I.—Note on the Skeleton of *Pareiasaurus Baini*.

By Prof. H. G. Seeley, F.R.S., F.L.S., F.G.S.

(PLATE I.)

THE skeleton of *Pareiasaurus Baini*, which I brought from the Bath near Tamboer Fontein, in Cape Colony, is shown in the accompanying photograph of the right side of the specimen, as it is now mounted in the British Museum. It is the only known example of the group of animals to which it belongs, in which almost every part of the skeleton is shown. The Dicynodonts were familiar to us from the discovery of many skulls; the Theriodonts were mostly known from snouts; and the *Pareiasaurus*, although originally described from skull remains, had become known from the fine axial skeleton of *P. bombideus*, which Mr. Thomas Bain sent to the British Museum many years ago. I therefore entertained hope that the limbs and other missing parts of the skeleton might reward personal exploration in the country. The area to be examined was clearly defined as lying approximately between the Prince Albert Road Station and Fraserberg; for Dr. W. G. Atherstone had found the type of the species near the former locality, and Mr. Bain had found the specimen described by myself in 1887–8 at Palmiet Fontein, at the foot of the Nieuwveldt Range, towards the latter place.

The southern position, within easier access of the railway, offered the best hope of success, since a few farmers are scattered over the country, and there was hope that their Hottentot shepherds might have observed bones lying upon the surface of the ground; though such remains only occur in small oases among immense unproductive or desert areas. Between the Zwarteberg, on the south, and the Nieuwveldt Range on the north, the country is generally level, or but slightly undulating. At Bad the rocks become folded and more elevated; and there, by the kindly offices of Mr. J. S. Marais, and accompanied by the late Mr. Thomas Bain, I first saw the fossil dimly outlined in the hard concretionary and slaty rock, some distance up on the hill, on the 11th August, 1889, and at once determined it as the *Pareiasaurus* for which I was systematically searching. The specimen had obvious defects, due to partial exposure, the compression of some of the limb bones, and the friable condition of parts which had long been under the expanding influence of the sun. On the following day I had the pleasure of removing the remains, with the aid of my friends, from the mountain side. It was my share of the task to direct and control the quarrying operations of ten men, all through the day, to identify every part of the skeleton as it was successively exposed, so as to prevent the picks from destroying it as soon as it was touched; to mark with vermilion colour every isolated block as it was broken away from the remains, so as to have hope that they would some day be joined together again; and finally to direct the carrying of the blocks down to the boxes in the waggon which was waiting to receive them in the valley below, so as to insure that pieces which were associated should not be widely separated from each other. With the exception of Mr. Marais and Mr. Thomas Bain, I had never previously met any of the men who shared with me the labour of getting the fossil away. After many accidents, resulting from its weight being greater than the boxes obtainable were able to endure, the fossil reached the British Museum, an unprepossessing heap of rock, among which were some indications of bones.

During three months I built those fragments together, so as to restore the remains to the aspect which they presented on the mountain side on that 12th of August. And then the rock was gradually removed by Mr. Richard Hall, under my constant supervision, extending over the greater part of two years. The bones were retained in the positions in which they were found at first, till it became manifest that, by partially separating them, they might be articulated with each other. Thus a partial restoration of the form of the skeleton has been made, without attempting to restore the vertebral column to its original curvature. To this Mr. Caleb Barlow has contributed in moulding the forms of some bones on the left side, now tinted a paler colour, which were not found.

At present it would be premature to say anything concerning this animal as a contribution to the stores of knowledge of animal structure in comparative anatomy. It admits of being compared with the known groups of reptiles recent and fossil as well as with mammals. Hereafter the value of these comparisons will become evident when the fossil allies of the *Pareiasaurus* take their places by its side. Its true affinities are to a great extent masked under superficial characteristics, such as are seen in the pitted armour which roofs over the skull, in a way which parallels the labyrinthodont type, so as to show that Labyrinthodonts more closely approach reptiles than had been previously demonstrable. The single occipital condyle, even though it is almost as concave as in a Teleostian fish, leaves no doubt that the animal finds its place among true reptilia. But no animal previously known has shown such a multitude of sharp recurved teeth on the palate, coupled with teeth in sockets in the alveolar margins of the jaw; which are like those of the marine lizard *Amblyrhynchus* in general type, though the number of denticles is greater, and the successional teeth appear to be arranged uniformly in the mandible below the series in use. The most singular structure of the palate is the lateral truncation of what are probably the transverse bones, so that those bones extend between the rami of the mandible. Notwithstanding the extremely heavy build of the animal, there is much that recalls mammals in the characters of the pelvis, the shoulder-girdle, and the fore and hind limbs; so that the fossil stands alone at present in its approximation in these regions of the skeleton to the highest vertebrata, though it is the shoulder-girdle chiefly which fixes its affinity with the Monotremata. The new knowledge of the reptilian skeleton which this animal supplies gives a meaning to the term Ordinal Anomodontia, by showing resemblances in the teeth to various groups of animals which could never have been suspected from the reptilian structure of the skull, or the mammalian structure of the extremities.

It has been a pleasure to contribute a fossil which has made this animal type more intelligible; but it is no less a pleasure to acknowledge that everything has been done by Dr. Henry Woodward to secure that the specimen should receive the best treatment possible, both before and after it was presented to the National Collection.

II.—A Criticism of the Astronomical Theory of the Ice Age, and of Lord Kelvin's Suggestions in connection with a Genial Age at the Pole.

By Edward P. Culverwell, M.A., Fellow of Trinity College, Dublin.

(Part I.)

WHILE the favourable reception which the Astronomical Theory of the Ice Age has met with among scientific men has been chiefly due to the writings of Dr. Croll, its more general acceptance, especially among the semi-scientific public, has been greatly assisted by the lucid and vigorous exposition by Sir Robert Ball, in his "Cause of an Ice Age," published in 1891. But notwithstanding the apparently exhaustive way in which Croll discusses the problem, and the fact that Sir Robert Ball's work has been published in the "Modern Science" Series (indicating that the theory has secured a place among the permanent acquisitions of science), I venture to think that a careful examination of the problem will show that the theory is but a vague speculation; clothed, indeed, with a delusive semblance of severe numerical accuracy, but having no foundation in physical fact, and built up of parts which do not dovetail one into the other. The following pages contain what I hope will be admitted to be a justification of this sweeping condemnation. The first portion of my paper deals with Croll's form of the theory; the second, to be published next month, deals with Sir Robert Ball's form.

Part I. Examination of Croll's "Climate and Time."

Of the 527 pages of which the body of this work consists, only a few are occupied with the *direct* effects of the theory, somewhat more with the indirect effects, over 150 pages with the theory of oceanic circulation, upwards of 200 pages with the geological record, the age of the sun, and glacier motion. Practically, the exposition of the theory is contained in the four following chapters:—

Chap. IV. Outline of the Physical Agencies which lead to Secular Changes in Climate (pp. 54–80).

Chap. XIV. Five pages of this chapter on The Wind Theory of Oceanic Circulation in relation to Changes of Climate (pp. 226–235).

Chap. XIX. Geological Time—Probable Date of the Glacial Epoch (pp. 311–328); and

Chap. XXV. The Influence of the Obliquity of the Ecliptic on Climate, and on the Level of the Sea (pp. 398–419).

There are two other Chapters, XXIII. and XXIV. (pp. 368–397), on "The Physical Causes of the Submergence and Emergence of the Land during the Glacial epoch," which may, perhaps, be considered to be more or less closely related to the astronomical theory, but, as they are quite independent of the *origin* of the glaciation, I have not included them, nor do I intend to discuss them here, neither do I intend here to discuss the position taken up by Dr. Croll in dealing with the obliquity of the ecliptic. I have given a short criticism of it in a paper which appeared in the Phil. Mag. of December, 1894.

I.—Statement of Croll's Position.

Croll's reasoning consists of a chain of arguments, and care is necessary to distinguish them one from the other. In his view the direct effect of the astronomical cause is to lower the terrestrial temperature considerably; this lowering sets up other agencies, the indirect ones, and these operate chiefly to produce an Ice Age. In other words, Croll sets himself to answer three questions:—

1. What was the direct effect of the increase in eccentricity upon the climatic and physical condition of the earth?

2. How did this direct effect set up the indirect agencies?

3. How did these indirect agencies operate to produce a Glacial epoch?

As Croll has nowhere classified the causes he assigns in relation to these questions, I will now endeavour to exhibit each in its proper place.

Croll's Answer to Question 1.

His answer to this question resolves itself into a chain of five links, denoted here by A, B, C, D, E, and F.

(A) In a period of great eccentricity, the hemisphere which has its winter in the part of the orbit remote from the sun will have a long winter and a short summer, the greatest length of the winter being 199 days as against our 179 days, and the least length of summer being 166 days as against our 186 days (Croll, p. 57).

(B) Owing to the greater distance of the sun in this long winter much less daily sun-heat will be received in the long winter on any latitude than is now received in an equal time on the same latitude; on midwinter day the decrease will be about 16 *per cent.* of the present amount (pp. 55–57, 323).

Hence—

(C) The winter temperature, as far as directly affected by sun-heat, will be reduced by an amount which may be estimated thus:—But for the sun-heat the earth would fall to nearly the absolute zero of temperature—say, to be on the safe side, it would fall to − 239° F. (Pouillet's temperature of space). Thus in midwinter the temperature of Great Britain (about 40° F.) is kept by the sun-heat about 280° F. above what we may call its *natural zero.* Hence, roughly speaking, the decrease of 16 per cent. in the midwinter intensity of sun-heat will lower the *excess* of midwinter temperature above the temperature of space by a *proportionate* amount, *i.e.* by 45° F. (pp. 35, 37, 323).

(D) The effect of this lowering of temperature, combined with the great length of the winter, will be to increase greatly the amount of the snow-fall. In his "Discussions on Climate and Cosmology," he says that "a simple lowering of temperature such as would secure that snow instead of rain should fall for six or eight months in the year would suffice," and adds that this would follow as a direct result of the increase in eccentricity ("Climate and Time," pp. 57, 58; "Cosmology," p. 53).

(E) Although the summer sun-heat will be increased just as much as the winter sun-heat is diminished, it will be unable to melt the additional snow, and the summers will actually be colder, notwithstanding the increased sun-heat. Thus from year to year there will be an accumulation of ice, which will tend to produce on the northern hemisphere a state of glaciation (pp. 58–66, 69, 324). On p. 67, discussing Mr. Murphy's views, Croll says: "It is not correct to say that the perihelion summers of the Glacial period must have been hot. There are physical reasons, as we have just seen, which go to prove, notwithstanding the nearness of the sun at that season, the temperature would seldom, if ever, rise above the freezing-point." The physical reasons he refers to will be given in full in the criticism of this argument.

(F) As the increase of eccentricity tends to produce a state of glaciation in the hemisphere whose winters are in aphelion, so "exactly opposite effects take place in the other hemisphere, which has its winter in perihelion. There the shortness of the winters, and the highness of the temperature, owing to the sun's nearness, combine to prevent the accumulation of snow" (p. 69; repeated on p. 402).

This is a fair outline of the direct effects of the increased eccentricity on climate, as urged by Croll. We must now give his answer to the question, what indirect agency is set up by this direct effect?

His Answer to Question 2.

(G). The direct tendency of the eccentricity when the northern winters are in aphelion, and the southern in perihelion, being to produce a state of glaciation in the northern hemisphere and a genial state in the southern, the *median* line between the trade winds will be shifted very much to the south, and the great equatorial currents of the globe would be entirely changed. The Gulf Stream would be stopped, and the warm water of the tropics, instead of being carried to northern latitudes, would be sent southwards (pp. 69–71).

(H) Another effect which Croll seems to classify under the indirect agencies is, that the great heat of the summer in the tropical regions would give rise to great evaporation, which would be carried up by the aerial currents, and at last fall in snow on the ice-covered regions of the north, where, he says, the greatest snow-fall would take place in summer.

His Answer to Question 3.

The answer to the third question is now easy. Dr. Croll has been at much pains to show how greatly temperatures in northern regions depend on the enormous amount of heat transferred by the Gulf Stream and other ocean currents, so that the stoppage of these currents completes the work begun by the previous agencies, and thus accounts for the vast amount of glaciation observed.

II.—Criticism of Croll.

I now take each cause in detail and examine it.

(A) This is undoubtedly the case.

(B) Of course there is such an effect, but Croll does not seem to have observed that at *midwinter* the effect of the greater distance of the sun in diminishing the supply of heat *is entirely confined to those regions of the earth on which the sun shines*, so that it is *scarcely felt in the Arctic regions*, and it is chiefly felt in the southern tropics, where, the heat received by solar radiation being greatest, the percentage decrease is also greatest. In fact, the only difference at the North Pole is, that while it is now only 179 days without any sun-heat, it will in the time of greatest eccentricity be 199 days in the same condition. But, since the lowest temperature appears to occur in January, it seems unlikely that the slightly longer absence of the sun would make much difference.

(C) This is really the fundamental argument on which the whole theory hinges. It is quite inconsistent with another statement of Croll's, regarded by him as almost equally important, that the influence of ocean streams in raising our winter temperature is extremely great. For, if the winter temperature be so greatly due to ocean currents and not to sun-heat, what can be more improper than to treat the winter temperature as wholly due to winter sun-heat when we are getting the reduction of winter temperature due to reduction of winter sun-heat? Yet this is what Croll does. He gets the enormous reduction of 45° in midwinter temperature on the ground that the reduction of midwinter excess of temperature over − 239° F. in Great Britain must be in proportion to the reduction of sun-heat; and then he tells us that so vast is the effect of the Gulf Stream on the temperature of Great Britain that a *further* great lowering of temperature must follow its removal. Here Dr. Croll seems to have forgotten the homely proverb that you cannot eat your cake and have it. Evidently he should have estimated the proportion which the winter heat received from the Gulf Stream bears to the winter sun-heat, and then he could have estimated the percentage reduction in the *whole* heat supply due to the known reduction in *sun* heat. In addition to this, it was quite out of date for him to take a *proportionate* reduction at all. Even when the first edition of "Climate and Time" was published, physicists knew that the reduction was far less, and four years before the second edition was published, the law of the 4th power, used later on in this article to show how Dr. Croll might have worked the problem, had been published by Stefan. But Dr. Croll was content to found his theory on an assumption of Herschel in his "Outlines of Astronomy," § 369 A, although his book was written to show that Herschel was quite wrong in his conclusions on this very matter.

To show how far even the most extreme midsummer and midwinter temperatures are from being proportional to the sun-heats received at those times, take Yakutsh in Siberia, supposed to be the most extreme of terrestrial climates. The excess of its summer temperature over the — 239° F. is about 309° F., and of its winter temperature about 199° F., but the midsummer sun-heat is to the midwinter sun-heat as 5800 is to 199, or as 309 is to 11. Hence we may draw two conclusions: if the excess of midwinter temperature over — 239° F. be due to the midwinter sun-heat, then, on Croll's theory, the midsummer temperature ought to be 5800° F. above the — 239° F.; or if, on the other hand, the summer excess of 309° F. be due to the summer sun-heat, then the midwinter temperature ought, if only dependent on sun-heat, to be only 11° F. over the — 239° F., *i.e.* it ought to be — 228° F., and the rest of the 199° F. excess over the — 239° F. must be due to heat derived from other regions of the earth. If we apply this reasoning to Great Britain the difference will be more striking still, because there the midwinter excess over the — 239° F. differs little from the midsummer excess. If, instead of taking Croll's sun-heat on the single days of least and most insolation, we take Ball's *average* daily summer and winter sun-heat, the result is not, perhaps, so grotesquely different from the assumption, but it is sufficiently different to show the absurdity of the supposition; for the ratio of the average daily sun-heat in summer to that in winter is about 1000 to 199, or 309 to 62. Hence, if the winter temperature be due to the sun-heat, the summer temperature should be 1000° F. over — 239°, or, say, 760° above the zero of the Fahrenheit scale; or, if the summer temperature be that due to sun-heat, then the winter temperature ought to be — 239°+62° F., or — 177° F., instead of about — 40° F.

The plan which I have adopted for measuring the fall in temperature is as follows:—It is not difficult to ascertain what parallel of latitude *now receives the same winter sun-heat as parallel* 50° *received in the period of great eccentricity when the winter was in aphelion.* We can also do this for the parallels of 40°, 60°, 70°, 80°, and 90°. I have made the necessary calculations on three different suppositions. First, following Croll's idea, I find what parallels now receive the same *midwinter* sun-heat; second, following Ball's method, I find what latitudes now receive the same *daily average* of sun-heat in winter, *i.e.* from equinox to equinox; third, I find what latitudes now receive the same total amount of sun-heat in their coldest 199 days as the others (40°, 50°, etc.) receive in the 199 days of the supposed Glacial winter. The results are:—

First Comparison.

Latitudes 43°, 52°, 61°, 70°, 80°, and 90° now receive on midwinter day, the same or slightly less heat than latitudes 40°, 50°, 60°, 70°, 80°, and 90° received on the midwinter day in the epoch of great eccentricity. Hence, on Croll's hypothesis, we should expect the midwinter temperatures of 40°, 50°, etc., in that epoch to be about the same as those of 43°, 52°, etc., at present.

Second Comparison.

Latitudes 43·3°, 52·4°, 61·7°, 71·3°, 81°, and 90° now receive in their winter of 179 days the same or slightly less daily average of sun-heat as 40°, 50°, 60°, 70°, 80°, and 90° would receive in their supposed Glacial winter of 199 days.

Third Comparison.

Latitudes 42·2°, 54°, 63·5°, 74°, and 84·5° now receive about the same daily average of sun-heat in the 199 coldest days of the present year as 40°, 50°, 60°, 70°, and 80° received in the 199 coldest days of the period of great eccentricity.

A

It is evident that in order to find those latitudes whose *midwinter* temperatures are now the same, so far as direct sun-heat is concerned, as those of 40°, 50°, 60°, 70°, and 80° in the period of great eccentricity, we must take the latitudes somewhere about those given by the second method. For though the *midwinter* sun-heat received now by the latitudes thus obtained is decidedly less than that received by 40°, 50°, etc., in the earlier period, yet as the daily average remained at its small value during a slightly longer time in the winter of great eccentricity, there might on that account be a somewhat lower midwinter temperature (though as the lowest temperature occurs in January all over the earth, it is not likely that the extra time would produce much effect).

As to the latitudes given by the third method, they receive so much less sun-heat during the middle of the winter than 40°, 50°, etc., received in an equal time during the epoch of great eccentricity that it seems quite evident that the present *midwinter* temperatures of 44·2°, 54°, 63·5°, 74°, and 85° must be considerably lower than those of 40°, 50°, 60°, 70°, and 80° were in the period of great eccentricity, so that we are quite safe in taking them as giving the extreme limit of possible change of climate, due *directly* to the diminished sun-heat.

Now to find the fall in temperature. As we go northwards from lat. 50° to lat. 70° the decrease in midwinter temperature is 15° F.

in the meridian of Greenwich, and a mean of 25° F. in the central meridians of the American and Asian continents; in other words, the midwinter temperature of 54° N. is at present about 5° F. lower than that of 50° N. in the continents, or, in the meridian of Greenwich, about 3° F. lower. (This is, of course, taking the *average* rate of fall between 50° N. and 70° N.) But the present midwinter temperature of lat. 54°, *as directly dependent on sun-heat*, has been shown to be lower than that of lat. 50° was in the epoch of great eccentricity. Hence the temperature of lat. 50° in the supposed Glacial epoch cannot, so far as direct sun-heat is concerned, have been as much as from 3° F. to 5° F. lower than its present temperature. Similar reasoning applies to the other latitudes.

Thus the conclusion is that the lowering of midwinter temperature from 50° N. to 70° N. due to diminshed winter heat in the epoch of great eccentricity cannot have been as much as from 3° F. to 5° F.

Another way to look at it is, that the midwinter sun-heat temperature of England, which is included between the parallels of 50° and 55°, cannot have been as low as that of the region from York to the Orkneys is now.

Thus the foundation of the astronomical theory breaks down completely. It requires us to suppose that the same quantity of sun-heat as that which now, falling on Yorkshire, gives us a mild and equable climate, will, if it falls on Cornwall, produce an Ice Age; or again, that if the present winter sun-heat at Oxford were to be reduced to the amount which now falls at Melrose Abbey, such deluges of snow would cover Oxford that a summer heat *far greater than that now received there* would be unable to melt it, so that from year to year so great an accumulation of snow would result that the Gulf Stream would be turned back to the Southern Hemisphere. Observe, *a summer heat far greater than that now received at Oxford;* for, in the 166 days of the short hot summer of great eccentricity, Oxford would receive as much summer heat as is now received in an equal time by latitude 35°, say by Tangier or Algiers (see a paper in the Phil. Mag. of December, 1894).

But it is unlikely that there was any fall whatever in midwinter temperature in Great Britain during the epoch of great eccentricity; for, as we have seen, that temperature depends very greatly on the heat received from the Gulf Stream. Now, between the Azores and Ireland, the Gulf Stream is known to travel at the rate of about 3·9 miles per day, or 10 degrees in six months. Therefore, the waters whose warmth in winter keeps our climate so temperate, depend for a great portion of that winter warmth on the summer sun-heat received at a point 10 degrees to the south-west on their path; and this, as I have said, was far greater in the epoch of great eccentricity.

The numbers I have given all relate to the greatest possible eccentricity of the orbit. If we apply them to the considerable eccentricity of about 100,000 years ago, as calculated by Leverrier, we must reduce them by about one-fourth part.

(D) With the disappearance of (C), this argument also disappears.

No doubt, if there were a fall of anything like 45° F. in the mid-winter temperature of Great Britain, there would be a great increase in the fall of snow; as it is, I have shown that there would be none worth speaking of—nothing that would not be melted by a couple of soft winter days.

(E) We now come to a point on which Croll insists at great length, namely, that summer heat is less effectual in melting winter snow than winter cold is in producing it. I might pass this by as I have passed (D) by, on the ground that there would be no snow to melt, but the question is so important from a climatic point of view, and so much of the evidence seems strongly opposed to Croll's view, that it is worth examining the matter at some length, especially as Croll's view on this point is almost as necessary to the astronomical theory as the views already dealt with in (C).

According to Croll (pp. 58–60), there are three separate ways whereby accumulated masses of snow and ice tend to lower the summer temperature, viz.:—

First, by direct radiation. No matter what the intensity of the sun's rays may be, the temperature of snow and ice can never rise above 32°. Hence their presence tends by direct radiation to lower the temperature of all surrounding bodies to 32°. . . . .

[Here follow illustrations as to the summer cold in Greenland and the high Alpine regions; also the statement that if India were covered with an ice-sheet, its summers would be colder than those of England.]

Second. Another cause of the cooling effect is that the rays which fall on snow and ice are, to a great extent, reflected back into space. Even those which are not reflected but absorbed, do not raise the temperature, for they disappear in the mechanical work of melting the ice. . . . .

Third. Snow and ice lower the temperature by chilling the air and condensing the vapour into thick fogs . . . which would effectually prevent the sun's rays from reaching the earth, and the snow in consequence would remain unmelted during the entire summer.

Here follow several pages of illustrations of cold climates, those of Greenland and Hudson's Bay in the Northern Hemisphere, and South Georgia, Sandwich Land, South Shetland, Straits of Magellan, and other places in the drift-currents coming from the Antarctic regions. Thus Croll's examples are all open to the fatal objection that they are selected from regions where the sun-heat has to contend, not only with the ice or snow actually on the ground, but with cold drift-currents which bear great masses of ice and snow from the Polar regions.

A question of this kind cannot be settled by such an eclectic method. It is not by taking all the cases which at first sight may appear favourable to the view we desire to uphold that we shall arrive at the truth. No doubt there are regions exposed to cold currents of Arctic or Antarctic origin which are very much colder in summer than we should expect from the sun-heat corresponding to their latitudes, just as there are regions where, owing to warm ocean currents, the winter temperature is much higher than we should anticipate if we neglected every consideration save the winter sun-heat received; but we must make our selection of instances in a fairer way than by taking any one of these groups.

No doubt direct sun-heat falling on ice or snow is not a very powerful factor in giving rise to a thaw. Even in these climates we may verify that observation. Often there are bright crisp days with a northerly wind after a fall of snow, and though we may enjoy the warmth of the sunshine, the snow lies on the ground apparently unaffected by it. But soon comes a southerly wind, on a raw misty day, which feels perhaps far colder to us, and a sudden thaw sets in. The snow, which has been hard, becomes soft and sloppy, and finally disappears with wonderful rapidity, as often during the night as during the day. From this we learn that though sun-heat falling directly on ice or snow may have but little effect in melting it, yet it is a most effective agent if first applied to warm the land or sea elsewhere, and thus indirectly to warm the air passing over it, which air afterwards passes over the snow.

What we see on a small scale here is displayed on a vast scale in the sudden thawing of the great river basins which empty into the North Polar Sea. Mr. Henry Seebohm, in his "Siberia in Asia," describes how suddenly the river ice breaks up, and with what almost inconceivable rapidity the snow thaws over a vast extent of country when the south wind sets in. In the companion book, "Siberia in Europe," p. 89, he says: "Summer now [10th May] seemed suddenly to have burst upon us in all its strength; the sun was scorching, the snow in many places melted so rapidly as to be almost impassable." But by far the most striking account is in his Presidential Address to the Geographical Section of the British Association in 1893. Here he speaks of the "great suddenness" with which the snow melts. Again (Report, p. 828): "The stealthy approach of winter on the confines of the Polar Basin, is in strong contrast to the catastrophe which accompanies the sudden onrush of summer."

Again, speaking of the coming of summer in the basin of the Yenesei: "During the month of May there were a few signs of the possibility of some mitigation of the rigours of winter. Now and then there was a little rain, but it was always followed by frost. If it thawed one day, it froze the next; and little or no impression was made on the snow. Between May 16 and 30 . . . . migratory flocks of wild geese passed over our winter quarters; but if they were flying north one day, they were flying south the next, proving beyond doubt that their flight was premature. The geese evidently agreed with us that it ought to be summer; but it was as clear to the geese as to us that it really was winter. We afterwards learnt that during the last ten days of May a tremendous battle had been raging 600 miles as the crow flies to the southward of our position on the Arctic circle. Summer, in league with the sun, had been fighting winter and the north wind all along the line, and had been hopelessly beaten everywhere, as we were witnesses that it had been in our part of the river. At length, when the final victory of summer looked the most hopeless, a change was made in the command of the forces. Summer entered into an alliance with the south wind. The sun retired in dudgeon to his tent behind the clouds, mists obscured the landscape, a soft south wind played gently on the snow, which melted under its all-powerful influence like butter upon hot toast; the tide of battle was suddenly turned, the armies of winter soon vanished into their water and beat a hasty retreat towards the pole. The effect on the river was magical. Its thick armour of ice cracked with a loud noise, like the rattling of thunder; every twenty-four hours it was lifted up a fathom above its former level, broken up first into ice-floes and then into pack-ice, and marched down the stream at least a hundred miles [in the 24 hours]. Even at this great speed it was more than a fortnight before the last straggling ice-blocks passed our post of observation on the Arctic circle, but during that time the river had risen 70 feet above its winter level, although it was three miles wide; and we were in the middle of a blazing hot summer, picking flowers of a hundred different kinds, and feasting upon wild ducks' eggs of various species. Between May 29 and June 18, I identified sixty-four species I had not seen previous to the break-up of the ice."

And yet on June 1st the snow was 6 feet deep at his post of observation, and averaged 5 feet in the million and more square miles which are drained by the Yenesei, an area four times that drained by the Danube: *so suddenly did the south wind melt an area of one million square miles covered with snow 5 feet deep.* Nor is this out of keeping with what occurs in the other Arctic river basins. As Mr. Seebohm puts it (p. 828), "the sudden arrival of summer on the Arctic circle appears to occur at nearly the same date in all the great river basins," though probably nowhere else is it so striking as in the Yenesei.

What becomes of Dr. Croll's theory of the difficulty of melting the snow? Surely we might, with more plausibility than Croll, affirm that the Glacial period was that of the short winter and long summer. For the greater heat in winter would then be almost wholly given to the more southern or tropical regions of the hemisphere, no difference whatever being made in the heat received at the North Pole; and since the summer heating of the Gulf Stream would be much smaller than at present, it would convey less heat northward in winter than at present. Hence we might then have even more winter snow in northern latitudes than now, while in the cooler summer we might look in vain for the same generous warmth in the south wind, and so the snow would increase over the more northern Arctic regions, and by cooling these would spread further and further south, till at last the whole land was wrapped in its icy mantle; and so on. In truth, when once we leave the region of quantitative results, and plunge into that of loose argument, we are reminded of the proverb—you pay your money and you take your choice. The subject is so complicated that a skilful advocate can always make out a plausible case by carefully selecting the arguments which support the view he defends, and leaving out all the others.

Still, I think that, after reading Seebohm's graphic account of the extraordinarily sudden triumph of summer, no one will be disposed to adopt Croll's view as set forth in (E).

(F) It seems hardly necessary to discuss this argument now. It is easy to see, and is shown in the paper already referred to, that there is even less difference, so far as sun-heat is concerned, between our present climate and that of the supposed "genial age" than between our climate and that of the supposed "Glacial age."

(G) Whether the stoppage of the Gulf Stream would result from a great lowering of temperature over the northern hemisphere is a point I am not prepared to give an opinion upon. But as an argument in connection with the astronomical theory, it is absolutely dependent on the previous acceptance of (C), (D), (E), and (F), and as these have been shown to be quite erroneous, it is unnecessary to examine into (G).

(H) In taking this position as to the summer fall of snow, Croll shows such a courageous resolve to take the bull by the horns, that a close criticism seems too prosaic, and the best course is to allow (H) to march out with all the honours of war.

(*To be continued.*)

III.—On a Soda Felspar Rock at Dinas Head, North Coast of Cornwall.[1]

By Howard Fox, F.G.S.

DINAS HEAD is a promontory 4 miles west of Padstow, jutting out into the sea from Trevose Head, and separated from it by an isthmus about 100 feet above sea-level, which is washed clear of soil by the ground seas which sweep over it from the north. The headland is 165 feet above sea-level at its highest point, and is almost as broad from north to south as it is long from east to west. The base and foreshore of the headland appear to be entirely composed of greenstone containing much calcite. The microscope shows it to be probably an altered dolerite.

Between the greenstone and the slate of the district, as well as interbedded with the slate, we find a rock that covers about an acre, and assumes various characters, but all of which contain nearly 10 per cent. of soda and from 64·4 to 66·6 per cent. of silica. The compact varieties of this rock are crypto-crystalline, and may easily be mistaken for cherts. The concretionary and spherulitic varieties show grains and blades of a felspar, which is doubtless albite. It varies in colour from creamy-gray to light-brown and dark bluish-gray; it weathers white, and is often studded with cavities, some of which are not unlike pholas-holes. These cavities are filled with a rusty-brown material containing crystallized quartz. In other places this rock contains lenticles and concretions of calcareous matter of considerable size, and, when it is interbedded with slate, it is densely studded with small rusty-brown spots, sometimes

[1] Read at the British Association Meeting, Oxford, August 10th, 1894.

irregular, and sometimes of such forms as would be yielded by rhombs; they are undoubtedly pseudomorphs after a ferriferous carbonate. It has, in places, all the appearance of a stratified rock, and is distinctly banded.

In one locality it assumes a nodular form with the nodules at the outer edges of the rock, showing a radiated or spherulitic structure. The spherulites vary from 2 to 10 mm. in diameter.

The greenstone is posterior to and intrusive in this rock, and abruptly cuts across, bends, and disorders its beds. Extreme crushing has, in places, altered the original junction-line between the two rocks, and thrust-planes and fault breccias are seen. Quartz-veins traverse both rocks, but are more numerous in the soda rock.

The slate is occasionally full of ferruginous spots, and contains rusty-brown concretions in the same manner as the soda rock; it is, on the northern side of the headland, interbedded with bands of blue limestone from a few inches to several feet in thickness. There are a few bands of dark impure chert at the western end of the headland.

A rock, rich in soda, called Adinole is said to occur as a contact product due to greenstone in the Hartz.[1] The question arises whether this Dinas Head rock is an Adinole or a soda felsite. Before stating the difficulties in the way of either hypothesis, we will examine the headland more in detail.

In approaching Dinas Head from Trevose Head there are blocks of quartz lying about on the grass which from a distance look like sheep. These blocks are apparently fissure quartz. One of them which lies nearest to the public road to the lighthouse is composed of orbicular quartz, internally radiated, the individual radiated spheres varying in size up to 1 inch in diameter.

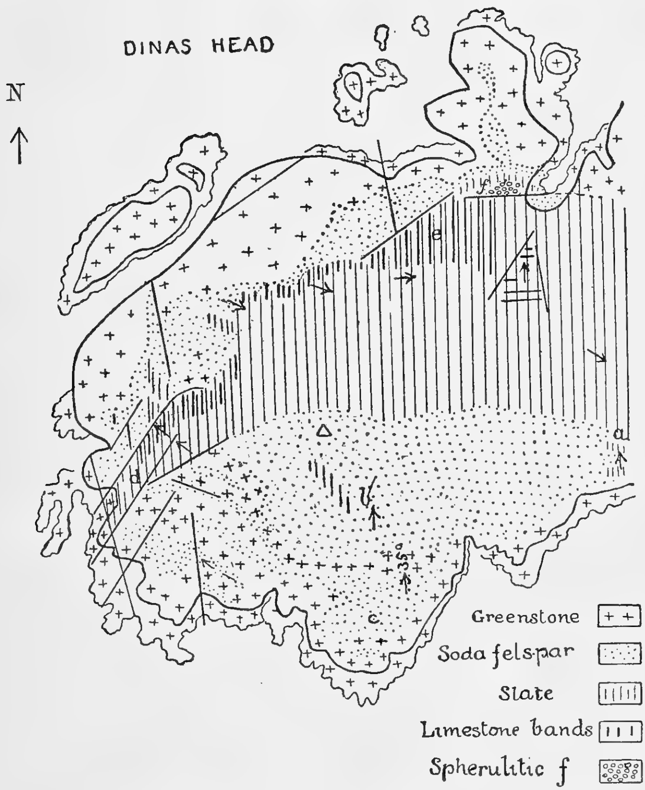
The isthmus connecting Trevose Head with Dinas Head is bare of soil, the slate exposed is thinly laminated, bluish-brown, and friable, with traces of badly-preserved organic remains. The slates show reeding structure. The sea-water that breaks over it from the north has worn channels to the edge of the precipitous cliff on the south side at "*a*" in the annexed Map (which is copied from the 25-inch parish map, and may be taken to be approximately accurate, though only indicating some of the numerous faults). In one of these channels, alternate beds of this soda rock and of slate are exposed for a length of thirty feet, dipping in a northerly direction in conformity with the prevailing dip of the district. The beds of the soda rock vary from 1 inch to several feet in thickness, they weather bluish-white, with prominent thin parallel bands or ridges so closely set that there is often only 1 mm. between them. The surface is pitted all over with minute cavities and brown spots. Mr. Teall kindly examined a section of this rock, and sent me the following description :—

"Compact banded bluish-gray rock with brown rusty spots. Under the microscope the structure of the main mass of the rock is seen to be crypto-crystalline, but the nature of the material cannot

[1] *Vide* Brit. Petrology, Teall, pp. 217–219.

be determined. The brown rusty spots are sometimes irregular and sometimes of such forms as would be yielded by rhombs. There can be no doubt that they are pseudomorphs after a ferriferous carbonate."

Proceeding westward we find near the highest point of the headland some slate surrounded by the soda rock at "*b*." The soda rock is here mostly compact, dark bluish-gray in colour, and weathers white. A knife will not scratch the dark rock but will scratch



Diagrammatic map of Dinas Head, 208 feet to the inch.

the white crust. One specimen from this spot shows the ferruginous material in closely set parallel bands, or in curved sutures, or massed together somewhat in circular form on one side, whilst the other side of the specimen is uniform in colour with several minute holes from ½ to 1 mm. in diameter.

Descending the cliff due south from this point we pass over alternate exposures of greenstone and soda rock. The latter near the bottom of the descent is at "*c*" thinly bedded, dipping in a northerly direction at an angle of about 35°. It is studded with cylindrical cavities, which have been filled with rusty-coloured material containing crystallized quartz. This rusty material occasionally weathers out as nodules 8–10 mm. in diameter, projecting from 10–15 mm. beyond the white surface of the rock. The rusty material has, however, in most cases worn away faster than the matrix, and left the rock dotted thickly with conspicuous rusty-coloured depressions. In some places the rusty material forms lenticles and fills up cavities between the beds of the rock.

Dr. Hinde examined a section of this rock for me, and thus refers to the white weathered portion: "The white crust appears as if of a flaky character and forming numerous extremely thin layers. Whether these represent layers of original bedding seems doubtful, but it is possible that it might be so."

As we proceed in a north-westerly direction from "*c*" we pass over exposures which show that the igneous rock was posterior to and intrusive in the soda rock, the beds of the latter being bent, disordered, and cut across, as seen in Fig. 2, which with Figs. 1 and 3, are taken from the original sketches of Sir Archibald Geikie, whom I had the pleasure of accompanying to the spot.

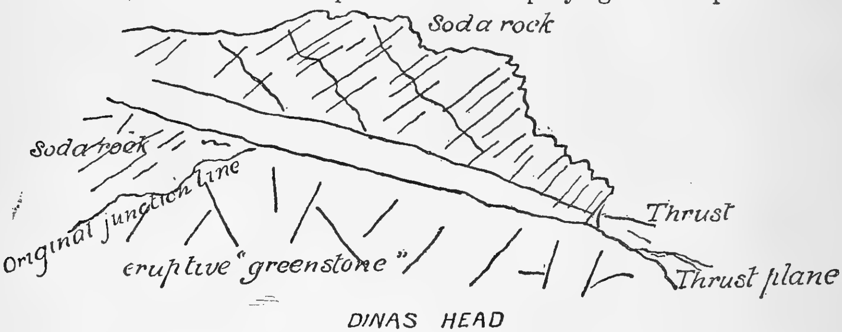


Fig. 1. Sketch of junction of greenstone and soda rock on Southern Cliff of Dinas Head, showing movement since intrusion of greenstone.

That there has been considerable movement since the intrusion of the greenstone is shown by Fig. 1, where a thrust-plane is indicated. In some places the rocks have been shattered and re-cemented by quartz, and quartz-veins run through both the igneous and the soda rock, being more numerous in the latter. In one place a mass of soda rock 15 feet long is enclosed in the greenstone.

Further west we find the cliff shattered with faults, and at "*d*" the soda rock and the dark compact slates contain round and oblong rusty-coloured concretions of dolomitic character, from an inch to several feet in diameter. The concretions frequently have concentric structures around them. Just above "*d*" there are dolomitic bands 4 feet thick, as shown in Fig. 3. Here a dolomitic band "*b*," 4 feet thick, is interbedded with dark cherty slates "*a*," in which are concretions and lenticles of dolomite, many of the concretions having concentric structure. The thrust-plane "*c*" has a dolomitic fault breccia lying in cakes about it. A section of a concretion is thus described by Mr. Teall: "A coarsely crystalline aggregate, mainly composed of a carbonate which does not effervesce with cold acid. Probably a dolomite."

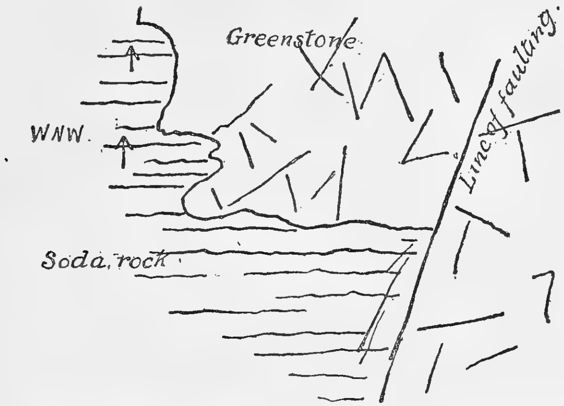
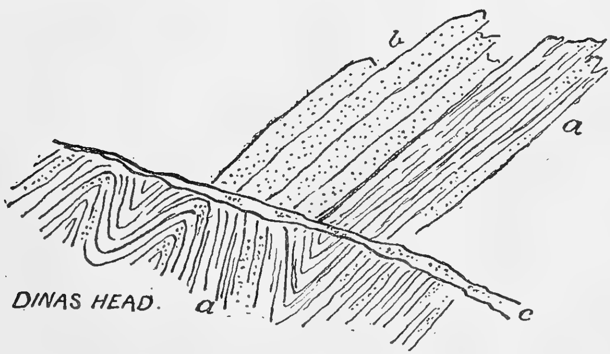


FIG. 2. Sketch of junction of greenstone and soda rock on Southern Cliff of Dinas Head, showing that the greenstone cuts across and disturbs the beds of the soda rock.

Further up the cliff the soda rock and slate are interbedded, both showing rusty-coloured lamination. The strata between these faults are much twisted and disordered. In one place a dark cherty band



IG. 3. Sketch of section on Western Cliff of Dinas Head, showing—
"*a*" Dark cherty slate with concretions and lenticles of dolomite. The concretions with occasional concentric structure.
"*b*" Dolomitic band about 4 feet thick interbedded with slate.
"*c*" Thrust-plane with a dolomitic fault breccia lying in cakes about it.

is seen to make a loop several feet long, enclosing calcareous rock.[1] Blue limestone bands are also interbedded with the slates in this district.

[1] We find similar bands of dark chert, rolled with dark calcareous rock, at Cataclews Point, $1\frac{1}{2}$ miles east of Dinas Head.

Continuing our progress along the northern side of the headland, we find the greenstone and soda rock much intermixed, and compact blue slate is interbanded with numerous blue limestone bands, from a few inches to several feet in thickness, dipping south of east. Both slate and limestone occasionally weather in circular holes and contain rusty-coloured material in the same way as the soda rock.

Dr. Hinde found that a section of the blue limestone from "*e*" was principally made of echinodermal fragments, probably of crinoids, and there were also portions of Polyzoa like *Fenestella.*

At "*f*" we find this soda rock, for an area of 30 square feet, assuming a gray nodular character. The compact rock passes into one composed of gray nodules from 3 to 10 mm. in diameter, as shown in Fig. 4. The nodules at the outer edge of one portion of this rock show spherulitic structure. The spherulites are crowded together, and occasionally attain a diameter of 10 mm. Thin veins of quartz traverse the nodules, which often weather gray, in cup-shaped prominences. In other cases they weather white, and the polygonal sutures, filled with ferruginous matter, give the rock a scale-like or mosaic appearance.

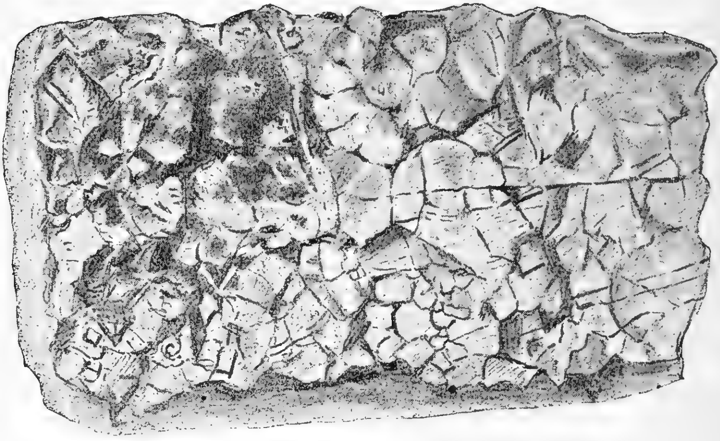


Fig. 4. Sketch (natural size) of gray nodular soda rock with spherulitic structure, from the Northern Cliff of Dinas Head.

Mr. Teall examined three sections of this rock, and reported as follows:—

"No. 353. A remarkable spherulitic rock. Spherules sometimes measuring $\frac{1}{4}$ inch in diameter.

The central portions of the spherules are generally composed of crypto-crystalline material. The outer portions of radiating blades or prisms of felspar, presumably albite. Ferric oxide, probably resulting from the decomposition of a ferriferous carbonate, is scattered through the slide in irregular patches, and concentrated in veins. Some of the patches by their form suggest that the ferric oxide is a pseudomorph after a carbonate.

The interference of adjacent spherulites produce polygonal sutures, in which the ferric oxide is sometimes concentrated; but it occurs also in the spherulites.

No. 354. Similar to the last. Ferric oxide in radial streaks between the blades or prisms of felspar which form the radial portions of the spherulites.

No. 355. Similar to above, but with the ferric oxide almost wholly concentrated in the polygonal sutures formed by the mutual interference of adjacent spherulites."

As the microscope failed to disclose the composition of this rock, I sent specimens of the three chief varieties to Mr. J. J. Beringer, F.C.S., of Camborne, who kindly consented to analyse them. He entrusted much of the work to his pupil, Mr. Arthur F. Hosking, and sent me the following results:—

I. Specimen was the light brownish chert-like variety, weathering white, with cavities filled with rusty-brown material from "*c*" in map.

II. Specimen was the dark bluish-gray compact variety, weathering white, from "*b*" in map.

III. Specimen was the gray nodular variety from "*f*" in map.

	I.	II.	III.
Loss on ignition	1·7	1·3	1·6
Silica	64·4	64·8	64·6
Titanic acid	1·0	1·5	1·2
Alumina	20·2	19·9	20·4
Ferric oxide	0·7	0·7	0·7
Lime	1·6	0·7	1·3
Magnesia	0·2	0·1	0·1
Alkalies	10·4	10·2	10·1

Mr. Beringer adds: "The silica in III. was not directly determined. The alkali is mainly soda; by trituration with acid it represented 9·6 per cent. of soda, on the assumption that soda was the only alkali present. In I. and III. the bulk of the iron and lime is in a form easily soluble in acids; this is partly true of II., but the soluble fraction is very small."

In a subsequent communication Mr. Beringer informed me that the potash in one of these specimens was 0·47 per cent.

I am indebted to Mr. J. Hort Player, F.C.S., of London, for the following analysis of the compact light-brown chert-like rock from "*c*," free from weathered crust or nodules.

Dinas Head Rock.

Silica	66·6
Titanic acid	·8
Alumina	19·6
Ferric oxide	·9
Ferrous oxide	·2
Magnesia	·3
Lime	·4
Soda	9·8
Potash	·7
Loss by ignition	·8
	100·1

April 28, 1894. J. Hort Player.

These analyses show that if this Dinas Head rock be an adinole it contains a larger per-centage of soda than any adinole hitherto analysed.

Schenck found in the Hartz adinole 7·14 per cent. of soda in one specimen, and Kayser[1] found 7·54 per cent. of soda in adinole next the diabase.

That the greenstones of the Dinas Head district contain enough soda to account for the impregnation of sedimentary rocks into which they have intruded may be inferred from Mr. J. A. Phillips' analyses of many so-called greenstones in North and Central Cornwall, published in the Quart. Journ. Geol. Soc. for 1878, in which he records several of them as containing over 5 per cent. of soda; one as much as 5·84 per cent.

Supposing the Dinas Head rock to be an adinole, two difficulties have to be met: How does it become interstratified with slate? How do the spherulitic and concretionary structures arise?

Mr. Teall informs me that the presence of ferriferous carbonate favours the theory of its being an altered sedimentary rock, whilst the spherulitic and concretionary structures favour the theory of its being an igneous rock, viz. a soda felsite or keratophyre.

I am not prepared to explain the origin of this rock, but it is certainly of interest on account of its remarkable composition.

IV.—On some Fossil Ostracoda from Canada.

By Prof. T. Rupert Jones, F.R.S., F.G.S., etc.

(PLATE II.)

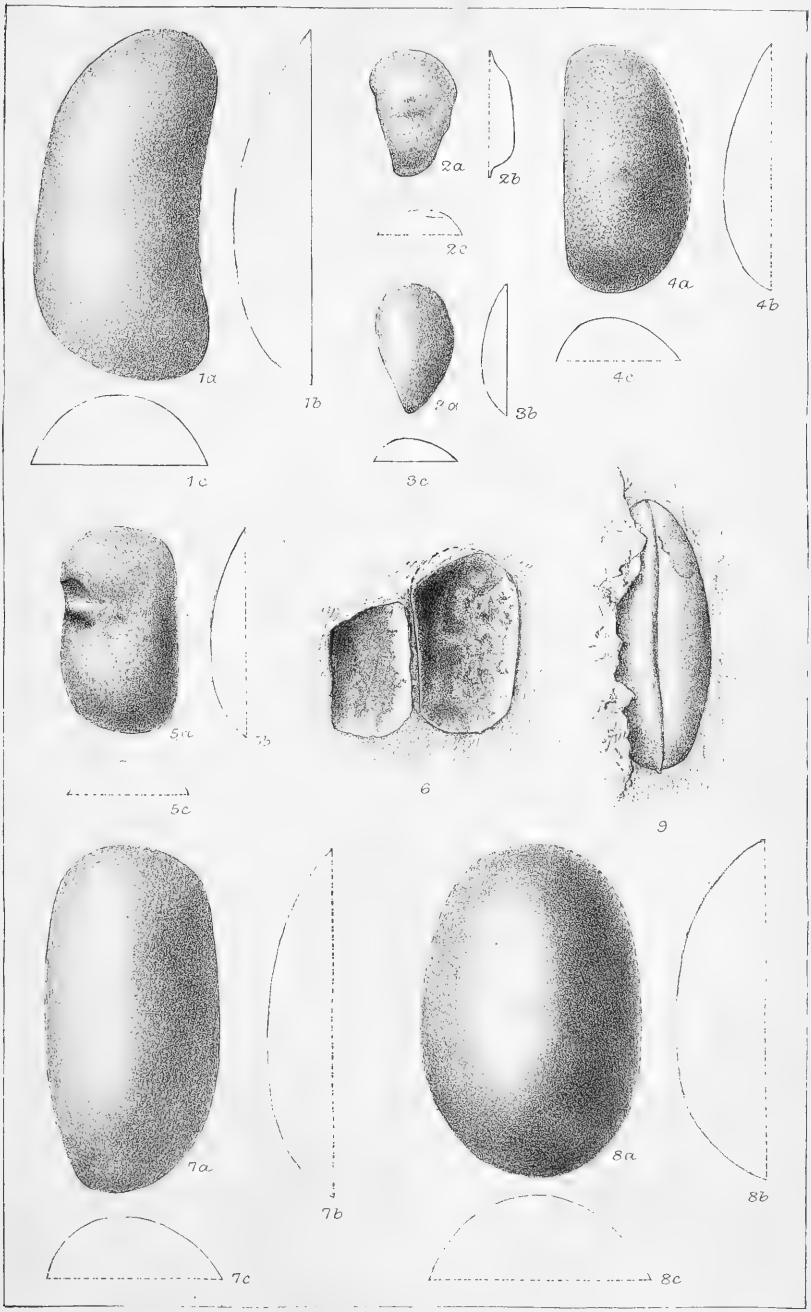
Contents.

§ 1. *Introduction.*

The specimens here referred to belong to the Geological Survey of Canada, having been collected—I. some (of Quaternary age) by Mr. J. B. Tyrrell, B.Sc., F.G.S., in 1887, on the Rolling River two miles above Heart Hill in Manitoba.

II. Small pieces of a loose block, lying by the South Branch of

[1] Kayser, Hartz Z. Geol. Ges. xxii. 1870, p. 103.



E. C. Knight del. et lith. West, Newman imp.

Fossil Ostracoda, Canada.

the Milk River, in Southern Alberta, North-west Territory, but belonging to the Saint-Mary-River Beds. Collected by Dr. G. M. Dawson in 1874, when he was the Geologist and Botanist to the British North-American Boundary Commission.

III. Some specimens from the Saint-Mary-River Beds of the Lower Laramie series, on the North Branch of the Milk River, and of either newest Cretaceous, or oldest Tertiary age; also collected by Dr. G. M. Dawson in 1874.

IV. One small specimen from the St.-Mary-River Beds; collected by Dr. G. M. Dawson in 1881, on the Old-Man River in the Alberta District.

With regard to II. and III. we note that in Dr. Dawson's "Report on the Geology and Resources of the Region in the Vicinity of the Forty-ninth Parallel," etc., 1875, the geology of the First [now the South] Branch of the Milk River is briefly noticed at page 130; and the Second [now the North] Branch (14 miles to the west) at page 131. The fossils generally at these sections appear to have freshwater characters for the most part (pages 155–158). See also further on, page 25.

§ 2. *Description of the Species.*

From among the several more or less distinct examples, the following have been selected.

Only with two or three of the figured specimens (as Figs. 1 and 3) is there direct evidence of the exact outline of the margins of the valves, as shown in Figs. *b* and *c* throughout the series, owing to the imbedment, or the close adherence of the valves to the rock by their edges. For the same reason, for want of direct evidence of the hingement of the valves, the generic position of the majority is very uncertain, and only provisionally suggested.

Mr. Frederick Chapman has kindly helped me in preparing and determining the specimens.

I. Seven small pieces of grey and yellowish friable marl, containing numerous thin shining valves, and casts of similar forms. These are from the Rolling River, Manitoba. The geological conditions are described at pages 115 E, and 116 E, of the "Report on North-western Manitoba, with portions of the adjacent districts of Assiniboia and Saskatchewan." By J. B. Tyrrell, M.A., B.Sc., F.G.S. Part E of Annual Report of the Geological Survey of Canada, vol. v. 1889–90–91. 8vo. Ottawa, 1892.

Thus:—

Rolling River was examined from a point a short distance west of the 101st meridian, where it is about 2250 feet above the sea. It is here a small stream in a valley fifteen feet deep, with a Spruce swamp on both sides. Its bed is covered with boulders, and its channel is much obstructed by beaver-dams. A short distance lower down it flows in a deep valley, the sides of which show some excellent sections of Pleistocene deposits. One of these sections on the north bank is as follows:—

	Feet.	in.
1. Stratified gravel	10?	0
2. Unstratified Till with striated pebbles	22	0
3. Stratified sandy clay, becoming almost a pure laminated clay at bottom, where it contains many plants and freshwater shells,—such as *Taxus baccata*, *Elodea Canadensis*, *Vallisneria*?, *Navicula lata*, *Encyonema prostratum*, *Denticula lauta*, *Licmophora*, *Cocconeis*; *Lymnæa catascopium*?, *Valvata tricarinata* (and a keelless variety), *Amnicola porata*?, *Planorbis parvus*?, *P. bicarinatus*, *Pisidium abditum*, and *Sphærium striatinum*	6	0
4. Stratified grey sandy clay	20	0
5. Slightly sandy stratified clay, coloured dark-brown with bituminous matter, and containing a few small bivalves	1	10
6. Plastic clay	5	0
7. Coarse stratified sand	12	0
Covered down to the water	12	0

The specimens under notice were probably taken from the stratum No. 3 of the foregoing section.

Candona, Baird, 1845.

1. Candona candida (Müller, 1785). Pl. II. Figs. 1*a*, *b*, *c*.

Length 1·88, height ·88, thickness ·8 mm.

The most common Ostracods in these marls are such as is shown by Fig. 1, evidently closely related to, and probably identical with, the freshwater *Candona candida* (Müller), especially as shown by pl. i. figs. 8*a*, *b*, *c*, and described at p. 19, "Monogr. Tert. Entom. England," Palæont. Soc. 1856, and "Supplement," 1889, p. 13. The posterior extremity, however, is thicker than in fig. 8*b*, and is such as is seen in some varieties of the species, as depicted by Brady and Norman in pl. 10, "Transact. Royal Dublin Society," series 2, vol. iv. p. 38, 1889, and chiefly in the male individuals. For a bibliography of *Candona candida* as a living Ostracod, see Wenzel Vávra's memoir on the Ostracoda of Bohemia, in the Archiv naturw. Landesd. Böhmen, vol. viii. No. 3, 1891, p. 48.

The specimens under notice are subreniform and rather elongate; with unequal ends, the anterior being smaller and more compressed than the posterior extremity. The dorsal margin is arched, but straight along the hinge-line; the ventral edge is sinuous, with its middle part incurved. Surface smooth, neatly and moderately convex; somewhat fuller behind than in the front third.

Several in the freshwater marl on the Rolling River, which at about 101° W. Long. and 64° N. Lat. runs from the Ducks Mountains into the Swan River for the Swan Lake; and this is connected with the south side of the northern part (Dowson's Bay) of the Winnepegosis Lake, in Manitoba. See the Geol. Mag. 1893, p. 388, for some remarks on an analogous *Candona* from the Montana formation in Utah, U.S.A.

One or more specimens having the appearance of *Ilyobates reptans* are imperfect.

CYTHERIDEA, Bosquet, 1850.

2. CYTHERIDEA TYRRELLII, sp. nov. Pl. II. Figs. 2*a*, *b*, *c*.

Length ·72, height ·44, thickness ·32 mm.

Trigonal, broadly rounded in front, obliquely subacute behind; surface not much raised, almost flat, and sloping off suddenly to the edges. Two or three small knobs or pimples are grouped on the middle of the valve, and near by there is one larger and closer to the dorsal edge. The surface also is punctate.

The outline and sculpturing of the shell are not strange in *Cytheridea*; *C. Muelleri*, var. *torosa*, Jones (Monogr. Tert. Entom. p. 42, pl. vi. fig. 12, is one of the nearest of the published forms). The species under notice, named after its discoverer, is rather common in the marl from Rolling River, Manitoba. It probably lived in brackish water.

The species Nos. 1 and 2 indicate freshwater and brackish condition for the deposits in which they occur.

II. Seven small pieces of an "unattached" block, found on the South Branch of the Milk River. They consist of dark-brown or blackish limestone, containing small Gasteropods like *Paludina* and fragments of *Cyrena*-like valves, together with several black and dark-brown, shining Ostracoda. Although met with where the South Branch runs over the Belly-River Beds[1] (Cretaceous),[2] this block was recognized as belonging to the Saint-Mary-River Series, as explained at 37 C of the "Geological and Natural-History Survey and Museum of Canada, Report of Progress, 1882–3–4," 8vo. Montreal, 1885, with maps.

PONTOCYPRIS, G. O. Sars, 1865.

3. PONTOCYPRIS PYRIFORMIS, sp. nov. Pl. II. Figs. 3*a*, *b*, *c*.

Length ·72, height ·4, thickness ·32 mm.

Trigonal, pear-shaped, boldly-rounded in front, contracted to a sharp point behind; boldly arched on the dorsal and sloping with a slight sinuosity on the ventral border, both meeting at an acute angle posteriorly. Surface smooth, moderately and almost uniformly convex, but slightly more swollen towards the ventral region. Probably of brackish-water habitat. One valve in blackish limestone from an unattached block found at the South Branch of the Milk River, N.W. Territory.

Among several published forms more or less resembling this in shape, one variety of Reuss's *Cytherideis lævigata* (in Geinitz's "Elbthalgebirge in Sachsen," 1874, p. 150, pl. xxviii. fig. 3) is perhaps the nearest in shape, but it is not so pyriform, and is much

[1] These strata on the South Branch (Report of Progress, 1885, page 39 C) show sandstones, with some ironstone; and a few miles further down these are overlain by greyish and blackish bedded shales and sandstones, with a carbonaceous layer; and in them, among some fragments of shells, *Unio* was determined.

[2] *Ibid.* p. 119 C.

thicker, the valve being more convex. A much more pyriform valve of *Pontocypris*, with an acute posterior extremity, is Reuss's *Bairdia subfalcata*, Sitzungsb. Akad. Wiss. Wien, vol. xviii. 1885, p. 253, pl. ix. fig. 91; but it is much narrower than our Fig. 3, and its ventral margin is much more incurved.

One specimen in the loose block of Saint-Mary-River Beds.

Cypris, Müller, 1785.

4. Cypris Dawsoni, sp. nov. Pl. II. Figs. 4*a*, *b*, *c*.

Length 1·32, height ·64, thickness ·56 mm.

A neat suboblong valve, straight on the ventral, elliptically curved on the dorsal margin; ends almost equal in their semicircular curve, but the anterior rather smaller and more compressed than the posterior; both curving off from the dorsal and meeting the ventral margin with a definite angle. Surface gently convex; smooth; minutely dimpled with probably the remains of a punctation nearly worn away or partially dissolved; it is also marked centrally with an obscure dark muscle-spot.

Named after Dr. G. M. Dawson, F.R.S., who collected this and many other interesting specimens of Natural-history in his expedition along the 49th parallel.

There are some few forms of the marine genera *Xestoleberis* and *Krithe* that have an approach to this figure in shape; but it is among some freshwater genera that we find the nearest resemblances. Ostracods of this form, with straight ventral and well-arched dorsal margin, and nearly equal ends, are mostly found among the freshwater *Cyprididæ*; and of the published figures we may point to—

1. *Cypris incongruens*, Ramdohr. Trans. Linn. Soc. vol. xxvi. 1868, p. 363, pl. xxiii. figs. 16-19.
2. *Scottia Browniana* (Jones). Trans. R. Dublin Soc. ser. 2, vol. iv. 1889, p. 72, pl. ix. figs. 23, 24.
3. *Erpetocypris strigata* (Müller). *Ibid.* p. 85, pl. viii. figs. 14, 15.

The first, however, differs from our Fig. 4 in the outline of both extremities; the second is by far too tumid, and has a too boldly arched back; and the third has the proportions of the ends reversed, that is, it is somewhat higher in front than behind.

This one specimen is in a piece of the loose block found at the South Branch of the Milk River, but belonging to the Saint-Mary-River Beds higher up the valley.

Ilyocypris, Brady and Norman, 1889.

5. Ilyocypris oblonga, sp. nov. Pl. II. Figs. 5*a*, *b*, *c*.

Length 1·12, height ·6, thickness ·10 mm.

Oblong, slightly sinuous on the dorsal and quite straight on the ventral margin, gently curved at the ends, each of which meets the dorsal edge with a curve, and the ventral with a blunt angle. The anterior slightly smaller than the other end. Surface gently and irregularly convex, sloping down to the edges; obscurely dimpled all over; marked with an obscure central muscle-spot in a faint depression, and behind it with two roughly triangular sulci, close together, and reaching to the hinge-line.

Candona euplectella, Robertson, Brady, and Norman, has a nearly oblong outline, but no sulcus, and is too thick to be comparable with our Fig. 5. On the other hand, some examples of the freshwater *Limnicythere* and *Ilyocypris* have variable transverse depressions and suboblong valves; and of these *Ilyocypris gibba*[1] (*Cypris*, Ramdohr) has the nearest resemblance to Fig. 5. *Bythocythere constricta*, G. O. Sars, is one of the few analogues among the marine *Cytheridæ*.

Four specimens in fragments of the unattached block of Saint-Mary-River Beds, above mentioned.

Nos. 3, 4, and 5 indicate brackish and freshwater habitats.

III. Six small specimens of light- and dark-brown limestone, four from the nodular, and two from the concretionary layer, with small *Paludinæ*, from the North Branch of the Milk River, which, in the "Report of Progress, Geol. Survey of Canada," 1885, at pages 13 C and 36 C, is described as rising in the foot-hills south of the 49th parallel; crossing that line near the 113th meridian, it pursues a north-easterly tortuous course. Its North Branch was termed the "Second Branch" in the "Report on the Geology and Resources of the 49th Parallel," p. 131; and its geology was described in the "Report of Progress," 1885, pages 36 C and 37 C, thus:—

The strata in the river-valley here belong to the Saint-Mary-River subdivision, showing about fifty feet of soft sandstones and shales, with harder bands, one of which is a nodular ferruginous limestone, one foot thick, with *Bulinus*, *Limnæa*, *Physa*, and *Sphærium*. A *loose* block of similar rock was found about fourteen miles south-eastward, at the crossing of the 49th parallel and the South Branch of the Milk River (termed "First Branch" in the Report of 1875); and the stratum to which it belonged is the same as that occurring in the upper part of the Saint-Mary-River Series (page 58 C). This series constitutes the lowest portion of the Laramie formation; and consists of sandstones, shales, and shaly clays in frequent alternations, and generally well bedded. Freshwater except near base: 2800 feet. See also pages 114 C, 97 C, 57 C, and 37 C, for other details. With the Willow-Creek Beds, next in upward succession, and the Porcupine-Hill Beds at the top, these three subdivisions constitute the Laramie Group in the District of the North-west Territory. But some of the Laramie is regarded as transitional from the Cretaceous to the Tertiary; the plant-remains being Tertiary, and the other fossils Cretaceous.

Cythere, Müller, 1785.

6. Cythere, sp. indeterminate. Pl. II. Figs. 6*a*, *b*, *c*.

Length 1·0? height ·6 mm.

Two contiguous valves, showing insides; both imperfect, but one

[1] For Synonyms, see Supplem. Monogr. Tert. Entom. Pal. Soc. 1889, p. 9; and Trans. R. Dublin Soc. ser. 4, vol. ii. 1889, p. 107.

of them (apparently a right valve) retains all its outline except the antero-ventral curve. The edges have been divested of their special characters by the loss of substance.

Valve broad-oblong, with the dorsal and ventral margins nearly straight and parallel; hinge-line distinct but not the method of hingement; semicircular posteriorly, and obliquely rounded (broken) anteriorly.

Such subquadrate carapaces occur among species of *Cythere*, *Cytheridea*, and *Loxoconcha*: as *Cythere fusca*, *C. Jurinei*, *C. lutea*, and *Loxoconche pusilla.* In the "Proceed. Bath Nat. Hist. Antiq. Field Club," vol. vi. 1868, pl. i. fig. 6, shows such an oblong *Cythere*, and figs. 5, 7, and 8 some *Cytherideæ* of similar shape, all from the Fuller's-earth Oolite.

The absence of characteristic features beside the mere outline precludes a definite determination beyond the fact that the species may be assigned to the marine genus *Cythere.*

This specimen of two valves occurs on the same piece of limestone with Fig. 7.

Candona, Baird, 1845.

7. Candona (?) Sanctæ-Mariæ, sp. nov. Pl. II. Figs. 7*a*, *b*, *c*.

Length 1·84, height ·92, thickness ·8 mm.

Suboblong and irregularly elliptical; semicircular in front, narrower and obliquely rounded behind; ventral edge slightly convex, dorsal partly straight (on the hinge-line), rapidly curving in front, and curved with a gentler slope behind, making a narrow and almost subacute oblique posterior margin. Surface smooth and uniformly convex, but more gently sloping in the dorsal than in the ventral region (Fig. 7*c*).

Two specimens in greyish-brown limestone of the nodular layer, with small molluscs like *Paludina, Planorbis*, etc. From the North Branch of the Milk River.

This form of carapace-valve is rare among the Ostracoda generally, but there is an approach to it in *Cythere* sometimes (as in *C. teres*, Trans. R. Dublin Soc., n.s. vol. iv. p. 133, pl. xiv. figs. 36, 37); also occasionally in *Krithe*, but from this it differs posteriorly. Its nearest figured representative is the freshwater *Candona lactea* as shown in the Trans. Linn. Soc. vol. xxv. pl. xxiv. figs. 54–58.

Cytherella, Bosquet, 1852.

8. Cytherella crucifera, sp. nov. Pl. II. Figs. 8*a*, *b*, *c*.

Length 1·75, height 1·2, thickness 1·04 mm.

Valve obtusely suboval; ends almost equal; one edge less fully curved than the other; uniformly convex, smooth, and marked with a small, round, central depression, which is divided into four little triangular spaces by a very slightly raised, whitish, cruciform line.

Unfortunately we cannot judge of the marginal characters of this specimen. The oval and smooth aspect suggests the marine *Cytherella* for the genus; and the full convexity is not inimical to the idea, for *C. ovata* (Roemer), *C. elliptica*, Brady, and particularly *C. lata*, Brady, are more convex than the generality of the species; and so also *Bosquetia robusta*, Brady, Robertson, and Norman, a near ally, though smaller, is relatively quite as convex. None of these exhibit so peculiar a muscle-spot as is seen in Fig. 8*a*. The valve under notice probably belonged to a *Cytherella*, but is different from any known.

One specimen from the Saint-Mary-River Beds on the North Branch of the Milk River, North-west Territory.

The species Nos. 6 and 8 indicate marine, and No. 7 freshwater conditions, for the Saint-Mary-River Beds from which they came. Sometimes fluviatile species are brought down to the sea-beaches; and for an example see Monogr. Tert. Entom. Pal. Soc. 1856, page 17. Nos. 3, 4, and 5 (pages 23, 24) from a loose block of Saint-Mary-River Beds are freshwater and brackish, without anything definitely marine. No. 9 also, from the Old-Man River, is in favour of freshwater conditions.

IV. One small specimen of brownish limestone of the Saint-Mary-River Beds from the Old-Man River, Alberta District, North-west Territory. It contains a distinct joint-edge, in the united dorsal margins of two valves of an Ostracod.

The Old-Man River, a tributary of the Belly River, runs eastward (about 48° 40′ N. lat.) from the Livingstone Range (about 114° 40′ W. long.); and its "north bend" (about 49° 70′ N. lat. and 113° 50′ W. long.) runs on the Saint-Mary-River subdivision (lowest) of the Laramie formation. See the "Report of Progress" for 1882–84, page 67 C, and Map No. 1.

Candona, Baird, 1845.

9. Candona (?), sp. indeterminate. Pl. II. Fig. 9.

Length 1·44, height ?, thickness ·56 ? mm.

Dorsal junction of two valves; hinge-line defined by the slight prominences terminating the inflection of the edges.

This resembles to some extent the external appearance of the hingement and dorsal aspect of several species among the marine *Cytheridæ*,—namely, *Cytherura*, *Xestoleberis*, *Krithe*,—but more closely that frequently seen in the freshwater *Cypris* and *Candona*, such as *Cypris virens*, *Candona elongata*, and *C. candida*; and it is here placed provisionally under *Candona*. Of course its specific relationship cannot be determined, for want of further evidence.

Note.—The *generic* relationships of all the foregoing species are for the most part uncertain, the hingement being very rarely indicated by exposure or definite outline.

EXPLANATION OF PLATE II.

(The figures are magnified 25 diameters.)

Fig. 1. *Candona candida* (Müller); *a*, right valve; *b*, edge view; *c*, end view. Fig. 2. *Cytheridea Tyrrellii*, sp. nov.; *a*, left valve; *b*, edge view; *c*, end view.	I. Rolling River. Pleistocene.

FIG. 3. *Pontocypris pyriformis*, sp. nov.; *a*, left valve; *b*, edge view; *c*, end view.	II. Loose block.	Saint-Mary-River Beds.
FIG. 4. *Cypris Dawsoni*, sp. nov.; *a*, left valve; *b*, edge view; *c*, end view.		
FIG. 5. *Ilyocypris oblonga*, sp. nov.; *a*, right valve; *b*, edge view; *c*, end view.		
FIG. 6. *Cythere*, sp. indeterminate. Two valves, imperfect.	III. North Branch, Milk River.	
FIG. 7. *Candona? Sanctæ-Mariæ*, sp. nov.; *a*, left valve; *b*, edge view; *c*, end view.		
FIG. 8. *Cytherella crucifera*, sp. nov.; *a*, right valve; *b*, edge view; *c*, end view.		
FIG. 9. *Candona* (?), sp. indeterminate. Dorsal aspect.	IV. Old-Man River.	

NOTICES OF MEMOIRS.

A DESCRIPTION OF THE SO-CALLED SALMONOID FISHES OF THE ENGLISH CHALK. By A. SMITH WOODWARD, F.G.S.[1]

OF English Cretaceous fishes three genera (*Osmeroides, Aulolepis,* and *Acrognathus*) are commonly assigned to the Salmonidæ. None have hitherto been described in detail, and the present paper is intended to give a full account of the osteology of the two first-mentioned genera, so far as the best specimens will allow. Nothing new has been discovered in reference to *Acrognathus*.

Osmeroides Lewesiensis is proved by several specimens in the British Museum to possess a large, though very thin gular plate between the rami of the mandible. The branchiostegal rays are numerous, and the opercular apparatus is complete. The marginal teeth are extremely minute and clustered in both jaws. The maxilla is arched, exhibiting a convex oral margin, and overlapped above by two large supramaxillaries, shaped as in the herrings. The parietal bones meet in the median line, excluding the supraoccipital from the cranial roof. Thin plates completely cover the cheek. Intermuscular bones appear to be present in the abdominal region.

The type skull of *Osmeroides crassus* (Dixon) is now described for the first time, and proved to be generically distinct from *O. Lewesiensis*. It has large, well-spaced conical teeth, and so much resembles the skull of *Elopopsis*, not hitherto recorded from the English Cretaceous, that the fossil may be provisionally assigned to this genus.

Aulolepis typus agrees with *Osmeroides Lewesiensis* in the possession of a large gular plate, the meeting of the parietal bones, the very small size of the teeth, and the form of the supramaxillaries. It is remarkable for the advanced situation of the pelvic fins, and for the prominent ridge produced by the "lateral line" on the scales of the caudal region.

In determining the systematic position of these fishes from the English Chalk, it is, of course, impossible to refer to the most

[1] Abstract of a paper read before the Zoological Society, November 20, 1894.

distinctive external feature by which Salmonoids can be separated from Clupeoids. The nature of the matrix would not admit of the preservation of an adipose dorsal fin, even if it were originally well developed. Three osteological characters of *Osmeroides* and *Aulolepis*, however, now made known for the first time, combine to suggest comparisons only in one direction, namely, with the modern genera *Elops*, *Megalops*, and their extinct allies. These characters are (i.) the union of the parietal bones mesially to the exclusion of the supraoccipital from the cranial roof; (ii.) the arched maxilla overlapped above by two larger supramaxillary bones; and (iii.) the presence of a large gular plate. It is true that although in the typical Salmonidæ the supraoccipital separates the parietals on the cranial roof, there are rare instances (e.g. *Thymallus*) in which the parietals are in contact throughout their length. Further, it is known that the double supramaxilla is not quite constant in the Clupeoides, Elopines, and their allies. It may also be argued that as Dr. Günther admits to the Clupidæ living fishes with a gular plate (*Elops*, *Megalops*), there is no reason for excluding from the Salmonidæ any primitive fishes which differ only from the living members of this family in the possession of such a plate. Nevertheless, so far as the present writer is aware, supramaxillaries of the form described above in *Osmeroides* and *Aulolepis* have not hitherto been observed in any Salmonoid, while they are the most common feature among Clupeoids and Elopines. The two Cretaceous genera under discussion may therefore be provisionally associated with the latter. The fishes named *Osmeroides* from the Chalk of Mount Lebanon may also be placed here, for they likewise exhibit a large gular plate; and *Elopopsis* is already assigned to the same systematic position by common consent. *Elops* and *Megalops*, indeed, have many more close allies in Cretaceous and early Tertiary strata than has hitherto been suspected, and the type they represent seems to have been dominant among the earliest Physostomi.

REVIEWS.

I.—THE GREAT ICE AGE AND ITS RELATION TO THE ANTIQUITY OF MAN. By JAMES GEIKIE, LL.D., D.C.L., F.R.S., etc. Third Edition, largely re-written. 8vo. pp. xxviii. and 850; Maps and Charts xviii.; Woodcuts 78, and Frontispiece. (London: Edward Stanford, 1894.)

THE long interval of seventeen years which has elapsed since the second edition of this work was published, must not be taken as an index that the subject of the "Great Ice Age" has during this period lost its interest with geologists or with the public generally, for the number of workers in this branch of geological investigation, and the amount of literature on it which is constantly appearing, seem to be alike on the increase, though not, perhaps, of late years so markedly in this country as in Germany and in the United States. Readers of this MAGAZINE are well aware of the persistent frequency with which glacial subjects are brought forward and discussed in its pages, and how divergent are the explanations given of the commonest phenomena. There still exist amongst us those who are able to combat skilfully with the pen in favour of such primitive views as the formation of Boulder-clay by cataclysmal deluges of water; who deny the capacity of glaciers to erode; and who advocate a portentously rapid elevation of mountain-ranges or the equally sudden submergence of large tracts of country to account for the destruction of one or two species of Mammalia. Views and opinions of this character are treated with scant notice by the author, and not deemed worthy of serious discussion, for he considers that they would long ago have been discarded by those pioneers in this branch of science who originally proposed them. The majority of present-day geologists will be likely to agree with the author in this matter, and they can afford to look with quiet indifference on the resurrection of these old-world views of a past generation.

A comparison of the present book with the edition of 1874 will give a very fair idea of the advances made, and the course and tendency of opinion on Glacial geology since this date. The author assures us that the general position remains the same, and that the additional evidence obtained confirms the view that there was an alternation of cold and genial conditions during the Glacial period, and that Man then lived in Europe. Following the lines laid down in the earlier edition, the character and succession of the glacial deposits in Scotland are first described at considerable length, and full particulars are given of the nature and origin of the Till or Boulder-clay, and of the striations and groovings on the rocks beneath it. Then, in a succession of chapters, the stratified and often fossiliferous beds subjacent to and intercalated with the Boulder-clays are considered, together with those beds which in many places overlie the Till. The question of rock-basins is next taken up, and then the probable formation of district ice-sheets and local glaciers, the relative position of the Arctic shell-beds, and the late Glacial and post-Glacial deposits of that country. Touching on glacial action in connection with the formation of the Boulder-clay, the author thinks that anyone now-a-days who has given the matter sufficient consideration must come to the conclusion that it is of glacial origin. Respecting the motion of glaciers, the theory of J. D. Forbes that it is due to the quasi-viscous or plastic nature of ice which moves down a slope by its own weight, is accepted as now established by the physical researches of late years, and on this point the experiments of M. Tresca are quoted, which show that the movements of ice under pressure do not fundamentally differ from those of any other solid under similar conditions, and that a mass of it a few hundred feet in thickness, with its temperature at or near the melting point, would, even if it rested on a horizontal plane, flow outwards in all directions until the shearing force came to counterbalance the pressure.

Summarising the evidence of the glacial and interglacial deposits of Scotland, the author gives a very striking picture of the geological changes which he considers them to indicate. There is, first, the Lower Till or Boulder-clay, the ground-moraine of a *mer-de-glace*, which covered all Scotland to a height of 3500 feet. This ice-sheet united with the inland ice of Scandinavia on the bed of the North Sea, and the united masses swept even across the Orkney and Shetland Islands. (2) The *mer-de-glace* melted away, and an extensive land-surface was laid bare, on which a flora and fauna of a temperate character flourished. In many places there are fresh-water and marine deposits of this period which rest on the Lower Boulder-clay, and are covered up by an Upper Boulder-clay. Then depression of the land commenced; the submergence may have amounted to 500 feet, and it was accompanied by an Arctic climate. (3) Another *mer-de-glace*, probably less extensive than the first, spread over the country and produced the Upper Till or Boulder-clay. (4) During the melting of this second *mer-de-glace* the Kames and åsar may have been formed, and probably some of the glacial lakes of the Southern uplands. (5) The melting of the second *mer-de-glace* seems to have been followed by a prolonged interval of milder climate, but the evidence for this depends rather upon some of the continental deposits than upon anything preserved in Scotland. (6) A third period of glaciation set in, but this time the ice only formed district sheets and valley glaciers. There was a contemporaneous submergence to the extent of 100 feet, shown by the Arctic flora in the Marine Clays. The glacial lakes of Lochaber are attributed to this period, and the high-level gravel terraces of the larger river-valleys. (7) The land was again elevated; the climate became milder, and Scotland was covered with forests and inhabited by a temperate Mammalian fauna. (8) The Estuarine Deposits and the Raised Beaches of about 50 feet above the present sea-level, covered as they are in places by the terminal moraines of valley glaciers, indicate that the Forest period was succeeded by a colder and wetter climate, which was favourable to the growth of peat. (9) An Upper Buried Forest seems to show that the country had been again raised, and that there was a drier climate, and another period of forest growth. (10) A colder climate and a slight submergence of 25 to 30 feet is shown by another deposit of peat covering the upper buried forest, and by raised beaches. (11) The present period, in which the land is slightly higher again, and the climate probably drier.

As compared with the glacial succession in Scotland, given in the preceding edition, the above summary indicates with considerable confidence not only a greater number of climatic changes in which Arctic conditions alternate with temperate, but also a very regular series of depressions and elevations of the land, and the association of the Arctic climate in each case with the period of submergence and the genial climate with the period of elevation.

Passing on to the description of the glacial phenomena of England, the author treats first of the beds exposed on the Norfolk coast, at and near Cromer, from which had been obtained the only reliable evidence as to the kind of plants and animals that flourished in England before the epoch of maximum glaciation. From the time of the Red Crag onwards, the number of northern forms of life continues to increase, whilst the southern forms die out, so that in the Chillesford and Weybourn Crags the Molluscan fauna has a thoroughly Arctic facies. On the other hand, the flora and fauna of the next succeeding Forest-bed series is of a temperate character, very similar to that which now prevails; and Mr. Clement Reid, who has so carefully worked out the Forest-bed flora, considers that it may have been contemporaneous in our area with the Arctic fauna of the Weybourn Crag. Dr. Geikie, however, does not think this probable, and favours the view that the Forest-bed was formed in a comparatively genial climate which succeeded the Arctic one of the Weybourn Crag. Be this as it may, there is no doubt whatever of the Arctic character of the climate which followed the period of the Forest-bed, as shown by the plants discovered by Nathorst in the overlying fresh-water bed, which indicate, according to Mr. Reid, a lowering of the temperature by about 20°. A still more severe period of cold accompanied the formation of the Cromer Till, the intermediate sands, gravels, and clays, and the contorted drift with which all geologists are so familiar. With respect to the "contorted drift," the author now regards it as a peculiar form of ground-moraine, in which masses of Chalk and different kinds of Pliocene and Pleistocene beds are jumbled together in the wildest confusion, and yet, curiously enough, this kneaded-up material usually rests with a horizontal junction on quite undisturbed beds. The intercalated beds of sand and gravel in the Boulder-clay series are attributed to the action of water flowing beneath the ice-sheet, and the author concludes that all the Pleistocene accumulations of the Cromer Cliffs are of glacial and subglacial origin, and belong to one and the same period of glaciation.

As to the succession of the glacial deposits in Lincolnshire and Eastern Yorkshire, Dr. Geikie agrees with Mr. Lamplugh that the Sewerby beach and the Speeton shell-bed are probably contemporaneous with the *Leda myalis* bed of the Norfolk cliffs, and that they were formed during mild conditions of climate before the advent of the great *mer-de-glace*, which crept in upon the land from the north-east, out of the bed of the North Sea, and produced the basement or lowest Boulder-clay. The Scandinavian erratics in this clay may have travelled all the way from their place of origin underneath the ice-sheet; the suggestion, which recently appeared in this MAGAZINE, that they had been transported as ballast in the Vikings' ships, is of too late a date to be noticed by the author. The formation of the purple clay, with its associated sands and gravels, has been referred by Mr. Lamplugh to the period of the retreat of the margin of the ice from Holderness. In this clay the erratics are more conspicuously of home origin. The marine gravels of Kelsea Hill are attributed to a later date, when the land had been submerged for 100 feet, and the presence of the Pleistocene Mammalia and of the fresh-water shell, *Corbicula fluminalis*, are accepted as proving an extended period of genial conditions since the time of the maximum glaciation. The Upper or Hessle Boulder-clay indicates the re-appearance of a great *mer-de-glace* in the North Sea; the erratics in this clay are also evidently from British rocks, and they show that the ice-sheet hugged the coast and was prevented from flowing right out to sea by the presence of the Scandinavian ice.

Passing now to North-west England, Dr. Geikie still firmly maintains that the Boulder-clays of this district are the ground-moraines of ice that overflowed from the basin of the Irish Sea, and he now considers that the "Middle Sands," formerly thought to be high-level "marine drifts," are simply morainic materials carried upwards to their present position by an ice-sheet—a view suggested many years since by Goodchild and Belt, and strongly advocated by the late Professor Carvell Lewis and others. Under the same category of gravelly moraines are also placed the shelly gravels described by Mr Nicholson from near Oswestry at levels of 900 to 1160 feet above the sea. The sands and gravels which in the Midlands are so prominently developed, are regarded as the work of torrential waters during the melting of the ice-sheet. The evidence of interglacial beds in the maritime areas appears to indicate a submergence after the melting of the *mer-de-glace*, but its extent is quite uncertain—probably it did not go beyond 300 or 400 feet.

In an interesting chapter on the Drift Deposits of Southern England the author refers to the "rubble-drift" or "head," the origin of which has lately been attributed by Professor Prestwich to marine action, which swept the materials from higher to lower levels, whilst the land was being raised by comparatively rapid jerks from an imagined subsidence of 1000 feet under the sea. As no trace of a marine origin is shown in these deposits, and there is no direct evidence of the presence of the sea, this hypothesis is by no means convincing. A more probable explanation is that the angular drift of the "head" has reached its present position by the action of frost and melting snows, and the gradual forward movement of saturated, thawing subsoils. It is reasonable to suppose that at the time when the country north of the Thames was entirely covered by an ice-sheet, the climate of the Southern districts was sufficiently severe to have frozen the surface soil to some depth, and to have allowed the accumulation of snow, and perhaps of thin fields of ice, and by the melting of these deposits in the summers whilst the soil was frozen, the present dry valleys in the Chalk might have been eroded and beds like those of the Coombe-rock formed, as suggested by Mr. C. Reid.

Want of space prevents us from commenting on the author's description of the glacial phenomena of Northern and Middle Europe, of the Alpine Lands, and other portions of the Continent; but the summary of this portion of the subject lays open so clearly the succession of events which the evidence is considered to have established that we venture to give a condensed version of it.

I. Pre-Glacial Times. In the older Pliocene the sea, which then covered considerable portions of the east and south of England and parts of Belgium, Holland, and France, was tenanted by a fauna indicating a genial climate. As time passed, the Southern forms disappeared, and were replaced by Northern types.

II. First Glacial Epoch. An Arctic fauna lived in the North Sea. The basin of the Baltic was occupied by an immense glacier. Glaciers also descended from the volcanic mountains of Central France, and the mountain valleys of the Alpine Lands were filled with ice which heaped up moraines on the low grounds. To this epoch belong the Weybourn Crag and the Chillesford Clay.

III. First inter-Glacial Epoch. The Arctic fauna retreated from the North Sea, and the southern part of it was now dry land, across which the Rhine and other rivers flowed. The flora was comparable to that now existing, and the Hippopotamus, Elephants, and other Mammals lived in this country. The period of the Cromer Forest-bed. Subsequently the temperate flora in England was replaced by Arctic forms.

IV. Second Glacial Epoch. An enormous *mer-de-glace* covered all the northern part of Europe, and reached as far south as Saxony. Arctic-alpine plants occupied the low grounds of Central Europe, and northern animals lived round the shores of the Mediterranean. To this epoch belong the Lower Boulder-clays and associated fluvio-glacial deposits of this country.

V. Second inter-Glacial Epoch. A temperate and southern flora took the place of the Arctic-alpine on the low grounds. The plants growing at this time in North Germany and Central Russia, indicate a climate milder than the present one in those regions. Hippopotamus and *Elephas antiquus* are included in the Mammalian fauna. Britain was connected with the Continent, and there was probably a land bridge between Europe and Africa. The Hessle gravels, Sussex beach deposits, etc., were probably formed in this period. Its long duration is shown by the depth to which the river-valleys were eroded.

VI. Third Glacial Epoch. Another extensive ice-sheet covered the greater part of the British Isles and a large area of the Continent, but it did not reach so far as the previous one. The glaciers of the Alps reached to the low grounds, and formed the moraines of the "inner zone." To this period are assigned the Upper Boulder-clay and its associated fluvio-glacial deposits.

VII. Third inter-Glacial Epoch. Temperate conditions, the evidence for which is principally derived from the youngest inter-Glacial beds of the Baltic coast-lands. Much of the old alluvial deposits of Britain and Ireland probably belong to this period, though hitherto classed as post-Glacial. Some of the beds in the Baltic area contain the remains of Mammoth, Woolly Rhinoceros, Horse, Irish Deer, and Urus.

VIII. Fourth Glacial Epoch. In the early stages Scotland was submerged to the depth of at least 100 feet, and an Arctic fauna lived in the sea. Glaciers came down from the mountains and filled the Highland fiords. The snow-line did not reach higher than 1000 or 1600 feet above the sea in Scotland. Another ice-sheet covered the Scandinavian peninsula, and the glaciers from it occupied the fiords of Western Norway. The Baltic basin was filled by an ice-stream which extended over North Germany and Denmark. Subsequently a wide area in Scandinavia was submerged in a cold sea. Large glaciers reached a long way down the Alpine valleys, but not so far as in the preceding Glacial epoch.

IX. Fourth inter-Glacial Epoch. At its climax, the conditions were sufficiently temperate to allow of the growth of forests in northern regions where they cannot live at the present day. Britain was united with the Continent and the Baltic was changed into a great lake.

X. Fifth Glacial Epoch. The coast-lands of Scotland were submerged to about 50 feet below their present level; local or valley moraines were formed in the British Isles, and their position indicates that the height of the snow-line was then about 2500 feet. Most of the corrie rock-basins of the British Isles may be assigned to this period. In the Alps the epoch is marked by the moraines of the so-called "second post-Glacial stage."

XI. Fifth inter-Glacial Epoch. An elevation of the land took place and the valley glaciers retreated. The upper "buried forests" in the peat-bogs of North-west Europe show that the climate was drier and very favourable to forest growth.

XII. Sixth Glacial Epoch. The later raised beaches indicate a slight submergence, not exceeding 20 to 30 feet, in Scotland. The climate was more humid and more suitable for the growth of peat than of forests. The snow-line in Scotland was at an elevation of 3500 feet.

XIII. The Present. Distinguished by the retreat of the sea to its present level, milder and drier climate, and the final disappearance of permanent snow-fields.

As in the case of Scotland, the above summary of the succession of events during the Ice Age in Europe generally, brings before us so many alternations involving radical changes of climate and repeated advances and retreats of the sea, that the question will naturally arise whether the fresh evidence gained during the last seventeen years is sufficient to support the idea that such a marvellous series of changes can have taken place in such a limited period of geological history. Looking back to the edition of 1877, we there find that the glacial deposits of Europe were considered to indicate *two periods* of intense glacial conditions, and that during the first of these there was a subordinate interval of milder climate, and a more strongly marked milder period—called the last inter-Glacial—intervened between the two severe Glacial periods. Now, however, an alternate succession of no fewer than *six Glacial* and *five inter-Glacial* epochs is put before us as the latest interpretation of the evidence. But even accepting the important additional evidence resulting from the more detailed study of the glacial deposits of Northern and Central Europe, it seems to us insufficient to establish that multiple succession of boreal and temperate epochs which is pictured to us as recurring, see-saw fashion, during the later portion of the Ice Age.

Treating of the "Valley Drifts," Dr. Geikie comments on the investigations of M. Ladrière in the river valleys of France and the North of Belgium, and considers that they throw great light on the characters of the valley drifts of the Thames. He questions the soundness of dividing these latter into an older high-level and a younger low-level series, and thinks that it is only the bedded gravels of the lower levels which are positively of fluviatile origin; the high-level loams and angular gravels which extend upwards to the plateaux are more probably local formations like the similar accumulations in Northern France. If those primitive implements, discovered by Harrison at the high-levels on the Chalk plateau of Kent, should be proved eventually to belong to the same age as the Plateau-drifts, the human period would date back to a much earlier period than has hitherto been dreamed of.

Reference is also made to the ice-cliffs on the shores of Northern Alaska, described by Dall, which form part of a broad ridge of ice about two miles in width and 250 feet high. Overlying this ice-rock is a bed of clay containing the bones of Mammoth, Horse, Elk, Reindeer, Musk-Ox, Bison, and Big-Horn. The author supports Dr. Penck's explanation that this ice-sheet must date back to Pleistocene times, and that it has the same origin as the frozen bottoms or grounds so commonly met with in the higher latitudes of North America and Asia. This dead ice-sheet, which is now wasting away, must belong to a period when the climate of those regions was much colder than at present. It is not the relic of any glacier, but it probably results from the accumulation of drifted snow in Glacial times.

Touching the period of the first appearance of Palæolithic Man in the European area, Dr. Geikie does not consider that we have unequivocal evidence of his presence until the second inter-Glacial epoch (*Elephas antiquus* stage), when he is characteristically represented by the Chellean or St. Acheul type of flint implements so common in the old river-gravels of the Thames and the Seine.

Two chapters, containing a very graphic description of the Glacial phenomena of North America, have been written by Prof. T. C. Chamberlin, who has taken a leading part in the study of the deposits of the Ice Age on that continent. Drift deposits are estimated to cover nearly one-half the area of North America, which means that the glaciers of the Ice Age spread themselves over about 4,000,000 square miles of territory. The main body of ice, appropriately called the Laurentide Glacier, probably originated in more than one centre in Labrador, and in the region north-west of Hudson's Bay, and the nuclei grew until their borders coalesced and the Hudson basin became a great reservoir of ice, from which issued the streams or sheets which covered the eastern five-sixths of the Dominion of Canada, and the larger part of sixteen of the Northern States of the Union and smaller portions of even others. The most southern point reached by the *mer-de-glace* was in the State of Illinois, between the Ohio and the Mississippi rivers, in lat. 37° 35′.

Prof. Chamberlin represents the Drift deposits of the great plain region of North America as a series of sheets overlapping each other in intricate fashion, and in this case only that outer zone or margin of each sheet which was not reached by the one next succeeding, retains its original form (except as modified by superficial agencies), whilst the inner buried zone was liable to much alteration by the over-riding ice of the later advances. It ought to be remembered that the outermost zone of deposits, which are called the earliest for convenience sake, are really those of maximum glaciation—the mid-winter of the Glacial period. The extent of the imbrication of the glacial deposits largely depends on the oscillations of the ice-margin and the intensity of the ice-action. If the ice-margin, in its advance, pushed forward all the loose *débris*, there would remain a series of concentric moraines instead of the imbricated sheet.

The constituents of the Drift deposits in North America closely resemble those of Europe. The Till or Boulder-clay is precisely similar in character. Individual sheets of it have an average thickness ranging from 20 to 60 feet; its maximum thickness in a few places is known to exceed 500 feet. Terminal moraines are truly of gigantic size: some have been traced for several hundred miles in individual distinctness. The chief of the complex belt of moraines has been followed from the Atlantic coast over the Appalachians, across the broad Mississippi basin, and then far out upon the North-western plains of Canada, and it may possibly have reached to the Arctic seas. The other products of glacial action, such as Drumlins, Åsar, Kames, Glacio-fluvial Aprons, Valley Drift, and Löss are also represented on an enormous scale.

Professor Chamberlin has tentatively proposed to subdivide the glacial deposits of North America. The lowest sheet is named the Kansan formation from the fact of its reaching as far as what are now the dry hot plains of Kansas, 1500 or 1600 miles distant from the centre of the radiation of the ice-sheet. This lowest deposit is essentially of Till, with assorted beds of sand, clay, and gravel.

The Kansan formation is followed by a later drift, named the East-Iowan, but between these two there is a well-developed soil-horizon, consisting of peat, logs, twigs, stems, and other vegetable *débris*, in which have been recognised remains of pine, oak, elm, sumach, walnut, ash, and hickory trees, with bones of *Equus*, *Lepus*, and *Mephitis*. Overlying the East-Iowan formation is a second horizon of soil and plant accumulations, and this in its turn is overlapped by a very marked glacial drift, the East-Wisconsin formation, the outer margin of which is formed by a distinct terminal moraine, usually one to five miles wide, and from 50 to 300 feet thick. The retreat and melting back of the ice resulted in the formation of immense lakes.

Very various opinions are held by American geologists as to the chronological interpretation of these various formations; some maintain the view of two periods of glaciation and two intervals of deglaciation; but there is a growing disposition amongst field workers to recognise three distinct Glacial, and as many inter-Glacial epochs. It would obviously be premature to attempt at present to correlate the glacial succession in North America with that in Europe, but the fact of important climatic oscillations during the Ice Age is as clearly shown in the former country as in the latter.

In this edition the consideration of the cause of the Climatic and Geographical Changes of the Glacial period forms the final chapter of the book. The author still holds that the astronomical theory of the late Dr. Croll appears the best solution of the Glacial puzzle, as it accounts for all the leading facts; for the occurrence of alternating cold and warm epochs, and for the peculiar character of Glacial and inter-Glacial climates, and further, it postulates no other distribution of land and sea than now obtains. This theory has undoubtedly thrown a flood of light upon the difficulties of the subject, and it may be that some modification of his views will eventually clear up the mystery.

This third edition of the "Great Ice Age" should be received by those interested in the study of Glacial Geology with as warm a welcome as that which was accorded to the first edition twenty years ago. Opinions will differ respecting some of the generalisations of the author, but all will agree on the value and importance of having the evidence on this subject brought down to date, and stated in a clear and impartial manner. G. J. H.

II.—The Life of Richard Owen.[1] By his Grandson, the Rev. Richard Owen, M.A. With the Scientific portions revised by C. Davies Sherborn. Also an Essay on Owen's Position in Anatomical Science by the Right Hon. T. H. Huxley, F.R.S. 2 vols. 8vo. Pp. 409 and 393, with Portraits and Illustrations. (London: John Murray.)

THE record of the life of so well known a man as the late Prof. Owen cannot fail to be of great interest, not only to those to whom his researches more especially appeal, or who have known him as a friend, but also to the more general reader. For Owen, although a scientific man whose province was principally that of Comparative Anatomy, and perhaps more especially that of Vertebrate Palæontology, was at the same time a man of very broad human sympathies, and devoted a large amount of his earlier life to the services of his fellow-men by acting on various hygienic commissions; he was further very successful both as a popular and a special lecturer; finally, by his efforts as Hunterian Professor at the Royal College of Surgeons, and afterwards as Superintendent of the Natural History Departments of the British Museum, he did more than any of his predecessors to bring the study of Natural History before the public, to force its recognition on, and obtain its continual support from, the Government. It is hardly an exaggeration to say that Owen was the most popular and widely known of all the scientific men the present century has seen.

These records consist of letters and extracts from the diaries of

[1] For an Obituary of Owen, accompanied by an excellent portrait, see Geological Magazine, 1893, Decade III. Vol. X. p. 49.

Prof. Owen and his wife, more especially from that of the latter, who, it appears, kept a most exhaustive account of all Owen's doings and work. It is delightful to notice what deep interest she took in all his researches, and how carefully she recorded their progress; and the fact that she did not complain even when the house was occupied by a defunct Rhinoceros or portion of an Elephant sufficiently hung to necessitate keeping all the windows open, shows that she was a most sympathetic wife for a scientific man.

Vol. I. commences with Owen's ancestry, and his early training at school and at home; his letters to and from his mother and sisters show what a lovable man he was. It is amusing to read of his having been stigmatized while at school as "lazy and impudent": what would that master think of his forecast if he could read these volumes? We find an interesting account of his early taste for ethnology in his adventure with the negro's head (page 23) during his apprenticeship to a surgeon at Lancaster. But it was not until he went to Edinburgh, where he founded the Hunterian Society, that his scientific inclinations were really manifested. From Edinburgh, acting on the advice of Barclay, he came to London to study at St. Bartholomew's under Abernethy, and it was owing to the recommendation of the latter that he was appointed Assistant Curator of the Hunterian Collection at the Royal College of Surgeons.

It is from this date (1826) that Owen's career as a scientific man commenced, and the greater part of Vol. I. is devoted to his life at the College of Surgeons. This is, perhaps, the most interesting part of the work, for we are able to trace how he gradually weaned himself from medicine and devoted himself more and more to comparative anatomy, due in the first place to the nature of his work, and also, probably, in a large manner to the unconscious influence of the great scientists with whom he came in contact. One of the earliest of these was Cuvier, who visited the College and invited Owen in return to Paris. His biographers evidently consider that the supposed influence of Cuvier on Owen's future work has been overestimated, but, as Huxley points out, Cuvier's work stands out so pre-eminently when compared with that of his contemporaries that it must have had considerable influence in directing the method of work of a young aspiring anatomist such as Owen then was, and the mere fact that no reference of such influence is recorded in Owen's diary goes for nothing.

It is perfectly marvellous to note the amount of energy which Owen must have possessed, for we read of his working all day at his catalogues, his dissections, his lectures, and his duties on various Commissions, then winding up the day with theatres or concerts, and commencing the next by sitting up to write scientific papers or, sad to relate! to consume novels.

During the thirty years of his connection with the College of Surgeons, the most important of Owen's scientific work was done; and we are here able to read of the rapid growth of his now world-wide reputation as an Anatomist and a Palæontologist. Here, too, we read of his social intercourse with all the celebrated men of those days. To the general reader this portion will especially appeal, for here we find interesting letters and anecdotes of Turner, Carlyle, Dickens, and many more distinguished men in every branch of life.

In the second volume we come to Owen's connection with the British Museum, and a special chapter is devoted to the account of his efforts and ultimate triumph in the removal of the Natural History Collections to a special building. Here are reproduced Owen's original plan and Waterhouse's first modification of the same; in both of these we recognise a building intended to serve primarily as a Museum but also provided with lecture theatre and teaching collections. How the present architectural structure, devoid of so many of the best features of the original design arose, is not explained.

Appended to the second volume is an interesting account tracing the development of Anatomical Science, and Owen's relation to the same, by Prof. Huxley. This is written in such a manner that it may be easily followed by the non-scientific reader. It seems a pity, for the sake of the latter, that this was not rather placed as an introduction to Vol. I.

The perusal of this work by the public would do much to dispel the favourite representations of scientific professors being necessarily dry old bores, for Owen was one of the most charming of men, and, in addition to his great qualifications as a scientist, was pre-eminently calculated to shine in society. The recognition of his social qualities may be seen all through his life, both by Royalties and Commoners; and we find him being entertained by the Prince of Wales, and on other occasions by his fellow scientists, at social meetings where every kind of "ology" was barred.

The two volumes contain some charming portraits of Owen, especially the frontispiece to the second volume; there are also illustrations of Owen's most important discoveries. As an Appendix we find a most imposing list of his distinctions, and a complete Catalogue of his works, numbering in all about 650. M. F. W.

III.—The Permian Fishes of Bohemia.

Fauna der Gaskohle und der Kalksteine der Permformation Böhmens. By Prof. Dr. Anton Fritsch. Band III. Heft 3. Pp. 81–104, Pls. 113–122. Prague, 1894.

Dr. ANTON FRITSCH has just issued another part of his well-known work on the Bohemian Gas-coal (Lower Permian). For some time he has been treating of the fishes, and now he is well advanced in the description of the Palæoniscidæ. The present instalment is as exhaustive as ever, and we cannot but admire the care with which the author turns to good use even the most fragmentary specimens.

Before treating of undoubted Palæoniscidæ, Dr. Fritsch places a section "Incertæ sedis" to which he assigns an imperfectly known fish under the name of *Acentrophorus dispersus*, sp. nov. If the generic determination of the species be correct, as seems likely, there need be no hesitation in referring it to the Semionotidæ to which the typical English species undoubtedly belong; but the hinder half of the Bohemian fish still remains to be discovered.

The description of the Palæoniscidæ is prefaced by von Zittel's definition of the family, and a translation of the Synopsis of the known genera given in the British Museum Catalogue of Fossil Fishes. The difficulty of recognising some of the characters mentioned in this Synopsis is also briefly remarked upon. It would have been more satisfactory, however, if Dr. Fritsch had likewise been able to discuss the still more difficult question of the genera of Palæoniscidæ described by Dr. Sauvage from the Permian of France, which may be assumed to have their counterparts in Bohemia. Perhaps this subject is reserved for the general chapter on the Palæoniscidæ, which is wisely postponed until the detailed descriptions of the Bohemian Permian genera and species are completed.

The new generic name *Pyritocephalus* is proposed for a small species previously recorded as *Palæoniscus sculptus.* It belongs to the group to which *Canobius* and *Amblypterus* are referred, and is remarkable for the close ornamentation of the head with large raised lines of ganoine. The fins are small, the dorsal opposed to the anal; and the scales are smooth, not deepened on the flank.

Another fish described as a new genus, and one of the greatest interest, is *Sceletophorus,* with the single species *S. biserialis.* This, too, is an Amblypteroid, but with very thin serrated scales and no fulcra even on the median fins. A few rounded scales immediately above the pectoral fin are described, and remains of the axial skeleton in the abdominal region are interpreted as displaying elongated ring-vertebræ. If this view be correct, Palæoniscidæ are shown for the first time with completed vertebral centra. We believe, however, that the "wirbelröhre" are merely the crushed bases of the neural arches through which the spinal chord passed (for they are no larger than the canal of the lateral line of the same fish); and in the specimen figured (pl. 116, fig. 1) the small hæmal elements may well be regarded as displaced upwards over the open space originally occupied by the notochord. Another fish, which Dr. Fritsch thinks may possibly prove to be the young of a species of *Sceletophorus,* is provisionally assigned to *Phanerosteon* under the name of *P. pauper.* This has scales only on the upper caudal lobe, and also displays traces of the endoskeleton, which are supposed to include hollow cylindrical vertebral centra. Here, again, the cartilages in question are disproportionately small, but the drawing does not enable us to make any suggestion as to their true nature; we can only regard them as much too problematical to be used for modifying current views as to the nature of the vertebral axis in the Palæoniscid fishes.

Amblypterus itself follows, and Dr. Fritsch decides to adopt the comprehensive definition of the genus first suggested by Traquair. He points out, however, that the numerous species can be arranged in groups which are respectively confined to different geological horizons. *Amblypterus Kablikæ* is first discussed, and this seems to be confined to the highest stratum of limestone in the Bohemian Permian. A new species, *A. verrucosus,* is then described as the earliest known Bohemian Palæoniscid. This is closely related to *A. Duvernoyi,* which next receives a brief notice. Dr. Fritsch doubts the advisability of assigning to the latter form as many so-called species as some previous authors, and points out the comprehensive character of the diagnosis of *A. Duvernoyi* in the British Museum Catalogue. He concludes the present "Heft" with an account of the form commonly known as *A. Vratislaviensis,* and begins a similar description of *A. Rohani.*

A glance over Dr. Fritsch's drawings will well repay the ichthyologist and anatomist; and the careful manner in which the different fossils are compared renders the work of equally deep interest to the geologist. We can only conclude by congratulating the Director of the Royal Bohemian Museum on the fact, that even the absorbing duty of arranging his new cases and exhibition galleries does not interfere with the progress of his great contribution to Palæozoic Palæontology. A. S. W.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—November 21st, 1894.—Dr. Henry Woodward, F.R.S., President, in the Chair. The following communications were read:—

1. "The Pleistocene Beds of the Maltese Islands." By John H. Cooke, Esq., F.L.S., F.G.S.

For the right understanding of the Pleistocene beds, a previous knowledge of the physiography of the islands and of the earlier sediments is necessary. A full description of the physiography and of the character of the sediments, so far as they are necessary for the understanding of the accumulations forming the subject of the paper, occupies its earlier portion. Especially noticeable is the absence of ordinary anticlinal and synclinal folding, and the predominance of monoclinal faults, which largely affect the character of the surface. These faults were formed prior to the deposition of the Pleistocene beds.

The plateaux of Malta, rising to a height of 600—800 feet above sea-level, occur south of the great east-and-west fault, which has a downthrow to the north. They have no Pleistocene deposits upon their summits.

Three classes of superficial deposits are described:—

(*a*) Valley-deposits, including (1) those found on the higher slopes of plains and plateaux, due to subaërial waste and rain-action, containing land-shells and mammalian bones; and (2) those situated at the bottoms of valleys, consisting of stratified layers of water-worn sand, gravel, and large pebbles, occurring in such order as to show that the agents which produced them have greatly decreased in intensity.

(*b*) Agglomerates and breccias found along coast-lines and fault-terraces, always at the foot of the fault-terraces, or along the lower slopes of the depressed areas: these accumulations are either submerged or lie at the water-line. Their materials are much water-worn, and land-shells are contained in many of the layers. The agglomerates are in many cases distinctly stratified; and the author concludes that the materials appear to have been swept down, during heavy rainfall, into the waters of land-locked creeks.

(*c*) Ossiferous deposits of caves and fissures, which have been described elsewhere.

2. "Geological Notes of a Journey in Madagascar." By the Rev. R. Baron, F.L.S., F.G.S.

The part of the island travelled over may be divided into four sections.

(*a*) *Antananarivo to the East Coast.*—The principal rock is a hornblende granitite-gneiss, but there is also much norite usually containing olivine. The general strike of gneiss and norite along this region is north-west and south-east, or north-north-west and south-south-east. The country is traversed by several large dolerite-dykes.

(*b*) *The Northern Part of the East Coast.*—Dolerite-flows predominate along the coast, and from their character are believed to have flowed from such fissures as are indicated by the dolerite-dykes noted in the preceding section. Some felsites, probably lavas, and felsitic breccias were also observed; also a granitite penetrated by epidiorites, and associated with chiastolite-slates. Many other rocks, schists, and eruptives were found.

(*c*) *The Northern End.*—Sedimentary rocks (sandstones and limestones) are extensively developed in this section, as well as much volcanic material. The sediments are of Jurassic and Cretaceous ages. The volcano Ambohitra is situated on these sediments, and has poured out olivine-basalts. Shells of recent species occur on the mountain-chain at the northern end.

(*d*) *The North-western Coast and Islands.* — Marine strata of Jurassic, Cretaceous, and Eocene ages are found in this area, together with various igneous rocks including trachyte, foyaite, nepheline-phonolite, hauyne-nepheline-phonolite, andesite, and basalt. South-west of Anorontsanga are four islands—three composed of volcanic rocks, and the fourth, Antanifaly, of nummulitic limestone.

3. "On a Collection of Fossils from Madagascar obtained by the Rev. R. Baron." By R. Bullen Newton, Esq., F.G.S.

The fossils forming the subject of this paper were collected in the northern part of the island. The author gives an account of the previous work on the fossils of Madagascar; this is followed by a description of the post-Tertiary, Tertiary, Cretaceous, and Jurassic fossils. The post-Tertiary fossils are for the most part terrestrial shells found on Ambohimarina hill, mainly of species still existing on the island. A few marine forms have been found elsewhere.

A description of species, many of them new, follows; and the author furnishes a list of all recognized fossils from the island, concluding with notes on certain limestones, including a *Globigerina*-limestone and one containing *Girvanella.*

II.—December 5th, 1894.—Dr. Henry Woodward, F.R.S., President, in the Chair. The following communications were read:—

1. "Supplementary Note on the Narborough district (Leicestershire)." By T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S., Professor of Geology and Mineralogy in University College, London.

The author revisited this district, briefly described by himself and Mr. Hill in 1878, at Easter 1893, and in September 1894. The old excavations had been greatly enlarged, but little of importance had been disclosed: no dykes and no new junctions with sedimentary rocks. But the crystalline rocks have been recently struck in a fresh locality between Narborough and Huncote, about half a mile west of the pit near the former village. As in that case, the rock lay very near to the surface; here the highest part of the boss was barely covered. The rock is hardly to be distinguished from that of the Narborough pit. The enlargement of the pit south of Enderby has exposed fresh sections of the junction of the slate and syenite, which has been now traced along the whole length of the pit from north to south, and some particulars are added to the former description.

The enlargement of certain of the pits has displayed some interesting sections of Boulder-clay resting upon the crystalline rocks. The latter are not appreciably ice-worn. The fragments in the Boulder-clay, identified by the author, were from the Carboniferous, Trias, Jurassic (especially Lias), and Upper Cretaceous formations. They indicated, in the main, a drift from a more or less north-easterly direction.

2. "The Tarns of Lakeland." By J. E. Marr, Esq., M.A., F.R.S., Sec.G.S.

The author has examined several tarns of the English Lake District. In those cases where the stream issues from the tarn over solid rock, he finds either (1) direct evidence that the tarn results from the blocking up of part of a pre-existing valley by drift, causing the deflection of the water to a direction different from that of the original stream in this locality; or (2) evidence which is perfectly consistent with such an explanation of the origin of the tarn.

Under the circumstances he would submit that tarns cannot be assumed to lie in rock-basins simply because the issuing stream flows over solid rock (and this assumption has been made), but that those who maintain the existence of such rock-basins must prove the occurrence of solid rock entirely around the tarn.

3. "Description of a New Instrument for surveying by the aid of Photography, with some Observations upon the Applicability of the Instrument to Geological Purposes." By J. Bridges Lee, Esq., M.A., F.G.S.

The instrument described in this paper consists essentially of a photographic camera fitted inside with a magnetic needle, which carries a vertical transparent scale divided and numbered to 360°, and also with cross fibres which intersect at right angles. The fittings and adjustments of the instrument are of such a character that the camera can be accurately levelled and directed towards any point in a horizontal direction, and when a photograph is taken in an ordinary way the bearing of the median vertical plane, which bisects the instrument through the photographic lens, will be recorded automatically on the face of the photograph.

The vertical fibre (and its image on the photograph) serves as an index to read the bearing; and the same fibre marks, by its shadow, a line right across the photograph, which marks the median vertical plane on the image.

The horizontal fibre is adjusted to mark on the image the horizontal plane which bisects the photographic lens.

The camera rests on a divided horizontal circle, which can be adjusted to a truly horizontal position by levelling-screws. There is a tripod stand and head, with suitable appliances for supporting and adjusting the instrument in position. The camera is provided with a rectilinear doublet lens and iris diaphragm and rack-and-pinion focussing adjustment. It is made of aluminium, and it is surmounted by a telescope adjustable in altitude and fitted with vertical and horizontal webs; and it is also surmounted by a revolvable tubular level.

The details of construction and the peculiar features and adjustments of the instrument are fully described in the paper, and some of the chief purposes to which it may be applied in furtherance of geological research are pointed out.

4. "The Marble Beds of Natal." By David Draper, Esq., F.G.S.

A "crystalline limestone of enormous thickness" was mentioned by Mr. C. L. Griesbach, in 1871 (Q. J. G. S. vol. xxvii. p. 56), as occurring along the lower course of the Umzimkulu, in the county of Alfred in the southern part of Natal. Since the time of his visit there the country has been opened out by settlers, and some attempts have been made to utilize this marble. The chief mass of this rock is met with at about seven miles inland, in the Indwendwa hill-range, within the fork formed by the junction of the Umzimkulu and the Umzimkulana, over 700 feet above sea-level, and continuous with the tableland westward. This consists of granite, overlain with the massive marble, roughly stratified, which is denuded north and south of the hill, into the gorges of the two rivers, and is continued on the opposite flanks until cut off by faults. The north fault divides it from the Table-mountain Sandstone lying on clay-slate; and the south fault divides the granite from the Table-mountain Sandstone and clay-slate. The bedding of the marble dips towards the rivers on each of their flanks, and strikes E. and W.

In quality the marble varies from coarse to fine-grained, and in colour from pure white to deep red. The coarse-grained variety contains 5 to 13 per cent. of carbonate of magnesia. Calcareous tufa, in some places several feet thick, has been formed from the marble.

From the junction of the two rivers eastward, slate is seen below Table-mountain Sandstone; and on the latter is a long stretch of the Dwyka Conglomerate to the coast, greatly disturbed for the most part, and pierced by two dolerite-dykes, between which a patch of Ecca Shales is preserved.

The author concludes that the marble was deposited on the granite, and probably on the Malmesbury Slates near by, before they were disturbed; that it does not extend far under the neighbouring hills; and that some of its local detritus indicates that the rivers ran at higher levels within relatively recent times.

CORRESPONDENCE.

MR. DEELEY AND MR. HARKER: "TWO BIRDS WITH ONE STONE."

Sir,—In my view there is no more profitable way of advancing knowledge than by good-humoured controversy. I only wish my opponents' banter was a little more playful. Mr. Deeley is mistaken in supposing that I, of all people, can object to his attacking old problems. What I called impertinent, was attacking *very old problems* without first learning what other men had had to say to them, coupled with the assumption that the long life's-work of such patient masters of their craft as Studer, and Forbes, and others in the Alps, was going to be all set right by Mr. Deeley's summer jaunt to Mont Blanc.

What they proved and what recent experiments in the laboratory have confirmed is the plastic nature of glacier ice. Mr. James Geikie, who formerly advocated Croll's transcendental theory of ice-motion, has completely abandoned it in his new volume on the Ice Age, in favour of Forbes' view. Mr. Deeley, some time ago, had a private transcendental theory of his own on the subject, which I cannot find that anybody understood, much less adopted. I do not know whether he still holds to it, or is now satisfied by the experiments of McConnel, Kidd, and others, that Forbes was completely right. I take it from some phrases he uses that, like Mr. Geikie, he, too, has surrendered. If he has not, we are beating the air, for I am bound to say I neither understand the physical nor the mechanical basis of his ice theory.

If he now holds, as all the world holds, that ice is a viscous body, then he must also hold that it acts like one, and that when it has a sloping back it will not move at all on account of the shearing resistance of the ice, unless the slope of its back is equal to that of a glacier-bed when motion first ensues in a glacier. Forbes showed that this meant a considerable slope. The question for Mr. Deeley (entirely apart from all geological difficulties) is how to secure and maintain such an ice slope as would carry boulders to Britain from the Christiania Fjord, and then move on till it terminated in a scarped cliff of ice at the 100 fathom line, and this when the upper part of the Dovrefelds was entirely free from ice as it now is from markings. This is one only of a dozen difficulties surrounding an ice hypothesis which has been evolved apparently without any thought of the critical problems which have to be met at every turn. To those whose geological and mechanical reasoning follows the same groove as my own, it seems impossible, as it seemed impossible on the same grounds to Pettersen, to Bonney, to Matthieu Williams, and to Milne-Holme, whose experience of glacial phenomena, combined with a knowledge of Western Norway and Eastern Britain, entitle them, I think, notwithstanding Mr. Harker's sneer, to the very first rank as authorities on the geological side of this particular issue.

I have argued the case out in detail in my book on the "Glacial Nightmare," at which I sincerely wish Mr. Deeley would look before advancing arguments which have all been answered by anticipation.

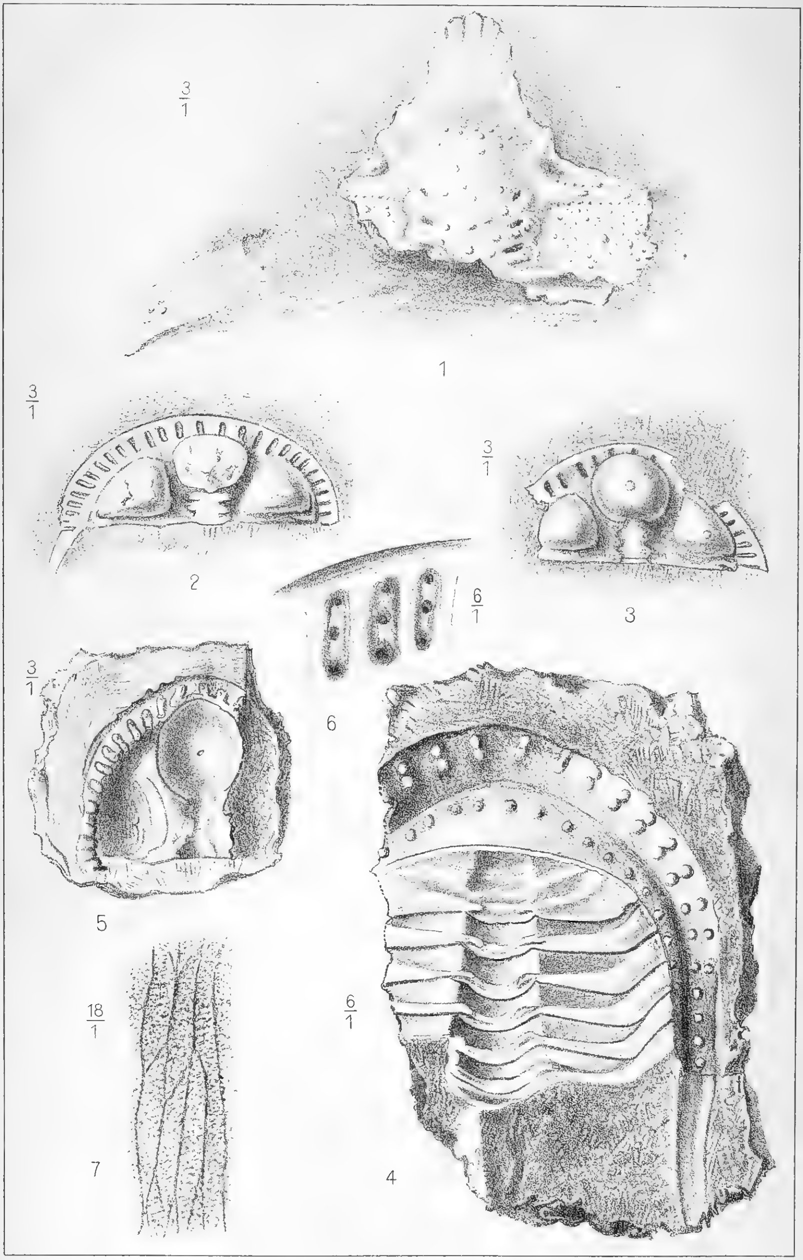
Mr. Deeley's reference to the Antarctic ice, which also occupies a considerable space in my book, seems to me entirely beside the question. The Antarctic ice, in so far as we have evidence, is planted on a high plateau of land. When it reaches the sea it does not march on as the Norwegian ice-sheet is supposed to have marched on, athwart the deep Norwegian channel, and then across the North Sea to the 100 fathom line, and there expose a great cliff, but it breaks off into icebergs *in shallow water*, and these icebergs float away. All this is perfectly rational. How it in any way supports the North Sea monster I know not. In the one case the ice behaves like other ice; in the other case it would behave, it seems to me, as no ice ever behaved before or since, except in a geological nightmare.

I will now turn to Mr. Harker. Although he affects to despise the virtue of modesty, he says "he has not written a word on the Scandinavian ice-sheet, and has kept his views on that subject modestly to himself." Is this so? In the Transactions of the Yorkshire Geological Society, where he discussed the question of these boulders at length, he distinctly refers them to Scandinavia, and actually says, "*the movements of the ice*, and the consequent directions of transport, render this conclusion probable." I think, after this, he ought to have called the boulders not "damaging" but "damaged."

If Mr. Harker no longer believes that ice brought the boulders from Scandinavia, then *cadet quæstio*. To disprove that hypothesis was the purpose of my writing. To be coy in making a confession on such a point after what he has written is to borrow a weapon from another sex than ours. We are not striving for some rhetorical advantage, but for the truth, and the truth is not served by carefully putting under a bushel the light that we may possess, and taking refuge in struthious logic. The question between us is, how are we to account for the Laurvig boulders? I suggested as a possibility that they may have been partially ballast, and partially stones used as anchors, net-weights, etc.

Nothing that Mr. Harker has yet said seems, to me, to have reduced the probability of that suggestion, *and it is only a suggestion.* He asks me whether the Vikings "ballasted their ships with little pieces of rhombenporphyr, and used small pebbles of laurvikite for anchors." Is this supposed to be argument? If Mr. Harker thinks that the big stones, which were on the beach a thousand years ago, when the Vikings were about, have not been ground into small ones by this time, he is probably singular in his views, but apart from this most ballast is simply gravel. He next alleges the fact that the sea is invading the land on this coast. How the fact that the coast is a retiring coast affects the relative position of the beach as between high-water and low-water I know not. Does Mr. Harker think that when the sea invades the land, to the extent of a hundred yards, say, it leaves its old beach behind. Again, he says, "there is no *port* in Holderness": what has that to do with it? It was probably because there was no port there that the whole fleet of pirate ships which attacked Northumbria in 793 was lost on this very coast, and that many others were similarly lost at other times. Again, he bids me remember that a couple of the boulders in question were found at Cambridge. This I learnt after I wrote my first paper, and I am bound to say that it immediately struck me as a fact not for me to digest, but for the champions of the North Sea ice-sheet to take to heart. Does Mr. Harker postulate a Norwegian ice-sheet in Cambridgeshire? else how does he account for these stones? That Cambridge and all the Fenland was not ravaged in every direction by the Vikings when the country round the Wash was virtually a lake *I do know,* and I need not draw the necessary inference. The sporadic character of the finds is surely a lesson in itself to be coupled with the admission made by Mr. Harker, that the stones about which we are discussing have not been found inland in Yorkshire, and only on the shore. If an ice-sheet or icebergs brought them, and others like them, to Cromer and Cambridge, how is this to be explained? Again, I would seriously ask if any human being who has seen ice at work, either in glaciers or icebergs, ever saw anything less like ice-moved stones than these rounded water-worn boulders? Ice carries a considerable part of its great stones intact and unweathered on its back from end to end without rolling or rubbing them, and then deposits them with the boulders made by its own streams in moraines or in detached blocks at its terminus and sides, and does not select one or two special points easily accessible to boats and ships, *and there only* leave a few choice specimens *of water-worn* stones mixed with a vastly greater proportion of stones which have confessedly come from the opposite direction!

I must repeat, in conclusion, that the question is too important to be settled by a few flippant sentences. My position is that on every ground, *a priori* and empirical, the evidence goes to show that it is impossible to attribute the transport of these stones to an ice-sheet or icebergs from Scandinavia, as Mr. Harker argued in his well-known Yorkshire Memoir, and as I presume from his ambiguous phrases he argues still. If he can suggest a more reasonable and simple explanation of the presence of these stones where they have been found than mine, I will gladly accept it. Hitherto he has failed to do so: hence these tears! H. H. Howorth.



Edwin Wilson Cambridge.

NEW BALA TRILOBITES.

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WOODWARDIAN MUSEUM NOTES.

I.—NEW TRILOBITES FROM THE BALA BEDS OF CO. WATERFORD.

By F. R. COWPER REED, B.A., F.G.S.

(PLATE III.)

AMONGST the numerous species of Trilobites which occur in the impure limestones of Bala age in Co. Waterford, two new and undescribed forms were recently found by me in the course of a preliminary examination of that area. At present the exact horizon of the beds has not been determined, but they may undoubtedly be referred to the Bala series. One of the new species belongs to the genus *Cybele*, and is a most bizarre form, with a long, snout-like projection of the anterior margin. The other is a new species of *Trinucleus*, bearing some resemblance to Angelin's *T. bucculentus*, which occurs in beds of "regio Ba" in Norway.

The following descriptions give in detail the characters of the new species.

Cybele tramorensis, n. sp. (Pl. III. Fig. 1.)

The only specimen of this new species was discovered in the townland of Quillia, and consists of a head-shield which is unfortunately not quite perfect; but it shows sufficient new characters to warrant us in considering it specifically distinct from any hitherto described.

It is semicircular in outline, with an anterior projecting process, and it is about twice as wide as long. The glabella is oblong, and the sides converge a little towards the anterior end, which is in the shape of a slightly convex-forwards arc. The glabella is gently elevated above the cheeks, but is rather flattened in front. The side-furrows are four in number, including the neck-furrow. The first or anterior one is merely an elongated deep pit, which does not join the axal furrow; it is directed forwards at an angle of 45° to the axis of the glabella. The frontal lobe is thus only marked off by this pair of isolated pits. The second or middle side-furrow is also an obliquely-set indentation inclined to the axis of the glabella at an angle of about 70° and directed forwards and outwards; at its inner end it is deep, but suddenly decreases in depth when traced outwards, and leads into the axal furrow by only a very shallow groove. The first lobe which it limits posteriorly is a short rounded ridge, not marked off very distinctly by the axal furrow at its outer extremity.

The third furrow is parallel to and as deep as the second at its inner end, but does not decrease in depth to the same extent in its outer portion. The second lobe has a rounded termination, but, except for this character and a greater length, is much like the first. The neck furrow is parallel to the third furrow, and rather deep along its whole length; it bounds posteriorly the third lobe, which is more prominent and better defined than the second lobe. The lateral extension of the neck furrow and the neck lobe are not well preserved, but the latter appears to have been slightly wider than the third lobe. The axal furrows are shallow. In front of the first lobe they are practically non-existent, for the ocular ridge and "terminal pit" lie across their forward course.

The surface of the glabella is sparsely strewn with a few large tubercles which do not show any symmetrical arrangement. Smaller tubercles are visible between the large ones, and minute pits also occur, but not very numerously. Each of the two hindmost lobes bears two tubercles of large size; and the anterior end of the glabella shows an aggregation of large and small tubercles without any linear or other regular order. The anterior end of the glabella is steep and abruptly truncated; it is separated from the peculiar anterior margin by a very faint depression. The middle portion of the anterior margin projects to a distance of just half the length of the glabella as a central flat spatulate process, in the specimen before us bent upwards at an angle of 45°. It is traversed by five low, but distinct, flattened ridges, separated by narrow and faint grooves which deepen in their forward portion. These ridges and grooves radiate from the front of the glabella in a fan-shaped manner; and on the anterior border of the spatulate process the ridges end as five short blunt projections. The border of this process has, therefore, a notched appearance. Two or three much fainter ridges and grooves occur on each side of the five central ones, producing a slight serration of the margin.

A clue to the origin and formation of this peculiar process seems to be given by the presence in a few species of *Cybele* of several radiating spines of greater or less length on the anterior margin; and if, for instance, in *C. coronata* (Schmidt) these spines were fused laterally together so as to leave only their tips free we should get a snout-like projecting process very similar to that in the Irish form. That such is the origin and composition of the spatulate process is rendered additionally probable by the presence of the radiating ridges, for they would represent the last traces of the formerly separate spines. In *C. coronata*, however, the spines diverge more strongly than do the ridges on the spatulate process of this new species.

Just outside the point on the anterior margin from which this process starts forwards, and slightly in front of the anterior outer angles of the frontal lobe of the glabella, there rises a low but well-marked rounded ridge which runs forwards and a little outwards, to become a prominent rounded tubercle projecting beyond the margin, which has here a width equal to about half the length of the spatulate process. This marginal tubercle corresponds with the "side-tubercle" of Schmidt, which is present in most species of *Cybele*, but is wanting strangely in *C. coronata*, to which the Irish form is most closely allied.

Close beneath the posterior outer slope of the ridge leading up to the "side-tubercle" is a deep circular pit, called by Schmidt the "terminal pit." It lies at the anterior end of the axal furrow, and is a most conspicuous object on the head-shield. According to Schmidt it corresponds with a similarly-situated pit in some species of *Cheirurus*, and is concerned in the attachment of the hypostome. The pit is, in the form under description, bordered posteriorly by a strong horizontal ridge—the ocular ridge—which runs outwards to the eye, at right angles to the axis of the glabella, and opposite to the first side-furrow. It is probably parallel to the posterior margin of the head-shield, but of this one cannot be quite certain owing to the imperfect preservation of that part. This ocular ridge has a row of minute pits close along the base of each side, and it also bears two large tubercles.

The anterior edge of the cheek runs outwards and backwards in a nearly straight line to meet the outer extremity of the ocular ridge at the small eye which is situated at a distance from the side of the glabella nearly equal to the width of the frontal lobe. The triangular space thus enclosed between the "terminal pit," the ocular ridge, and the front border of the cheek is inclined slightly downwards and forwards. It bears a central tubercle, and is also granulated and minutely pitted. Behind the ocular ridge lies the main portion of the cheek; its inner corners are almost rectangular, but its outer side has an outward as well as a backward trend from the eye, so that the width of the cheek measured along its posterior margin is more than half as much again as that of the glabella. At the bluntly pointed outer posterior angle the cheek is rather sharply bent down, and this downward bend seems to extend forwards some way along the outer side; otherwise the cheek is almost flat and horizontally extended. On its surface it carries two or three large tubercles and many smaller ones, in addition to numerous minute pits.

In the absence of any portions of the thorax or pygidium, a fuller description of the species at present is impossible.

On reviewing the previously described species of *Cybele*, one sees that this Irish form more closely approximates to *C. coronata* (Schmidt) than to any other. With this species, which occurs in C_2 (Brandschiefer) of Estland, it agrees in the axal furrows being very shallow, in the position and characters of the side furrows, in the strong horizontal eye-ridge with side punctures at the level of the first side-furrow, in the position of the eyes, in the general shape of the cheeks, and in the relative dimensions of the various parts. If my interpretation of the origin of the spatulate process is correct, the long "crown" of spines in *C. coronata* may also be regarded as a point of similarity. The Irish form, however, differs from this species in the glabella not being strongly arched forward in front, in the smaller size of the frontal lobe, in the presence of the "side-tubercles," in the greater width of the anterior border, in the triangular portion of the cheek that lies in front of the ocular ridge not being vertical, in the greater depth of the terminal pits, in the smaller width of the cheeks, in the irregular disposition of the tubercles on the glabella and cheeks, in the presence of two tubercles on the eye-ridge, and especially in the spatulate anterior process. These differences appear to me to be quite sufficient to justify a new species being formed for the reception of the Irish *Cybele*; and from the locality near which it was found it may appropriately be designated *Cybele tramorensis.*

DIMENSIONS.

Length of glabella from neck furrow to anterior extremity	·350 inch
Breadth of glabella at level of the second lobes	·275 inch
Greatest width of cheek (measured along posterior border)	·475 inch
Distance between "terminal pits"	·350 inch
Length of anterior "spatulate process" (measured from anterior extremity of glabella)	·175 inch
Distance of eye from side of glabella (measured along ocular ridge)	·250 inch

Trinucleus hibernicus, n. sp. (Pl. III. Figs. 2–7.)

This new species of *Trinucleus* is extremely abundant in that portion of the Bala series which is exposed at Newtown Cove, near Tramore. The average length of this form is a little more than half an inch; a rolled-up specimen measured ·6 inch, but some of the head-shields found were larger than that of this individual, while a few were smaller; but these differences may only be due to age. The head-shields, which are by far the commonest part of the trilobite preserved, very rarely have any of the body-rings attached. The head-shield is rather longer than the thorax and pygidium together, according to the above-mentioned rolled-up specimen, but in those individuals in which the head-shield has a semicircular outline it is rather shorter.

There appear to be two forms of this species which are characterized by the shape and certain features of the head-shield. In one form this part has a slightly pointed front and approaches a parabolic shape. In the other form it is broader and semicircular. Certain other differences in the length of the glabella, the sulci in the fringe, and lateral spines will be severally pointed out in the description of these parts. Probably these two forms represent the sexes, the pointed one being the male (?).

The head-shield in the male is less than twice as wide as long, but in the female the width is to the length as 9 : 4. The glabella consists of a prominent globular frontal lobe set on a narrow basal stalk. This large globular frontal lobe invades more than half the width of the fringe, and in the male slightly overhangs also the other half. It bears a central tubercle. Behind this lobe the glabella is sharply contracted to form a narrow parallel-sided stalk, about half the width and less than half the height of the frontal lobe, but equal to it in length. This stalk-like portion has two pairs of small transversely elongated lobes. The anterior pair is situated close under the great frontal lobe, which has its posterior border notched by the first pair of furrows. The posterior pair of lobes, which are slightly smaller and less distinct than the anterior, are situated about half-way between the neck lobe and the anterior pair.

The neck lobe is very narrow, and is only marked off from the rest of the glabella by a shallow, transverse groove. Behind the cheeks the neck segment is distinguishable as a gradual elevation of the posterior margin of the neck furrow, which has a steep anterior slope. But as the neck segment is followed towards the outer angle of the cheeks it assumes greater prominence, broadens and becomes a rounded distinct ridge usurping two-thirds of the width of the neck furrow.

The triangular cheeks are much inflated and rise abruptly from this furrow to rather more than half the height of the frontal lobe, from which they are separated by a deep axal furrow. The axal furrow is in this part narrower than it is posteriorly, where it widens out and becomes less deep, so as almost to attain the width of the glabella stalk. This widening of the furrow is due to the sudden contraction of the glabella behind the frontal lobe, and to the inner side of the cheek making nearly a right angle with the posterior edge of the head-shield instead of following the outline of the glabella. The cheeks do not overhang the fringe, but rise from its inner border with a pronounced convexity; the inner and posterior borders of the cheeks form steep and abrupt slopes.

A tubercle similar to that on the frontal lobe is situated on the most elevated point of each cheek. A fine reticulated kind of sculpture, with elongated meshes, ornaments the cheeks and glabella. There is no facial suture or "eye-line" visible.

The fringe surrounding the front and sides of the head-shield is parabolic in outline in the male, but semicircular in the female, as already mentioned. It is of constant width throughout, except in front, where the glabella invades it to half its width, and at the posterior angles, where it slightly expands. Its average width is a little less than one-third the length of the glabella. The upper surface of the fringe, which is gently concave, with a rounded edge, bears 20–26 radially-elongated deep sulci, of which the anterior are rather broader and more open than the posterior. Along the bottom of the 14–18 median sulci lie three conical pits (Pl. III. Fig. 6): the anterior one is smaller than the other two and does not communicate with the lower surface of the fringe. The two other larger pits, of which the posterior is of greater size, communicate with the lower surface by means of a minute pore at their base—the apex of the cone—which leads into a similarly arranged and corresponding pair of inverted conical pits opening on the under surface of the fringe. Whereas the anterior pit is only present in the median 14–18 sulci, the two larger pits with their corresponding pair of lower-surface pits are present in all the sulci of the fringe. In the last four or five sulci on each side the two pits on the upper surface approach more closely to each other until in the last two or three sulci they have actually fused more or less into one. In the cast of the lower surface of the fringe (Fig. 5) it is seen that there are only two pits present in each sulcus, and that these do not fuse together in the few last radial sulci on each side as the corresponding ones do on the upper surface, whereas in the anterior radial sulci on the lower surface the two pits approximate or even tend to fuse into one. There is also seen on the lower surface a marked smooth space, nearly equal in width to the sulci, running behind them in a pointed arch and separating them from a single series of small pits which do not show on the upper surface. The median front portion of this series is situated on a triangular depressed area which posteriorly is extended into narrow vertical prolongations, separated from the rest of the fringe by a continuation of the unpitted space. These prolongations, which are in fact the upwardly-bent inner margins of the fringe, decrease in width till they end at the base of the genal spines and bear the single row of small pits. What appears, therefore, in the impression as a cushion, corresponds to an actual concavity on the lower surface of the fringe. The genal or lateral spines start from the outer posterior angles of the head-shield; each spine is stout at its base, but tapers rather rapidly to a point; it is also grooved along its whole length and has an outward curve. As far as I can draw conclusions from the fragmentary material at present at my disposal the spines in the male are longer than those in the female. The degree of outward curvature is also liable to variation.

The thorax with its six body-rings has the axis strongly convex. The pleuræ are horizontal as far as the fulcrum, but are at that point bent gently downwards and slightly backwards. The fulcrum is situated at a distance from the axis of rather less than two-thirds the whole length of the pleura. A shallow furrow starts from the anterior inner angle, and runs to the outer posterior angle of each pleura, increasing in breadth as it is traced outwards. It is bordered in front by a narrow rounded margin of constant width which is formed by the raised anterior edge of the pleura. The posterior part of the pleura is abruptly elevated behind the oblique furrow, but slopes down gently to the posterior margin. In the extra-fulcral portion the furrow occupies nearly the whole width of the pleura. The free ends of the pleuræ are truncate.

The pygidium, which is about one-third the length of the head-shield, is rounded and transversely expanded (being nearly three times as broad as long), and has a moderately convex axis occupying in breadth about one-fifth of the surface. This axis tapers slightly to an obtuse end which almost touches the posterior margin, and is crossed by three or four faint annulations. Two to four indistinct grooves are visible on the lateral lobes of the pygidium, the broad posterior border of which is sharply bent down.

Affinity.—The figures in Angelin's "Palæontologia Scandinavica" (*Trilobita*, t. xli. figs. 1, 1*a*, *b*, *c*, p. 84) of *Trinucleus bucculentus* (Ang.), if they had been supplemented by a more minute description, would have enabled us to institute a more exact comparison than is now possible; for undoubtedly the Irish form approaches more closely to this species than to any other. The points of agreement with Angelin's species are (1) the general appearance and amount of inflation of the parts of the head-shield; (2) the shape of the glabella and its lobes; (3) the tubercles and ornamentation on the glabella and the cheeks; (4) the presence of radial sulci; (5) the general characters of the pygidium. The peculiarities of the Irish form, and its differences from the foregoing species, are (1) the non-projection of the glabella beyond the fringe; (2) the shape of the cheeks and their lack of any lateral overhang of the fringe; (3) the minute size and relations of the sulci, and the pits in them; (4) the outward curvature of the spines.

The lower surface of the fringe and the thoracic rings are not figured by Angelin, but the Irish form has in them features not found in other figured or described species. Under these circumstances the Irish form deserves to rank, for the present at any rate, as a distinct species, and it may be called after its home, *T. hibernicus.*

EXPLANATION OF PLATE III.

Fig. 1. *Cybele tramorensis.* × 3.
Fig. 2. *Trinucleus hibernicus.* ♀ Head-shield nearly perfect, showing general shape and characters. Variety with many lateral sulci. The glabella is worn and imperfect. × 3.
Fig. 3. Ditto. Head-shield showing lobes of glabella, tubercles, etc. × 3.
Fig. 4. Ditto. ♂ Impression of thorax and of lower surface of fringe of rolled-up specimen. × 6.
Fig. 5. Ditto. Impression of head-shield of rolled-up specimen Fig. 4. × 3.
Fig. 6. Ditto. Portion of upper surface of fringe, showing pits in median sulci. × 6.
Fig. 7. Ditto. Reticulate ornamentation of glabella and cheeks. × 18.

II.—A Criticism of the Astronomical Theory of the Ice Age, and of Lord Kelvin's Suggestions in connection with a Genial Age at the Pole.

By Edward P. Culverwell, M.A., Fellow of Trinity College, Dublin.

(*Continued from the January Number, page* 13.)

(Part II.)

In the previous portion of this paper, which appeared in the January Number, I examined the form in which Croll presented the astronomical theory of the Ice Age and endeavoured to show how absolutely unsound his argument is. It is, however, at least as necessary to discuss the form in which Sir Robert Ball presents it; for much of the recent success of the theory, outside the school of modern geologists, was due to the weight naturally attached to the fact that a writer of Ball's scientific eminence believed he had so materially strengthened Croll's astronomical argument, that had Croll himself been aware of its full force, he would not have felt bound to call in such auxiliary agencies as a diversion of the Gulf Stream from its course. If, then, the theory, as presented by Croll, was able to win its way with such success among scientific authorities, it must surely be irresistible in the new and more powerful form. But it will be seen that, so far from strengthening Croll's position, Ball's statement weakens it very materially.

I. Examination of Sir Robert Ball's "Cause of an Ice Age."

The first pages which deal with the astronomical explanation of the Ice Age are pp. 43–47. Here Ball practically agrees with Croll; the only difference being that while Croll takes − 239° F. as the "natural zero," or temperature, to which the earth would fall if the sun-heat were removed, Ball takes −300 F. Thus, all the objections to Croll's argument C (see the paper in the January Number) apply equally here. In addition to what I have there pointed out, I give the following discussion to show how the method on which Ball and Croll rely, if properly followed, confirms my contention.

Let us try to apply this method to the temperature of Great Britain, amending it where it is in direct conflict with known physical laws. We must proceed somewhat as follows: Since the temperature reaches its maximum and minimum in July and January respectively, we know that in each of those months the total heat received is equal to the total heat lost. Now, the loss arises from two causes—first, heat lost by radiation from the earth; and second, heat lost by transference to other parts of the globe. Similarly the gain arises from radiation from the sun, and from heat transferred from other parts of the earth. We can strike a balance between the heat lost and gained by transference, and call it the heat gained by transference; but we must, of course, remember that this will be a negative quantity if more heat be transferred northward than is received from southward.

Now we assume with Croll that the radiation from the surface of the earth is to be treated as a direct radiation into space; that is to say, we neglect what is probably one of the most important factors in terrestrial temperatures, the blanketing effect of the atmosphere. Then, assuming the truth of Stefan's law, we suppose the loss by radiation to be proportional to $(460+t)^4$. Hence, if H be the heat transferred, and S the sun-heat and stellar radiation received, then since in January and July, when the temperature is stationary, the heat received must equal the heat lost, we get the equation,

$$H + S = A(460 + t)^4$$

where A is the coefficient of radiation. As we do not know the value of H, we must make various assumptions and see what their effect will be. First, suppose that in July $H = 0$. Then, taking lat. 55° as representing Great Britain generally, we have for July $S = 1700$, and $t = 60°$ F., and for January $S = 265$ and $t = 40°$ F., the 1700 and 265 being, of course, on an entirely arbitrary scale. Hence for July,

$$1700 = A(460 + 60)^4$$

which gives

$$A = \frac{1700}{(520)^4}$$

Hence for January,

$$H + 265 = \frac{1700}{(520)^4}(500)^4$$
$$= 1455$$

This gives for H, the heat transferred to us from the Gulf Stream, etc., in January, the equation

$$H = 1455 - 265 = 1190$$

Now, in order to get the direct effect of diminished sun-heat, let us suppose that the heat transferred in January in the epoch of great eccentricity is the same as that now transferred, and we get for the temperature at that period the equation

$$1190 + S' = \frac{1700}{(520)^4}(460 + t)^4$$

where S' is the reduced sun-heat radiation in the epoch of great eccentricity. But the sun-heat is reduced by about 16 per cent., so that if we neglect the star-heat we get for S' the value 223. Hence the equation becomes

$$1190 + 223 = \frac{1700}{(520)^4}(460 + t)^4$$

and this gives for t a value between 36° F. and 37° F. Hence, on this supposition the fall in temperature would be between 3° F. and 4° F., about the same as that obtained by my much safer method of comparison.

If we suppose that in July we receive a balance of heat from the Gulf Stream and air-currents, we should get a still smaller lowering of temperature in the supposed Glacial epoch. For instance, if H, the July heat transferred, was equal to the July sun-heat, then the above fall in temperature would be reduced by almost exactly one-half. If, on the other hand, we lose half our summer sun-heat by transference to more northern latitudes, then the fall in temperature would be about 7°, nearly double that obtained on the first supposition.

I do not give this as a safe method, because in the first place it neglects the effect of the *blanketing* by the atmosphere; in the second place there is the uncertainty about H, and in the third place although it is quite certain that the radiation increases faster than the temperature, yet Stefan's law may not be strictly applicable to the radiation of the earth in space. I insert it merely to show that a little physical knowledge of the problem they were dealing with would have saved the astronomical geologists from making such extraordinarily mistaken estimates of the effect of the decreased sun-heat on terrestrial temperature.

The fact that the lowest temperatures occur almost simultaneously about January all over the globe, as shown by the "Challenger" isothermal maps (just as the highest temperatures occur about July), indicates that the upper regions of the atmosphere have a very great controlling influence on the loss of heat by radiation, and that instead of considering that the earth radiates heat off to space it would be more correct to regard it as radiating to those high altitudes of atmosphere in which, for two reasons, the temperature is probably much more uniform between the poles and the equator than it is nearer the earth's surface. For in the first place, there is probably a very rapid interchange of air between the poles and the equator, and in the second place, the upper strata of the atmosphere are warmed by the sun with far more constancy than the lower strata; even at the earth's surface twilight lasts till the sun is 18° below the horizon, and as we ascend the horizon is depressed. If it were not for this, we should expect the polar regions to go on cooling down during all their long night of winter.

From p. 48 we pass to p. 78, where the exposition of the theory really begins. There is nothing in the well-known theorems here set forth which calls for comment till p. 89, where I find the first indication of a statement, repeated more than once later on, to the effect that Dr. Croll was under the erroneous impression that the winter sun-heat was equal to the summer sun-heat, the difference in temperature arising only from the greater length of the winter. It is due to Dr. Croll that this misconception should be removed, and I am sure Sir Robert will be the first to acknowledge the justice of the correction. In "The Cause of an Ice Age," p. 89, we read: "Do not read this as if it asserted that the heat received during summer is equal to that received during winter. This is not true, but it has been often asserted. It is, in fact, the fundamental error which has vitiated the astronomical theory of the Ice Age *as previously presented*, and which it is the chief object of this little book to expose."

Again, p. 115: "Not only did I find that the true law had been overlooked but it became apparent that sometimes another law had been adopted which was absolutely incorrect. I found, furthermore, that the astronomical theory of the Ice Age as ordinarily stated was contaminated with absolute blunders in the simple mathematical questions which are involved."

Having then quoted what is certainly either a careless mistake or a mere oversight of Herschel, who incidentally states that half the heat of the year is received in summer and half in winter, Sir Robert proceeds (p. 118): "Indeed, on such a matter it was not unnatural that the words of Herschel should have been adopted without any very careful scrutiny. *I examined Croll's book carefully on this point.* . . . . So far as I can gather from the various allusions to the astronomical element of the problem in his writings, *it would seem as if he entertained the same view as that which is incorrectly set down in the 'Outlines of Astronomy.'*" Again, p. 135: "He [Dr. Croll] appears, in common with many others, to have been influenced by Herschel's unfortunate inadvertence."

I had read Croll's "Climate and Time" before I read "The Cause of an Ice Age," and I certainly had not received the impression that Croll was under the misconception supposed by Ball. Indeed, it seemed to me a thing incredible that anyone should *really* suppose the winter sun-heat at, say, the North Pole, was equal to the summer sun-heat at the same place. Accordingly I examined Croll, and I cannot find the slightest ground for the idea that Croll entertained the erroneous view referred to; but, on the contrary, he more than once lays down the law in the correct form in which Ball states it, and in p. 87 of "Climate and Time" Croll incidentally shows how well aware he was of the true nature of the distribution of annual heat. Speaking of the latitude of Edinburgh, he says: "The quantity of heat received during winter is *scarcely one-third* of that received during summer," and further down on the same page he speaks of the "*deficiency of heat received in winter from that received in summer.*"

In the first of these quotations from Croll we see one great difference between his method and Ball's, a difference in which the advantage seems to me to lie wholly with Croll. For, while Croll carefully bears in mind the different relations which exist between the winter and summer sun-heats in different latitudes, Ball *lumps together the winter sun-heat over the entire northern hemisphere,* and compares it with the summer sun-heat over the *entire* hemisphere. He does not suggest any *reason* for introducing the sun-heat over the tropics in a question which relates only to the temperature of the northern latitudes. He does not seem to think it necessary in any way to justify or explain the application of the numbers 63 and 37 (which, of course, do give the relative summer and winter sun-heats received over the entire of either hemisphere); he merely *states* that it is impossible to discuss the astronomical theory of the Ice Age unless these figures form the refrain of every argument (pp. 90, 91). But in fact these figures, 63 and 37, have little or no relation to the astronomical theory of the Ice Age, which is really the theory of the temperature of the northern latitudes in the winter of great eccentricity. For the temperature at any latitude is determined by four factors—

(1) The gain of heat transferred to it from warmer latitudes by means of air and ocean currents.

(2) The loss by heat transferred from it to colder latitudes by air and ocean currents.

(3) The sun-heat received by it.

(4) The heat radiated by it into space.

Now neither the summer nor winter value of any one of these quantities is represented by, or proportional to, the numbers 63 and 37. They vary from latitude to latitude, and it would be impossible for any single pair of numbers to represent the combined effect of the very complicated quantities over the different latitudes to which the theory of the Ice Age must be applied.

But if we are to take two numbers to represent the summer and winter sun-heats which determine the temperature of the glaciated regions, we should at least take figures which bear some relation to the sun-heats which actually fell on those regions. Now, since considerably more than half the annual sun-heat falls between the equator and latitude 30° (as is evident from the fact that sin 30° $=\frac{1}{2}$), and since this amount is not far from equally divided between summer and winter, it follows that out of 100 units of heat falling annually on the northern hemisphere, say 25 falls in summer and 25 in winter within latitude 30°, leaving only about 63—25 and

37—25, or 38 and 12, for the summer and winter sun-heats on the portion of the hemisphere north of latitude 30°. This rough and ready calculation is made merely *to show how far the numbers 63 and 37 are from any numbers which could be supposed to give the ratios of the summer and winter sun-heats in those regions of the earth with whose temperature during the long winter of great eccentricity it is the business of the astronomical theory to deal.* The actual percentage of summer and winter sun-heat are—for lat. 50°, 73 and 27 (nearly 3 to 1); for lat. 60°, 82 and 18 (more than 4 to 1); and for lat. 70°, 91 and 9 (more than 10 to 1). How greatly must the astronomical theory of the Ice Age, which is neither more nor less than the theory of the temperature of these latitudes during the long winter of great eccentricity, be weakened by substituting for these numbers the uniform ratio of 63 to 37!

Again, the mode in which Sir Robert uses these figures 63 and 37 to arouse in the untrained imagination the picture of a winter of appalling severity is very unsafe. The argument is put on p. 135. If in the period of great eccentricity "the [nearly] double supply of heat [63 measures] be poured in like a torrent during the short season [166 days], while the single supply of heat [37 measures] is constrained to do duty over the long season [199 days], then an intolerable climate is the result. The total quantity of heat received on the hemisphere in the course of a year is no doubt the same in each case; but its unsuitable distribution bespeaks a climate of appalling severity—an Ice Age, in fact."

It will probably come as a surprise to most readers of this passage to learn that they are even now suffering under a still more intolerable climate than this, one of far more "appalling severity." In the latitude of Dublin, where the book was written, while 63 measures of heat were poured in like a torrent during the 166 hottest days of the year, not 37 but only 22 measures of heat are left to do duty over the long period of the 199 coldest days; that is, *less than two-thirds of the amount which is supposed to produce an Ice Age.* In fact, we have to go as far south as Madrid, Naples, or Constantinople, in lat. 41°, to get the summer and winter distribution of sun-heat during the 166 and 199 days in the appalling proportions of 63 and 37.

There are two other quantitative statements relative to alteration in temperature made by Ball. The clearest is on pp. 130, 131, where he deduces the result of a method of using the numbers 63 and 37 to obtain a numerical statement. He finds that in the Ice Age the mean annual range of temperature of Great Britain will be increased from its present value of 20° F. to 28° F. Surely this is a *reductio ad absurdum* of the theory. There is hardly a climate in the northern hemisphere where the range is not much greater than 28° F. In latitudes 40°, 50°, and 60°, in America, the ranges are 50° F., 65° F., and 75° F. respectively, but we have no Ice Age there. Why should a range of 28° F. in Great Britain be supposed to produce an Ice Age? The reason given is (p. 131): "It is to be observed that, generally speaking, the coldest places are those of the greatest mean annual range. We are, therefore, *entitled to infer* that the effect of such a change in the eccentricity as we have supposed would be to increase the range, lower the temperature of the hemisphere, and thus induce the Glacial period." How are we to discuss such an assertion? It amounts to this, that *without examining what the alleged connection between annual temperature and annual range is,* and *without any previous attempt to ascertain what temperature is necessary to bring about an Ice Age,* we are "entitled to infer" that a range of 28° F. in Great Britain would induce the Glacial period! So far from that being the case, the most cursory examination of the far greater ranges of temperature in non-glaciated regions at present seems to entitle us to infer that the supposed increase of range would be quite powerless to effect the desired, or indeed, any very marked change in climate.

The other quantitative statement is to be found on p. 105, where, still working on the basis of the 63 and 37, Ball calculates that in the Glacial winter there would be a deficiency of 7 per cent. in the average daily supply of sun-heat as compared with our present winter supply, the unit being the average annual daily sun-heat. As the unit, according to Ball's supposition, keeps Great Britain 350 degrees above the natural zero, this might be supposed (according to the erroneous theory adopted by Ball and Croll alike) to produce a lowering of 24·5° F. in the winter temperature of Great Britain. Ball does not here make the calculation, but I make it on his principles in order to show how small is the result obtained by Ball as compared with that of Croll, who gets a lowering of 45·3° F. in the winter temperature of Great Britain. Hence, so far from Ball being correct in thinking that if Croll had known his form of the purely astronomical portion of the theory, he would not have considered the alteration of the Gulf Stream a necessary adjunct, it would seem as if Croll would then have wanted a second Gulf Stream to help him for the 45·3 *minus* 24·5 degrees of refrigeration he would have to abandon.

I now pass to another point. It was long ago stated by Tyndall that great heat to produce evaporation was as necessary in giving rise to a Glacial age as great cold to produce condensation. After agreeing with this, Ball states that the astronomical theory shows where to look for the necessary heat. He points out correctly that the annual quantity of heat received by the whole earth is not lessened, and he continues (p. 109)—"If, therefore, the glaciated hemisphere received during its winter a deficient supply of heat, to which the glaciation owes its origin, *the defect of heat upon this hemisphere will have to be compensated for elsewhere.* More favoured regions of the globe will accordingly enjoy a more copious supply of sunbeams, and thus those volumes of aqueous vapour will be provided which, put in circulation by the winds, are deposited in the form of snow when the ice-sheets are growing." Here is an oversight, not unlike that of Herschel, to which reference has been made. The sentence I have italicised should read, "the defect of *winter* heat on this hemisphere is compensated for," not else*where*, but else*when*, *i.e.* "in summer on the same hemisphere." The "more favoured regions" are enjoying a *cooler* summer than usual, for, in the Glacial winter the whole earth is further from the sun than usual, and every region receives less heat. Hence it follows that if the extra heat of the short Glacial summer is to produce the increased evaporation, and if the snowfall is to be in winter, it is necessary that the moisture thus evaporated in summer shall be held in the atmosphere till precipitated by the cold of winter. Croll, who saw well the difficulty here involved, boldly asserts that the chief snowfall will be in summer.

I have now disposed of every argument of importance put forward by Ball, and shown that the theory as presented by him does not even *claim* to account for at all as great an effect as that asserted by Croll. For, as has been shown above, Croll claims a lowering of 45·3° F. in the mid-winter temperature of Great Britain, while Ball's theory only gives about 25°. Hence it is quite a mistake to suppose that though Croll's mode of presenting the astronomical part of the theory may require to be strengthened by considering the changes produced by ocean currents, such auxiliary causes are rendered unnecessary by the changes Ball has introduced. Evidently they would be more necessary on Ball's theory than on Croll's.

Hence the net result of the discussion is that the theory remains where Croll left it.

In concluding a long and somewhat dry criticism, I may be allowed to express my satisfaction in finding that the conclusion I have reached on purely physical grounds, negative though it be, is so far in accord with the views of the modern school of geologists that it permits of the date of the prehistoric glaciations being fixed in accordance with the geological evidence, and, as I venture to think, finally removes a restriction as to the date of the Ice Age, which many geologists had felt to be an unreal one.

[Since writing this paper, my attention has been directed to Sir H. H. Howorth's *Glacial Nightmare*, in which there is a long and able criticism of the Astronomical Theory of the Ice Age, in which a summary of the criticisms advanced by previous writers is included. The chief feature of this paper, *i.e.* the mode of calculating a limit to the probable alteration in terrestrial temperatures due to direct sun-heat, is not of course referred to, not having been published until last year.]

As to the genial age, we have the great authority of Lord Kelvin for thinking that it might be due to a more open Arctic Sea in which a great influx of warm water was maintained. See *Geological Climate* in his recently republished *Lectures and Addresses.*

After saying that a sinking of 1000 feet would submerge vast areas of land, and leave the North Pole very free and open to access by sea, he continues: "Just think of a current of three-quarters of a nautical mile per hour, or 70 miles in 4 days, 40 fathoms deep, flowing across the Arctic circle to the Pole. This would cover the whole area by one fathom, and if 7·1° C. above the freezing-point would bring in enough heat to prevent freezing, if in 24 hours as much heat were radiated away, as, taken from 7·2 inches of water at zero, would transform it to ice. This is no doubt much more than the actual radiation would be if the water were 0°C. at the Pole and 7·1° at the Arctic circle." Add to this a south wind at 15 miles per hour through 2300 feet above the surface, and also at 7·1° C. (which would carry as much heat as 15 fathoms of the water), and we have the agencies suggested by Lord Kelvin in 1877 for the production of a genial period at the Pole. But suppose we grant that they would keep the Arctic circle from frost, is there the least probability of such agencies ever coming into play? The Gulf Stream flows at less than 4 miles per day, and we are asked to suppose a current flowing at 18 miles per day! Where is the impelling force to come from? Apparently Lord Kelvin suggested that the difference in specific gravity due to temperature might be the motive power, but in view of the final abandonment of temperature differences as causes of ocean currents on a large scale, this cannot be admitted as sufficient to produce a current of anything like the required depth or velocity, and whether we assign winds or difference of specific gravity as the cause, we are met by the difficulty that, as we have ultimately to depend on differences of temperature in different latitudes, Lord Kelvin's result seems inconsistent with his cause, for he supposes the temperature differences to be almost annihilated. Again, in January, we have to go far south of the Arctic circle to get a temperature of 7·1° C. (nearly 45° F.). Again, if the forest trees of Greenland, Grinnell Land, and Spitzbergen were only found at a height of 1000 feet above the present sea-level, it might be rational enough to account for the high temperature of which they are the evidences by supposing a submergence of the land to that extent, but, since this is not the case, we cannot postulate such a submergence to explain the phenomena.

As to an explanation of prehistoric glaciation, I am afraid I have nothing very definite to offer. Of course an alteration of altitude is sufficient, but the geological requirements do not seem to admit of a very free use of this method of explanation.

If, indeed, we could see any probability that at a former age the south winds passed in the upper regions of the atmosphere in summer, as they now do in winter when the surface wind is from the north, so that there was a continuous and permanent north wind blowing across the Arctic circle down to temperate latitudes, then we might find a full explanation of an ice-age gradually spreading southward over the land, especially as such winds would either impede or reverse the Gulf Stream. I am not at present, however, able to suggest any cause for such a difference from the present distribution of the winds.

It is not unlikely that there never was an Ice Age, but that there have been at times various local glaciations such as we now see in Greenland. The present glaciation in Greenland is supposed to be in great part due to the cold-water current which flows along its shores from the Polar regions, and this, in its turn, is in part due to the entry into those regions of the Gulf Stream, so that the glaciation of Greenland is the counterpart of our genial climate. Into these geographical conditions I do not, however, propose to enter here; I will content myself with a general argument for the geographical theory of glaciation as opposed to the astronomical, namely, that whereas the change in the winter isothermals due to sun-heat in times of great eccentricity amounts at most to about 4° of latitude, the present changes in winter isothermals amount to over 33°, as where the 0°C. winter isothermal passes from south of New York to north of the North Cape, a shift due to geographical conditions about eight times as great as any shift due to astronomical conditions could be.

Is it possible that there may have been any considerable interchanges of atmosphere between the earth and the regions of space through which it has passed? It is certain that there must have been some such interchange. Whether the atmospheric pressure is increasing or diminishing depends on whether, in the course of the earth's motion through space, more of the interstellar molecules get entangled in the earth's atmosphere than, leaving that atmosphere, get entangled in the interstellar gases through which the earth happens to be passing, and are thus dragged away from the earth. If once we were allowed to assume the magnitude of these changes, the whole difficulty of explaining Glacial or genial ages, so far as temperature changes are concerned, would vanish. For instance, if due to some gaseous conditions of space, or perhaps to the absorption into the atmosphere of the gaseous components of meteorites or shooting stars, there be an addition to the atmospheric pressure of one millimetre in three centuries, and if this process has been continued for 20,000 or 25,000 years, then it follows that, some 25,000 years ago the atmospheric pressure would have been less by about one-tenth part than it is at present. This would be equivalent to raising land and sea by about 2500 feet, for the blanketing effect of the decreased atmosphere would be about the same as that which now lies above a mountain 2500 feet high. Thus a Glacial epoch might be produced *without any alteration in the geographical conditions.* And if, on the other hand, either through the earth plunging into a more gaseated region of space, or through some catastrophe, the atmospheric pressure were to be much increased, the resulting increase of temperature might be very great, and a genial age might be the result—a rise of 50° F. might readily be got.

No doubt there is much that may fairly be called "vague speculation" in this suggestion; but there is an advantage even in that, for the more vague it is the more difficult to refute it. Certainly I do not think it can be refuted by calculations such as those of Mr. G. H. Bryan, p. 682 of the 1893 Report of the Brit. Assoc., on the supposition that the temperature is constant and that the gases have established themselves in a permanent state. Thus he finds that at any given instant there are very few particles ready to leave the atmosphere of a large planet. But the very essence of this supposition is, that the distribution throughout interstellar space is not permanent and does not follow the error law. If two bodies flying about in space come into collision they may generate a mass of gas, and if this mass of gas happens to get in the earth's path it may be caught up. Indeed, if we assume that the earth's atmosphere maintained a strict equilibrium with the interstellar molecules at, say, a distance of 1000 miles from the earth's surface, then a doubling of the almost infinitesimal pressure there, would necessitate a doubling of the pressure at the earth's surface. Of course this supposition is only used for the purpose of illustrating the fact that a small alteration of interstellar pressure, if spread over a sufficiently vast space, might eventually give rise to a considerable change in the atmosphere. Moreover, when considering the applicability of Mr. Bryan's investigations, we must not forget the enormous speed with which the earth meets the interstellar gases. Hardly any molecules of those gases can be travelling at anything like the speed with which the atmosphere charges into them. When in addition I remember that the atmosphere is in a state of rotation, during this charge into the interstellar matter, I comfort myself with the thought that the problem of atmospheric interchanges is so complicated that I may at all events hope to enjoy my hypothesis for a considerable time before anyone succeeds in giving it a really decisive overthrow. Its great advantage as a theory of the Glacial epoch is, that it does not require geographical changes such as are usually postulated in connection with all other theories, even the Astronomical one.

III.—The Evolution of the Brachiopoda.[1]

[A Sequel to Dr. Thomas Davidson's "What is a Brachiopod?"][2]

By Agnes Crane.

(PLATE IV.)

Part I.

FOR many years I have been deeply interested in the general history of the Brachiopoda, and I have enjoyed the acquaintance, correspondence, and friendly encouragement of most of the eminent biologists and palæontologists who have devoted themselves to the elucidation of the complex structure of this class. Here I must name with reverence Davidson, long my friend and master; Barrande, of Prague; James Hall, of Albany; William King; Eugène Deslongchamps, the Norman naturalist; Suess, of Vienna; Friele, of Bergen; Morse, of Salem; and Dall, of Washington; "all honourable men," and many others of the *fin du siècle* school, whose names will be noted in the sequel.

During this period the history of the class has been completely re-written. The Brachiopoda now seem to justify the prescience of

[1] Read at Chicago, August 24, 1893, before the Women's Auxiliary Branch of the World's Congress (Section Geology), Department of Science and Philosophy; also before the Brighton Natural History and Philosophical Society, November 13, 1893.

[2] Geol. Mag. 1877, Dec. II. Vol. IV. pp. 145–155, and 199–208.

Darwin. Formerly regarded as one of the most obstinate difficulties in the way of the demonstration of the evolution of invertebrate life on earth, they now bid fair to become a remarkable illustration in favour of it. It is no longer possible to doubt that the life-history of the Brachiopoda does yield convincing testimony of the truth of the law of Evolution, and to the establishment of this fact American scientists have largely contributed. Their work is the more creditable to them because so often carried on amidst a constant fight for "appropriations" and a liability to upset from the exigencies of the political situation—trials happily unknown to our more favoured scientists. In the Western world the minds of scientific workers in general seemed more favourable to the acceptance of the great principles of Evolution conceived and first promulgated in Europe. In America they sought rather to prove the argument than to controvert it. They were, perhaps, less blinded by that third eyelid "the nictitating membrane" which their genial and witty philosopher, Wendell Holmes, has declared to be common alike "to reptiles, some birds, and theological students," and by means of which, he said, "they shut out," not all the light, "but all the light they do not *want!*" The genus is not absolutely unknown in this country, although more rare than formerly. It is to American biologists that we owe not only the systematic correlation among invertebrates of the development of the individual (ontogeny) with the phylogeny or evolution of the group to which it belongs, but also the important discovery of the radicals of many classes of molluscan animals. Such ancestral root-stocks have been determined by Hyatt for the Cephalopoda, by Jackson for Pelecypoda (in *Nucula*), and by Beecher for the Brachiopoda. The radical of the Brachiopoda is the Lower Cambrian genus the father-like *Paterina*, of which more anon.

The Brachiopoda, it is well known, have persisted through all the life epochs of the geological past. Their bivalve shells occur fossil in all marine deposits ranging from the Primordial to the Quaternary. They were, however, much more abundant during the "old time" and medial ages of geological history than during these "latter days" of the earth. Out of the 277 described genera 186, or two-thirds of the whole number, appeared in Palæozoic seas, and a goodly number were evolved during the great Secondary epoch.

Thousands of species or "mutations" have existed in the past, but now they can be numbered by tens instead of by thousands, for there are fewer surviving species than there were genera in the Palæozoic era. The actual number of living species was estimated by Davidson—in that posthumous "Monograph on the Recent Brachiopoda" which it became my sad duty to edit for the Transactions of the Linnæan Society—at 99 certain, and 29 doubtful species, referable to 22 genera and subgenera. With the modern tendency to generic subdivision and stricter revision of species it is probable that this estimate will be reduced rather than augmented, so far as the number of species is concerned (27).[1]

[1] These numbers, in parentheses, refer to the Bibliography given at the end of Part II.—Edit. G.M.

The living forms are universally distributed in the seas of the world. Their range in depth is no less extended. They occur in shallow waters, at low water-mark, and varying degrees of depth, from 200 to 600 fathoms being the usual limit of the majority of species. Several far-ranging abyssal species were dredged in from 1000 to 2000 fathoms. The delicate transparent shell of that interesting little Terebratuloid *Liothyrina* (*Terebratula*) *Wyvillei*, Dav., was actually obtained in a living condition by the "Challenger" Expedition from the enormous depth of 2900 fathoms, or three miles and a quarter, at the bottom of the South Atlantic Ocean (30).

Such manifest adaptability to varied environments is probably one of the main causes of the persistence of the group throughout the geological ages. The Brachiopoda seem to flourish alike in tropical seas and the frigid abysses of the ocean. They are extremely tenacious of life in captivity, pursuing—

"The noiseless tenour of their way"

for months and even years together. An occasional yawn seems to be their only diversion. The animals are, however, sensible to light and close their valves abruptly on the interposition of any shadow. The "gape" is less than in the oyster. Civilized man who swallows that succulent, but often insanitary, bivalve, is apt to draw the gastronomical line at the Brachiopod, but in the Philippine Islands where Lingulæ abound and are cast up by the sea, like mussels on our shores, the natives collect them for food. It is evident from the small space alloted to the animal in some of the fossil species that there was very little to eat in them. Many fishes are ardent, if somewhat indiscriminating, "collectors" of Brachiopods. One would imagine the spinose forms would prove rather indigestible; but the contemporary sharks and other fishes were furnished with powerful crushing teeth, and doubtless made "small bones" of those ornamental appendages.

The use of these spines, so extensively developed in adult individuals of several families, is not actually determined. In some species they were evidently flexible, and served as moorings or as clasping organs, as in the case of that little Productoid which Fischer and Œhlert re-named *Etheridgina* in honour of its first describer, for this *Productus complectens* clasped its spines round the stems of the sea lilies, swaying to and fro in the ocean's depths. In other forms they were tubular, and Dr. John Young has described species with double spines, one contained within the other (74). Such may have subserved the function of respiration, or to admit water to the interior of the shell preventing the introduction of impurities, as De Verneuil had previously maintained. The spines obviously afforded no protection to the species in the struggle for existence, for only one spinose form survives out of many members of various families thus ornamented. This interesting example is that of the little living Rhynchonelloid which was dredged by Döderlein in Sagami Bay, Japan, and was named *R. Döderleini* by Davidson just before his death (31). This curious survival belongs to that sub-section of spiny Rhynchonelloids denominated *Acanthothyris* by D'Orbigny, so abundantly represented in the Oolitic seas. That acute Norman palæontologist, Eugène Deslongchamps, however, considered it more closely reproduced the fashion of spinose ornamentation, characteristic of certain Palæozoic genera, as the spines are arranged in regular rows at intervals, as in *Atrypa*, a Palæozoic form, and are not irregularly dispersed over the surface, as in the spinose Rhynchonellæ of the Jurassic epoch (34).

There are, indeed, "all sorts and conditions" of Brachiopoda; they vary in size from a pin's head to nearly a foot in length and in breadth (*Productus giganteus*), from the Carboniferous Limestone. Their familiar forms present so many queer shapes and ornaments that it is impossible now to detail their external features.

But something must be said with regard to the animal inhabiting the shells, for the days of the simple conchologist, content with mere externals, have passed away—or he survives only for the benefit of the dealer. The study of what was scornfully termed the "nasty animal" has become one of the most important conditions of biological research from the earliest free-swimming larval phases to the adult fixed condition of the individual. The embryologist now follows the life-history of a Brachiopod from the ova through all its stages of development. The bathmologist watches it from the first moment of the growth of the *protegulum*, or initial shell-covering, through infancy to youth, from youth to adolescence, from adolescence to maturity, from maturity to decline, and from decline to absolute senility of extreme old age, when the venerable Brachiopod, like more exalted organisms, again reverts to its infantile characteristics. Then, alas! it sheds its surface ornaments, becomes bald, so to speak, and may even become obese!

It is to the recognition of the value of these methods of investigation, or the twin sciences of embryology and auxology, or bathmology, as Hyatt prefers to term it, inaugurated by Heckel, of Jena, extended by Hyatt, of Boston, and systematically applied to the Brachiopoda by Beecher and Clarke, that in a measure we owe the revolution of thought concerning the evolution of the Brachiopoda.

The class is again subdivided into two sub-classes distinguished by certain divergent features of both shells and animals, yet possessing some points of the nervous, circulatory, muscular, and reproductive systems in common. The animal in both sub-classes —developed from ova discharged from the fringed margins of the mantle into the sea-water—begins life as an active free-swimming ciliated embryo. It develops "eye-spots" and a peduncle by which in many species it becomes attached by its hinder body-segment, henceforth adopting a sedentary life. The shell, which is secreted by the muscular "mantle" envelope, then makes it appearance.

Brachiopoda belonging to the simpler and somewhat older type are characterized by hingeless and often impunctate shells in which phosphatic elements usually preponderate, with valves kept in place solely by shell-muscles. The "arms" or breathing organs are of a cartilaginous nature exclusively. The circulatory system is rudimentary, the liver large, and the digestive canal has a terminal orifice, lateral in *Lingula*, dorsal to the median line in the anomalous *Crania*. The hingeless Brachiopoda are heartless creatures, and the circulation of the colourless lymph is effected by ciliary action. This group was named *Lyopomata*, or "loose valves," by Owen; *Inarticulata*, by Huxley; and King's name of *Tretenterata* indicates the important physiological distinction (48).

The *Arthropomata*, *Articulata*, and *Clistenterata*, on the other hand, are characterized—as their respective names imply—by jointed valves or articulated, essentially calcareous shells, with *hinged* valves united by interlocking hinge-teeth fitting into sockets in the opposite valve and in the majority by the absence of a visceral foramen. The cartilaginous arms are supported either by short bands or crura, by calcified loops, or spiral frameworks. The more highly developed members of the hinged sub-class have a lymphatic heart and supplementary vesicles (*Magellania venosa*), and a true vascular system. But accessory hearts are not uncommon in the animal kingdom. There is one situated, for instance, in the tail of the eel, which, perhaps, accounts for its extreme liveliness. In all the surviving species of this articulated sub-class the digestive tube terminates in a cœcum. Evolution does not always imply progress, however, and this is one instance of the origin of a sub-class through degeneration.

This peculiar physiological feature—a reversion to the simpler digestive process of the sea-anemone—is not predicable of the earliest fossil articulated Brachiopoda; for in some species of the protrematous and telotrematous orders the visceral foramen was retained. This visceral foramen was present in *Athyris*, *Rensselœria*, and *Cryptonella*, *i.e.* in members of the spire-bearing and Terebratuloid stocks at the earliest epoch of their derivation from the antecedent Protremata. Its closure was concurrently evolved no doubt with the gradual development of the interlocking hinged shell and subsequent growth of the shell-plates which ultimately covered in the deltidial area of the umbonal region. The change originated in that order Protremata, so prolific in short ranging genera. Is it unreasonable to assume that the period of this great functional derangement, a physiological crisis in the history of the development of the race, exercised an unfavourable influence on the vitality of the first articulated order in which it originated? It is a certain fact that only one genus out of more than eighty which have been referred to this order of Protremata have survived to the present day. The majority enjoyed but a comparatively short range in time; the sole survivor is *Lacazella Mediterranea*, characteristic of the secondary family of *Thecididæ*, and I am inclined to ascribe the persistence of this genus to the extraordinary development of internal calcareous spicula which permeate the mantle and form a protective covering to *all* the vital organs of the little animal inhabiting the shell—an absolutely unique feature among the Brachiopoda.

The class in general has otherwise progressed during evolution by expansion of the anterior elements of the body, development of the heart and vascular system, and by the restriction of the pedicle opening to one valve of the shell. We can trace in the primitive members of the order Neotremata one manner in which this change originated. In the elongated forms of the non-perforated shells of the *Atremata* the long peduncle passes out freely between two valves. In some of the earlier forms a small notch is developed in that valve which becomes eventually the pedicle valve. In the primitive *Neotremata* this notch deepens, widens as in *Discinolepis,* and in *Orbiculoidea* and *Discina* it has become almost centrally situated, for the shell grew up later and enclosed the shorter byssus or mooring organ (Pl. V.[1] Figs. 12; 16 *a, b, c*; 20).

Hence a long peduncle is usually associated with elongated or oval shells, a solitary life, and free axial movement. A short byssus yielded less space to move in, and growth became concentrical. Thus the "disc shells" are co-ordinated with the short mooring organ. Both existing members of the "newly perforated" order (Neotremata) adhere in masses to each other or to rock-surfaces, and the consequent crowded condition of their environment affected the shape and growth-direction of the individuals. In *Crania,* which cling in clusters by their lower valves to rock-surfaces, the margins of the central shells cannot expand and the shell grows more in an upward direction; hence we get the conical helmet shells resembling a French cap of liberty. The divergence between the outer and inner shells of such a mass of individuals produces what some would consider as almost specific differences.

Such are some of the sad effects of overcrowding among the Brachiopoda. These serve as instances of the mechanical origin of genera and species.

The history of the class is almost coeval with the century. Before that time the Brachiopoda were generally regarded as curiosities; or, if their molluscan character was recognized, they were usually grouped in that class of Lamellibranchiate bivalves which it is once again the fashion to call Pelecypoda. Cuvier was the first to determine correctly the natural affinities of the Brachiopoda (23). He placed them in a class by themselves at the base of his sub-kingdom, Mollusca, and gave them their not over-exact name of Brachiopoda, which Duméril subsequently adopted. Milne-Edwards classed them later with the Polyzoa and Tunicata in a separate sub-kingdom to which he gave the name of Molluscoida, or the mollusc-like animals.

The actual affinities of the Brachiopoda have been the subject of much debate and discussion. There is now a general tendency to revert to the classification of Cuvier. The early worm-like larval stages considered by Steenstrup, Morse (54, 55), and Kowaleveski as proof of the vermian affinities of the Brachiopoda are regarded as "recapitulatory phases" indicative of the parallel descent from one common source of the widely-divergent animals belonging to the sub-kingdoms Annulosa and Mollusca.

[1] These figures refer to Pl. V., which will accompany the conclusion of the article when the Bibliography will be given.—A. C.

I have seen no reason to change the opinion, strongly expressed in 1881, that where the Brachiopoda go the Polyzoa must follow (16). A parallel arrangement of the simpler hingeless forms with the inferior Polyzoa—a very instructive and significant series—reveals so many anatomical points in common that it is difficult to affirm any closer relationship. Milne-Edwards' name may still be retained for this group, from which, however, the Tunicata have been almost unanimously ejected. Conchologists have an inveterate habit of figuring the shells, from the physiologist's point of view, wrong way up.[1] If we turn the *Lingula* right side up we see at once the resemblances to the inferior class of moss-animals.

The possibility of demonstrating descent with modification among the Brachiopoda, so numerous in form and so persistent a race of organisms, early attracted the attention of Darwin. He was much struck with a series of *Spiriferæ* which had been arranged on a tablet to illustrate the succession and variation of species of that genus by Mr. J. W. Salter, Palæontologist of Her Majesty's Geological Survey, in the Jermyn Street Museum.

Since these lines were written a further instalment of Hall and Clarke's great work on the Palæozoic Brachiopoda has been issued (38, 39). By a singular coincidence I find that these authorities therein propose a classification of the numerous species of the genus *Spirifer* into six sections or groups of species, according to their external ornamentations and because it serves to indicate within the integrity of the genus lines of progress leading to resultants which are no longer congeneric. In other words, specific variations among the Spirifers lead up to the evolution of other spire-bearing genera.

It is now more than thirty years ago since Darwin first addressed a letter to Thomas Davidson, historian of the British Fossil Brachiopoda, suggesting that "no one could work out the subject better than he." "I am inclined to suspect," he wrote, in April, 1861, "that on the whole the evidence of the Brachiopoda would be favourable to the notion of descent with modification. Many curious points would occur to anyone thoroughly instructed on the subject who could consider a group of beings under the point of view of descent with modification" (p. 24; 29).

"Mr. Davidson is not at all a full believer in great changes of species, which will make his work all the more valuable," wrote Darwin subsequently, with characteristic fairness, to Robert Chambers, author of "The Vestiges of Creation." The correspondence between Davidson and Darwin on this subject was afterwards published in "The Life and Letters of Charles Darwin," edited by his son, Francis Darwin, and will be found on pp. 366–367 of the second volume of that most interesting record.

In 1876 Davidson published a French edition of the excellent

[1] I am glad to note that Prof. Alpheus Hyatt has reversed all the figures of the illustrations to his remarkable memoir "Phylogeny of an Acquired Characteristic," a powerful argument opposed to the Weismannian hypothesis, issued in the Proceedings of the American Philosophical Society, vol. xxxii. No. 143.

paper entitled, "What is a Brachiopod?" (29), issued in the GEOLOGICAL MAGAZINE two years later: he therein stated, apparently considering the comparatively few species that survive rather than the many that perished—"We have no positive evidence of those modifications which the theory involves, for types appear on the whole to be permanent as long as they continue, and when a genus disappears there is no modification, that I can see, of any of the forms that continue beyond so far as the Brachiopoda appear to be concerned" (29).

Two years later Joachim Barrande, a French Legitimist, and formerly tutor to the Comte de Chambord, whose long exile from France he shared in Bohemia, published an epitome of the general results of his own vast labours in the Silurian system of Bohemia (1). This distinguished palæontologist stated independently that he could adduce no evidence derived from his study of the Silurian Brachiopoda of Bohemia of the existence in that area of the modified descendants of antecedent species (1), He therefore felt unable conscientiously to affirm from personal knowledge that the Brachiopoda would be of much use in demonstrating the truth of the principle of Evolution. Barrande died of grief a few days after the funeral of his king and master, Henri Cinq King of France. But one would hardly expect an adherent of the "white flag," a Legitimist, a believer in the divine right of kings, to be a convert to Evolution. Allowance must always be made for the personal equation and effects of the environment.

Davidson always admitted that varietal changes take place of such a marked character as to make it difficult to define the species, and this led him to express the belief that such groups of species were not of independent origin. He seemed thus to be convinced of the extreme variation of certain species whilst maintaining the permanence of genera.

Now the tendency of all modern research appears to demonstrate the extreme elasticity or flexibility of genera. At times uncertainty prevails as to what constitutes specific, as distinct from generic, characters. We are confronted with the problem of isomorphism, or the apparent *external* similitude of species generically differentiated by marked peculiarities of *internal* structure. So that we often get species, heretofore referred on external characters to one genus, split up into several genera or subgenera, based on divergent characters of internal structure. The fossil *Orthidæ,* for instance. This occurs all along the line, for the recent species of what was formerly termed the genus *Waldheimia,* of King, are now divided into six or seven genera and subgenera; although, judging from external characters alone, it is not always easy to differentiate them, for specific features sometimes change less than generic ones. The reasons for the separation are not fully apparent, until we come to investigate the transitional stages of their individual development, which reveal passing phases we may expect to find, nay often have found, characterizing adult forms fossilized in antecedent strata. Others are predicable—just as some of the earlier stages of the ancestry of the horse were predicated and have since been actually discovered in a fossil condition.

During the eight years that elapsed between the publication of the English edition of "What is a Brachiopod?" in 1877 (29) and that of his "Summary of the British Fossil Brachiopoda," in 1884 (28), it is surprising that Davidson had not modified his opinion on the matter. We find him stating (p. 386 *et seq.*) that he still found the subject of the descent with modification of the Brachiopoda "beset with so many apparently inexplicable difficulties that year after year has passed away without my being able to trace, in a satisfactory manner, the descent with modification among the Brachiopoda which the Darwinian theory requires." He appears at most to have admitted a kind of "dual control"—species sometimes modified themselves; genera originated in a different manner. But, really, the supervision of generic creation and extinction would have been no sinecure.

"It is probable,"—we now quote *verbatim*,—"that at least a large proportion, if not all of so termed species, may be nothing more than modifications of shapes by descent of a limited number of primordial types; but it is very difficult in the present state of our information to show *passages between the genera among the Brachiopoda*,[1] so well as among other groups of animals, which the theory of Evolution absolutely requires" (28).

In 1894, thanks in a great measure to the life-long researches of James Hall and the sagacious labours and enlightened views of John M. Clarke, Palæontologists to the Geological Survey of New York, it is no longer possible to deny the existence of such passages between many of the Palæozoic genera. Much of the evidence was really accumulated by both Barrande and Davidson, although they failed to recognize its full significance (38, 39, 40, 41).

The Evolution of the Brachiopoda was the subject of frequent friendly discussions between Mr. Davidson and myself, but we never agreed upon it, for being ultimately convinced of the general application of the law of the Evolution of organic life on the earth, a sense of humour prevented me from considering the Brachiopoda as specially created for brachiopodists to describe. My views were sufficiently indicated in an article contributed on the Molluscoida (*Brachiopoda* and *Bryozoa*) (16) to the fifth volume of "Cassell's Natural History," in 1881. But it is one thing to assert, *à priori*, the logical postulate: another to substantiate it by cumulative testimony, as Hall and others have recently done. Truly, as Paley has well said, "they alone discover who prove."

One great stumbling-block in Davidson's way was his strong belief in the immutability of genera. This conviction is fully expressed on p. 391 of his "Summary" before referred to (28). In a footnote he gives a list of 23 Tertiary and Cretaceous genera regarded as valid by foreign authors, and rejects their claims to generic rank. Of these 23, twenty at least are now recognized by

[1] The *italics* are my own.

Beecher, Dall, Douvillée, Deslongchamps (34), Fischer, and the Œhlerts (63), as forming, in many instances, natural connecting links or passage-forms between other genera, and the remaining three were ultimately accepted by Davidson himself in his last posthumous "Monograph on the Recent Brachiopoda" (27).

He had evidently an almost invincible repugnance to the multiplication of generic names and definitions. "Were we to indulge," he wrote in 1884, "the system of making genera out of every trifling and unimportant difference, the number would become so great that it would not only confuse the subject, but render the study of the Brachiopoda one of repulsive difficulty" (28).

The modern school of *fin du siècle* brachiopodists consider that it is the combination, under one generic name, of species with divergent internal features which perpetuates this confusion. They look upon such forms, as for convenience we call genera, as natural occurrences in nature, not as mere arbitrary scientific abstractions designed for the gratification of those nomenclatorial propensities apparently inherent in mankind since Adam modestly named all creation that was known to him. If a genus comprises an assemblage of forms of which certain characteristics are universally predicable, it seems but reasonable to conclude that any deviation from the universal rule should form an exception and be placed in another genus. Up-to-date biologists, therefore, prefer to restrict the number of species, regarding many forms of so-called species merely as divergent resultants from age and environment, and consider the erection of "trifling" differences into generic or subgeneric characters as perfectly justifiable, so long as they are found to be permanent features of adult structure (4, 5, 6).

These minute generic divergences from the original type are justly regarded as so many links in the chain of the generic descent of the race in general, by which they can trace collateral branches with their numerous ramifications. That some of the main lines die out while the collaterals and their respective ramifications continue to be represented, is nothing unusual in genealogical investigations. In other cases the main line persists, as in *Lingula*, whilst many of the smaller branches of the linguloid stock became extinct and left no immediate descendants.

Just at present we are willing to admit that the study of the Brachiopoda presents many difficulties to one occupying—like myself—a neutral vantage ground, respecting the older palæontologists whose valuable labours in many cases alone rendered possible the significant deductions of that New School with whose methods I am in full sympathy. But we must not be deterred by difficulties, however "repulsive" they may be, from the pursuit of truth, and, as students, we must learn to adapt ourselves to the new methods and novel nomenclature, the results of which will in the end clear up the minor questions which still obscure a complete demonstration of the evolution of the Brachiopoda. It is well to remember, as Lowell has well said, that "the foolish and the dead alone never change their opinions."

NOTE.—It is time some examination was made of the well-worn argument with regard to the "unchangeable persistence of the Brachiopoda" once more repeated by that brilliant and popular writer, Prof. Henry Drummond, who is supposed to reduce the hard facts of science to the mental pabulum adapted to modern social innocents (Ascent of Man, 1894). The facts respecting this "unchanged persistence" and the percentage of survivals will be duly presented in a textual and tabulated form. Hence, it will now suffice to state that out of 47 families only seven survive. One genus out of the 24 included in the ancestral order ATREMATA persists, from the Lower Silurian upwards, and that is *Lingula*. But this "persistent" *Lingula* was preceded by a number of antecedent forms many of which died out before its generic characters were established. Three genera out of 31 members of the divergent order NEOTREMATA still survive; only one, *Crania*, "persists" from the Lower Silurian upwards. Both these are relatively shallow water forms, mostly rock-fixed and shore haunters. The sole survivor out of 82 genera of the order PROTREMATA belongs to a secondary (Thecidoid) type. The remaining known genera, about 140 in number, of which somewhat less than thirty survive, all belong to two out of the three main subdivisions of the fourth order of TELOTREMATA, which was scarcely differentiated in the Lower Silurian age. Taking Mr. Schuchert's careful estimate of genera (tabulated March, 1893), we find that, at a rough estimate, two Palæozoic genera out of 175 all told "persist." Thus the rate of "unchanged persistence" among the Brachiopoda is less than one per cent. of the generic mutations evolved—or, say one per cent., making full allowance for generic differences determined by Hall, Clarke, Beecher, and others since that article was issued. Neither of the so-called "persistent genera" appears in the primordial fauna, and the recent species of both these composite genera bear unto this day visible traces of their obolleloid and paterine Cambrian ancestors. So much for the unchanged "persistence" of the Brachiopoda. Radical stocks, as Professor Hyatt has recently shown (*loc. cit.* 44*), may continue to be represented, but not by "persistent" identical generic types. Among the Tetrabranchiate Cephalopoda the result is even more marked than among the Brachiopoda, as the generic term *Nautilus* is strictly applicable only to recent species, and possibly to some Tertiary offshoots of the main *Nautiloid* persistent stem and primordial radical.—A. C.

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

IV.—A COMPARISON OF THE PEBBLES IN THE TRIAS OF BUDLEIGH SALTERTON AND OF CANNOCK CHASE.[1]

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

THE pebble-bed in the Trias of Budleigh Salterton has attracted much notice, but I am not aware that its materials have been compared with those of the corresponding bed in the Bunter group

[1] A paper, read in substance before Section C, at the Meeting of the British Association at Oxford.

of the English Midlands.[1] For this purpose I recently spent a short time at the former place, and think the results worth placing on record. I select for comparison the pebble-bed on the more northern part of the wild Staffordshire moorland called Cannock Chase, with which I happen to be especially familiar. The points of resemblance shall be noted first, those of difference afterwards.

The outcrop of the Devonshire pebble-bed is usually a hilly moorland, naturally overgrown with bracken, gorse, heath, and ling. There are scattered copses of Scotch firs (planted). That is the characteristic scenery of Cannock Chase. The pebbles are numerous, and lie in a sandy matrix. They vary from subrotund to well rounded, the larger specimens being sometimes almost subangular. They seldom exceed a foot in the longest diameter, are very commonly from 3 to 5 inches, and smaller specimens are abundant. Here and there are intermittent beds of sand, nearly or quite free from pebbles, in thickness from a few inches to two or three feet; false-bedding is often distinct; the pebbles are occasionally impressed one by another, though rather less frequently than in Staffordshire, for they are not, I think, quite so closely packed. But the general resemblance of the two deposits is very marked.

Where I had the best view of the relation of the Budleigh Salterton pebble-bed to the underlying and overlying deposits, I found it pass rather quickly, and apparently regularly, into the marl below, the pebbles, perhaps, generally being a little smaller than usual for the last few inches, and the matrix more marly. The pebbles also run rather small at the top, for any larger than a duck's egg are rare in the last four feet; the upper surface of the bed is usually even, and it is succeeded by a thick deposit of false-bedded red sand, which has a general resemblance to the Bunter sand of the Midlands.

Next as to the materials of these pebble-beds. Vein-quartz is common in both. Quartzites of more than one variety are yet more common. Speaking in general terms, the same types occur in both deposits, though not in the same proportion. I reserve, however, further particulars till I come to mention the differences, merely observing that in both a fairly hard quartzite, the surface of which has a somewhat speckled look, due to the presence of very small grains of felspar, is rather common. But I was surprised to find at Budleigh Salterton specimens of the moderately coarse hard quartz-felspar grit, which so closely resembles the Torridonian of Scotland, to the presence of which in the Midlands I have already called attention. Specimens of a dark-green to almost black rock occur in both deposits, which will presently receive a fuller notice. Both also contain some felstones, with more basic rocks of compact structure and purplish colour; also granitoid rocks in a very rotten condition. The last are rare in the Midlands; still rarer and more obscure at Budleigh Salterton. In neither region are fossiliferous

[1] A very full description of the pebble-bed, with notes on the pebbles by Mr. Carter, and references to literature up to 1880, is given by the late Mr. T. Davidson. "Palæont. Soc." vol. xxxv. (1881).

quartzites or grits at all common; indeed, if I may reason from my own experience, I should say there was about as good a chance of finding them in the one place as in the other.

Next as to the points of difference. On the whole, I think, pebbles of about four inches diameter and from that to a foot are rather commoner at Budleigh Salterton than on Cannock Chase. Certainly in the pits on the latter one sees a smaller number of the subrotund to subangular stones from 8 inches to a foot long. There is also a rather marked difference in the form of the better-rounded specimens. Pebbles which are nearly prolate spheroids occur in both deposits, but that is the common shape in Staffordshire, while those in Devonshire are more usually oblate. This is very conspicuous in walking by the seaside along the pebbly beach, probably because the specimens have been finished off, possibly even to some extent selected, by recent wave-action. The eye is at once arrested by a certain flatness in outline, which may be indicated by saying that the dominant type of pebble is an ellipsoid, the diameters of which are roughly as the numbers 5, 4, and 2.

As to materials, vein-quartz pebbles are, I think, rather commoner in Devonshire. Of the quartzites, both districts show several varieties, varying from merely hard grits to rocks so uniform in structure and so completely cemented as to break with an almost smooth surface and subconchoidal fracture. The latter type, however, is not common at Budleigh Salterton and is abundant on Cannock Chase. Nevertheless, I found one or two specimens at the former place which cannot be distinguished from the noted liver-coloured quartzite of the latter. Slightly felspathic quartzites are commoner at Budleigh Salterton, in fact a minute "speckling" of the stone is one of the first things which catches the eye.[1] The dark compact rocks are rather common at Budleigh Salterton, not so on Cannock Chase. In the former place they are very frequently almost subangular and as large as the rest, pieces full 6 inches in diameter not being rare; on the latter, they are generally rather small and better rounded. Fragments chipped from five of the dark-green pebbles were powdered and examined under the microscope.[2] All showed tourmaline, so two of them were sliced. Both consisted mainly of granular quartz and tourmaline; the latter mineral occurring mostly in grains, sometimes almost films, occasionally in prisms and needles. The first are generally brown in colour, now and then passing into a dull blue; their shape and aspect often suggest that the mineral originally was a ferro-magnesian mica, and that the replacements may not always be complete. The prisms vary from brown to blue, and the needles appear to represent a paler variety than the others. Both these forms are most abundant in small quartzose veins which traverse the pebbles. Here sometimes the sides and one end of a crystal are well developed. The general aspect of the specimens suggests

[1] Here also the lighter coloured stones become a whiter colour, after they have been cleaned from the matrix, than they do in Staffordshire, though perhaps this difference may not be of much value.

[2] I am indebted to Miss C. A. Raisin, B.Sc., for kind help in this matter.

a sedimentary rock which has been affected by contact-metamorphism and has had its aluminous constituent converted into tourmaline.

Another pebble, dark in colour, with thin bands or streaks of a grayer tint, was sliced after tourmaline had been detected in the powder. It consists mainly of quartz and the above-mentioned mineral, but indubitable tourmaline is present in a quartzose vein. In the paler bands quartz predominates; in the darker mica or tourmaline. In the latter are some small rounded spots of chalcedonic quartz. These suggest the possibility of an organic origin (? radiolaria), but I cannot venture to speak more positively. The rock, I believe, was originally a stratified clay and silt, which subsequently was affected by contact-metamorphism, followed by the production of tourmaline.

Lastly a pebble (from the beach) which exhibited well-marked bands of a gray and a dull-brown colour, very minutely granular, was sliced, after its powder had suggested the presence of tourmaline. The lighter layers are mainly chalcedonic quartz with small films of brown mica or tourmaline, the darker mostly of the last mineral, which also occurs in grains and prisms, these being perhaps more common than in the other specimens. Here also are veins with prismatic and acicular tourmalines, but in the darker layers spots or lacunæ occur which are occupied by quartz and tourmaline, sometimes prismatic, often acicular, the latter seemingly paler in colour. The slice also contains some granules of a darkish mineral, occasionally opaque, but sometimes rather translucent, and of a muddy golden-brown colour, possibly cassiterite. This rock appears to have had the same history as the last one.

These specimens correspond with some of the fine-grained tourmaline-bearing rocks which may be obtained from the zones of contact-metamorphism around the granite masses of West Devon and Cornwall. I did not, however, observe any of the coarse-grained quartz-tourmaline rocks, which I have often seen in the latter county; for instance, near St. Austell and to the west of Penzance. Dark green pebbles with a general resemblance to certain of the above-named occur, as already stated, in the Midlands; but these, so far as I have examined them microscopically, though they contain tourmaline, present considerable structural differences, and are not suggestive of contact-metamorphism.

Fragments of igneous rocks, while not abundant at either locality, are distinctly commoner and more varied in Staffordshire; there, with the same amount of work, I could collect at least a dozen varieties of quartz-felsite; in Devonshire I found at most two or three, only one of which was anything but rare. The same is true of the more decomposed rocks, both basic and crystalline. In Staffordshire I should have seen ten specimens of igneous rocks where in Devonshire I saw one. In the former county also, what may be called "miscellaneous sedimentaries," such as sandstones, mudstones, chert from the Carboniferous Limestone, etc., are commoner.

I was not able to recognize any of the following rocks: the gneissoid and hornblendic rocks, the serpentines or gabbros of the

Lizard district, the schists of the Start, the granites of Cornwall or Dartmoor, the Devonian limestone, the Palæozoic slates (perhaps hardly to be expected) or their associated grits of the south-west region. Among the quartzites and quartzitic rocks a few might be Devonian, and some others probably represent the quartzites (earlier Palæozoic) of southern Cornwall,[1] but the majority did not quite correspond with any of the rocks which I have seen *in situ* in the South-west of England, and, though my knowledge is nothing like complete, I have sampled a fair number. Moreover, I was not reminded at Budleigh Salterton of the fragments in the Meneage conglomerate. The felstones may represent some of the western elvans, but, as already said, they are comparatively rare; the other igneous rocks, still more rare, are not characteristic.

The materials, then, seem not generally to represent the rocks now exposed in Cornwall and Devon. I had expected to find a large proportion of rocks from this region, as in the case of the breccias, which are so fully exposed further west. I was surprised to observe a very marked difference in this respect, and a much closer correspondence with the lithological character of the Midland pebble-beds. The fragments are far better rolled than those of the breccia beds, and thus very probably have had a much longer journey. I do not, however, suppose that they are derived from the same source as the pebbles in the Midlands. The ascertained facts as to the distribution of the Trias, which it is needless to recapitulate, make this practically impossible, and the fairly constant direction of the false bedding indicates the action of currents from a more or less western quarter. But the presence of the curious quartz-felspar grits, and of quartzites resembling those of North-west Scotland, including even the peculiar liver-coloured type, suggests the possibility that the ancient mass of Archæan crystallines, which once swept round from the Scoto-Scandinavian region to North-western France, may have been fringed in more than one district with rocks of Torridonian and Durnessian types.[2]

V.—Questions and Answers on Ice-Motion.

By Rev. E. Hill, F.G.S.; late Tutor of St. John's College, Cambridge.

A PASSAGE in Mr. Deeley's letter in the December Number suggests to me that some readers may like an opportunity of clearing their thoughts on some points connected with the motion of ice. After a tutor's fashion, I will ask some questions. Let any reader consider the answers he would give, and then compare with mine which shall follow.

If ice be a viscous body, how can the Antarctic ice stand "presenting a vertical wall to the ocean, 150 feet high"? So, in a better known case, how can the walls of crevasses in a glacier retain their

[1] Mr. Pengelly (Geol. Mag. 1878, p. 238) considered the fossiliferous quartzites to be practically identical with those of Gorran Haven.

[2] See a very suggestive paper by Mr. Ussher, Quart. Journ. Geol. Soc. vol. xxxv. (1879), p. 245.

shape? And again, how can the so-called Glacier-tables subsist? Why does not the ice of the stem squeeze out under the weight of the top stone, and let it down?

I do not write for mathematicians and physicists, who will smile at these questions, and may improve my solutions. I write for all who having read them must hesitate before answering. These would be my answers if asked the questions in an examination. Reversing their order: A *Glacier-table* is due to a melting away of the exposed surface by the sun, while the ice beneath a large stone is unmelted. If the surface sinks by that waste faster than the protected stem shortens by compression, the stem will lengthen. The squeeze *might* make the stem thicken, and *should*, unless the waste of thickness by evaporation, etc., exceed the increase which the compression can produce. *Crevasses* are due to a tension acting on the mass of ice. If viscosity cannot close the fissure faster than tension is opening it the crevasse once open must remain so. When the flow of the glacier has carried the ice past the tension-position the crevasses will close. The *Antarctic ice*, if a viscous body, must flow outwards into the ocean until it is ready to float, and till its strains from floatation or other causes are more than its strength can bear. At this point masses will break off and float away, leaving where they broke from the wall-like face described. A similar wall on a small scale due to a like cause bounds (or did, when I saw it, bound) the Aletsch glacier along the Marjelen See.

As another question: If that ice be viscous, why does it not flow up the Marjelen side-valley as well as down the main Aletsch channel? Answer: It does so flow, to an extent measured by the amounts melted away from that face, and broken away.

The following, less simple, problem may enable some readers to test their ideas on the matter of ice moving "uphill." I suppose everyone has seen the undulated erection called a switch-back railway. Suppose a continuous train of cars in contact along the whole length of rails: if free to move, the weight of the topmost ones will force the whole train forward. Suppose the cars replaced by blocks of ice, separate but in contact; no doubt a similar motion will ensue. But now, suppose the interstices between successive blocks all filled up, so that they are united into one continuous thick ribbon, or undulated beam of ice; what will happen then?

Then, in motion forwards, convex parts would have to compress, concave parts to extend. I have no doubt that if the upper end be at a level high enough, some motion will result. What that motion will be, whether the same forward flow as of the separate blocks, or a shattering to pieces of the ice at points of greatest stress, or a thickening in the hollows, or a combination of these, depends on the amount of breaking-strain and the rate of viscous flow. If, however, the stress be enough to cause any viscous yielding, the ice in the hollows will thicken, the mass forced uphill will increase, the force required to move it will in turn increase, and the thickening be accelerated (assuming, of course, a continual supply of ice at the starting-point); whilst, on the other hand, it may be seen that conversely the ice on the summits would have a tendency to thin. If the erection have parapets of small height, when the ice-stream thickening rises higher than the parapets, parts will ultimately break away. This answers to the Aletsch glacier flowing past the opening of the Marjelen See valley. But if the parapets were very high, I think that ultimately the hollows must fill up to at least the levels of the summits, and so produce an undulating but generally descending slope. Such, indeed, we see in actual glaciers, if there be rock-basins hidden in their beds.

I have not sought the figures for the viscosity and breaking-strain of ice. Blocks in a frost can lie about without perceptible change; the roof of the Esquimaux's snow-hut does not sink down on his head during the night; the walls of the Montreal winter-castle remained as long as they were wanted. Perhaps ice does not begin a viscous flow till the force reaches a sufficient amount. A stick of sealing-wax may lie on its side for months without noticeable alteration, but "hang a weight to a bar of it, and it will yield" (Lord Kelvin, "Popular Addresses," vol. ii. p. 344).

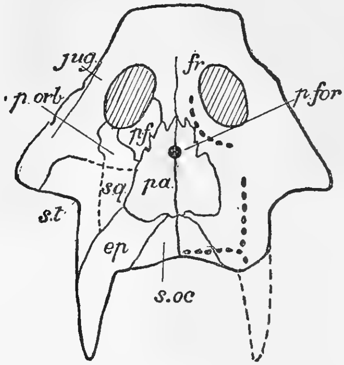
Practically we see that the Swiss and Greenland glaciers do move as viscous bodies. They follow paths of least resistance, and these paths are much the same as water would follow. I have been asked—What should happen when a glacier from a side valley debouches on to the top of a larger one in a main valley? Much the same as what happens when a tributary flows into a main river, as may be seen where the glacier from under the Sparren-horn debouches on to the Aletsch. Water is viscous and ice is viscous, though in very different degrees. "Water does not run uphill," we say, but in a pipe it does. Ice can move uphill if it must, but we do not find it flowing uphill if there be an equally eligible down-hill path available. This is the argument of a letter of Professor Bonney's in Nature (22nd February, 1894), which met with little reply. The subject tempts me to a further pursuit, but I will not transgress the limits which I indicated in beginning.

VI.—Note on a Specimen of *Keraterpetum Galvani*, Huxley, from Staffordshire.

By C. W. Andrews, B.A., B.Sc., F.G.S.
of the British Museum (Natural History).

In a collection of Coal-measure Vertebrata made by Mr. J. Ward, of Longton, and recently acquired by the British Museum, there is an imperfect, crushed skeleton of a small Labyrinthodont from the Ash-coal Shale of Longton Hall Colliery, Staffordshire. This specimen was noticed by Miall in 1874 in his British Association Report on the Classification of the Labyrinthodonts, where it is referred to *Urocordylus*, some of the characters given in his diagnosis of that genus being taken from it. Some measurements of the skull were added. The same specimen was afterwards figured in Mr. Ward's paper "On the Geological Features of the North Staffordshire Coal-field" (Trans. N. Staffs. Instit. Mining

Engineers, vol. x. 1890, pl. ix. fig. 2) as *Keraterpetum Galvani*. This figure, which is natural size, unfortunately does not show any details of the structure of the skull, some account of which may be of interest.



Dorsal surface of skull of *Keraterpetum Galvani*, Huxley. *s.oc.* supra-occipital, *ep.* epiotic, *sq.* squamosal, *s.t.* supra-temporal, *pa.* parietal, *p.f.* post-frontal, *p.orb.* post-orbital, *jug.* jugal, *fr.* frontal, *p.for.* parietal foramen.
The thick dotted lines on the right side of the figure mark the position of the lateral line pits. Twice natural size.

The general outline of the skull (see figure) closely resembles that shown in the figure of the type specimen of *Keraterpetum Galvani* given by Huxley (Proc. Roy. Irish Acad. vol. xxiv. 1867, pl. xix. fig. 1). The snout is blunt and rounded, and the hinder border of the skull is produced backward into two pairs of cornua, of which the external pair, formed by the quadrate region, is much less prominent than the internal pair (epiotic), and as far as can be seen, does not extend quite so far backward as the base of the latter. The exact limits of the outer pair are rather indistinct, and of the inner pair, that on the animal's right is broken away. In the posterior region of the skull, the dorsal side of which is exposed, the outer surface of the cranial bones is well seen, but in front only the impressions of bones remain and it is almost impossible to determine their arrangement. On the counterpart, however, this can be made out to some extent. The external surface of the bones is covered by a sculpture of pits arranged roughly in parallel or radiating lines, an ornament closely resembling, on a small scale, that seen in *Loxomma*. The pits are close together, being separated only by narrow ridges. At the bottom of many of them there is a small pore with a slightly raised rim, such as occur also in *Loxomma*. These pores were probably connected with dermal glands. Running directly forward from the hinder border of the skull, near the inner side of the base of the epiotic cornua, there is on either side a row of larger pits which can be traced to the neighbourhood of the eye, where it is probably continuous with a still more distinct series forming a curved line parallel to the postero-internal border of the orbit. Across the occipital region there is a transverse row of large pits connecting the two lateral series. The whole mark the position of the lateral line system of sense organs.

The sutures between the cranial bones are for the most part obscure, but by careful examination with the lens the arrangement, shown in the figure, can be made out with a fair degree of certainty. The supra-occipitals together form a roughly triangular area, of which the base is the hinder border of the skull; the anterior angle is truncated by the parietals, while the sides are united by suture with the epiotics. These latter, which bear the long, backwardly projecting cornua, are bounded by the parietals in front, and the squamosal antero-externally. The squamosal abuts on the parietal internally, but its outer boundary is not clear. I believe that traces of a suture running antero-posteriorly close to the pits of the lateral line, can be made out. If this be so the bone external to this suture, and forming the angle between the outer and inner cornua, will be the supra-temporal. It is separated externally by an obscure suture from a bone which may be quadrato-jugal. The parietals together form a triangular area with rounded posterior angles. In the median suture about two-thirds of its length from its hinder extremity is the round pineal foramen. The outlines of the post-orbital and post-frontal are not very clear, but the lines given in the figure mark their approximate boundaries as shown in the counterpart of the specimen. On the right side a portion of the jugal can be seen forming the outer border of the orbit, but it is crushed and obscure, as also are the maxillæ, premaxillæ, nasals, etc.

In the type specimen of *K. Galvani* the actual sutures between the cranial bones are not shown, but judging from the figure given in the memoir above quoted, their form and arrangement must have been the same as in the present specimen, which was rightly referred to that species by Ward.

If the skull here described be compared with that of *K. crassum*, figured by Fritsch (Fauna der Gaskohle, Bd. 1) we find that very great differences exist between the two species. The most notable of these are: (1) In *K. crassum*, if the epiotic cornua be left out of account, the hinder border of the skull forms a straight line, while in *K. Galvani*, the occipital border is far behind the outer (quadrate) angle (see figure). (2) In *K. crassum*, Fritsch figures the epiotic cornua as distinct elements articulating by a kind of ball and socket joint with the epiotic (?) bones.[1] In *K. Galvani* the cornua are simple backward prolongations of the epiotics.

(3) In the former the orbits are separated by a space equal to

[1] The morphological value of these separate epiotic cornua is doubtful. Fritsch himself suggests that they may either be simply portions of the epiotic bones or may constitute the whole of them, the bone to which they articulate being in that case undetermined. It may be pointed out that these elements occupy the position of the post-temporals of fishes, and may possibly indicate the former occurrence among the *Stegocephali* of a connection between the posterior region of the cranium and the pectoral girdle.

about six times the diameter of one of them, while in the latter the interval is only equal in width to one of the orbits. (4) The roofing bones of the skull, at least in the posterior region, differ considerably in form and arrangement in the two species. This is particularly noticeable in the case of the parietals, which in *K. crassum* form together a rectangle about twice as long from side to side as from before backwards. (5) In *K. crassum* the sculpture of the cranial bones consists merely of a few widely separated pits.

The differences between these two forms appear, therefore, to be so great as to render it impossible to refer them both to the same genus, and *K. crassum* should, therefore, be referred to as *Scincosaurus crassus,* the name originally applied to it by Fritsch in 1875.[1]

Concerning the resemblance of this skull to that of *Urocordylus* it is difficult to speak with certainty, since the skull of the specimen on which Huxley founded that genus is unfortunately very badly preserved (see *loc. cit.* pl. xx. fig. 1). In it no epiotic cornua are to be seen, and these structures are also wanting in *U. scalaris,* Fritsch, the skull of which also differs widely in other respects from that of *K. Galvani*. In *U. reticulatus,* Hancock and Atthey,[2] these cornua are well developed, but the specimen resembles *K. Galvani* in so many respects that it is not improbably a young individual of that species.

The remainder of the skeleton is not well preserved. The serration of the upper border of the neural spine, characteristic of the family Nectridea, is clearly visible in some of the dorsal vertebræ. The whole of the tail is missing, so that comparison in that respect with *Urocordylus* is out of the question. A large part of one of the lateral plates of the thoracic buckler is preserved, and in form exactly resembles the bone figured as *scapula* (?) by Huxley (*loc. cit.* pl. i. fig. 1). In this specimen the surface of the bone shows a sculpture of pits in rows radiating from its posterior spine-like prolongation. Scattered about the skeleton there are several scutes with a sculpture like that of the cranial bones, of which, indeed, some may be fragments; the others are probably the larger scutes figured by Huxley, pl. xix. fig. 3. Of the limbs only obscure traces of the femur and humerus remain.

NOTICES OF MEMOIRS.

Abstract of the Fourteenth Report to the British Association on the Earthquake and Volcanic Phenomena of Japan.

(Drawn up by the Secretary, Prof. J. Milne, F.R.S., F.G.S.)

The first part of the Report gives a list of the earthquakes recorded in Tokio during the last year. The second portion gives an account of observations made with horizontal pendulums. These pendulums consist of a horizontal boom about five feet in length held up by a fine brass wire. At the extremity of the boom

[1] Sitzungb. der k. bohm. Ges. der Wissensch. 19 März, 1875.

[2] Nat. Hist. Trans. Northumberland and Durham, vol. iii. p. 310.

there is a light metal plate with a slit in it parallel to the length of the boom. Underneath this floating slit, but at right angles to it, there is a narrow slit in the top of a box. Light passing through the two slits goes into the box as a point, which is received on a drum carrying a photographic film. These instruments, which are usually arranged in pairs, are placed to point N.W. and N.E. or parallel and at right angles to the strike of a distant range of hill. Two have been used at Kamakura on the solid rock, and two at Yokohama and one at Kanagawa on the soft tuff rock. These instruments were in caves. Also I have had two underground on the alluvium and one at my house on a solid stone column in Tokio.

The movements recorded have been as follows :—

1. *The Wandering of Pendulums.*—All the horizontal pendulums, wherever situated, have slowly wandered from their normal position. Those situated on the rock have often gradually moved to one side and then returned, the double excursion usually taking from two days to a week. These wanderings might be due to a local warping of the supporting column; but inasmuch as it has generally happened that the periods of great movement and of comparative rest have coincided in time, it would seem that the movements are in all probability due to a more general cause. Because certain movements have usually been marked (but by no means always) at or after a rainfall, it seems possible that they may be connected with fluctuations in the volume and flow of underground water,—the pendulums nearest to this water moving the most.

2. *Daily Waves.*—In no instance have I observed a diurnal movement of the pendulums at stations situated on the rock. In Tokio the movements occur underground and on the surface; they happen at the same time and they are proportional in magnitude. At my house, for example, at about 10 a.m. a tilting commences on the N.E. side, and it reaches a maximum of one or two seconds of arc about midnight, when a sinking takes place until about 6 a.m., when the pendulums remain fairly steady for some hours, after which they again commence to rise. Because it was observed that the movements underground were greater than those recorded on the surface, it seemed possible that they might find an explanation in the fact that the underground instruments were nearer to pervious strata in which water fluctuated than the instruments installed in my house. By quickly emptying a well in my garden of about two tons of water which was run off down a hill, the pendulum on a column (104 feet distant) behaved as if the ground had been relieved of a load and therefore had risen on the well side. Because the direction of movement of the pendulums underground and on the surface is away from the side from which during the day the greatest load is being removed by evaporation, it is not unlikely that the main features of the diurnal wave may be due to this cause.

3. *Earth Pulsations* (*Tremors*).—In Italy I understand that earth tremors are as marked underground on the rock as they are on the surface. In Japan, on three underground rock foundations, I have not observed a single case of earth tremors. Both underground and

on the surface in Tokio they are marked, lasting many hours. As I have previously spent so much time in analysing tremor records, the present records remain untouched. Tremors occur with a low barometer, but more generally when there is a steep barometric gradient. It seems possible that these conditions may result in giving the surface of the ground an ocean swell-like motion through the agency of subterranean water.

4. *Earthquakes.*—At Kamakura, on the hard rock, the greatest earthquake motion has been given by the pendulum which records tilting parallel to the dip, suggesting the idea that in this direction there is an easier yielding (like the opening and shutting of a concertina) than there is in a direction parallel to the strike. On March 22, I and my colleague, Mr. C. D. West, watched an earthquake for 1 h. 47 m., during which time the pendulum did not *swing*, but was *forced* backwards and forwards intermittently and with extreme irregularity. These earthquakes are in the form of earth waves and usually come from a great distance. A sharp shock which may be felt throughout Tokio, and at many places in the country, does not disturb the pendulums, and it is difficult to find a blurr on the photographic trace.

REVIEWS.

I.—Geographical Morphology.

Morphologie der Erdoberfläche. By Dr. Albert Penck, Professor of Geography in the University of Vienna.

Ratzel's Bibliothek Geographischer Handbücher. J. Engelmann. Stuttgart, 1894. 8vo. 2 Vols. Vol. I. pp. xiv.+471, 29 Figures. Vol. II. pp. x.+696, 38 Figures.

As the study of geography must have commenced unconsciously in the very earliest days of man's existence on the earth, it is not surprising that this science long ago acquired a rigid conservatism, and lack of scientific method, and a burden of imperfectly defined popular terms. In England descriptive topographical geography is still hampered by this inheritance. Abroad, however, more scientific methods have been rapidly gaining ground, especially in Germany and Austria, and in the United States. In the two first geography reached its highest level in Richthofen's admirable "Führer für Forschungsreisende" and Suess's "Antlitz der Erde." In America the writings of Gilbert and W. M. Davis have founded a school which has advanced the subject with great energy. The works of these authors are, however, bulky and scattered, and a systematic text-book of orography has been a desideratum for some time past. Dr. Ratzel, the editor of the well-known "Bibliothek Geographischer Handbücher," persuaded Prof. Penck to undertake the preparation of one. The task has, however, taken more than ten years to fulfil, for the literature of geodesy, geography, and geology have had to be carefully worked through.

The book consists of three parts. The first deals with general morphology. This will probably be of most interest to geologists, for the subject is barely noticed in geological text-books, and there is no English geographical manual which gives it adequate notice. In this section much useful information is given in a concise and simple form, upon various branches of geodesy, which can elsewhere be only found in such works as Günther's Geophysik (1885), or Handbuch der mathematischen Geographie (1890). Penck gives the latest conclusions upon the earth's form, and the methods and results of morphometry. Thus in regard to the former, he states that the question of the amount to which the form of the earth deviates from a true ellipsoid of revolution is now reduced to from ± 200 to ± 250 metres. As an example of the latter may be noticed the care with which the altitude systems adopted by different countries in Europe are tabulated and compared; some of these are based on a supposed natural line, such as the British "sea-level," and others on a recognizedly artificial standard, such as the German "Normal Null." No two nations adopt the same standard: thus the levels in Belgium are all 3·39 m. lower than in Germany, and the standard in Ireland is more than 7 feet lower than that of Great Britain. The uncertainties both in the accepted longitudes and altitudes are clearly pointed out. Thus we are warned that even when the latter are based on trigonometrical observations they are not absolute; for the error of refraction cannot be altogether eliminated. The considerable amount of this is shown by two cases quoted: thus Hartl found that the difference of altitude of two points 28 kilometres apart, varied from 13·6 metres at 5 a.m. to 36·2 m. at 10 a.m. And Bauernfeind found that the difference between the summit of the Dobra and the Kapellenberge in Bavaria increased from 25 m. at 3 a.m. to 35·6 m. at 11 a.m.

This part of the book discusses the methods and formulæ used in the determination of the principal measurements of the earth's surface, and also gives the results: thus there are tables of the latest estimates of the ratio of land to water, the area and cubic contents of the different continents and oceans, the lengths of coast-line, the proportions of the continents at given distances from the sea, etc. Two of the most interesting chapters are those on the geographical homologies, which have been recently so graphically illustrated by Prof. Lapworth, and that on the question of the permanence of oceans and continents, of which discussion a useful bibliography is given. In regard to the latter it is interesting to note that the author fully maintains that the specific gravity of the earth below the oceans is greater than below the continents.

In the second part of the work the surface of the earth is described. It is regarded as made up of a number of "land-forms," which are grouped into eight classes: these are plains; heaped up masses, such as dunes and sinters; valleys; highlands (thallandschaft) or the masses cut up by valleys, including plateaux, and some types of mountains; basins or "wannen"; mountains; areas of subsidence; and finally caves and ravines. The agents that produce and mould these various forms are also described. This part of the work is of value as a digest of the classifications and literature of structural geography. It uses throughout the terminology of Richthofen and

Suess, and gives many diagrams to explain that of the latter. The thorough acquaintance with geographical and geological literature, which Prof. Penck's writings always show, enables him to treat this part of the subject most exhaustively and completely. It is, moreover, surprisingly well up to date: for example, Bertrand's recent paper contending for the persistence of lines of dislocation is noticed (and adversely criticised), and Heim's recent description of Pleistocene earth movements in the Alps is included, though these and others were issued only in 1894. The summaries of literature and the collections of local geographical terms are extremely useful. In most things the author is very advanced, but in glacial matters he is strongly conservative: he attributes to ice great erosive power, and thinks that both cirques and rock-basins have been formed by it, and maintains the existence and action of ground-moraines. The two most valuable sections in this part of the book are those describing the distribution, origin, and classification of basins and mountains. It is in reference to these that the works of Suess and Richthofen have had the greatest influence, and where an authoritative statement of the present position of the subject is of most service. The origin of many of the greatest basins is not yet fully settled: thus, in reference to the Caspian, Sjögren's recent explanation of this as a synclinal fold disputes Suess's view that it is a "Senkungsfeld" or area of subsidence.

The last part of the book is entitled "The Sea." It describes the action of the sea by coast erosion, tides, and currents, and by floating ice; it also describes the formation of deltas, mangrove swamps, and coral reefs; it classifies coast-lines, and shows how these have varied both by the rising or falling of the land and by variation in the level of the surface of the sea. Finally comes a description of the sea-floor and a classification of islands. An admirable index of authors and subjects renders the vast number of references to literature in the volumes readily accessible.

The work is not one which can be easily summarized, for it is encyclopædic in its detailed summary of facts and classification. It is a book of reference which is indispensable in every geographical and geological library. J. W. G.

II.—Climbing and Explorations in the Karakoram-Himalayas. By W. M. Conway. Supplementary volume containing Scientific Reports by Prof. Bonney, Dr. Butler, W. M. Conway, W. L. H. Duckworth, Lt.-Col. Durand, W. B. Hemsley, W. F. Kirby, Miss Raisin, and Prof. Roy. 8vo. pp. 127, with Frontispiece Portrait of the Author, and 2 Coloured Maps. (London: Fisher Unwin, 1894.)

This Supplement to Mr. Conway's Exploration in the Himalayas, contains the scientific results of his expedition. The first of these is an account of the Eastern Hindu Kush, by Lt.-Col. Durand, who gives an interesting account of the people of this country, especially of Chitral, or "the land of mirth and murder," as he appropriately terms it from the customs of these people; an instance of whose sanguinary practices we have recently seen recorded in the daily Press. Following this we find a list of measured altitudes taken by means of a barometer up to 22,600 feet, the two higher ones being measured by a Theodolite; that of K. 2, Mr. Conway makes to be 27,750, or 500 feet lower than the measurements given in the Great Trigonometrical Survey of India. These, and the two very excellent coloured maps with their description, are by Mr. Conway, and they practically represent an unexplored country, as previous to 1892 this region had only been roughly sketched out by Colonel Godwin-Austen, who, in 1860–61, examined the lower parts of the glaciers, and marked the position of the chief ridges; it is only since the introduction of mountain-climbing that the details of these large glacial areas have been brought to light, and these we owe to Mr. Conway's indefatigable energy.

The author's work was not solely confined to the production of maps, for he also collected numerous rock-specimens and minerals, plants, and insects: these have been identified by various specialists, and lists are printed giving the names of the specimens, the localities and the heights where they were obtained. They form valuable records, and constitute an excellent example for future explorers.

The rocks, etc., have been examined by Professor Bonney and Miss Raisin, who give a detailed account of the various specimens, which consist of serpentines, diorites, and schists, several of which are said to resemble known Alpine rocks, granites, gneiss, and felstones; one schist in particular is found to contain a new form of hydrous biotite, having an extra large percentage of lime. The sedimentary rocks consist of limestones, slates of possibly Carboniferous age, sandstones, grits, and conglomerates, bearing some resemblance to the older Cambrian rocks of Wales. Among the minerals is a curious jade-like rock, which appears from its structure and analysis to be new, and the authors regard it as an unusual mixture of certain known minerals.

The concluding part is by Professor C. S. Roy, and contains an interesting account of mountain sickness, and a series of pulse-curves taken by Mr. Conway at different elevations, and under very varying conditions, which are all carefully recorded. Although Professor Roy is still unable to come to any definite conclusion as to the real cause of the pulse variations, and whether heart-failure is, or is not, essential in mountain sickness, still these notes will be very useful to any intending mountain-climbers.

III.—An Introduction to Modern Geology. By R. D. Roberts, M.A., D.Sc. 8vo. pp. vii. and 270, with 9 Plates, 51 Figures in the text, and 3 Tables. (London: John Murray.)

THIS little book forms one of the University Extension Series of Manuals intended primarily for the use of Students attending the lectures connected with that movement. It will, however, have a much wider circulation, as it is admirably suited for the needs of any student commencing the study of geology, and the presence of references makes it serviceable to those who are more advanced.

It is a great pity that the author found it necessary to change the title, as the adjective in the present one is very aggressive.

The plan adopted in treating first from the physical, then from the structural, and finally from the evolutionary standpoint of the Earth's crust, is an admirable one, and has been well carried out.

The author very wisely confines himself as far as possible to the geology of the British Isles; this gives the book a special value to beginners as an educational work, for by expounding to students the features of their own country, and explaining the nature of the changes which have gone on, or are still in progress around them, some of which they may be able to verify for themselves, they gain a sounder knowledge of the subject than they would from the description of the more striking changes, etc., which might be collected from abroad, and with which they could only deal on paper.

Still, considering the small size of the book, it is a little extravagant to devote a whole chapter to the volcanic phenomena of the Island of Eigg, but, on the whole, the problems visible there, and the conclusions deduced from them, form an excellent lesson to the student of what may be done in reconstructive geology.

The matter in the chapter on deep-sea deposits might well have been expanded at the expense of three of the illustrations, for we find two whole pages devoted to two views of Brooke's deep-sea sounding apparatus, and one to a beautiful figure of a *Globigerina*, the latter being the only organism figured from these deposits, the characters of the remaining organisms being left wholly to the imagination of the reader; in several cases the bare name only being given, without any reference to its nature or to what group the organism belongs.

The description of the hard parts of a coral as an internal skeleton is hardly worthy of a "modern" book, considering that it has been known for about ten years to be a secretion of the ectoderm and therefore a morphological exoskeleton. Also the definition of the animal of *Globigerina* as a speck of protoplasm which has no parts or organs of any kind is hardly in keeping with the otherwise up-to-date nature of the book.

The illustrations, though in some instances a little lavish, are very good, and many quite new, the coloured maps being especially fine.

REPORTS AND PROCEEDINGS.

Geological Society of London.

December 19th, 1894.—Dr. Henry Woodward, F.R.S., President, in the Chair. The following communications were read:—

1. "The Lower Greensand above the Atherfield Clay of East Surrey." By Thomas Leighton, Esq., F.G.S.

This paper embodies the results of the author's examination of the Lower Greensand of East Surrey during the three years 1892–94; and it is stated that two papers published by the Geologists' Association (vol. xiii. pp. 4 and 163) are to be taken as introductory to this one. The area discussed in this paper extends from Leith Hill in the west to Tilburstow Hill in the east; and the divisions of the Lower Greensand chiefly referred to, are those hitherto known as the Bargate, Sandgate, and Hythe Beds. The author states that the Lower Greensand of East Surrey shows that formation to consist of beds deposited in a marine estuary or narrow sea, not far from land and within the influence of strong currents, extending generally from N.W. to S.E., so that, without palæontological evidence, no correlation of beds here with those exposed at Sandgate and at Hythe is possible. He arrives at this conclusion by following the outcrop of the various chert-beds, which, after Dr. G. J. Hinde (Phil. Trans. Roy. Soc. vol. clxxvi. 1885), are accepted as of sponge origin (deep-water deposits), and further by following the outcrop of the pebble-beds, described by Mr. C. J. A. Meÿer (Geol. Mag. for 1886, p. 15).

In Part 1 of the paper the author discusses the district to the west of the Mole, and endeavours to show that the view set forth in the Weald Memoir of the Geological Survey, to the effect that between Dorking and Leith Hill the lower horizons of the Lower Greensand undergo a change in composition, although possibly verbally correct, is geologically incorrect, since the lithological change is from south to north, from beds laid down in deep water to beds laid down in shallow water. In his communication to the Geologists' Association of last year, the author showed that the pebble-bed at the base of the Folkestone Sands was at Abinger intimately associated with the Bargate Beds; and he now states that he has identified this pebble-bed in the Dorking-Horsham road section, described by Prof. G. S. Boulger and himself in 1892, and at two other places to the east. The drifts of the same neighbourhood are then discussed, and it is found that at the top of and on both sides of the Lower Greensand escarpment, which, as stated by the Geological Survey, is here sandy throughout, there are gravels obviously deposited by a considerable stream consisting chiefly of Lower Greensand chert (entirely of Lower Greensand material) with, amongst the rougher material, lenticular beds of fine pebbles composed chiefly of débris from the Bargate Beds. Fragments of Lower Greensand chert have been obtained from the alluvium or from the beds of the streams now draining the Weald area to the south of Dorking. The soil over the Weald Clay as far south as Holmwood Common has everywhere yielded to the author fragments of the same chert. Hence it is argued that the chert-beds now seen upon Leith Hill to the west formerly existed over the Weald to the south of Dorking, and that the fragments now lying about the surface have been left by denudation, as described by Dr. G. J. Hinde (*op. cit.*). Since, however, as has been stated, the present Lower Greensand escarpment to the north consists of "sandy beds" only, there must be a lithological change from south to north (deep-water beds to shallow).

Part 2 of the paper is devoted to the district east of the Mole. Where the escarpment rises above the alluvium of the river the author finds the Bargate Beds with pebbles (at Park Hill, Reigate) separated from the Folkestone Sands only by a thin bed of Fuller's Earth and a layer of sandy chert. The section is now first described; the dip has been observed and proved, and by measurement this pebble-bed is shown to lie at approximately the same horizon above the Atherfield Clay as when it was last seen west of the Mole. From Reigate eastwards to Tilburstow Hill the same beds are seen in the numerous hollow lanes and pit-sections. The pebble-beds are found approximately on a definite horizon; but whilst they become of less importance eastward, the overlying cherts, first seen at Reigate, become of greater importance in that direction. The thin bed of Fuller's Earth, also first seen at Reigate, thickens to the east likewise.

2. "On the Eastern Limits of the Yorkshire and Derbyshire or Midland Coalfield."[1] By W. S. Gresley, Esq., F.G.S.

The author attempts to throw light on the question of the easterly extension of the Yorkshire, Derbyshire, and Nottinghamshire coalfield beneath the newer rocks. He notices the general trend of the strata, the sizes of other British coalfields, the question of the origin of mountains, stratigraphical considerations, and the faults of the North of England. His object is rather to suggest what he believes to be novel ways of treating the subject than of reaching conclusions or locating limits.

3. "On some Phases of the Structure and Peculiarities of the Iron Ores of the Lake Superior Region." By W. S. Gresley, Esq., F.G.S.

The author has been studying heaps of ore brought from the region lying south-west of Lake Superior since 1890. He describes certain structural features of the ore-fragments, and discusses the evidences of mechanical movements and chemical alteration exhibited by these fragments.

CORRESPONDENCE.

THE GEOLOGICAL AGE OF THE ROCKS OF CHARNWOOD FOREST.

Sir,—As some uncertainty seems to hang about the origin of the name "Cambrian" as applied to the rocks of Charnwood Forest, will you allow me to make a short statement on the subject.

Having had occasion recently to refer to the Survey Memoir "On the Geology of the Leicestershire Coalfield," published in 1860, for another purpose, I turned to the passage dealing with the Charnwood Forest rocks; and as regards the origin of the name "Cambrian" as applied to them by the Survey, I thus wrote (p. 11): "In the absence of organic remains, these rocks have been referred by Professor Sedgwick and Mr. Jukes to the Cambrian period; amongst other reasons, from their resemblance to the rocks of this age in Wales. They have been described in detail by Mr. Jukes,[2]

[1] See also a paper on the same subject by Mr. Arnold Lupton, entitled "On the Geology of the West Yorkshire Coalfield" (Trans. Federated Inst. Mining Engineers, vol. vii. pt. 1, p. 137).

[2] Geology of Charnwood Forest, appended to Mr. Porter's History of Charnwood Forest.

and the Geological Survey of the range has been executed by my colleague Mr. H. H. Howell."

From this it will be seen that the age of these rocks was determined by no less an authority than Professor Sedgwick, the founder of the Cambrian system in Wales, supported by his friend and pupil Professor Jukes, and the ground of this determination is the resemblance of the Forest beds to the Cambrian beds of North Wales. Who amongst men should have been better able to recognize this resemblance than the distinguished founder of the Cambrian system? Nor was the opinion of Professor Jukes less entitled to weight, as Jukes spent several years of his Survey life amongst the old rocks of North Wales. For six months of my own Survey life I was his companion and pupil in the same region; and when a few years afterwards I had opportunities of examining the rocks of Charnwood Forest I was able to recognize the similarity of physical character, upon which Sedgwick and Jukes to a great degree relied in determining the geological age of the rocks; nor, notwithstanding what has been written by more recent authors, am I able to see good reason to alter the opinion I then held.

On reading over again the brief description of these rocks (as far as regards their non-plutonic masses), written at a time when their characters were vividly impressed on my mind, and when there was no dispute regarding their age, I see how similar is the description to one which might be applied to the Lower Cambrian beds of Merionethshire. "Crossing the axis we find the beds as far as Upper Black Brook, consisting of bluish-purple and green slates, of a coarse character, alternating with fine grits." The eruptive masses are then described, and their resemblance to the contemporaneous and intrusive masses of North Wales is pointed out (p. 12). Since these words were written much new light has been thrown on the composition and structure of the igneous masses by Professor Bonney and other petrologists. In 1860, the application of the microscope to thin sections of rock was scarcely begun; but the determination of the geological age of the whole series of the Charnwood rocks is not affected by microscopic definitions of the eruptive beds.

I have still much hope that fossils may yet be discovered in these old rocks. After the discovery of a Trilobite in the slates of Llanberis no one need despair; and any young geologist who desires to break fresh ground and win his spurs would do well to turn his attention to the slates of Charnwood Forest.

Edward Hull.

THE MAKING OF MOUNTAINS—A REPLY TO MR. MELLARD READE.

Sir,—May I ask you to allow me space to answer, as briefly as possible, a letter, in the Geological Magazine for December, 1894, in which Mr. Reade attacks my theory on the making of mountains.

I must in the first place object to a statement implying that I have, to a certain extent, changed front. Mr. Reade remarks: "Mr. Vaughan *now* says, that he does not rely upon decrease of volume due to pressure, but upon the transference of material," etc. I *never did* rely on decrease of volume, as Mr. Reade will see if he reads my original article more carefully, whereas, again and again, I insisted upon the main principle of transference of material.

Further on I read, that Mr. Reade has found out that the maximum elevation which could possibly be produced, according to my theory, is 1000 feet. Absurd though I believe this result to be, from my own calculations, I shall be most grateful if he will indicate his method of analysis, as the problem seems to present exceptional mathematical difficulties. Looking at the question in its simplest aspect the analysis employed must take account of each of the following phenomena:—

(1) The gradual contraction of a spherical cap with the consequent production of tension at its boundaries and frictional stress beneath.

(2) The inbending of the crust, and consequent outshear of material from beneath, with the necessary production of frictional stress. For this outsheared material must set up tensions and compressions in the superincumbent crust; the tensions being directed from the centre of the area outwards, and the compressions producing folding and ridging, principally at the boundaries, in the regions immediately preceding those of upheaval.

(3) The rate of contraction beneath the area, which will necessarily be made more rapid by the extension of material, and the consequent exposure of hotter layers to the cooling influence.

In fact, we have to deal with elevation due to distortion of the inner nucleus, and this cannot be limited to the amount by which the suboceanic shell can contract; for the viscous stresses due to outshear of subjacent material will compress the bounding parts of the area into folds and ridges. The only rough limit which can be assigned is, that the volume of the elevations above sea-level cannot exceed the volume of the ocean.

Another objection which my critic urges is that, since my theory demands that the surrounding continental crust should yield to the intrusion of rock underneath, the area could not bend inwards, because it has no anchorage. Here he has totally neglected the friction beneath the sinking area, arising from the outshear of material, which it seems to me will be powerful enough, not only to hold the area, but to fold and ridge its boundaries.

Lastly, Mr. Reade seems to argue that, granted the anchorage, the tension of rock would not be sufficient to allow of enough pressure to produce any tending inwards. In this reasoning he has entirely omitted the vastly important time factor; for, in reasoning on all geological phenomena, the length of time available is the most important point in the problem; since there are few geologists who will not grant that the making of a mountain range is spread over a vast number of years.

Now, it is well known that any practically solid body, acted upon by differential stresses, however small, will yield to their influence, if the time be sufficiently prolonged. Hence there is no need for the tension to exceed or even approach the breaking tension of steel.

To illustrate the great importance of the time factor, I will assume the extreme case, that entire rupture is immediately produced all round an isolated suboceanic area, in spite of the natural effect of the viscous friction beneath. The mechanical problem is then reduced to the following: An inner nucleus of highly heated material is surrounded by a spherical shell of rock. From this outer shell a spherical cap is cut out, reduced in area, and replaced, so that it does not quite fit and is in consequence entirely separated from the rest of the shell; every particle of shell and cap being subjected to the attraction of gravity tending towards the centre of the sphere.

The forces acting upon the non-fitting cap are simply its weight and the pressure of the subjacent nucleus; and it is to be noticed that, in the actual case, the weight of the suboceanic crust is almost certainly greater than that of the continental (see Pratt, "Figure of the Earth").

In the case of any portion of the rest of the shell the forces are: weight, resistance of nucleus, *together with* the supporting compression at its boundaries, arising from the fact that the area forms part of a continuous shell.

Hence the pressure on the nucleus will be greater under the suboceanic than under the continental crust. Thus, remembering that there is practically no limit to the time factor, transfer of material will take place slowly from beneath the oceanic to beneath the continental regions, and this the more easily on account of the high temperature at which the subjacent rocks exist.

I believe that I have now answered Mr. Reade's objections, which seem to me somewhat hastily conceived and dogmatically expressed; but I must confess to being unable to understand how the last sentence in his letter has any bearing on the points at issue. He says, alluding to my theory: "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." I cannot answer this objection, because I cannot imagine which is the man, nor which the chair beneath him; nor can I see how one is attempting to pull the other. As Mr. Reade has never made any reply to my criticism of the theory which he advocates, may I definitely ask him how he explains the undermentioned geological facts?

It is well known that, during many periods, great thickness of sediment have continuously accumulated, every part of which must have been laid down in shallow water; and that contemporaneously the area of denudation has been rising.

Does it not follow that, if two miles (say) of rock has been deposited continuously under shallow-water conditions, that the sea-flow must have been depressed through that distance, and that, consequently, an equivalent amount of subjacent rock has been squeezed out? I entirely fail to see how this is in accordance with Mr. Reade's theory, that, as sediment accumulates, the area of sedimentation rises; for, considering the slow rate at which deposition goes on, the elevational effects (if any) due to accession of heat must be contemporaneous with sedimentation.

Again, referring to the Himalayas and the plains south of that range, Mr. Osmond Fisher says (Ch. x., "Physics of the Earth's Crust): "The conclusion seems irresistible that, corresponding to the long though occasionally interrupted depression of the plains, a correlative elevation of the great range, which has supplied the deposits, has been going on." This seems to me totally at variance with Mr. Reade's theory of contraction by denudation.

9, Pembroke Vale, Clifton. Arthur Vaughan.

OBITUARY.

PROFESSOR ALLEN HARKER, F.L.S.

Born 1848. Died December 19th, 1894.

By the early death of Allen Harker, the Royal Agricultural College at Cirencester has lost one of its most active and popular Professors. Appointed in succession to Dr. Fream, in August, 1881, Prof. Harker soon gained the esteem and affection of all his students by his admirable courses of instruction, both in the field and in the lecture-room, and by his genial character. It is no easy task now-a-days to teach Botany, Zoology, and Geology; and even when lessons are restricted to their special applications to Agriculture, the work of the Professor is necessarily of an arduous nature. Prof. Harker, however, carried on his labours with much enthusiasm, and devoted all the time he could to researches on those subjects with which he had to deal in his lectures. He made known, through the Proceedings of the Cotteswold Club, of which he was an active member, many new facts in the local geology. He first drew attention to the fine exposure of the Kellaways Beds in a new railway cutting at South Cerney, where many large "doggers" or concretions of calcareous sandstone were opened up, and where a number of fossils were obtained. Other sections of Cornbrash, Forest Marble, and Great Oolite displayed in cuttings along the same railway between Cirencester and Chedworth, were also described by Prof. Harker, and he discovered in the Great Oolite traces of the organism determined to be *Solenopora* by Prof. H. A. Nicholson, and subsequently described as *S. jurassica* by Dr. Alexander Brown.[1]

In Cirencester itself the records of various well-borings occupied Prof. Harker's attention, and he was enabled by the account of the strata and their fossils, to determine the presence of a small faulted tract of Oxford Clay and Kellaways Beds that had previously escaped notice.

When, in 1887, during the Presidency of Mr. F. W. Rudler, the Geologists' Association paid a visit to Cirencester and its neighbourhood, Prof. Harker acted as guide in the excursions made to Birdlip, to the Royal Agricultural College, and to South Cerney.

He died, after a painful illness, on December 19th, 1894, aged 46.

[1] See Harker, Proc. Cotteswold Club, vol. x. p. 89; H. B. Woodward, Memoir on the Lower Oolitic Rocks of England, p. 290; and Brown, Geol. Mag. Dec. IV. Vol. I. 1894, p. 150.

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ORIGINAL ARTICLES.

I.—On a Collection of Fossils from the Lower Greensand of Great Chart, in Kent.

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

1. The Lower Greensand of Great Chart.
2. List of the Fossils.
3. Affinities of the Fauna.
4. The value of the Sandgate Fauna.
5. The Synchronism of parts of the Gault and the Lower Greensand.

I. The Lower Greensand of Great Chart.

The rarity and imperfect preservation of the fossils in the upper part of the Lower Greensand, in the south-east of England, has always added considerably to the difficulties in the study of that series. The Atherfield Clay and the Hythe Beds both have well-marked faunas, though fossils are often absent from the latter. The palæontological evidence is, however, much less satisfactory in the case of the two uppermost of the four divisions into which the Lower Greensand is usually divided. A fair number of fossils occurs in these at Folkestone, but further to the west the lithological nature of the beds changes, and fossils are found in but few localities.

In the "Geology of the Weald" Mr. Topley recorded (p. 129) 11 species from a quarry at Great Chart, near Ashford. The horizon was assigned to that of the Sandgate Beds because the fossils occur overlying the Kentish Rag, or limestones of the Hythe stage. As this is the westernmost point in Kent at which fossiliferous representatives of the Sandgate Beds are said to occur, the locality is an important one. I therefore made a collection of its fossils in the winter of 1889–1890, both in order that the fauna might be represented in the British Museum Collection, and in the hope of getting more information as to the palæontological value of the Sandgate Beds. The fossils occur mainly as internal casts; their identification is accordingly difficult and unsatisfactory; but as the collection includes over 140 specimens, it has been possible to fit together the evidence of several specimens of the same species, and thus to determine the most important characters.

The quarry from which the fossils have come is situated a little to the south of an old moated house—Singleton Manor. The workings are carried on for the Kentish Rag, of which 30 feet are shown in the section. The hassock which separates the rag is more argillaceous than is usually the case. The section is as follows:—

Soil.	
Green sandy clay.	
Layer of phosphatic nodules, with fossils	1 foot.
Broken rag with many *Exogyra Couloni*	2½ feet.
Kentish Rag and Hassock	30 feet.

II. List of Fossils.

Species.	Author.	Range in Time.
	VERMES.	
Serpula filiformis	Sow.	
	BRACHIOPODA.	
Terebratula sella	Sow.	Neoc.† Apt. Glt.
Waldheimia Wanklyni	Walker	Apt.
Terebratella Fittoni	Meyer	Apt.
**Rhynchonella sulcata*	(Park.)	Apt. Glt.
*——— *Gibbsiana*	(Sow.)	Apt. Glt. Cenom.
	LAMELLIBRANCHIATA.	
Exogyra Couloni	(Defr.)	Apt.
[Syn. *Exogyra sinuata*	Sow. *non* Lam.]	
**Neithea quinquecostata*	(Sow.)	Apt. Glt. Cenom.
**Gervillia anceps*	Desh.	Rh. Apt.
Idonearca glabra	(Park.)	Up. Apt. Low. Glt.
——— *subnana*	(Pict. and Rx.)	Low. and Mid. Glt.
Nucula albensis	D'Orb.	Mid. Glt.
**Trigonia aliformis*	Park.	Apt. Glt. Up. G. S.‡
——— *ornata*	D'Orb.	Urg. Neoc. Apt.
Astarte allobrogensis	Pict. and Camp.	Low. Glt.
Arctica angulata	(Sow.)	Up. Apt. Low. Glt.
Venus vassaicensis	D'Orb.	Low. Apt.
——— *parva*	J. de C. Sow.	Apt.
——— *galdrina*	D'Orb.	Neoc. Apt.
——— *Orbignyana*	Forbes	Low. Apt.
Thetis lævigata	(Sow.)	Apt.
Thracia, aff. *simplex*	(D'Orb.)	Low. Glt.
**Arcomya plicata*	(Sow.)	Apt.
*——— *neocomiensis*	(Leym.)	Urg. Neoc. Apt.
	GASTEROPODA.	
Natica Hugardiana?	D'Orb.	Neoc.
——— *buliminoides*?	(Desh.)	Neoc.

* Species accepted on Mr. Topley's authority.

† Urg. = Urgovian; Neoc. = Neocomian; Rh. = Rhodanian; Apt. = Aptian; Glt. = Gault; Cenom. = Cenomanian; Up. G. S. = Upper Greensand.

‡ The Upper Greensand is used in this case instead of the Cenomanian, for the horizon at Blackdown, at which this fossil occurs, is probably the equivalent of the Gault and not of the true Cenomanian.

III. The Affinities of the Fauna.

Mr. Topley recorded 11 species, of which *Serpula filiformis* is a useless worm-tube, and two are excluded from the above list owing to doubt as to the correctness of their identification. These are *Exogyra conica*, a record which was probably based on a young *E. Couloni* and *Terebratula oblonga*, which probably ought to have been identified as *Terebratella Fittoni*; these two Brachiopods often, when badly preserved, resemble one another somewhat closely. Mr.

Bather has kindly examined my specimens with care, and determined them all to be *T. Fittoni.*

The above list, therefore, adds 15 species to the fauna: these are of interest as they are forms with a more restricted distribution than the 11 valid species in Mr. Topley's list. The following table shows the affinities of the species:—

Species confined to Neocomian	2	(both doubtful)
,, ,, Aptian	8	
,, ,, Gault	4	
,, ranging from Urgovian to Aptian	2	
,, ,, Neocomian to Aptian	1	
,, ,, ,, Gault	1	
,, ,, Aptian to Gault	3	
,, ,, Aptian to Upper Greensand ..	3	

This summary clearly shows that the affinities of this fauna are with the Aptian or Gault; for of the 24 species included, 18 occur in the former, and 11 in the latter, while 15 are confined to the two stages. Two species occur only in the Neocomian, but they are based only on internal casts of univalves, and their evidence is of little value. The affinity is closest with the Aptian, but the fact that 11 species are present which occur in the Gault and that three range into the Upper Greensand, point to the fauna being high up in the Aptian stage.

This is in full agreement with the stratigraphical evidence; for the bed overlies the Kentish Rag, and occurs below the Gault, though the direct superposition of the latter is not shown in the section.

IV. The Value of the Sandgate Fauna.

The fauna having been thus determined as Upper Aptian, both from palæontological and stratigraphical evidence, there remains only the question as to whether it is most allied to that of the Sandgate or that of the Folkestone divisions of the Lower Greensand, and whether there is adequate palæontological reason for the separation of these two beds.

Eight of the species in the bed at Great Chart occur in the Sandgate Beds in the district where that stage is most typically shown. All of these, however, with the exception of *Arctica angulata*, occur also in the Folkestone Beds at Folkestone; and in this there is another species (*Thetis lævigata*), found at Great Chart, but not yet recorded from the Sandgate Beds of Sandgate. Thus palæontologically the Great Chart phosphatic bed is as closely allied to the Folkestone as it is to the Sandgate Beds. It may be objected that, as of these nine species six also occur in the Hythe Beds of Hythe, Lympne and Maidstone, the palæontological evidence is too indefinite to be worth much. This, however, only proves that the Hythe, Sandgate, and Folkestone Beds represented a comparatively short period. The species characteristic of the Hythe stage do not occur in either of the latter at Folkestone or Great Chart. The Sandgate and Folkestone Beds together contain a number of species which are characteristic of a higher horizon. Such are *Waldheimia Wanklyni, Terebratella Fittoni, Rhynchonella sulcata, Astarte allobrogensis,* *Venus parva*, etc. The three Brachiopoda nearly always occur in the upper part of the English Lower Greensand, when this is fossiliferous, as in the Bargate Beds near Guildford, and in the outliers at Faringdon and Upware. These five species may be taken as typical of the stage between the Hythe Beds and the Gault. They do not, however, support the division of this interval into two. The faunas of the Folkestone and Sandgate Beds at Folkestone, have been shown by further collecting to be practically identical. The differences between them appear to be only a lithological accident. The collection from Great Chart confirms this view, as the fauna is equally allied to each of the other two.

Objections to the identification as Sandgate of sundry isolated patches of rocks in the Lower Greensand of Western Kent and Surrey, have frequently been raised. These seem fully justified by the palæontological evidence which supports the following triple division of the Lower Greensand deposits of the South-east of England:—

1. Upper Aptian or Gargasian, including	Folkestone Beds of Folkestone (excluding the *mammillare* zone).
	Sandgate Beds.
	Phosphatic Beds of Great Chart.
	Bargate Beds of Guildford.
	Fuller's Earth Series of Nutfield.
	Faringdon Sponge Gravels.
	Lower Greensand of Upware and Bedfordshire.
2. Lower Aptian or Bedoulian	Hythe Beds and Kentish Rag.
	Main Chert Series of Godalming, Hindhead, Ewhurst, and Leith Hill.
3. Rhodanian...	Atherfield Clay.

V. The Synchronism of Parts of the Gault and the Lower Greensand.

Hitherto it has been generally assumed a change from the deposition of sand to that of clay, marked the division between the times of the Lower Greensand and of the Gault. The sands below a certain line are called the "Folkestone Sands" and are included in the Lower Greensand; the clay immediately above it is regarded as marking the commencement of the Gault. In the Geological Survey maps this lithological change is taken as the line of separation of these two series. For their purposes, this is the only possible and practically useful course that could have been adopted. The palæontological evidence is too difficult in application. But when this lithological line is accepted as the definite time limit between the periods of the Gault and the Lower Greensand, it is necessary to demur. Another explanation is possible.

Mr. Meyer showed,[1] more than twenty years ago, that the Upper Greensand of Blackdown is really Upper Gault; M. Barrois[2] has

[1] C. J. A. Meyer, "On the Cretaceous Rocks of Beer Head . . . ." Quart. Journ. Geol. Soc. vol. xxx. 1874, p. 385.

[2] C. Barrois, "L'âge des couches de Blackdown (Devonshire)," Ann. Soc. géol. Nord. t. iii. 1876, pp. 1–8. "Recherches sur le terrain Crétacé supérieur de l'Angleterre et de l'Irlande," Mém. Soc. géol. Nord. t. i. 1876, p. 69.

fully supported this conclusion. Mr. Jukes-Browne[1] has also recently pointed out that the Upper Greensand of Western Wiltshire is really only a calcareous sandy facies of the Gault. Similarly it is possible that the change from the sands characteristic of the Lower Greensand to the clays characteristic of the Gault, happened later in Surrey and the West of Kent than it did on the east coast. If so, then the "Folkestone Sands" of Guildford and Dorking were still in process of deposition after the formation of the last of the Folkestone Beds, and while the Gault was being laid down in the east of Kent.

This question cannot be finally answered until a collection of fossils has been made from the very base of the Gault in Eastern Surrey, sufficient for the determination of the exact zone to which this belongs. On the ordinary assumption, it ought to be the zone of *Hoplites interruptus.* There are, however, reasons to believe that this zone is absent from the area to the south of London. In spite of having watched whatever exposures of Gault I could find along the line between Guildford and Caterham, I have never been able to find any Ammonite belonging to a zone lower than that of *Hoplites splendens.* Nor can I find any reliable record of the occurrence there of the fossils of the lower zones.

Hoplites interruptus seems restricted in England to the Folkestone area and the Red Chalk. It has, however, been recorded[2] from the Richmond boring. If this record be correct, so probably also is the ordinary assumption as to the age of the "Folkestone Sands" of Surrey. The fossil is stated to have come from the depth of 1100 feet, while *Hoplites splendens* is recorded from a depth of 1128 feet. Such an inversion of the zones seemed improbable, and this led to a search for the specimen on which this record was based. The specimen is now in the British Museum (Natural History), and Mr. G. C. Crick has kindly examined it. He reports that though much broken its characters are distinct, and it is unquestionably not an *Hoplites interruptus,* but a specimen of the large fluted form of *H. splendens.* The *interruptus* zone is therefore still unrecorded from the London area or to the south of it.

The *Ammonite* in the core from the depth of 1128 feet is, however, also a typical specimen of *H. splendens,* and occurs only 13 feet above the base of the Gault. This species ranges from the 4th to the 7th zone of the Gault. If we make the somewhat improbable assumption that this specimen came from the very lowest possible point at which it could have occurred, then zones 1–3 are reduced to a thickness of only 13 feet. Thus either the three basal zones are proportionally much thinner at Richmond than they are at Folkestone, or else one or more of them is there absent. The latter view appears the more probable, as it explains the absence of the fossils of the same three zones from the line between Guildford and Godstone. If so, as in this area, there is no unconformity between but a gradual

[1] A. J. Jukes-Browne, "The Geology of Devizes, with Remarks on the Grouping of Cretaceous Deposits," Proc. Geol. Assoc. vol. xii. 1892, pp. 264–266.

[2] Quart. Journ. Geol. Soc. vol. xl. 1884, p. 736.

passage from the Folkestone Sands to the Gault, these three zones must be represented by part of the former. Then the commencement of the "epoch" of the Gault is represented not by the base of the fossiliferous clays but by some part of unfossiliferous sands now included in the Lower Greensand.[1]

This proposal is not altogether a new one, for the view was long ago expressed that part, if not all, of the Folkestone Beds of Folkestone must be included with the Gault. Thus Gaudry[2] advocated this in 1860, and he has been followed by many Continental authors and by Prof. Cole.[3] This step has not, however, been generally accepted, owing to the difficulty of separating the *Ac. mammillare* zone from the rest of the Lower Greensand. Thus M. Barrois maintains that we must include in the Gault, not only the Folkestone, but also the Sandgate and Hythe Beds, owing to the unity of the faunas of these three horizons; and that, as they contain the zone of *Ac. mammillare*, they therefore belong to the Gault. He says,[4] "il est hors de doute que la partie supérieure de ce Lower Greensand (*Folkestone Beds*) est notre zone de sables verts à *Am. mammillaris* . . . . . ils [the fossils of this zone] sont tous du gault, et ce niveau ne peut être séparé du gault." And he proceeds: "Si les Folkestone beds appartiennent au gault, les Sandgate beds, Hythe beds, qui n'en diffèrent que d'une façon insensible, devront aussi appartenir au gault; on ne peut songer à mettre une division d'étage au milieu du Lower greensand."

Acanthoceras mammillare does not occur in the Lower Greensand except in the uppermost of the four divisions into which Price has divided the Folkestone Beds.[5] This narrow zone must be included in the Albian and regarded as part of the basement bed[6] of the Gault; but only this. The three lower divisions of the Folkestone Beds and the Sandgate Beds, as well as the Hythe, are all below the horizon of *Acanth. mammillare* and are therefore earlier than the Albian.

The following Table expresses the views here advocated of the relations of the Lower Greensand and Gault in Kent and Surrey:—

This Table illustrates the differences between the formation scale and the time scale. For the purposes of the map the separation of the Gault and the Lower Greensand is of course necessary. But

[1] At a recent meeting of the Geological Society, Mr. T. Leighton announced the discovery of a fossil in the Folkestone Sands. This is a cone which has been identified by Mr. Carruthers as *Pinites hexagonus*, Carr. (Geol. Mag. 1871, Vol. VIII. pp. 540–544, Pl. XV.), a species previously known from the Upper Gault (zone ix.) of Eastware Bay. It is interesting to find that the only known fossil from the Folkestone Sands inland is a Gault species.

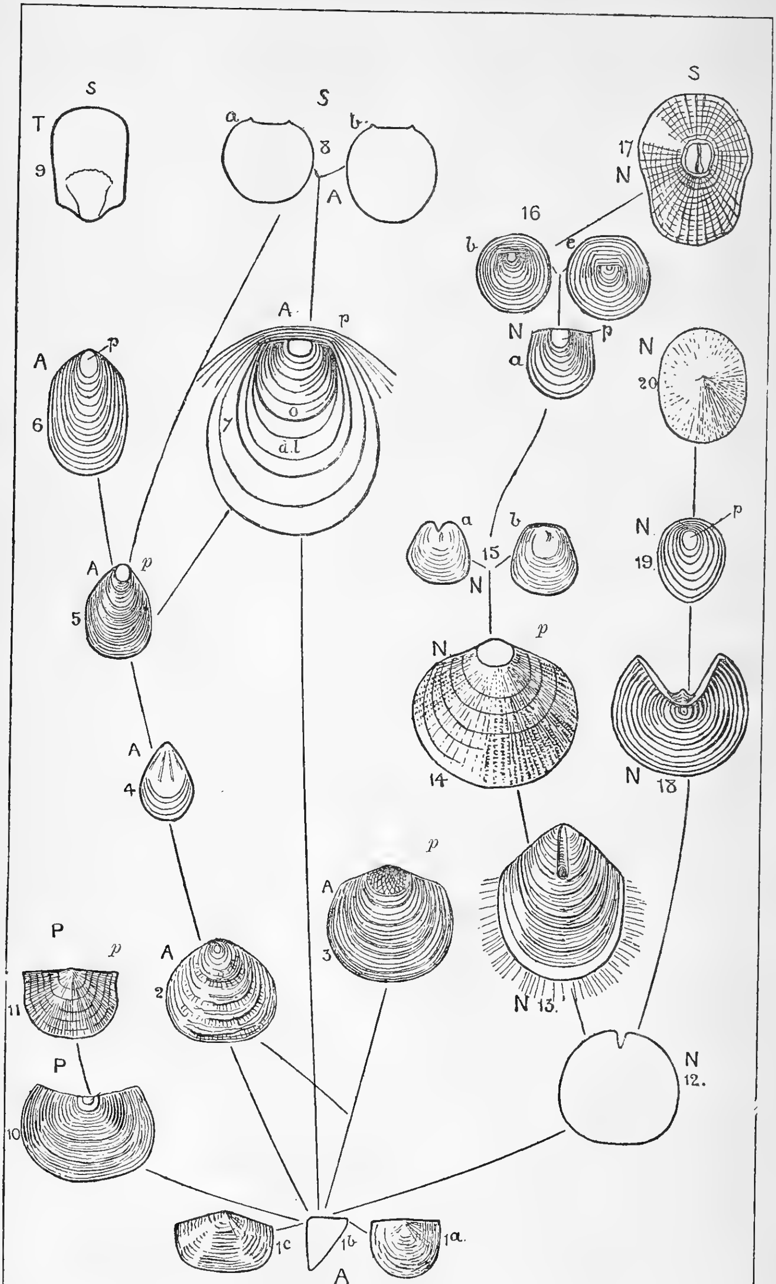
[2] A. Gaudry, "Sur la découvert de l'*Ostraea Leymerii* à Wissant (Pas-de-Calais)," Bull. Soc. géol. France, sér. 2, t. xvii. p. 32.

[3] G. A. J. Cole, "Aids in Practical Geology," ed. 2, 1893, p. 387.

[4] C. Barrois, "Sur le Gault et sur les couches entre lesquelles il est compris dans le bassin de Paris," Ann. Soc. géol. Nord. t. ii. 1875, p. 56.

[5] F. G. H. Price, "On the Lower Greensand and Gault of Folkestone," Proc. Geol. Assoc. vol. iv. 1875, p. 139.

[6] The frequent "very decided passage from one to the other" (*i.e.* Folkestone Beds to Gault) has been pointed out by Mr. Topley. "On the Lower Cretaceous Beds of the Bas-Boulonnais." Quart. Journ. Geol. Soc. vol. xxiv. 1868, p. 474.



Stages of generic development of Brachiopoda.

for other questions, such as that of the migrations of the Lower Cretaceous faunas, a time scale which is independent of lithological characters is equally necessary. These two scales are not contradictory, but complementary, and each must be retained for its special purposes—the one for local purposes and the other for a universal

Time Division.	Representatives in East Kent.	Representatives in Surrey.	Characteristic Species.
Albian.	Gault: Upper Zones, Nos. 4 ?–9. Gault: Lower Zones, Nos. 1–3 (+ x ?). Folkestone Beds. *Ac. mammillare* Zone.	Gault. "Folkestone Sands," or "Upper Ferruginous Sands."	*Hoplites splendens*, etc. *Hoplites interruptus*, etc. *Acanth. mammillare.*
Upper Aptian.	Folkestone Beds (Divisions I.–III. Sandgate Beds, and Phosphate Bed of Great Chart).	Bargate Stone. Nutfield Fullers' Earth Beds, etc.	*Waldheimia Wanklyni.* *Terebratella Fittoni.* *Rhynchonella sulcata.* *Avicula pectinata.*
Lower Aptian.	Hythe Beds (Kentish Rag, etc.)	Main Chert Series. Lower Ferruginous Sands.	*Waldheimia tamarindus.* *Acanth. Cornuelianum.* ——— *Martini.* *Hoplites furcatus*, etc.
Rhodanian	Atherfield Clay.	Atherfield Clay.	*Aporrhais Robinaldina.*
Neocomian	Weald Clay, etc.	Weald Clay, etc.	

time scale. Thus they correspond in history to the methods of dating events by dynasties or by centuries. If this be understood there need be no confusion between them, though the statement that part of the Lower Greensand is Gault, sounds like saying that this week is part of last week. But we can say without such paradox, that part of the Lower Greensand is of Albian age, though that stage is in England typically represented by the Gault.

II.—The Evolution of the Brachiopoda.

By Agnes Crane.

(PLATE V.)

(*Continued from the February Number*, p. 75.)

Part II.

It is evident that neither Barrande nor Davidson, who maintained the opinions I have summarized till the last in their publications, were able to recognize the evidence deducible from a study of the Brachiopoda favourable to the theory of their evolution.

The solution of the problem was left for a contemporary worker in the same field of inquiry, and for the younger school of American brachiopodists versed in all the modern methods of embryological and palæobiological research. The veteran is Professor James Hall, Director of the Geological Survey of the State of New York, that excellent training-ground for such able palæontologists as Whitfield, Walcott, and Clarke. Beecher and Schuchert, we believe, also studied Brachiopoda at Albany in Hall's private and State collections. It was at Albany that the Memoir on the Development of some Silurian Brachiopoda, by Dr. C. E. Beecher and Mr. J. M. Clarke (14), was published in 1889.

The material for this Memoir was derived from a collection weighing seven tons. From this fifty thousand specimens of Brachiopoda were washed out, sifted, selected, and referred to their respective genera and species. The horizon was that of the Niagara shales of the Upper Silurian formation; locality, Waldron, Indiana, U.S.A. All stages of growth of the individuals of a species were thus obtained. Some of these, if found by different observers in various localities at other times, might well have been referred to distinct species, whereas when placed in a line with the smaller and larger examples of their species the relationship becomes at once apparent, and the individuals fall into their place in the natural series.

From their laborious research the authors, Messrs. Clarke and Beecher, deduced the highly suggestive conclusion that the early stages of species belonging to such distinct groups as *Rhynchonella, Spirifer, Athyris, Nucleospira*, and the Meristoids, resemble each other so closely that the genera can then be determined only by comparatively trivial features.

This Memoir was followed, in 1892, by that remarkable "Introduction to the Study of the Palæozoic Brachiopoda," by James Hall and J. M. Clarke (38), which bids fair to become the Bible of the brachiopodist, and to revolutionize the study of the Brachiopoda in general. And it is to Albany that we now look for the completion of those fruitful studies in the generic evolution of this ancient Class.[1]

Our knowledge of the larval and later stages of individual growth in the living species is mainly due to the investigations of Fritz Müller, McCrady, Morse (56, 57), Brooks (12), Beyer (10), Shipley, Schulgin, Kowaleveski, Lacaze-Duthiers (51), Friele (36), Eugène Deslongchamps (33), Dall, Beecher (4, 5), and Fischer, Daniel and Pauline Œhlert (59, 60, 61).

It is, therefore, to Hall and Clarke that we owe the most searching inquiry into the genetic relationships and characteristics of the numberless ancient fossil forms of the class (38), and to Beecher and Clarke (14) important and suggestive studies in individual or ontogenetic development of Silurian species, and to the first-named correlations in ontogeny with phylogeny (8).

[1] The main text of part ii. vol. viii. Brachiopoda (Palæontology of New York) has since been issued. The printing of the volume of quarto plates is, we regret to learn, still delayed, through no fault of the authors. We have been favoured by Professors Hall and Clarke, since the first part of this paper went to Press in January last, with advance sheets of their "Summary of the Evolution of the Genera of Palæozoic Brachiopoda," destined to accompany the volume of Plates, and thus to complete their masterly survey of the Brachiopoda.

Let us now summarize the principal results of these combined studies from "the life" and from "still life," for the palæobiologist begins his inquiries at the point where those of the embryologist usually terminate.

We find that complex or synthetic types are by no means rare. The farther back we search the geological records the greater is the number of types uniting characters which subsequently become differentiated and accentuated, and serve to distinguish the diverse members of widely separated families.

The occurrence of genera with such mixed characters that descriptive palæontologists of the older school found it difficult to determine to which of two families they should be referred [1]—as Davidson sometimes frankly lamented,—coupled with the frequently expressed difficulties of separating many so-called species, should have originated doubts as to successive specific or generic creations.

Reversionary types are also met with which exhibit a tendency to go back to some earlier adult phase of genetic characterization. Such living "atavistic" types are *Gwynia*, *Cistella* among Megathyrids, and *Dyscolia* among Terebratuloids, *Atretia* (17) of the Rhynchonelloids, *Rhinobolus* among the fossil Trimerelloids, and *Aulosteges* among the Productoids.

The study of the individual development of larval forms of different species reveals past phases in the history of the evolution of the genus to which they belong, and its ancestral relationships. It becomes evident that these successive transitional stages were often stereotyped as adult genera fossilized in the records of the rocks. If this can be demonstrated of one branch, one order of Brachiopoda, we maintain that it follows logically that the principle is true of all branches, although the methods and lines of variation may have deviated. In other words, the same goal is reached by travelling different ways, as can be actually proved in more than one instance.

Now, it is impossible to deny that such a successful demonstration has been accomplished through the combined results of various researches on the structure and development of the recent Terebratuloids by Friele (36), Deslongchamps (34), Morse (57), Dall (24), the Œhlerts (59, 61), and Beecher (4), and for the Palæozoic Brachiopoda by Hall and Clarke (38). From Clarke and Beecher's (14) studies of a large series of individuals of several Silurian species we may also learn how easily abnormal forms originate at different periods of individual growth, and that these direct and indirect divergents, due to physiological causes accelerated by the environment, may give rise to new generic or subgeneric forms. The descendants of these generic variants, again prematurely

[1] This difficulty becomes naturally most apparent when treating of the Primordial and later Palæozoic genera, and is less marked among later developments. Hall and Clarke, as is well known, consider the employment of family groups, and even broader divisions, as "so palpably a violation of nature's method as to make itself felt as an incumbrance," and therefore use them merely as conventional and convenient.

launched into the sea of life, perpetuated a race of individuals with the same accelerated characters and propensities (3).

Furthermore, we discover as we proceed with our inquiries, that such distinctions as are expressed in the class names *Lyopomata* or "loose valves," comprising all the genera with inarticulated valves, and the *Arthropomata*, or "attached valves," including all those with articulated valves, are not in reality fundamental distinctions. It is now known that some forms of Brachiopoda once existed which fairly bridged the gulf, formerly considered impassable, between these two natural groups of hinged and hingeless forms, and that in more than one direction. We may cite as examples, *Neobolus, Spondylobolus, Trematobolus,* and *Kutorgina* of the Cambrian period, *Trimerella* and *Monomerella* of the Silurian, and *Barroisella* of the Devonian (*Lingula subspatulata,* M. and W., type), which indicate different approximations between the hingeless and the hinged forms (38). The fact, moreover, that Mr. G. F. Mathew (52) was compelled to describe his new genus *Trematobolus* from the St. John horizon in North America as an articulated Brachiopod of the order Inarticulata, emphasizes this point in a very marked manner.

Let us now briefly consider some of these recent genealogical revelations. It will, I think, be generally admitted that each distinct group of Brachiopoda is first represented by small species, somewhat insignificant in size and number of genera, although perhaps rich in species and individuals in favourable localities.[1] In 1877 Dall (26) and Davidson (24) estimated the number of known genera at 130, dividing them respectively into eighteen and fourteen family groups. In 1887 Fischer and D. and P. Œhlert (63) admitted sixteen. This year Mr. Charles Schuchert (64) took a fresh census, tabulated 279 genera as valid, and classed them into forty-seven family and sub-family groups. Two-thirds of these were differentiated in the Palæozoic era, ranging from the Primordial to the Carboniferous and Permian inclusive. But only nine of these passed up into the Mesozoic, when, however, some fresh types appeared which gave rise to a secondary evolution on fresh lines of development. Six out of the *seven surviving* families were represented in the Palæozoic. The genealogy of the Thecidiidæ is interrupted at the Carbo-Permian epoch, but there is good reason to believe that their remoter ancestors lived as long ago as the Silurian.

The Cuvierian class Brachiopoda is still subdivided by Beecher (4) and Schuchert (64), Fischer and the Œhlerts (63), into the sub-classes *Lyopomata* and *Arthropomata* of Owen, as the distinction of loose and attached valves is one which conveniently characterizes an immense majority of the described forms. The sub-classes were again subdivided into six orders by Waagen (68) in 1883, into eight by Neumayr (58), and by Dr. Beecher (4) into four in 1891. His classification (5) seems a rational one, based on the nature of the pedicle-passage and certain stages of shell growth. It embodies some of the best features of the systems of Von Buch, Deslongchamps (33, 34, 35), King (48), Gray, Davidson (28), Dall (25,

[1] *Stringocephalus* and *Schaphiocœlia* are abnormal exceptions.

26), Waagen (68), Hall (38), Barrande (1), etc., as considerably extended and emended of late by Schuchert (64, 66).

The Atremata, with a free pedicle-passage between both valves, are the oldest and simplest forms of Brachiopoda, represented in the Lower and Middle Cambrian by *Paterina*, *Obolella*, etc., but *Lingula*, a surviving type, did not appear before the Lower Silurian period.

Of the twenty-four known hingeless atrematous genera, no less than nine appeared in the Primordial fauna. Of their immediate ancestors, as yet we know nothing. Twenty-two in all appeared during the Palæozoic era. Two little "tongue-shaped" shells still represent them—*Lingula* in the Eastern oceans and *Glottidia* in those of the Western hemisphere.

The Atremata gave rise almost simultaneously in the Primordial seas to members of the orders Neotremata and Protremata; for types it is now generally conceded are more plastic at or near their points of origin.

The Neotremata comprises all the disc-like hingeless forms with pedicle passage restricted to the ventral valve. These diverged from the Atremata by way of the round punctured shells of the family of the Trematidæ. Thirty-one genera are referred to this order, which is represented in existing oceans by the long-lived *Crania*, *Orbiculoidea*—also known as *Discina*,—and by the modern branchlet of *Discinisca*.

The order Protremata includes the large number of 82 articulated genera with a single plate deltidium, classed by Schuchert (64) into two suborders[1] and fourteen families, many with but a short range in time. The earliest forms of the primary division are considered to have originated from the Atremata, *viâ* the Cambrian species allied to the genus *Kutorgina* (*K. cingulata*, Billings, type), and were chiefly restricted to the Palæozoic oceans. Others appeared at the close of that great epoch, or with the dawn of Mesozoic time. The only direct living representative of the Protremata, as defined by Beecher, is the Thecidoid *Lacazella Mediterranea*, Risso. Other members of the family to which this species belongs are known to occur in the Jurassic, possibly in the Trias. Then there is a break in continuity of descent, but there is good reason to believe that the remoter ancestry of the Thecidiidæ will eventually be traced through the adhering Productoids back to the Silurian Strophomenoids, which have the same habit of attaching themselves by one valve to foreign objects, or, like many neotrematous genera, to each other.

It was from the Protremata, prolific in short ranging genera, that the important order of Telotremata originated in that family of Pentameridæ, abundantly represented in Silurian seas, and it is believed by the genus *Camarella* in the Primordial oceans. It diverged in two main lines of descent, with numerous collateral

[1] I. *Trullacea*, from *trulla* a scoop, for the spoon-shaped plate, the spondylium of Hall.

II. *Thecacea*, from *theca* a cover, referring to the deltidium in one plate covering the three-cornered fissure in the apical portion of the ventral valve.

branches, one of the extinct Spiriferoid, Meristoid, and existing Rhynchonelloid, and the other of the Terebratuloid type, still more familiar. By far the largest number of Brachiopoda—half of all the known genera—belong to this order of TELOTREMATA,[1] which is characterized by the deltidium in two plates, and the presence of variously modified calcified supports to the brachial or breathing organs of the "arm"-footed mollusc-like animals.

Thus, to sum up the ordinal relationships, the atrematous order represents the short main trunk of the Brachiopodal phylum—the NEOTREMATA and PROTREMATA chief divergent, but now dwindling branches, while the secondary, but more robust branch of the TELOTREMATA, which originated in the PROTREMATA, has given rise to more numerous stems, branchlets, and offshoots than all the rest put together. By far the larger number of surviving genera and species belong to this flourishing branch of the Brachiopodal family tree.

So much for the ordinal evolution of the Brachiopoda, which has been indicated in the diagram already published (Plate IV.), in which the top line represents the seas of the present day, and the bottom one the Primordial oceans of long past ages (GEOL. MAG. p. 65, February, 1895).

Let us now consider some instances of the evolution of genera.

The simplest form of all known Brachiopoda[2] is that small semi-elliptical, horny, imperforate hingeless shell *Paterina*, the little father of all the Brachiopoda. The genus was founded on a Lower Cambrian species first referred to *Kutorgina* and *Obolus* by Billings and Walcott,[3] but assuredly not belonging to the first-named genus if *Kutorgina cingulata*, Billings, from the Middle Cambrian be taken as its type, for that is a calcareous shell with indications of a hinge-area, and there seems reason to consider it as an ancestral form of the articulated PROTREMATA (Pl. V. Fig. 10.)

In external shape the atrematous *Paterina* (Pl. V. Figs. 1*a*, *b*, *c*) bears a close resemblance to the horny imperforate protegulum, or earliest developed shell covering, which makes its appearance in the phylembryonic stage (when class characters can be first determined with certainty) of all larval Brachiopoda. According to Beecher, nearly every Brachiopod goes through a "paterine" stage of development (5). The Primordial little "coin-shaped" shells known as *Obolella* (Fig. 2) pass through their transient paterine stage, and the resultant Obolelloids play an important part in the genealogy of *Lingula* (Figs. 5, 7), one of the few "tongue-shaped" shells of the atrematous order still existing. For the Linguloid type was evidently derived from the preceding Obolelloid which had attained

[1] The earliest known forms of the telotrematous sub-orders ROSTRACEA, HELICOPEGMATA, and ANCYLOBRACHIA approximate. There is reason to believe that the ROSTRACEA and ANCYLOBRACHIA are older than the HELICOPEGMATA or SPIRIFERACEA.

[2] "And it might be fair to say of all possible Brachiopoda"—add Hall and Clarke (*op. cit.* p. 912, 1895).

[3] The earliest form and type species is *Paterina Swantonensis*, Walcott, sp., from the Lower Cambrian of Vermont, first described as *Obolus* (*Kutorgina*) *Labradorica*.

its culmination, or period of maximum development, in a faunal epoch antecedent to the appearance of the true *Lingula*, which is therefore not the most ancient form of all the Brachiopoda (38).

Prof. W. K. Brooks had long since noted the Obolelloid shape of the shell in the larval phases of recent *Lingulæ* (*Glottidia*) (12), just as a Linguloid phase of shell growth had been previously recognized by Morse as characterizing an early stage of *Terebratulina septentrionalis* still living on the east coast of Maine (Pl. V. Figs. 8*a*, 8*b*, and Fig. 9) (56, 57).

When we consider the tendency to abbreviation, which is a general feature of later embryological stages, it is astonishing that palæontologists should have been able to trace so many satisfactory genealogies.

The Lower Silurian true *Lingulæ* gave rise to many generic ramifications, some of which were short-lived. Two genera—*Lingula* and the divergent *Glottidia*—survive in existing oceans, the first on the eastern, the second on western shores, both in shallow waters.

Some of the early Lingulelloids, such as *Lingulella* (Pl. V. Fig. 4) and *Lingulepis*, fore-runners of *Lingula*, were of a very mixed type, having the outward form of *Lingula* combined with the narrow pedicle slit and simple muscular arrangements of the antecedent Obolelloids (38). While *Trematobolus* from the St. John group has been described by Mr. G. F. Mathew as an "articulated Brachiopod of the Inarticulate order," it combines the features of *Siphonotreta*, *Schizambon* (Fig. 13), and *Obolus* in the ventral valve and those of *Orthis* in its dorsal valve (52, 53).

Hall's new genus *Barroisella*, a lineal descendant of Silurian *Lingulæ*, is an illustration which survived in Devonian seas of *one* way in which the hingeless loose valves approach the articulated or attached valves. It presents so marked a specialization of the deltidial callosities as to indicate their approximation for articulating and interlocking purposes. This genus left no descendants.

In *Lingulops* (Pl. V. Fig. 6) and *Lingulasma*, now raised into family rank by Winchell and Schuchert (64), we get proofs of the influence of physiological causes on the origin of genera. They are said to be "platform bearing" *Lingulæ*, outwardly resembling *Lingula*, while their internal structure yields evidence of their actual relationship with the Silurian Trimerelloids. It took a Canadian (Dr. Billings), several Americans (Hall, Meek, Whitfield), a Swede (Dr. Lindström), the canny Scot (Davidson), and that far-seeing Professor of Queen's College, Galway, William King, a slayer of *Eozoon* organism, and one of the most philosophical of British writers on Brachiopoda, to decipher the enigma of these strange fossils. I was present at their introduction to the scientific world. The structure and affinities of the group were first made known in detail at the Brighton Meeting of the British Association in 1872, when Davidson read a joint paper by himself (32) and William King (49), and James Hall led the discussion.

These thick-shelled Trimerelloids may, perhaps, be regarded as the "dyspeptics" of the Brachiopod race, inasmuch as the large size and consequent displacement of the organ usually called "the liver" (stomacal gland of Joubin) (47) affected the position of the muscles, which grew strong in proportion as the shells grew massive. The combination of increased muscular energy and resulting augmented secretion of shelly substance or "stereom" in the area of muscular attachment caused the formation of a solid plate, which has been gradually changed into a more or less vaulted platform. The evolution proceeded on two distinct lines. One deviated from *Lingula*, travelled *viâ Lingulops* and *Lingulasma*, with muscular scars excavated or sunken as in *Lingula*. The other diverged from Primordial *Obolus* through *Elkania* to *Dinobolus* with elevated muscular attachments. Both lines culminated in the Trimerellidæ before the close of the Silurian period in Canada, the United States, and Gotland, Sweden (32).

Similar instances of development on parallel lines can be traced in the longer known families of the Rhynchonellidæ and the Terebratellidæ (King *emend* Beecher). It has been clearly demonstrated by Deslongchamps (34), Buckman and Walker (13), that the "acute," the four-cornered, the "spinose," and some other Rhynchonelloid groups of the Jurassic period—I now quote *verbatim*—"carry on as they ascend each their own course of development side by side." The earliest forms of the intermediate Proto-rhynchoids are found in the Lower Silurian.

The results of the various researches into the development of the Terebratuloids have been so recently summarized by myself[1] in this Magazine and elsewhere, that it is not necessary to go into details of what may truly be regarded as a test case of the evolution of the Brachiopoda.

Friele (36), Dall (24), Deslongchamps (28, 29), and Beecher (7) have traced the specific development of the northern members of the long-looped Terebratellidæ, and those of the southern oceans have been the subject of detailed comparison and research by Dr. P. Fischer, and those excellent French Zoologists Daniel and Pauline Œhlert (59), whose collaboration has been so fruitful in research, and is full of promise for the future.

It is with pleasure I refer to Madame Pauline Œhlert as an earnest co-worker with her distinguished husband, and, so far as I am aware, the only other member of my sex who is actively interested in the study of the recent and fossil Brachiopoda (59, 60, 61, 62, 63).

So far as the Terebratelloid branch is concerned the combined results of all investigations reveal two lines of generic evolution. One travelled by the northern and the other by the southern species of the family. In each the earlier stages, gwyniform and cistelliform, are identical, and indicate descent from a common Megathyrid source (7, 8). The northern forms pass successively on through the platidiform, ismeniform, mühlfeldtiform, terebratelliform, and culminate in the dalliniform phase represented in boreal

[1] Geol. Mag. Dec. 3, 1893, p. 321. Natural Science, vol. ii. No. 11, Jan. 1893, pp. 46–52.

oceans by *Waldheimia septigera* and *Macandrevia cranium.* The austral species diverge, after assuming the cistella stage, through a bouchardiform, mergerliniform, magasiform, magaselliform, terebratelliform, and magellaniform phase, of which the fine Falkland species *Magellania* (*W.*) *venosa*, Sol., is the type of final evolution (59, 61).

These forms or phases, transitional and successive, in the living species often represent adult stages known to be permanently stereotyped as characteristic genera in the fossiliferous deposits of the Tertiary, Cretaceous, and Jurassic formations. In the Devonian epoch the Terebratelloid branches become merged in the main stem. The well-marked Devonian genus *Tropidoleptus*[1] is, according to Hall, a true platidiform type, and one of the oldest known representatives of the Terebratellidæ, while *Cryptonella*, also of Devonian age, is likewise regarded by him as a direct ancestor of the Magellanian stock (*Waldheimia*). There is evidence that both branches originated in the earlier "stropho-orthoid" stock of the protrematous order. The annectent genus *Amphigenia*, on the other hand, approximates both to the Rhynchonelloid branch and the main Terebratuloid stem, as represented by the Lower Devonian *Rensselœria*, "half Pentameroid, half Centronelloid," and others of the centronelliform type. Its appearance in the Upper Helderberg series of the Lower Devonian somewhat antedates that of *Rensselœria. Amphigenia* is punctate and unites the muscular scars of the Terebratuloid with a spondylium and the brachial processes of a Rhynchonelloid, and thus connects the Pentameroids with the Terebratuloids. Among the earlier orthidian and pentamerine stocks the Proto-rhynchoids also originated in Lower Silurian times, culminating in the persistent Rhynchonelloid stem, still represented by the more modern offshoots *Hemithyris* and *Acanthothyris* of the Telotrematous order, so prolific near its source in the comparatively short ranging spire-bearing genera, of which the last representatives died out in the Triassic oceans.

But it is impossible, even in the generous space limits permitted, to go farther into details of descent with modification among the Brachiopoda. We have seen, as we search together the records of the ancient fossiliferous rocks, how the confines of the *classes* merge into one another, that *orders* converge and certain *genera* pass almost insensibly the one into the other.[2] Our knowledge has, indeed, advanced with giant strides of late, thanks to the critical and searching investigations of the numerous able scientists of diverse nationalities interested in this group of organisms, and to those of America, France, and Germany in particular. I feel sure that there is awaiting us in the not far distant future a complete demonstration of the evolution of the Brachiopoda.

[1] This genus has no deltidium on the brachial valve.

[2] "Even among the generic groups there is so often an almost intangible transition from one to another that the employment of distinctive terms seems at times quite perfunctory; but with the increase of such difficulties the nearer our classification may be regarded as approaching the true method of development."—*Vide* p. 908, Hall and Clarke's "Handbook of the Brachiopoda," Part II. Albany, 1895.

NOTE.—"The Brachiopoda need not detain us long," writes Prof. S. J. Hickson, M.A., D.Sc. Lond., on p. 115 of "The Fauna and Flora of the Deep Sea," 1894 (Modern Science Series). It is, perhaps, just as well they did not, for we fail to comprehend his subsequent remarks thereon in the light of modern research. "*Atretia*," he proceeds, "is the only genus peculiar to deep water." If by "peculiar" he means that the genus is found in deep water exclusively (the usual sense of the word) we would refer him to the types of *Atretia Brazieri*, Davidson, which have been preserved for some years in the Davidson Collection in the Geological Department of the Natural History Branch of the British Museum. This Australian species was determined, named, and described by Dr. Davidson (see Proc. Zool. Soc. Lond. p. 181, April, 1886), for his "Monograph on the Recent Brachiopoda" (Trans. of the Linn. Soc. of Lond. 1886–1888, vol. iv. Zoology, p. 175, pl. xxv. figs. 16, 17*a*). Therein he will find the Australian species of the genus was obtained by Mr. John Brazier off Port Stephens, New South Wales, in twenty-five fathoms, which can scarcely be regarded as "deep water." Much has been learned and published with regard to the distribution of the recent Brachiopoda since the publication in 1880 of Dr. Davidson's "Report on the Brachiopoda of the Challenger Expedition," which was the first issued.

With regard to Prof. Hickson's further statement as regards *Lingula*, moreover, it can no longer be maintained "that shells almost identical with those of the living species are found abundantly in the Cambrian strata." It has been repeatedly observed in recent years by Hall, Clarke, Beecher, and Schuchert that *true Lingulæ* first appear in the Trenton series of the Lower Silurian epoch. The Cambrian species, formerly referred to that genus, are now known to belong to more primitive genera, *Lingulella* and *Lingulasma*, and that these were preceded by various Oboloids and Obolelloids and the radical *Paterina*. If the diagram of generic evolution which accompanied the first part of my paper in the February Number of this MAGAZINE dispels the persistent illusion respecting the primeval antiquity of the genus *Lingula*, and its unchanged persistence since early Cambrian time, it will have served its turn. Of the manifold imperfections of that "attempt to indicate the ordinal and main generic relations of the Brachiopoda," no one can be more aware than the writer. Since its publication I have been favoured, through the kindness of the authors, Professors James Hall and John M. Clarke, with advance sheets of the final chapter—"the Evolution and Classification of the Genera of the Brachiopoda"—of their excellent "Handbook of the Brachiopoda," now on the eve of publication in America. The classification appended is a judicious and compact one, combining their own views with those of Waagen, Beecher, and Schuchert. Including *Paterina*, which is placed outside the pale of both the sub-classes LYOPOMATA and ARTHROPOMATA, as belonging exclusively to neither, but a parent source of both, and excluding *Eichwaldia* and *Aulacorhynchus* as "Incertæ Sedis," no less than three hundred and twenty-seven genera are recorded therein. They are grouped in thirty-five families. Subfamilies are not recognized. This is about one-fourth less than Mr. Schuchert's scheme required, but the actual number of genera has been increased by forty-eight, viz. from 279 to 327, of which, strictly speaking, not one "persists unchanged" from the Lower Cambrian to the recent period.

We may be permitted to quote in conclusion the words of Professors Hall and Clarke: "To us the genus represents the structural unit, a point of departure; species, diverse expressions of the generic type; families, associations of genera representing the offspring of a common parentage." . . . . "A classification is a broken and punctuated expression of organic affinities and interrelations necessary to an easy treatment of any group of organisms, capable of expressing many truths in regard to the development of a race, but even in its most perfect state an index and a confession of faulty knowledge."[1]

A. C.

EXPLANATION OF PLATE V.

Letters A. Atremata; N. Neotremata; P. Protremata; T. Telotremata; = Orders.

p. paterina stage; *o.* obolelloid; *l.* linguloid; *a. l.* adolescent linguloid (Fig. 7). S. Surviving genera.

FIG. 1 *a, b, c.* A. *Paterina Labradorica*, var. *Swantonensis*, Walcott. Lower Cambrian, Vermont.

FIG. 2. A. *Obolella crassa*, Hall (after Hall).

FIG. 3. A. *Obolus* (*Botsfordia*) *pulchra*. × 3 (after Mathew). St. John Group, N. B.

FIG. 4. A. *Lingulella Dawsoni*, Mathew. × 3. St. John Group, N. B.

FIG. 5. A. *Lingula lamellata*, Hall (after Hall). Niagara Group, N. Y.

FIG. 6. A. *Lingulops Whitfieldi*, Hall (after Hall). × 3. Hudson River Group.

FIG. 7. A. *Lingula riciniformis*, Hall (after Winchell and Schuchert). Lower Silurian, Minnesota. *p.* protegulum, or paterine stage; *o.* obolelloid; *a. l.* adolescent linguloid growth stage (greatly enlarged).

FIG. 8 *a, b.* A. *Glottidia* (*Lingula*) *pyramidata*, Stimpson (after Brooks). South Carolina Seas. Obolelloid stages of shell growth of the living species.

FIG. 9. T. *Terebratulina septentrionalis*, Couthouy (after Morse). Coast of Maine. Showing linguloid phase of shell growth.

FIG. 10. P. *Kutorgina cingulata*, Billings (after Hall). × 3.

FIG. 11. P. *Orthothetes lens*, White (after Hall). × 3.

FIG. 12. N. *Discinolepis granulata*, Waagen (after Waagen). Cambrian, India.

FIG. 13. N. *Schizambon* (?) *fissus*, Kutorga (after Hall).

FIG. 14. N. *Trematis Ottawensis*, Billings (after Hall). Nat. size.

FIG. 15 *a, b.* N. *Schizobolus truncatus*, Hall sp. (after Hall). × 3. Genessee Slate, N. Y.

FIG. 16 *a, b, c.* N. *Orbiculoidea minuta*, Hall (after Beecher). Three growth stages, showing the change from the paterina stage (*a*) with transverse cardinal margin, to the circular outline of the adult; *a.* paterina; *b.* nealogic; *c.* ephebolic stages.

FIG. 17. N. *Discina striata*, Schumacher. West African Coast.

FIG. 18. N. *Schizocrania filosa*, Hall (after Hall). Hudson River Group.

FIG. 19. N. *Pholidops Cincinnatensis*, Hall (after Hall). × 4. Hudson River Group.

FIG. 20. N. *Crania setifera*, Hall (after Hall). Niagara Group.

[1] Handbook of the Brachiopoda, Part II. 1895. By James Hall and John M. Clarke.

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An * denotes Memoirs published subsequent to the date of dispatch of this paper to the Women's Auxiliary Branch of the World's Congress, held at Chicago, August 24th, 1893.

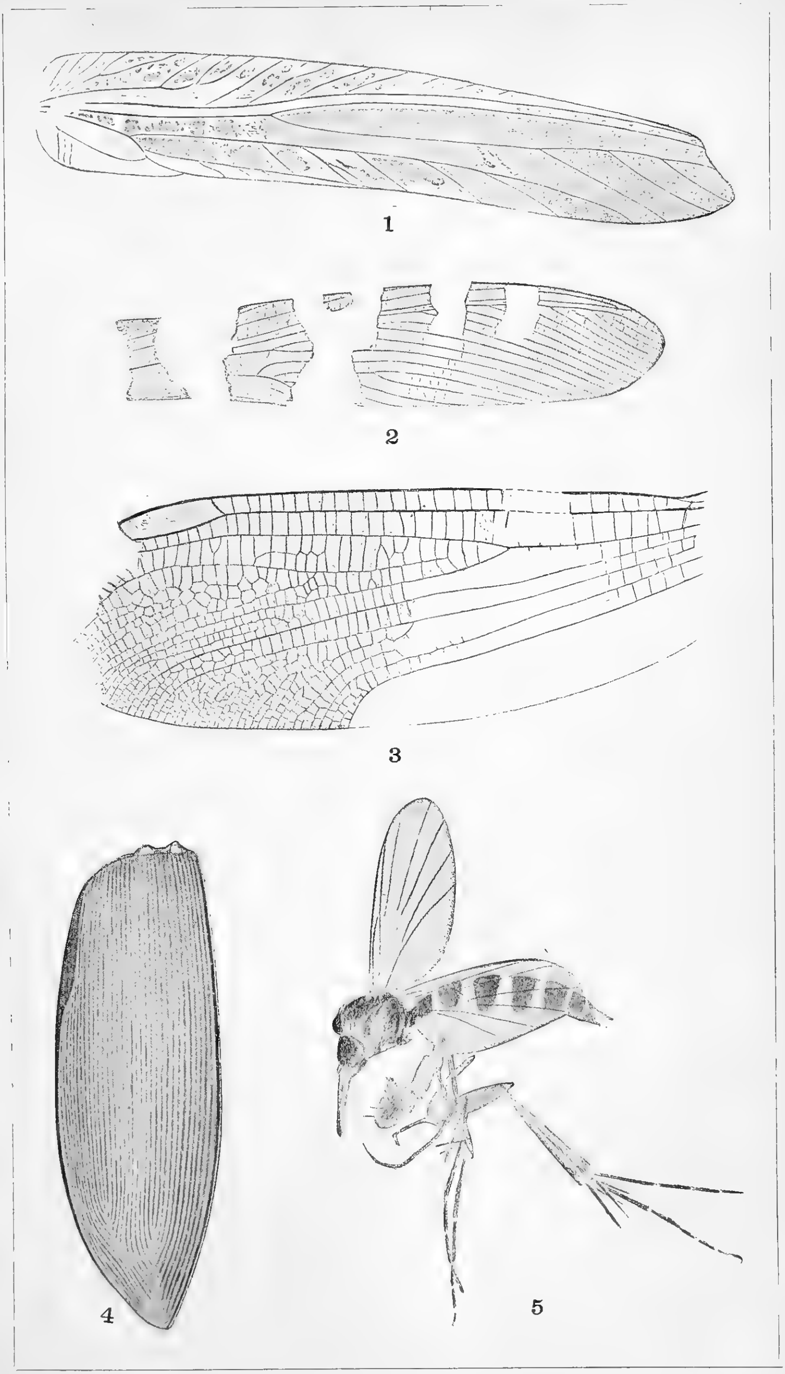
III.—The Miocene Insect-fauna of Œningen, Baden.

By Samuel H. Scudder, Cambridge, U.S.A.

(PLATE VI.)

THANKS solely to the labours of the late Oswald Heer, the fossil insect-fauna of Œningen is better known than that of any other locality or horizon in the world. But it is by no means so well known as it should be; for although Heer, in his latest enumeration of the specimens seen by him (Urwelt der Schweiz, 2e Aufl. 1879, p. 383), repeats precisely the same figures he has already given in 1861 (Recherches sur le climat du pays tert., p. 197), indicating in an interval of eighteen years no addition to his material (over 5000 specimens), his repeated additions to the number of species from that locality show that he had not fully worked over what he had. Indeed, thirty years ago, I arranged for exhibition in the Museum of Comparative Zoology at Cambridge a collection of nearly one hundred and fifty named species secured by Prof. Louis Agassiz from Heer, of which more than forty still remain undescribed; there are also a considerable number of merely nominal species enumerated by Heer in his Urwelt der Schweiz and elsewhere, duly catalogued by me in my Index to Fossil Insects (Bull. U. S. Geol. Surv. No. 71), but as yet neither described nor figured. In addition to this it may be noted that in the enumeration referred to above Heer mentions 543 species of beetles, while less than 270 nominal species have yet been published from Œningen, and only seven species from the Swiss Miocene, included in the enumeration.

Recently, by the request of Mr. R. D. Lacoe, of Pittston, Penn.,



J. Henry Blake del.

Fossil Insects from Œningen.

I have examined with some care his large collection of fossil insects from Œningen, larger, perhaps, than any outside of Zurich, for it consists of about 3500 specimens, of which fully one-half may be made use of to advantage. From the better specimens I have separated over four hundred species; and as not a few unpublished forms occur among them, I have thought that a summary account of the collection, with a notice of a very few of the forms, might prove interesting to others, especially as I can add some statements regarding species determined and named by Heer, but not yet published, certain species named by him being accessible, as already stated, in the Museum at Cambridge, and a few in my own small collection. Altogether I have examined about 4000 specimens.

The 428 species which I have separated in Mr. Lacoe's collection are divided among the orders as shown in the following table, in which they are placed beside Heer's enumeration of the species which had passed through his hands, and each reduced to percentages for better comparison :—

	In Heer's Collection.		In Lacoe's Collection.	
	No. of Species.	Percentage of whole.	No. of Species.	Percentage of whole.
Orthoptera	20	+ 2	8	− 2
Neuroptera	29	+ 3	13	+ 3
Hemiptera	136	− 16	57	+ 13
Coleoptera	543	− 62	294	− 69
Diptera	64	+ 7	17	− 4
Lepidoptera	3	− 1	0	0
Hymenoptera	81	+ 9	39	+ 9
Total	876	100	428	100

From this table it appears that the relative number of species in the different orders is almost strictly identical in the two enumerations, and enables one to assert with much assurance that in number of species the Coleoptera of Œningen are vastly preponderant, including about two-thirds of all; and that first the Hemiptera, and next the Hymenoptera follow, the Diptera lagging somewhat behind, with a feeble and not very differing representation of Neuroptera and Orthoptera.

Among the Orthoptera by far the most abundant insect is Heer's *Decticus speciosus*, of which, including reverses, I have seen sixty-four specimens, all tegmina, and in one case accompanied by a part of the hind wings. There is one specimen (No. 6861) which may be another species, very much smaller than the others, which vary from 43 to 60 mm. in length, while this is only 30 mm. long., and yet is a female. Females appear to be more frequently preserved than males, for of such as can be distinguished, the basal area being sufficiently preserved, there are 26 males to 15 females. It is not very well figured by Heer in his woodcut, since the pale flecks are not round, or only occasionally so, being rather short oblique bars;

the specimen he has figured also does not show the costal edge, or rather represents the costal area as exceedingly narrow, and thus gives a false impression. I have, therefore, refigured it here (Pl. VI. Fig. 1). The insect in reality belongs to *Drymadusa*, Stein, and is distantly allied to the living European *D. spectabilis*, Stein; but it differs from it in having straighter and slenderer tegmina, and considerably narrower costal area; all the other interspaces, too, are narrower, and while the neuration is practically identical, there are no stout distant cross-veins between the principal nervures such as are present in the living species, and especially in its female, though occasionally a single feeble one, or possibly two, may appear between the main branch of the posterior radial and the ulnar at their nearest approximation, or at the base of the former; as in *D. spectabilis*, the main branch of the posterior radial arises about opposite the extremity of the mediastinal vein.

If I have rightly determined as *Phaneroptera vetusta*, Heer, a number of specimens from Œningen, then that insect belongs to an undescribed extinct type of Phaneropteridæ, apparently allied to *Arythœa*, Stål., and in which the tegmina are very slender and the main branch of the anterior radial (Brunner's nomenclature) is united near its base to the ulnar vein by an oblique and strong cross-vein; this main branch has three well separated branchlets, not clustered at the tip; if the ulnar has any branches, they are exceedingly slight and have but a narrow area to cross. The anterior radial runs in the apical half of the tegmina midway between the mediastinal (which extends far towards the apex) and its own main branch, and in the upper of the two interspaces thus formed the cross-veins are tolerably numerous and oblique (transverse apically), in the lower similarly numerous and transverse.

No Orthoptera belonging to the true Acrididæ have heretofore been recognized at Œningen; but in Mr. Lacoe's collection is a single specimen (No. 6844) and its reverse of the larger and more important part of one of the tegmina of an insect, showing pretty clearly by its form and neuration that it belongs to *Acridium* in its restricted sense. It may be called *Acridium Œningense* (Pl. VI. Fig. 2). The posterior branch of the discoidal vein has five branches with an intercalary between each pair; the median vein forks in the usual manner, presumably in the middle of the wing, which, if so, is then about 51 mm. in length, indicating an insect about the size of *A. tartaricum*, Linn.; the ulnar vein forks a little before the median, its upper branch arching towards, but in no way connected with it; what is remarkable, and found in no other *Acridium* or *Schistocerca* I have noticed, is that the lower branch of the upper fork is itself divided soon after it origin. The close reticulation of the base of the tegmina extends to the middle of the wing, beyond which the cells are quadrangular. There is some indication that the tegmina were broadly mottled or clouded, but this is not certain. The length of the fragment is nearly 36 mm., and its breadth 8 mm.

The Neuroptera of the collection show at least four undescribed species of *Termitina*, of which one belongs to *Calotermes*, a genus not before recognized at Œningen, while the others appear to belong to a new type of white ants with closely crowded, branching, sub-longitudinal veins in the anal area. There are also several species of what is apparently a new generic type of Phryganidæ.

Two or three specimens of a Dragon Fly's wing occur (Pl. VI. Fig. 3) which I refer with little doubt to *Agrion iris*, Heer. They show that I was correct in referring this species to *Lestes* (Tert. Ins. p. 127), but an examination of these specimens shows that it cannot be placed in any of the subgenera established by de Selys, in his "Synopsis des Agrionines," 1862, but is strikingly different from any of them, though apparently nearest *Megalestes*. The group, which may be called *Stenolestes* (*στενός*, Lestes) would be characterized by the following features, which from the fragments preserved must of necessity embrace only such as can be drawn from the portion of the wing beyond and including the nodus: Nodal sector arising from the principal at about eight[1] cells beyond the nodus; the intercalary ultranodal sector not at all angulate, but its general course broadly sinuous; all the other sectors straight, except when curved next the margin; several intercalary sectors between the nodal and the subnodal, many between the median and the sector brevis and between the ultranodal and the nodal, but excepting at extreme margin, only a single one between the subnodal and the median sectors. There are about thirty postcubitals and the pterostigma is elongate, about five times as long as broad, and surmounts eight cellules, an exceptionally large number for a *Lestes*.

Among the Hemiptera are several galls easily referable to Heer's *Pemphigus bursifex*, but also two or three others which probably or pretty certainly represent the work of other plant lice. There are several new Jassidæ and Lygæidæ. In the Coreidæ Heer has recognized (Mus. Comp. Zool.) another species of *Syromastes* and another *Alydus*, and there are six or eight new species of this family in Mr. Lacoe's collection. The Pentatomidæ are the most numerous group, and here again Heer has recognized an additional species each of *Cydnopsis* and of *Pentatoma*, while in Mr. Lacoe's collection there are eleven species of *Cydnopsis*, of which five are new, and there is an additional species perhaps referable to *Eurydema*.

The Coleoptera are too numerous to mention in much detail, but of genera among Curculionidæ not before noted at Œningen I have recognized *Balaninus*, *Baris*? *Cryptorhynchus*, *Tychius*, *Bagous*, *Tanysphyrus*, *Rhinocyllus*, *Hylobius*, and *Plinthus*; while Heer recognizes *Cionus*, *Phytonomus*, *Hipporhinus*, and *Hypera*, besides half a dozen additional species of *Cleonus* and two each of *Larinus* and *Sitona*; I have also referred several species each to *Hipporhinus* and *Sitona*, and find new species of *Phytonomus* and *Apion*. Among the Otiorhynchidæ I am inclined to refer several species to *Otiorhynchus* and one to *Tanymecus*, while others appear to fall in the neighbourhood of *Aphrastus*, *Artipus*, *Ophryastes*, *Liparus*, and *Epicærus*. Heer recognizes two additional species of *Lytta*

[1] It is at the most from three to five cells beyond the nodus in all modern types.

among the Meloidæ, and I have seen others, while one of his appears to be identical with his *Prionus spectabilis*; all these are mainly represented by elytra only. Among the Chrysomelidæ, Heer recognizes a new *Galeruca* (of which there are seventy specimens in Mr. Lacoe's collection) and a new *Chrysomela* and *Oreina*; other new species before me seem to be referable mostly to genera already known from Œningen. Heer names a new *Prionus* only in the Cerambycidæ; but in Mr. Lacoe's collection are a number of striking new forms which appear to fall in genera allied to *Agapanthia, Desmocerus, Tylonotus*, and *Callidium*. There is little that is new among the Scarabæidæ: but Heer names a new *Melolonthites*, and in Mr. Lacoe's collection is a new *Geotrupes* and something near *Trichius*. Ptinidæ have not heretofore been recognized at Œningen, but I have seen what is probably an *Anobium*. In the Lampyridæ, Heer names an additional *Lampyris*, and Mr. Lacoe's collection contains three species in whole or in part referable to *Telephorus*. In the Buprestidæ, Heer recognizes *Agrilus* and names new species of *Perotis, Capnodis*, and *Buprestites*, while in Mr. Lacoe's collection are undescribed species of *Agrilus, Acmæodera*, and *Ancylocheira*? Heer sent Agassiz three species of *Elater* and five different species, unnamed, which he referred to *Elaterites*. Mr. Lacoe possesses numerous examples of two of these species of *Elater* besides two others, and of other Elateridæ a new *Cardiophorus*, two new species of *Ampedus*? and two referred with doubt to *Eucnemis*. Heer names two new species each of *Nitidula* and *Hister*, and one of *Coccinella*, while Mr. Lacoe has two other new species of *Coccinella* and two falling somewhere near *Rhizobius*. None of the described Staphylinidæ are in Mr. Lacoe's collection; but the four species which it contains appear to fall in, or in the vicinity of, *Megarthus, Acidota, Oxyporus*, and *Staphylinus*. In the Hydrophilidæ, Heer names a new *Hydrobius*; and a new species of *Hydrophilus* allied to *H. spectabilis*, Heer, but slenderer and smaller, occurs in Mr. Lacoe's collection. Finally, in the Carabidæ, Heer names two new species of *Harpalus* and an *Elaphrus*, a genus not before recognized at Œningen; while in Mr. Lacoe's collection I find three other new species apparently referable to *Harpalus*, two new species of *Pterostichus*, one which may be a new *Amara*, and others which appear to fall in or near *Badister, Diplochila*, and *Bembidium*, besides a remarkable new *Calosoma*.

Six species of *Calosoma* are already known from Œningen. The seventh, to which it seems well to call attention, is represented only by elytra (Pl. VI. Fig. 4), as is the case with most of the species already figured; but it is readily distinguished from all of them by the double number of striæ, there being thirty-two instead of sixteen, which is the most other fossil *Calosomæ* have. The striæ are more delicate than in the other species, but perfectly sharp, and are delicately punctate throughout, the puncta in one stria about as distant as those of neighbouring striæ. There are no large impressed puncta (a character common to two other species from Œningen), and the transverse striation of the interstices, peculiar to *Calosoma*, is very faint. The twelfth stria, counting from the sutural edge, terminates abruptly a little beyond the middle of the distal half of the elytra, and the four adjoining striæ on one side unite with their mates of the other side, by curving around its extremity in wider and wider curves, while the sixth and seventh unite in a similar but much more angular fashion with the eighteenth and seventeenth. In like manner the twenty-fourth stria from the sutural margin terminates almost exactly at the middle of the distal half of the elytra, and the twenty-second and twenty-third striæ unite with the twenty-sixth and the twenty-fifth around its extremity. One elytron (that figured No. 4873) is 16 mm. long. and 5·25 mm. broad; a second (No. 4878) less perfect one is a trifle larger. The form of elytron is almost precisely that of *C. nauckianum*, Heer, from Œningen, but has a slightly more produced apex. The species may be called *Calosoma Heeri.*

Among the Diptera, a single specimen occurs of a new generic type of Tabanidæ, allied to *Tabanus*, in which the upper sinuate branch of the third longitudinal vein is widely forked at the tip, and the lower branch, curving downward, terminates not on the border of the wing but on the upper branch of the fourth longitudinal vein just before its apex (No. 7056). There are two species of *Tipula*, at least one of them a *Tipula* in the narrowest sense. The Bibionidæ consist of three species of *Plecia* and two of *Penthetria*, none of which can be referred to described species.

There is a single specimen (No. 6893) of a minute fly, unusually well preserved, indicating a new genus of Mycetophilidæ, which may be called *Necromyza* (*νεκρός, μύζω*). The marginal vein of the wing reaches the end of the subcostal; the auxiliary vein impinges on the subcostal just beyond the origin of the cubitus, which arises at about two-fifths the distance from the base to the apex of the wing; the brachial cross-vein is at the middle of the wing; the second posterior cell extends back to the humeral cell itself, and the fourth posterior cell is even longer, reaching as far as the middle of the humeral cell. These characters easily distinguish it from any Mycetophilidæ known to me, the most nearly allied being, perhaps, *Brachypeza.* The hind thighs are stout, longer than the thorax; the hind tibiæ, which are twice as stout at apex as at base, are armed with a pair of stout apical spines half as long as themselves, while the hind tarsi are half as long again as the tibiæ. The insect is 3 mm. long. The wings are faintly fuliginous, and the antennæ, chancing to converge in front of the head, give an appearance of a long beak. It may be called *Necromyza pedata* (Pl. VI. Fig. 5).

The only other Diptera of interest are three species of Cecidomyian galls, one probably to be referred to *Cecidomyia Bremii*, Heer.

Among the Hymenoptera, the ants comprise the bulk of the material, and there seem to be several new species of *Formica* and *Myrmica*, besides some others of uncertain position, but certainly new, and still others falling near *Sima* and *Prionomyrmex.* There is a species of *Sphex*, a genus already recognized by Schöberlin, but not by Heer, and an insect which may possibly be *Bombus* *grand vus*, Heer, but which belongs to a new genus of Apidæ, in which the neuration more closely resembles that of *Eucera*.

EXPLANATION OF PLATE VI.

Fig. 1. *Drymadusa speciosa*, Heer, sp.; male fore-wing $\frac{2}{1}$.
Fig. 2. *Acridium Œningense*, sp. nov.; fore-wing $\frac{2}{1}$.
Fig. 3. *Stenolestes iris*, Heer, sp.; outer portion of fore-wing $\frac{3}{1}$.
Fig. 4. *Calosoma Heeri*, sp. nov.; elytron $\frac{4}{1}$.
Fig. 5. *Necromyza pedata*, sp. nov.; $\frac{12}{1}$.

IV.—An Interesting Contact-Rock, with Notes on Contact-Metamorphism.

By W. Maynard Hutchings, F.G.S.

FOR a considerable time past I have been engaged, in collaboration with Mr. E. J. Garwood, in an investigation of the rocks in contact with the Whin Sill. The results of our joint work, geological, petrographical, and chemical, will be published in detail in due course. In the meantime there are some special observations, made on some of the rocks in question, which have more or less bearing on some of the points dealt with in a paper I contributed to the Geological Magazine last year (Geol. Mag. 1894, pp. 36 and 64).

These observations having been made since that paper was printed, I have thought that it may be worth while to give an account of some of them, more especially as regards an interesting bed of altered shale which occurs at Falcon Clints. It is at this locality that the contact-action of the Whin Sill is very strikingly developed, there being an exposure showing fine garnet-limestones and other altered rocks. The bed in question is 75 feet below the contact, from which it is separated by a series of layers of limestones, sandstones, and shales, all altered. It is 8 feet thick, and rests on the basement conglomerate of the Lower Carboniferous.

It is for the most part a darkish gray, compact rock, with no remaining fissility. Its appearance is in many respects like that of some felsites. Its most striking macroscopic characteristic is that it contains large numbers of spherical, and approximately spherical bodies, like peas, and of various sizes up to rather over half an inch in diameter. These nodules are of a darker colour than the rock. They are not at all evenly dispersed in it, being at some places comparatively rare and scattered, while at others they are closely packed, and in some cases touch one another. At some parts of the rock they can be easily taken out unbroken, leaving perfect hollows where they have been; at others they are not in this loose condition, and can only be got out in bits by smashing the specimen. This difference is due to a slight weathering-action having, in some of them, caused the formation of a less coherent skin between the nodule and the containing rock.

Microscopic examination shows that this bed is not quite uniform in its nature throughout, and chemical tests confirm this. Thicker beds of shale or clay in the Carboniferous are nearly all found to vary in nature, as successive layers contain varying proportions of quartz and of fine clay-material, so that their chemical composition may differ a good deal *quantitatively*; and it is partly to such initial variations, and partly to consequent differences in the metamorphic action of the igneous rock, that we must ascribe the differences that we find in the microscopic examination of slides from several points in this bed, which is macroscopically a fairly uniform mass.

To give an idea of this interesting rock it will be best to describe separately two or three typical sections, whose nature will give a good general idea of the various points to be observed at this exposure of the bed in question.

Thus, from numerous hand-specimens collected near together, several slides have been made in which some of the spots have been included; in this case spots which are firmly incorporated in the rock and cannot be detached.

In ordinary light a very thin section shows the main portion of the rock to be composed of a uniform gray mass, in which are bedded abundant grains of clastic quartz of an average size of about $\frac{1}{80}$ inch, but ranging up to as much as $\frac{1}{30}$ inch in diameter. The gray ground-mass shows a vast number of rutile-crystals of very small size. They are not in the form of the "clay-slate needles," but in the relatively short and blunt form, with definite terminal developments, so usual in altered rocks. There are also the numerous small zircons, and the small hemihedral crystals of tourmaline, so characteristic of clays, shales, and slates. In all respects this rock corresponds to an altered moderately quartzy clay or shale, such as can be examined in any number of instances in the Carboniferous beds.

In polarized light this gray ground-mass shows, however, most interesting developments. Most of it is seen to consist of rounded, irregular, or more or less definitely bounded grains of a mineral, or minerals, lying bedded in and surrounded by a material which is mostly quite isotropic, but at other times shows an indistinct effect of birefractive substances developing within it.

At some places we have the polarizing grains closely packed together, with so little of the surrounding isotropic material that they amount to a true interlocking mosaic; at others they are very much more separated, and we have quite large spaces of the surrounding material, perfectly isotropic, but containing the swarms of minute rutiles, small flakes of white mica, and a certain amount of indistinct dusty and granular substances diffused in it.

A large portion of the polarizing grains can be proved to be quartz, some of them can be identified as felspar, though this is more difficult, and a good proportion cannot be made to give any definite optic tests at all. The grains are not yet water-clear, nor yet so sharply defined as those of a perfectly developed contact-mosaic; there is a certain amount of dimness in them, which is accentuated also by their envelopment in isotropic base full of microlites. It is, however, certain that we have here a production, due to the metamorphism of the shale, of quartz with more or less of felspar. All these grains are in every way perfectly and sharply distinguished from the original clastic grains of the shale; not one could by any possibility be mistaken for original material, even if only for the reason that they are full of minute rutiles and other material from which the clastic grains are quite free.

Here and there white mica is developed in larger flakes, lying in all directions, and, as before remarked, there is a good deal of the mineral in minute flakelets. But, on the whole, mica is a subordinate mineral in these special slides.

The clastic quartz-grains are a very interesting study. They are all more or less corroded and altered round their outer portions. The angular outlines of the original grains are in nearly all cases quite preserved, but the outer portions are no longer quartz. They are seen to be attacked and altered by the material of the isotropic base, and the altered rim so produced contains a large amount of white mica. In many grains this mica is seen to penetrate well into the quartz in little bays and gulfs, or as isolated streaks. It is largely in the form of sheaves and radiating groups of flakes.

In some cases the corrosion and alteration of the quartz-grain has taken an even more striking form. Thus, *e.g.*, one grain with an average diameter of $\frac{1}{45}$ inch is altered to about half its extent. The inner portion is still pure unaltered quartz, with its cavities and bubbles; the outer part is faint yellowish in colour, and quite sharply marked off in ordinary light from the original mineral. With lowered condenser it shows a granular and fibrous structure; in polarized light it is seen to consist of clear transparent isotropic matter, and to contain numerous sheaves and spherulitic bundles of polarizing fibres and needles, which can be optically identified as felspar. The outer boundaries of the original grain are quite sharply marked off against the surrounding mass of hard mosaic and isotropic matter.

In other corroded quartz-grains nests of anthrophyllite have formed, as clusters of prismatic needles; or we have beautiful little deposits of andalusite crystals in elongated prismatic form, with the dichroism unusually well shown.

Turning now to the nodules which are cut in these sections, we find points of great interest, which assist us in interpreting the nature of the rock and the processes by which it has been altered. The nodules are sharply defined, and are darker at the edges than towards the centres. This darkness is due to concentration of pigment, and also to the presence of some ferruginous colouring in parts. In these nodules are large patches of perfectly clear, transparent, almost colourless, and quite isotropic matter, containing no rutiles or other enclosures. With high powers and with suitable illumination, it may be seen that these patches are not quite structureless. There is a minute granulation discernible, and in some of them it passes to a fibrous condition. Other patches of similar material contain large bundles and sheaves and spherulitic aggregates of felspar-needles with a little quartz.[1] And inter-

[1] It used to be considered that in sheaves and spherulites of this description all *negative* fibres were felspar and all *positive* fibres were quartz, but it has been

mediate stages may be seen in which the needles of felspar and quartz are beginning to form in the isotropic matter, and so on down to a stage where the patches just begin to pass from the isotropic state into a development in which they commence to show a faint and speckly polarization.

In some of the nodules large amounts of anthrophyllite needles have formed in the patches, and a little andalusite is also seen. These fields of isotropic matter, and the new formations of minerals, are seen in these special slides, mainly at the outer portions of the nodules, and at these parts there are none, or very few, of the original clastic quartz-grains, while such as are there are much corroded away, and often represented only by small residues.

In the inner portions the clastic grains are as abundant and as regularly diffused as in the main mass of the rock, while the new formations are much less, or are absent, except that a little isotropic matter lies in among and around the grains, and here and there a little new mosaic is formed.

Full study of these sections gives the impression that we are here looking at a very interesting and instructive stage of the metamorphism of a shale. The finer-grained material has been completely affected by the re-solution of a large part of its original constituents, and out of the matter so formed a mosaic of quartz with felspar is seen in process of crystallizing. The process was brought to a close before such re-crystallization was complete, and so we have left for our observation a large proportion of the residual substance, which we may regard as representing the indefinite product of solution, or of aqueous fusion, of some of the original constituents, which we have such good reason to conclude takes place in the processes of contact-metamorphism.

In the larger quartz-grains we see that this process of solution was attacking them to a considerable degree, and had it continued, would have completely dissolved them away. That we can here see all this in progress, as it were, is due to the fact that we are dealing with the effects of only a moderate bulk of igneous rock, and to other favourable circumstances. If, for instance, the metamorphism were due to a large mass of granite (or to a similarly large mass of dolerite), the earlier conditions which caused the solution (or aqueous fusion) of the constituents would have lasted long enough to destroy the clastic quartz-grains to a far greater extent, or entirely; and the conditions during which the re-crystallization went on would have also lasted longer, and we should have had a completed "contact-mosaic" with either no residual "base" or only a small amount of it, and this not, or only to a small extent, isotropic, such as we may see in the aureoles round some granites.

In the nodules, as above described, we have the same process

demonstrated that this is not necessarily so, as felspar fibres may also be positive, though it is more rare. So that though negative fibres are felspar only, positive fibres may be either felspar or quartz, and the relative degree of bi-refraction must assist in distinguishing as far as possible. (See full *resumé* of this subject in Zirkel's Petrographie, vol. i. 1893, pp. 474 and 476.)

going on, but under special modifications which are not readily explicable. The solution of original materials has taken place very completely at the outer parts of the nodules, so much so that here even quartz-grains have disappeared and we have areas wholly made up of the product of the solution. Here also we see a gradual and unmistakable crystallizing out of felspar and quartz in this material, in an even more striking manner than in the main mass of the rock, because we can here more distinctly trace the passage of this isotropic base into an aggregate of different minerals.

It may be noted that the formation in these nodules, and elsewhere in the rock, of isolated patches of anthrophyllite and andalusite, tends to the conclusion that the inter-action of the components of the shale was not limited to such very short distances as have been inferred by observers in other cases (*see* Harker and Marr, Quart. Journ. Geol. Soc., vol. xlix. p. 368), but that a more considerable amount of interchange and transfer of materials has taken place. A similar opinion was expressed by Miss Gardiner in respect of contact-rocks at New Galloway (*see* Quart. Journ. Geol. Soc., vol. xlvi. p. 579). The analysis of a hand-specimen from which some of the sections described above were cut gives—

Silica	60·15	per cent.
Alumina	25·43	,, ,,
Ferric oxide	3·95 [1]	,, ,,
Lime	0·45	,, ,,
Magnesia	trace	,, ,,
Potash	1·25	,, ,,
Soda	2·01	,, ,,
Water	7·20	,, ,,
	100·44	

We can now consider other series of slides and see other phases of the same processes. As regards the main mass of the rock, we have variations in the relative amounts of the components, and of their present condition. At some parts there is much more mica and very little of the mosaic of good-sized grains of quartz and felspar forming, with little or none of the isotropic matter. The amount of clastic quartz, and the size of the grains, varies also, and so does the degree to which they are attacked and corroded. Other specimens may be obtained of which slides show that they consist in the main of a fine-grained aggregate of quartz and felspar, passing down into a quite cryptocrystalline felsitic-looking mixture, and opening up, on the other hand, here and there into numerous clear and glassy patches, which in polarized light are seen to consist wholly of groups of well-twinned plagioclase, which can be identified as albite in many individuals, whilst the extinctions of some others point to the probable presence of a species allied to oligoclase.

These very fine-grained mixtures of quartz and felspar (mainly albite) are a frequent product of the alteration of shales or slates by dolerites (diabase), and are fully described by authorities writing

[1] A part is present as ferrous oxide—hence excess in the analysis.

on such alterations in the Harz and elsewhere. They are also seen at other parts of the Whin Sill contacts, besides the locality with which we are now dealing. They are known as *adinoles*, and will be so spoken of in what follows. A large part of the typical adinoles shows the mixture of quartz and felspar in a quite unresolvable, cryptocrystalline condition, and its true nature, apart from chemical evidence, can only be ascertained through the circumstance that nearly all occurrences of it open up here and there, in perfect continuity, into patches of so much coarser grain that the components can be clearly made out.

It is usual to designate as adinole more specially the contact-rock close to the intruded igneous mass, and to associate with the name also an increased percentage of silica, which it can be shown in many cases to possess. But there are many reasons, upon which I need not enter here, why these restrictions should not be placed upon the name, and in favour of the rationality, in adopting the term, of applying it to all the alteration-products of shales, slates, etc., by basic intrusions, in which a fine-grained mixture of quartz and plagioclase has resulted.

As regards the nodules, they vary mineralogically in every degree of *quantitative* composition, but seem to be all due to the different degrees of the same processes indicated above. Many of them show nothing beyond an aggregation of pigment, and a quite narrow ring of material differing from the rock outside and inside their areas. These occur in parts of the rock which are not so much affected by re-solution of materials. The quartz-grains are very little attacked in these cases, and are the same inside as outside the ring. Such nodules are really to be described as mere shells of a special alteration-product, enclosing areas of the less altered or differently affected material among which they have been formed. In other nodules, again, the shell widens and can be better studied, and it is seen that instead of fields of isotropic matter with sheaves and spherulites of felspar and quartz, we often have the adinole-material varying from cryptocrystalline to microcrystalline. In such bands the clastic quartz is in all stages of disappearance. Sometimes it is quite gone, but more usually corroded grains may still be seen, the final stage being that only small blebs and speckles of it remain to show where the larger grains once were. Where the shell is of any considerable width it is very often distinctly banded in concentric layers of more or less varying colour, and it frequently varies also in the degree of crystalline development in these layers. There are also frequently concentric cracks in these shells, which appear to indicate some strain during final cooling of the rock, or more probably during the final consolidation and crystallization of the material forming the shells.

These shells of more considerable width still surround and enclose, in most cases, a kernel of the altered rock, similar to what exists outside, but there are also cases in which the entire nodule consists of this adinole material, and we have then approximately spherical bodies of more or less banded substance, yellow to brownish in colour, with no remains of the quartz-grains of the rock except the little residual blebs and grains, and streaks.

Where such largely or fully-developed nodules of adinole are seen we have also a formation of the same material in the main mass of the rock, among the clastic quartz-grains; but the action in these nodules has always been, as it were, intensified. We do not see in the main mass any such areas of complete dissolving of the quartz, and complete development of adinole, comparable to those of some of the large nodules.

It may be mentioned that in addition to this exposure at Falcon Clints, there is another occurrence of nodules known in the contacts of the Whin Sill. It is seen exposed at Rowntree Beck, and is here again in a bed of altered shale, 24 feet below the junction. They are of larger size than those described, having longest diameters of as much as 2 inches, and are more flattened in shape. One such large nodule, studied in thin sections, shows that the outer portion is again composed mainly of adinole, while the inner part is a mosaic of quartz, perfectly "regenerated," the grains interlocking and containing abundance of the enclosures of little rounded fused-looking globules, so characteristic in typical contact-mosaics. Dispersed through the nodule is a large amount of anthrophyllite, and there is also a good deal of chlorite (delessite) which has resulted from its decomposition.

These large nodules differ in some respects of detail from the former examples; but there can be no doubt that they owe their formation to the same processes and respresent the drawing together and concentric deposition of a substance formed in the shale during contact-metamorphism, the action of the substance having been also intensified and more highly developed owing to such concentration.

In my former paper on contact-action, I spoke of a material which can be seen in among the minerals of some altered slates at granite-contacts. In its most typical form of occurrence it shows a characteristic granular structure in ordinary light, and with crossed nicols it shows either a minutely speckly polarization, or stages of the development of this into white mica and other minerals. I pointed out that this material is perfectly *new*, bearing no relationship to anything which existed in the unaltered slates or shales, and that its appearance is so very characteristic that once remarked and studied it can never be overlooked. My suggestion was that this material also represents in these rocks the residues of the dense solutions, or aqueous fusions, of some of the constituents, such solutions having acted as solvents and transformers of other components not originally dissolved.

This substance, with all its appearances and characteristics as described, is more or less present in many of the altered shales near the Whin Sill. It is seen in varying amount in the rock I have been describing, though here its development is not very pronounced, the isotropic matter being in much greater abundance. It always bears the same relationship to the other minerals as it does at granite-contacts.

Since writing the former paper I have examined specimens of it on a much better scale than any I had then seen. Thus there are occurrences of shale at contact with, or enclosed in the Whin Sill mass, which have been left altered mainly, and in one case almost wholly, to this condition. One such rock gives sections which are made up entirely of a ground-mass of this fine speckly material, not far removed from an isotropic condition, with a good amount of white mica and a little dark mica crystallizing out of it in radial bunches and fan-shaped aggregates. Not a vestige of anything of the original shale has remained, except the ever present zircons and the abundant re-crystallized rutiles. This has been a shale rather unusually rich in alkalies (over 7 per cent.), and very free from quartz. It has been extra amenable to solution-action, and it is not possible to study thin sections of it in its present condition and doubt that very nearly all its ingredients had passed into some sort of solution, and that the indefinite and amorphous product was not very far advanced in a process of re-crystallization when fall of temperature put a stop to further development.

It is assuredly a circumstance worthy of note, that in the contact-metamorphism of rocks of the same general nature (clays, shales, and slates) by intrusions of granite, and again by intrusions of dolerite, we can find one and the same characteristic substance appearing, and playing one and the same part in its relationship to the formation of certain minerals, this substance being an absolutely *new* product never seen in the original rocks, nor seen, so far as I am aware, in anything but this particular class of contact-rocks.

Finally, to return to the special bed of rock at Falcon Clints, we may look again at the analysis. It is not intended here to enter into any detailed consideration of the interesting chemical questions involved in the alteration of shales, etc., by *basic* rocks, which questions will be more fully gone into at some future time. I may, however, briefly allude to the point as to the increase of soda in such altered rocks. That such increase has frequently taken place is quite beyond question, as I pointed out in my former paper, unless we wish to absolutely reject much very excellent evidence.[1] Many of the altered shales of the Whin Sill contact will also bear testimony to the same effect. It is not possible in this case to compare analyses of any given stratum of the rock at successive stages of approach to the actual contact, because the Whin Sill is intruded parallel to the strike, and the thickness of any

[1] High authorities, in reviewing all the evidence, have had to come to the conclusion that such transfer takes place at basic contacts; as, for example, Zirkel in his detailed consideration of the contact-effects of diabases (Petrographie, vol. ii. 1894), and also Roth (Chemische Geologie, vol. iii. 1893). No geologist has made such a special study of the chemical side of petrology as Roth, and a great amount of the evidence on this particular question is collected and summarized in the volume named. In reviewing this evidence Roth says that, according to it, "there is a decided contrast between the contact-effects of granite, syenite, etc., and those of diabase: in the former case no introduction of material into the altered slates and no chemical differences due to distance from the eruptive rock; whereas in contact with diabase we have introduction of silica and soda into the altered slate, and at the same time chemical difference according to distance from the eruptive rock."

given bed affected is not sufficient to allow of comparisons. Thus, the bed we have specially considered is eight feet thick. Its alteration is as intense at the bottom as it is at the top, and chemical tests also show that no differences occur on which stress could be laid in this connection. And so with the other beds affected. But we know that clays and shales in the Carboniferous beds invariably contain much more potash than soda, say from three to four times as much. This is fully borne out also among the rocks at the Whin Sill. Some of the shales of which I have made analyses show that no chemical change has taken place in them, and in such cases the potash and soda are in the normal proportions,—as near as may be, for instance, as in the analyses published by me of clays from the Coal-measures.

When in these beds we find altered shales or clays with more soda than potash, or even with an approach to equality in these bases, we are quite safe in concluding that this striking alteration in the normal proportions is due to the intruded soda-bearing rock in some way. This is the case with the rock we are now considering; the soda is considerably in excess of the potash. As to how the transfer has taken place in these cases, there seem to be three possible causes to be considered. It may have taken place at the time of the intrusion, by actual passage of igneous magma; it may have been effected after intrusion, and during the subsequent heating and cooling of the sedimentary rocks, by the passage of hot aqueous or vaporous compounds, or both; or, it may be brought about after complete cooling, and long after all "contact-action," by the percolation of water from the igneous rock during weathering.

The first of these conditions may apply, to a limited extent, close to contact. It certainly does not apply to the bed now in question, which is 75 feet from contact, and separated from it by several other alternating beds of shale, limestone, and sandstone. The third condition may frequently apply to a small extent and sometimes to a considerable one. But, in the present special instance (and in others in the same district), microscopic study of the rock precludes the supposition that subsequent percolation has deposited soda-compounds in it. When we have a specimen consisting of a hard, compact, felsite-like mass, which the microscope shows to consist of a mosaic of quartz and felspar, we cannot readily understand how the original rock could be removed, and this deposited, by percolation. And still less can we do so when we have a rock consisting of quartz, felspar, isotropic matter and white mica. It would be different if it were more or less cracked and rotten, and showed zeolites in it, but of this there is no trace.

We must deal with the fact that transfer *does* take place, in spite of the many difficulties in the way of understanding exactly how it is effected; such difficulties as arise when we have to note that in one given section of beds there will be cases in which evidence of transfer is wanting, though beds further from the contact are strong in such evidence. Such difficulties are, at any rate, not greater than, and are indeed analogous to, others which we have to face in considering some undoubted facts as to contact-metamorphism in general.

So far as concerns the particular case in point, and the conclusions we may draw from it, the question is not in any way affected by the manner of transfer of the soda, nor even by the possible denial of any such transfer at all.

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

REVIEWS.

I.—Reported Discovery of an Animal intermediate between Man and the Anthropoid Apes.

Pithecanthropus erectus. Eine menschenæhnliche Uebergangsform aus Java. By Eug. Dubois. 4to. pp. 1–39, with two Plates. (Batavia, 1894.)

REPORTS of the discovery of the remains of animals intermediate between Man and the Anthropoid Apes are always to be received with scepticism, since the resemblances between the skeletons of the higher Primates are so considerable that abnormalities, due to disease and other causes, are liable to be regarded as evidence of the existence of intermediate forms. There can be little doubt that this is what has happened in the present instance, portions of an abnormal human skeleton having been made the types of a new genus and species, *Pithecanthropus erectus*, for the reception of which a new family, the Pithecanthropidæ, has been established. The name *Pithecanthropus* was originally employed by Haeckel to denote a hypothetical animal forming a connecting link between man and the higher apes, and it is in this light that the creature, to which the name is now applied, is regarded, where they were found associated with extinct mammalia.

The remains upon which such important conclusions have been based consist of the upper portion of the cranium, a tooth (m. 3), and a left femur, all of which were found near the village of Trinil, on the Bengawan River, Java, and are considered to have belonged to a single individual. The rock from which these bones were obtained is a volcanic ash, a deposit which in a country like Java, subject to frequent volcanic eruptions, must often enclose the remains of men and animals that have been overwhelmed. A somewhat similar case of the discovery of human remains in volcanic rock is recorded by Scrope in his work on the volcanoes of Central France, two skeletons having been dug out of a bed of "tuff" near Le Puy, in the Auvergne district.

The skull, of which the upper and hinder portions are preserved, is dolichocephalic, and measures 18·5 cm. in length. All the sutures are closed, and there are no bony crests for the insertion of muscles. The photographs show that the whole surface is covered with pits and rugosities which might be the result of weathering and *post-mortem* injuries, but have much the appearance of a diseased condition. The cubic contents of the brain-case are estimated to have been approximately 1000 cubic centimetres, so that in this respect the fossil would appear to come about midway between the skulls of Man and the Gorilla. This calculation is to a large extent conjectural, since the whole of the lower portion of the brain-case is wanting.

The tooth, which is a third upper molar, is considered by the author to indicate that the jaws, though having to some extent been reduced, were of the type found in the Gibbons and Chimpanzee, but the evidence is quite insufficient to support such conclusions. This specimen is almost certainly human, the last upper molar in man being a somewhat variable structure.

The femur is without doubt human, since it agrees both in size and in all important structural characters with that of a man of medium height. It is not quite normal, but has on the inner side of the shaft near the upper end a considerable irregular outgrowth of bone, which may be, as the author suggests, the result of a wound, or of some pathological condition. The photograph shows that the whole surface of the femur is rough, but, as in the case of the skull, this may be the result of *post-mortem* changes.

That the remains described are those of a man suffering from disease which caused the sutures of the skull to close prematurely, giving rise to a microcephalous condition, and led to the irregular outgrowths of bone on the femur, is almost certain, and at any rate is an explanation of the facts that must be disposed of before the author's conclusions can be accepted. C. W. A.

II.—Memoir of Sir Andrew Crombie Ramsay. By Sir Archibald Geikie, F.R.S., Director-General of the Geological Survey of Great Britain. 8vo. pp. xi. and 397, with 13 Portraits. (London: Macmillan and Co. Price, 12*s.* 6*d.* net.)

THOSE who have read the Lives of Edward Forbes and of Murchison will have looked forward with keen interest to the appearance of this volume, written as it is by one so deft in the art of biography. Although nigh half an ordinary life-time has passed since the first of these Memoirs was published, our author comes again before us with the same enthusiasm in his work, with the same sympathy for his hero; and fitting together his materials in the same masterly way, he has given us an admirable portraiture of Ramsay and of many of his associates. Leaving that genial geologist to tell his own personal experiences the author has enriched the pages with picturesque descriptions, with explanatory notes, and not a few touches of humour.

Ramsay was best known to the scientific public through his long connection with the Geological Survey, and as Professor of Geology at University College, London, and afterwards at the School of Mines. A master in the broader questions of stratigraphy and physical geology he was a clear exponent of facts, while his original and often bold theories, expressed both in lectures and in writings, stirred others with enthusiasm and undoubtedly exercised great influence on the progress of geology. Moreover, his lectures to working men formed the nucleus of his famous introduction to geology, "The Physical Geology and Geography of Great Britain."

His early interest in geology, when engaged in business in Glasgow, led Ramsay to undertake an original survey of the Isle of Arran. This work brought him under the favourable notice of Murchison, and led to his receiving an appointment on the newly-established Geological Survey under De la Beche. For forty years he took an active part in the work and administration of the Survey, first as Assistant Geologist, then as Local Director for Great Britain, later on as Director for England and Wales, and finally as Director General for the United Kingdom.

The story of his life is thus in its main incidents a history of the Geological Survey with some record of its progress. Opportunity is also taken by his biographer to relate many interesting facts about the Museum of Practical Geology and the School of Mines, which owed their existence to the energy of De la Beche.

So far as regards the progress of the Geological Survey the volume deals mainly with Ramsay's work and that of his colleagues in Wales. He joined the staff in 1841 in Pembrokeshire, when he was twenty-seven years of age. There the freedom of the life, the active outdoor work, and its boundless interest, combined to render most enjoyable the change from a Glasgow counting-house; and for a long while, "Day after day, as he went out with map and hammer, it seemed to him still holiday work."

The life of a field-geologist is often contemplated with a feeling akin to envy by enthusiasts who, tied to business, are able to give but a few weeks each year to outdoor geological work. They picture the sunny side of survey life, and a great portion of it is sunny. The geologist has, however, to carry on his work day after day, for weeks and months together. He may have a pleasant enough tramp in the morning across hill and dale to the tract he has to examine, but after scrambling about for some six or seven hours, he may have a weary march homewards laden with the stony spoils of the day. Again, in the teeth of an east wind, or when any other wind blows strongly, the time of the geologist is not so happily spent as it might be in a tranquil atmosphere. Sir Archibald Geikie gives an interesting sketch of "Life in the Survey," and remarks that "the mere physical endurance which it often requires is enough to tax the strength of a strong man." Moreover, as he justly adds, "The isolation and loneliness at stations where no congenial society of any kind is to be found, the necessity of frequently moving camp to begin all the domestic experiences and discomforts over again, and the poor pay for which all this drudgery has to be undergone, these and other hardships which may be easily imagined test the scientific enthusiasm of a geologist."

Pleasant it is to know that two of Ramsay's early associates on the Survey are still living—Aveline, who joined the staff in 1840, a year before him, and Selwyn, who was appointed in 1845.

Portraits are given of them, as well as of De la Beche, Logan, Bristow, Gibbs (fossil-collector), Oldham, Smyth, Jukes, Forbes, Murchison, and Salter. The likeness of Ramsay, excellent as it is, represents him at the age of 68, when he had just retired from public life; the face has become somewhat saddened, and we must turn to the portrait given in the Life of Murchison for Ramsay in the prime—a handsome, vigorous man, cheery and buoyant in spirit.

For about ten years Ramsay toiled hard in the active work of the Survey, until the mapping of Wales was completed, and he continued to carry on a certain amount of personal surveying until 1854. His time, however, had become more and more occupied with the general direction and supervision of the work of his men, and he practically abandoned the task of mapping after having started the Survey in Scotland.

It is astonishing to consider how much field-work he accomplished in the period of fourteen years, for we learn from the list of his publications that he took part in the work of six whole sheets, and of thirty-nine quarter-sheets of the map in England and Wales, and of one sheet in Scotland. Moreover, he was engaged in constructing a number of horizontal sections across various mountainous parts of the country, and the labour thus involved can scarcely be realized nowadays when contoured maps enable the geologist to plot each section without difficulty. No doubt the field-work was carried on far more briskly in those early days of the Survey than would be possible or right at the present time. More numerous subdivisions in the rocks are now required, and the boundaries can be traced far more accurately than was possible on the old one-inch maps. Those who now start with the maps of the present day, with the help too of the advanced methods of research in petrology and palæontology, may find plenty to do in regions surveyed long ago. They do not, however, have to start with a plain ordnance map, and in a district where the only geological guides were the sketch maps of William Smith, or the small maps of particular areas published in the Transactions of the Geological Society.

The junctions between the great formations had to be determined, and their particular boundary-lines traced across an almost unknown country, in some areas complicated by faults and disturbances and by various eruptive rocks. It was a glorious time for those who were keenly interested in such work: and none more so than Ramsay and his associates in Wales—Aveline, Selwyn, and Jukes.

In the "Letters" of J. Beete Jukes we were favoured with many glimpses of life on the Geological Survey; of the arduous work and the determination of the men, and of the pleasant hours of relaxation after the work of the day was done. So also in the memoir of Ramsay, we read of the interesting coach journeys, the sojourns at quiet country inns, and the occasional merry meetings of the surveyors and of Salter, the palæontologist.

On one occasion Ramsay relates that he "went out with Smyth, Jukes, Selwyn, Gibbs, and the dogs, to look at Jukes's ash-beds. We had a goodish day's work on bits of detail. Jukes should have showed me something larger, but detail seems his forte. He is ever in doubt, even when nearly convinced, about little things, and yet grasps the subject so well notwithstanding, that he produces better work and understands it better than any man on the Survey."

"Next day one of the canine companions of the party, 'Jukes's dog Governor, amused himself by slaying a sheep, which cost his master 7*s.* 6*d.*'"

Ramsay himself, as will be gathered from the foregoing remarks, was somewhat impatient of detail, preferring to deal with broad generalizations. When in the field overlooking the work of his men, he cared not to engross his mind too continuously with geological facts, and his conversation was illumined by his passionate love of poetry and of literature in general. Even Murchison, when in the field with him, was apt "to talk far too much geology." In later years Ramsay appeared to manifest perhaps too little sympathy with the careful, but often very minute work, brought before the Geological Society of London; but revisiting Wales, he writes from Portmadoc (1874): "I am busy revising a deal of country and realizing all the discoveries that have turned up since Selwyn and I were here more than twenty-five years ago."

Changes there must be in methods of work and in the interpretation of phenomena as knowledge increases; changes also come about in our social proceedings. Those who attend the Anniversary Meeting of the Society and the dinner afterwards, will hardly do as Ramsay did in 1848. He says: "We broke up about eleven, and in the long-run Smyth, Reeks, Bristow, and I had some supper. Got home at half-past three."

Of the scientific work achieved by Ramsay we have a good summary in the concluding chapter of this volume: a fitting termination to the record of his career, of his travels abroad as well as in this country, of his eager study of glacial phenomena, and of his bold theory of the origin of certain lake-basins. To learn the history of these and other matters the student will gladly take up this Memoir by Sir Archibald Geikie; and whether or not he has had the privilege of personal acquaintance with Ramsay, the student or the general reader interested in the progress of science, will welcome this memoir of a genial and gifted Geologist.

III.—The Physical Geology and Geography of Great Britain: A Manual of British Geology. By the late Sir Andrew C. Ramsay, LL.D., F.R.S., etc., Director-General of the Geological Survey of the United Kingdom. Sixth Edition. Edited by Horace B. Woodward, F.G.S., of the Geological Survey. 8vo. pp 421, illustrated with a Geological Map printed in colours and 137 woodcuts. (London: Edward Stanford, 1894.) Price 10*s.* 6*d.*

It is now sixteen years since the fifth edition of Sir Andrew Ramsay's Geology appeared (see Geol. Mag., 1879, p. 277), having gone through five editions in ten years. The last edition was issued three years before its author retired from the post of Director-General, after which time his literary labours ceased.

The new edition has by careful excisions been reduced from 639 to 422 pages, so as to approach more nearly to the convenient size of the earlier editions of the work. The stratigraphical portion has been reduced by about 61 pages; the Glacial chapters by about 38 pages; the other reductions come under the head of Historical Geology, the Races of Man, etc.

Mr. Horace Woodward, the editor, has bestowed great pains and labour on the new edition; and both the stratigraphical and the palæontological parts have been carefully revised, and the names of fossils corrected.[1] He has very properly kept intact the author's views on Subaerial Denudation, which Ramsay was the first to teach and illustrate.

The strict subdivisions of the subject-matter in each chapter have been more strictly adhered to than in the earlier edition, and without altering the author's style the book has been brought up to date as far as possible.

This manual will still be valued as the work of one of the most able and thoughtful geologists of our time, whose broad views on the stratigraphy and on the physical features of this country due to the structure and character of the rocks composing it, and how they have been affected by denudation, will always be read with pleasure and profit by all students. The book is also provided with an excellent index.

IV.—A Dictionary of Birds. By Alfred Newton, Assisted by Hans Gadow, with Contributions from R. Lydekker, C. S. Roy, and R. W. Schufeldt. In 4 Parts (3 issued). 8vo. pp. 832, numerous Figures in the Text, and 1 Map. (London: Adam and Charles Black, 1893–4.)

The Third Part of this very useful Dictionary has just been issued, after a rather long interval, and it is to be hoped that the concluding part will soon follow.

Books in dictionary form are extremely handy for reference and commend themselves to everyone, especially if they are as well executed as is the book now under our notice, and there is no doubt that this dictionary will be very serviceable not only to ornithologists but also to all students of Natural History.

A great deal more is contained in these volumes than the title might lead one to expect, for we find in addition to the excellent accounts of birds given under their scientific and popular names, numerous articles dealing with the anatomy, with the habits, distribution, and past and present history of birds. It is in fact a text-book of Ornithology arranged in dictionary form.

Interesting as all these articles are, still some of those already published have a greater claim to the geologist's notice than others; especially those dealing with fossil birds, with the extermination,

[1] One name, *Chara medicaginula*, is, however, still spelt (on p. 203) *Chara medicagulina*.

migration, and geographical distribution of recent birds, and we will hope for a good account of the skeleton in the concluding part.

The special portions devoted to the different groups of fossil birds are contributed by R. Lydekker, and some of these form small but complete monographs of the groups described; but it is a little difficult to comprehend why certain extinct birds were picked out for special description, while a large number of others were lumped together in a general article on fossil birds; thus we find excellent articles on the Moas and the Odontornithes, but *Archæopteryx* and *Æpyornis* are only briefly described under the general title of fossil birds, and the latter is not even mentioned in the alphabetical list. These unaccountable distinctions rather destroy the utility of the book, so far as the general student is concerned.

We see now that the hallux is considered to be present in most if not in all the Moas. Formerly, according to Lydekker (Manual of Palæontology, vol. ii. p. 1226, 1889), it was considered to be present only in the Palapterygidæ and to be absent in the true Dinornithidæ.

The anatomical articles by Dr. Gadow ought to be very useful, and their presence shows that ornithologists now recognize the fact that a bird consists of other structures besides feathers, beak, and claws. That this is thoroughly realized by the highest avian authorities is well seen in the article on the Flycatchers, p. 273, where Prof. Newton, referring to the *Muscarpidæ*, says, "every ornithologist must own that its precise definition is at present almost impossible and must await that truer knowledge which comes of investigating structural characters more deeply seated than any afforded by the epidermis."

The third part (Moa—She), just issued, fully maintains the standard of the earlier parts, and contains many interesting articles, two dealing with fossil birds, viz. Moa and Odontornithes, one on the Moorhen, including an account of *Notornis*, with an excellent figure of the head of that nearly extinct bird; then there are full accounts of the moult, of the muscular, nervous, and reproductive systems; on nidification, and of course short accounts of numerous birds, among which we may notice those on the Ostrich and Rhea, the rapidly disappearing parrot, *Nestor*; of that singular group of birds the Nightjars, with an interesting figure taken from life of the curious form of the pennant-winged Nightjar, showing the way in which this bird carries its enormously enlarged second primary wing-feathers. There is also a good account of the Sandgrouse, whose peculiar irruptions into England have caused so much interest of late years.

The illustrations are very variable and hardly numerous enough. Why should such a little known bird as the Quezal, however beautiful, want an entire page for its portrait, when so many others are unillustrated? Many of the figures are extremely good, especially those of the King-penguin, the Secretary bird, and the Seriema of doubtful systematic position. But for the most part we have to be content with beaks and portions of birds' heads from Swainson.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—January 9th, 1895.—Dr. Henry Woodward, F.R.S., President, in the Chair. The following communications were read:—

1. "The Formation of Oolite." By E. B. Wethered, Esq., F.G.S.

In previous communications the author has described pisolites formed by the growth of *Girvanella*, and some true oolitic granules having a like origin. He has long entertained the opinion that all oolitic granules are of organic origin, but has not, up till now, been in a position to prove this.

He describes the form of the granules, which frequently exhibit a series of concentric layers of calcium carbonate around a nucleus, and also dark striæ and patches, the former placed more or less at right angles to the nucleus. The concentric layers often exhibit an irregularity which the author maintains to be incompatible with their chemical origin, and he considers that each layer represents tubular forms of growth. Again, granules are found made of calcium carbonate occurring in two forms—a vitreous portion representing the organic structural part, and an amorphous portion consisting of ordinary carbonate of lime, which is either infilling or secreted material, possibly both.

In discussing the origin of the crusts around the nuclei, the author treats of the radial structure which is so marked a feature in the crust of oolitic granules. This structure has the appearance of light and dark striæ when seen by reflected light: the light are tubules which have grown at right angles to the nucleus, whilst the dark are secondary formations.

He refers to Rothpletz's description of the oolitic granules of the Great Salt Lake, which are stated to have originated from the growth of lime-secreting algæ, and thinks it possible that the fossil forms are of like origin, though not necessarily due to organisms allied to algæ, and possibly even lower in the scale of life; *Girvanella* was the first type of oolite-forming organism discovered, and it is simply a tubule.

2. "On the Lias Ironstone around Banbury." By Edwin A. Walford, Esq., F.G.S.

The ferruginous limestone of the Middle Lias of the Banbury district occurs practically within a ten-mile circle around Banbury. The stone (the Marlstone of the Geological Survey) is an "oolitic" cyprid-limestone with much molluscan and crinoidal débris and some quartz-grains. The author describes the lithological characters of the rock, and their variations, as traced laterally and vertically, giving a full description of its local development, with detailed account of the sections in the principal exposures. The marlstone of this area is dissimilar from that of Gloucestershire both in appearance and in fossil contents, the Gloucestershire stone being of earlier deposition and representing better the base of the Banbury series, rather than the stratum which is richest in iron. From the blue clays of the *margaritatus*-zone up to the rock-bed itself there is a slow change of conditions, and the fauna points to slow tranquil sublittoral conditions. The author reserves his views as to how the rock-bed obtained its ferruginous elements.

He gives a description of the palæontology and economic uses of the deposits, and appends analyses of various ironstones from the district, made by the aid of Sir B. Samuelson.

3. "Notes on the Geology and Mineral Resources of Anatolia (Asia Minor)." By W. F. Wilkinson, Esq., F.G.S.

The route traversed from northwards to southwards through the city of Broussa lay through a country composed of sedimentary rocks (largely limestones with some shales and conglomerates). In the mountains metamorphic rocks were met with, and also igneous rocks. The principal igneous rocks noticed are granites and serpentines; in the latter chrome-iron-ore occurs, and is worked.

II.—January 23rd, 1895.—Dr. Henry Woodward, F.R.S., President, in the Chair. The following communications were read:—

1. "Carrock Fell: a Study in the Variation of Igneous Rock-masses. Part II. The Carrock Fell Granophyre. Part III. The Grainsgill Greisen." By Alfred Harker, Esq., M.A., F.G.S.

The augite-granophyre of Carrock Fell is first described in its normal development, special attention being drawn to the various types of micrographic intergrowths which it exhibits. The variation of the rock is next examined, and, in particular, a curious basic modification which occurs near its junction with the gabbro described in a former paper. The granophyre here passes into a coarse type rich in augite, iron-ores, and apatite, its silica-percentage falling to as low as 58. The author attributes this to the acid magma having incorporated in itself portions of the highly basic margin of the gabbro. The latter rock seems to have been fused or dissolved by the magma, with the exception of certain of its more refractory minerals which survive in the modified marginal part of the granophyre.

The latter part of the paper deals with a remarkable quartz-mica-rock found on the north side of the Skiddaw granite. It differs in some respects from the Cornish greisens, and resembles in its mode of occurrence certain pegmatites in the Scottish Highlands. The author considers the rock to have been extruded from the granite in connection with the post-Silurian crust-movements of the district, while its composition has probably been further modified by subsequent chemical changes.

2. "The Geology of the Country around Fishguard (Pembrokeshire)." By F. R. Cowper Reed, Esq., B.A., F.G.S.

The tract of country forming the subject of this communication occupies the northern part of Pembrokeshire, from Newport to Strumble Head. All the beds are of Ordovician age, with the possible exception of those on Dinas Island, and have a general east-to-west strike with a high dip to the north. Arenig Slates occupy the southern part of the district. Typical Llanvirn Beds with the *Placoparia*-fauna occur at Fishguard, and above them the *Didymo-*

graptus Murchisoni-zone of the Lower Llandeilo is found. On this horizon are the first traces of volcanic activity: acid lavas and tuffs are here interbedded with the slates. The Middle Llandeilo is partly faulted out in Goodwick Bay, and near Newport is penetrated by huge intrusive sheets of diabase. The Upper Llandeilo is marked near its base by a thick zone of lava-flows, which are overlain by fossiliferous shales. Hartfell graptolites have been found in the overlying grey and black slates. The lavas and breccias on Strumble Head are held to be on the same horizon as those near Newport.

All the lavas are acid; some are soda-potash felsites. Nodular, banded, and perlitic structures are sometimes visible. Crypto-crystalline, microlitic, and micropoikilitic types of ground-mass are possessed by these lavas; the latter type is held to be probably a contact-phenomenon. The intrusive masses consist of diabase, with important tachylitic and variolitic modifications.

3. "On the Mean Radial Variation of the Globe." By J. Logan Lobley, Esq., F.G.S.

The author submits considerations (chiefly derived from the characters of the earlier sediments) which lead him to suppose that crust-folds have not been produced by continuous contraction of the Earth, and that the planetary heat and mean radius of the Earth have been practically invariable during the period which has elapsed since Cambrian times.

III.—February 6th, 1895.—Dr. Henry Woodward, F.R.S., President, in the Chair. The following communications were read:—

1. "On Bones of a Sauropodous Dinosaur from Madagascar." By R. Lydekker, Esq., B.A., F.R.S., V.P.G.S.

The bones described in the paper were collected by Mr. Last to the east of the town of Narunda, on the north-eastern coast of Madagascar. They include vertebræ, limb-bones, and portions of pectoral and pelvic girdles. These bones are described in detail, and the animal which possessed them is referred to the genus *Bothriospondylus*, Owen: a dorsal vertebra, described in the paper, being taken as the type of the new species.

The identification of the Malagasy reptile with a type occurring in the Jurassic rocks of England harmonizes with the reference of some of the strata of the island to the Jurassic period.

2. "On the Physical Conditions of the Mediterranean Basin which have resulted in a Community of some Species of Fresh-water Fishes in the Nile and the Jordan Waters." By Prof. E. Hull, M.A., LL.D., F.R.S., F.G.S.

The author summarizes the evidence in favour of the existence of barriers in post-Miocene times, separating the Mediterranean area into a chain of basins. He brings forward arguments in support of his contention that the waters of the eastern (Levantine) basin became fresh during a period when the area of evaporation was smaller, and the supply of river-water greater, than at present. Into this fresh-water lake the waters of the Nile would flow directly.

He has elsewhere given reasons for believing that the Jordan Valley from Lake Hulch to Arabah was the bed of a lake over 200 miles long, and at least 1300 feet above the present level of the Dead Sea. He suggests that the waters of this lake escaped into the Levantine basin through the plain of Esdraelon. With such physical conditions existing, the fauna of the Levantine basin would have a means of spreading throughout the whole system of waterways connected with it.

In conclusion the author adds some observations on the changes which occurred in the Mediterranean area subsequent to the post-Miocene epoch of earth-movement.

3. "On the Loess and other Superficial Deposits of Shantung (Northern China)." By S. B. J. Skertchly, Esq., and T. W. Kingsmill, Esq., C.E. (Communicated by Sir John Evans, K.C.B., F.R.S., F.G.S.)

The following deposits are described in the order of their antiquity:—

(1) Recent Fluviatile deposits.

(2) Marine sands with *Cardium*, *Ostræa*, and *Bulla*, extending to a height of 200 feet above sea-level, and indicating former submergence to that amount.

(3) Old River-gravels, often resting on loess, and possibly contemporaneous with the marine gravels. They furnish part of the evidence relied on by the authors for supposing the existence at that time of a climate moister than the present one.

(4) Loess.

(5) Basement-gravels having the same relation to the loess that the Upper Greensand bears to the Chalk.

The loess east of the Pamirs is extensively developed over an area of upwards of one million square miles. It is sometimes over 2000 feet thick, and occurs up to several thousand feet above sea-level.

Evidence is brought forward by the authors with the intention of establishing the absolute want of connection between the Chinese loess and the present river-systems, its original stratified condition (as shown by variation of tint and horizontality of layers of concretions), and its subsequent rearrangement to a great extent. The absence of marine shells is discussed, and the suggestion thrown out, with diffidence, that the shells have been destroyed by percolating water.

The authors give their reasons for supposing that the loess is a marine formation, and state that the sea need not have reached to a higher level than 600 feet above the present sea-level, for the Pamir region, where it occurs, 7000 feet above the sea, is an area of special uplift.

They maintain that there are no proofs of the glaciation of Northern and Eastern Asia, so that the Chinese loess can have no connection with an area of glaciation. They state that the zoological, ethnological, historical, and traditionary evidence alike point to the former depression of Asia beneath the sea, and the subsequent desiccation of the land, consequent upon re-elevation.

CORRESPONDENCE.

DR. CROLL'S THEORY OF THE ICE AGE.

Sir,—As Mr. Culverwell's articles in the Magazine and the review of Dr. James Geikie's new edition of "The Great Ice Age" have recalled attention to Dr. Croll's celebrated theory, it may be interesting to your readers to hear the opinion of the great astronomer Adams upon the question. In turning over some old letters only yesterday I came upon one dated 28th February, 1866, which I received from him on the subject, in which, after some remarks upon Herschel's art. 184, of which he says he is "not inclined to think there is much in it," he wrote: "I do not myself believe in the change of eccentricity of the earth's orbit being a cause of climatal changes on the earth. The effect, if any, would depend only on the *square* of the eccentricity; and this always remains so very small, that I believe the effect on the earth's mean temperature would be almost insensible. Depend upon it, geologists who look in this direction for the cause of Glacial epochs are entirely on the wrong tack. It seems to me much more likely that the actual act of emission of heat from the sun is variable, than that the change of eccentricity of the orbit should have any sensible effect."

If this be the case, Croll's theory is reduced to Adhémar's, who, in his Révolutions de la Mer, 2nd edition, 1860, published his view that Glacial epochs were caused by the mere alternate presentation of the north and south poles of the earth to the sun, owing to the precession of the axis; no reference being made by him to changes of eccentricity. It is remarkable that Croll did not know of Adhémar's work when he first published his theory. I had heard two friends talking about it at a meeting of the Geological Society, which led me to buy the book, and finding no allusion to Adhémar in Croll's papers, I drew his attention to it.

In what I have now written I do not wish it to be thought that I am expressing any opinion of my own upon the subject, but I think these matters of ancient history may prove of interest to your readers.

O. Fisher.

Harlston, Cambridge, *7th February*, 1895.

PROFESSOR HULL AND THE CAMBRIAN AGE OF THE CHARNWOOD CLASTICS.

Sir,—I do not think that Professor Hull's letter in last month's Geological Magazine will do much to convince students of the older rocks that the Charnwood clastics are of Cambrian age. He relies chiefly upon the authority of Sedgwick and Jukes. The views of these eminent men on matters coming within their knowledge would undoubtedly carry great weight with the younger generation; but it would be the height of rashness to suggest that they would have continued to adhere to their opinion had they lived to the present day. Since their time a new chapter of the geological record has been opened. In the Midland Counties large formations have been discovered that bear a much closer relation to the Charnwood rocks than do the Lower Cambrians of North Wales. Professor Hull states that the publication of these results has not led him to alter his opinion. But has he examined the new evidence? Has he studied the Uriconian slates and grits of Shropshire? Does he know the slaty rocks of the Herefordshire Beacon, near Malvern, which in 1880 I correlated with the Salopian pre-Cambrians? Professor Bonney and the Rev. E. Hill have demonstrated that the Charnwood clastics are of volcanic origin, and Mr. Allport has done the same for the Uriconian of Shropshire. Both in hand-specimens and in microscopic slides the rocks of Charnwood and of Shropshire evince the most marked similarity. The slates and grits of the Lower Cambrian of North Wales, on the other hand, are ordinary sediments. Macroscopically, they are somewhat like the Charnwood clastics; microscopically, they are widely different. As Sedgwick and Jukes did not study these rocks under the microscope, they were naturally unaware of this difference. Professor Hull has survived to a happier epoch, and he can judge for himself. He would also find it an interesting task to study the basal Cambrian strata that Professor Lapworth has discovered in Warwickshire, and the volcanic rocks that underlie them. After he has done so, he will find it hard to believe that the shales and quartzites of Nuneaton are the equivalents of the ash-beds and agglomerates of Charnwood. Why Professor Hull should go 90 miles off to correlate the Charnwood clastics with rocks which but superficially resemble them, when he can find formations that really do resemble them within half that distance, is a problem that I must leave the Professor himself to solve. C. CALLAWAY.

SANDORE, WELLINGTON, SALOP, *8th February*, 1895.

DESTRUCTION OF ECCLES CHURCH, ON THE NORFOLK COAST.

SIR,—An ancient landmark on the coast of Norfolk, one well known to readers of Lyell's "Principles of Geology," has been destroyed by the breakers during a severe storm, on January 23rd of this year. The old tower of Eccles church has for many years remained as a witness to the destruction of our shores. Since the Conquest, the greater part of the village of Eccles, between Happisburgh and Winterton, has been destroyed. The church itself was abandoned nearly three hundred years ago. In 1833, as noted by Samuel Woodward, its remains were still to be seen partially buried, as it were, within the "Marram Hills" or sand-dunes. In 1862 the hillocks of sand were drifted further inland, and the tower of the church was left standing on the foreshore, several yards below high water-mark, with the basement portion of the nave still showing in places amid the beach sand and shingle. Now the sea has beaten down the tower. It fell in a north-westerly direction in the very teeth of the gale, the sea breaking furiously against the edifice, and the spray at times going over its summit before the final catastrophe. Huge masses of masonry now lie about in strange confusion to mark the spot where once stood this famous church; but ere long probably every vestige of it will be obliterated.

Norwich.

A GLACIAL COMMITTEE FOR NORTH AMERICA AND EUROPE.

Sir,—The following are the names of members of the International Glacial Committee created at Zurich last summer. The list is to be completed by representatives of Russia and Italy.

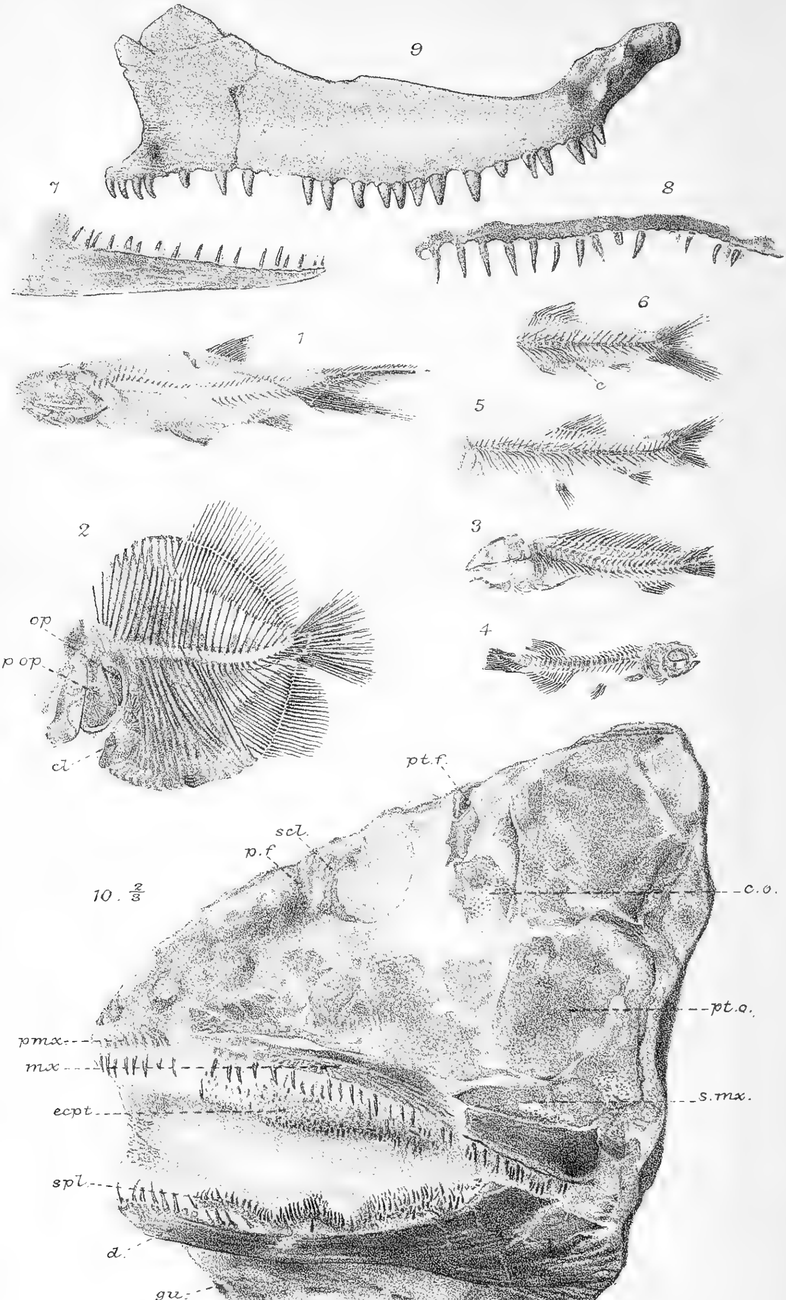
Countries.	Names.	Address.
United States, N. America	Prof. Dr. F. Reid	Baltimore.
Austria	Prof. Dr. Richter	Graz.
Germany	Prof. Finsterwalder	Munich.
France	Prince Roland Bonaparte	Paris.
Switzerland	Prof. F. A. Forel and Dr. Leon du Pasquier (as Secretary)..................	Morges.
Denmark	Dr. K. I. V. Steenstrup...	Copenhagen
Norway.........................	Dr. A. Ojen	Christiania
Sweden..........................	Dr. Svenonius.............	Stockholm
Great Britain	Capt. Marshall Hall	Easterton Lodge, Parkstone, Dorset.

The committee has powers to adopt its own organization, and is to report to the General Committee of the Congress, wnich was invited by the late Tsar to meet at St. Petersburg. Prof. Forel is the Organizing Secretary. Marshall Hall.

Easterton Lodge, Parkstone, Dorset.

Mr. Robert Etheridge, Jun., formerly of the Geological Department in the British Museum (Natural History), and who for the last few years has occupied the position of Palæontologist to the Museum and the Geological Survey of New South Wales, Sydney, was appointed on the 1st of January to the office of Curator of the Australian Museum, Sydney, N.S.W., in the place of Mr. E. P. Ramsay, F.L.S., F.G.S., who has retired, having been in failing health for some years. Mr. R. Etheridge, jun., has distinguished himself both in this country and in Australia by his scientific researches, and has just been awarded the Clarke Medal from the Royal Society of New South Wales for his contributions to Australian geology.

With deep regret we have to record the death of Mr. J. W. Hulke, F.R.S., Foreign Secretary of the Geological Society of London, which took place on February 19th, after a brief illness. In addition to his great scientific abilities, and his distinguished position as a surgeon, he had endeared himself to a wide circle of friends by his amiable personal qualities. We hope to give a suitable notice of his scientific work in the April Number.



G. M. Woodward del. et lith. West, Newman imp.

1–9. Purbeckian Fishes.
10. Osteorachis macrocephalus.

THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE IV. VOL. II.

No. IV.—APRIL, 1895.

ORIGINAL ARTICLES.

I.—A Contribution to Knowledge of the Fossil Fish Fauna of the English Purbeck Beds.

By Arthur Smith Woodward, F.L.S., F.G.S.,
Of the British Museum (Natural History).

(PLATE VII. Figs. 1–9.)

1. The Purbeckian Fishes of the Vale of Wardour, Wiltshire.

SINCE the publication of the notes on some new fishes from the English Purbeck and Wealden Beds five years ago,[1] the Rev. W. R. Andrews, of Teffont, has kindly entrusted to the writer for examination a fine series of Purbeckian fishes from the Vale of Wardour. All the members of this fauna are remarkably diminutive, compared with those met with in the corresponding formation in Dorsetshire; but nearly all the species are well preserved, and some are sufficiently novel to be worthy of detailed description. The Pycnodont genus *Mesodon*, which was first described from the English Purbeck in the paper already cited, is here represented by one or two more forms; the Lepidosteoid *Macrosemius* is now first definitely recorded as a British fossil; additional examples of *Pleuropholis* extend previous information of that genus; new specimens of *Leptolepis Brodiei* add to the known specific characters of this fish; and the opportunity is now afforded for publishing a figure of the small Palæoniscid, *Coccolepis Andrewsi*.[2]

Coccolepis Andrewsi, A. S. Woodward. Plate VII. Fig 1.

1891. *Coccolepis Andrewsi*, A. S. Woodward (*ex* R. H. Traquair, MS.), Catal. Foss. Fishes, Brit. Mus. pt. ii. p. 254.

A small species attaining a length of about 0·06 m.; maximum depth of trunk contained at least six times in the total length; upper caudal lobe excessively elongated and slender. Fin-rays with distant articulations. Dorsal fin arising slightly in advance of the middle point of the back, opposed to the hinder portion of the pelvic fins, as deep as long, and its maximum depth not exceeding that of the trunk at its point of origin; anal fin scarcely deeper than long, about two-thirds

[1] A. S. Woodward, "On some New Fishes from the English Wealden and Purbeck Beds referable to the genera *Oligopleurus*, *Strobilodus*, and *Mesodon*," Proc. Zool. Soc. 1890, pp. 346–353, pls. xxviii., xxix.

[2] For a valuable account of the stratigraphy of the formations in which these fishes occur, see W. R. Andrews and A. J. Jukes-Browne, "The Purbeck Beds of the Vale of Wardour," Quart. Journ. Geol. Soc. vol. l. (1894), pp. 44–69.

as long as the dorsal, arising completely behind the latter and situated close to the caudal fin. Scales very coarsely granulated; fulcra of upper caudal lobe slender, much elongated, and very numerous.

The above diagnosis, published in 1891, was based on a nearly complete fish, presented by the Rev. W. R. Andrews to the Museum of Practical Geology. The specimen itself, however, has not hitherto been described and figured, and the writer is now indebted to Mr. E. T. Newton, F.R.S., for the privilege of again referring to it in the present contribution. The specimen is partly preserved in counterpart, and the best side is shown of the natural size in Pl. VII. Fig 1.

Axial Skeleton.—The head appears to be typically Palæoniscid, though too imperfect for description; the only noteworthy features are a few slender conical teeth in the mandible, and traces of delicate broad branchiostegal rays below. The axial skeleton of the trunk is well exhibited through the thin squamation, and appears as already described in *C. liassica* from the Lias of Lyme Regis.[1] The neural and hæmal arches are at least superficially ossified, and preserved throughout the length of the fish. Their total number to the origin of the caudal fin is approximately thirty-eight, and of these about sixteen may be reckoned as caudal. There are no ribs, the hæmal arches in the abdominal region being merely a series of diminutive cartilages, best seen in the counterpart of the fossil here figured. The neural spines in the abdominal region are stout and relatively large, not fused with their supporting arches; but both these and the hæmal spines are firmly fixed to their arches in the tail. At the base of the caudal fin the hæmals are enlarged for the direct support of the dermal rays; and a series of very small, though stout, hæmals is continued for some distance along the lower margin of the upper caudal lobe. The neural arches at the base of the tail are apparently aborted, and there is a series of distinct supporting ossicles beneath the fulcra of the upper caudal lobe. There is no trace of ossifications referable to the notochordal sheath.

Appendicular Skeleton.—All the fins except the pectorals are well preserved. Ordinary fulcra are absent; but at the origin of each fin there are three or four short, unjointed rays gradually increasing in length to its highest point, where the normal rays begin, with distant articulations and (in the caudal fin at least) with distal bifurcation. The pelvic fin is about as long as deep, arising midway between the pectoral arch and the anal; its rays are shown to be not less than twenty in number, but the supports are unfortunately not observable. The dorsal fin, arising opposite the hindermost portion of the pelvic pair, has about sixteen articulated rays; and a more imperfect specimen presented by Mr. Andrews to the British Museum (No. P. 6302) seems to exhibit five endoskeletal supports for the six foremost articulated rays. The anal fin is somewhat smaller than the dorsal, but its number of rays appears to be the same; and the series of supports, well preserved in the British Museum fossil, comprises fourteen for the whole fin, while the foremost of these basals is much the longest.

[1] A. S. Woodward, "Notes on some Ganoid Fishes from the English Lower Lias," Ann. Mag. Nat. Hist. [6] vol. v. (1890), p. 433.

The caudal fin is crushed in the type specimen and imperfect in the other, so that the inequality or equality of the lobes cannot be determined.

Squamation.—The whole of the trunk is covered with small, thin scales, which have the appearance of overlapping; but they are too obscure for detailed description. A few large tubercles of ganoine are distinctly observable on the flank of the abdominal region.

Horizon and Locality.—Lower Purbeck: Teffont.

Mesodon macropterus, Ag., var. *parvus*, nov. Plate VII. Fig. 2.

The type specimen of this variety is nearly complete, wanting only the anterior portion of the head. It is shown of the natural size in Pl. VII. Fig. 2, and is sufficiently well preserved to enable the principal characters of the trunk and fins to be ascertained. The dorsal contour is much arched, though rounded, and the maximum depth of the trunk in advance of the origin of the dorsal fin equals its total length, measured from the hinder border of the operculum to the extremity of the caudal fin. The head with opercular apparatus, when complete, would probably occupy not less than one-quarter of the total length.

Head and Opercular Apparatus.—Of the head, only fragments of the hinder cranial roof-bones remain above, while an indecipherable impression of the hyomandibular and its connections appears behind. The preoperculum (*p.op.*)[1] as usual is the largest ossification in the opercular fold, this being triangular in shape, with the apex directed upwards. The bone is twice as deep as its maximum breadth, and is marked only by radiating lines. The operculum (*op.*) is relatively small and narrow, tapering to a point below, and about two-thirds as deep as the preoperculum. It seems to have been smooth externally, being crossed only by one small oblique ridge.

Axial Skeleton of Trunk.—The notochord must have been persistent as indicated by the vacant space, and there are no ossifications in the sheath. The bases of the neural and hæmal arches, though robust, are not much expanded. The neural and hæmal spines are all fused with their supporting arches and, except in the caudal pedicle, are observed to be long and slender, bearing the ordinary median laminar expansion in front; the hæmals at the base of the caudal fin, to the number of about ten, are relatively robust and expanded distally for the support of the rays. The total number of arches, excluding the latter, is about thirty.

Appendicular Skeleton.—Of the pectoral arch, the clavicle (*cl.*) only is exposed in position behind the opercular bones. It is seen to be expanded below and tapering above, with remains of the pectoral fin posteriorly at a considerable distance above its inferior extremity. The basal lobe of the pectoral fin exhibits seven of its supporting cartilages radiating from its short attachment. Traces of very feebly developed pelvic fins occur at a point much nearer to the origin of the anal fin than to the pectoral arch: they consist of delicate, distally

[1] The bone here named "preoperculum" has hitherto been named operculum, while the "operculum" has always been described as supraclavicle. The writer will shortly publish proof of the accuracy of this amended interpretation.

bifurcating rays, but nothing can be discerned as to their supporting elements. The dorsal fin arises about the middle point of the trunk, though not quite at the summit of the dorsal convexity: it is imperfect in front and at the distal border, but comprises about thirty-five well-spaced delicate rays. The anal fin is similar, but much shorter, comprising not more than twenty-six rays. The caudal fin is stouter than the other median fins, and its rays, to the number of about eighteen, are produced into more prominent bifurcations distally.

Squamation.—Remains of thick scales, of the usual form, occur over the anterior half of the fish, with prominent ridge-scales (about fourteen in number dorsally), and extending as far as a line joining the origin of the dorsal and anal fins. No superficial tubercular ornament can be observed, but this circumstance may well be due to imperfection in preservation. On the caudal region there is no evidence of any squamation; but a series of small, elongated, tubular ossifications seems to show that even in its hinder half the course of the lateral line was protected by hard parts.

Specific Determination.—The fish thus described is much smaller than any example of *Mesodon* hitherto known, and is probably another adult member of the remarkably dwarfed fish-fauna characteristic of the Lower and Middle Purbeck in the Vale of Wardour. It is distinguished from *M. Daviesi*, the only described Purbeckian species, by its larger head, deeper trunk, and the slightly smaller number of rays in its dorsal and anal fins. With *M. macropterus*, however, from the Lithographic Stone of Bavaria, it is almost identical, except in size, agreeing with this fish in its general proportions and the number of rays in the dorsal fin. The anal fin has four or five rays fewer than usual in *M. macropterus*, and the scales seem to cover quite half of the trunk. Until the discovery of more specimens with the dentition, Mr. Andrews' fish may therefore be provisionally placed in the last-mentioned species as a distinct dwarf variety named *parvus*.

Horizon and Locality.—Middle Purbeck: Lime Kiln Quarry, Teffont.

Mesodon, sp.

Another specimen of *Mesodon* obtained by Mr. Andrews from the Middle Purbeck of the Lime Kiln Quarry, Teffont, is too imperfect for specific determination, but is worthy of a brief notice. The total length of the fish is about 0·13 m., and the proportions of its head and trunk are as in *M. macropterus*. All the teeth exhibited, including those of the principal splenial series, are indented at the apex, and some of the round lateral teeth are also crenulated. The squamation is preserved over half the trunk, and at least seventeen vertebral arches are indicated in the caudal region. The median fins are very imperfect, but the caudal fin clearly exhibits the form characteristic of *Mesodon*.

Macrosemius Andrewsi, sp. nov. Plate VII. Fig. 3.

This species is founded upon a small specimen, 0·32 m. in length, without the caudal fin. Both sides of the fossil are preserved, and one is shown of the natural size in Pl. VII. Fig. 3. The length of the head with opercular apparatus considerably exceeds its maximum depth, and is contained about three-and-a-half times in the total length to the base of the caudal fin. The maximum depth of the trunk is twice that of the caudal pedicle.

Head and Opercular Apparatus.—Though much fractured, the head has precisely the aspect of that of *Macrosemius*, and the straight parasphenoid, parallel with the hinder part of the cranial roof, is distinctly shown in section. A few large styliform teeth occur in the short jaws; while below and behind the ceratohyal some slender branchiostegal rays are preserved.

Axial Skeleton of Trunk.—The persistence of the notochord is indicated by the vacant space between the neural and hæmal arches of the axial skeleton of the trunk; but there are robust small hypocentra and pleurocentra, especially conspicuous in the abdominal region. Ribs are shown extending not quite to the ventral border of the abdomen; and the hæmal arches in the caudal region are very stout at the base of the caudal fin. It is difficult to count the vertebræ, but there cannot have been less than thirty-five.

Appendicular Skeleton.—Portions of all the fins are shown, but the caudal and pectorals are especially fragmentary. The pectoral fin-rays are very long compared with those of the pelvic fin, which is small and situated much nearer to the anal than to the pectorals; the much-expanded proximal end of the pelvic support is observable. Unless the state of preservation is deceptive, the dorsal fin arises slightly further back than usual in the genus, above the fifth pair of ribs; but there seem to be stout fin-supports in advance of this, and some rays may thus, perhaps, have been accidentally destroyed. The number of rays distinguishable is about twenty-five, and they are all slender, showing distant articulations, though no clear evidence of bifurcations, while the length of those in the caudal region apparently does not exceed the depth of that part of the trunk; the supports are comparatively robust, tapering and curved forwards at their lower extremity. The anal fin, as ordinarily, is quite small, comprising only seven or eight rays.

Squamation.—There are remains of very thin scales over the whole of the trunk, but nothing can be ascertained of their characters. Of the large fulcral scales at the base of the caudal fin, only one imperfect example can be seen above and below.

Specific Determination.—The fish thus described most closely resembles a small species from the Upper Portlandian of Savonnières-en-Perthois, Meuse, France, described by Dr. Sauvage under the name of *Macrosemius pectoralis*.[1] The counterpart of the type specimen of this form has recently been acquired by the British Museum, and so admits of direct comparison. The Purbeckian fish, however, is only about two-thirds as large as that from the French Portlandian, and is distinguished by its more robust caudal region, perhaps also by the smaller number of rays in its dorsal fin. The fact that its hinder dorsal fin-rays are not observed to bifurcate, as they certainly do in the French fish, may be due to imperfect preservation. The smaller degree of ossification of the vertebral elements may or may not be due to the immaturity of the new specimen. In any case, the proportions

[1] H. E. Sauvage, Bull. Soc. Géol. France [3] vol. xi. (1883), p. 477, pl. xii. fig. 17.

of Mr. Andrews' fossil entitle it to specific distinction, and it may appropriately bear the name of *M. Andrewsi* in compliment to its discoverer.

Horizon and Locality.—Middle Purbeck: Teffont.

Fry of Pleuropholis.—Plate VII. Fig. 4.

The considerable thickness of the scales in *Pleuropholis* has hitherto prevented any glimpse being obtained of the internal skeleton in that genus. It is therefore of interest to find in Mr. Andrews' collection some immature individuals in which the squamation is still undeveloped. One of these is shown of the natural size in Pl. VII. Fig. 4, and exhibits the greater part of the skeleton.

The notochord must have been persistent, but the arches are robust. In the abdominal region the neural arches and their spines are separate; but in the caudal region both the neural and hæmal spines are shown to be directly fused with their supporting arches. There are well-developed, though slender, ribs, not reaching the ventral region. The tail ends in a slender upturned production of the notochord, with expanded hæmal spines below. The small pelvic fins are situated midway between the pectorals and the anal; the dorsal and anal fins are large, and their rays are proved to be exactly equal in number to the supports. The only trace of the squamation is the middle portion of the deep flank-series, which exhibits a certain amount of superficial ganoine.

Horizon and Locality.—Lower Purbeck: Teffont.

Leptolepis Brodiei, Egerton. Plate VII. Figs. 5, 6.

[Brodie's Foss. Insects, 1845, p. 15, pl. i. figs. 1–3.]

The fine new specimens of this diminutive fish collected by Mr. Andrews add a little to our knowledge of the species; and two examples of the trunk are shown of the natural size in Pl. VII. Figs. 5, 6.

The caudal vertebræ are now proved to be about twenty, and the abdominal vertebræ also not less than twenty in number. Intermuscular bones are conspicuous in the abdominal region of the original of Fig. 5, and there also appear to be traces of the short free neural spines. The small pelvic fins, each with about eight rays, arise opposite to the origin of the dorsal. The latter is large, comprising ten rays, of which the first three are much closer together than the others. The anal fin arises considerably behind the middle point between the pelvics and the caudal, and is very small and low, comprising seven rays. The caudal fin, hitherto unknown, is very robust, consisting of stouter rays than those in any of the other fins. A long mass of coprolitic matter (*c*) is observable in the original of Fig. 6, between the pelvic and anal fins, indicating that the anal opening must have been situated immediately in front of the latter fin.

Horizon and Locality.—Lower Purbeck: Lime Kiln Quarry, Teffont.

2. Some undescribed Jaws of Fishes from the Purbeckian of Swanage, Dorsetshire.

There are still several undescribed fishes represented by fragmentary remains from the Purbeck Beds of Swanage. Among these fossils are some detached jaws of considerable interest, and two forms seem worthy of immediate notice.

Caturus tenuidens, sp. nov. Plate VII. Figs. 7, 8.

This form of jaw, not uncommonly met with in the Purbeck Beds of Swanage, requires a provisional name, and two typical specimens are shown of the natural size in Pl. VII. Figs. 7, 8. Fig. 7 represents the greater part of a right mandibular ramus, which may be regarded as the type of the species, and Fig. 8 shows a left maxilla, both from the outer aspect. Another left mandibular ramus in the British Museum (No. P. 442) is also typical. The dentary bone is almost smooth externally, only displaying some rugosity towards its inferior border, and its hinder margin is excavated for union with the angular element. Posteriorly it suddenly rises into the coronoid process, which is bent somewhat inwards; anteriorly it tapers to an acute point, curved a little upwards. The teeth are very slender, often slightly bent at the apex, and not expanding at the base; they are comparatively uniform in size, not crowded, and the height of those in the middle of the series is considerably less than the depth of the bone at their insertion. The maxilla is very narrow, but robust, and with a slight sigmoidal curve; its teeth, which are similar to those of the dentary, are largest in front, and gradually decrease in size backwards.

The jaws thus described are indistinguishable from those of the genus *Caturus*, to which it is almost certain they will eventually prove to pertain. Among described species they appear to approach most closely the corresponding parts of *Caturus furcatus* and *C. pachyurus* of the Bavarian Lithographic Stone; but in both these species the teeth are more expanded at the base, and those of the middle of the dentary seem to be at least as deep as the bone at their point of insertion. It is also most improbable that the fossils now under consideration represent the young of *Caturus* (*Strobilodus*) *Purbeckensis*, which has jaws and teeth of very different proportions. They may therefore receive the provisional name of *Caturus tenuidens.*

Œonoscopus, sp. Plate VII. Fig. 9.

A right maxilla in the British Museum, shown of the natural size in Pl. VII. Fig. 9, seems to indicate a genus of fishes not hitherto recorded from British strata. It is not sufficient for specific determination, but a brief account of its characters may lead to the discovery of other remains of the same fish. The bone is much laterally compressed, and considerably more than twice as deep behind as in front; its hinder margin is slightly excavated; while a large and robust anteriorly-directed process for the palatine articulation curves slightly inwards from its anterior end. Its outer face is almost smooth, being very faintly rugose, and the oral margin is only slightly sinuous. The teeth do not vary much in size, and are small, but stout and conical, with the blunt enamelled apex turned somewhat inwards. They are hollow and smooth, and closely, though irregularly, arranged. Some teeth are broken away from the gaps observed in the series.

This fossil resembles the maxilla of *Megalurus*, though very much larger than the bone in any known species of that genus; and on instituting comparisons, it will be found to agree still more closely both in size and proportions with the corresponding element in *Œonoscopus.*[1] Two examples of *Œonoscopus cyprinoides* from the Bavarian Lithographic Stone (Brit. Mus. Nos. 37795–*a*) are available for reference, and the maxilla is tolerably well preserved in both. The writer has thus little hesitation in predicting that one more genus will soon be recognized as common to the Purbeckian fish fauna of England and the Lower Kimmeridgian fish fauna of the Continent, which have long been known to exhibit the closest relationship.

EXPLANATION OF PLATE VII.

FIG. 1. *Coccolepis Andrewsi*, A. S. Woodw.—Lower Purbeck: Teffont. [Museum of Practical Geology.]

,, 2. *Mesodon macropterus*, var. *parvus*, nov.—Middle Purbeck: Lime Kiln Quarry, Teffont. *cl.* clavicle; *op.* operculum; *p.op.* preoperculum. [Collection of Rev. W. R. Andrews.]

,, 3. *Macrosemius Andrewsi*, sp. nov.—Middle Purbeck: Teffont. [British Museum, No. P. 6303.]

,, 4. Fry of *Pleuropholis*, showing incomplete flank-scales over vertebral column.—Lower Purbeck: Teffont. [Collection of Rev. W. R. Andrews.]

,, 5, 6. *Leptolepis Brodiei*, Ag.—Lower Purbeck: Lime Kiln Quarry, Teffont. *c.* coprolitic contents of intestine. [Collection of Rev. W. R. Andrews.]

,, 7, 8. *Caturus tenuidens*, sp. nov.; right dentary and left maxilla, outer aspect.—Purbeck Beds: Swanage. [British Museum, Nos. 40657, P. 442*a*.]

,, 9. *Œonoscopus*, sp.; right maxilla, outer aspect.—Purbeck Beds: Swanage, [British Museum, No. 33477.]

,, 10. *Osteorachis macrocephalus*, Egert.; imperfect head, left lateral aspect, two-thirds nat. size.—Lower Lias: Lyme Regis. *br.* branchiostegal rays; *c.o.* circumorbitals; *d.* dentary; *ecpt.* ectopterygoid; *gu.* gular plate; *mx.* maxilla; *p.f.* prefrontal; *pmx.* premaxilla; *pt.f.* postfrontal; *pt.o.* postorbital; *s.mx.* supramaxilla; *scl.* sclerotic; *spl.* splenial. [Oxford University Museum.]

Unless otherwise stated, the figures are of the natural size.

(The description of *Osteorachis macrocephalus*, from the Lower Lias, Lyme Regis —Pl. VII. Fig. 10—will appear in the May Number.—EDIT. GEOL. MAG.)

II.—THE STRUCTURE OF GLACIER-ICE AND ITS BEARING UPON GLACIER-MOTION.

By R. M. DEELEY, F.G.S., and GEORGE FLETCHER, F.G.S.

DURING last August the writers made a short stay in Switzerland and the Savoy, with a view to examine the structure of the ice of several of the larger glaciers. For this purpose a rough polariscope was used. It was so designed that a sheet of ice about two inches square, made very thin by cutting and melting, could be placed between the polarizer and analyzer. Notwithstanding that the thin slide so prepared, and held between glass plates, melted away rather rapidly, we succeeded in making a number of drawings of sections cut from the ice at different parts of the glacier, and at various angles with the line of motion. In some cases, however,

[1] O. G. Costa, Ittiol. Foss. Ital. (1853), p. 2. Also described under the names of *Macrorhipis* (A. Wagner, Abh. k. bay. Akad. Wiss. math.-phys. Cl. vol. ix. 1863, p. 723), and *Attakeopsis* (V. Thiollière, Poiss. Foss. Bugey, pt. ii. 1873, p. 23).

where the structure was very fine-grained, the samples melted away before they could be sketched.

To the unaided eye such slides show the outlines of the crystalline particles very imperfectly. When examined through the polariscope, however, the whole structure is distinctly revealed.

We do not by any means feel that, in our rather rapid survey, we have been able to work out the subject with the care it demands, or that in a short article full justice can be done to those who have preceded us. For a full discussion see "The Glacial Nightmare," by Sir Henry H. Howorth, vol. ii. p. 519. Still, as the information we have already obtained seems to throw light upon the character of the veined structure, and to lend some support to a theory of Glacier-Motion, propounded by one of us in 1888,[1] we venture to put on record some of the results we have obtained.

Until quite recently, the granular nature of Glacier-Ice has not received very close attention. Hugi,[2] however, in 1843, remarked on its granular structure, and Forbes, in a particular case, says, "the mass was granular, and without structure or bands of any kind," without veined structure we presume he meant. Heim, McConnell, Bertin, Grad, and others have, however, by primarily regarding a glacier as a crystalline aggregate, made us familiar with the "Glacier grain." In a recent paper[3] Messrs. McConnell and Kidd say: "Glacier-Ice is a sort of conglomerate formed of glacier grains (Gletscherkörner), differing, however, from a conglomerate proper in that there is no matrix, the grains fitting each other perfectly. In the winter, at any rate, the ice on the sides of the glacier caves looks quite homogeneous. But when a piece is broken off and exposed to the sun's rays the different grains become visible to the naked eye, being separated probably by thin films of water. Though the optical structure of each grain is found under the polariscope to be perfectly uniform, the bounding surfaces are utterly irregular, and are generally curved. The optic axes, too, of neighbouring grains seem arranged quite at random."

Even now, however, the exact details of the process by which the snow is converted into glacier ice have not been traced. Forel states that he imitated the structure by alternately moistening and freezing snow. Unfortunately, during our trip, we did not examine a section showing the passage of snow into compact ice. On the slopes, near the summit of Mont Blanc, after a very windy, cold, and somewhat snowy day and night, the snow was granular, each grain being about the size of a mustard seed, a result no doubt partly brought about by the freezing during the night of the snow melted during the day, and partly by the condensation in the pores of the snow of water-vapour. At the end of the Grand Plateau, and at the base of the slope up which the way to the summit passes, is a trail of débris formed of névé ice from a small secondary glacier well above the snow-line. The fragments of this ice were formed

[1] Phil. Mag. February, 1888.
[2] Die Gletscher, 1843, p. 10.
[3] Proceedings of the Royal Society, vol. xliv. p. 333.

of the usual glacier grains, many of considerable size. On the average they were, as near as can be remembered, as large as peas or even beans. Indeed, in many instances where the névé was examined the ice was coarsely granular. Regarded from a distance the névé appears to be very finely stratified, layers of comparatively pure blue ice alternating with white ones. On close examination this stratified appearance is seen to be practically wholly due to the distribution in layers of countless imprisoned air-bubbles. Each granule of ice, it must be remembered, is a truly crystalline, if not a crystal, particle. As McConnell and Kidd say, "the optical structure of each grain is found under the polariscope to be perfectly uniform," but the "bounding surfaces are utterly irregular and are generally curved." In spite, however, of this irregularity of outline, and random arrangement of the optic axes, *the lines of bubbles traverse the mass in definite layers.* Indeed, it is clear that the granular structure of the névé is entirely independent of the disposition of the air-bubbles. After a fall of snow, surface melting leads to the production of a mass of more or less spherical granules of ice, the interstices between which are occupied by air. Further accumulations of snow leads to pressure, the granules are compressed, and much of the air may be expelled. But under certain conditions of weather a surface layer of snow may be melted, and, freezing again, may form an impervious layer, and the adjacent air-bubbles be unable to escape, even under the pressure resulting from further falls of snow. Thus we have bands of air-bubbles parallel with the surface and alternating with strata of blue ice which are comparatively free from air. Meteorological conditions will, therefore, have a great influence upon the volume of air imprisoned. In the Grindelwald we found the ice remarkably pure and blue as compared with the ice coming down from the Mont Blanc range.

One would suppose that any internal molecular rearrangement would lead to the displacement of the air-bubbles, but this is not the case. The small granular particles of ice referred to undergo a rapid metamorphosis. They grow, some of them increasing in size at the expense of others, until they may exceed one or two inches in diameter, and would probably increase indefinitely but for the stresses existing in the glacier which cause their fracture. The mode of growth, and also the effects of fracturing, are discussed later. It is remarkable that these changes in the shape and size of the ice-grains do not appear to affect the arrangement of the air-bubbles, the layers of which are extremely regular, the transference of water in a molecular condition from grain to grain failing to affect the position, in space, of the air-bubbles, which are seen to traverse the crystalline grains.

It is to Hagenbach that we owe the suggestion that the large crystals slowly absorb the smaller ones. Forel had suggested that the crystals all grow in size by infiltration and freezing. This view, however, has been shown to be untenable. Against Hagenbach's theory it has been urged that the glacier grains in any given district are virtually of the same size, whereas the theory requires that there should be large and small ones. In the glacier proper this alleged equality of size between the various crystal grains certainly does not exist, as will be seen from the sections we give, nor does it, as far as our memory serves, in the névé. Crystals $1\frac{1}{2}$ inches long are frequently to be seen side by side with very small ones.

During this growth of the ice-grains dilatation does not, of course, take place, neither is there a true absorption or liberation of heat, for evaporation and solidification go on at the same rate. Although it is not quite clear why some of the grains should increase in size and others disappear, the transference of the molecules from crystal to crystal offers no difficulty, for when exposed to dry air ice evaporates, surface molecules detaching themselves from the mass, and even in air saturated with moisture particles doubtless get free, and this is perhaps more nearly the condition obtaining between the grains. When the water vapour has reached its maximum density, as Maxwell says, "according to the molecular theory . . . evaporation is still going on as fast as ever; only condensation is also going on at an equal rate."[1] In the interior of a glacier the surface molecules of the grains are probably more unstable than they are on surfaces exposed to the atmosphere, but instead of the molecules obtaining their freedom, they simply pass from granule to granule. However, explain the fact as we may, such a growth of the granules does take place, and it is clear that it must take place at the expense of the smaller individuals.

It is only under certain meteorological conditions that the granular structure can be made out without the use of the polariscope. However, on several occasions, when it was looked for, it was seen developed in perfection. The most favourable circumstances seem to be a dry atmosphere a little below the freezing point. Under such conditions, on looking obliquely at an ice surface, shaded from the sun, the outline of each crystal grain can be clearly seen. Occasionally, the surface of a grain will be quite smooth; the majority are, however, seamed with exceedingly small furrows, which give the surface much the appearance of watered silk, or the skin on the palm of the hand. On each crystal the direction of the lines is different. In the ice-caves at the foot of the glaciers the structure is at times very beautifully shown. Figure 1 shows the nature of this surface structure, and the arrangement of the grains. It was sketched in the ice-cave of the Rhône Glacier. The conditions did not allow us to determine the relation between these striæ and the directions of the optic axes on the glacier. The matter is now receiving our attention. The striæ are, doubtless, analogous to those often seen on the surfaces of other crystals, and are due in all probability to the alternation of two faces of crystallization.

When névé reaches lower levels and becomes a portion of the glacier proper, quite a new structure begins to show itself. This is the well-known *ribboned* or *veined* structure. In some cases this structure develops roughly parallel with the stratification of the

[1] "Theory of Heat," seventh edition, p. 324.

névé, in others, even at right angles to it. Forbes, in his occasional papers on the theory of glaciers, gives admirable descriptions of the disposition and coarser features of the veined structure, but his treatment of its minuter structure is by no means clear or satisfactory. Our first acquaintance with it was in the Bondhus Glacier which descends from the Folgefond in Norway. Here we found

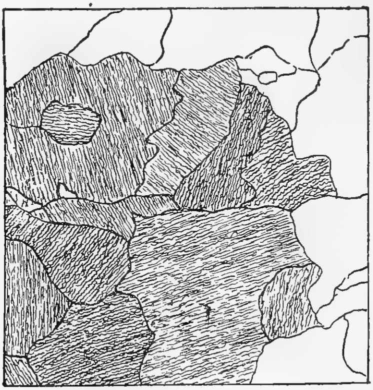


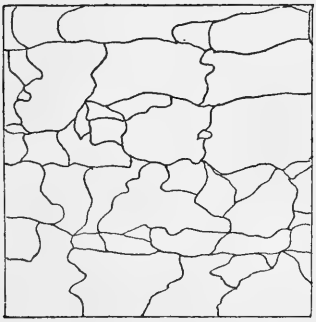
Fig. 1. (Scale $\frac{5}{8}$) Striated ice-crystals in the ice-cave of the Rhône Glacier.

that the veining resulted partly from the arrangement of the crystal grains, partly from a variation of the shape of the grains, and partly from variations in their dimensions. Further acquaintance with the phenomenon served to convince us of the truth of this. In the artificial cave cut in the foot of the Obergrindelwald Glacier, the veining, or the structure which, on weathering, produces veining,

Fig. 2. ($\frac{2}{3}$) Structure of ice in the grotto at foot of Obergrindelwald Glacier. The section is vertical and at right angles to the direction of flow.

is beautifully shown. At the end of the cave is a pillar of ice *in situ*, behind which is placed a light to enable the structure to be seen. Figure 2 is a sketch of a portion of the ice of this pillar. Figure 3, showing a slice from the ice-cave of the Rhône Glacier, also exhibits the structure. It will be seen that most of the grains have a greater horizontal than vertical extension and that they are roughly arranged in layers with approximately horizontal *shear planes.* These shear planes are sometimes very sharp but by no means always so. In some cases it can only be said that the bounding surfaces are more regular in one particular plane than they are in others.

In many cases where the shear planes are best marked the grains are smallest. Indeed, we have layers an inch or more thick, in which the crystals are large as in Figure 6, and the bounding surfaces utterly irregular. Between them are layers composed of smaller crystals with more or less clearly defined shear planes.



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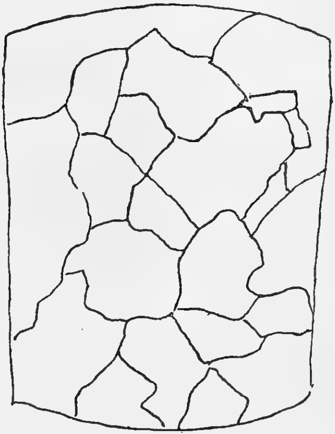

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FIG. 3. ($\frac{1}{1}$) Section of ice in ice-cave of Rhône Glacier. The section is vertical and parallel with direction of motion.

FIG. 4. ($\frac{1}{1}$) Horizontal slice. Ice-cave, Obergrindelwald Glacier.

Here the grains have been broken by excessive strains. Figures 4 and 5 show slices cut from the Obergrindelwald Glacier. In both cases the sections were cut nearly horizontally, *parallel* with the veined structure. Vertically, the grains being flattened, were so small in these particular samples, that the ice melted away before a sketch showing its structure could be made.

Figure 6 is a sample from the *Eismeer* of the same glacier. Here the grains were all large, the veined structure being almost absent. Figure 7 is a vertical section from the *Mer de Glace.* It shows very clearly how greatly even adjacent crystals vary in size. Although we have remarked that the descriptions of the structure given by Forbes are unsatisfactory, it is only fair to point out that his theory, or perhaps his *final* theory (suggested by the writings of others as well as his own observations), seems to be sound. He says:[1] "The fundamental idea is this, that the veined or ribboned structure of the ice is the result of internal forces, by which one portion of ice is dragged past another in a manner so gradual as not necessarily to

[1] "The Theory of Glaciers," p. 255.

produce large fissures in the ice, and the consequent sliding of one detached part over another, but rather the effect of a *general bruise* over a considerable space of the yielding body. According to this

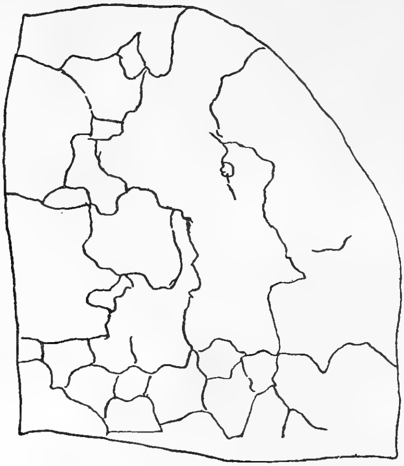

Fig. 5. ($\frac{1}{1}$) Horizontal section. Obergrindelwald Glacier.

view, the delicate veins seen in the glacier, often less than a quarter of an inch wide, have their course parallel to the direction of the sliding effort of one portion of the ice over another." That, in a

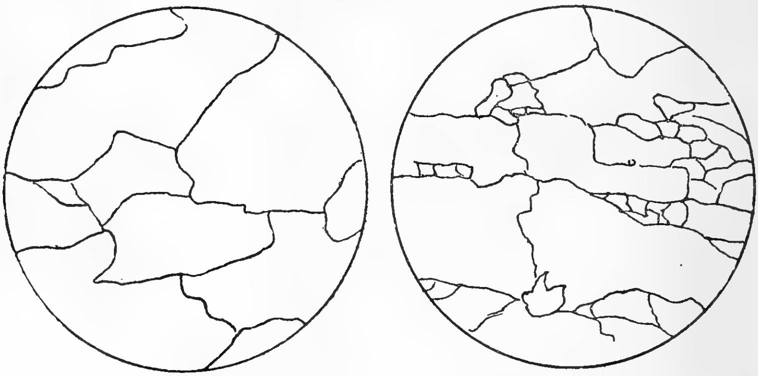

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Fig. 6. ($\frac{1}{1}$) Horizontal slice from Eismeer of Untergrindelwald Glacier—from beneath medial moraine. Here the ice was clear blue. No veining seen.
Fig. 7. ($\frac{1}{1}$) Vertical section from Mer de Glace Glacier.

few words, the veining is due to the formation of a series of discontinuous *shear planes.* Unfortunately, in his early letters Forbes was led to say that the well-known "dirt-bands" . . . . "are nothing more than visible traces of the direction of the internal icy structure."[1] Tyndall, however, has shown that the dirt-bands are not "external evidence of their structure."

Opposite the Hotel du Montanvert the dirt-bands and the veined structure are almost parallel over the whole width of the glacier. Higher up, however, they cease to be congruent. In all cases, as far as our experience goes, the direction of the veined structure, rather than being at right angles to the direction of greatest pressure, was such as would be produced by the *shear* the glacier undergoes in changing its shape, or rather the relative position of its parts during its descent. The cut (Fig. 8), after Forbes,[2] shows

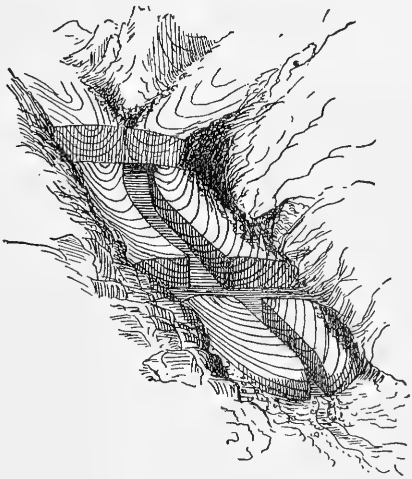


Fig. 8. (After J. D. Forbes.)

fairly well the direction in which the veined structure runs. Perhaps at the bottom of the ice the veins should have been shown more parallel with the sides. The veins run up to the surface in the middle owing to the fact that below the snow-line the surface of the glacier, which is rapidly melting, exposes the edges of the shear planes. Pressure alone could hardly give rise to lamination or cleavage. When, however, the pressure produces a re-arrangement of particles, or a change of shape, shear takes place and lamination results.

The laborious observations of J. D. Forbes and others have taught us how a glacier, considered as a whole, moves. It is quite clear that a glacier, as a whole, is viscous. Its river-like flow is regular and continuous, and owes nothing, or nearly nothing, to the formation of crevasses. And, indeed, a lump of Glacier-Ice does exhibit marked viscosity. A continuously-applied pressure produces permanent deformation, and it would appear that under any stress,

[1] "The Theory of Glaciers," p. 22.
[2] *Ibid.* p. 247.

the constituent particles are able to slide over each other. But it is only under certain circumstances that this can take place. While a mass of Glacier-Ice is viscous in all directions, it has been found that a single crystal of ice is only viscous in a direction at right angles to the optic axis.[1] A single crystal, or a portion of a crystal, will yield to continuous transverse stress applied in a direction parallel to the optic axis, but will not yield in a direction at right angles to the axis—in brief, viscous shear may take place in one plane only. Now, if all the crystalline grains constituting a glacier had their optic axes arranged parallel with the direction of motion, or if there were a large majority of grains so arranged, it would not be difficult to account for the mode of motion of a glacier; but there is not any such relation between the optical structure of the glacier grains and the direction of motion. If we imagine shear to take place in any single grain, the motion will be stopped by adjacent crystals exhibiting rigidity in that plane. Indeed, it does not appear that a glacier in moving can make any use of the fact that ice-grains are viscous in one plane, for the direction of that plane varies in almost every grain. How, then, does the glacier move? Why does it, as a mass, exhibit viscosity?

When a plastic or viscous substance undergoes change of form without change of bulk, the distortion in its simplest form may be regarded as due to the formation of great numbers of parallel shear planes. In such a case every molecule of each plane must change its position with respect to every other layer of molecules. On the other hand, if the substance be built up of a number of rigid grains of all shapes and sizes, closely fitting and adhering to each other, the nature of the change necessary to give rise to distortion is much less simple. In such a case not only do we require shearing between the interfaces of the particles but also a change of shape of the particles themselves. And this must go on in ice without producing more than local ruptures, for its tenacity and shearability are sufficiently high to resist general fracture. To account for Glacier-Motion, therefore, we have to show that the glacier grains can not only increase in size but also change their shapes under the smallest stresses, and also that they can, under similar conditions, slide over each other without actual fractures resulting.

We will first consider the question of change of shape and size. Fig. 9 shows an ideal case of a number of particles lying between two parallel planes, the upper of which is moving more rapidly than the lower one. The small arrows near to or crossing the interfaces indicate the direction in which shear must take place, and also show those surfaces which, being pressed together, must be wasting, and those surfaces which, being in tension, must be growing. Although we shall deal with the case as though each crystal had rectilinear motion only, it must be remembered that they will also have a tendency to roll over each other as well. This, however, rather

[1] "On the Plasticity of Glacier and other Ice," by James C. McConnell, M.A., and Dudley A. Kidd, Proc. Roy. Soc., vol. xliv. No. 270. Also "On the Plasticity of an Ice Crystal," by James C. McConnell, M.A., *ibid.* vol. xlix. No. 299.

reduces than adds to the difficulty of the problem, as does also the viscosity of ice-grains along planes at right angles to the optic axis. We have seen that a very large number of the molecules at the interfaces of the crystals are free; that is, they sometimes form portions of one crystalline structure, and sometimes of another. Probably within a few minutes all the surface molecules have been free, and have, therefore, been at liberty to assume positions more in accordance with the conditions of stress and strain in the mass. For instance, the conditions of stress will be different for each of the faces separating the three crystals, 2, 4, and 5 of Figure 9. One is

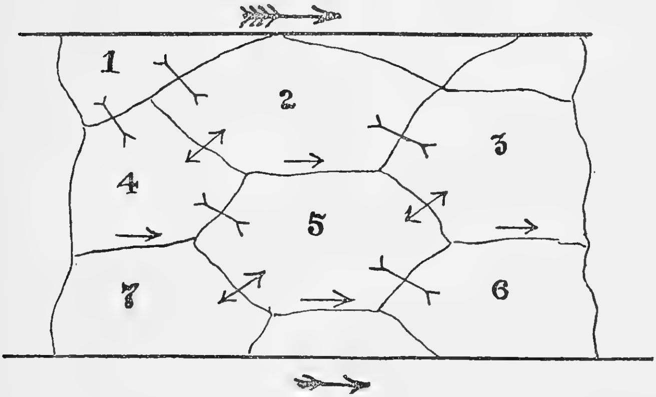


FIG. 9.

in compression, the other in tension, and the third in shear, and consequently the structure between 4 and 2 is more open (being in tension) than that between 4 and 5, the adjacent faces of which are in compression. Under such circumstances, it is reasonable to suppose that there would be a migration of molecules from the opposed faces of 4 and 5 to the opposed faces of 4 and 2. An exceedingly slow change of this kind would be sufficient for our purpose. There now remain the faces, such as those between 2 and 5, to consider. In these the case is one of simple shear. To make it clear that continuous shear can take place along such a surface without fractures, we will quote from the paper on Glacier-Motion previously referred to. This illustration is a general one, applying to all the interfaces: "Take a plate of steel, say twenty-four inches long, three inches deep, and half-an-inch thick. Firmly fix one end to a suitable support so that the steel plate shall form a girder with its greatest depth in a vertical position. Then distribute a number of weights along the length of the bar. It at once becomes deflected; that is, shear, *elastic shear*, is produced." . . . "We will now drill a row of holes along the plate, and when this has been done, the girder, having been weakened, will be found to have taken a still greater amount of set. Still further increase the set by drilling several rows of holes. So far, all the operations have been possible ones; but I must now draw upon the imagination somewhat, and perform operations which cannot be carried out in practice. Take the material removed from the numerous perforations in the plate, and replace it so that the plate becomes whole again. It is evident that though again solid, only that metal which formed part of the original perforated plate is in a state of strain, that filling the holes is taking no share of the load. We will again drill a number of holes, this time in the spaces between the older perforations, and another increase will take place in the deflection of the plate. A strain will also be put upon the metal in the first series of holes bored; and, in addition, a greatly increased strain upon what remains of the original plate. By repeating the operation the girder could be deformed to any desired extent, and, if necessary, such a violent strain thrown upon any one point that local rupture would ensue."[1] In a glacier, each interfacial molecule which obtains its freedom is regarded as having melted, and, like the material drilled from the plate, ceases to be a support to the mass, and when it becomes attached again (*i.e.* freezes) it does so under quite different conditions, and may not take any portion of the stress until further movement has occurred.

Imagine a glacier upon whose mass gravity has previously had no effect to be suddenly put within the sphere of the earth's attraction. It would, of course, immediately undergo a change of form, for ice is an elastic substance. Strains are produced in it, each proportional to the corresponding stress, and the ice takes a small step in the direction of least resistance. But although it is brittle and elastic, and much more cohesive than many rocks which enter into the composition of stable mountain ranges, the fact that the proper motion of its molecules at or near the freezing-point is so energetic that they shake themselves free, renders the mass viscous,[2] and it slowly flows, even under the influence of very minute stresses.

In the paper on Glacier-Motion previously referred to, no reference was made to the structure of Glacier-Ice, the illustrations being general ones. At that time it was not known to what extent a crystal of ice was viscous. Any attempt to go into detail under such circumstances could not have been other than unsatisfactory. Neither was the real structure of Glacier-Ice sufficiently known. No doubt it had been described over and over again, but so many of the descriptions are imperfect, and the contradictions are so palpable, that it would have been quite impossible to decide between the various authorities.

By making polariscopic examinations of thin sections of ice much may be done not only to throw light upon the cause of glacier motion, but also upon the origin of such buried ice-masses as those met with in Arctic regions, just as the microscopic examinations of rock-sections has thrown light upon the history of many rock-masses.

[1] "Theory of Glacier-Motion," by R. M. Deeley, F.G.S., Phil. Mag. Feb. 1888.
[2] For definition see Maxwell's "Theory of Heat," 7th edition, p. 276.

III.—An Interesting Contact-Rock, with Notes on Contact-Metamorphism.

By W. Maynard Hutchings, F.G.S.

(*Concluded from the March Number, page* 131.)

THE phenomena to be observed in this special rock seem to me to strikingly bear out some of the ideas and views I expressed in my former paper, when I 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."

Of course, it is very largely considered that contact-action is a hydrothermal business,—that it is due to heated water in some way. But that still leaves the exact mode of operation of the processes very vague, so that it is desirable to follow up any clue, or line of observation which may possibly lead to more definite insight into the course of the changes involved. It is for this reason that I have thought a detailed description of this rock might be of interest.

Much that was only surmise or inference as to other rocks, may here be seen, as it were, in action before our eyes, and we seem able to follow the whole course of the re-constitution of the components of this shale. Such exceptionally instructive examples will perhaps not often be found, involving as they do a special balance of conditions.

It will be noted in the analysis that the water is over 7 per cent. This is a high percentage of combined water if compared with that in fully developed hard, compact slates, and with that in their alteration-products. But we are here dealing with what were once comparatively soft shales, which contained more water originally. The water in this analysis is not due to secondary hydrous infiltrations. In the large specimens used for analysis care was taken to ascertain, by microscopic examination, that practically no such secondary hydrous minerals were present. The water is mainly contained in some of the minerals of metamorphism, and in the isotropic base, probably largely in the latter.

A considerable number of determinations of water have been made in specimens from many points along the contact, and a very uniform amount of about 7 per cent. is found in nearly all the altered shales. This uniformity is striking and agrees also fairly well with the normal contents of water of shales and clays such as these were (see for instance analyses of clays in my former paper). It would appear that the water contained was not driven off, and was all utilised in the metamorphism.

With regard to contact-metamorphism, geologists have tended of late to accept the view that it is due only to *thermal* action, to the increase of temperature caused by the intrusion of an igneous mass. Indeed, it may be noted that some of our leading writers on the subject use the term "thermo-metamorphism" more and more, and almost abandon the name of "contact-metamorphism." This may be right, and most of us have more and more assumed that it is so, perhaps without quite stopping to consider how much of simple *assumption* is involved. The evidence has appeared strong against any theory that something passed from the igneous rock into the rocks among which it was intruded, something besides mere heat, and which was vitally concerned in the alterations which took place. But still it may not be wise to regard the subject as being disposed of. We have yet so many things to understand, and so many strange facts to harmonise and explain, that it will be well to leave this an open question for some time to come; and for the present it may be better to retain the use of the term "contact-metamorphism" and not commit ourselves.

Speaking for myself personally, I may say that continued study of this fascinating subject has made me much more doubtful than I was, even a year or two ago, and more particularly since I have had my attention specially fixed on the contact-effects of *basic* rocks. Some of the points to be considered are not quite easy to get over, and are certainly not by any means settled.

That fused material, actual igneous magma, passes over into and is incorporated with the invaded rocks to any extent, is probably an idea safely to be rejected, and is indeed probably held by very few geologists. We may have areas of considerable and intricate *permeation*, as for instance described by Mr. Barrow in the South-Eastern Highlands (see Quart. Journ. Geol. Soc., vol. xlix. p. 331). This, however, is a different matter and easily distinguished.

But take the case of the intrusion of a granite into a mass of slates. We know there was water in the slates, and we assume that to the action of this water are largely due the changes which are worked in the rocks under the influence of the heat of the intrusion. We must admit a certain, and indeed considerable, amount of freedom of movement of this heated water, and of the solutions to which it gives rise, within the invaded rocks. But we know also that the granite was charged with considerable water, or more properly with solutions, when it was intruded, and it does not appear that we have any reason to suppose that at the junction of the two rocks there shall have existed a barrier such that none of these solutions could pass. It is more reasonable to suppose that at the junction, and for some considerable distance beyond it, the temperature of the invaded rock, already more or less high owing to the depth of cover, will soon be raised to something not too far from that of the *margin* of the granite, and that solutions will be able to pass for a time freely. It not only seems natural that this should be so; it seems almost impossible to assume anything else under the conditions we are bound to suppose.

Now, as regards granite-intrusions, the chemical evidence is usually held to show that no transfer takes place. But if we look at this evidence we shall see that it is not, perhaps, so strong as we have supposed. It mostly bears on the alteration of slates or allied rocks. In a very large proportion of these the alkalies, in their quantity in the rock and in their relative proportions to each other, are not so very far removed from what obtains in an average granite, and in some cases the resemblance is even striking. If, therefore, a transfer of alkalies took place from the granite, a moderate amount of such transfer would not bring about any change in the chemical constitution of the slates sufficiently striking to serve as proof, especially in view of the variations in the slates themselves, which have to be allowed for in making such comparative analyses over certain distances. We know that the alkalies of the granite are just what would chiefly be transferred if a solution passed from it into the slates; there is ample evidence to show that alkalies were in solution in the liquids of the granites. Therefore, from the above considerations we do not appear to have conclusive evidence, from analyses, that such transfer of solutions did *not* take place.

On the other hand, when we come to consider the rocks affected by contact with *basic* intrusions, we get in many cases very forcible chemical evidence that such transfer *did* take place. We are here again considering slates and allied rocks, in which the quantity and relationship of the alkalies are the same as before. But in the rocks from which the transfer is supposed to have taken place the alkalies are in totally different proportions. Here we have soda as the leading alkali, and whereas even a considerable transfer from a granite to a slate would not make a notable difference, such a transfer from a dolerite would often strikingly upset the balance of the alkalies in the slates and become apparent in the analyses.

Hence it may perhaps be the case, not, as is often assumed and stated, that material is not transferred from a granite but is transferred from a basic rock; but that it is really transferred in both cases, being only rendered so strongly apparent in the case of basic rocks for the reasons I have suggested.

Nor can we well imagine any reason which should explain why a transfer should be able to take place from a dolerite and not from a granite.

If at the time of contact a certain amount of alkaline solution passed into the slates, even though it were not large, it might cause most important effects. It might at least *start* the whole process of transformation, and it may well be conceived as possible that without some such start any mere *thermal* action would not much affect the mineral constitution of the invaded rocks. The mere water in them might not be able, by itself, to effect the necessary solutions, or only to a limited extent, and with extreme slowness: but once started by the injection of powerfully active solutions at the junction of the rocks, the contained water could join in and carry on the work. Instances might be cited from experimental and industrial work, where analogous influence is exerted by small quantities of some re-agent or compound in thus setting processes going. At any rate there seem to be sufficient grounds for not deciding that contact-action is purely thermal, and we may yet find good reasons for retaining more or less belief in the "mineralizing agents" which have been so much written about, though their nature was left more or less vague and mysterious.[1]

The question, indeed, may be asked as to why, if nothing but thermal effects are concerned, we do not get rocks which have undergone changes similar to those with which we are familiar as "contact-action," but under the influence of depth-temperature alone? We are acquainted with rocks of immense age, and which have been covered up to enormous depths, corresponding to very high temperatures, but which do not show any of the special characteristics of contact-metamorphism;—not one of the particular minerals which we have learned to associate with it; not even a trace of brown mica, which we know is formed easily even at the comparatively outer portions of contact-areas. And this is true of rocks such as chloritic phyllites, which are specially sensitive in this respect.

There are not wanting good reasons for thinking that there may be an abrupt line of separation between the effects of "contact-action" and any other process with which we are acquainted,[2] and that a list of minerals, for instance, could be stated, whose development in sedimentary rocks, so far as our knowledge goes, takes place *only* as an effect of contact-action.

If that should be so, we should not be justified in speaking of this action as simply thermal, unless we can find evidence that elevation of temperature alone has ever produced, or can produce, these minerals.

Round every mass of intruded igneous rock which we are able to study, we find certain definite results produced,—physical changes effected, and new minerals developed. We find the same things over and over again, and learn to look upon them as quite assured characteristics of the rocks round such intrusions.

If we meet with the same characteristic minerals in all respects, but where no intrusion of igneous rock can be discovered, we are not

[1] Of course, it does not follow that nothing but alkalies would be transferred, though alkaline compounds, mainly silicates, would be far away the principal material. We may well suppose that other matters would also be present, and that among them would be small proportions of fluorine-compounds, which have long been known to exercise such a very powerful influence in synthetic experiments on the formation of minerals, and which may, as has, indeed, been frequently supposed and stated about them, exercise a similar power in starting and maintaining the metamorphic processes in the rocks.

[2] If this be so, and a rock cannot be metamorphosed simply by heat and the action of its own confined water, we cannot look for any success in experiments on samples of rock heated in platinum, or other sealed metallic containers, to retain the water. This may be the reason why so little is recorded in this direction, and even a portion of what is recorded is not satisfactory evidence. There may have been many failures not recorded at all, though it is almost as valuable, in many cases, to record failures as successes. I will set the example of recording failures by stating that recently I have heated a fire-clay, rich in alkali, in a moist condition, to a low red heat for one month in a wrought-iron bomb. All the water was retained perfectly, but the clay was not affected in any way, except that its *combined* water was 1 per cent. less after the experiment, showing that some of its hydrous minerals had been dehydrated by the red heat. This clay would have been very susceptible to metamorphism if it had been invaded by a granite or a diabase. Subsequent experiments at a strong red heat failed entirely, as my bombs gave way under the pressure of the contained water-vapour, the iron getting too soft at the higher temperature.

taking a very risky step if we look upon it as probable that there is an intrusion to account for what we see, but that it is hidden from us. An exposure of plutonic rock is only an accident of denudation after all. It seems a more risky step for us to assume that because we do not here see the intruded rock, we can ascribe all the well-known characteristics to some other cause, or even to no definite cause at all. Dynamic metamorphism, for instance, has probably in some cases obtained the credit for many things which possibly may yet be shown not to belong to it at all, simply because dynamic action has taken place in regions in which great contact-action has also occurred, though the proof of the igneous intrusions is hidden, while the dynamic evidence is clear. Some important recent work has been in the direction of thus proving certain districts to be contact-areas, in which the observed phenomena of the rocks had been attributed to other causes.

Great dynamic action and igneous intrusions are apt to go together, as we know; but whereas we find certain minerals in *all* contact-areas, we know of plenty of areas of intense dynamic action, where they do not occur; not any trace of any of them.

Great as are the demonstrable effects of dynamic metamorphism in altering structures, in developing certain new minerals, and in regenerating others which are in a decayed condition, there are yet many minerals which we may decline to accept as *proved* to be within its powers to produce, even when we see them in regions of intense dynamic action. A great aim of future petrological study will be the endeavour to establish something reliable on these points.

It may be, and there would be reasons to be advanced for the belief, that dynamic action ever so intense can only, so far as the production of new minerals in a rock is concerned, do the same things, on a much intensified scale and in less time, as can be done by simple "metasomatic" action. White mica, for instance, is unquestionably in the power of dynamic action to develop on a great scale in felspar-bearing rocks. But white mica is also produced copiously during the simple *decay* of felspar. Garnet, again, may be cited as a mineral produced by dynamic action and also, if not so strikingly, by decay of other minerals; and additional cases might also be adduced. Some of them, like the two above, are also well-known contact minerals, and so are common to all three causes.

But andalusite, sillimanite, and cyanite, for instance, may be here named as among the list above suggested as not yet proved to be capable of formation in sedimentaries except by contact-action. We may even still pause, and ask for proof that dynamic or regional metamorphism can produce brown mica, that most constant and copious accompaniment of contact-action; and the same position of enquiry may also be taken as regards *new* felspar, that is, felspar produced in rocks in which it did not exist before the metamorphism, as in many slates and phyllites, and as distinguished from cases where decayed existing felspars are regenerated and re-crystallized, as in the metamorphism of much-weathered igneous rocks and their tuffs and ashes, or from cases in which new felspar is simply an infiltration-product.

In addition to the particular *minerals*, it is not unlikely that some of the "spots" so frequent in altered slates, etc., may be phenomena which are special to contact-action, and not produced in any other way, even when we are not able to trace them *directly* to intrusions.

Zirkel, in his recently completed Petrographie (vol. iii. 1894), in dealing with the mica-schists, phyllites, etc., alludes at several places to the fact that spotted rocks occur among them, where we have no direct evidence of contact-action. In commenting on this, at one place, he speaks cautiously as to there being no "recognizable connection with eruptive rocks"; at another place he speaks more dogmatically as to the spotted schists being in no way due to contact-action. As we know that spots are produced at considerable distances from the actual contacts, and as, apparently, characteristic rocks of this nature have not been shown to be produced in any way except by intrusions, it is surely not safe to adopt any decided view, based simply on the absence of *visible* igneous rocks.

One of the most interesting occurrences of spots known to me is in some of the rocks of the Ardennes, which are not, I think, regarded as contact-rocks, but which are always, on the contrary, described as standard examples of "regional" action. These spots do not seem to have been noticed by Renard and others in their examinations of these rocks.

I have a specimen of the well-known "coticule" of Viole Salm, with part of the contiguous band of dark slate attached to it, for which I am indebted to Prof. Renard. The coticule is light yellowish in colour. Very thin sections show it to be made up mainly of white mica, mostly lying flat in the plane of bedding, with the abundant manganese-garnets and rutiles disseminated very evenly all through it. There is a little quartz; and a total absence in the slides of any darker minerals or pigment. Viewed in ordinary light, the whole field is quite uniform, but in polarized light large numbers of dark spots appear. They are seen to be framed more or less strongly in rims of extra-accumulated white mica, just as spots are often framed in dark mica and so rendered conspicuous in ordinary light. These rims of colourless mica do not show at all in ordinary light, and one is unable in any way to make these spots stand out from their surroundings, by adjustment of illumination or otherwise, the garnets and rutiles being present in them in the same amount and uniformity of dissemination as in the rest of the rock. With crossed nicols they are seen to be isotropic, but to contain, in addition to the garnet and rutile, large numbers of dimly-polarizing, very minute grains and flakelets which cannot be determined. The average diameter of these spots is about $\frac{1}{100}$ inch, and sections cut parallel and vertical to bedding show that they are approximately equal in all directions, a large proportion being spherical or oval. The study of sections in various directions also disposes of any idea that there is here any *compensation* in question; the main material, the groundmass, of these spots is really isotropic and colourless. There are so many of them that in a section measuring $\frac{5}{8}$ inch by $\frac{3}{16}$ inch, over one hundred can be counted.

It is highly striking and curious to view with a low power the uniform colourless field, and then to push in the analyser and see these perfectly dark spots appear all over the slide.

The darker band of slate, cut in the same sections, is also mainly white mica and contains large amounts of the garnets, but also much iron ore in dark grains, and abundant minute flakes of transparent red hematite. There are here, also, spots of the same size and form, in the same number and diffusion, but they are marked off in ordinary light quite strongly, because they contain accumulations of small grains of red iron ore. In polarized light they are still more strongly marked, as in addition to the colour of the ore they have the darkness due to isotropic matter.

If one had these rocks shown to one, not knowing anything of their origin, one would be almost certain to refer them to contact-action.

No doubt depth-temperature may be of the greatest importance in influencing the *degree* to which rocks will be affected by contact-action. A deeply-bedded rock with a high temperature may be naturally expected to be more easily and more intensely affected by an intrusion than one less deeply covered. Good geological evidence exists in some cases to show that this has distinctly been so.

Again, rocks that have been intensely folded and crushed may have had their temperature greatly raised in the process, and may be also in other ways, by the effects of minute cracking and fracture, rendered more susceptible to the effects of an intrusion taking place immediately afterwards.[1]

But the greatest depth-temperature, or the most intense dynamic action, may be powerless to do more than to prepare and assist, so far as concerns the special changes we have known as *contact-metamorphism*; and these changes really may depend upon the *chemical* action of an intruded igneous mass.

The whole of this interesting subject of the metamorphism of rocks is as slippery and dangerous as it is fascinating, making its treatment the ground for a battle-field in which the war-cries of "dynamic," "contact," and "thermal" are sometimes urged with a force not equalled by the strength of evidence at command, and in which the effects on combatants have certainly been occasionally of a *thermal* nature. I only venture to timidly set my foot into a part of one corner of this dangerous field because it has seemed desirable to draw attention to one or two points of possible importance to consider further, before we take what is yet only an *assumption* for a proved case, and thus perhaps delay our arrival at the truth; an arrival which will in any event be probably long postponed, in the matters we are now considering, owing to the special difficulties surrounding the investigation and to the scarcity and doubtful nature of a good deal of the evidence we can hope to collect.

[1] Mr. Barrow has pointed out (*op. cit.*) how greatly intense folding of beds may increase their depth of cover, and so their temperature. He also alludes to some of the evidence that greater depth, and its consequent higher initial temperature, can be shown to have influenced the degree of contact-metamorphism.

REVIEWS.

I.—On the Discovery of *Cyathaspis* in the Silurian Formation of Gotland.[1] By G. Lindström. Communicated to the Royal Swedish Academy of Science, December 12, 1894.

FOR some years past drainage works have been carried on in the marshy tracts of Gotland, and in most cases it has been necessary to excavate wide and deep channels in the beds of limestone and shale to carry off the water. In this way not only have many instructive sections been laid open to view, but also many very productive localities for fossils, more particularly since through weathering the excavated rock falls to pieces and sets free the shells, which, as a rule, are not very firmly enclosed.

During this last summer one of these canals has been constructed in the village of Lau, on the south-east coast of Gotland. It is nearly half a mile in length, and reaches from the plateau north of the church down to the shore of the Baltic. For the greater part of this distance it passes through marl shales of a more than usual soft character. These shales rest below the limestones which form the knolls round Lau church, so well known from containing the operculate corals of the two species *Rhizophyllum Gotlandicum* and *R. elongatum*, together with other well-preserved fossils, some of which are present in the underlying marl shales, which also are rich in organisms. A peculiarity of this fauna is that all the shells occurring in it are extremely thin, whilst the same forms from other localities have thick shells. Moreover, they do not show any indication of having been rolled in water. This circumstance, together with the fine character of the shale, points to a considerable depth of water, in which the animals lived beyond the influence of wave action. The deposit may also have been formed in the still water of a sheltered bay, for the almost entire absence of corals, elsewhere so numerous, indicates under any circumstances smooth-water conditions.

Altogether, up to the present time, I am acquainted with about fifty species from the marl shales of this canal. Of Crustaceans we know a *Calymene*, *Bumastus sulcatus*, *Proetus conspersus*, an Eurypterid, a *Ceratiocaris*, and some forms of *Leperditia* and *Beyrichia*. Of Cephalopods, some forms of *Orthoceras* and a *Gomphoceras*. Of Annelids, *Trachyderma*; four forms of *Conularia*, several Gasteropods, with about eight Lamellibranchs and Brachiopods. Through such species as *Proetus conspersus*, *Aviculopecten Danbyi*, M'Coy, and others, the fauna of the Lau shales shows its relationship to the other South Gotland faunas, such as the oolite and sandstone of Bursvik, but it has also a faunistic connection with the Östergarn beds.

An inhabitant of Visby, Mr. A. Florin, who has for the last twenty years collected fossils for the palæontological section of the National

[1] Öfversigt af Kongl. Vetensk.-Akad. Förhandlingar, 1894, No. 10, Stockholm, pp. 515–518. Translated by Dr. G. J. Hinde.

Museum, sent during this last autumn several collections from the Lau canal-beds, and lately there was amongst them a pair of shining, oval objects, with a peculiar sculpture; and so well preserved that it was not difficult to recognize them as the dorsal shields of fishes of a very ancient type. The strongly arched and shining shield-plate consists of four parts grown together; a central, which is the largest piece; on each side of this a small elongate lateral piece, together with, in front, a transverse rostral plate. This latter is wanting in one of the specimens, and the more perfect example, which lies with the front portion somewhat below the first, has a small triangular process projecting from the rostrum. Both specimens are imperfect at the back, so that the margins cannot be distinguished. The surface of the shield is wrinkled with faintly elevated, longitudinal lines, which on the front portion of the central plate, where it meets the rostrum, are divided up into smaller portions and small knobs. The lines on the rostrum run transversely; they also become broken up so as to form smaller bundles. Thus each of the five plates which form together the complete dorsal or head-shield, has its surface-lines disposed independently. On the surface of the same slab there lies a comb-shaped shining scale, also the impression of another, somewhat larger. These have probably formed part of the covering of the tail of the fish.

The dimensions of the most complete specimen are: length 55 mm., breadth 32 mm., thickness ·75 mm.; the central plate 40 mm. long by 25 mm. wide; a lateral plate 7 mm. wide; rostrum 10 mm. long, 16 mm. wide. One of the scales covers 8 × 4 mm.

The whole structure of these shields indicates a fossil belonging to the Pteraspidæ and nearest to the genus *Cyathaspis*. From this, however, it differs in the triangular prolongation of the rostrum. With the genus *Tolypelepis* of Pander,[1] since more fully described by Rohon,[2] it has a certain resemblance in the glistening wrinkled surface, but judging from the descriptions it markedly differs in its general structure. It will require some further interval to carry out a thorough investigation of the characters of this Gotland fossil before naming it and assigning its position.

Some small, almost microscopic, head scales were washed out of clay at Hammarudd near Östergarn by the Russian palæontologist Volborth,[3] in 1860, and they have, moreover, been described by Rohon. According to him they belong to two species of *Thelolepis*, L. Ag., *T. parvidens*, Ag., and *T. Volborthi*, Rohon, both of which also occur in England and on the island of Oesel, but at a still higher horizon than on Gotland.

It is well known that a considerable number of Pteraspid fishes have been found in the Upper Silurian of Galicia and Podolia,[4] but

[1] Monographie der foss. Fische des Silur. Systems der russ.-baltischen Gouvernements; Petersb., 1856, p. 60.

[2] Die obersilur. Fische von Oesel; Mém. de l'Acad. Imp. de St. Pétersbourg, vii. 3, t. xli. No. 5, p. 76.

[3] Quart. Journ. Geol. Soc. 1861, p. 552; Rohon, *l.c.* pp. 32 and 36.

[4] v. Alth, Ueber die palæoz. Gebilde Podoliens. Abhandl. der k.-k. Geol. Reichsan. Bd. vii.

only in the uppermost beds, on the borders of the Devonian, to which formation also belong the by far greater number of these fossils which have been discovered in England, Spitzbergen, etc. The Gotland forms, on the other hand, lie deeper, in one of the oldest beds of Gotland—the widely extended marl shales which appear nearly all over the island below the limestone. There is no possibility that the marl shales of the east coast differ stratigraphically from those of the west coast, however unlike they may be palæontologically. A description of the dissimilar faunas which these shales contain has already been given by me[1] some years since. Up to the present no fossil fish has been discovered in the newest strata of Gotland. These from Lau are therefore the oldest known fish from the entire Upper Silurian in so far as the marl shales are homotaxial with the Wenlock beds. But still further—Since it has been found that the Conodonts in the Cambrian Greensand of St. Petersburg are not fish remains, and as those from North America described as Lower Silurian are completely Devonian in type, and from their position in disturbed beds cannot be considered with any degree of possibility as true Lower Silurian, we must regard the Gotland *Cyathaspis* not only as the oldest known fish but also as the oldest vertebrate, which, until a further discovery is made from still older beds, lends to it an importance which it would not otherwise have possessed. G. J. H.

II.—On the Age of the Earth. By Prof. John Perry, F.R.S. "Nature" (January 3rd, 1895), vol. li. pp. 224–227.

Of the many attempts to determine limits to the earth's age, one of the best known is that derived by Lord Kelvin from the cooling of the earth. In order to reduce the problem to the simple form required by mathematical analysis, Lord Kelvin was obliged to make several assumptions. He imagined the earth to be a homogeneous solid mass, with the same conductivity and other heat-properties as the surface rock. He supposed it to have been initially at a uniform temperature of 7000° F. throughout, and that its surface was suddenly brought to, and kept at, the temperature 0°. And, lastly, though aware that there might be a small loss of potential or chemical energy, he assumed the earth to be losing energy only in the form of sensible heat. Then, from the known average rate at which the temperature increases with the depth, he obtained 100 million years as a probable value of the earth's age, and 20 million and 400 million years as the limits between which it must certainly lie.

The value of Lord Kelvin's estimates of course depends entirely on the closeness with which the natural and assumed conditions agree, and Prof. Perry points out that, in taking the conductivity uniform throughout the earth, the two sets of conditions are in reality made to differ very widely. It is not unreasonable to

[1] Ueber die Schichtenfolge des Silur auf der Insel Gotland. Neues Jahrb. 1888, Bd. i. p. 147.

suppose, as he suggests, that the earth consists of a shell of rock similar to what we have now at the surface, and of an interior mass which conducts heat much more rapidly than the outer crust.

Now, if this be the case, the effect of the greater interior conductivity will obviously be to keep the joining surface of the shell and nucleus at a higher temperature than the surface at the same depth in Lord Kelvin's imaginary earth. Near the surface of the earth, therefore, the rate at which the temperature increases with the depth would be greater now in Prof. Perry's than in Lord Kelvin's earth. But this rate decreases as the time since consolidation increases. Hence, a given downward rate of increase of temperature (say 1° F. in 50 feet) would be reached much earlier with Lord Kelvin's than with Prof. Perry's conditions. In other words, if Prof. Perry's supposition be correct, and on this point most geologists will probably agree with him, Lord Kelvin's estimate of the age of the earth errs by being far too small.

How much too small cannot be determined, but it is sufficient for geological purposes to know that the upper limit of 400 million years may have to be greatly increased, and that one of the orders to stop payment on the Bank of Time is for the present practically withdrawn. C. Davison.

III.—Reconstruction of the Antillean Continent. By J. W. Spencer, Ph.D., F.G.S. Bulletin of the Geological Society of America, vol. vi. pp. 103 to 140, January, 1895. With a plate.

Dr. SPENCER was led to undertake this investigation by his study of submerged valleys in higher latitudes, and he found that similar evidence existed in the Antillean region. Recent geological work in Florida and in some of the West Indian islands led him also to visit Cuba and to study its geological structure. One result of this visit has already been published in this Magazine, and now we have another important contribution to West Indian geology.

The first part of the essay is a study of submarine geography: the author points out that the continental shelf of the east coast is continued in the broad plateau on which the Bahama Islands stand, and that outside this upper shelf there is a much lower one, termed the Blake Plateau by Prof. Agassiz, which lies at an average depth of 2700 feet below sea-level; from this there is a steep slope down to 12,000 feet (2000 fathoms).

The outer margin of this lower shelf is indented by embayments from the deep water beyond, and the submarine plateau is trenched by deep and narrow depressions which appear to be submerged valleys[1] formed by river erosion, and these valleys open into the embayments.

[1] Dr. Spencer's application of the term *fjord* to these valleys is not quite in accordance with European usage, for their coastal portions are filled with alluvium and are not open inlets.

Particulars are given of some of the channels which cross the Blake Plateau; some of them are traceable for 200 or 300 miles and reach a depth of 10,000 feet before they are lost in the sub-oceanic embayments. The deep troughs which furrow the Bahama Plateau present the same features, and a study of the United States hydrographic charts of the Gulf of Mexico exhibits a similar state of things—an upper continental shelf to about 600 feet, and then a slope, in some places gradual, in others steep, down to depths of 9000 to 10,000 feet. Both shelf and slopes are traversed by valleys, the floors of which are often several hundred feet below the plateaux on each side, and these valleys seem to be prolongations of those by which the modern continent is drained.

All these features are shown on the map which accompanies the paper, and below the Straits of Florida a broad submerged valley is seen *draining westward* into the Gulf of Mexico, not into the Atlantic. The Sea of Honduras and the Caribbean Sea are basins comparable to the Gulf of Mexico, but the floor of the former seems to have been deformed by late orogenic disturbances which have produced long depressions parallel to the mountain ranges of Cuba and Jamaica.

Dr. Spencer's conclusion from all the evidence is, that after making all allowance for possible foldings the northern side of the Gulf of Mexico has been sunk not less than 8000 feet, and that the south-east part of North America, together with the Greater Antilles, has been depressed for 10,000 or 12,000 feet; that before this depression the two Americas were united along the West Indian ridge, and that the deep basins of the Caribbean, the Honduras Sea, and the Gulf of Mexico were broad plains through which rivers ran *westward* into the Pacific Ocean. He believes that these conditions lasted till a comparatively recent date and that when the barrier of Central America was raised the Antillean basins sank.

He next endeavours to determine the probable dates of elevation and subsidence, a study which of course involves a correlation of the various formations that have been described by different authors in the several islands of the West Indies. This part of the essay is not quite so satisfactory, partly because too little is yet known of the geology of the West Indies, and partly because Dr. Spencer's own observations in Cuba are not yet published, so that we are here presented with some of his conclusions without all the data on which they are founded. His reading of Antillean history is as follows:—

In Eocene times there were islands round which shallow-water deposits were formed, but no continental connection. The Miocene period was one of deep subsidence, and deposits, largely of deep-water origin, were accumulated to a thickness in some places of more than 2000 feet, the Pacific and Atlantic being broadly united. During Pliocene times came a great upheaval, and the sea floor was raised to elevations of from 8,000 to 12,000 feet above the present sea-level. The Antillean region was united to both Americas, and the drainage was westward into the Pacific.

"In Cuba, Jamaica, and San Domingo, resting upon the upturned edges and denuded surfaces of Miocene and earlier formations, there is a deposit of soft earthy white or creamy limestone, made out of the mechanical residue of older limestones, with some small masses of corals and shells. All the observed species in Cuba are the same as the living ones. To this formation the writer has given the name of the Matanzas series. Owing to the modern facies of the organic remains Salterain has included it in the post-Pliocene, but states that it may be Pliocene." Dr. Spencer correlates this with certain deposits in Florida, Yucatan, and elsewhere, and infers a great subsidence and drowning of the Pliocene land at this time.

But the present position of the Matanzas limestone and the deep valleys which have been cut through it indicate a subsequent upheaval of the whole region equal to that of the Pliocene elevation. This was a second continental period, but it seems as if the Atlas of the Antilles soon became tired of holding up the land at such a height, and so let it down again for a time in the later Pleistocene to receive another set of marine deposits (Zapata and Columbian). Finally there were other movements of less extent, by which the present arrangement of sea and land has been produced. With respect to the formation of the Central American barrier, Dr. Spencer thinks that it was accomplished entirely within Pleistocene time. Islands doubtless existed there from early Tertiary times, but the deformation which converted them into a ridge and the Antillean Seas into basins did not *begin* till late Pliocene time, and the Pacific waters were not finally shut out till the very latest, or post-Zapata, upheaval of the land.

Dr. Spencer has evidently thrown all his well-known energy and acumen into this investigation, and may be congratulated on the work he has accomplished in connection with it. Many of his conclusions are doubtless based on substantial evidence and ascertained facts, but the wonderful series of earth-movements which he postulates depends on correct correlation of deposits in different parts of the area, and in this matter there is at present room for difference of opinion. Future researches may possibly necessitate some modifications in the later part of his history, and he will have to prove that the latest deformation did not include a north and south upheaval of the Windward Ridge as well as a warping up of Central America, for this seems to me very possible. However this may turn out it would not materially affect the broader generalizations now made, as to the former continental extension, and as to the late date of the Central American barrier.

Dr. Spencer is fully sensible of the startling nature of his conclusions, but so far as the magnitude of the vertical movements are concerned they will not astonish anyone who has accepted the results of recent work in Barbados.

A. J. Jukes-Browne.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—Annual General Meeting.—February 15th, 1895.

Dr. Henry Woodward, 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 1894. In the former the Council congratulated the Fellows on the satisfactory condition of the Society's finances, and pointed out that the decrease in the number of Fellows, to which attention had been drawn in the two previous annual reports, has been much less apparent during the past year.

The number of Fellows elected in the course of 1894 was 48; of these 36 qualified before the end of the year, making, with 7 previously elected Fellows, a total accession of 43 during the twelvemonth. In the same period the losses by death, resignation, and removal amounted to 54, the actual decrease in the number of Contributing Fellows being 5. The result of the work of checking the exact number of Fellows, both by the List and on the books, showed that at the end of 1894 the total number of Fellows, Foreign Members, and Foreign Correspondents, was 1321, 305 being Compounders, 862 Contributing Fellows, 75 non-Contributing Fellows, 40 Foreign Members, and 39 Foreign Correspondents.

The Balance-sheet for the year 1894 showed Receipts to the amount of £2643 5*s.* 10*d.*, and an Expenditure of £2656 2*s.* 8*d.*, being an excess of Expenditure over actual Income of £12 16*s.* 10*d.* The Balance in favour of the Society on December 31st, 1894, amounted to £358 9*s.* 1*d.*

The Council then refer to the raising of the Composition Fee as a result of the deliberations of the Finance Committee, and express their regret at the resignation of the Treasurer, the Rev. Thomas Wiltshire, after thirteen years' tenure of office.

The completion of Vol. 50 of the Quarterly Journal was announced, and the Fellows were informed that the List of Additions to the Library would in future be issued as a separate publication. The Index to the first fifty volumes of the Journal had proved a more arduous task than was at first anticipated, and there was no prospect of its being issued to the Fellows during the current year, although every effort would be made to expedite the work.

In conclusion, the Awards of the various Medals and proceeds of Donation Funds in the gift of the Society were announced.

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 more especially to the large accession of books and pamphlets from the libraries of Sir John Evans, the Rev. J. F. Blake, and the late Mr. W. Topley. The Report further recorded the completion of the work of registering the type and other important specimens of the British Collection in the Society's

Museum by Mr. C. Davies Sherborn, F.G.S., and expressed the opinion that this work should be continued in the Foreign Collection, so soon as a grant from the Society's funds can be made for the purpose.

In presenting the Wollaston Medal to Sir Archibald Geikie, D.Sc., LL.D., F.R.S.L. & E., F.G.S., the President addressed him as follows:—Sir Archibald Geikie,—

It is one of the greatest pleasures of my office to be the medium of the Council in conveying to so distinguished a recipient as yourself the Wollaston Medal—the highest token of appreciation which it is within their power to bestow; and to assure you, at the same time, of the unanimity of good will and esteem which marks its presentation.

I find it a most difficult task adequately to express, in a few words, an idea of the great services that you have rendered to Geology, whether as an active worker and observer in the field, for forty years, or as an eloquent and polished literary exponent of the science which we cultivate.

In 1863 you published not the least important of your Memoirs, "On the Phenomena of the Glacial Drift of Scotland," in which you gave the earliest connected account of the various Drift-deposits and chief Glacial features of your native country, and you then advocated the agency of land-ice in the formation of the great accumulations of Boulder-clay and Till. This, and the later surface-changes, with their geologic and historic associations, have ever interested you, and in your "Scenery of Scotland" you have rendered the subject most instructive and interesting to others also, both by pen and pencil.

The regions of Skye have always had a peculiar fascination for you. In your earliest contribution to this Society you described the subdivisions and enumerated the fossils of the Lias of that island.

Later on your attention became directed to the Volcanic Rocks of the Inner Hebrides. These researches, which were eventually embodied in your great Memoir on "The History of Volcanic Action during the Tertiary Period in the British Isles," will hold a lasting place in geological literature.

You early studied the microscopic structure of rocks, and the eruptive ejectamenta of different periods engaged your attention.

Your Memoir on the Carboniferous Volcanic Rocks of the Basin of the Firth of Forth (1879)—one of the earlier fruits of these researches—deserves especial mention; and you were eventually led to consider generally the history of volcanic action in Britain, an account of which is given in the two Presidential Addresses delivered by you before this Society (1891–92). I may also allude to your Memoir on the Old Red Sandstone; to your researches among the older rocks, and to the admirable manner in which you have directed the labours of your staff on the Geological Survey, especially in their work among the Scottish Highlands, where the geologist is confronted by some of the most difficult and complicated of geological problems. Your great Text-Book of Geology; your attractive Memoirs of Edward Forbes, of Murchison, and lastly, that just published, of Ramsay—attest the facility with which you wield the pen, as well as the hammer. It has been my good fortune to claim you among my personal friends since first we met in 1864, and many good papers by you have appeared in the GEOLOGICAL MAGAZINE, as well as in the Quarterly Journal. May you long continue to hold the important position of Director-General of our Geological Survey, to the well-being of the members of your staff, and to the advancement of Geology in this country.

Sir Archibald Geikie, in reply, said:—Mr. President,—

To receive from the Geological Society its highest award, and thus to be enrolled in that list of illustrious names so intimately associated with the birth and progress of Geology, is a distinction of which a man may well be proud. I am deeply grateful to the Council for the honour which they confer upon me, and to you, Sir, for the kindly but too eulogistic words with which you have handed to me the Wollaston Medal. For any services which I have been able to render to the cause of our favourite science I am mainly indebted to the enthusiasm with which, in my boyhood, the science itself inspired me. Geology early fascinated me, and she fascinates me still. She filled me with earnest desire to devote my life to her service, and so overmastering did this desire become that, although destined for a wholly different career, I was finally allowed to follow whither she led. That ardour has lasted ever since, and I am not conscious that it has yet begun to grow dim, even although sometimes one may perhaps feel the hills to be a little steeper and the miles a little longer than they used to be thirty or forty years ago.

But, passing from merely personal considerations, I receive this award with peculiar satisfaction, because I regard it as another link in the chain of mutual kindness and helpfulness which binds together this Society and the Geological Survey. Among the recipients of the Wollaston Medal I find the names of all my predecessors at the head of the Survey. That you should have added my name to the list is doubly gratifying, for it may, I trust, be taken as a proof that the feelings of cordial sympathy, which have so long united the two bodies, have not been weakened during my tenure of office. Survey men are proud of their connection with this Society, and they share, I know, in the gratification which this new expression of the Society's good will towards us cannot but create in our minds.

If anything could add to the personal pleasure of the award it would be that the medal should be placed in my hands by an old and valued friend like yourself. It is such little touches of human interest which warm and light up formal ceremonies like these. But there is a further source of satisfaction in the fact that while you, Sir, are President of the Society, you are also, at the same time, the worthy and honoured head of that great department of the National Museum which is specially consecrated to the cultivation of our beloved science. The Triple Alliance of the Society, the Museum, and the Survey is a league neither for offence nor for defence, but stands as a symbol of that brotherhood which unites the promoters of science in one common bond, and as a type of that union of the spirit of emulation with the spirit of co-operation to which the advance of Geological Science in this country is so largely due.

The President then presented to Mr. W. W. Watts, M.A., F.G.S., late Fellow of Sidney Sussex College, Cambridge, and now of the Geological Survey of England and Wales, the Balance of the Proceeds of the Wollaston Donation Fund, addressing him as follows:—Mr. Watts,—

In presenting to you the Balance of the Wollaston Fund the Council of the Geological Society desire to recognize the value of your work amongst the Igneous Rocks, both in the field and with the microscope.

Your papers "On the Igneous and Associated Rocks of the Breidden Hills" (1885), "The Igneous Succession in Shropshire" (1888), and "On the Geology of the Long Mountain" (1891), give evidence of your careful study of the stratigraphy and palæontology of the older Palæozoic rocks, and of the petrology of the igneous rocks associated with them.

Your observations on the Corndon dolerite showed, for the first time, that a mass of igneous rock presenting a definite laccolite-structure was to be found in this country.

The general results of your work are embodied in the important Memoir on "The Geology of South Shropshire," by Prof. Lapworth and yourself (published in the Proceedings of the Geologists' Association, 1894).

For several years you have rendered much valuable service as Secretary and Recorder of Section C, at the British Association.

Latterly you have devoted yourself more especially to the study of Igneous Rocks, and the Geological Survey is to be congratulated on having secured your services.

Mr. Watts, in reply, said:—Mr. President,—

I am deeply sensible of the honour conferred upon me by the Council in awarding me the Wollaston Grant, but I am overwhelmed by the feeling of my own unworthiness when I read the roll of distinguished men, including the President, who have previously received this award. It is a great pleasure to take it from the hands of one who has, throughout my career, shown me unvarying kindness and consideration; and my pleasure is further enhanced by the fact that at the same time my chief, Sir Archibald Geikie, receives the oldest medal granted by the Society. What work I have done has been largely due to the help and encouragement that I have received from Prof. Lapworth, with whom the paper on the Geology of South

Shropshire was written during last year. I think it is a subject for congratulation, not only within the ranks of the Geological Survey but outside them, that such candid statement of fact and such free discussion of opinion are, under its present direction, not only permitted but encouraged amongst the officers of that Survey.

In handing the Murchison Medal (awarded to Prof. Dr. Gustav Lindström, For.Memb.G.S.) to Dr. G. J. Hinde, V.P.G.S., for transmission to the recipient, the President said:—Dr. Hinde,—

The Council of the Geological Society have unanimously awarded the Murchison Medal to Prof. Gustav Lindström, F.M.G.S., of the State Museum in Stockholm, in recognition of his long and valuable services, extending over 46 years, devoted to the description of the fossil faunas of the Silurian System, in the classical district of Gotland. Thirty years ago Prof. Lindström settled the structure and affinities of that truly remarkable group of the Operculated Corals (1866, 1871, 1883) and the curious Brachiopod genus *Trimerella* (1868); he has dealt with the Silurian Corals of North Russia, Siberia, and North China, and described the Triassic and Jurassic fossils of Spitzbergen. His great work on the Silurian Gasteropoda and Pteropoda of Gotland merits special and honourable mention; as also his paper on the singular Cephalopod *Ascoceras* (1888–90). By his discovery of a fossil air-breathing Scorpion (*Palæophonus*) in the Silurian of Gotland he assisted to carry back land-animals into Silurian times. His Catalogue of Silurian Crustacea and of Swedish Fossils, and his labours to illustrate both the Crinoidea and Trilobita of Sweden (left unpublished by Angelin), must also be mentioned. Nearly all these memoirs have been simultaneously issued in Swedish and English, so that Prof. Lindström's works form really an integral part of our own literature.

These are, after all, but a few out of the many important researches which have occupied Prof. Lindström's long and laborious life. He is already a Foreign Member of our Society; now the Council desire to add the further recognition of his distinguished services to Geology by sending him this appropriate Medal, with their heartiest good wishes and regards.

Dr. Hinde, in reply, said:—Mr. President,—

I esteem it a privilege to have been asked by my friend, Prof. Lindström, to represent him on this occasion. He desires me to express his regret at his inability to be present in person, and he has forwarded to me a letter conveying his acknowledgments, which reads as follows:—

"Allow me to express my deeply-felt gratitude for the honour which the Council of the Geological Society have bestowed on me by the award of the Murchison Medal.

"It would not have been possible for me to receive a more appropriate and gratifying mark of approval of my labours in Silurian Palæontology than this, as I may, in truth, say that I owe to Sir Roderick Murchison the first stimulus to my palæontological studies. In 1845, when I was quite a boy, much wondering at the marvellous things I saw enclosed in the limestone-rocks of my native island of Gotland, Sir Roderick, accompanied by M. de Verneuil, visited the island and ranged its strata, along with the other old 'transition rocks' of Sweden, in his newly-founded realm, 'Siluria.' This fact acted on me as a fresh revelation, and indicated the path upon which to proceed.

"Later on in life, after having profited by the vast learning of my venerable friend and teacher, Prof. Sven Lovén, I visited London to study your splendid collections, and Sir Roderick was the first to show them to me and to introduce me to the Meetings of your illustrious Society. Thirty-four years are gone by since then, but who could ever forget the words heard within its precincts from such men as Lyell, Horner, Owen, Murchison himself, and other heroes of the science?

"My gratification at receiving the honour of the Murchison Medal is the more enhanced by its coming through your hands, Mr. President, whom I can claim as the oldest living acquaintance that I have in England, and to whom I moreover owe a great debt of gratitude for much kindness shown during a period of more than three decades."

May I be allowed to add, Mr. President, that, though Prof. Lindström's services to Palæontology—of which you have spoken so sympathetically—date back to a period nearly fifty years ago, yet they are by no means concluded, for since the announcement was made of the Council's intention to award this Medal there has appeared a paper by Prof. Lindström in the "Transactions" of the Royal Swedish Academy of Sciences, containing a description of a new species of fish from strata of Wenlock age in Gotland, which is claimed to be not only the most ancient fish, but the oldest vertebrate fossil yet discovered.

The President then presented the Balance of the Proceeds of the Murchison Geological Fund to Mr. Albert Charles Seward, M.A., F.G.S., addressing him in the following words:—Mr. Seward,—

The Council of the Geological Society have awarded to you the Balance of the Proceeds of the Murchison Geological Fund, in recognition of your work on Fossil Botany, and to aid you in your further researches in this field of investigation. Your early training in Vegetable Biology gives you a great advantage in the study of fossil plants, and your various papers during the past seven years, as well as the Catalogue of Wealden Plants upon which you are now engaged, and of which the first part is published, give promise of still more valuable results in the future, which I trust you may live to verify.

Mr. Seward, in reply, said:—Mr. President,—

In expressing my heartiest thanks to the Council of the Society for the Award which I have just received at your hands, I can only venture to hope that my future endeavours in the study of fossil plants may, to some extent, make amends for the insufficiency of my present claim to such generous recognition.

In the list of past recipients of the Murchison Award there are included the names of some of the pioneers of Palæontological Science, and it must always be my aim, as it is indeed my duty, to follow their example in the promising and rich field of research in which they so successfully laboured. I should like to add, Sir, that my thanks are due to you for the stimulus which you have given to my work. It was through your initiative that I was enabled to undertake the task of describing our Wealden flora, a work which I hope to complete with as much speed and accuracy as may be.

In handing the Lyell Medal (awarded to the Rev. J. F. Blake, M.A., F.G.S.) to Prof. J. W. Judd, F.R.S., V.P.G.S., for transmission to the recipient, the President addressed him as follows:—Prof. Judd,—

The Council have awarded the Lyell Medal to the Rev. J. F. Blake, in recognition of the valuable services which he has rendered to Geology and Palæontology by his zealous and disinterested labours during the past quarter of a century. In that important work on "The Yorkshire Lias," by Prof. Ralph Tate, F.G.S., and himself, published in 1876, he gave the first detailed account of the palæontology of the successive stages of the Lias, with records of the stratigraphical characters of each. He furthermore described and figured many of the organic remains, and especially the Cephalopoda, which then, as in later years, attracted his attention.

Continuing for a while to devote himself to the study of the Jurassic rocks, Mr. Blake communicated to this Society papers on the Kimeridge Clay and on the Portland Rocks; and (together with Mr. W. H. Hudleston, F.R.S.) an elaborate memoir on the Corallian Rocks of England.

Mr. Blake's Monograph on British Fossil Cephalopoda from the Palæozoic rocks (1882) deserves especial mention.

In later years he has wandered in many fields among the older Palæozoic and Metamorphic rocks—ever and anon seeking relief among less ancient deposits.

In his "Annals of British Geology," of which three volumes have appeared (1890–92), Mr. Blake has laboured most industriously to render further service to Geological Science.

Will you convey to Mr. Blake, with this Medal, our most sincere wishes for his health and for the success of his mission to Baroda? In India he will doubtless gather fresh stores of geological knowledge, the acquisition of which has been his happiest pursuit in life.

Prof. Judd, in reply, said:—Mr. President,—

I cannot but regret that the recipient of this Medal is not able to be with us this afternoon, and to hear the graceful terms in which you have spoken of his work. Mr. Blake has been called away to India, to discharge important duties there, and I cannot but feel that his exile from home will be rendered more tolerable by this recognition of his past work and by the assurance, which this Award will surely convey to him, that his numerous friends in this country are not unmindful of him. He has asked me to "represent to this Meeting what solid satisfaction the Award gives him," and he requests me to add that "any geological work I have done, or may be doing, has never been done for the sake of honour, but, as Prof. Lodge once said, 'if a man feels that he has a call for any line of research, he is bound to obey it, and woe to him if he fails to do so. Necessity is laid upon him!' In the rough and tumble of the work, it is often a matter of doubt whether the call has been rightly obeyed, and whether the work is as good as it should be. As against such discouragement, this Award will always remain a bulwark. It will be a perpetual reminder that my co-workers sympathize with me, and appreciate every effort at its full, or more than its full, value."

The President then presented one-half of the Balance of the Proceeds of the Lyell Geological Fund to Mr. Percy Fry Kendall, F.G.S., and addressed him as follows:—Mr. Kendall,—

Some twelve years ago your attention was directed to the study of the fossils of our English Crags, and in 1886, in conjunction with the late Robert Bell, F.G.S., you gave to this Society an excellent account of the fauna of the newly-discovered Pliocene beds of St. Erth in Cornwall. Since then your observations have been concentrated chiefly on Glacial deposits, and in elucidating some of the difficult problems connected with their origin. I would especially call attention to your very full and careful account of the Glacial Geology of the Isle of Man (1894), in which you have shown yourself a most enthusiastic and painstaking geologist. The Council desire your acceptance of this moiety of the Lyell Fund—which may serve to attest their appreciation of your scientific labours.

Mr. Kendall replied in the following words:—Mr. President,—

The honour which the Council of the Geological Society have conferred upon me was entirely unexpected, as I have not as yet ventured to submit any of the results of my work upon the superficial deposits of our country to the ordeal of criticism in this room.

I have had in my career the good fortune to be brought under the influence of two Fellows of the Geological Society, to whose inspiration and example I owe more than words of mine can express, and by whom I have been directed into fields of enquiry that have yielded me subjects of study of constant and absorbing interest.

The late Mr. Robert G. Bell, whose unobtrusive, and for the most part unpublished, labours are known to but few, gave me a training in Upper Tertiary Palæontology which I have found of priceless value in the study of the more recent deposits. To the late Prof. H. Carvill Lewis, moreover, I owe a deep debt of gratitude for awakening in me, during a too brief intercourse, an interest in the complicated and fascinating problems of Glacial Geology.

The Award of a moiety of the Lyell Fund I gratefully accept as an assurance from my brother geologists that my observations have been of some help in advancing the science, though they have led me to conclusions which are not generally adopted. Thus encouraged I shall return to my pleasant labours animated by a new zeal.

The President then handed the other moiety of the Balance of the Proceeds of the Lyell Geological Fund (awarded to Mr. Benjamin Harrison, of Ightham) to Prof. T. Rupert Jones, F.R.S., F.G.S., for transmission to the recipient, and addressed him as follows:—Prof. Rupert Jones,—

The Council of the Geological Society desire to express to Mr. Benjamin Harrison their appreciation of his earnest labours carried on for more than fifteen years in the neighbourhood of Ightham, resulting in the remarkable discoveries of Palæolithic Flint Implements of special character lying on the surface of the plateau at all levels up to nearly 600 feet above the sea. Some idea of their abundance may be formed from the fact that Mr. Harrison has collected more than 400, within a radius of five miles of Ightham.

Mr. Harrison's discoveries in the Plateau-gravels of Kent have resulted in important communications from Prof. Prestwich to this and other societies, and I now beg you to convey to Mr. Harrison this Award, as a slight testimony of the interest which the Council have taken in his work, and of their desire to aid him therein.

Prof. Rupert Jones, in reply, said:—Mr. President,—

I shall have very great pleasure in conveying this Award to Mr. Benjamin Harrison, and with your permission I will read the following note which I have received from him:—

"It is difficult for me to express my thanks for the honour conferred upon me, and for the kind words of the President.

"At first I carried on my geological investigations almost alone, but was encouraged by Professor Prestwich and Sir John Evans; and my work soon developed into a systematic search for Flint Implements in the Valleys of the Shode, Medway, and Darent, and more recently on the Chalk Plateau.

"Some of the Stone Implements thus found, which were used by an ancient Kentish people, are so rude that it is with diffidence that, by some persons, they have been accepted as the handiwork of Man. But it is an evidence of the great interest which they create that, while the question of their origin has been a subject of doubt in some quarters, the Society has on this occasion and in this manner encouraged further search for these geological relics.

"This chapter in the early history of mankind is yet very fragmentary, but I confidently anticipate the discovery and careful study of further material for its completion by some of the many distinguished observers who have interested themselves in the subject."

In handing the Bigsby Medal to the Hon. T. F. Bayard, Ambassador of the United States, for transmission to Charles D. Walcott, Esq., F.G.S., Director of the United States Geological Survey, the President addressed him as follows:—Sir,—

It was the desire of the late Dr. J. J. Bigsby, F.R.S., the founder of this Medal, that it should be awarded biennially, "as an acknowledgment of eminent services in any Department of Geology—irrespective of the receiver's country."

Moreover, "the recipient must not be older than 45 years last birthday." It therefore appeared to the Council of the Geological Society to be peculiarly appropriate to present it to-day to Mr. C. D. Walcott, the Director of the United States Geological Survey, who is now in his 45th year. This is also the fourth occasion upon which this Medal has been transmitted to eminent Geologists in America, where so many of Dr. Bigsby's own researches were carried on.

Few men have attained to a more distinguished position in Geology, or have achieved a larger share of original work in twenty years, than Mr. Walcott. He long held the post of Palæontologist on the U.S. Geological Survey; then that of Chief Geologist; and lastly he has been appointed Director.

As palæontologist, Mr. Walcott laboured most assiduously for many years at the investigation of the structure and organization of the Trilobites, and was the first satisfactorily to show, by means of thin sections, the limbs and branchial appendages of these Palæozoic Crustacea. The accuracy of his work has been largely confirmed by the subsequent discoveries of Trilobites showing limbs from the Lower Silurian of Rome, New York.

As a stratigraphical geologist, Mr. Walcott has contributed many papers to science, but his most exhaustive labour has resulted in the production of his great Monograph on the fauna of the Lower Cambrian, or "*Olenellus*-zone," which defines most clearly a remarkable series of rocks, containing the oldest fossil fauna yet discovered, and capable of being paralleled and identified by its fossils nearly all over the world.

These ancient rocks contain no fewer than 59 genera and nearly 150 species of organisms, from sponges, corals, and trilobites to mollusca; and this assemblage of genera appears to be extremely constant over widely-separated areas of the earth's surface.

Do me the favour, Sir, to convey this Medal from the Council of the Geological Society to Mr. Walcott, in token of the admiration with which we regard his work as a geologist, and as expressive of the warm sympathy and attachment existing between English and American men of science to-day.

The Ambassador of the United States replied as follows:—Mr. President,—

There is but a single drawback to my pleasure on this occasion, and that is the absence of my fellow-countryman, Dr. C. D. Walcott, whose merits, and services to science, you have so generously recited, and by this Medal have so fittingly rewarded.

Dr. Walcott has been awarded this Medal *ex debito justitiæ*—not merely *honoris causa*—and I feel the greatest satisfaction that I should have been deputed by him to receive it in his name and stead, and permitted by your courtesy so to act for him.

The gratification of Dr. Walcott will be sincere, and his feelings may be best expressed by the couplet—

"Praise from such lips 'tis mine with joy to boast—
They best can give it who deserve it most."

And the gratification will not be confined to him, but throughout that broad land it will extend among his countrymen, who will be proud and well pleased to see merit recognized, and honour bestowed upon one of that country's deserving sons.

And I must personally acknowledge more than my equal share of the pleasure that I feel in the bestowal of the honour, for I am here as the Envoy of my Country—and especially charged with the maintenance of friendship, good will, and confidence between the people of both nations—so that, when I realize the service performed by such an occurrence as this in swelling the current of good understanding and friendship between the peoples of the two countries, my sense of obligation to your Society and its Fellows is sensibly strengthened.

For my fellow-countryman I receive this mark of distinction—and in his name, and in the name of his country, and for myself, I return you thanks.

The President then proceeded to read his Anniversary Address, in which he first gave Obituary Notices of several Fellows and Foreign Members deceased since the last Annual Meeting, including the Chevalier Dr. Josef Szabó (elected a Foreign Member in 1884); M. Gustave Honoré Cotteau (elected a Foreign Member in 1891); Prof. George Huntington Williams (elected Foreign Correspondent in 1892); William Pengelly (elected in 1850); William Topley (elected in 1862); Henry Bean Mackeson (elected in 1844); the Rev. Edward Hale, Joseph Bickerton Morgan, Lord Swansea, better known as Sir Hussey Vivian, Bart. (elected in 1850); and James Adey Birds.

He congratulated the Fellows upon the completion of the 50th volume of the Quarterly Journal, and the preparation of an Index for fifty years (now in progress).

He referred to the generally satisfactory state of the Society's affairs, to the desirability of extending the Library, and the inutility of any longer maintaining a Museum, the space occupied by which was needed for books. On the subject of finance the President expressed the opinion that sufficient funds had been invested to safeguard the interests of the Society. He alluded to the loss sustained by the retirement of Prof. Wiltshire, who had held the office of Treasurer for thirteen years. He also commended to the Fellows the Council's selection of Dr. Blanford to succeed him in that office, as likely to be very beneficial to the Society. The President advocated the desirability of admitting ladies to the Evening Meetings of the Society, and referred to a number of instances in other Societies where a similar privilege had been accorded to them.

He then proceeded to give a brief summary of *Some Points in the History of the Crustacea in Early Palæozoic Times.* Referring largely to the papers and Memoirs published during the past thirty years, and more especially to those in the Society's Quarterly Journal, he described the researches of Salter, Hicks, Woodward, Lapworth, Linnarsson, Holm, Brögger, Schmidt, Peach and Horne, and of C. D. Walcott.

Referring to the search for the limbs in Trilobites, he mentioned the discoveries of Billings, Mickleborough, Matthews, Vaillant, C. E. Beecher, and C. D. Walcott, of H. M. Bernard, and others. Under the Phyllopoda and Ostracoda he referred to the researches of Packard, Salter, Rupert Jones, Woodward, M'Coy, Barrande, and Clarke, dwelling specially on the recent genus *Nebalia.* He alluded also to the lifelong labours of Prof. Rupert Jones on the Ostracoda. He hoped next year to complete the newer Palæozoic and the Secondary and Tertiary Crustacea.

This portion of the address was illustrated by diagrams of various forms of Palæozoic Crustacea.

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.; Prof. W. Boyd Dawkins, M.A., 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.; R. S. Herries, 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.; R. Lydekker, Esq., B.A., F.R.S.; Lieut.-General C. A. McMahon; J. E. Marr, Esq., M.A., F.R.S.; H. A. Miers, Esq., M.A.; E. T. Newton, Esq., F.R.S.; F. Rutley, Esq.; J. J. H. Teall, Esq., M.A., F.R.S.; W. Whitaker, Esq., B.A., F.R.S.; Rev. H. H. Winwood, M.A.; H. 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.; W. H. Hudleston, Esq., M.A., F.R.S.; R. Lydekker, Esq., B.A., F.R.S.; Lieut.-General C. A. McMahon. *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*: W. T. Blanford, LL.D., F.R.S.

II.—February 20th, 1895.—Dr. Henry Woodward, F.R.S., President, in the Chair. The following communications were read:—

1. "Contributions to the Palæontology and Physical Geology of the West Indies." By J. W. Gregory, D.Sc., F.G.S.

The earlier part of the paper is largely concerned with the corals of the raised reefs of Barbados, and, on account of the confusion in the synonymy of the West Indian corals, the synonymy of the species is given in some detail. A list of the mollusca of the Low-level Reefs follows.

The occurrence of the "Oceanic Series" of beds over wider areas than generally recognized is proved by the existence of Radiolarian Marls in Cuba, as announced in the discussion on Messrs. Jukes-Browne and Harrison's paper (Q.J.G.S. vol. xlviii. 1892). The author gives a list of species of Radiolaria from the Cuban deposit, all of which are also found in that of Barbados. Additions to the fossil fauna of Antigua are recorded.

In discussing the age of the Barbados rocks, the author states that there is now no doubt that the following is the sequence :—

Raised Coral Reefs...	Low-Level: Pleistocene. High-Level: Pliocene.	
Oceanic Series.........	*Archæopneustes-abruptus*-limestone. Thalassic Marls.	Miocene (and possibly partly Pliocene) and partly Oligocene.
Scotland Beds............	Oligocene (probably Lower).	

The fauna of the Low-level Reefs proves their late Pleistocene age. Until more mollusca are collected from the High-level Reefs, it will not be possible to decide whether the whole are Pleistocene, or whether some must be included in the Pliocene; it is probable that the latter will have to be done. The Scotland Beds are referred to the Oligocene. This narrows the limit for the time of formation of the deep-sea oozes. Further light is thrown on this question by examining the evidence for the period of submergence of the Panama Isthmus, from consideration of the resemblances of the marine faunas on either side, and the earliest migrations of terrestrial animals across the Isthmus since its elevation. He puts the period of final emergence of the peninsula in Miocene, or late Oligocene times, and maintains that there is no evidence of the connection of Atlantic and Pacific in this region since then.

He gives reasons for supposing that a subsidence of the Caribbean Sea was simultaneous with this emergence of the Isthmus, and that this subsidence plunged part of the area now occupied by land into abysmal depths in which were deposited the deep-sea oozes of Barbados, Trinidad, and Cuba. In some part of the Miocene or Pliocene re-elevation began, and shallower-water deposits (the *Archæopneustes*-limestone) were laid down. Elevation continued, resulting in the formation of coral-reefs and their final uplift to different levels above the sea.

2. "Whitehaven Sandstone Series." By J. D. Kendall, Esq., F.G.S.

The Whitehaven Sandstone, with its associated shales, is a purple-gray deposit sometimes having a thickness of 500 or 600 feet. The author gives details of many sections of the series, which also contain thin coal-seams and occasionally *Spirorbis*-limestone.

He combats the view that it is stained Middle Coal-measure deposit, and gives his reasons for believing that it rests unconformably upon the Middle Coal-measures, and also that it has not received its colour by abstraction of colouring-matter from the Permian beds, but that the colour actually belongs to the deposit. He describes sections which show that the deposit has a wider distribution over the Cumbrian district than is allowed by previous writers.

3. "Notes on the Genus *Murchisonia* and its Allies, with a Revision of the British Carboniferous Species, and Descriptions of some New Forms." By Miss J. Donald.

The generic characters of *Murchisonia* as now defined are given in the paper, and the various divisions of the genus are examined, including four which appear to be intermediate between *Murchisonia* and *Pleurotomaria*.

The Carboniferous species of the genus are revised and eleven new forms described, raising the total number of known Carboniferous forms to about forty.

III.—March 6th, 1895.—Dr. Henry Woodward, F.R.S., President, in the Chair. The following communications were read:—

1. "A new Ossiferous Fissure in Creswell Crags." By W. L. H. Duckworth, Esq., and F. E. Swainson, Esq. (Communicated by Prof. T. McK. Hughes, M.A., F.R.S., F.G.S.)

The fissure explored by the authors is about 30 feet above the level of the artificial lake at Creswell Crags. At the top occurred a white earth (with human and other remains), passing down into a red sand with remains of fox, badger, roe-deer, and other mammals. Beneath the latter deposit, and separated from it by a fairly sharp line of demarcation, came the cave-earth proper, with Palæolithic implements and bones of *Rhinoceros tichorhinus*, *Bison priscus*, *Ursus spelæus*, *Hyæna crocuta* var. *spelæa*, and *Cervus tarandus*.

The authors suppose that this cave-earth is derived from an older deposit and has been transported to its present place by water, though there is evidence that the transport has been from no great distance. Consequently they followed the fissure inwards, until brought to a stop by a mass of travertine, which they penetrated with a small hole. They hope to explore the fissure beyond this travertine on a future occasion.

2. "Notes on the Chemical Composition of some Oceanic Deposits." By Prof. J. B. Harrison, M.A., F.G.S., and A. J. Jukes-Browne, Esq., B.A., F.G.S.

The authors formerly experienced great difficulty in comparing their analyses of the Oceanic Deposits of Barbados with those of modern oozes made by Dr. Brazier. Since then Dr. Murray has placed samples of recent Red Clay and *Globigerina*-ooze at their disposal, and these were analysed by Prof. Harrison and Mr. John Williams.

The results of analysis of the Red Clay were arranged as follows: Argillaceous constituent 67·85 per cent., pumiceous matter 23·26 per cent., organic constituents 5·88, and adherent sea-salts 3·61 per cent. The authors found that the argillaceous constituent was not a mixture of an orthosilicate of alumina and hydrated peroxide of iron, having the proportion of silica to alumina as 14 to 12, but a more highly silicated compound in which the proportions were as 33 to 12. It was in fact a ferruginous earth, such as would result from the decomposition of palagonite and of a basic volcanic glass, fragments of which were frequent in the Pacific red clays. The pumiceous matter was the débris of an acid pumice containing 7 per cent. of soda, and apparently therefore the pumice of a soda-felsite. Comparing the analyses of the recent Red Clay with those of Barbadian red clays, they find the differences to be such as would result from mixtures of the palagonitic earth with various acid and basic pumices. A mixture of the palagonitic earth with the pumiceous dust which fell on Barbados in 1812 would have a composition closely corresponding to that of the Oceanic Clay of Barbados.

The recent calcareous ooze closely resembles the more calcareous "chalks" of the Barbadian Oceanic Series, but the latter contained much colloid silica and fine clay. The differences between the analyses of the recent ooze and of English chalk, when certain allowances are made, were found to be but small. The recent calcareous ooze contained many more *Globigerina*-tests than Tertiary or Mesozoic chalks, but it is suggested that this is due to our possessing only the surface-layers of the *Globigerina*-ooze.

In one important respect all the different kinds of deposit which were examined resembled one another, namely, in the infinitesimally small quantity of quartz which they contained.

The authors' examination of the recent oceanic deposits, and a comparison of them with the raised Barbadian deposits, only increased their conviction that the latter were of truly oceanic origin.

CORRESPONDENCE.

LOWER GREENSAND FOSSILS IN KENT.

Sir,—I am indebted to Messrs. Jukes-Browne, Monckton, and Leighton for calling my attention to an unfortunate omission in Part V. of the paper published in the March Number of the Geological Magazine. The word "Eastern" was omitted from before England in line 22 from top of page 101. Six times on that page it is repeated that attention is being restricted to the area "of Guildford and Dorking," "the line between Guildford and Godstone," "the line between Guildford and Caterham," "the London area or to the south of it," etc. I had never thought of questioning the occurrence of *Hoplites interruptus* in Wiltshire or even the West of Surrey. It is recorded from Devizes in the paper of Mr. Jukes-Browne, quoted on the same page; good specimens from that locality are exhibited in the show-cases both at Jermyn Street and in the British Museum (Natural History). That this species as well as the lower *Ac. mammillare* should reappear to the West of Guildford area, in association with the Lower Greensand outliers, appeared inevitable.

Mr. Leighton has sent me four fragments of an Ammonite from Westcott, which are no doubt referable to *Hoplites interruptus*. Mr. Leighton has therefore obtained the fossils "from the very base of the Gault in Eastern Surrey," without which, as it is said in the paper, "no final answer to the question discussed in Part V. can be given." Mr. Leighton has fortunately found there a nodule bed at the base of the Gault. It appears to be at the very base. The *Ac. mammillare* zone is therefore still absent; so that the replacement or thinning out of the *mammillare* and *interruptus* zones in the area of London and to the south of it, has in the Dorking district only affected the former, and not both of them. If the *mammillare* zone be included with the Gault, as seems now generally agreed, then the conclusion of the fifth part of the paper, that "the commencement of the 'epoch' of the Gault is represented not by the base of the fossiliferous clays, but by some part of the non-fossiliferous sands now included in the Lower Greensand," is quite valid. Mr. Leighton's discovery of the nodule bed at Westcott proves, however, that the extent to which this is the case was exaggerated in the paper.

March 11, 1895. J. W. Gregory.

ON *PINITES HEXAGONUS*, CARRUTHERS.

Sir,—I desire to correct the statement in the foot-note, relating to my paper at a recent meeting of the Geological Society, referred to on page 102 of Dr. Gregory's paper.[1] I said at the meeting that the specimen had been sent to Mr. Carruthers some months before for determination, and that he at once replied (on May 25, 1894) that it appeared to agree with a specimen he had described from the Gault of Eastware Bay, sent to him by Mr. Starkie Gardner, but if I would explain the exact horizon of Mr. Mangles' specimen he would look further into the matter. That I did, and but for unforeseen circumstances Mr Carruthers' note would have been in the hands of the meeting. The species has *not yet* been determined, but no doubt it is one of those which have been recorded from the Gault.

I think it is a pity that Dr. Gregory has included unfossiliferous beds, about which we have no relative evidence, in the table on page 100 of his paper. Of course, if we were under obligation to divide the Lower Greensand into divisions, fossils or no fossils, the Survey classification could be retained by simply placing the Leith Hill Cherts and Dorking Clayey Sands, into which they pass, in the Sandgate Beds. As to the latter of these (the Clayey Sands), this was suggested in 1892 by Professor Boulger and myself, and two years later by Mr. F. Chapman. Were it necessary, other difficulties brought out by detailed mapping could be similarly dealt with. Looking at Dr. Gregory's table, one is inclined to enquire, since he deals with the Leith Hill Cherts, where the Reigate-Tilburstow Hill Cherts are to be placed? Thos. Leighton.

March 5, 1895.

GAULT AND LOWER GREENSAND.

Sir,—Dr. Gregory's paper on some fossils from the Lower Greensand of Great Chart, in Kent, is a welcome contribution to the classification of the Lower Cretaceous series of the Wealden area. His views with regard to the general grouping together of the Sandgate Beds, Bargate Beds, Fuller's Earth, and Farringdon Beds coincide with a conclusion I came to some years ago. His subdivision of the whole series into three instead of four, and his correlation of the two upper groups—the (1) Folkestone and Sandgate, and (2) the Hythe Beds—with the Aptian of the continent, is exactly the arrangement I suggested in this Magazine nine years ago.[2]

[1] Geol. Mag. March 1895.

[2] Geol. Mag. 1886, Dec. III. Vol. III. p. 316 *et seq.*

Whether it is desirable to introduce the term Aptian into English nomenclature is another question, into which I forbear from entering. The suggestion that some part of the Folkestone sands may be equivalent to the basal part of the Gault made by my friend Mr. Strahan in the Geological Survey Memoir on the Isle of Wight, second edition, 1889. It will no doubt be decided by future investigations, but I must be allowed to point out that it stands on very different ground from the equivalency of the Upper Gault and Upper Greensand. That has been established by palæontological evidence, the other has not.

One more word as a caution, and this is that the numerous zones into which the Folkestone Gault has been divided cannot all be recognized elsewhere: I do not think the Lower Gault generally can be divided into more than *two* zones, those of *Ammonites interruptus* and *Amm. lautus*. A. J. Jukes-Browne.

OBITUARY.

JOHN WHITAKER HULKE, F.R.S.,

President of the Royal College of Surgeons of England; Foreign Secretary of the Geological Society of London.

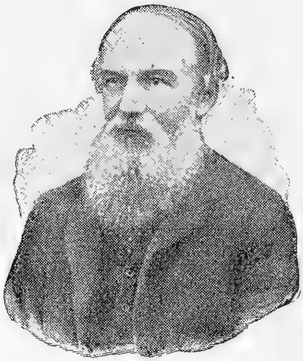
Born November 6th, 1830. Died February 19th, 1895.

Geologists, both at home and abroad, indeed, men of science generally, will have learned with deep concern of the death of Mr. J. W. Hulke, the Foreign Secretary of the Geological Society, the President of the Royal College of Surgeons of England, and Senior Surgeon to the Middlesex Hospital.

Viewed as a surgeon, Mr. Hulke had a career of singular distinction as well as of wide range. But he was also a most accomplished geologist and palæontologist. He was a learned Shakespearian; also an excellent linguist, and while keeping up a more than ordinary acquaintance with the classics, he was a fluent and accurate French and German scholar, and possessed also a knowledge of Italian. He was a first-rate botanist, both in the lecture-room and the field, as may be seen from the opening half of the Hunterian Oration this year, which illness prevented him from delivering. He was an excellent diagrammatic artist, painted in water-colours, and was not unskilled in modelling.

John Whitaker Hulke was born on November 6th, 1830, being the elder son of a well-known and widely respected general practitioner at Deal. The original family name was Hulcher, his ancestors being Dutch by origin, who had escaped from Holland during the Spanish persecutions under Philip II. and Ferdinand, Duke of Alva, and settled on the Kentish coast. There for some two hundred years they have followed the vocation of medicine. He was educated at King's College School, and at Neuwied, in Germany, and at the age of nineteen entered the medical school of King's College, where he was a dresser to Mr. (afterwards Sir) William Bowman, and house surgeon to Sir William Fergusson.

It was while he occupied this position that he attended the Duke of Wellington in his last illness, his father being the Duke's regular medical attendant and obtaining leave to avail himself of his son's services as assistant. In 1854, when the Crimean War broke out, he was early to volunteer, and at the beginning of 1855 was appointed assistant surgeon to the British Civil Hospital at Smyrna.



J. Whitaker Hulke, F.R.S., For. Sec. Geol. Soc. Lond.[1]

Thence he was sent to Sebastopol, and in that awful campaign of irremediable sickness, gross mismanagement, and gallantry as often as not ineffective, bore himself, in the opinion of everyone, with patient courage as a brave soldier. On his return from the East he became medical tutor of King's College Hospital, and having previously been elected a Fellow of the Royal College of Surgeons of England, was appointed in 1858 assistant surgeon to Moorfields Hospital. He had previously been elected assistant surgeon to King's College Hospital, where, having duly served his allotted period, he was appointed, together with Dr. Charles Murchison, a colleague at King's, to the Middlesex Hospital, of which institution he was the senior surgeon at the time of his death.

Mr. Hulke's earliest mark was made in Ophthalmology. He obtained the Jacksonian Prize of the Royal College of Surgeons of England for an Essay on the Morbid Changes of the Retina; his Treatise on the Use of the Ophthalmoscope (1861) formed an excellent introduction for most of the profession to the new system of intra-ocular examination; his Arris and Gale Lectures delivered before the Royal College of Surgeons of England, and subsequently published, dealt with the Minute Anatomy of the Eye. Mr. Hulke was made a Fellow of the Royal Society in 1867, in recognition of the value of his papers on the Anatomy of the Retina in Amphibia and Reptiles. But although so highly and widely recognized as an authority on the eye, Mr. Hulke was no less esteemed by the profession as a general surgeon, and the record of his work in the wards of Middlesex Hospital remains a monument to

[1] Reproduced from the *Lancet* by permission. We are also indebted to this paper for the greater part of this obituary notice.—Edit. Geol. Mag.

his skill and patience. He was a pioneer in cerebral surgery, though all the teaching of his masters must have biassed him to look upon interference with the brain as a very serious matter. As an operator he was admirably careful, and his intimate anatomical knowledge counted for something in the marked caution of his procedure. As a clinical teacher he had few, if any, equals in London. He was lucid, learned, and simple. Where a point required exposition he was certain to know everything that could be said, but he was never tempted into needless display of erudition, and never talked for talking's sake.

We have briefly referred to Mr. Hulke's knowledge of botany, but his position as a geologist merits more extended mention here. He was one of the first authorities on vertebrate palæontology. Out of about fifty papers which he contributed to scientific societies thirty-three relate to fossil Reptilia. Of these the most important are on *Hypsilophodon Foxii*, from the Wealden of the Isle of Wight (Quart. Journ. Geol. Soc. 1873–74, and Phil. Trans. 1882–83); *Polacanthus Foxii*, Hulke (Phil. Trans. 1881–82); on *Ornithopsis Seeleyi* (Quart. Journ. Geol. Soc. 1879, 1882); on Dinosaurian remains from the Kimeridge Clay of Northamptonshire (Quart. Journ. Geol. Soc. 1887); on a maxilla of young *Iguanodon* (Quart. Journ. Geol. Soc. 1886); the shoulder-girdle of Ichthyosauria and Plesiosauria and Recent contributions to the skeletal anatomy of the Dinosaurs (Presidential Addresses Geol. Soc. 1883–84). From 1882 to 1884 he was President of the Geological Society; in 1887 he received the Wollaston gold medal, the highest award which is in the power of the Society to bestow; and from 1890 to his death he was the Society's Foreign Secretary. He has left behind him a large collection of specimens, mostly obtained with his own hands from the Undercliff in the Isle of Wight. His collection has just been presented to the British Museum (Nat. Hist.) by Mrs. Hulke, in memory of her husband.

Few men have held more official posts than Mr. Hulke. At the time of his death he was President of the Clinical Society of London. It may not be out of place to repeat here the words of the retiring President, Sir Dyce Duckworth, when inducting his successor: "You have elected to-night as my successor one whom we all respect and acknowledge as a master of the surgical art, one whose modesty, rectitude, and fearlessness are only equalled by his skill and kindness of heart. Mr. Hulke, will, I feel sure, add lustre to the post he comes to fill." From 1886 to 1887 he was President of the Ophthalmological Society, and he had also been President of the Pathological Society of London, and had been for many years, and was, at the time of his death, librarian to the Royal Medical and Chirurgical Society. He was elected President of the Royal College of Surgeons, England, in 1893, in succession to Mr. Bryant, having been a Vice-President from 1888. He was a member of the Court of Examiners for ten years from 1880. His greatest work in connection with the Royal College of Surgeons was, undoubtedly, the formation of the Research Laboratory of the Conjoint Board. The scheme for this was Mr. Hulke's, and he was Chairman of the Joint Laboratories Committee from its foundation. The work that has been done and is now doing there speaks sufficiently for the wisdom of the scheme. At the Royal Society, of which he was elected a Fellow in 1867, he served on the Council during 1879, 1880, 1888, and 1889; and was also a member of the Scientific Relief Committee. His communications to the Transactions of the Society were numerous, and the last of them was read before the Society on May 12th, 1892—"On the Shoulder-girdle in Ichthyosauria and Sauropterygia."

His strict devotion to duty was no doubt answerable for his death. He took no holiday during the past year, his time being too occupied to permit him to do so, and the incessant and acute strain was telling upon him at Christmas. This much he admitted. On the night of Thursday, Feb. 7th, a terribly bitter night, he was summoned to the hospital to operate upon a case of strangulated hernia, from which he did not return until 3.30 a.m. On the following day he had a little bronchitis, but did not keep his bed. Indeed, he operated on Saturday at the Middlesex Hospital on a case of cerebral abscess, and went to the wards again on Sunday (Feb. 10th) and Monday (Feb. 11th). But later in the day he had to recognize that he was seriously ill, and the bronchitis increasing, pneumonia supervened, and he died on Tuesday, Feb. 19th, about noon.

> "His life was gentle; and the elements
> So mix'd in him, that Nature might stand up
> And say to all the world, This was a man!"
> *Shakespeare.*

JAMES ADEY BIRDS, B.A., F.G.S.

Born November 9th, 1831. Died December 15th, 1894.

James Adey Birds was descended from an old Derbyshire family, the Birds of Locko, Stanton Hall, and Bakewell, Derbyshire. He was the son of the Rev. W. T. Birds, and was born November 9th, 1831, at Preston Rectory, Salop. He was educated at Rugby, and graduated at Christ Church, Oxford. He took a deep interest in geology, was a careful observer of geological facts, and communicated several papers to the Geological Magazine between 1866 and 1881, notably on "A bed of Chalk-flints near Spa, Belgium" (1866), on the "Post-Pliocene formations of the Isle of Man" (1875), on the "Geology of the Channel Islands" (1878), "'Beekite' in the Channel Islands" (1879), "Foreign Pebbles on our South Coast" (1881), etc.

Mr. Birds was elected a Fellow of the Geological Society in 1878. He was a good classical scholar and linguist, and prepared an English rendering of Goethe's "Faust" (published by Longmans in two volumes in 1880).

He formed an excellent geological collection, which he bequeathed to the borough of Derby, the chief town of the county where his ancestors had so long resided. He died at West Bournemouth, on December 15th, 1894, in his 64th year.

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No. V.—MAY, 1895.

ORIGINAL ARTICLES.

I.—Notes on the Geology of Mashonaland and Matabeleland.

By J. A. Chalmers, A.R.S.M., and F. H. Hatch, Ph.D., F.G.S.

Introduction.

THE history of the Zambesian territories now known as "Rhodesia" is extremely meagre. Of the country prior to the advent of the Matabele in 1838, little is known, except from the few records, chiefly Portuguese, that have been preserved. It should be mentioned, however, that an interesting link between the Sofala and the Zimbabwi ruins near Victoria exists in certain gold tacks or rivets, possibly used in the manufacture of gold ornaments, which have been found in both these places, while we believe that at intervals along a route to the coast, ruins of towers have been found, that in all probability have been used as stations on the way.

That Zimbabwi, near Victoria, and similar ruins in other parts of Central South Africa are relics of the greatest antiquity, is generally accepted, and it is also probable that a search after gold was the main object of the adventurous and enterprising people, not South African, who were in possession. The massive structure of the ruins, laboriously composed of regular square granite blocks, not much larger than bricks, together with the general design and elaboration, foreign to Negro creations, impress one with the idea that a masterful invading race dominated the enslaved aborigines.

One portion of the Zimbabwi ruins of Victoria was probably a temple, the other a stronghold or keep such as might have been necessitated by the partial and unstable nature of the sway exercised by the invaders.

It is probable that in later times, even within the last century, the Portuguese had settlements in Mashonaland, and that they both carried on mining operations themselves, and traded for gold won by the natives. In the north, at Tete, on the Zambesi, alluvial gold can still be purchased from the natives. The gold is collected by them in reeds.

The later facts of history are briefly as follows :—Mosilakatse, driven from the Transvaal by the Boers in 1837, crossed the Limpopo, and by dint of his warlike propensities, and the valour of his Zulu followers, established in the course of three years a mastery over the greater part of Central South Africa between the Limpopo and Zambesi Rivers, creating the Matabele supremacy. This supremacy he and his son and successor, Lobengula, maintained until the series of events following the formation of the British South African Company culminated last year in the Matabele war, the overthrow of Lobengula, and the occupation of Matabeleland by the adventurous and plucky 800 who advanced to Buluwayo.

Topographical and Physical Features.

The area of Matabeleland and Mashonaland, now consolidated, is upwards of 135,000 square miles. The territory has no seaboard. The nearest coast is that of Mozambique, Sofala being about 108 miles, and Beira 160 miles from the border. The eastern boundary as regards Portuguese territory has not yet been finally agreed upon. It is probable that it will be about the 33rd degree of east longitude, with a tongue projecting westward to include Masse-Kesse in Mozambique. Some distance south of Masse-Kesse the boundary trends westward, ending about the intersection of the Limpopo River and 32 east longitude. The western boundary of Matabeleland proper is indefinite, but the Chartered Company's rights, so far as the British Government is concerned, are co-extensive with the British sphere of influence, between the Limpopo and the Zambesi, exclusive of Bechuanaland, reaching as far as longitude 25 E. The backbone or "hogs-back" of the country is formed by an irregular belt of high plateau land, or high "veldt" as it is termed in South Africa, with an altitude varying from 3500 to 5000 feet. This belt, embracing the most salubrious portions of Matabeleland and Mashonaland, stretches from south-west of Buluwayo, in a north-easterly direction to Umtali in Manicaland, passing just north of Victoria, but including Salisbury. It forms the main divide of the river systems of the country, being the source of the tributaries of the Limpopo or Crocodile River and the Sabi River on the south, and those of the Zambesi on the north.

There can be no doubt that the country is on the whole well-watered; and although many of the smaller streams are mainly replaced by broad beds of sand in the dry season, still the traveller can scarcely ever be said to suffer from scarcity of water, either for his own needs or for his cattle.

Geological Structure.

That the physical features of a country are to a large extent dependent on the geological formations which compose it, is nowhere better illustrated than in Mashonaland and Matabeleland. The rocky structure is remarkable for its uniformity over large areas;

in like manner the scenery and physical characters are strikingly persistent. Sedimentary deposits are of rare occurrence. The great bulk of the country is granite, the remainder being formed chiefly of metamorphic rocks; the whole doubtless constituting a portion of that ancient floor of granite and metamorphic rocks that elsewhere underlie the subsequent sedimentary or igneous accumulations. It is of course possible that this vast area of granite and metamorphic rocks was at one time wholly or partially covered by detrital deposits; but if so, they have been subsequently denuded and only in isolated instances do any traces of them still remain. Sandstone deposits with workable beds of coal are said to occur near the Zambesi, north of Buluwayo. Sandstones, grits, and conglomerates are also reported to occur in the Victoria district, but under what geological conditions we are unable to say. In any case, however, we can state that the major portion of the surface of the country is underlaid by granite rock forming broad expanses of flat or rolling veldt, from which rise occasionally huge agglomerations of immense boulders and fantastically shaped kopjes, the home of the despised Makalakas and Mashonas, where they were used to seek refuge from the raids of the Matabele. At intervals, too, the granite rises into rugged mountain ranges with rude broken outlines, and scored and scarped bosses of bare rock, as for instance in the Matoppo Hills, south of Buluwayo.

Turning now to the metamorphic rocks or schists which constitute the gold belts of the country, we find them occurring as broad bands and patches in the granite. In passing from an area of granite to one of schist the traveller is struck by the contrast presented by the two types of scenery. The country loses its bare and rugged aspect; the contours become soft and more undulating or even hilly; the soil, hitherto sandy and sterile, becomes clayey and fertile; the hills are covered with trees, and give rise to numerous streams; and in some of the districts (the Seleukwe and Victoria) the alternation of thickly wooded hills with fertile valleys forms scenery that would be noted for its beauty in any country. To what geological conditions may these differences in scenic or physical features be ascribed? We think the more broken character of the schist country is due to the variable nature of the component rocks, and to the fact that they are turned up on edge, rendering them more susceptible to the attacking forces of atmospheric disintegration.

The Origin of the Gold Belts.

In discussing the origin of the auriferous rocks, a series of interesting questions present themselves for solution.

1. What is the geological relation of the schist to the granite?

2. Why are the auriferous veins chiefly confined to the schist belts and their immediate neighbourhood?

3. Is there any community in origin between the veins and the schists?

We will endeavour to find answers to these questions. The rocks composing the metamorphic series are chiefly chlorite and hornblende schists, with which are associated epidiorites, actinolite rock, diabases, dolerites, and other basic igneous rocks. The intimate association of basic igneous rocks with the schists was a fact we have had ample opportunity for noting, and our observations lead to the conclusion that the schists have been derived in great measure from those rocks, and that their foliated or schistose structure has been produced by a mechanical process analogous to "shearing" and referable to certain movements of the earth's crust along zones of fracture or weakness.[1]

The sequence of events in the formation of the schists would be somewhat as follows:—The granite crust acted upon by enormous lateral pressure and tension produced by shrinkage, folding, and rucking would tend to develop main lines or zones of strain, weakness, and fracture, through which the molten basic magmas hitherto pent up within the earth's crust would be forced up to form dykes and intrusive masses of igneous rock along these zones. The earth-movements, continuing along the main lines of fracture, would effect the mechanical metamorphism of these rocks to schist, and perhaps simultaneously cause the formation of open fissures; and these, offering a free passage to mineralizing solutions, would give rise to the quartz lodes that form the auriferous deposits of the country. It is reasonable to suppose that a portion of the granite would also be involved in the zone of movement; and indeed we find evidence of this in the fact that gneiss or foliated granite is generally found on the margin of a schist belt or within the belt itself.

Transitions from an unaltered igneous rock to a highly foliated unctuous schist are clearly discernible in many parts of the gold belt. The minute structural and mineralogical changes involved in the transition can be best studied with the aid of a microscope. Starting, say, with a dolerite or diabase, the gradation of change will be roughly as follows:—Dolerite being a rock composed of plagioclase felspar and augite, the first step is the conversion of the augite to hornblende. This is one of the most common changes in the whole range of petrology. Augite and hornblende are practically identical in chemical composition, but have a different crystalline structure. Hornblende is, however, more stable than augite at ordinary temperatures; consequently the first results of molecular rearrangement in rocks containing augite is the paramorphism of that mineral to hornblende. The rock produced by this joint change consists therefore of plagioclase felspar and secondary hornblende, and is known as an epidiorite.

The next change is a breaking down of the felspar, producing a granular aggregate of quartz and reconstructed felspar, and a rolling out of the hornblende into ribbons or folds. This process, known as foliation, produces a hornblende schist. The metamorphism progressing, the hornblende becomes replaced by chlorite,

[1] See W. Gibson, Quart. Journ. Geol. Soc., vol. xlviii, p. 404; also A. R. Sawyer, *ibid.* vol. l, p. 144.

and the rock is sheared into the highly foliated and unctuous slaty rock known as chlorite schist.

A similar process of metamorphism acting in acid igneous rocks, gives rise to sericitic (mica) schist, but these are of much rarer occurrence than the basic schists in the gold belts of Mashonaland. It is in the regions of most intense metamorphism that the veins occur. In the great majority of cases, therefore, the country rock of the lode is chlorite schist. In a few cases the veins occur in gneiss, but we are not aware of any instance in Mashonaland or Matabeleland of a lode having been found in the granite.

We are now in a better position to answer the questions previously stated.

1. The relation of the schists to the granite is probably one of original intrusion in the form of basic igneous rock, and not of deposition of sedimentary beds on the top of a granite floor.

2 and 3. The auriferous veins are chiefly found in the schist belts or their immediate neighbourhood, because they owe their origin to a sequence of dynamic phenomena intimately connected with those that gave rise to the schists themselves.

A corollary of great importance for the future of the Mashonaland gold-fields can be deduced from the foregoing, namely: That the schist belts are continuous in depth, and are not liable to be cut off by the granite, as has been maintained on the assumption that they were sedimentary deposits resting on a granite floor.

Gold-bearing Districts.

There is a rude parallelism in the direction of the schist belts, their trend being roughly east and west across Matabeleland and the southern portion of Mashonaland; and it is an interesting fact that similar schist belts (also auriferous), occurring in Zoutspanberg, have the same general trend. Travelling up from Tuli to Buluwayo, three belts of schist are traversed. The first is encountered some 45 miles north of Tuli; it is a small strip of metamorphic rock three to five miles wide. The next is the newly-discovered Gwanda belt lying 60 to 70 miles south of Buluwayo. This is a fairly broad belt, being 8 to 10 miles in width, while westward it trends towards the Tati gold-fields, and eastward it probably connects with the belt known as the Naka pass. Schists also occur for some 20 miles south of Buluwayo, and it appears probable that belts trending to the coast connect with the Victoria gold-fields. Travelling eastwards from Buluwayo several regions of metamorphic rocks are passed, the most important being those of Bembise, Shangani, Seleukwe, Gwailo, etc. The principal districts visited by us are the Mazoe, the Umfuli, Victoria, Umtali, Mogundi, and the Seleukwe.

The camp of the Mining Commissioner of the Mazoe district is about 27 miles north of Salisbury. The limits of the metamorphic area round the upper Mazoe are in no direction well defined. Southwards the geological features of the country are to a great extent obscured by a heavy surface wash, but it seems very probable that between the Mazoe and Salisbury there is a continuous schist and slate formation, and that the Mazoe and Salisbury districts are practically one. Eastwards of the Commissioner's camp there are at least five or six miles of schists and greenstones, while westward the schists extend for about ten to twelve miles without interruption. To the north-east along the Mazoe river for about 30 or 40 miles a number of claims were marked out in the early part of 1891. Most of these, however, have since been abandoned, and little further prospecting has been done in that direction. The whole Mazoe district from a few miles north of Mount Hampden, which is twelve miles from Salisbury, is broken and hilly, varied by stretches of flat pasture land and swamps along the river sides. The direction of the hill ranges is, roughly speaking, north-east and south-west, but the numerous spurs and frequent branching off of one range into another make any detailed description of the contour of the country as impossible as it would be uninteresting. Many of the veins in the Mazoe district traverse igneous rocks. The Vesuvius Reef is a dark bluish quartz, separated by from one to two feet of clay selvage from the country rock, which may be called felspar porphyrite. The Alice Reef occurs in a coarse basic crystalline rock, the immediate wall of the vein being altered so as to present a schistose structure. Other veins occur in chloritic and other schists, and appear in the majority of cases to follow the foliations of the country rock.

In this connection we would remark, as it may give rise to some discussion on the vexed question of classification, that we do not consider that the fact of a vein following the general direction of foliation of the country rock, militates against the existence of a true fissure, or argues any lack of permanency of the vein in depth.

What is known as the Umfuli district comprises a number of smaller tracts in the neighbourhood of the Umfuli River in Mashonaland. The intervening country may yet in parts be proved to be auriferous.

The Hartley district extends about 11 miles from the Umfuli along a flat stretch of country, uninterrupted save by the two or three granite kopjes known as the Hartley Hills. The eastern portion of the district, including several of the best known reefs, is granitic and gneissose. Westwards on both sides of the Umfuli, gneiss gives place to schists and clay slate.

Concession Hill, where developing operations are now being carried on, lies 16 miles west-south-west of Hartley. The central ridge of this and the adjoining Duchess Hill is a body of chert and jasper, 40 to 50 feet thick on Duchess Hill, and reaching 100 feet or more on Concession Hill. Parallel bands of the same rocks are found along the flanks of the hills, alternating with chloritic schists and slates. The formation dips south-west at an angle of more than 70 degrees. In the Duchess Hill, where a shaft has been sunk 100 feet and cross-cuts driven, gold is found to occur in the chert bands chiefly in the form of thin scales or flakes; and similarly in Concession Hill, though here the gold is associated more with quartz and highly ferruginous veinstuff. Much of the gold in the Concession Hill deposit is visible to the naked eye, occurring in a kind of arborescent crystalline form resembling a pattern of sea-weed. On the south-west side of the hill there is an old stope from 2 to 5 feet wide and reaching a depth of 50 feet in hard rock. In this stope an iron pick was found in such good preservation that it hardly seems likely that the working is of very ancient date, and the same may be said in other cases in which timbers showing but little decay have been found at depths of 30 to 40 feet, or where waste dumps occur neither overgrown nor to any extent mixed with soil.

Speaking generally of old workings in Rhodesia, the general impression of those who have studied them is that they can be assigned to no one period; some say there were three distinct periods, but there seems to be little evidence for so precise a conclusion. We saw no old shafts near the workings on Concession Hill. It seems probable to us that in many cases the old miners did not hoist mineral, but carried it up inclined foot-roads, along the strike of the veins, as is done in Mexico and other less advanced mining countries to this day.

The town of Victoria is on the Pioneer Road from Tuli to Salisbury and about 180 miles south of the capital. The new township is rather more than a mile outside the actual gold belt, being in the granite country lying to the north. The average width of the schist formation may be taken roughly as between 10 and 11 miles. The greatest breadth is from Victoria towards Fern Spruit and the Tokwe River, where it reaches a breadth of 20 miles. The belt extends probably, as already stated, as far as Buluwayo in Matabeleland. It has certainly been traced from the western boundary of Mashonaland some 70 miles eastwards beyond the Umbelique River, and there seems little doubt that it continues to the Sabi River, if not further. The main body consists of chlorite and hornblende schists, together with diabasic and hornblendic igneous rocks. Talcose schist and steatite also occur, and towards the Tokwe River strongly foliated gneisses are found. The general dip of the foliation is southerly, the strike being east and west. Mr. Wybergh has favoured us with the following section across the belt from Victoria to Zimbabwi, a distance of 15 miles. First, a small band of chlorite and talc schists with beds of steatite is crossed. Then follows a small bed of ironstone and quartzite, succeeded by three miles of decomposed schists. Beyond this the formation is described as sandy, massive beds of sandstone occurring with seams of conglomerate (at Willoughby's Camp). The district generally is hilly, in parts mountainous, and is on the whole well covered with bush and well watered.

Umtali lies south-east of Salisbury, from which it is distant about 140 miles by road. From Chimoio, the present railway terminus, it is distant 55 miles, and from Beira 200 miles. The schists of the auriferous belt have been traced from Mozambique westwards to beyond the Odzi River, say 35 miles west of Umtali. The width of the belt varies from one to two miles at the western end, to ten in the eastern portion. The chief interest in the district centres in the Penhalonga Range, a sharp ridge commencing a few miles east of Umtali, and extending six or seven miles towards Masse-Kesse. The backbone of the ridge is a bed of hard banded quartz rock and ironstone, the formation of the range gradually consisting of various metamorphic schists; in places soft talcose steatitic and chloritic varieties prevail, while in other parts a harder quartz-felspathic type occurs. Just west of the highest point of the ridge (the Crow's Nest) the formation is broken through by a belt of igneous rock (diabase or dolerite) which forms a cross spur constituting the divide or watershed between the Revue and Umtali Rivers, on the north side of the ridge, and giving rise to the Zambesi on the south side. The principal reefs of the district are the Rezendi and Penhalonga, the latter famous on account of the deposits of chromate of lead in brilliant red crystals, which characterize the best portions of the reef. The Umtali district is among the healthiest as well as one of the most beautiful parts of Mashonaland.

One of the properties of the Victoria District Gold Mining Company is situated on Victoria Creek, about twelve miles south of Victoria. The vein strikes N.N.E. and S.S.W., dipping at 35 degrees to 45 degrees to the W.N.W., which is opposed to the dip of the schist foliation, which is about 50 degrees east. The walls of the vein are formed by chlorite schist, a rock of wide occurrence in the district. The vein sheet is of irregular or lenticular character, varying considerably in width in different places. The mineralized portion of the vein consists of a band of dark-coloured quartz, brown in the oxidized and hydrated portions, but elsewhere grey. The colour is due to the presence of iron in various combinations, hematite and limonite being the minerals of greatest influence in the colouration of the quartz. Besides these minerals there are also present iron-pyrites, copper-pyrites, malachite, azurite, and gold. The pay band varies from four to five feet down to a few inches. It is easily distinguished from the unpayable quartz by the difference in colour, the latter being white. The mine has been opened by a main incline shaft down 130 feet, from which drifts have been carried on the 55 and 115 feet levels; drifting on the first level amounts to 400 feet, and on the second to 106 feet.

The Cambrian Reef is situated in the eastern portion of the Victoria gold belt, about 50 miles from Victoria, and close to the Shashi River. The reef consists of a quartz vein in gneiss formation, which towards the Shashi changes to hornblende schist and basic igneous rocks. The strike of the vein is parallel to the foliation of the gneiss, viz. S.E. and N.W. It dips at a high angle to the N.E. The outcrop is bold, forming a rocky kopje apparently indicating a reef of considerable breadth. There is little doubt, however, that the apparent size of the outcrop is increased by the reef having fallen over, away from the dip side, as erosion of the country rock proceeded. The vein-filling material is mainly white quartz, but there are also seams of dark grey and brown quartz. The coloured quartz owes its colour to the presence of iron minerals and indicates a greater amount of mineralization than the white portions. The gold occurs mainly in patches, chambers, pockets, and crevices in the reef, and many good specimens of "visible" metal can easily be obtained by a little search.

The Dunraven property in the Seleukwe district contains a number of quartz lodes, some of which are roughly parallel, others intersecting to form a network of veins. The workings are approached by an adit run in from the side of the hill; above, on the hill side, are some extensive old workings. Several reefs of considerable dimensions have been discovered in the adit, and these are now being driven on. The gold is free and is associated with the usual iron and copper minerals.

The Inez Reef in the Mombi district is one of the best known in the country. It is traceable at or near the surface for a distance of a mile or two, striking N.W. and S.E., and dipping S.W. The best part of the reef is a shoot, extending 100 feet along the strike, and to the greatest depth yet attained, viz. about 90 feet. The average width of reef here is 6½ feet, with a grade of probably nearly 1½ ozs. per ton (by fire assay). A crushing of 40 tons from the best part of the reef yielded 68 ozs. on the plates—34 dwts. per ton. The quartz is compact with for the most part little mineral, the gold being fine and apparently evenly disseminated. Near the hanging wall, however, there is sometimes a vein from 2½ to 14 feet in thickness, heavily charged with antimonite, and antimony ochre; the sulphide is massive and almost pure. The hanging wall of the reef is chloritic schist. The footwall is metamorphic, but of more obscure character; the rock is often granular in texture and contains secondary calcite.

The Camperdown property is in the Seleukwe district, Matabeleland. The particular hill on which the property is situated is composed chiefly of banded chert and ironstone, similar to Concession and Duchess Hills. Interbanded with the country are veins or seams containing sugary quartz and iron oxides, which carry gold, and have been worked by the ancients through numerous pits and burrows on the rabbit-warren method. It is probable that a number of different seams have been worked at shallow depths, the workings extending promiscuously along and down the hill side. Another class of deposit on the Camperdown is the fissure vein, with very high dip. In one part of the hill it would appear as if both kinds of deposits had been worked together. A long vertical stope can be seen with traces of quartz on the walls, which at one point is enlarged into a shaft about 15 to 20 feet deep to tap one of the flat-lying interbanded deposits.

Near the Camperdown, as in fact in all the gold districts of the country, are to be seen the stones used by the ancients for grinding quartz. They are generally blocks of the harder varieties of rocks, from 20 to 100 lbs. in weight, with shallow depressions worn into the upper face. Sometimes near a river, mortars can be seen, hollowed out of the solid rock.

Since the recent re-discovery of the Ayrshire Reef, it has been prospected by four or five shafts at irregular intervals along the strike. The first shaft was put down through an old working and into solid rock to a depth of 45 feet from the present surface, or to a total depth of about 60 feet below the normal surface of the country. This shaft has now fallen in, but a new one has been sunk alongside of it to a depth of 55 feet. The second shaft was sunk in a vein of felspar which eventually dipped out southwards, but was intersected by a cross-cut at 55. On each side of the felspar vein is diorite very rich in gold; it assays from 2 to 20 ozs. and even in parts 160 ozs. to the ton. This remarkable, if not unique, occurrence of gold was made the subject of a communication to the Geological Society by Mr. Alford last year.[1] He had sections cut, and states that the reef was in a quartz-diorite. In another shaft, 1000 feet from the first, the diorite is again exposed, but prospecting had not been carried far enough when we visited the property to prove the extent of the deposit. A general sample taken across the bottom of the shaft assayed 11 dwts. Since then a cross-cut has been driven to the felspar vein which outcrops in the old working in which the shaft was sunk, and the report is that the diorite has here again proved extremely rich. The reef seems to be a dyke of diorite traversing the granite or gneiss, which is the predominating country rock, in an easterly and westerly direction. The width of the diorite is nowhere proved, nor even the extent to which it is auriferous. It would appear that the gold, more or less, hugs the felspar vein, occurring on either side of it. The felspar vein is found throughout the length of the workings: apparently one persistent vein which would in this case be a valuable index to the best part of the deposit. The felspar contains only traces of gold.

Alluvial Deposits.

With regard to alluvial deposits we are permitted to quote from Mr. Hammond's Report to the Chartered Co. that "As far as my examination extends I could see no evidence of alluvial or placer deposits; in fact the topographical character of the country visited by me is such as to almost preclude the possibility of the occurrence of alluvial deposits of any extent or importance. This statement refers to those portions of Mashonaland and Matabeleland which I examined. In Manicaland the topographical conditions are different, favouring the occurrence of auriferous alluvial deposits of limited extent. I saw some of those deposits which had been worked by the ancients. The probability is that such deposits as have occurred have been, for the greater part, already worked out."

Conclusions.

Prospecting in Rhodesia is made easy for the present generation, for, with the rather remarkable exception of the Victoria district, practically all the known mineral areas of the country show evidence

[1] Quart. Journ. Geol. Soc. vol. l, p. 8 (Proc.).

of having been the field of former mining operations. Probably 90 per cent. of the reefs known at the present day have been previously exploited at one time or another; that the Victoria gold belt should be an exception is remarkable, lying as it does in close proximity to the best known and most extensive ruins in the country. The fact seems, in the absence of explanation, rather to go against the generally accepted theories with regard to Zimbabwi and gold-mining; or, as has been suggested, with, to our mind, small ground, it may be that old workings exist in the district, that are now filled up and have been concealed by natural agencies.

The general method of prospecting in a new district is to get hold of the natives in the neighbourhood, and by practical persuasive arts, in which beads and salt play an important part, to make them act as guides to the holes and depressions that mark the position of old workings. Sometimes an outcrop has been left, but more often the old workings are the only indication remaining. Having pegged off a line of old holes and as much of the extension as he feels inclined to incorporate with it, the intelligent prospector proceeds by panning from the old dumps and loose quartz lying about, and, by a critical examination into the relative sizes and depths of the overgrown holes, to select a site for his shaft. The object naturally is to strike the reef where, from the evidence at hand, it is likely to present a good section, and in this the prospector is so often successful that if such first strikes could be taken as a gauge of the average grade of the reefs, there could be no doubt whatever of immense future prosperity to the mining industry of Rhodesia.

While the majority of reefs pegged in the country will probably never yield one sovereign for two that are sunk in them, it would be extraordinary indeed, considering the great number of reefs proved to exist, if there were not some prizes in the lottery. They may be few and big, or few and mediocre, or they may be many, but to condemn or extol the country, as a whole, in its present stage of development, would be in our minds rash and prejudiced. Given a proper discrimination in the selection of properties, and the exercise of judgment in the expenditure of capital, the country certainly commends itself to the attention of capitalists.

The immediate future of mining in Rhodesia, and in fact the immediate future of Rhodesia itself, depend almost entirely on the success of gold-mining. Silver is of comparatively small importance. We say the immediate future, for, whatever the mineral prospects of Southern Zambesia may be, we have small doubt that in the course of a few decades, possibly half a century, the country will, with its healthy and fertile uplands, support a considerable population on its pastoral and agricultural merits alone.

II.—On the Liassic Fish *Osteorachis macrocephalus*.

By Arthur Smith Woodward, F.L.S., F.G.S.,
Of the British Museum (Natural History).

(PLATE VII,[1] Fig. 10.)

AMONG the fishes of the Lower Lias of Lyme Regis, Dorsetshire, described by Egerton from imperfect evidence, is the genus *Osteorachis*, with the single species, *O. macrocephalus*.[2] The original description and figure are so unsatisfactory that nothing beyond the name of the fish is quoted even in Zittel's "Handbuch" (vol. iii, p. 230), while this bears an appended query; and the author's definition of the genus is certainly much too vague to admit of any precise determination of its systematic relationships. Under these circumstances it is of interest to return to a consideration of the fish in the light of more recently discovered specimens, which seem to the present writer to comprise not only examples of the trunk but also, at least, one satisfactory head.

The type specimen, now in the British Museum, is shown only in a general way in Dinkel's drawing, and Egerton's description is far from explanatory. It comprises the imperfect head with the greater portion of the trunk obliquely crushed and exposed from below. Remains of a large gular plate appear between the fragments of the smooth mandibular rami; and there are clusters of small, remarkably slender, hollow teeth. The premaxilla cannot be identified with certainty, but one obscure portion of bone seems to show the bases of a single close series of larger teeth; another fragment, exposed from its oral face, must have originally borne at least three series of the typical small teeth. On one large expanded bone, which may be entopterygoid, the teeth cover an extensive area and are in part merely fine granulations. The hyomandibular is well shown on one side, but in Dinkel's drawing it is not distinguished from an adjoining element which appears to be the displaced metapterygoid. The process of the hyomandibular for the support of the operculum is long, but its hinder end is connected with the upper and lower extremities of the element by a thin lamina of bone. Behind the hyomandibular, parts of the operculum and suboperculum are seen from within. The vertebral centra are not "completely ossified," but are represented merely by distinct hypocentra and pleurocentra; their arches are obscurely indicated through the displaced squamation. The tubercles on the scales are occasionally elongated, and on the hinder portion of some of the flank-scales they are observed to pass into transverse striæ which terminate in feeble denticulations. The fins are too fragmentary for detailed description.

Some further account of the characters of the trunk and fins of *Osteorachis* is given by Egerton from another specimen, now in the British Museum (No. P. 3655). The structure of the head, however, has never been more precisely indicated. The opportunity is now afforded to supply this deficiency by a fossil from the Lower Lias of Lyme Regis, preserved in the Oxford Museum. This is a skull,

[1] For this Plate (VII) see the April Number Geol. Mag.

[2] Quart. Journ. Geol. Soc. vol. xxiv (1868), p. 500, and Figs. and Descript. Brit. Organic Remains, dec. xiii (Mem. Geol. Surv. 1872), no. 5, pl. v.

proved to belong to *Osteorachis* by its characteristically clustered slender teeth; and the writer is indebted to Professor A. H. Green, F.R.S., for facilities to make a detailed study of it.

The specimen in question is preserved in indurated Lias, and much fractured by crushing. It is laterally compressed, and at the same time somewhat distorted, so that the jaws on the left side are opened and parts of the inner dentition are exposed. This left side presents the features of greatest interest, and it is shown of two-thirds the natural size in Pl. VII, Fig. 10. The cranium itself is too imperfect for description, but its roof is observed to have been in part very finely tuberculated. There is an ossification in the postfrontal (sphenotic) region (*pt.f.*), and the same remark applies also to the prefrontal (lateral ethmoidal) region (*p.f.*). The orbit in the fossil is occupied by a fragment of the ossified sclerotic (*scl.*). The cheek is shown to have been completely covered with plates to the border of the preoperculum, and several of these exhibit traces of a very fine tuberculation, while other portions are more coarsely rugose. Two very large *postorbitals* (*pt.o.*) are distinct, and there are also remains of a *circumorbital ring* (*c.o.*). Within these fragments above the maxilla can also be seen portions of a large thin smooth plate, which is not improbably the *entopterygoid*. The *maxilla* (*mx.*) is long and slender, fractured in two places, and either destroyed or obscured at its anterior extremity. It is stout in front, thin and slightly deepened behind, with its outer surface partly smooth, partly rugose. Its hinder third is overlapped by a small elongated *supramaxilla* (*s.mx.*) which is deepest posteriorly, acutely pointed in front, and exhibits a finely tuberculated external surface. Its oral border is nearly straight for the greater part of the length of the element, but there is a downward trend behind, perhaps exaggerated in the fossil by the accidental splitting of the bone. Its teeth are all long and slender, nearly of equal size, well spaced and arranged in a single series. They are enamelled to the base and distinctly hollow. The *premaxilla* (*p.mx.*) is only obscurely indicated, but extends for a considerable distance along the oral margin, and bears probably not less than ten long slender teeth, similar to those of the maxilla; seven of these teeth are preserved. The left mandibular ramus, showing the high coronoid region, is also fragmentarily preserved, and the *dentary* (*d.*) bears a single series of teeth, like those of the margin of the upper jaw, and not exceeding the latter in size. Most of these teeth are displaced or broken away, and cross-sections of the bases of some are exposed. The great interest of the jaws, however, centres in the streak of clustered dentition both immediately below the maxilla and immediately above the mandible, but distinctly internal to each. The teeth of these clusters are shown to be exactly similar to those on the margin of the jaw, but much smaller and more closely arranged; and they all appear to be readily broken off the bones supporting them. The upper cluster (*ecpt.*) doubtless pertains to the ectopterygoid, while the lower cluster (*spl.*) may be referred with certainty to the splenial. Between the rami of the mandible there are remains of a large gular plate (*gu.*) in front, and a few branchiostegal rays (*br.*) behind.

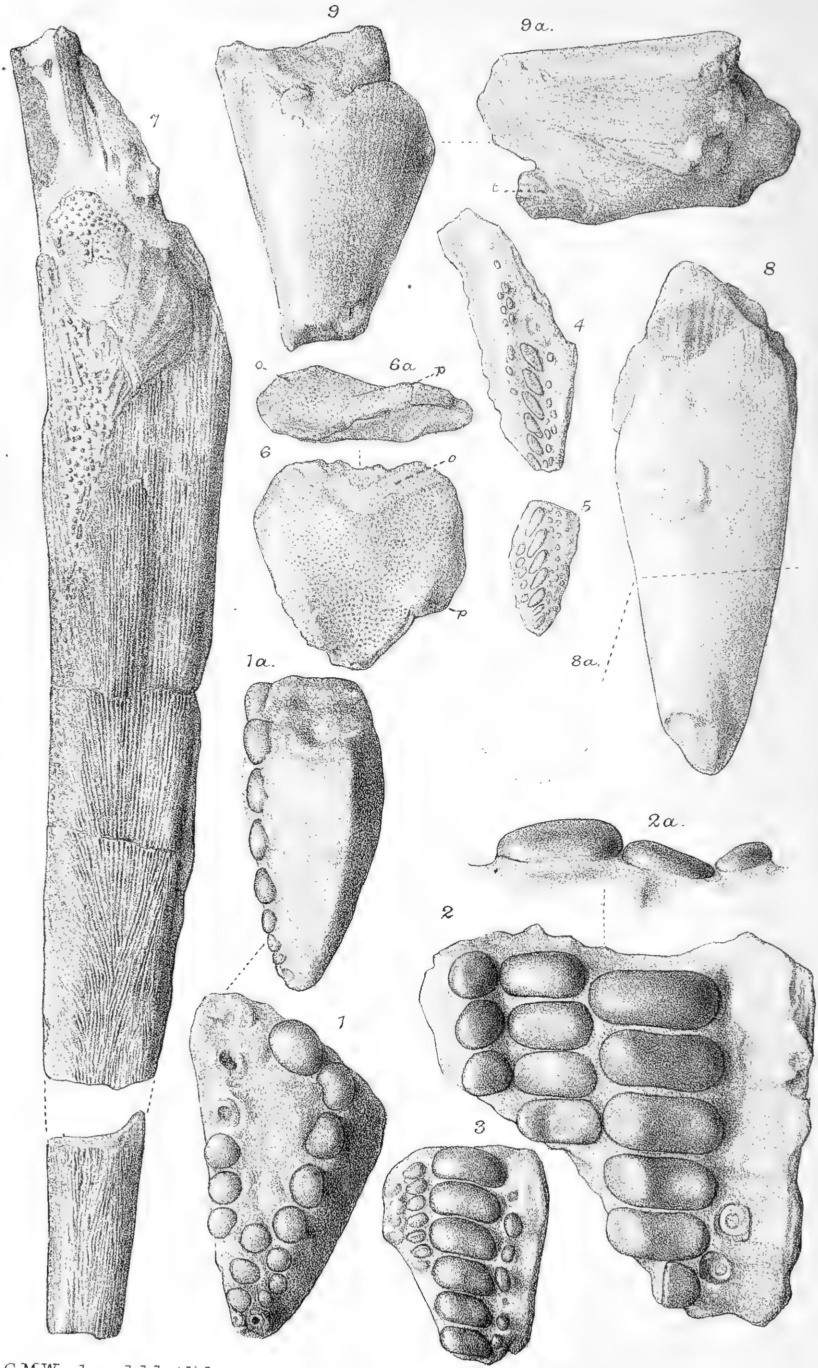
The characteristic inner teeth not only serve to identify the skull just described, but also seem to necessitate the reference of two other specimens from Lyme Regis to *Osteorachis*, and probably to *O. macrocephalus* itself. These are imperfect fishes bearing the names of *Harpactira velox*[1] and *Heterolepidotus grandis*,[2] each about a metre in length, the first in the British Museum and the second in the Davis Collection, Halifax. They not only exhibit the teeth, but also remains of the typical squamation; and they are important as making known the greater part of the fins.

Harpactira velox has never hitherto been satisfactorily determined; and, remembering that the unique example of this fish displays neither vertebral elements nor ossified vertebral arches, there may still be some hesitation in accepting its identification with *Osteorachis*. The great amount of disturbance, however, to which the specimen has been subjected is indicated by the fact that the left suboperculum is displaced to the hinder part of the caudal region. Moreover, we may cite another example of a fish from the Lias of Lyme Regis in which the fins remain in position, while nearly the whole of the well-calcified series of vertebral arches is wanting (*Chondrosteus acipenseroides*, Brit. Mus. No. P. 3367). The present writer is thus convinced that the evidence of teeth and scales must outweigh all other considerations; and a careful comparison of the original specimens compels him to relegate the name *Harpactira velox* to the synonymy of *Osteorachis macrocephalus*. This unique type fossil exhibits the imperfect head obliquely crushed, and the greater part of the right mandibular ramus is exposed from the inner aspect. The dentary is much fractured in front, though showing the coronoid elevation behind; while the splenial is displaced, but sufficiently complete to display its clustered small slender teeth and the excavation of its hinder margin. Some of the characteristic teeth are also scattered below the jaw. The right hypohyal occurs; and the large gular plate is completely preserved, this being two-thirds as broad as long, obtusely rounded in front, truncated behind. The exposed portion of the suboperculum is slightly more than twice as broad as deep, ornamented with a very fine and close tuberculation; and there is a small ascending process at its antero-superior angle. Scales occur sparsely in the region of the pelvic, dorsal, anal, and caudal fins, all exhibiting a fine tubercular ornamentation. On the few principal flank-scales which are preserved, the tubercles have a tendency to elongation and pass in the hinder half into conspicuous striæ. The peg and socket for articulation are very large, as usual. The ventral scales are shown to have been narrowed, as also are those immediately covering the base of the caudal fin-rays.

Scales of the form just described are much better preserved in the so-called *Heterolepidotus grandis* of Davis; and the fins of both the specimens in question are apparently identical in general characters and disposition with those of the genus *Eugnathus*. It is not yet known, however, whether the fulcra in *Osteorachis* were biserial or uniserial.

The result of these further comparisons therefore is, that *Osteorachis macrocephalus* belongs to the same family as *Eugnathus*, and is generically distinguished from this fish by the enlargement of the inner clustered teeth, and the comparative tenuity of its scales.

[1] Egerton, Geol. Mag. Dec. II, Vol. III (1876), pp. 441, 576.
[2] J. W. Davis, Journn. Linn. Soc. Zool. vol. xviii (1885), p. 293, pl. vii.



G. M. Woodward del. et lith.

West, Newman imp.

Cambridge Greensand Ganoids.

III.—A Synopsis of the Remains of Ganoid Fishes from the Cambridge Greensand.

By Arthur Smith Woodward, F.L.S., F.G.S.,
Of the British Museum (Natural History).

(PLATE VIII.)

THE remains of fishes discovered in the Cambridge Greensand are all very fragmentary, and have not hitherto been subjected to the detailed comparison with other Cretaceous Ichthyolites which their interesting stratigraphical position renders desirable. Many specimens, however, are capable of at least generic determination, while many others are sufficiently characteristic fragments for the definition of the species. The present writer has thus been much interested during the past few years in studying collections of these fossils, and the following notes embody some of the results in reference to the ganoid fishes. The British Museum (Natural History) having recently acquired the collection made from the Cambridge Greensand by Mr. Thomas Jesson, F.G.S., nearly all the known species are now represented here; but the writer has also availed himself of the privilege of making use of the fine series in the Woodwardian Museum, Cambridge, and the Philosophical Society's Museum, York, thanks to the kindness of Professor McKenny Hughes, Mr. Henry Woods, and Mr. H. M. Platnauer. Mr. James Carter, M.R.C.S., has also kindly lent some Pycnodont jaws from his private collection.

Genus Lepidotus, Agassiz (?).

A few scales identical in form with those of the genus *Lepidotus*, showing the produced angles of the overlapped portion, are contained in the Jesson Collection (Brit. Mus. No. P. 7232). The largest measures about 0·03 m. in the depth of its exposed area. They all seem to have been smooth, but a small boring organism has destroyed much of the surface.

Family PYCNODONTIDÆ.

Genus Athrodon, Sauvage.

The genus *Athrodon* has already been recorded from the Cambridge Greensand on the evidence of an abraded splenial bone; and there is some reason for also assigning to it a vomer with seven irregular longitudinal series of teeth, in the Woodwardian Museum.[1] A second species is now indicated by another splenial in Mr. Jesson's collection, and this appears to be distinct from all forms hitherto described.

1. *Athrodon crassus*, A. S. Woodward, Geol. Mag. Dec. III, Vol. X, (1893), p. 435, Pl. XVI, Fig. 3.

Type. Right splenial: Woodwardian Museum, Cambridge.

[1] A. S. Woodward, Geol. Mag. [3] Vol. X (1893), p. 435, Pl. XVI, Fig. 4.

2. *Athrodon Jessoni*, sp. nov., Pl. VIII, Figs. 1, 1*a*.

Type. Right splenial: British Museum (Jesson Collection).

Splenial bone very robust, but narrower than in *A. crassus*, with large, closely-arranged smooth teeth, mostly circular, disposed in three nearly regular longitudinal series. Anteriorly the three series are about equal in size; posteriorly the median teeth are slightly the larger.

The dentition on the type, and only known specimen, measures 0·02 m. in maximum width and 0·04 m. in length. The seven teeth of the innermost series are well preserved, except the foremost, and the hinder four are very slightly longer than broad. There is a small supplementary tooth within anteriorly. Of the median series, three round teeth remain in front, and then only one at the hinder end, this being slightly broader than long. The three middle teeth of the outer series are preserved, and behind these are the bases of two others; they are nearly equal in size to the teeth of the inner series, but not antero-posteriorly elongated.

Genus Cœlodus, Heckel.

Cœlodus is also represented by two specific types of splenial dentition; and two forms of vomer in the Woodwardian Museum may perhaps be placed here.[1] The first species, already described, seems to be tolerably common; while the second species is as yet known only by the unique fossil described below.

1. *Cœlodus inæquidens*, A. S. Woodward, Geol. Mag. Dec. III, Vol. X (1893), p. 491, Pl. XVII, Fig. 5.

Type. Left splenial: British Museum (No. 36157).

2. *Cœlodus cantabrigiensis*, sp. nov. Pl. VIII, Figs. 2, 2*a*.

Type. Right splenial: British Museum (Jesson Collection).

A large species known only by the splenial dentition. Teeth on the splenial bone smooth; those of the principal series scarcely more than twice as broad as long, and nearly equal in width to the two flanking series; inner flanking teeth twice as broad as long, and twice as broad as the teeth of the outer series, which are scarcely broader than long; a row within the principal series represented by few small teeth.

Though relatively gigantic, this form of dentition is almost identical with that of the Wealden *Cœlodus Mantelli.* Even the almost unworn teeth in the Cambridge Greensand fossil, however, are destitute of any trace of the deep apical indent characteristic of all the Wealden teeth; there need thus be little hesitation in regarding the present form as specifically distinct. The front teeth of the type specimen figured are deeply excavated by wear during the life of the animal; and the inner supplementary teeth are indicated only in front by two bases.

[1] A. S. Woodward, *loc. cit.* 1893, p. 492, Pl. XVII, Figs. 3, 4.

Genus Anomœodus, Forir.

A large form of splenial dentition from the Cambridge Greensand has already been provisionally ascribed to *Anomœodus*, and it is now possible to add undoubted evidence of a diminutive species of this genus, besides a more doubtful example of a medium-sized form.

1. *Anomœodus superbus*, A. S. Woodward, Geol. Mag. Dec. III, Vol. X (1893), p. 489, Pl. XVI, Fig. 5.

Type. Left splenial: Woodwardian Museum, Cambridge.

2. *Anomœodus confertus*, sp. nov. Pl. VIII, Fig. 3.

Type. Imperfect right splenial: collection of James Carter, Esq.

Teeth on splenial bone very closely arranged, and none except perhaps the outermost with apical pit; those of the principal series not more than twice as broad as long, truncated at each end, their long axis directly transverse, and their antero-inner point very feebly turned forwards; inner teeth in a single irregular series of moderate size, and each slightly longer than broad; those of the innermost flanking series scarcely as large as the latter, somewhat broader than long, and irregularly oval [outer flanking series unsatisfactorily known].

The type specimen is the best fragment of this species hitherto observed by the present writer, and the outer margin of the splenial thus remains to be discovered. The dentition seems to most closely resemble that of *A. Muensteri*, but is readily distinguished by the proportions of the principal teeth.

3. *Anomœodus Carteri*, sp. nov. Pl. VIII, Fig. 4.

Type. Right splenial: collection of James Carter, Esq.

A small species known only by the splenial dentition, which is well spaced. Teeth of principal series very obliquely set, pointed at each end, not more than half as long as broad, and when unworn with a slight transverse coronal furrow; outer and inner teeth very small and irregular, with crimped apical pit, none broader than long, but the majority longer than broad; inner teeth with tendency to arrangement in two series; flanking teeth in about three series of approximately equal size.

The type specimen, shown of natural size, from the oral aspect in Pl. VIII, Fig. 4, exhibits the outer toothless border of the splenial element characteristic of the genus *Anomœodus*; and this well-preserved fossil is completely divested of matrix. On its inner face there is a longitudinal groove for the reception of the persistent meckelian cartilage. A second fragmentary specimen in Mr. Carter's collection is similar; and a third example of the splenial in the York Museum (Pl. VIII, Fig. 5) only differs in small particulars. In the latter the innermost teeth are relatively large and with obliquely directed long axis; while the flanking teeth, which are partly obscured by matrix, are arranged in three comparatively regular series.

This form of splenial dentition most nearly resembles that of *A. angustus*, but is distinguished by the form and proportions of the flanking teeth.

Family EUGNATHIDÆ.

Genus Lophiostomus.

This genus has hitherto been found only in the Chalk, and but a single example of the skull is known. It is thus of great interest to record the discovery of two fragments of the cranium in the Cambridge Greensand, which evidently pertain to a new species.

Lophiostomus affinis, sp. nov. Pl. VIII, Figs. 6, 6*a*.

Type. Occipital half of cranial roof: Brit. Mus. (Jesson Collection).

As shown by the figures which represent the upper and right lateral aspects, the imperfect fossil on which this species is founded indicates a skull of similar form and proportions to that of the typical *L. Dixoni*. The superficial ornament, however, consists of finer elongated tubercles; while the frontal prominence (*p.*) on either side is very slightly elevated compared with that of the typical species. The occipital border is preserved, showing a broad smooth surface of overlap (*o.*); and this border is not straight but somewhat excavated by a re-entering angle. No certain indications of sutures between the component elements can be observed.

The second specimen, in the Woodwardian Museum, Cambridge, shows exactly the same portion of the cranial roof with identical characters, but is also interesting as preserving the occipital region. As in the preceding specimen, there is no trace of a prominence on the squamosal, such as appears to be present on the right side of the only known skull of *L. Dixoni*. The cartilages of the occipital and otic regions are well ossified, and there is a deep conical fossa in the articular face of the basioccipital. There are indications of a deeply jagged median suture between the frontal bones, but otherwise the limits of all elements are indistinguishable.

Family ASPIDORHYNCHIDÆ.

Genus Belonostomus, Agassiz.

This genus is represented in the Cambridge Greensand not only by fragments of the characteristic presymphysial bone, but also by portions of the skull and scales. Two imperfect scales in the Woodwardian Museum are as large as those of the Australian species, *B. Sweeti*, and similarly ornamented; while the portions of skulls are of two kinds, one equally large, the other comparatively small and depressed.

Only the hinder half of the skull is preserved in each case. Of the larger form there are four examples in the Jesson Collection (Brit. Mus. No. P. 7235), measuring from 0·04 m. to 0·05 m. across the post-frontal region, and all exhibiting the robust ossification of the otic elements. The basisphenoidal region is much laterally compressed, but no sutures can be observed between any of the bones, and even those of the cranial roof seem to be fused into a continuous shield. The latter is elaborately ornamented with closely-arranged, vermiculating rugæ and tubercles.

The smaller form of skull, known only by two specimens in the Woodwardian Museum, is much depressed and scarcely exceeds 0·02 m. in width across the post-frontal region. The cranial roof is likewise rugose, but exhibits very clearly the limits of the parietal and frontal bones. The parietals are much elongated antero-posteriorly, united by a wavy suture and bordering the hinder extremity of the frontals with their antero-external production. The interdigitations of the mesial frontal suture are especially deep and conspicuous.

Family PACHYCORMIDÆ.

Genus Protosphyræna, Leidy.

Perhaps the commonest remains of ganoid fishes met with in the Cambridge Greensand are portions of the rostrum of *Protosphyræna.* Not only are they abundant as specimens; they are also of more varied form than the corresponding fossils met with in any other English Cretaceous horizon. In fact, if the rostrum alone suffices to characterize the species of *Protosphyræna,* as is commonly assumed and as seems probable, no less than five new types can be distinguished among these specimens. The typical species, *P. ferox,* also occurs, and the characters of all of them may be briefly summarized as follows:—

1. *Protosphyræna ferox,* J. Leidy, Trans. Amer. Phil. Soc. vol. xi (1857), p. 95. Woodcut, Fig. 3.

Rostrum much elongated and attaining a length of about 0·3 m., with a transverse diameter of 0·05 m. at its base where the vomerine teeth are implanted; circular in transverse section throughout its whole length (Figs. 3*b*, *c*), except within a short distance of the vomerine teeth, where it becomes slightly flattened on the upper part of its sides and the top (Fig. 3*a*) and passes into the gradually widening flattened cranial roof; its external surface ornamented with reticulating rugæ, of which the most prominent are longitudinally directed.

2. *Protosphyræna tenuirostris,* sp. nov. Woodcut, Fig. 1.

Type. Rostrum: Woodwardian Museum, Cambridge.

Rostrum much elongated and slender, somewhat flexed upwards shortly in advance of the vomerine teeth, and attaining a length of about 0·24 m., with a transverse diameter of 0·027 m. at its base where the vomerine teeth are implanted; transverse section (Figs. 1*a*–*c*) remarkably cylindroidal throughout its length, slightly depressed in its middle portion; external surface marked by fine longitudinal ridges.

A slightly more attenuated form of rostrum from the Cenomanian of Kursk, Russia, probably of this species, is ascribed to "*Saurocephalus striatus*, Ag." by V. Kiprijanoff, Bull. Soc. Imp. Nat. Moscou, vol. xxxiii, pt. i (1860), p. 666, pl. x, fig. 3.

3. *Protosphyræna Keepingi*, sp. nov. Woodcut, Fig. 4.

Type. Imperfect rostrum: Woodwardian Museum, Cambridge.

Rostrum remarkably stout and short, circular in transverse section, only slightly flattened on the top at its base (Fig. 4*a*); external surface ornamented with reticulating rugæ.

This species is known only by the unique type specimen obtained by Mr. Henry Keeping.

4. *Protosphyræna ornata*, sp. nov. Pl. VIII, Fig. 7.

Type. Imperfect rostrum: Woodwardian Museum, Cambridge.

Rostrum much elongated and attaining a length of about 0·2 m., with a transverse diameter probably of 0·02 m. or 0·025 m. at its base where the vomerine teeth are implanted; vomerine area elongated, and the rostrum much laterally compressed, except towards its attenuated distal extremity, which is round in section; the rounded upper contour of the rostrum gradually becoming raised into an obtuse median longitudinal ridge at its base and ornamented with coarse rugæ, which frequently subdivide into tubercles and are mainly longitudinal in direction though partly turned obliquely downwards; the lateral portions ornamented with much finer longitudinal rugæ, which tend in part to converge at the middle of the side and form a slight median longitudinal ridge on the inferior aspect for some distance in advance of the vomerine area.

This appears to be the commonest species of *Protosphyræna* in the Cambridge Greensand, and the rostrum is readily distinguished both by its lateral compression and the unique ornamentation. The type specimen, shown of the natural size from the left lateral aspect in Pl. VIII, Fig. 7, is the finest example hitherto discovered.

5. *Protosphyræna depressa*, sp. nov. Pl. VIII, Fig. 8.

Type. Rostrum: Woodwardian Museum, Cambridge.

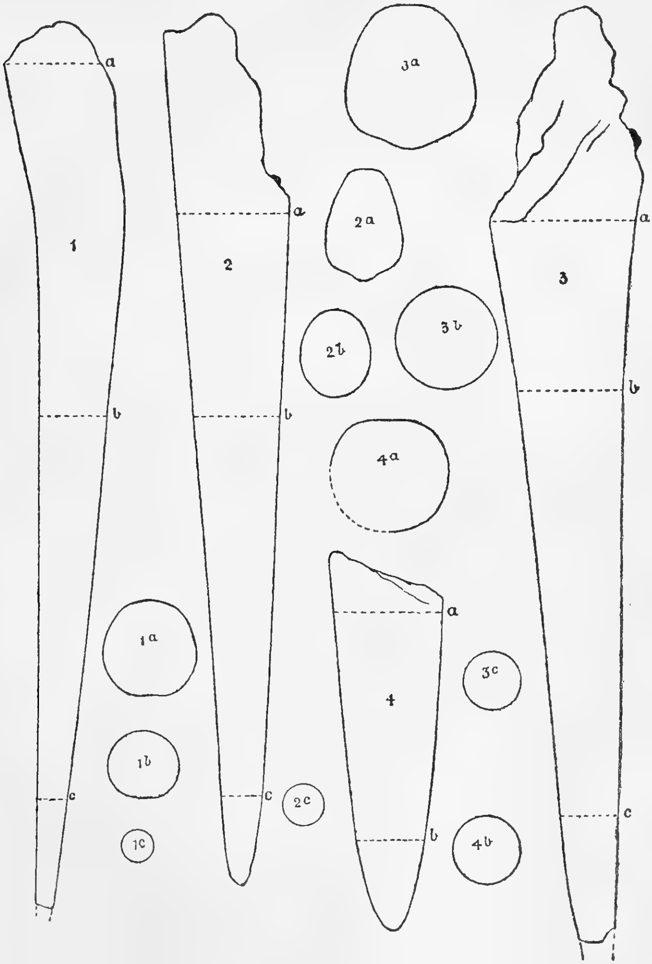
Rostrum comparatively short and depressed, its length apparently not exceeding 0·055 m. in a specimen measuring 0·025 m. in transverse diameter where the vomerine teeth are implanted; upper aspect flattened, almost hollowed, and the sides converging below so that the transverse section (Fig. 8*a*) appears triangular with rounded angles; surface smooth or in part slightly rugose.

6. *Protosphyræna brevirostris*, sp. nov. Pl. VIII, Figs. 9, 9*a*.

Type. Base of rostrum: British Museum (Jesson Collection).

Rostrum comparatively short and acute, its length apparently not exceeding 0·05 m. in a specimen measuring 0·025 m. in transverse diameter where the vomerine teeth are implanted; upper aspect and sides flattened, the latter converging below in a median inferior keel, making the transverse section triangular at the end of the vomerine region; surface nearly smooth.

This species has already been incidentally mentioned in discussing



Outlines of Rostra of *Protosphyræna* in lateral aspect and transverse section, one-half natural size.

FIG. 1. *Protosphyræna tenuirostris*, sp. nov.—Cambridge Greensand. [Woodwardian Museum, Cambridge.]
FIG. 2. *Protosphyræna compressirostris*, sp. nov.[1]—Kentish Chalk. [Brit. Mus. No. P. 5631.]
FIG. 3. *Protosphyræna ferox*, Leidy.—Kentish Chalk. [Brit. Mus. No. P. 5630.]
FIG. 4. *Protosphyræna Keepingi*, sp. nov.—Cambridge Greensand. [Woodwardian Museum, Cambridge.]

[1] This species may be characterized thus: Rostrum much elongated, and

the affinities of *Protosphyræna*,[1] and is specially remarkable on account of the shortness of the snout. The type specimen exhibits apparently the greater part of the ethmoidal region, and wants only the extremity of the snout. On the obscured inferior aspect there are traces of the large, laterally-compressed vomerine teeth (Fig. 9*a*, *t*,) and there appears to be no flattened area in advance of them. The transverse section is shown to be triangular as described, and on the upper surface there seem to be some feeble indications of coarse longitudinal rugæ partly subdivided into tubercles. A second, more abraded specimen (Brit. Mus. P. 7252) has a slightly larger and longer snout with a triangular flattened area immediately in front of the vomerine teeth; but the differences it presents are not greater than such as may be reasonably explained by individual variation.

The ganoid fish fauna of the Cambridge Greensand is thus almost as unique as its reptilian fauna. Nearly every fragment which admits of satisfactory comparison, differs specifically from allied fossils occurring elsewhere; and the number of forms represented is also remarkable.

EXPLANATION OF PLATE VIII.

FIG. 1. *Athrodon Jessoni*, sp. nov.; right splenial, from the oral and symphysial (1*a*) aspects. [British Museum, No. P. 7238.]

FIG. 2. *Cœlodus cantabrigiensis*, sp. nov.; right splenial, from the oral and hinder (2*a*) aspects. [British Museum, No. P. 7236.]

FIG. 3. *Anomœodus confertus*, sp. nov.; right splenial, oral aspect. [Collection of James Carter, Esq., F.G.S.]

FIG. 4. *Anomœodus Carteri*, sp. nov.; right splenial, oral aspect. [Collection of James Carter, Esq., F.G.S.]

FIG. 5. Ditto?; anterior end of left splenial, oral aspect, partly obscured by matrix. [Reed Collection, York Museum]

FIG. 6. *Lophiostomus affinis*, sp. nov.; hinder portion of cranial roof from the upper and right lateral (6*a*) aspects; *o*. overlapped occipital border; *p*. prominence above orbit. [British Museum, No. P. 7233.]

FIG. 7. *Protosphyræna ornata*, sp. nov.; imperfect rostrum, left lateral aspect. [Woodwardian Museum, Cambridge.]

FIG. 8. *Protosphyræna depressa*, sp. nov.; rostrum, upper aspect, and transverse section (8*a*). [*Ibid.*]

FIG. 9. *Protosphyræna brevirostris*, sp. nov.; imperfect rostrum from the upper and left lateral (9*a*) aspects. *t*. vomerine tooth. [British Museum, No. P. 7253.]

All the specimens were obtained from the Cambridge Greensand, and the figures are of the natural size.

attaining a length of at least 0·19 m., with a transverse diameter of 0·02 m. at its base where the vomerine teeth are implanted; laterally compressed in its proximal half, the transverse section here being an oval with vertical long axis (Fig. 2*b*); circular in transverse section in its distal portion (Fig. 2*c*); the top of the base gradually becoming flattened as it passes into the cranial roof. External ornament as in *P. ferox*.

[1] A. S. Woodward, "On the Affinities of the Cretaceous Fish *Protosphyræna*," Ann. Mag. Nat. Hist. [6] vol. xiii (1894), p. 510, footnote.

IV.—On the Occurrence of *Phoca rugosidens*, Owen, in Maltese Strata.

By John H. Cooke, F.G.S., F.L.S.

In a memoir which was read before the Geological Society of London in 1870, and which was published in the Proceedings of that Society and in the Malta papers, Dr. A. A. Caruana[1] makes mention of a portion of a rib and of a lower jaw of a mammal which were obtained from the Globigerina Limestone at El Kbajer, near Kolla el Baida, in the island of Gozo; and after referring to the fact that no Carnivora had, up to that date, been found in the Maltese Islands, he described the El Kbajer fossils as being "a portion of the lower jaw of a Hyæna with several teeth *in situ*."

The fossils were presented by Dr. Caruana to the University Museum, Valetta, and for nearly twenty-three years they remained there, labelled "Remains of Hyæna."

In the year 1890, I drew the attention of Dr. John Murray to the remarkable description which was attached to these specimens; and in 1891 I entered into correspondence with, and forwarded sketches and photographs of the remains to, the late Prof. van Beneden, of Louvain. Both of these eminent geologists confirmed my suspicions as to the mistake into which Caruana had fallen.

Right mandibular ramus of lower jaw of *Phoca rugosidens* (Owen); Globigerina Limestone, Gozo, Malta. The original is preserved in the University Museum, Valetta. The tooth drawn in outline shows the form of the cusps of a single detached molar.

The principal specimen, which is firmly embedded in a compact block of Globigerina Limestone, consists of the right ramus of the lower jaw of a *Phoca*. It contains three entire molars, and a portion of a fourth. All of them are *in situ*; and they are in a capital state of preservation. The enamel of the teeth is very rough; and the margins are boldly though unequally serrated on both sides. One of the molars, situated towards the posterior extremity of the jaw, clearly exhibits the bifurcation of its roots. This is the finest specimen of the remains of a fossil Seal that has yet been recorded from the Maltese Islands.

[1] Caruana, A. A., Quart. Journ. Geol. Soc., vol. xxvi, p. 434; "Malta Observer," March, 1870.

While hunting for further evidences of these animals in the same locality as that whence this fossil was obtained, I was fortunate enough to find an isolated molar in the bed which is situated between the first and the second nodule seams, and from information which I obtained as to the exact locality in which the Malta University specimen was obtained, as well as from a comparison of its matrix with the rocks at El Kbajer, there can be no doubt but that they were both obtained from the same horizon. The molar tooth found by myself shows the lower portions of its bifurcated root. It measures $\frac{1}{2}$ an inch in length, and $\frac{3}{8}$ of an inch in breadth. The enamel is rough and uneven, and it is scored with white striations of unequal lengths, which run in parallel lines longitudinally down both sides of the tooth. Along the posterior margin there are two very pronounced serrations, while on the anterior margin, and in immediate juxtaposition with the crown, there is a small one.

The layer of rock in which this and the University specimen were discovered forms the base of the Laughian series in the Maltese Islands. According to Fuchs,[1] this and the overlying layer, which is an argillaceous variety of the Marl beds, find their analogue in the Horner Schichten of the Vienna basin. It is a reddish-yellow rock of variable character. It averages about twenty feet in thickness, and is remarkably persistent throughout both Malta and Gozo. In organic remains it is one of the most prolific of the divisions of the Globigerina limestones.

The ribs and jaws of *Halitherium*,[2] and the teeth of *Diodon*, *Myliobates*, and *Phoca* are not rare, while most of the mollusca found in the Marls and in the overlying argillaceous or transition bed occur here in profuse abundance.

Pecten Koheni[3] makes its first appearance in this bed. The stratum is bounded above and below by a layer of phosphatized remains of sea life. The upper seam varies in thickness from nine to fifteen inches; the lower seam ranges from an inch to two feet thick. Both seams consist of an aggregation of irregularly shaped nodules, intermixed with which are considerable quantities of the phosphatized remains of molluscs, corallines, echinoderms, crustaceans, fish, and mammals, the whole being firmly bound by an interstitial cement composed of foraminiferal and other calcareous matter. The lower seam is more compact than the upper one, and the line of demarcation between it and the overlying bed is therefore more pronounced. For a distance of several feet below the upper phosphatic layer the phosphatized remains of pteropods and other minute organisms are diffused at irregular intervals throughout the rock.

It was at about this horizon that the Malta University specimen

[1] Fuchs, Th., "Das Alter der Tertiärschichten von Malta," Sitz. d. k.-k. Akad. der Wiss. Wien, Bd. lxx, p. 92.

[2] Adams, Prof. A. L., "On the Discovery of the remains of *Halitherium* in the Miocene Deposits of Malta," Quart. Journ. Geol. Soc. vol. xxii, p. 595, 1866.

[3] *Vide* Fuchs, Th., "Ueber den sogenanten 'Badner Tegel' auf Malta," for description and figure.

was found. The matrix in which the jaw and teeth are embedded has considerable numbers of minute phosphatic nodules distributed through it, and also great numbers of the phosphatized remains of *Hyalæa* and *Vaginella*.

Dr. John Murray considers that this portion of the Globigerina Limestone was deposited on a rising sea-floor, and in, approximately, about 300 fathoms of water.[1]

The late Prof. Leith Adams found several teeth of *Phoca* in the rocks around the Bay of Marsa Forno, Gozo. These he forwarded to the late Professor Sir R. Owen, and on them Owen founded the new species *Phoca rugosidens*. I have carefully gone over the district around Xenchia and Marsa Forno, and have come to the conclusion that Adams' fossils could only have come from the upper layers of the Globigerina bed.

From a comparison of the Malta University specimen and of the isolated tooth found by myself, with those found by Adams and with the description given by Owen, the two former are undoubtedly, I believe, specimens of the extinct species described by Owen under the name of *Phoca rugosidens*. I may note that the late Professor van Beneden, after having seen my sketches, suggested that the specimen might be an example of *P. Scillæ*. I was preparing to send my specimen to him, when I heard of his death. Besides these, numerous canines of a *Phoca* have from time to time been found in the upper Globigerina layers and in the "Greensands." Several very fine examples of these are carefully preserved in the Malta Museum. Remains of fossil seals were discovered in the Malta beds in the early part of the seventeeth century.

Scilla[2] figured some teeth in 1670; and Agassiz and Gervais, commenting on Scilla's illustration, pointed out that it was referable to the genus *Phocodon*.

There is in the Naples Museum a fine specimen which is labelled *Phoca Scillæ*, and which is said to have come from Malta. This specimen has been figured and described by Costa[3] in his appendix to the "Paleontologia del Regno di Napoli." It is much to be regretted that the authorities of the Museum at Naples possess no definite information either as to the locality or the horizon whence it was obtained.

V.—On Scottish Inter-Glacial Deposits.

By Clement Reid, F.L.S., F.G.S.

In the new edition of his "Great Ice Age," Professor James Geikie devotes a good deal of space to the inter-Glacial peats found in Scotland. Perhaps, as the plants from nearly all these deposits have passed through my hands, I may be allowed to venture

[1] Dr. John Murray, "The Maltese Islands, with special reference to their geological structure," Scot. Geograph. Mag. September, 1890.

[2] Scilla, "De Corporibus Marinus," 1670, Roma; "De rana speculazione," 1780.

[3] Costa, O. G., "Paleontologia del Regno di Napoli," part ii, p. 83, Tav. vi, figs. 16, 18.

on a criticism, though I have only had the opportunity of examining two of the localities in the field.

The inter-Glacial date of these masses is accepted by Professor Geikie, and by many other Scottish geologists, and in my notes on the Geological History of the Flora of Britain[1] their view was adopted, though with great hesitation as regards one of the principal localities, a railway-cutting in Cowden Glen, in Renfrewshire. Subsequent work on the abundant material sent by Mr. James Bennie and other observers, and an examination of the Hailes and Redhall quarries, has convinced me that the majority of the plants found in the three most important deposits are of comparatively late date, probably not older than the Neolithic period.

Taking the localities one by one, in the order of their botanical importance, the first place must be given to the section seen in the railway cutting at Cowden Glen ("Great Ice Age," pp. 102–104). This locality I have not examined, so can only speak of the botanical evidence; but it may be remarked that several competent observers have already objected to the acceptation of the peat as inter-Glacial, on the ground that the drift there is constantly slipping down the steep slope, so that the occurrence of Boulder-clay over the peat is insufficient to prove that the peat is the older of the two. When writing my previous paper[2] I remarked that "the plants do not throw any light on the question, for they are all species still living in the district." But since then I have received a larger series of specimens from Mr. Bennie, and among them two seeds of the garden or opium poppy (*Papaver somniferum*). I have not the slightest doubt as to the accuracy of this determination; but it is extremely improbable that such a plant was a native of Britain in inter-Glacial times. The whole assemblage of the plants, and the state of preservation of the animal remains, such as caddis-cases, winter eggs of *Spongilla* and *Cristatella*, and fragments of *Daphnia*, suggest to me an extremely recent date for this deposit.

Next in importance is Hailes Quarry, close to Edinburgh (see "Great Ice Age," p. 99). Here the botanical evidence is somewhat different, for the base of the peaty loam yields a truly Arctic flora, while the higher parts contain only temperate plants. It is possible that the bed with Arctic willows may be inter-Glacial, though I was unable to find any Boulder-clay above it; but as regards the upper portion, the occurrence of charcoal, of seeds of flax, fool's parsley, corn marigold (*Chrysanthemum segetum*), chamomile (*Matricaria inodora*), and hemp-nettle (*Galeopsis Tetrahit*) is against the great antiquity of this deposit.

As regards Redhall Quarry, also close to Edinburgh, the evidence seems even more decidedly to be against the inter-Glacial age of the peat (see "Great Ice Age," pp. 100–101). The section was not clear when I visited it, so I can say nothing as to the stratigraphical evidence, except that the slope of the ground seemed quite sufficient to cause slipping in so unstable a deposit as the Till. The botanical

[1] Annals of Botany, vol. ii, No. vi, August, 1888.
[2] *Op. cit.* p. 183.

evidence, however, is very strong, for the peat yields about fifty plants, including *Fumaria officinalis, Spergula arvensis, Linum perenne* (or *L. usitatissimum*), *Alchemilla arvensis, Carum Carui, Chrysanthemum segetum, Matricaria inodora, Centaurea Cyanus, Sonchus arvensis, Galeopsis Tetrahit*, and *Euphorbia Helioscopia*. These eleven species, and perhaps some of the others, are probably weeds of cultivation. The flax seeds and capsules, judging from the abundance of these remains, may be the refuse of bundles of the cultivated plant put to steep in the marsh. If the seeds belong, on the other hand, to the wild flax, it is strange that they should be so abundant in a peaty deposit, for this plant does not usually grow in marshy places, and is not at the present day found so far north.

The three localities above described are the only ones in Scotland that yield a characteristic temperate flora from beds supposed to be older than part of the Till. There remain, however, several deposits which I am inclined to accept as of inter-Glacial, or perhaps Glacial, date; but these, unfortunately, like all the peaty masses undoubtedly included in the Till, yield nothing but a poverty-stricken, uncharacteristic flora, all the species having an extremely wide range. Kilmaurs, in Ayrshire, where so many remains of the Mammoth have been found, is probably the best known of these localities (see "Great Ice Age," pp. 133, 149, 162). Many seeds were sent to me from this place, but among them there were only six species of flowering plants. Indeed, this poverty of the flora seems to be a common, though not universal, characteristic of deposits in which Mammoth remains are abundant; it was equally marked, for instance, in the Mammoth-bearing loams of Endsleigh Gardens, in London, described by Dr. Hicks.

Another locality where peaty deposits lie unmistakably under Till is at Chapelhall, near Airdrie. This section was first described, many years since, by Sir Archibald Geikie, and on applying to the Geological Survey of Scotland I obtained a box containing several hundred seeds. The result, however, was most disappointing, for they all belonged to two common marsh plants which range throughout the north Temperate and Arctic regions. A further series from other sections at Airdrie yielded about a dozen species, including the dwarf Arctic birch.

In making these comments on the evidence brought forward to prove inter-Glacial periods in Scotland, I do not wish to be misunderstood. I have no objection to recognize such alternations; but for several years I have tried to examine on its own merits the evidence for each supposed inter-Glacial deposit in Britain. In many instances the case completely collapses, but in others it becomes stronger the more closely it is examined. Thus we are gradually bringing to light a definite inter-Glacial period with a characteristic fauna and flora; but before we can pretend to understand the peculiar conditions, it is absolutely necessary to weed out all spurious or doubtful evidence. The case will be enormously weakened in the eyes of all naturalists by the inclusion of such deposits and fossils as those of Cowden Glen, Redhall, and Hailes.

VI.—Can a Diorite become an Acidic Gneiss?

By C. Callaway, D.Sc., M.A., F.G.S.

I HAVE already answered this question in the affirmative in my papers on "Metamorphism in the Malvern Hills,"[1] though I am aware that the assertion has been contested. Nevertheless, the possibility that diorite and quartzite may have a common origin was suggested by Prof. Zirkel as far back as 1876; and in 1892 Mr. W. S. Bayley, of the Geological Survey of Minnesota, distinctly affirmed that a certain quartzite was nothing more or less than "a completely altered gabbro." My conclusion, therefore, is not without support, and, though it has been strongly attacked, it refuses to succumb. I trust I shall be allowed in the present paper to reply to one or two of the objections to it. My remarks refer only to the Malvern area.

So far as I can gather, it has been objected that there is no true passage between the diorite and the gneiss. I have, it is suggested, made an error of observation, and have overlooked breaks in the sections examined. No one has ever pointed out any of these breaks, though I have exhibited series of specimens to the International Geological Congress, to the British Association, and to the Geological Society of London; but I suppose that the belief in the extreme improbability of the alleged change has led to the conclusion that there *must be* error of oversight on my part. It is the old argument of Hume over again—it is easier to believe that Callaway has gone wrong than to believe that a quartzose gneiss should have been formed out of a diorite.

Many mistakes of this kind have no doubt been made. Before the microscope was applied to the study of rocks, they were sometimes almost inevitable. The writer has studied some of them in Anglesey, Caernarvonshire, Donegal, Connemara, and elsewhere. He is therefore fully alive to the risk of error, and has carefully refrained from coming to the conclusion that one rock passes into another until it has been forced upon him by prolonged study in the field and with the microscope.

But perhaps I had better define what is the exact nature of this passage from diorite to gneiss. In the first place, I do *not* mean that there is somewhere a junction between them, at which they are mixed up together in a very intimate manner. Thus, we often find a granite and a grit almost in contact, with the granite passing into an arkose, and the arkose into the grit. Sometimes observers of undoubted competence have described this as a case of a true gradation, and have inferred from it the metamorphic origin of the granite, but no experienced petrologist would make such a mistake now-a-days.

In the next place, I do not intend simply to assert that there is a true passage between the diorite and the gneiss. A mere

[1] Quart. Journ. Geol. Soc., August, 1889, pp. 485, 486; August, 1893, pp. 418–420.

gradation between two kinds of rock proves nothing[1] as to the genetic connection between them. In an igneous magma, for example, one part of a mass may be acidic and the other basic, and they may grade imperceptibly into each other.

What I mean will be best elucidated by an illustration: A piece of beef is roasting before the fire. The central part of the mass is raw and the outer layers are more or less cooked. By cutting into the meat, we see the gradation between the raw and the cooked parts. We also see the cause of the change produced. The proof of the roasting of the meat is therefore complete.

This illustration represents the kind of evidence for the production of acidic gneiss from diorite offered us by the Malvern rocks, and it hardly exaggerates its clearness. We can observe in the rocks the crushing up of the constituents increasing in intensity, and parallel with this change is a mineral transformation. Or the change in the minerals gradually comes in as we approach a plexus of granite-veins. Or both of these causes of alteration may be combined. The evidence of increasing heat as we penetrate a shear-zone is seen in the recementation of minute fragments and shear-lenticles, or in the progressive clearness of the minerals, or in both characters united. Further proof of secondary action is furnished by the relations of the minerals in the completed gneiss, in which we sometimes observe that mica, felspar, and quartz are all moulded upon calcite, which in these rocks is unquestionably a secondary product.

The other objections which have been urged against my conclusions on the origin of the acidic gneiss are chiefly of a chemical nature. The elimination of magnesia and alumina, especially the latter, and the production of biotite out of chlorite, iron-oxide, and potash, are apparently regarded as so improbable that no amount of evidence furnished by field-sections or microscopic slides can establish their reality. This position I contest. I respectfully urge that the chemical theories must give way to the geological facts. If a rock containing 18 per cent. of alumina and 7 per cent. of magnesia has been converted into one in which the percentages are respectively 9 and 0·5, then alumina and magnesia *have* been eliminated. The analyses of Mr. Player prove that the diorite and the acidic gneiss respectively contain the proportions here stated; and, since the one has been changed into the other, we are driven to conclude that the elimination has taken place.

Magnesia and alumina, especially the latter, are no doubt very stubborn things to get rid of; but we have no right to assume that they cannot be eliminated under any circumstances. Laboratory experiments are of very little use to us here. We are quite incapable of determining beforehand what may or may not take place in a granite-diorite shear-zone, where the rock is crushed

[1] Since the above was written, the "Annals of British Geology" for 1893 has appeared, in which the Rev. J. F. Blake (p. xxi) falls into the astonishing error of attributing to me the precisely opposite opinion. It is not surprising that new views should make slow progress when they are thus misunderstood and misrepresented.

into microscopic lenticles, saturated with mineral solutions, and raised sometimes to the point of fusion. If a diorite can be traced without a break into a reconstructed acidic rock, in which the proportions of alumina and magnesia have been reduced, I conceive that we are justified in concluding that, under enormous pressures and at high temperatures, certain chemical changes are brought about which are not produced under ordinary conditions. I do not think I can fairly be called upon to demonstrate the exact mode of operation. It is a step in advance to prove that the thing has been done; *how* it has been done is a further question.

I may point out that there are at Malvern two principal types of gradation between diorite and an acidic gneiss. In the *Ragged Stone Hill* type—(1) the rock has been crushed into a laminated mylonite previous to refusion and reconstruction; (2) the shear-zone contains no granite-veins, though a few felsite-veins are present; and (3) magnesia, but not alumina, has been eliminated, so that the resulting gneiss is highly micaceous. In the *Swingard's Hill* type—(1) the rock becomes progressively sheared towards the fusion-band, and mylonite is not produced; (2) the diorite is interlaced with countless granite-veins; and (3) both magnesia and alumina being eliminated,[1] the result is a quartzose gneiss or gneissoid quartzite.

The diorite of the first type is a granitoid variety (my No. 3); in the second series, it is medium-grained (my No. 1). The chemical composition of both varieties is substantially the same. The difference of behaviour under crushing may have something to do with the greater or less compactness of the rock, the more compact kind more readily slicing into lenticles while shearing. Why alumina is sifted out in the one case and not in the other, there is not sufficient evidence to determine.

I have been quite alive to the alternative view that the diminution in the percentage of alumina may be due, not to the going out of alumina, but to the coming in of silica. If this were admitted, it would not affect the main contention of this paper—that, as a matter of fact, the diorite *does* pass into an acidic gneiss. Furthermore, it would confirm another of my conclusions, that, in the Malvern metamorphism, chemical energy has been exceptionally intense; for this required silica can only have been supplied by the adjacent plutonic rocks.

But the microscopic evidence points to the actual removal of the alumina. If silica had been introduced, it would appear as an intruder amongst crystals of felspar, mica, etc.; but the slides show nothing of the kind. The quartz appears as blebs and granules within the contours of the felspar-crystals. Or it entirely takes the place of the felspar, while the general shape of the crystal is retained, and frequently traces yet remain of a micaceous sheath to the crystals. Or several of the felspars are replaced by silica, and yet scraps of the biotite survive amidst the quartz to outline the position of former felspar-crystals.

[1] In addition, of course, to other bases.

These facts appear to make it highly probable that alumina has been eliminated; but I wish, in concluding, to again point out that the removal of this base is not vital to my general conclusion. I regard it as certain that the diorite has become highly acidic, whether by combined elimination of bases and introduction of silica or by elimination only.

VII.—Peculiar Occurrence of Land and Fresh-water Shells in the Lincolnshire Oolite.

By Beeby Thompson, F.C.S., F.G.S.

(With a page Section.)

In the latter part of 1893 Mr. Albert Wallis, of Brigstock, in Northamptonshire, incidentally told me that he had found some well-known land shells *in* the Lincolnshire Oolite at Brigstock. The section from which these shells came I knew quite well, and Mr. Wallis was well acquainted with recent shells, so it seemed important to ascertain in what manner they found their way into the Oolitic Beds. Having talked the matter over with my friend Mr. Lionel E. Adams (Treasurer of the Conchological Society of Great Britain), we decided to go over to Brigstock, and examine the section and the shells, and arrive, if possible, at some explanation of their peculiar position. Accordingly, on June 16 of last year, we met Mr. Wallis there for the purpose indicated.

The district in which Brigstock is situated has been described by Prof. Judd[1]; but in his Memoir two different sections are referred to as at Brigstock Mill (see pp. 101, 149, and 191). That described on page 149 is the one that we are concerned with, and is the one to which the term Brigstock Mill most appropriately belongs, for it is quite close to an old windmill, on the road towards Stanion, *i.e.* on the north-west of Brigstock, and about a mile, or less, from the village.

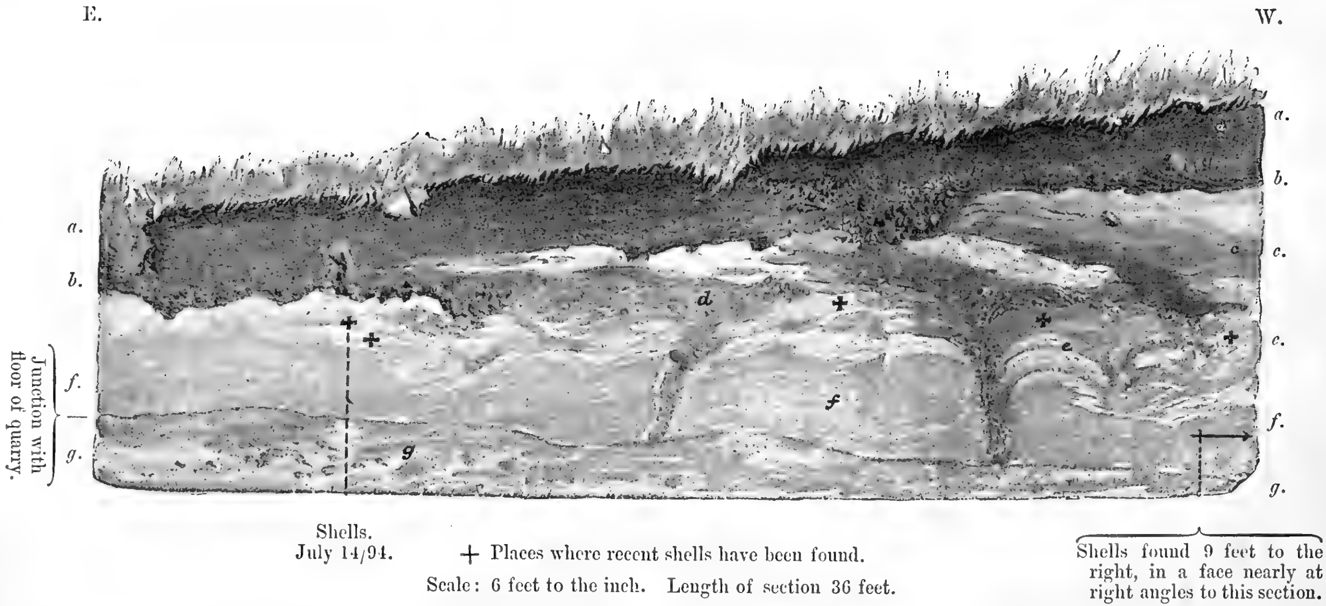
The section Prof. Judd describes on pp. 101 and 191 of his "Geology of Rutland," Lord Lyveden's pits, I find was commonly known as the "brick-kilns," and is not now open; it was situated on the north side of the road just about half way between Brigstock and Stanion.

Description of Inferior Oolite Section at Brigstock Mill.

1. The upper part of the section consists of soil, Boulder-clay, and gravel. The Boulder-clay is scarcely distinguishable from the soil above, except perhaps that it is a little redder and stiffer; but both contain very numerous pebbles and fragments of flint and chalk, such as are usually found in the "drift" of the district. In places the stones are so numerous as to almost constitute a gravel.

2. Under the above, for a variable distance vertically, everything is very confused—Boulder-clay, stones, fine sand, and shelly oolite being very much mixed up, and consequently the junction with the true Oolitic Beds below is very irregular. The thickness of this part

[1] "The Geology of Rutland," etc., by John W. Judd. Memoirs of the Geological Survey, 1875.



+ Places where recent shells have been found.

Scale: 6 feet to the inch. Length of section 36 feet.

a, a. Soil to brown drift, with few stones and boulders.
b, b. Brown clayey drift, with many boulders (oolitic, and flint, and chalk predominating), Boulder-clay.
c, c. Sandy clay in bands without boulders; probably disturbed Upper Estuarine clay.
d. Distorted Oolite and Boulder-clay, much confused.
e. Redistributed Oolite in small stratified beds, with flint and oolitic water-worn stones and recent shells + often distorted.
f. Disintegrated Oolite with large lumps of hard oolitic rock.
g. Floor of quarry.

Section of Lincolnshire Oolite and Drift at Brigstock, showing positions in which Land and Fresh-water shells were found by Mr. Albert Wallis.

may be three or four feet; but it thins out considerably towards the adjacent road.

3. The Lincolnshire Oolite here belongs to the so-called "shelly facies" (Judd), that is, it consists almost wholly of small shells or fragments of shells, mostly water-worn, or encrusted with carbonate of lime, so that all trace of the finer ornamentation is lost, together with concretions not obviously connected with the shelly character. Gasteropods are more numerous than any other form of fossil.

[At some places in the neighbourhood the fossils of this "shelly facies" of the Lincolnshire Oolite are better preserved, and it was from such, near to Weldon, that so many of the forms recently described by Mr. Hudleston, in his Monograph on the Inferior Oolite Gasteropoda, came.]

The upper portion of the Oolite is soft and sandy-looking, and can be picked out quite easily with a knife. The lower portion is mostly harder, more compact, and even somewhat crystalline; and nodular or hummocky masses of this rise, in places, into the softer zone above. The entire thickness exposed is as variable as the clay and soil, etc., resting on it, but in the deepest part reaches nine or ten feet.

4. Here and there in the section are gullies, or "pipes," filled in with Boulder-clay or gravel; they begin in the confused layers (2), and mostly reach below the present working.

The page section illustrating this paper has been produced from a coloured diagram kindly made for me by Mr. Wallis last summer, 1894, and is a record of his personal observations.

The section is really worked as a gravel-pit, and the finer oolitic material, when screened, appears to be very good for garden paths and such like purposes. It appears that the villagers have a right to the gravel, whereas the soil above is private property, and so things are in a peculiar position, and the privilege of digging gravel is greatly curtailed.

The recent shells that have been found at Brigstock all occurred *in* the limestone, at four or five different places, some distance apart horizontally, and at variable depths. The first and chief find was at a spot, now enclosed and covered in by a hen-shed, some ten feet below the surface of the ground, and seven feet below the upper surface of the limestone. Here the shells occurred in a little patch of clay, quite unconnected with the surface or the Boulder-clay, so far as could be ascertained; that is, they were not found in or near to one of the "pipes" previously referred to.

The shells that have been found are, or were at first, fairly perfect, although extremely fragile, and bleached. They include the following species:—

Succinea putris.	*Helix nemoralis* or *arbustorum*?
Cochlicopa lubrica.	*Pupa marginata.*
Helix pulchella.	*Pisidium pusillum.*

The shells were named by Mr. Lionel E. Adams, but one or two were submitted to Mr. J. W. Taylor, of Leeds, for confirmation.

Next come the interesting questions of how and when these shells got embedded in the limestone. To the question how? we can give a fairly definite answer. The upper part of the Lincolnshire Oolite, for at least as far down as these shells were found, must have been disturbed and re-deposited by water, or ice and water, and the shells introduced at this time; for although they have been found at four or five places, in none of these was there any crack or pipe leading to the surface, through which they could have made their way down, even supposing such fragile shells could have survived the journey.

The "pipes" or gullies containing clay and stones have been particularly searched for these shells, but without reward; this is not surprising, for the "pipes" are not wide enough (they vary from a few inches to a foot at the most) for the matter in them to have been precipitated down in mass, even supposing they were at any time open tubes or crevices. Besides, it is pretty certain that these "pipes" were slowly made and enlarged by water percolating from the surface to the springs at the base of the Oolitic series, so that all the material now filling them has gradually got in and worked itself down. Nearly all the flatter stones in them are on edge, a position they would naturally assume in making their way down in the manner indicated, because it is the one offering least resistance to their passage.

It is unlikely that fragile shells could have survived the protracted journey involved by this explanation, even if introduced at any period, at the top, enclosed in a matrix of clay or soil. It is almost certain, however, that the "pipes" are much newer than the period of the introduction of the shells into the limestone (see below).

Having arrived at the conclusion that a re-deposition of the Oolitic Beds, as far down as the shells were found, was a necessary corollary to their being so found, a particular search was made for other evidences of it, and we found, without difficulty, here and there in the Oolite, *about as low down as the shells were found, but no lower*, pebbles and small pieces of flint similar to those found in the "drift" above. Very likely the hummocky masses of indurated limestone previously referred to (3) indicate, where they occur, the depth to which the disturbance which permitted of the introduction of the shells extended.

The question of when? this re-deposition occurred is a more difficult problem to solve. I can find no record of the occurrence of these land and fresh-water shells in any of the Glacial deposits, yet it would appear that they cannot be more recent than the Glacial period. I would offer the following hypothesis on the subject: The animals that formerly inhabited these shells lived in the district near to where they are now found prior to the Glacial period, and their habitations got gradually buried in the soil or clayey subsoil; from this position they were moved with masses of the underlying rock by the advancing ice, and mixed with material from other districts, thus forming the oldest Glacial deposits of the district, of which scarcely a trace in its original form now exists. During the period known as "Inter-Glacial" the melting of the ice produced strong currents of water which washed away most of the argillaceous matter of this early Boulder-clay, leaving only the coarser material, such as sand and gravel, and even baring and disturbing the underlying rock, and re-depositing its material. It is not impossible for the shells we are considering to have been preserved during all this time, if surrounded by a matrix of clay, for beautifully preserved fossils (derived) are often found in the Boulder-clay, and I have even found them in the gravels below, though rarely.

The disturbance and re-deposition of the Lincolnshire Oolite present no difficulties, for there are other instances of re-deposited beds. A considerable area, not far from Northampton, is covered by re-deposited and finely-washed Northampton sand, and this has Boulder-clay above it, and so is older than the latter.

I have carefully examined a very similar section to the one referred to in this paper, situated at Little Oakley (see Judd's "Geology of Rutland," p. 191), and so has Mr. Wallis, but there was no evidence of re-deposition, and no shells could be found. At this place a stream enters the pit from below the Oolitic Beds and passes out under the same, and no doubt discharges into the Harper Brook not far away.

I may say, in conclusion, that a fluviatile origin for the shells was considered, and regarded as untenable.

VIII.—On a Sandy Ironstone occurring above the Chalk at Capel, near Dover.

By Frank Rutley, F.G.S.;
Lecturer on Mineralogy at the Royal College of Science, London.

BETWEEN Dover and Folkestone there are certain deposits of ferruginous sandstone or sandy ironstone, well known to geologists, and somewhat doubtfully referred to some portion of the crag. They may be the equivalents of the Lenham Beds, which are assumed to be the lower part of the Coralline crag, and which have been correlated with the Diestian Beds of Belgium. This view is entertained by Prof. Prestwich, Mr. Clement Reid, and others, and is based upon palæontological evidence (chiefly from Lenham, near Maidstone), from which locality Mr. Reid procured casts of the following fossils:[1]

Ficula (Pyrula) reticulata	*Pectunculus glycimeris*
Ringicula ventricosa	*Diplodonta rotundata*
Turritella incrassata	*Terebratula grandis*, etc.

On the other hand, some geologists, including the late Mr. H. W. Bristow, Mr. W. Whitaker, and the late Mr. W. Topley, have been inclined to regard these deposits as coeval with the Lower London Tertiary and possibly as equivalents of the Oldhaven or Woolwich Beds.

Be this as it may, no one yet appears to have inquired into the microscopic character of these highly ferruginous deposits.

A section made from a specimen of sandy ironstone, which I

[1] The Pliocene Deposits of Britain, 1890, p. 42.

collected years ago at Capel, near Dover, shows, under the microscope, that it is composed almost exclusively of quartz-sand and limonite. The latter substance, which appears of a deep brownish-red colour in reflected light, does not exhibit any pisolitic or other structure, but is simply an amorphous cement which holds together numbers of minute grains of quartz-sand, some of which are rounded, while a large proportion of them are sharply angular. Here and there a small grain of felspar, of somewhat turbid aspect, shows in convergent light a dark brush or the cross of a bisectrix, which separates into dark brushes on rotation, but such grains are of comparatively rare occurrence, and the sand of the deposit may, therefore, be regarded as an almost pure quartz-sand. In these grains fluid lacunæ, containing bubbles, may be detected under high powers, and occasionally small rod-like crystals may be seen as inclusions in a quartz-grain. These appear in many cases to be rutile.

The question naturally arises whence this fine quartz-sand came. We meet with none of the grains which are composite in character, that is to say, there are no fragments composed of agglutinated grains such as one would expect to meet with if the material had resulted from the *immediate* disintegration of a quartzite or schist, neither are these grains composed of two or three adherent crystals of different minerals such as would come from the immediate disintegration of a granite or other eruptive rock. The fact that there is comparatively little attrition involved in the transport by water of such minute grains would sufficiently account for the sharply angular character of a large proportion of them. There is, consequently, nothing to prove that they may not have travelled a long distance. That they were originally derived from the disintegration of eruptive rocks is tolerably certain, but it is more than probable that such material subsequently entered into the composition of some sedimentary rock, a sandstone, or a quartzite, and that it is from the disintegration of some such rock that the sand in question has been more immediately derived.

According to Dr. Sorby, about one-third of the grains constituting the Hastings Sand, at Hastings, are rounded by attrition.[1] This seems to be about the proportion of rounded grains in the sand of the ironstone we are now considering, and it does not appear by any means improbable that these sand-grains may have been derived either from the detritus of certain beds in the Greensand of the South-eastern Counties, in which Dr. Sorby detected an average of from $\frac{1}{2}$ to $\frac{1}{3}$ of rounded grains, or from the Hastings Sand. The denudation of the Weald would have provided vast quantities of such material, and Prof. Prestwich considers "that the anticlinal arch over the Wealden area had been formed and the Chalk greatly eroded, so that in some places the Greensands below the Chalk had been laid bare, before even the lowest of the Eocene beds was deposited."[2] It, therefore, appears highly probable that the sands

[1] Anniversary Address, Geol. Soc. Lond. 1880, p. 34.

[2] Jukes' "School Manual of Geology," 4th edition, edited by A. J. Jukes-Browne, p. 334.

resting on the Chalk at Capel, Lenham, and elsewhere in Kent, have been derived from detritus supplied by the denudation of Neocomian strata.

On the other hand, that sands such as these might have been directly derived from the disintegration of granitic rocks, is not impossible. Speaking of the quartz-grains derived from quartzose felsite, Dr. Sorby says: "But very often there is a remarkable rounding of the angles, which might easily lead anyone to think that they were water-worn. Even the grains of quartz derived from granite sometimes show this character to a less extent, but the rounding is usually accompanied by small surface ridges, which clearly show that their rounded form was not due to mechanical wearing."[1] This phenomenon is the result of corrosion of the surfaces of the quartz-grains by alkaline solutions formed by the decomposition of the felspathic constituents of the rock, and it therefore remains to be decided whether the sand grains in our ironstone were rounded by corrosion or by attrition. If the former, then we may assume that the sand has been immediately derived from some granitic rock; but where it came from is a difficult question to answer. If from any great distance, the material might have been ice-borne, but this is pure speculation; and from the absence of grains composed of several adherent crystals or grains of different mineral constitution, I am inclined to favour the view that such rounding as these grains present is due to attrition, and that they have been derived from sandstones, probably of Neocomian age. Under what conditions they were deposited in post-Cretaceous times I venture to express no definite opinion; but it seems hardly probable that the cementing process took place under the pressure of any appreciable thickness of superincumbent rock, since the quartz-grains are more or less widely separated by the cementing material, a circumstance which would seem to indicate that the sands were subjected to little or no pressure from overlying deposits, and consequently that the ferruginous matter of the cement was not infiltered from superjacent strata. That the deposit is not lacustrine seems sufficiently proved by the fossils which have been found in it.

IX.—The Tower of Eccles-by-the-Sea.

By Rev. E. Hill, F.G.S.

THE church-tower of Eccles-by-the-Sea, on the coast of Norfolk, once buried in the moving sand-dunes, has been rendered classical by Lyell through his description of it in his "Principles." Such a monument should surely not be allowed to pass away without an obituary notice.

Lyell gives drawings of its appearance in 1839 and in 1862. In April 1893 Professor Bonney and I, while at Cromer, paid a visit to it, making measurements and sketches. The foot of the tower was then about thirty yards from a neap-tide high-water mark, and its level scarce four feet above: spring-tides must have nearly or

[1] *Op. cit.* pp. 21, 22.

quite reached it. After our visit a gale, in November 1893, bared the foundations of the church: plans were made, which have been preserved. On Wednesday, January 23rd, 1895, a storm arose, described by a resident as beyond anything he had seen. At six p.m. the waves were breaking furiously against the tower and their spray was flying over its summit. At seven it had fallen.

The line of sand-hills forms a defence against the sea for a level tract of cultivated country behind. My sketch indicates a breadth of about twenty yards for this rampart and a height of some twenty or thirty feet. An account says that "the havoc to the sand-banks baffles description . . . . they are not half their original size in breadth and height . . . . the sea overflowed the gap-way and the manor house was in danger of being inundated . . . . Eccles has had a very narrow escape of the catastrophe which happened in 1605, when hundreds of acres of land, with sixty-six houses and their inhabitants, were swept away in one night."

Lyell adduces this ancient ruin among his evidences of the encroachment of the sea on the eastern coasts of England. His figures appear faithful, for the appearance and dimensions of the sand-dunes at our visit were just the same as in them. The figure of 1839 shows the tower emerging from the very centre of the line of sand-hills. That of 1862 shows it nearly free of them on their seaward face, at a distance from their centre about equal to its own height. As its height was about forty feet this might indicate that the sand-hills had travelled inland about forty feet in twenty-three years. At our visit in 1893 we found the line of dunes entirely separated from the tower, and we measured its distance from their centre as about thirty yards, which gives an advance of ninety feet in fifty-four years. Lyell alludes to the possibility of a subsidence in the coast, but this is not required to explain the march of the sand-dunes.

I have to thank Professor Bonney for the loan of his notes, and the Rev. J. S. Whitney for an answer to enquiries, and for an extract from the "Eastern Daily Press" of January 26th, 1895, containing an account of the event.

X.—On the Genus *Plutonides* (non *Plutonia*) from the Cambrian Rocks of St. David's.

By Henry Hicks, M.D., F.R.S., F.G.S.

Quite recently, Mr. B. B. Woodward, F.G.S., of the British Museum (Natural History), called my attention, for the first time, to the fact that the name *Plutonia*, which I adopted for a genus of Trilobites in 1868, had previously been used by Stabile (Atti. Soc. Ital. Sci. Nat. vii, p. 121, 1864) for a genus of Mollusca. As Stabile's generic term has therefore a priority of four years it is necessary that I should rename the Trilobite, and it has been suggested to me by Mr. Belinfante, B.Sc., Assist. Sec. Geol. Soc., that *Plutonides* would be the most suitable term and the one least likely to lead to confusion. In the Report of the British Association for 1868, p. 69, where the genus is first mentioned, after describing the beds in which it occurs I refer to it as follows: "The new genus, for which the author proposes the name *Plutonia*, is only known to occur in these beds. This remarkable fossil is of very large size, equalling, indeed, in this respect *Paradoxides Davidis.* It is, perhaps, also more nearly allied to the genus *Paradoxides* than to any other known, but its peculiar character of being covered all over with very strong tubercles, associated with an unusual position for the eye suture, and straight, very long thoracic pleuræ, is sufficient to stamp it a new and distinct genus."

It was more fully described by me afterwards in the Quart. Journ. Geol. Soc. vol. xxvii, p. 399, as *Plutonia Sedgwickii.* One species only has been discovered and no complete specimen. As mentioned above it resembles, in some particulars, the genus *Paradoxides*; but I know of no species in that genus which has such wide pluræ, or such a pronounced ornamentation on all parts of the body. The pygidium has not been found; but some fragments which have turned up seem to indicate that it approached more nearly that of *Anopolenus* than to *Paradoxides. Plutonides* greatly exceeded in size any specimens of *Anopolenus* yet discovered, as portions of the body, which I obtained, show that it could not have been less than seven inches across at its greatest width, or one inch wider than the largest *Paradoxides* found by us at St. David's, now in the Museum of the Geological Society. Its length, however, would evidently be less than *Paradoxides,* with fewer segments to the thorax.

REVIEWS.

I.—Collected Papers on some Controverted Questions of Geology. By Joseph Prestwich, D.C.L. (Oxon), F.R.S., F.G.S. (London: Macmillan & Co., 1895. 8vo, pp. xii and 280.)

THE book before us consists of a series of articles, the subjects of which have occupied the author's attention during many years, and concerning some, if not all, of which he is more or less at issue with many of his fellow-geologists. "With respect to the main facts of geology," says Professor Prestwich, "we geologists are in general of one opinion, but with respect to the explanation of many of those facts, we hold very divergent opinions."

Article 1 treats of "The Position of Geology," and is directed against the prevailing school of geologists in this country who hold the doctrine of Uniformity—uniformity of action both in *kind and in degree* throughout all geological time; and the Continental school who hold uniformity in *kind or law,* but not *uniformity in degree.*

The points touched upon embrace the rate of sedimentation, calculated upon the transporting power of rivers, which are estimated to lower the level of the land one foot in 6000 years, or one thousand feet in 6,000,000 years. The author remarks that the rate might be doubled if the calcareous matters held in solution, as well as the matter held in suspension, were taken into account. Professor Prestwich also objects to a *mean rate* of elevation of land at $2\frac{1}{2}$ feet in a century taken from the coast of Norway, when at the North Cape it is as much as five feet in a century.

He refers to the vast antiquity of man, based on his contemporaneity with the extinct mammalia and the recurrence of Glacial periods, but whilst he condemns the needless demands of glacialists who fix the disappearance of Palæolithic man and the Quaternary fauna at 80,000 years back, he states that it is possible, on other grounds, that the antiquity of man will have to be carried back further into the Glacial period (see footnote, p. 8).

Other estimates of time are based on the Westleton marine shingle-bed, Bucks, at 600 feet above O.D., and the same bed in Suffolk occurring at sea-level; on the Moel Tryfaen shell-bed at 1400 feet elevation, estimated at 88,000 years; and the raised beaches of Norway 200 to 600 feet, assumed to be from 8000 to 24,000 years old. From the Westleton bed he argues that the time-estimates, based on the other raised beds, are worthless, in which we cordially agree.

Professor Prestwich then protests against those physicists who maintain the theory of a rigid crust, and cites the modern raised beaches, etc., as evidence in refutation of such a view. He also doubts the assumption of a solid crust of 800 to 2500 miles in thickness, and prefers to leave it an open question, and suggests that it is probably not more than 20 to 30 miles thick.

Article 2 is devoted to "Considerations on the date, duration, and conditions of the Glacial Period, with reference to the Antiquity of Man." Here the author makes use of the data regarding modern glaciers and other evidence to show that the enormous periods of time required by Croll's theory are uncalled for, and the evidence for successive Glacial epochs unsatisfactory.

Professor Prestwich's next essay is "On the primitive characters of the Flint Implements of the Chalk-plateau of Kent, with reference to the question of age and make." This article is illustrated by twelve plates of worked flints, showing the various characteristic forms that are relied upon by the author to establish the presence of man antecedent to the time when these implementiferous flint-gravels were formed, and long antecedent to that when the present valley-system had been excavated.

The fourth article, "On the Agency of Water in Volcanic Eruptions, and on the primary cause of Volcanic Action" (illustrated by plate xiii), is followed by one "On the thickness and mobility of the Earth's Crust from the geological standpoint"; the sixth and last being "On Underground Temperatures—with observations on certain causes which influence the conductivity of rocks; on the thermal effects of saturation and imbibition; and on a source of heat in mountain-ranges, as affecting some underground temperatures."[1]

[1] It may interest some of our readers to know where these articles first appeared. Art. 1 appeared in the "Nineteenth Century" for October, 1893, p. 551. Art. 2, in the Quart. Journ. Geol. Soc. August, 1887, vol. xliii, p. 393. Art. 3, in the "Journ. Anthrop. Inst." for 1892, p. 246. Art. 4, Proc. Roy. Soc. April, 1885, p. 117. Art. 5, *ibid.* April, 1888, p. 156. Art. 6, *ibid.* 1885, p. 1.

The six articles make a very useful and readable volume, which every geologist should possess. They are full of valuable facts and suggestions, and are the result of long years of patient and careful observations and study by one of the most able geologists of this century; and, although we may not agree with the author in all his views, we cannot but feel interested in the subjects he so ably lays before us.

II.—The Fossil Insects of the Primary Periods. By Dr. Charles Brongniart, of the Natural History Museum, Paris. (Recherches pour servir à l'histoire des Insectes Fossiles des Temps Primaires). St. Etienne, 1894.[1]

THIS valuable monograph is the result of sixteen years' continuous devotion on the part of the author to the study of that remarkable Palæozoic insect fauna, so wonderfully preserved in the fine Coal-shales of the Commentry Collieries, situated in the Department of the Allier, Central France.

Some fifty or sixty years ago the acknowledged rarity of fossil insects in strata older than the Wealden or Lias, and their unrecorded existence in Palæozoic rocks, naturally led to false assumptions to account for their absence; climatic conditions being alleged as noxious and unfavourable to air-breathing animals. Since that period, however, isolated discoveries in the Coal-measures of England, Germany, and America have shown how unsafe it is to generalize from negative evidence in speculations of this kind.

It has been reserved to one favoured locality in a circumscribed area of Central France to furnish more specimens of fossil insects and in a better and more complete condition than in all the previously known localities of the world put together, thus showing that insects were abundant, as might have been anticipated from the rich forest growth of the period, and that the existence of insect feeders as Spiders, Scorpions, and insectivorous forms of Reptilia might also have been prognosticated.

The discoveries at Commentry are entirely due to M. Henry Fayol, the Engineer and General Manager of the Commentry Coal-pits, whose enlightened zeal and careful attention to the fossil contents of the strata in the works under his charge have yielded such ample reward.

One group of these fossil insects, the largest in point of number of individuals, the family of Blattidæ or Cockroaches, is only outlined in its principal genera in the present work, Dr. Brongniart reserving them for a special and more exhaustive study in a future contribution.

The monograph is divided into three parts, to which is added an atlas of plates forming a separate volume.

The first part gives an historical account of the works which have been already published on fossil insects, followed by a bibliographical

[1] This work forms the thesis presented by M. Brongniart to the Faculty of Sciences, Paris, to obtain the grade of Docteur ès Sciences Naturelles, which has been recently awarded him.

index of authors and references brought up to date, an extremely valuable list, for much of which the author is indebted to Professor Scudder's Bibliography of Fossil Insects (1882).

The second part consists of a study or investigation of the neuration of the wings of *living* insects, belonging to the orders Neuroptera, Orthoptera, and Fulgorida, groups to which the Palæozoic types seem to be most nearly allied.

This portion of the work the author has felt compelled to undertake for the more intelligible comparison of fossil forms with their living representatives. The variety of names given by different authors to the nervures and other critical parts of the wing structure has caused much confusion. The importance of a clear and distinctive nomenclature of the plan of neuration will be recognized by entomologists, as the classification of fossil insects mainly rests upon the position and distribution of the nervures or veins of the wings, which are too often the only parts preserved.

M. Brongniart remarks on this portion of his work that "we have now, thanks to this study of the neuration, a foundation on which to attempt the description of fossil species, not only of the Coal-measures, but also of all geological epochs. Naturalists who devote themselves to the study of fossil insects will be able to resort with profit to our illustrations, and to our text to establish comparisons."

The third part of the monograph deals with the specific object of the work,—the Comparative Study of the Fossil Insects of the Carboniferous rocks with living types, by the light of the numerous examples found at Commentry, many of which have been so marvellously preserved that we have not only the wings but also different parts of the body to assist in identification.

Mr. S. H. Scudder, the eminent American entomologist, who has written so much on fossil insects, in his memoir on the "Affinities and Classification of Palæozoic Hexapoda,"[1] unites all the Coal-measure insects in one great division, under the name of Palæodictyoptera (a term previously employed by Goldenberg), as he considers they all belong to extinct species and are exclusively developed in Palæozoic deposits.

Dr. Brongniart, on the contrary, does not agree with this opinion, which he regards as a too hasty conclusion from insufficient and fragmentary materials, and says "that Mr. Scudder, in establishing this classification, had not at his command specimens so well preserved and so numerous as mine, and that by the study of the insects of Commentry we are able to demonstrate that the Palæozoic types can be classified in the orders created for living species."

Dr. Brongniart recognizes three orders: the Neuroptera pseudo-Orthoptera, the Orthoptera, and the Homoptera, in a group having affinities with the Fulgorida.

The order Neuroptera, the author says, "is largely represented and already affords at this remote epoch a great variety of forms. Some species are of gigantic size, and at all events it is well to

[1] Memoirs of the Boston Society of Natural History, vol. iii, No. xi, 1885.

bear in mind, that nearly all these insects surpass in size their living representatives." Several families are included in this order, among which are the Protephemerida, whose neuration recalls that of the living Ephemerida (May-flies), of which they may be considered the precursors; and the Platypterida, of which the genus *Lamproptilia* contains two species of large size, whose span of wing attained some seven to eight inches, and what is also remarkable, the wings bear evidence of having been richly coloured and ornamented by rounded spots.

The family Protodonata comprises species which may be considered as the predecessors or ancestors of living Libellulæ (Dragonflies). These ancient types were often of gigantic size; one species, of which we have a superb restoration figured in the atlas, measured about 70 centimetres or 28 inches in the spread of wing, giving one a lively idea of these aerial giants of other days.

The family Protoperlida resembles the actual Perlida, whose larval state is passed in the water, and while in that condition their food is the larvæ of May-flies and other insects. All the foregoing are insects with incomplete metamorphoses and whose larvæ live in the water.

In the order Orthoptera Dr. Brongniart has placed all those fossil insects which resemble living species of the order. Thus, among the Carboniferous insects he identifies species which can be approximated to several existing families, such as the Blattidæ, the Locustidæ, the Acrididæ, and the Phasmidæ.

That these early precursors of the Blattidæ, our familiar Cockroaches, were a numerous and widely distributed family in the forests of the Carboniferous epoch may be predicated from the fact of their remains having been found in most of the European and American Coal-fields; but in no locality have they been met with in the same abundance and perfection as at Commentry, where nearly a thousand specimens have been collected by M. Fayol.

The Protolocustidæ, of which numerous remains have been found, appear to have so close a relationship to our living Locusts or Grasshoppers, not only in the form and neuration of the wings but also in the characters of other parts of the body, that they seem, in M. Brongniart's opinion, scarcely to have required being placed in a distinct family.

The Acrididæ or Cricket family was also represented by numerous individuals, two genera of which have been distinguished.

Coming to the last order discussed by the author, the Homoptera, of which there are but few representatives at Commentry, and these differing in several characters from existing types, have been referred to the group Fulgorina.

It will be noted that in this summary of the fossil insects of the Carboniferous rocks, no mention has been made of the Coleoptera or Beetles, although certain insect borings found in fossilized wood have been ascribed to them. Had, however, beetles existed at this remote epoch, it would be natural to expect other authentic indications of their presence than mere borings; such, for example, as the hard wing-cases or elytra, which are by no means rare among the insect remains of the later Mesozoic period. These curious and interesting borings have not only been found in the silicified fossil wood of the French Coal-field of the Loire but they also occur in the calcareous nodules, containing plant-remains, of the Lower Coal-measures at Oldham, near Manchester. Although these perforations simulate similar destructive operations of actual wood-boring beetles, it would be an unsafe conclusion, without further evidence, to pronounce them to be their work, as they may be due to a burrowing larva of some other and as yet unknown insect.

As might be expected, we have no traces in the Palæozoic rocks of the higher orders of insects, such as the Lepidoptera and Hymenoptera (Butterflies and Bees).

The atlas of 37 plates accompanying the text will be regarded with especial pleasure, not only for the intrinsic interest of the fossils delineated but for the beauty and clearness of execution of the figures. The first 12 plates are devoted to the figures of the neuration of living insects to serve as terms of comparison with fossil types. These drawings have been made by the aid of the *camera lucida* from nature by M. Brongniart and reproduced directly by the heliogravure process. The remaining 25 plates are occupied with the figures of the fossil insects of Commentry, the drawings of which are mostly of natural size and of scrupulous fidelity, due to the extreme care and labour expended on them by the author. Some of the figures are photographed directly from the specimens themselves and reproduced in heliogravure.

It is a fact worthy of record and an example to be encouraged, to note that this work, which appeals perhaps but to the few, and whose author could not hope for material gain by its publication, has been printed at the cost of "La Société de l'Industrie Minérale de Saint Etienne," to whose wise and generous use of the funds at its disposal the scientific public is indebted for a valuable accession to palæontological literature.

The examination of this abundant insect fauna of Commentry, so well depicted in the specimens figured in the atlas, will doubtless claim the notice of entomologists and palæontologists as to the immense antiquity of the class Insecta. Not only do the great variety, perfection, and size of the specimens cause astonishment, but their close resemblance in many instances to living forms arrests attention. MARK STIRRUP.

III.—ANNALS OF BRITISH GEOLOGY, 1893. A Digest of the Books and Papers published during the year; with an Introductory Review. By J. F. BLAKE, M.A., F.G.S. 8vo, pp. xxiv, 365; with 90 Illustrations. (London: Dulau & Co., 1895.)

ONCE again Professor Blake's welcome volume makes its appearance. This time we are glad to note its originator speaks more hopefully of the future, and we earnestly trust it may become a "hardy annual." The conditions are that it shall receive continued and steady support; and by British geologists, at least, this will surely not now be withheld, seeing its great utility, which each succeeding year of publication enhances.

The present issue is conducted on the same lines as the last, "with the exception of the greater brevity of the notices of publications of a text-book nature"; a wise improvement, and we only wish Prof. Blake could be also induced to forego the section "Foreign Geology (published in Britain)," for reasons explained on previous occasions.

The book is a wonderful piece of work, and a monument of patient industry (730 papers read and abstracted!), and though we sympathize in his resentment at its being called "a compilation," we think Prof. Blake does himself injustice when he says "it is as pure a piece of original research as I have ever been guilty of"; surely he does not wish it to be inferred that, to take a single example, his monograph on the Corallian Rocks of England was nothing more than a digested abstract of the work of others? Slips there are undoubtedly in places, but how can such be avoided in a work of this description? Gratitude for its production would blind all but the most captious reviewer to far more serious defects. The heartiest thanks of all geologists should be Prof. Blake's.

REPORTS AND PROCEEDINGS.

Geological Society of London.

March 20th, 1895.—Dr. Henry Woodward, F.R.S., President, in the Chair. The following communications were read:—

1. "On Fluvio-Glacial and Interglacial Deposits in Switzerland." By C. S. Du Riche Preller, M.A., Ph.D., F.G.S., F.C.S., A.M.I.C.E., M.I.E.E.

This paper is the outcome of one published in the Geological Magazine of January 1894, on the "Three Glaciations in Switzerland," in which the author described various glacial deposits near the lake of Zürich. He now describes a series of fluvio-glacial conglomerates and interglacial lignite deposits near the lakes of Zürich, Constance, Zug, and Thun, which, together with analogous deposits at the base of the Eastern, Western, and Southern Alps, constitute further evidence of two inter-Glacial periods, and therefore of three general glaciations, the oldest of these being of Upper Pliocene, and the others of Middle and Upper Pleistocene age respectively. As regards the origin, age, and the time required for the formation of several of the Swiss deposits referred to in the paper, the author arrives in several respects at conclusions differing from those recently enunciated by others. The author also argues that the first inter-Glacial period was probably of shorter duration than the second; and in confirming his former conclusion that every general glaciation marks a period of filling-up, and every inter-Glacial period marks a period of erosion of valleys, he avers that, if this conclusion be correct, it must needs be destructive of the theory of glacial erosion.

2. "The Bajocian of the Mid-Cotteswolds." By S. S. Buckman, Esq., F.G.S.

The Mid-Cotteswolds is defined as the district between the valleys of the Frome and the Chelt. A description of twenty-five sections is given, dealing principally with the strata found between the Upper *Trigonia*-grit and the upper Freestone—such strata being called, for the purpose of present distinction, "the intervening beds." Of these twenty-five sections, seventeen, lying between Stroud and Leckhampton, are discussed in Part I of the paper to show the succession of the intervening beds, to point out that Cotteswold geologists have confounded two distinct deposits, the Lower *Trigonia*- and Gryphite-grits, to prove that the former, and not the latter, is the more persistent stratum, and to give evidence that denudation, called "Bajocian denudation," has, prior to the deposition of the Upper *Trigonia*-grit, cut right through the intervening beds in the neighbourhood of Birdlip, so as to make a shelving trough six miles wide and about thirty feet deep.

The remaining eight sections are described in Part II of the paper. They lie eastwards of Leckhampton, and are given to show the discovery of another ammonitiferous horizon in the Cotteswolds, yielding angustumbilicate *Witchelliæ*. It is proved that this bed is above the Notgrove Freestone and below the Upper *Trigonia*-grit; so that it is really an addition to the stratigraphical sequence hitherto recognized in the Cotteswolds. Its ammonites show it to have been deposited contemporaneously with the middle of the Sandford Lane Fossil Bed, and yet it is removed by ten to twelve feet from the Gryphite-grit=lower part of that bed. In the Mid-Cotteswolds this important *Witchellia*-bearing bed is only preserved over an area of about 1½ square miles, because it has been mainly removed by Bajocian denudation; and only one side of one small quarry yields a favourable exposure. No other locality showing this deposit has yet been found in the county.

Two plotted diagrams are given to show the developments of the beds in the different sections, and to illustrate the result of the Bajocian denudation. In an Appendix to Parts I and II various notes are given, and attention is called to a remarkable oyster as a document of historic value evidencing the Bajocian denudation.

Part III of the paper gives the chronological sequence of Brachiopoda in Dorset and the Cotteswolds in the Inferior Oolite, to show their value for purposes of exact correlation when ammonites are absent; and to illustrate that the Brachiopods are a good medium of exchange in regard to the strata of the Cotteswold and Dorset districts respectively, that in some cases they are such in regard to the two districts, and in other cases they fail in this respect, so that ammonites become the only true medium of exchange between the beds of different basins.

An Appendix to Part III describes certain new species of Brachiopoda, and gives notes upon others.

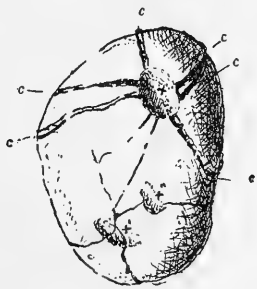
CORRESPONDENCE.

THE INDENTATION OF THE BUNTER PEBBLES.

SIR,—In "Annals of British Geology," 1892, p. 52, is a review or abstract of a paper entitled "The Trias of Cannock Chase," by T. M. Reade. In this abstract we read, "The indentation of the pebbles he considers to be the result of contact-solution, the water being retained at these spots by capillary action."

Now, whether this theory of the origin of the pittings or little surface dimples on some of these pebbles is a probable one or not I do not discuss, but a specimen of one of the Cannock Chase pebbles I happen to possess (picked up by myself in the ballast on the London and North-Western Railway, near Lichfield, about eleven years ago) bears unmistakable evidence that the indentations upon it were produced by a squeeze or pressure; for this reason one end of the pebble (a reddish-brown quartzite, by the way) is not only severely fractured into four or five pieces, but is also miniature faulted. The lines of fracture radiate from typical indentations or dimples upon opposite sides of the pebble. Here, then, at all events, is an actual instance of a Bunter pebble not only indented by other pebbles in contact with it *in situ* in the conglomerate, but it is evident the pressure upon its sides was great enough to split it and dislocate its fragments. The once-open cracks, so produced, are now filled with calcite, which acts as a cement, holding the several portions of the pebble together. This fact supports the physical or mechanical origin of the indentations of the Bunter pebbles. Can Mr. Reade adduce *evidence* in support of the chemical theory, of which it does not appear he gave any in his paper?

Here is a sketch of one side of the particular pebble I refer to.



× = One of the indentations $\frac{5}{16}$ in. long.
×′ ×″ Lesser indentations with finer cracks in contact therewith.
c, c, c, cracks in pebble, now filled with calcite.

NOTE.—Corresponding indentations on opposite side in a larger one than this.

ERIE, PA., U.S.A., *7th February,* 1895. W. S. GRESLEY.

BUDLEIGH SALTERTON PEBBLES.

Sir,—Referring to Professor Bonney's interesting discovery[1] of schorlaceous rocks in the Budleigh Salterton pebble bed, which bed after all is but a new Red Conglomerate, it should be borne in mind that schorlaceous fragments are abundant in the breccias near Teignmouth, and elsewhere in the Red Rocks of Devonshire. It would be well to compare them, in order to ascertain, if possible, whether they have a common origin. Schorlaceous rocks, as is well known, vary greatly.

With respect to the suggestion now again brought forward by Professor Bonney that the Red Sandstones of Devonshire evidence currents from the westward,[2] the fact should not be overlooked that the mica schists found in the Bigbury Bay conglomerate, to the northward and westward of the Bolt Head, indicate transport from the south and east, harmonizes well with the commonly accepted view that many of the Budleigh Salterton fossiliferous quartzites are of southern derivation. A. R. Hunt.

MISCELLANEOUS.

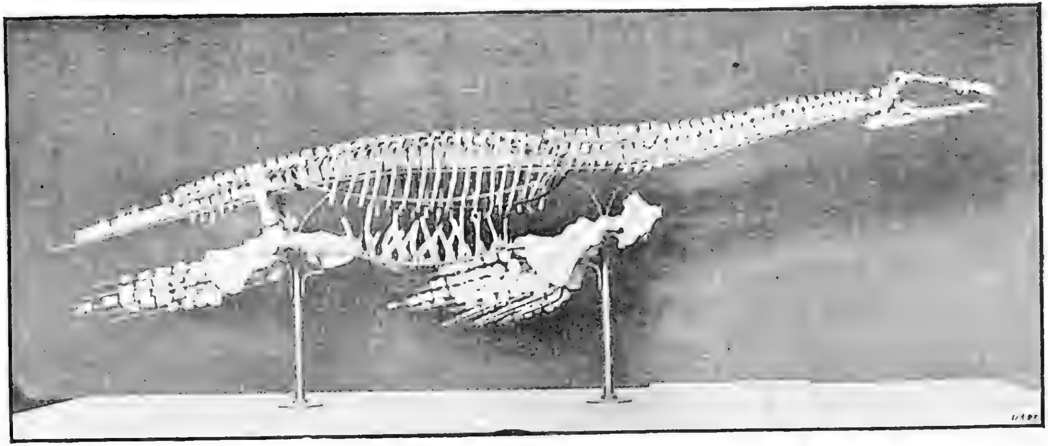
"Geological Society of South Africa."

A largely attended meeting was held in the Chamber of Mines Board-Room, Johannesburg, Transvaal, on February 4th, 1895, for the purpose of forming a Geological Society. Dr. Hugh Exton, F.G.S., occupied the chair and addressed the meeting. The following resolutions were then moved and seconded, and carried unanimously: (1) that a Society be formed to be called "The Geological Society of South Africa"; (2) that Mr. Lionel Phillips be the first Honorary President; (3) that Professor T. Rupert Jones, F.R.S., F.G.S., and Dr. W. Guybon Atherstone, F.G.S., be Honorary Vice-Presidents; (4) that Dr. Hugh Exton, F.G.S., be the first President, and Messrs. A. R. Sawyer, F.G.S., and John Ballot, the first Vice-Presidents. (5) The Executive Council was then formed as follows: Messrs. C. Aburrow, Ed. Button, A. R. Boucher, J. S. Curtis, J. A. Chalmers, S. Farrar, F.G.S., H. D. Griffiths, A. Goerz, L. Grahame, J. Dampier Greene, J. H. Johns, E. C. Jones, E. J. B. Knox, C. Wilson Moore, W. M. Phillips, T. Reunert, E. Kemper Voss, Peregrine O. Wilson, and F. White. (6) It was unanimously resolved that Mr. David Draper, F.G.S., be appointed Secretary of the Society. It was resolved that those gentlemen who signed their names at that meeting be the first members; that the list remain open till 28th February, after which election to be by ballot.

The greatest enthusiasm prevails, and the Secretary fully anticipates that 300 members will join by the end of the month. All communications for the Society should be addressed to David Draper, Esq., F.G.S., P. O. Box 450, Johannesburg, Transvaal.

[1] Geological Magazine, February, 1895, p. 77. [*Memo.*—"All showed tourmaline, so two of them were sliced. Both consisted mainly of granular quartz and tourmaline." Hence schorlaceous.—A. R. H.]

[2] *Ibid.* p. 79.



Photograph of the skeleton of a young Plesiosaur, from the Oxford Clay, Fletton, near Peterborough; part of the "Leeds Collection" in the British Museum (Natural History), S.W.

Length of original specimen six feet.

THE

GEOLOGICAL MAGAZINE.

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No. VI.—JUNE, 1895.

ORIGINAL ARTICLES.

I.—Note on a Skeleton of a Young Plesiosaur from the Oxford Clay of Peterborough.

By C. W. Andrews, B.A., B.Sc., F.G.S.
Assistant in the British Museum (Natural History).

(PLATE IX.)

ONE of the most notable additions made to the Gallery of Fossil Reptilia in the Natural History Museum during the last few years is the beautifully preserved Plesiosaurian skeleton which is represented in Plate IX.

This specimen was obtained by A. N. Leeds, Esq., of Eyebury, near Peterborough, from a pit in the Oxford Clay at Fletton, in the neighbourhood of that town, and is a splendid example of the results obtainable by a careful collector who is able and willing to devote time and energy to personally superintending the removal from the deposits in which they are found of those specimens brought to his notice. The neglect of ordinary precautions has led to the loss or separation of too many valuable associated series of bones for it to be necessary to insist on the extreme value of such careful work as that of Mr. Leeds, to whom we are indebted for one of the finest collections of Mesozoic reptiles and fishes ever made.

In the present specimen (Leeds Coll., No. 36) the bones are quite uncrushed and free from matrix, and, though some of the more delicate ones were found broken into numerous fragments, it has been possible in most cases to piece them together, every fragment having been carefully preserved and numbered. The skull, owing to the fragile nature of many of its constituent bones, is, unfortunately, much broken and is imperfect, but the rest of the skeleton is complete, with the exception of some caudal vertebræ and chevrons, a few ribs, and some small paddle-bones. The whole has been skilfully mounted by Mr. C. Barlow, and now presents the appearance shown in Plate IX.

For reasons given in a recent paper[1] I consider that this skeleton is that of a young individual of *Cryptoclidus Oxoniensis*, Phillips, sp. A short description of the chief osteological characters exhibited by this specimen may now be given :—

[1] Ann. Mag. Nat. Hist. ser. 6, vol. xv (1895), p. 333.

The skull is comparatively short, the snout being blunt and rounded; its length is about one-third that of the neck. The premaxillæ, which are covered with irregular ridges, each bore five or six slender teeth, the crowns of which are nearly smooth.

The pineal foramen is large, and is situated between the anterior ends of the parietals. These bones form a high crest between the temporal fossæ, and posteriorly are produced outwards into short processes which unite with the ascending rami of the triradiate squamosals, the ventral rami of which unite closely with the quadrate, while the anterior, wanting in this specimen, formed the hinder portion of the temporal arcade. These squamosals are very like the same elements in *Sphenodon*, and probably are equivalent to squamosal+supratemporal.

The *basioccipital*, which is still free from the basisphenoid, bears the whole of the nearly hemispherical occipital condyle. The *basisphenoid* is deeply excavated anteriorly by the pituitary fossa, and has adherent to its ventral surface a plate of bone which is prolonged anteriorly. This element, which must be regarded as a *parasphenoid*, is well shown in some Pliosaur skulls in the British Museum, in which it runs forward for some distance between the pterygoids which unite with its outer edges.

On the outer side of the exoccipitals, and when seen from the outer surface of the skull, apparently arising from those elements, are the large paroccipital processes which are directed outwards and downwards. If this region be examined on the internal surface, it is seen that these processes spring from distinct elements (the *opisthotics*), still separated from the exoccipitals by deep clefts, although externally the sutures are obliterated. The opisthotic shows the impression of two of the semicircular canals. The *supra-occipital*, which is very large, is also channelled by a portion of the auditory labyrinth, there being no trace of a distinct epiotic ossification.

The mandible seems to have carried from 20 to 22 teeth; each ramus is about 23 centimetres in length.

The cervical vertebræ are 31 or 32 in number; the neural arches and cervical ribs are all free from the centra, a character depending merely on the age of the individual; the centra are short with oval articular faces, which are much less concave than in the adult; the neural spines are short and stout, and the anterior and posterior zygapophyses are respectively slightly concave and convex transversely; there is also a zygosphenal articulation.

No union has yet taken place between the centrum of the axis and that of the atlas (*i.e.* the odontoid); this latter bears the two halves of the atlantal neural arch, which are widely separated from the anterior wedge bone forming the lower fourth of the cup for the reception of the occipital condyle.

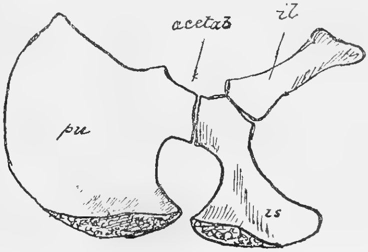
There are two or three pectoral and 21 or 22 dorsal vertebræ. Behind these are three or four vertebræ bearing short, somewhat expanded ribs, which articulate between arch and centrum; these appear to be sacral. The caudals bear small rib-like chevrons, which do not unite below to close a hæmal canal and rarely fuse with the centra.

The abdominal ribs are strongly developed. They are arranged in several transverse rows, each consisting of a median piece and paired lateral pieces. In a former paper[1] I stated that there are two of these lateral pairs, and in the present specimen they are so mounted. In Mr. Leeds' collection, however, in a specimen[2] in which the ventral ribs are retained in their natural position through being partly imbedded in a hard concretionary mass of clay, there are clearly three lateral pairs, and this is also the case in, at least, some of the Liassic Plesiosaurs.

The pectoral-girdle has been figured and described in the paper just quoted.

The humerus at this stage shows scarcely any trace of the great distal expansion which characterizes it in the adult, but the radius is already very large compared to the other paddle-bones.

The ilium is a curved rod of bone, laterally compressed at its upper end and rounded at the lower, which in this specimen was evidently covered in life with a cap of cartilage, the articular surfaces not being ossified. In an adult ilium (see Figure) of the same species the lower end bears two articular surfaces—the larger



Pelvis of adult of *Cryptoclidus Oxoniensis* seen from within.
il, ilium; *pu*, pubis; *is*, ischium; *acetab*, acetabulum.

for union with the ischium, the smaller forming a portion of the hinder edge of the oval acetabulum; there is no surface for the pubis. The hatchet-shaped ischium has three subequal articular surfaces at its upper end, the posterior for the ilium, the median forming the middle and greater part of the acetabulum, and the anterior for the pubis. This latter is a broad plate of bone with convex anterior and concave posterior border; proximally it unites with the ischium and forms the anterior portion of the acetabulum.

The femur is rather less expanded distally than the humerus, a difference much more marked in the adult. The remainder of the hind-paddle calls for no special notice.

Plate IX. was prepared from a photograph taken by A. Gepp, Esq., of the British Museum (Natural History), to whom my cordial thanks are due.

[1] Ann. Mag. Nat. Hist. ser. 6, vol. xv (1895), p. 334.
[2] I am indebted to Mr. Leeds for drawing my attention to this specimen.

II.—On the Age of the World as depending on the Condition of the Interior.

By the Rev. O. Fisher, M.A., F.G.S.

In *Nature* of the 7th of March, Lord Kelvin reported the results of a series of experiments, which render it almost certain that Prof. J. Perry's hypothesis of the conductivity of rock increasing with the temperature is unsupported by evidence. He also stated that he had been led by later study to modify his original estimate of the age of the world, and to reduce it to about the same as estimated by Mr. Clarence King, viz. 24 million years. Thus geologists would find themselves restricted to a still shorter period for the evolution of the events of the world's history than they supposed.

It must, nevertheless, be carefully remembered that the estimates of the world's age above referred to proceed upon the hypothesis that the earth is solid throughout, whereas the more obvious interpretation of geological phenomena appears to point to the opposite conclusion, that the crust is comparatively thin, and floats upon a substratum of molten rock of rather greater density than its own.

The principal argument for the solidity and rigidity of the earth is derived from the existence of tides in the oceans; for it is held that, if the interior were liquid, there would be subterranean tides in it, which would carry the crust and the enveloping ocean up and down in concert together, so that the measurable depth of the water to the bottom would always remain unchanged; for, although a tidal deformation of the ocean surface would be present, it would not be able to be noticed. It is plain that this apparent obliteration of the tides would require that the deformation in the substratum with its floating crust and the deformation in the enveloping ocean should occur at any given place simultaneously and equally; that is to say, there would have to be high tide in the crust where and when there was high tide in the water, and low tide in the crust where and when there was low tide in the water, and in each case with the same range of rise and fall. This requires that the surface of the crust should be deformed to the exact shape that the moon's attraction would produce in a liquid globe, and that the same should be the case also with the surface of the ocean. But, seeing that a tide is formed by the local accumulation of matter by differential horizontal flow, it seems highly improbable that the exact form of the tidal spheroid could be produced in the crust, because the irregularities in the under-surface of it, corresponding to and supporting the continental elevations, would so break up and deflect the tide wave in the substratum on which it floats, that the exact form of the tidal spheroid would not be generally maintained beneath the crust, just as it is known not to be maintained at the surface of the ocean owing to the deflection caused by coast lines, whence arise the irregularities known as the "establishments of ports." Thus the exact form of the tidal spheroid would be maintained in neither crust nor water surface, and tides would accordingly be observed. If this be a correct explanation, it would seem likely that, where there is an exceptionally large unbroken area of ocean, and consequently a comparatively smooth extent of under-surface to the crust, in such a region the proper form of the tidal surface might be more nearly preserved both for the subjacent liquid rock and for the water, and the measurable tide would consequently be small. Now such is the case in the central parts of the Pacific, scarcely any proper tide being observable at the Sandwich Islands.

No argument for rigidity can be drawn from a fortnightly tide, because observations hitherto made have not demonstrated that one exists.

If the above apology for believing in the possibility of a liquid interior can be admitted, it will follow that, the bottom of the crust being constantly laved by molten rock, we should have a mode of communication of heat from beneath which would continually delay the cooling and thickening of the crust, and have an effect upon the temperature gradient at the surface similar to that which would have resulted from Professor Perry's hypothesis, supposing it to have been true.

If we accept Professor Darwin's theory of the genesis of the moon, there are cogent reasons for believing that interior liquidity is more than probable.

It seems to be admitted on all hands that the earth was once a molten spheroid, rotating at a speed much exceeding the present of once in twenty-four hours. The theory is, that at some early period the moon was thrown off from the earth, and that since that time its distance has gradually increased to the present 239,000 miles. This increase in the moon's distance, implying a large amount of work done in opposition to the earth's attraction, has been obtained at the expense of the energy of the earth's rotation, through the medium of tides produced in the earth and in the ocean, but chiefly in the earth itself. The leverage by which the moon has acted on the tidally deformed earth has necessarily been greater at the circumferential than at the central parts. Consequently the retardation of rotation has proceeded from without inwards, so that the inward parts have always rotated somewhat more rapidly than the outward, and a consequent friction and generation of heat has been set up within, which has been much more considerable in the central than in the outer parts. The amount of heat so generated would have been, to use Professor Darwin's own expression, "prodigious," and, upon his estimates, "the whole heat generated from first to last gives a supply of heat at the present rate of loss for 3560 million years." With this enormous amount of heat being perpetually communicated to the inner parts (and there does not appear to be any reason why the supply should have hitherto entirely ceased) how could the globe have become wholly solid at the melting temperature for the pressure at every depth? It seems that, having been once liquid, it can never have had the chance of becoming sufficiently cool to solidify. If this be the true statement of the case, no reliable estimate of the age of the world, based on considerations of the present temperature gradient at the surface, has hitherto been made.

If the interior be liquid, and the central parts have been constantly receiving greater accessions of heat than the parts more distant from the centre, convection-currents must have been set up, and must have played the chief part in the secular cooling. The age of the world would therefore be dependent upon the degree of their activity, which is not known. Another important consequence would follow, because the currents would necessarily have a horizontal flow in the parts of their course where the liquid had ceased to rise and had not yet begun to descend; and this would produce a horizontal stress on the superincumbent crust, acting more powerfully upon it at those places where the bottom was most uneven, as beneath mountains. Thus we should be able to account for one cause, at least, of the compressing force for which geologists are in search.

Woodwardian Museum Notes.

III.—Supplementary Notes on the Drygill Shales.

By G. L. Elles and E. M. R. Wood, Newnham College, Cambridge.

In the Geological Magazine, 1887, Professor Nicholson and Mr. Marr drew attention to a group of fossiliferous shales detected in connection with the Borrowdale Volcanic Series.

At the request of Mr. Marr, we undertook the examination of larger collections of fossils made from the same locality, and the object of the following notes is to place these on record, and, in the light of further palæontological evidence, to assign to the beds a more definite horizon.

As Professor Nicholson and Mr. Marr showed, these beds occur on the north side of a great mass of Skiddaw Slates in what has been termed the Caldbeck Fells area. The shales to which we wish to direct attention are situated north of the intrusive masses of Carrock Pike and Great Lingy, and are of interest as lying between the Skiddaw Slates on the one hand, and the Volcanic Series of Caldbeck Fells on the other. They occupy the summit of the valley between High Pike and Carrock Pike, and are exposed in Drygill, whence Professor Nicholson and Mr. Marr have given to them the name of the Drygill Shales.

The following section is described by them in Drygill in descending order:—

1. Drab-coloured shales, unfossiliferous.
2. Blue-grey shales, weathering white.
3. Dark blue-grey or black mudstones.
4. Volcanic rocks.
5. Dark fossiliferous mudstones with Trilobites and Brachiopods.

The general dip of the beds is to the S.S.W., and the beds of the south fork of Drygill are probably the same as those exposed in the highest part of the main gill, since the faunas are almost identical, and differ markedly from that belonging to the beds exposed in the lowest part of the same. The following is a complete list of the fossils as yet identified from the Drygill Shales, with their ranges. Many of the specimens have evidently been much affected by the mechanical deformation to which the rocks have been subjected; scarcely any of them are complete and many are very obscure.

TRILOBITA.

NAME.	REMARKS.	RANGE.
**Ampyx rostratus* (Sars.)	Common	Llandeilo—Bala.
Ampyx tetragonus (Angelin)		Bala (Trinucleus Schiefer of Sweden).
Ampyx tumidus (Forbes)		Bala.
**Stygina Murchisoniæ* (Murch.)	Common	Llandeilo—Bala.
Trinucleus seticornis (Hisinger)	Common	Bala.
Trinucleus concentricus (Eaton)	Common	Bala—Upper Llandovery (?)
Trinucleus, sp. (allied to *affinis*)		Bala (Trinucleus Schiefer).
Phacops (*Pterygometopus*) *alifrons*? (Salt.)		Bala.
Phacops (*Acaste*) *appendiculatus* (Salt.)		Bala.
Phacops, sp.		
Dindymene ornata (Linn.)		Bala (Trinucleus Schiefer).
Calymene Blumenbachii (Brong.)		Tremadoc—Aymestry (?)
Calymene senaria (Conrad)		Llandeilo—Wenlock.
**Calymene cambrensis* (Salt.)		Llandeilo—Bala.
**Lichas laciniatus* (Dalm.)		Bala (Brachiopod Schiefer).

OSTRACODA.

NAME.	REMARKS.	RANGE.
**Beyrichia complicata* (Salt.)		Llandeilo—Bala.

BRACHIOPODA.

NAME.	REMARKS.	RANGE.
**Obolella*?		
**Plectambonites sericea* (Sow.)		Llandeilo—Wenlock Shale.
Plectambonites transversalis (Wahl.)		Bala—Aymestry.
Plectambonites quinquecostata (M'Coy)		Llandeilo—Upper Llandovery.
**Orthis testudinaria* (Dalm.)	Very common	Llandeilo—Upper Llandovery.
Orthis elegantula (Dalm.)		Llandeilo—Upper Ludlow.
Lingula ovata (M'Coy)		Llandeilo—Bala.

LAMELLIBRANCHIATA.

NAME.	REMARKS.	RANGE.
Ctenodonta varicosa (Salt.)	Common	Bala.
Ctenodonta levata (Hall)		Bala.
Ctenodonta, sp.?		
Orthonota, sp.?		
Modiolopsis?		

GASTEROPODA.

NAME.	REMARKS.	RANGE.
Murchisonia, sp.		
Pleurotomaria turrita (Portl.)		Bala.
Pleurotomaria, sp.		
Bellerophon?		

CEPHALOPODA.

Orthoceras, sp.

* Denotes species previously recorded by Nicholson and Marr.

The fossils recorded above are by no means uniformly distributed throughout the beds; the following were found only in the south fork of the gill, and the highest part of Drygill proper:—

Trinucleus seticornis.
Trinucleus concentricus.
Trinucleus, sp. (allied to *affinis*).
Phacops (*Pterygometopus*) *alifrons.*
Phacops (*Acaste*) *appendiculatus.*
Phacops, species.
Lingula ovata.

Calymene cambrensis and *Orthis testudinaria* do occur here, but are far more common in the lower part of the gill.

From the above lists it will be seen that the beds of the south fork, and of the upper part of Drygill, are characterized by the abundance of *Trinucleus*, while in the beds of the lower part of the gill species of *Ampyx*, *Stygina Murchisoniæ*, and *Orthis testudinaria* are very abundant.

It is obvious, therefore, that we have here two distinct faunas represented, and we would suggest that the beds in the south fork and upper part of Drygill belong definitely to a somewhat higher horizon than the beds exposed elsewhere in the stream.

Age of Drygill Shales.—Professor Nicholson and Mr. Marr (*loc. cit.*) suggested that there was a resemblance between the Drygill Shales and Dufton Shales, but considered that the abundance of such fossils as *Orthis testudinaria*, *Leptæna sericea*, *Calymene cambrensis*, *Ampyx rostratus*, and *Stygina Murchisoniæ* pointed to the beds being at about the horizon of the Llandeilo Limestone.

Species from Drygill Shales.	Coniston Limestone of Norber (Settle).	Dufton Shales.	Sleddale Group.	Quarrel Hill (Girvan).
Ampyx rostratus	x	...	...	x
Ampyx tetragonus	...	x	x	...
Ampyx tumidus	...	...	x	...
Trinucleus seticornis	x	x	x	x
Trinucleus concentricus	x	x	x	...
Calymene Blumenbachii	...	...	x	x
Calymene senaria	...	x	x	...
Lichas laciniatus	...	...	x	...
Plectambonites sericea	x	x	...	x
Plectambonites transversalis	x	x	x	...
Plectambonites quinquecostata	x	...	...	...
Orthis testudinaria	x	x	x	...
Orthis elegantula	x	...	x	x
Lingula ovata	...	x	x	...
Beyrichia complicata	x	...	x	...

They originally considered that the beds were younger than the Skiddaw Slates and older than the Coniston Limestone, but in a more recent paper (Geol. Mag. 1892) Mr. Marr expressed his belief that this correlation was erroneous, and that the Drygill Shales were probably more closely allied to the Coniston Limestone.

In the light of further palæontological evidence, we would emphatically confirm this suggestion. We believe that the beds lie above the Borrowdale Volcanic Series, and we are convinced that they are most closely related to the Dufton Shales of the Cross Fell area, and to the Sleddale Beds of the Lake District proper.

Lithologically they do not differ more among themselves than do the Dufton Shales, which they resemble closely, since both are in the main composed of dark, flaggy, calcareous mudstones. The preceding table shows the species common to the Drygill Shales, Dufton Shales, the Sleddale Group, etc.

Summary.—The result then of our examination of the fossils of the Drygill Shales is to show the predominance of Bala Limestone forms, and the close parallelism of the beds with others of the same age in the Lake District.

Although correlated with the Bala Limestone as a whole, we think that the Drygill Shales are capable of further subdivision, viz. into (1) an Upper Group, characterized by the abundance of *Trinucleus*; (2) a Lower Group, characterized by the abundance of *Ampyx* and *Orthis testudinaria*, though it is not suggested that this subdivision is of more than local importance.

Note.—We take this opportunity of thanking Mr. Marr for many valuable suggestions, and of gratefully acknowledging the help given us by our friend Miss E. G. Skeat of Newnham College, in the identification of some of the fossils.

Our list of fossils was compiled from collections made at various times from Drygill, all of which are now in the Woodwardian Museum.

IV.—Shell-Structure in the Ammonoidea.

By Ernest H. L. Schwarz, A.R.C.S.

From the Geological Research Laboratory, Royal College of Science.

THE shell-structure of the Ammonoidea has received very inadequate attention from palæontologists; in most cases authors are content with describing the shell of the recent Nautilus, and saying that that of the Ammonites is exactly the same. Prof. Judd therefore suggested that I should take the subject up, when working as a research student under him. As a result, I have found that the resemblance of the Nautilus- to the Ammonite-shell is literally true; but the structure of the extinct forms throws an altogether new light on that of the recent one, while the usual homology of parts between the two requires, I think, revision.

In the Nautilus there are two main layers composing the walls of the shell: one nacreous and inner, the other porcellanous and outer. Of these, that corresponding to the inner layer is usually preserved in the Ammonoidea. In the Clymeniidæ, no details of shell-structure have been published; but in the Goniatites, Hyatt[1] has figured a *Gon.* (*Glyphroceras*) *crenistria*, Phill., from Rudesheim, showing the two layers, but both are probably parts of the same layer, since mineralization has destroyed the original structure.

In the Ammonites proper, the earliest example showing the original lustre and structure on record is *Ceratites nodosus*, de Haan,

[1] Bull. Mus. Comp. Zool. Cambridge, iii, 1852.

from Hanover.[1] In the later rocks innumerable cases occur in which the shells show their natural play of colour, such as the Oxford-clay Ammonites, *Am.* (*Psiloceras*) *planorbis*, Sow., from Watchet, or *Am.* (*Microceras*) *planicosta*, Sow., from the Marston Magna Marble of Wiltshire. Hyatt[2] has figured sections of the last with a short description, but he took the recent Nautilus as a key to the understanding of the parts, therefore I think it worth while to redescribe it with the help of a large series of sections of other Ammonites.

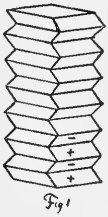
In the Ammonites and Nautili the inner layer appears to be composed of fine laminæ of calcium carbonate and conchiolin, alternating in varying thicknesses, but always very fine; Blake[3] gives $\frac{1}{200000}$ to $\frac{1}{300000}$ inch as the thickness of those of the recent Nautilus, and the Ammonite laminæ are about the same. These laminæ have been taken to constitute the primary structure of the shell,[4] and this idea is helped by the fact that the shell tends to split parallel to them, and thereby causes dissolution and re-crystallization to follow the same lines, by sucking the water into the cracks by capillary attraction; hence we see in the mineralized shell the laminæ reproduced. But under favourable conditions, as when the shell is preserved in clay, such as is beautifully seen in *Am.* (*Ludwigia*) *opalinus*, Rein., from Haresfield, this laminated structure becomes obliterated, while the real primary structure is preserved. This consists of innumerable prisms standing perpendicular to the surface, and united (probably, as we shall see later, by the interlocking of their component crystals) into a self-supporting tissue. These prisms also may be faithfully reproduced in other minerals, as in the Blackdown Ammonites, *Am.* (*Schloenbachia*) *varicosus*, Sow., and *Am.* (*Hoplites*) *denarius*, Sow., where the shell has a pink, faintly-iridescent hue, which may be converted into marked iridescence by soaking chips in Canada balsam, when they will show the prisms well, although they now consist of silica; and also in the Gault Ammonites, e.g. *Hoplites splendens*, Sow., where the pyritized prisms may be seen on looking at the surface with a ¼ inch objective by reflected light. In *Am.* (*Ludwigia*) *opalinus*, Rein., *Am.* (*Amaltheus*) *ibex*, Quenst., *Am.* (*Cosmoceras*) *Jason*, Rein., as they usually occur, the shell is white and opaque, though otherwise unaltered; when thin tangential sections of these are soaked in Canada balsam they become perfectly iridescent, and show unmistakably the prismatic- without the laminated-structure: shells which have the latter only are incapable of regaining their natural lustre. This deals the death-blow to the theory of iridescence caused by outcropping of the laminæ in fine lines, as illustrated by the celebrated Barton buttons; or by means of alternating films of different optical density, provided by the calcium carbonate and conchiolin; while it clearly indicates that

[1] F. von Römer, Jahresber. Schlesisch Gesells., Breslau, 1873.
[2] *Loc. cit.* [3] British Fossil Cephalopoda.
[4] Carpenter, Brit. Assoc. Reports, 1847, p. 46; Sorby, Pres. Address, Geol. Soc., 1879, says the laminæ are pierced by fine needles of aragonite, p. 31.

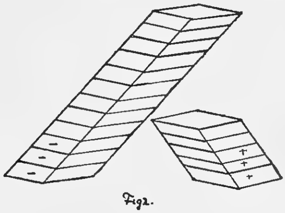
the true cause is to be found in the ultimate structure of the prisms. In offering a new theory, I will suppose that calcium carbonate is deposited in the form of flat rhombohedra, since I have reason to believe that the shells of Ammonites and Nautili consist of calcite; but if the calcium carbonate crystallizes in the rhombic system, a similar form could be substituted without injuring the conclusion.

The shell substance as it is poured out from the mantle surface consists of a gelatinous mass, holding calcium carbonate in solution (mucoso-cretacée of Blainville[1]), and may be seen in that condition on the inside of a newly-opened oyster-shell. This homogeneous secretion hardens by the separation of the calcium carbonate in the crystalline state, while the conchiolin moulds itself around the growing crystal. Eventually, then, there is formed a thin membrane of conchiolin with innumerable flat rhombohedra lying imbedded in it; the animal matter on their broad faces forming the conchiolin laminæ, while that on the short faces forms the boundaries of the future prism. Now supposing the subsequent layers place their positive rhombohedra on the positive ones of the first, and the negative on the negative, we shall finally get two sets of columns leaning in opposite directions (Woodcut 2), such as

1.



2.



we find in the shells of Gasteropods.[2] If, however, the positive rhombohedra are placed on the negative ones of the layer before, and *vice versâ*, we shall get columns perpendicular to their base, but with a jagged outline (Woodcut 1). That the crystals of one layer have the power to influence those of the next is shown in the outer layer of the Nautilus, where the proximal granules are in optic continuity with the prisms below.

The latter of the two cases is that which may very well be imagined to obtain in the nacreous shells of the Cephalopoda; for it explains why the columns hold together so firmly, namely, by the interlocking of the projecting angles of the rhombohedra; and, also, light entering such a tissue would be reflected and broken up into its constituent colours by the myriad points, and would emerge coloured in all the tints of the rainbow, as we actually see to be the case. The conchiolin in the recent Nautilus is not very apparent round the individual crystals, owing to its being caught between the zigzag boundaries; but in the extreme edge of the section, where it

[1] Manuel de Conchyliologie, 1825.

[2] Rose, Abh. Akad., Berlin, 1858, also Carpenter, *loc. cit.*

is only one lamina thick, it becomes much more marked. Dotted about the tangential section there are specks of conchiolin which look as if they were tubules, but these are not seen in longitudinal section and may be explained as places where two adjacent crystals fail to interlock. In parallel polarized light, the tangential section of the prisms, which show as tiny ovals, are not isotropic, proving that they are not crystal prisms with basal planes; while in convergent polarized light a beautiful monaxial cross is given (as is the case also in the recent Nautilus), due probably to the aggregation of organic and inorganic particles.

In the longitudinal section of the extreme edge of the living-chamber of *Am.* (*Microceras*) *planicosta*, Sow., Fig. 1 (p. 253), the newly-formed prisms fan out slightly, producing a crinkling of the surface, which afterwards disappears by the straightening out of the prisms. This is due, undoubtedly, to growth by intussusception; not by means of actual canals as Kœnigsborn[1] and others have supposed, but rather by the shell-building material being passed on through the conchiolin, just as water in the soil is passed on from grain to grain, though no conduit is seen. Carpenter has also shown that slight intussusception goes on in the Lamellibranch shell, for he says that the boundaries of the prisms in *Mya arenaria*, L., become obliterated in old age.

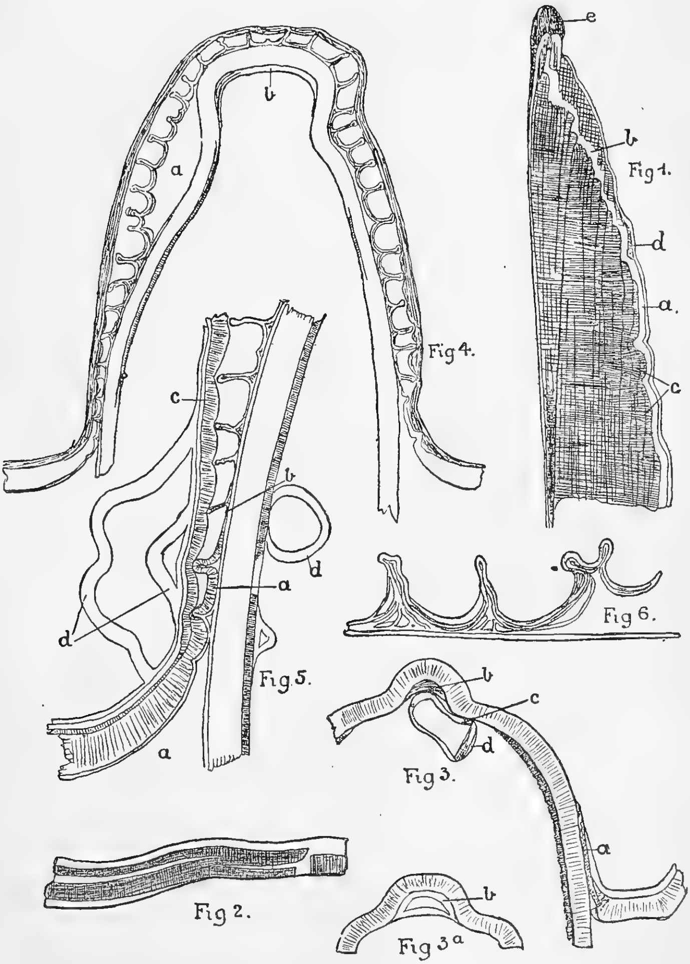
The outer layer, corresponding to the porcellanous one of the Nautilus, is usually taken to be represented by a clear crystalline deposit external to the prismatic zone, as is shown in *Am. planicosta* figured by Hyatt.[2] But my section, Fig. 1, of the same, from the same material, shows that this is nothing else than part of the inner layer, which has split before the rest, and so drawn in the re-crystallizing water, for the clear band is seen dipping inwards and separating the true prismatic layer at the edge. In another section, Fig. 2, showing the wall of the living-chamber, the evidence of the origin of this outer layer is still plainer. In most cases that I have examined the so-called outer layer in like manner seems to be the outer part of the prismatic layer re-crystallized; it is, however, probable that a porcellanous outer layer did exist, but, owing to its granules not being united into a self-supporting tissue, it was quickly dissociated on the death of the shell. Thus, in Fig. 1 the horny matter at the end seems to have terminated such a layer which has gone, while in a Lias nodule containing *Am.* (*Grammoceras*) *radians*, Schloth., there appears to be an actual granular layer (*a*), preserved between two adjacent whorls, Fig. 3. Again, in *Crioceras Calloviense*, Morris, there is a clear band of re-crystallized matter surrounding even the extreme edges of the spines; this is probably the representative of the outer granular layer, for if it were part of the inner, one would think that it would break through the bases of the spines.

[1] Untersuch. ü. crust. Panzer u. Mollusk. schaal., Berlin, 1877. Of course I do not mean here that growth from within can go on to the extent that Méry postulated, Hist. de l'Acad. rog. des Sci., Mém., 1710.

[2] *Loc. cit.*

The outer layer then, though it can be demonstrated in a few cases, is ordinarily absent in the preserved shells.

The septa of Ammonites are identical in structure with that of the nacreous layer, though the septa of the recent Nautilus presents many differences from the true nacre.



EXPLANATION OF FIGURES.

Fig. 1. Section of the extreme edge of the living-chamber of *Am.* (*Microceras*) *planicosta*, Sow. *a*, so-called outer layer passing between portions of the prismatic layer at *b*; *c*, prisms slightly bent from the straight line; *d*, layer separating the prismatic from the vanished outer layer; *e*, terminal rim of conchiolin.

Fig. 2. Section of the same showing the so-called outer layer running between portions of the prismatic layer.

Fig. 3. Section of *Am.* (*Grammoceras*) *radians*, Schloth., from Bridport, showing the fourth whorl with a granular layer, *a*, interposed between it and the next; *b*, deposit in the keel; *c*, siphuncle with the outer sheath, *d*, N.B. the shell-wall is not continued over the back of the smaller whorl.

Fig. 3*a*. A section of the fifth whorl showing the deposit (*b*) in the keel splitting to form the hollow keel.

Fig. 4. Section of the junction of the seventh and eighth whorls in *Am.* (*Amaltheus*) *margaritatus*, Schloth., showing the wrinkled layer. At *a* it has been pushed away from the inner shell; *b*, deposit in the keel, which does not split in this species.

Fig. 5. Portion of the same enlarged. *a*, *a*, nacreous layer of the larger whorl terminating abruptly at *b*; *c*, nacreous layer resting on the apices of the wrinkled layer, and which is not continuous with that of the sides of the shell; *d*, *d*, *d*, sections of the septa.

Fig. 6. Three wrinkles enlarged, from the same.

In forms with a hollow keel, constituting the group *Falcoideii* of v. Schwarz,[1] the space included in it is commonly considered to be bounded on the inner side by the prismatic layer, and on the outer by the porcellanous one.[2] I have not been able to examine the typical case of *Am.* (*Oxynoticeras*) *oxynotum*, Quenst., as all our English specimens are represented as casts; but what I have said about the doubtful nature of the so-called outer layer seems to throw suspicion on its ever so occurring. In *Am.* (*Grammoceras*) *radians*, Schloth., however, in about the third whorl, a thin layer of prismatic tissue arises in the keel, quite separate from the usual nacre; this grows in thickness as the shell increases in size, till about the fifth whorl it splits, and encloses a triangular cavity which eventually becomes the hollow keel in the adult. The cavity, then, is bounded by its own peculiar paries (*b*), and is really a separate tube closed at the end, and has all the nacreous layer external to it (see Fig. 3*a*). In *Am.* (*Amaltheus*) *margaritatus*, Schloth., a similar deposit occurs, but does not split. Whether the hollow keel is invariably formed in this way, I have not examined sufficient material to state.

An analogous phenomenon is the case of hollow tubercles whose cavity is cut off from that of the air-chambers; in casts, therefore, the prominences are not represented. Such is the case in *Am.* (*Liparoceras*) *Henleyi*, Sow., where the prismatic layer divides, and a thin bridge of nacre separates the two cavities.

That the chambers do contain gas, I think, is proved by those of the Nautilus containing a gas differing from ordinary air in its greater percentage of nitrogen[3]; and their use, I think, may be understood from the habits of their living relative, the octopus,[4] which are in all probability similar. This latter when it darts upon anything, such as a crab falling through the water, shoots backwards just above it, and the prey is caught in the swirl following in the animal's wake, and is easily surrounded by its arms. It would obviously be an advantage if the hinder portion,

[1] Inaug. Dissert. Tübingen, Salzburg, 1873.

[2] Hyatt, Arietidæ, p. 216; Haug, Neues Jahrb., 1885, pt. iii, p. 593.

[3] Vrolik, Ann. Mag. Nat. Hist., xii, 1843, p. 173.

[4] Steinmann, Berich. d. Naturforsch. Gesell., Freiburg, 1889, vol. iv.

or that which cleaves the water, were lifted up in readiness to spring, and this appears to have been one of the functions of the shell.

The peculiar layer interposed between two successive whorls in some Ammonites has been termed the "wrinkled layer" by Hyatt,[1] as a translation of the "Runzelschicht" of Sandberger[2] and Quenstedt,[3] or the "Conche ridée" of Barrande.[4] It is homologous with the "black layer" of the Nautilus, which sometimes presents a striated appearance.[5] It has been observed in *Clymenia* (*Oxyclymenia*) *striata*, Münst., and *Cl.* (*Oxyclymenia*) *pseudogonites*, Sandb.[6] In the Goniatites it is also, occasionally, seen,[7] as in *G.* (*Gephyroceras*) *intumescens*, Beyr., and *G.* (*Tornoceras*) *retrorsus*, v. Buch. In the early true Ammonites, also, it is very frequently well preserved, as in *Arcestes, Cladiscites, Ptychites, Gymnites*,[8] *Protensites*,[9] etc.; in the later forms it has not been so often recorded, but when it does occur it does so in a greater degree. In *Am.* (*Liparoceras*) *Henleyi*, Sow., it forms strong spiral ribs over the ventral wall. In *Am.* (*Amaltheus*) *margaritatus*, Schloth., it reaches its highest development, as was pointed out by Quenstedt,[10] and I have specimens from Dundry and Bridport showing it well. In the latter specimen the wrinkled layer arises about the fifth whorl, or at the age when the keel first becomes prominent, and in two more whorls attains the complexity figured in Figs. 4–6. In the more enlarged drawing (Fig. 5) the inner layer of the larger whorl is seen to end abruptly where it reaches the inner whorl, and takes part only in the first three wrinkles. At the fourth, the true wrinkled layer begins, consisting of a brown horny material pleated into steep parallel folds, which often split or bifurcate. In life it probably consisted of pure conchiolin: and as we often find a black material taking the place of conchiolin, as between the prisms of the shell of *Turbo pica*, the homology between the black layer of the Nautilus and the wrinkled layer is strengthened. Resting upon the apices of the folds is the dorsal inner layer, which is not continuous with the inner layer, such as is found on the free sides of the shell.

The only use that I can see for a layer so developed is that it served as a spring cushion whereby the shocks which the animal gave to its shell when shooting backward were deadened, the conchiolin being eminently adapted for the purpose. And this view is supported by the fact that in *Am. margaritatus* it first appears at the same time that the keel does, which was used to divide the water and allow the animal to dart more quickly.

[1] Bull. Mus. Comp. Zool., Cambridge, 1871, vol. iii, p. 91.
[2] Verstein. d. Rhein. Schichtsyst. in Nassau, 1850, p. 58.
[3] Petrefaktenkunde Deutschlands, pt. i, 1846.
[4] Syst. Silur., vol. ii, p. 23, 1867.
[5] Palæontographica, vol. iv, p. 184.
[6] Verhandl. d. Naturhist. Vereins. d. preuss. Rheinlande, 1853, vol. x.
[7] Keyserling, Reise in das Petschoraland, St. Petersburg, 1846, p. 274.
[8] Mojsisovics, Med. Trias Provinz, Abh. geol. Reichsanst., Wien, 1882.
[9] Hauer, Trias v. Bosnien, Denksch. Akad., Wien, 1892, vol. lix.
[10] *Loc. cit.* p. 93, fig. 14*d*.

Under the name "Epidermiden" there have been described markings on the inner surface of the living-chamber of the fossil-chambered Cephalopoda, which are probably homologous with the soft lattice markings on the inside of young Nautili.[1] Barrande (*loc. cit.*) has described them in detail for the fossil Nautili and Goniatites of the Silurian, under the name "stries creuses" (sometimes stries d'eraillure; German, Ritzstreifung[2]), and noticing that they are absent in forms with a contracted mouth, he argues that their function was to secure the animal in its shell. In these forms they consist of very fine close-set striations oblique to the direction of the ornaments of the shell. Similar structures are developed in Ceratites,[3] but especially in the Triassic Ammonites, *Ptychites*, *Klipsteinia*, etc. In later forms they have not been frequently observed, probably owing to the small attention paid to casts of the interior when specimens with the shell on can be obtained: however, I have noticed them in a large *Am.* (*Microceras*) *capricornis*, Schloth., from Chideock. The "stries creuses" were formed probably during the time that the hinder portion of the mantle was secreting the new septum; for, while that was going on there would be an absolute necessity for the animal to be kept firmly fixed in its new position, and to be able to withstand the pressure of water from without. The muscles of the mantle therefore became tightly stretched, thereby producing little ridges and hillocks around areas of non-compressibility, and a condition of things arose similar to the "goose-flesh" of the human integument, which is caused by contraction of the skin round the hair papillæ.

In *Am.* (*Deroceras*) *Dudressieri*, d'Orb.,[4] *Am.* (*Arietites*) *obtusus*, Sow., and *Am.* (*Arietites*) *stellaris*, Sow.,[5] there appears to be a third layer deposited on the exterior of the shell in senile forms, and presents an ornamentation which is unique among the vast series of forms.

The siphuncle in the Ammonites is often beautifully preserved as a horny tube frequently distorted from its normal circular form, Fig. 3. This is equivalent to the inner conchiolin sheath of the Nautilus' siphuncle, and in many cases (Fig. 3*d*) there is evidence of a sheath surrounding this inner one, but in no case that I have examined does this second one bear spicules as in *Nautilus pompilius*, L.[6]

[1] Sandberger, G., Schrift d. oberhess. Gesells. f. Natur u. Heilkunde, No. vii, p. 79, 1859.

[2] Sandberger, G., Jahrb. d. Vereins. f. Naturkunde, Wiesbaden, vii, p. 292, 1851.

[3] Eck, Zeits. deutsch. geol. Gesells., p. 276, 1879.

[4] Wright, Lias Ammonites, Pal. Soc., pl. xxv.

[5] Oppel, Die Juraformation, Jahresh. d. Vereins. f. Naturkunde, Stuttgart, vol. xii, 1855.

[6] Brooks, Proc. Boston Nat. Hist. Soc., vol. xxiii, p. 380.

V.—Note on Pseudo-Spherulites.

By Lieut.-General C. A. McMahon, V.P.G.S.,
and W. Maynard Hutchings, F.G.S.

THE January number of this Magazine contains an interesting paper on a soda-bearing rock from Dinas Head, Cornwall, read by Mr. Howard Fox, F.G.S., at the Oxford meeting of the British Association. Mr. J. J. Harris Teall, F.R.S., supplied notes on the microscopic structure of some of the specimens; and four chemical analyses by Mr. J. Hort Player and Mr. Arthur F. Hosking are given in the paper, from which it appears that the specimens analysed are composed of from 64 to 66 per cent. of silica; from 19 to 20 per cent. of alumina; 9·8 of soda; and small amounts (generally under 1 per cent.) of potash, titanic acid, ferric and ferrous oxides, magnesia and lime.

A sketch of a nodular spherulitic specimen is given at page 18, Geol. Mag. 1895.

In a subsequent paper[1] read by Mr. Fox before the Royal Cornwall Geological Society in 1894, other specimens from the same locality, the microscopical examination of which was undertaken by one of the authors of this paper, are described.

Some of the soda rocks from Dinas Head, which form the subject of this paper, contain a number of nodules closely resembling spherulites to which it seems desirable to invite the attention of petrologists. They are mostly in rounded forms, but owing to their interference with each other's growth, thin sections of them, under the microscope, sometimes present irregular hexagonal outlines. Superficially examined they greatly resemble true spherulites, and have been accepted as such by some good observers.

The main question which arises in connection with these spherulites is, whether they are of igneous origin, and denote a vitreous igneous rock, or whether they represent contact action exercised on a sedimentary rock. After a prolonged study of the specimens sent to him, General McMahon came to the conclusion that they are sedimentary rocks indurated and altered into a variety of porcellanite, or adinole, by contact metamorphism.

The structure of the base in which the pseudo-spherulites are imbedded might be described as micro-granular or crypto-crystalline; and it is not, taken alone, of sufficiently distinctive character to enable a petrologist to answer the above question offhand. One sees this structure in some altered sedimentary beds, and also in some igneous rocks. In such cases one has, before arriving at a verdict, to search for felspar prisms, or microlites, scattered about in the base, and these are rarely absent in rocks of igneous origin. In the rocks under discussion, if we exclude the pseudo-spherulites from consideration, not a single lath-shaped prism of felspar, or microlith, is to be found in the base. On the contrary, one of the slides contains evidence which points decidedly to a sedimentary

[1] Notes on the Cherts and Associated Rocks of Roundhole Point, Cataclews Point, and Dinas Head. Trans. R.C.G.S. 1894.

origin. Here and there a very fine-grained lamination is to be observed in the base. The micro-granules are arranged in perfectly parallel straight lines, very close together, and possess a rigidly parallel structure, like the lamination of a very fine-grained sedimentary rock, and unlike the foliation of an igneous rock. It seems altogether unlikely that a fine-grained laminated structure, like that seen in the slide referred to, in rigidly parallel lines, could have been produced here and there in isolated patches in a vitreous rock of igneous origin. Their presence, however, in a partially melted fine-grained sedimentary rock is easy of comprehension.

The pseudo-spherulites in the Dinas Head specimens present, on careful examination, some features different from the normal spherulites of glassy igneous rocks. The pseudo-spherulites do not exhibit a dark cross when revolved between crossed nicols. Indeed, the base of these sperulites, namely, the micro-granular, or crypto-crystalline material seen in the centres, and between the blades of the felspar prisms, which radiate from the margins of the spherulites towards their centres, does not possess a fibro-radial structure at all; and does not in any way differ in structure from the crypto- or micro-granular base outside the boundaries of the pseudo-spherulites.

In normal spherulites the radial fibres, or fibrous prisms, have straight extinction; whereas in the Dinas Head pseudo-spherulites the prisms which radiate from the outer edge towards the centre (which they never reach) are those of a triclinic felspar and have, in every case, oblique extinction.

The conclusion reached by General McMahon regarding the pseudo-spherulites of the Dinas Head soda rocks is, that they are the product of contact action by a basic trap on a sedimentary rock which either contained, in whole or in part, the chemical constituents of albite; or into which those constituents were introduced, in whole or in part, at the time the contact action took place.

As the presence of spherulites in a vitreous rock has been regarded by many petrologists as evidence of the igneous origin of the rock in which they occur; and as a metamorphic origin has not hitherto, so far as we are aware, been suggested for spherulites, this determination seemed worth noting.

The independent researches of Mr. Hutchings, in another locality, carried out at the same time, has supplied the needed confirmation. This confirmation is all the more important as no doubt can be entertained regarding the sedimentary origin of the rocks studied by Mr. Hutchings and described in the March number of this Magazine. They are shales forming part of beds of limestone, sandstone, and shales, in contact with the Whin Sill, and still retaining in their altered condition abundance of clastic quartz-grains and other witnesses to their original nature, even if this was not as positively assured as it is by the field evidence.

In these altered shales Mr. Hutchings describes at pages 124, 125 nodules which exhibit under the microscope much the same general character as those of the Cornish rocks, and which contain in some cases numerous well-developed spherulitic aggregates of fibres of felspar and quartz, some of the best of which show tolerably good black crosses on rotation in polarized light, and are as well entitled, or even more so, to the name of pseudo-spherulites as are those in the soda rocks of Dinas Head.

The above observations, taken together, seem to establish conclusively that spherulitic structure is not, taken alone, evidence of the igneous origin of the rock exhibiting it; and, further, that spherulites are sometimes the product of contact-metamorphism.

VI.—On the Conversion of Olivine into Serpentine.

By Professor W. J. Sollas, D.Sc., F.R.S.

In the last volume of the Annals of British Geology (1893), just published, Professor Blake gives an abstract of a paper by me on "Variolite from Roundwood,"[1] and incidentally calls attention to the discordance between the formulæ given by General McMahon,[2] Dr. Roth,[3] and myself, to explain the conversion of olivine into serpentine. I hasten at once to correct a slight error which occurs in my equation, but which, fortunately, does not affect the principal result of the argument, as the correct formula was used in making calculations. Amended, my equation is as follows :—

$$\underset{\text{Olivine}}{2\,Si\,(O_2\,Mg)_2} + 2\,H_2\,O = \underset{\text{Serpentine (Tschermak)}}{Si_2\,O\,(O_2\,Mg)\,(O\,H)_2\,(O\,Mg\,O\,H)_2} + Mg\,O$$

or,

$$\text{Ditto} = \underset{\text{Serpentine (Clarke and Schneider)}}{Si_2\,(O_2\,Mg)_2\,(O\,H)_3\,(O\,Mg\,O\,H)} + Mg\,O$$

The fate of the molecule of Mg O on the right is not indicated here. General McMahon's equation is essentially similar to this, but less detailed. Roth's may be represented thus :—

$$\underset{\text{Olivine}}{5\,Si\,O_4\,Mg_2} + 4\,H_2\,O = \underset{\text{Serpentine}}{2\,Si_2\,O_9\,Mg_3\,H_4} + 4\,Mg\,O + Si\,O_2$$

Since $4\,Mg\,O + Si\,O_2$ is equivalent to $Si\,O_4\,Mg_2 + 2\,Mg\,O$, it would appear that Roth puts one molecule of olivine into the left-hand side of the equation to take it out again on the right. The explanation of this is, that while four molecules of olivine suffice to supply the material of two molecules of serpentine, five molecules are needed to furnish the space occupied by this serpentine. The fifth molecule of olivine is carried away by water as well as one molecule of magnesia liberated in the process of serpentinization of the other four, and from this excess of material the minerals magnesite, hydrotalcite, and quartz, which are found associated with serpentine, are produced.

In my treatment of the process I simply pointed out that the hydration of olivine, by which it gives rise to serpentine, is accompanied by an increase in volume amounting to 30 per cent.,

[1] Sci. Proc. Roy. Dublin Soc. vol. viii, new series, p. 110.
[2] Proc. Geol. Assoc. vol. xi, p. 427.
[3] Abh. d. k. Akad. d. Wiss. Berlin, 1869, p. 329 (cited by Teall, British Petrography, 1888, p. 105), Chemische Geologie, Bd. i, p. 116.

the odd molecule of magnesia set free on the right-hand side of the equation being disregarded; and, since pseudomorphs of serpentine after olivine generally retain the precise form and dimensions of the crystals they replace, I conjectured that the surplus of 30 per cent. might be partly represented by the veins of chrysotile, which so frequently traverse serpentinous rocks.

Zirkel, in his great work,[1] discusses the subject, and points to an experiment of R. Müller,[2] who found that under the action of water containing carbonic acid powdered olivine lost a part of its silica and magnesia, and almost all its ferrous oxide, while the insoluble residue consisted of silica and bases in approximately the same proportion as in serpentine. The same distinguished author also suggests that the magnesia liberated from olivine may assist in the serpentinization of bronzite. I had already indicated that this might be possible (p. 110, *op. cit.*), but at the same time pointed out that the increase of volume in this case must be even greater than when olivine alone is concerned, as is shown in the following case:—

	Olivine.		Enstatite.		Water.		Serpentine.
Molecules	4	+	2	+	6	=	3
Volume	170	+	64·5	+	108	=	330

whence 234·5 volumes of olivine and enstatite give rise by hydration to 330 volumes of serpentine, an increase of 40 per cent. It will be observed that the volume of the water which enters into combination is neglected; if this be taken into account it will be found that in accordance with the general rule the volume of the final product is less than the sum of the volumes of its constituents.

A consideration of such changes as we have indicated is of interest from more than one point of view. The marked increase in the volume of the solid substances produced by hydration will lead us to look for the secondary minerals which must have been deposited in association with serpentine rock; while the large quantity of water absorbed in the reaction may well impress us with the important part played by the hydration of minerals in removing water from the liquid envelope and locking it up in the solid form within the earth's crust.

VII.—On the Age of the Trachytic Rocks of Antrim.

By Alex. McHenry, M.R.I.A.; Geological Survey of Ireland.

[Communicated by permission of the Director-General of the Geological Survey.]

SINCE the publication of the Geological Survey Maps and Memoirs of Antrim, some additional evidence has been obtained bearing on the age of the trachyte of that district. In the year 1888, when engaged in traversing a line of section running from Belfast in a northerly direction across county Antrim to the Giants' Causeway, I was fortunate enough to notice in a large chalk quarry at Templepatrick railway station evidence which

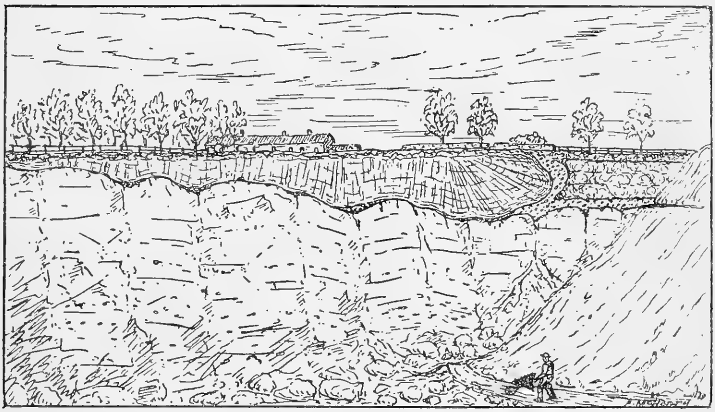
[1] Lehrbuch der Petrographie, 1894, p. 390.
[2] Min. Mitth. 1877, p. 36.

seemed to show that the trachyte was later than the Tertiary basalt sheets of the lower division; and, on further investigation into this interesting subject, additional evidence was procured that the trachytic eruption was older than the sheets of the upper series, and was, so to speak, of mid-basaltic age. Subsequently I accompanied the Director-General, Sir Archibald Geikie, on his visit of inspection to this locality, and he approved of my views. Professor Gilbert, of the United States Geological Survey, who was with us at the time, also agreed with the conclusions arrived at.

The accompanying sketches and sections will serve to illustrate the mode of occurrence of the trachyte and adjacent rocks. They were made at the time of my first visit to the quarry.

Fig. 1 shows the most important point in the evidence as to the relative ages of the trachyte and basalt. It will be seen that the trachyte during its eruption, in the form of a laccolite, swept the eroded chalk surface of its usual superincumbent flint gravel bed, which is composed of burnt chalk flints, chalk fragments, and

Fig. 1.



East end of Templepatrick Quarry, county Antrim, showing position of Chalk, gravel bed, Lower Basalt, and Trachyte. From sketch made in May, 1888.

red marly clay, and piled it up against the opposing and evidently pre-existing barrier of basalt, on its eastern side. The columnar structure in the trachyte is well marked, and has clearly converged, during the cooling process, from the outside towards the centre of the mass, while a beautiful and regular flow structure is apparent, running parallel to its outward margin, as shown in sketch.

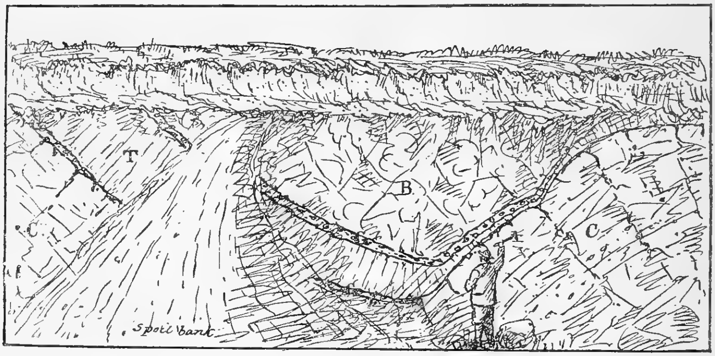
Remnants of the flint-gravel bed are to be seen in a few pockets and hollows of the eroded chalk surface, which were evidently left behind in more or less sheltered places, while the igneous mass was advancing.

This gravel bed, where it is in contact with the trachyte, has been baked and indurated into a compact and solid flinty mass, while in every other instance in which I have seen it in its usual or normal place between the chalk and basalt, it occurs in the form of a loose gravelly clay.

The trachyte in this locality is generally compact and fine-grained in texture, light-grey and white in colour, sometimes mottled pinkish; and on its weathered surface bears a close resemblance in colour to the underlying chalk, so much so, that a casual observer might at first sight suppose the chalk and trachyte to form portions of one rock-mass. The basalt is of the usual amygdaloidal character, and weathers spheroidally.

Fig. 2 shows the relative position of the rocks in the west end of the quarry, and it is interesting to note how the trachyte behaves in this instance. It has forced its way underneath the basalt along the zone of the flint-gravel bed, which it carries on its back, and at one place portions of the gravel bed rest both above and below it.

Fig. 2.



West end of Templepatrick Quarry, county Antrim.
C. Chalk. G. Flint-gravel bed. B. Lower Basalt. T. Trachyte.

At Ballypalady, $1\frac{1}{2}$ miles north-east of Templepatrick Quarry, evidence exists to show that the trachyte is older than the Upper Basaltic sheets, and at Libbert Bauxite Mine, near Glenarm, further proofs on this point are to be found in the trachyte-conglomerate and trachytic sands which occur between the Upper and Lower Basalts.

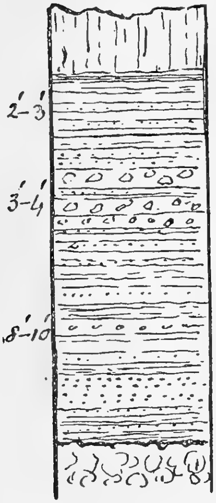
Fig. 3 is a section of the Ballypalady rocks which was, and is still, I believe, to be seen in the old open workings of the pisolitic iron-ore excavations. The bed of conglomerate contains rounded and subangular lumps and finer débris of the Templepatrick variety of trachyte, as well as fragments and detritus of the Lower Basalt, the whole being capped by Upper Basaltic sheets.

This is one of the localities from which beautiful plant impressions, leaves, fir-cones, etc., were obtained. These have been figured and described by the late Mr. W. H. Baily and Mr. J. Starkie Gardner.

Fig. 4 is a section of the Libbert Mine, Glenarm, from which a fine collection of plants, etc., was also obtained, when it was being worked for Bauxite some twenty years ago.

It may here be mentioned that those two plant localities are on the same geological horizon, namely, that of the widely extended pisolitic iron-ore zone of the county. The Ballintoy lignite, iron-ore, and Bauxite Mines are also on this horizon.

Fig. 3.
Ballypalady section, $1\frac{1}{2}$ miles north-east of Templepatrick.



Upper Basalt (compact and often columnar).

Brown laminated shale and volcanic ash (?).

Laminated brown impure earthy lignite.

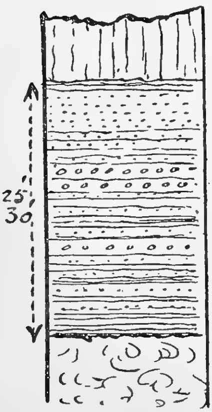
Brown and red variegated clays, marls, and sandy beds, with irregular layers of coarse conglomerate, composed of rounded and subangular fragments of trachyte and basalt.

Brown, red, and yellowish laminated marl, mudstones, and bole, with occasional layers of fine conglomerate (trachytic and basaltic), pisolitic iron-ore band, and plant beds.

Lower Basalt (amygdaloidal).

The trachyte-pebbles and fragments in this place (Libbert) are of the type of rock that occurs in the great mass at Tardree Mountains, to the south-west. I have observed this trachyte gravel in two or

Fig. 4.
Libbert Mine section, Glenarm.



Upper Basalt (compact black).

Lignite.

Bauxite.

Whitish, grey, and variegated laminated trachytic clay, marl, sand beds, and pebbly trachytic conglomerate.

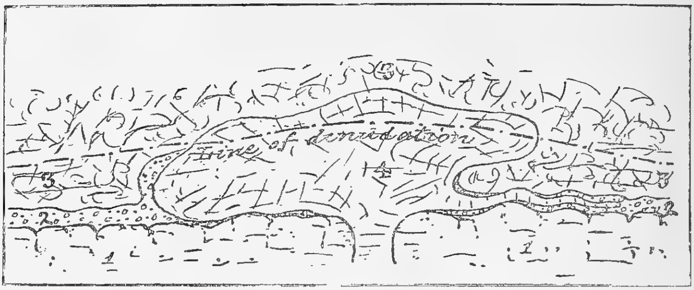
Whitish and grey fine-grained laminated trachytic beds, with plant remains.

Lower Basalt (amygdaloidal).

three other places between Glenarm and Tardree, and I have no doubt that it also exists in many other localities in county Antrim.

Figs. 5 and 6 are ideal sections, showing the probable conditions before and after the Upper Basaltic period.

Fig. 5.

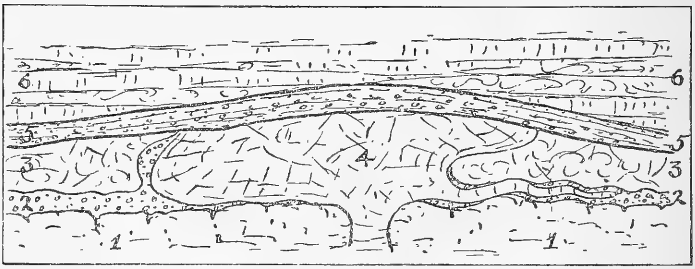


Ideal section showing probable mode of intrusion of the trachyte through Chalk and Lower Basalt.

1. Chalk with eroded surface. 2. Flint-gravel bed, composed of burnt chalk flints, chalk fragments, and red marly clay. 3. Lower Basalt. 4. Trachyte (laccolite).

Subsequent to my discoveries in county Antrim and, in the same year, when engaged in some work in the Mourne Mountain district, county Down, I was struck with certain similarities between the granite of this area and the acid rocks of county Antrim; namely,

Fig. 6.



Ideal section showing probable position of the (rocks) pisolitic iron-ore, trachyte gravel, and Upper Basalt, over the trachyte and Lower Basalt.

1. Chalk. 2. Gravel bed. 3. Lower Basalt. 4. Trachyte. 5. Horizon of denudation, along which were deposited the pisolitic iron-ore bed, trachyte conglomerate and sand, basaltic and ferruginous conglomerates, marls, and bole, containing plant and other remains. 6. Upper Basalt.

that the Mourne granite is often very trachytic in appearance, frequently resembling some of the varieties of the Tardree rock. It also cuts off basalt dykes, which are most probably of the Lower Basaltic series, and is itself, as well as these dykes, invaded and cut up by later basalts. Besides, there is a strong and most suggestive link between the rocks of the two areas (Antrim and Down) in the trachyte porphyry mass that occurs half-way between them, near Hillsborough, county Down. It is therefore highly probable that the Mourne granite is of Tertiary age.

VIII.—On a Recently Discovered Keuper Outlier near Kidderminster.[1]

By T. Crosbee Cantrill, B.Sc. Lond.

ABOUT two and a half miles east of Kidderminster, in North Worcestershire, is a wooded hill, marked and named Bissell Gorse on the original one-inch Ordnance Map [1831], Sheet 54, N.W. It is now on the six-inch Map [1882], Sheets Worcestershire VIII, S.E. and IX, S.W., named Bissell Wood. The hill lies just half-way between the villages of Stone and Churchill.

When examining the main Keuper-on-Bunter boundary, several years ago, in company with Mr. Walcot Gibson, now of H.M. Geological Survey, we were struck with the appearance of the hill as viewed from the main escarpment, and the idea occurred to us that possibly it would be found to be an outlier of Keuper, although mapped by the Survey as Bunter. Some time later I made a preliminary examination of the hill, and have more carefully examined and mapped it since.

The hill proves to be an outlier of Keuper Sandstone [f 5], resting on and surrounded on all sides by Upper Bunter Sandstone [f 3], the Keuper having been thrown down by a fault which runs along its south-east side, parallel with the main escarpment, half a mile to the south-east.

The relation of the outlier to the main mass of the Keuper is well seen from the one-inch Geological Map, Sheets 54 N.W. and 55 N.E., and from the accompanying Sketch Map and Section.

The lower boundary of the Keuper Sandstone arises on the eastern flanks of the Abberley Hills, where the Keuper rests directly on Silurian rocks. It then passes between Hartlebury and Stourport, having the Upper Bunter below, on the west, and Keuper on the east. The line then passes through the village of Stone, south-east of Kidderminster, then by the farm named Middle Dunclent, to Mount Segg—here running south-west and north-east—thence on to Broom, and so towards Stourbridge.

This boundary is marked by an almost constant escarpment, due to the greater weather-resisting properties of the Keuper beds and the extreme softness of the underlying Bunter, and this escarpment is specially bold on either side of Stone. Between Middle Dunclent Farm and Mount Segg, at about the position of the dip-arrow on the inch Map, the vertical distance between the edge of the scarp and the stream at its foot is about 130 ft.; and the scarp slope makes an angle of 20° with the horizontal, exceeding this towards the top.

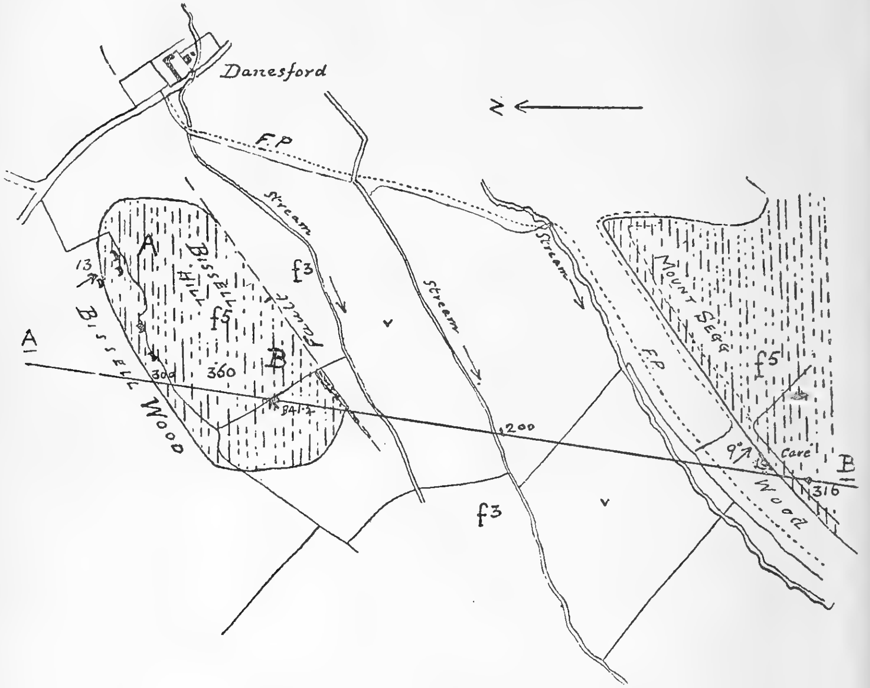
The shortest distance, measured at right angles to the strike, between the boundary line in the outlier scarp and that in the main scarp, is a little under half a mile.

The bottom of the broad valley excavated in the soft Upper Bunter between the outlier and the main escarpment is chiefly occupied by alluvial matter. Several streams flow through the

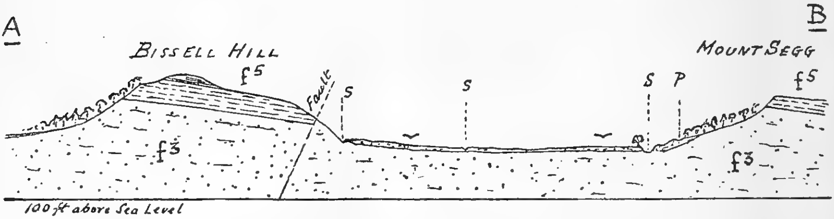
[1] Read before the Birmingham Natural History and Philosophical Society, Geological Section, Tuesday, 26th February, 1895.

valley: that at the foot of the scarp is the natural course; the others are for irrigation purposes.

Viewed in plan the outlier presents the form of an irregular



Map of Bissell Hill and Mount Segg.
Scale: 6 inches = 1 mile. A—B = drift deposits.



Section through Bissell Hill and Mount Segg along line A—B on Map.
f 5, Keuper; f 3, Upper Bunter; ⏝ Alluvium; p, footpath; s s s, streams.
Scale: Horizontal, 6 inches = 1 mile. Vertical, 1 inch = 400 feet.

T.C.C. del. Dec. 1894.

ellipse, the major axis of which runs north-east and south-west, *i.e.* parallel to the main scarp. The greatest length is about 500 yards, and width 230 yards. It is marked along the north-west side by a steep wooded escarpment, formed by the ordinary weathering of the more durable Keuper basement beds overlying the soft Upper Bunter Sandstone. The boundary between the two formations runs along the scarp some yards below the summit, and sweeps round the north-east and south-west ends of the hill and runs into the fault which forms the south-east boundary along the whole length.

Viewed from the north-east or south-west the outlier is seen standing as a bold eminence in advance of the main escarpment. The general contour of the hill is represented with sufficient accuracy in the Section given above. The highest point is about 360 feet above ordnance datum. This is 44 feet higher than the crest of the main escarpment.

The main escarpment, at various points of its course, offers abundant rock-exposures. The Bunter, being usually too soft for building-stone, and too hard for sand, has seldom been worked. But the thin shelf of Keuper along the top of the scarp has been largely drawn upon for the foundations and lower courses of neighbouring farm buildings, and such-like purposes, and these old quarries, with their steep pick-scarred faces, offer excellent sections, especially as they have not been worked for many years. Several small openings occur on Mount Segg, but there is a much finer series along the scarp of the outlier itself, all long since disused. The principal of these are roughly indicated on the Sketch Map.

The basement beds of the Keuper [f 5] in the district consist of a sandstone, coarse, usually thick-bedded, hard, but incoherent, and of a dull reddish-brown colour. There are in some beds small pebbles interspersed throughout the mass, usually of yellow and white vein quartz; but many consist of rolled fragments of a very fine dark-red clay or marl. In some sections, coarse, highly calcareous, hard bands—cornstones, locally known as catbrain—occur, consisting of a mass of small rolled fragments of red marl, and occasionally of quartz, embedded in sand, and the whole cemented together by an excess of calcium carbonate. One such band occurs at about 30 or 40 feet above the base, though apparently consisting not so much of a regular bed as of disconnected lenticular masses at about the same horizon. Some of the beds are fissile and highly micaceous, and occasionally marl bands occur.

The whole mass is exceedingly variable; it is practically impossible to fix any definite horizons, save, perhaps, that of the cornstones, and generally no two sections are exactly comparable—beds thinning out or entirely changing in lithological character in a distance of two or three yards.[1] Such is the general character of the basement beds of the Keuper [f 5] in the district.

These beds in some sections rest on an apparently uneven surface of the Upper Bunter Sandstone, occasionally with a layer of rolled red marl fragments intervening. In other places the beds seem to pass into the underlying Bunter without any distinct plane of

[1] Consult Hull, "Permian and Trias Rocks of Midlands." 1869. Memoir of Geol. Survey.

separation, the change being signalized by a finer texture, softer nature, and brighter colour.

The Upper Bunter Sandstone [f 3] is a bright brick-red coloured sandstone, very fine-grained, soft, and altogether devoid of pebbles or fragments larger than the rest of the grains. It is normally thin-bedded, and fissile. If mica flakes occur, they are so small as to be almost invisible to the naked eye. The whole mass is practically homogeneous from top to bottom.

It should perhaps be stated that no fossils occur in any of these beds, whether Keuper or Bunter, in the district under consideration. Having given some account of the Keuper and Bunter beds of the main escarpment, we will now compare them with the rocks of Bissell Hill, taking the chief exposures in order, beginning at the north-east end of the outlier scarp.

1. Just outside the wood, on a rough, uncultivated patch of ground, at the bottom is seen typical Bunter *in situ*, and two feet higher coarse dull-red Keuper Sandstone, also *in situ*. By removing the turf in between, the Keuper is seen to grow finer, and then to abruptly pass into Bunter without any other change than that of colour. About three yards to the right, by digging, a few rolled fragments of red marl are found to occur at the junction.

2. Entering the wood, just in the angle, we find similar Keuper beds about 18 feet above the junction just described.

3. A few yards farther on, and close up to the hedge, is a conspicuous rock-face, and old débris cones, overgrown with herbage and sturdy trees, lie in front.

The section here is as follows, in descending order:—

Section at the East Quarry.	ft.	in.
1. Cornstone	1	0
2. Sandstone, hard, calcareous, greyish-red	0	6
3. Marl, friable, chocolate-coloured	3	0
4. Sandstone, thick-bedded, soft, coarse, and red, passing into 5	10	0
5. Sandstone, hard, highly calcareous	0	3
6. Shale, thinly laminated, soft, micaceous, and sandy, red-coloured	1	0
7. Grit, calcareous	1	0
	16	9

Notes on the above Section.

The beds 4 and 7 contain, irregularly distributed throughout the mass, small dark-coloured hard spheroids, about half an inch in diameter, and some smaller, formed by the grains of sand being cemented together by calcium carbonate and a manganese compound, probably the black oxide, MnO_2. These nodules being harder, stand out on the face of the rock, and are conspicuous by their darker hue. They effervesce with dilute HCl, and are highly charged with manganese; a fragment treated by Hoppe-Seyler's test,[1] giving a bright pink colour due to permanganic acid. An apparently similar phenomenon was described by A. Norman Tate, F.C.S., to the Liverpool Geological Society in 1863, as occurring in

[1] See Fresenius, Qual. Chem. Analysis, edited by Groves, tenth edition, p. 122.

Trias Sandstone in that district. In several places the black sandstone was distributed much in the same manner as currants in an ordinary cake; a metaphor exactly descriptive of the case at Bissell Hill.[1]

4. A few yards farther on, and at a lower level, beyond an overgrown débris mound, is a small pit in front of a high face of rock, with abundant pick marks. The following section is afforded:—

Section at the Pit Quarry.	ft.	in.
1. Marl, friable, chocolate-coloured	1	0
2. Sandstone, soft, yellowish-red, with marly patches	1	0
3. Sandstone, fissile, micaceous, passing into 4	2	0
4. Sandstone, soft, dark, fine-grained	2	0
5. Marl parting	0	1
6. Sandstone, similar to 4	0	11
7. Marl, soft, micaceous, sandy, laminated, and fissile	0	4
8. Sandstone, soft, dull red, passing into 9	4	0
9. Sandstone, coarse, yellowish-red, with large quartz grains and a few large rolled marl fragments	1	0
10. Marl, friable, chocolate-coloured	0	3
11. Sandstone, dull red	0	10
12. Marl parting	0	1
13. Sandstone, similar to 11	1	1
	14	7

Probably the top beds in the Pit Quarry underlie the bottom beds in the East Quarry, with some few feet of intervening beds not exposed.

5. Beyond a débris mound, and at about the same level as the middle beds of the Pit Quarry, is a small crag of rock showing the following beds:—

	ft.	in.
1. Marl	0	6
2. Sandstone, fine, micaceous	1	0
3. Sandstone, soft, dull red	4	0
4. Sandstone, coarse, calcareous, with small marl pebbles	0	6
	6	0

These are probably beds 7, 8, and 9 of the Pit Quarry, though modified even in the short distance of about three yards.

6. Immediately below exposure 5 is the Bunter Quarry, the only one on the whole scarp. It shows nothing but the typical Bunter Sandstone, bright red, fine-grained, without mica or pebbles. It is thin-bedded, and dips into the hill at about 13°. The topmost beds in this quarry are six feet vertically below the lowest visible Keuper beds in the overlying exposure, so that the position of the boundary is here fixed to within about eight feet.

7. About the same level as the top of the Bunter Quarry, and some 30 yards farther on, is a small projecting crag of Bunter.

8. Higher up, and about 30 yards still further on, is a small crag of Keuper, probably concealed by vegetation during the summer.

9. About ten yards farther on, and close up to the hedge, is a small working in the Keuper, showing the following section:—

[1] See also Proc. Birm. Nat. Hist. and Mic. Soc. 1870, p. 55.

		ft.	in.
1.	Sandstone, soft, fine-grained, micaceous, red, with greenish-grey spots	1	0
2.	Sandstone, soft, coarse, very incoherent, dull red, passing down into 3	2	0
3.	Sandstone, fine, dull red	12	0
4.	Sandstone, calcareous, with large flakes of white mica	1	0
5.	Sandstone, soft, fine-grained, dull red, passing down into 6	4	6
6.	Sandstone, coarse, hard, calcareous, dull reddish-grey, with marl pebbles	0	6
	[Below this the beds become very irregular by curved bedding.]		
7.	Sandstone, coarse, soft, red, with marl pebbles	5	0
		26	0

These beds are probably of about the same horizon as those at the East Quarry.

10. Half a dozen yards further on is the West Quarry, the largest and last on the scarp. The bedding is very irregular, and the section is probably as follows:—

Section at the West Quarry.

		ft.	in.
1.	Sandstone, soft, red . . . at least	6	0
2.	Marl band, irregular	0	2
3.	Sandstone, laminated, fissile, micaceous	2	6
4.	Sandstone, hard, coarse, dull red	4	0
5.	Sandstone, hard, calcareous, dull reddish-grey	0	6
6.	Marl band	0	2
7.	Sandstone, like 4	3	0
		16	4

There is some faint resemblance here to the beds exposed in the quarry last described, half a dozen yards away.

11. Some considerable distance on, at about ten yards down the slope, are some shallow trenches in coarse dull-red sandstone, of the Keuper.

The above are the main exposures on the scarp slope. As the general dip seems to be about E.S E., probably the beds at the top of the East Quarry are the highest exposed along the scarp, and are about 35 ft. above the base: reckoning the lowest beds in the East Quarry to overlie the highest in the Pit Quarry, and the bottom beds in the latter to be about four feet above the Bunter.

A cornstone band crops out nearly at the top of the hill, and the summit, of dull-red sandstone, is about 60 ft. above the top of the Bunter: so that we have in the outlier a thickness of at least 60 ft. of Keuper beds.

At the south end of the hill, overlooking the valley, is a grassy bank, too steep for cultivation, along the bottom of which for some yards the fault rock projects in thick masses. Immediately below the fault rock the Bunter appears. The fault rock itself consists chiefly of slabs of very hard sandy rock, ringing under the blows of the hammer, highly calcareous, and dark-coloured with manganese oxide. It frequently contains small cavities. At certain points broken and slickensided fragments of Bunter occur. The slabs dip into the hill at an angle of 60°; the hade of the fault is therefore 30° and its direction is north-east and south-west, with the downthrow to the north-west.

A few feet higher up and at the south-west end of the bank, on the downthrow side of the fault, a fine-grained sandstone occurs, only distinguished from typical Bunter by being somewhat paler. Probably this is, however, a fine-grained Keuper, as at the north-east end of the bank, a few yards away, and about a dozen feet higher up than the fault line, is a mass, *in situ*, of sandstone, coarse, soft, dull reddish-brown, micaceous, and containing rolled marl fragments — undoubted Keuper — so that the Keuper comes right down to the fault plane, or to within five or six feet of it.

We can roughly calculate the throw of the fault thus: At the cave in Mount Segg [see Sketch Map] the dip is 9° at right angles to the scarp. At the Bunter Quarry, on the Bissell Hill scarp, the dip is about 13° at right angles to the scarp. We may assume the dip to remain fairly constant for the distance between the two scarps. Taking its average value as 11°, which is equivalent to a rise of 1 in 5, and the rectangular distance between the respective boundary lines as 2200 feet, we have in 2200 feet a rise of 440 feet, *i.e.* the base of the Keuper at Bissell Hill, had there been no fault, would have been 440 feet higher than at Mount Segg. But we find that it is actually at about the same altitude, viz. 300 feet above sea-level. There must, therefore, have been a downthrow to the north-west of about 440 feet, and without this the Keuper would have been long since removed.

The fault is represented in the Sketch Map as a single line of fracture dying out in each direction. Whether this is really the case is open to question, as there is no evidence to be obtained. It may continue, perhaps, in a south-westerly direction to merge into a fault which passes near the village of Churchill,[1] each having a downthrow to the west.

Conclusion.—We have seen that the top beds of Bissell Hill agree perfectly with the Keuper Beds [f 5] of the main escarpment, and that the lower beds of each agree in being undoubted Upper Bunter [f 3]. The Keuper capping is isolated from the main mass and is therefore an outlier, and has been produced by the downthrow of a strike fault parallel to the two escarpments.

At A and B [on the Sketch Map] are scattered numerous rock fragments, chiefly derived from the Clent district to the north-east.

NOTICES OF MEMOIRS.

Note on a Paper on "Eozoönal Structure of the Ejected Blocks of Monte Somma."

In a letter to the Editor, Sir W. Dawson, of Montreal, has communicated his reasons for the belief that the appearances described lately by Dr. Johnston-Lavis and Dr. J. W. Gregory, in their paper on "Eozoönal Structure of the Ejected Blocks of Monte Somma,"[2] have no relation to *Eozoön Canadense*, either in mode of occurrence and mineral character or in microscopic structure. He

[1] See Geol. Survey Map, Sheet 54 N.W.

[2] Scientif. Trans. Roy. Dublin Society, series ii, vol. v, part vii, pp. 259-277, five plates; October, 1894.

refers especially to the typical specimens of Eozoön in which the laminæ remain as calcite, while the chambers are filled with serpentine, or more rarely with malacolite, and the canals and tubules with serpentine or dolomite.

1. As to mode of occurrence and mineral character, in the Vesuvian paper it is wrongly stated that the typical Eozoön is enclosed in a pyroxenic igneous rock. The best specimens have all been found in the thick "Grenville Limestone" of Sir William Logan, estimated by him at 750 feet in its average thickness, though with a few intercalated thin bands of gneiss and quartzite. In the vicinity of Côte St. Pierre in the Seigniory of Petite Nation, where some of the best specimens of Eozoön are found, the outcrop of this limestone has been traced continuously and mapped by the Geological Survey for twenty-five miles, and in the same district it occurs over an extent of more than one hundred miles on the reverse sides of synclinal and anticlinal folds, where it may be recognized by its character and associations as well as by its holding Eozoön. It is true that grains, nodules, and thin interrupted bands of a white variety of pyroxene (malacolite) occur sparingly in this limestone; but neither in their chemical composition nor in their mode of occurrence have we any proof or even probability of an igneous (intrusive) origin. This was the matured conclusion of the late Dr. Sterry Hunt; and Dr. F. D. Adams, at present our best authority on these rocks, is of the same opinion.

The Grenville Limestone has been much bent and folded, and with its accompanying beds has been subjected to regional metamorphism. In the Petite Nation localities, however, it has not, as far as known, been invaded by igneous dykes or masses.

Specimens of Eozoön included in this limestone vary from single individuals ranging from an inch to six inches in diameter to aggregated groups of a foot or more; and microscopic examination shows that, in some of the beds in which they occur, there are innumerable fragments showing the same structures scattered on the bed-planes, and associated with the minute globular chamberlets which I have named *Archæosphærinæ.* The specimens of Eozoön may be seen weathered out on the surfaces of the limestone exactly in the manner of Stromatoporæ on the surfaces of the calcareous rocks of the Cambrian, Ordovician, and Silurian.

In certain layers of the Grenville Limestone grains and concretions of serpentine and malacolite occur without Eozoön, and specimens of Eozoön with only so much of such minerals as may be contained in their chambers. There are also instances in which specimens of Eozoön occur attached to or partially imbedded in such nodules, just as Sponges and other organisms occur associated with flints in chalk, or as Stromatoporæ occur in connection with concretions of chert in Palæozoic limestones. The origin of the concretions themselves must have been contemporaneous with the formation of the limestone.

2. *Form and Structure.*—An inverted position of Eozoön seems to have been adopted by the authors of the paper and by Zittel.

Although the plates apparently show some of the forms described in the paper as lying parallel to igneous veins, and as their selvages, or as rounded masses like nodules and geodes, on closer inspection essential differences may be observed. The Vesuvian specimens consist of continuous laminæ of crystalline igneous matter, including interrupted or lenticular layers of calcite. Eozoön on the contrary, when well preserved, consists of a continuous skeleton of calcite made up of broad layers slightly pitted on their surfaces, and connected at intervals; while the siliceous material appears as a substance filling wide flattened mammillated chambers more or less limited, and presenting amœboid lobes at their extreme edges, and passing finally in the upper part into rounded chamberlets. This difference should commend itself to any palæontologist, but I am aware that it may be overlooked by cursory observers. Scores of specimens have been sent to me of banded rocks, supposed by their finders to resemble Eozoön, though, in arrangement of parts, the converse of it.

Perfect detached individuals of Eozoön are usually of inverted conical form, springing from a narrow base and widening upward in the manner of some sponges and corals. When close together they often become confluent, and when these confluent masses or layers appear to be hollow or doubled, I believe that this usually results from the folding of the containing bed;. and the laminæ may be observed to be bent and crushed at the flexures.

In the specimens figured in the paper, the characteristic microscopic structures of Eozoön are entirely absent. There is no trace of the beautiful and complicated system of canals; and the fibrous structures compared with the minute tubulation are merely prismatic fibrous crystals, like the secondary veins of chrysotile which sometimes cross and deteriorate our specimens of Eozoön. With reference to these chrysotile veins, while their filling of minute and often transverse and branching cracks shows that they are merely aqueous deposits of later origin than the structures which they traverse, and while their appearance under high powers is very different from that of the tubuli of the calcite layers, they have no doubt been, when parallel to the layers, and in poor specimens, fertile causes of error. They are absent from the more perfect specimens. I may also explain that while the finely tubulated margin of the calcareous layers can be seen to terminate abruptly against the filling of the chambers, it passes gradually in the interior of the layer into the larger canals when these are present. Naturally also, the finely tubulated wall often fails to show its structure, just as anyone who has examined large series of sections of Nummulites may observe in these fossils; and the tubuli are often filled with dolomite or calcite very difficult to distinguish from the substance of the calcareous lamina.

The late Dr. Carpenter quite understood the distinction between the veins of asbestiform serpentine and the organic structures, and he hoped to have prepared an exhaustive memoir on the subject, including my material as well as his own. Had this intention been fulfilled many subsequent mistakes might have been avoided.

The writers of the paper do not seem to notice that in the St. Pierre specimens the fine canals and tubuli are often filled with transparent dolomite, difficult to perceive without very good preparations and properly managed light. In roughly prepared specimens, and without careful attention to illumination, these delicate structures are often quite invisible. I have sections properly prepared which show the finest and most complicated tubulation in a manner equal to anything I have seen in any fossil Foraminifera from more recent formations, while other slices cut from the same specimen, but possibly slightly heated or subjected to mechanical jars in polishing, show little except a curdled appearance of the serpentine and a multitude of cleavage-planes in the calcite. In like manner in preparing decalcified specimens, a little heat or an acid too strong or not quite pure may remove all the dolomitic casts of tubuli, and may erode those of serpentine. From causes of this kind I fear many who have pronounced very decided opinions on Eozoön have not actually seen perfect examples of its structure.

While, therefore, I must agree with the writers of the paper that their specimens from Somma belong to the category of those banded structures found in concretions and geodes, and at the lines of contact of igneous and aqueous rocks, with which those who have advocated the organic origin of Eozoön are not unfamiliar, and which they have all along been solicitous to distinguish from it, I must emphatically deny that they resemble, either in composition, mode of occurrence, or form and structure, the Laurentian Eozoön of Canada.

REVIEWS.

I.—Synopsis of the Air-breathing Animals of the Palæozoic [Rocks] in Canada, up to 1894. By Sir William Dawson, C.M.G., LL.D., F.R.S. Pages 71–88, from the Transact. Roy. Soc. Canada, Section IV, 1894.

LITTLE more than fifty years ago very few relics of any *air-breathing* animals were known to exist in strata of Palæozoic age. Since then Canada, especially the Eastern Province of the Dominion, has yielded numerous interesting examples of such animals, high in grade above the common kinds of fossil creatures of protozoan, cœlenterate, and molluscan families. Logan's discovery, in 1841, of fossil Batrachian footsteps in the Lower Coal-measures at Horton Bluff, in Nova Scotia, was the first indication of the existence of air-breathing vertebrates in the Carboniferous rocks (Proceed. Geol. Soc. London, vol. iii, 1842, p. 712). In 1844 Dr. King announced the discovery of foot-prints in the Carboniferous of Pennsylvania; and Von Decken the finding of skeletons of Batrachians in the coal-field of Saarbruck. The first discovery of the osseous remains of any Palæozoic land vertebrate in America was that of *Baphetes planiceps*, found by Sir W. Dawson in the Pictou coal-field in 1850 (Quart. Journ. Geol. Soc. vol. x, 1856,

p. 209, pl. ix. Described and figured in Dawson's "Air-breathers of the Coal-period," 1863, pp. 5–7, pl. i, figs. 1, 1*a*; and "Acadian Geology," 1868, pp. 328, 359).

In 1851 several relics of some small animals of the Batrachian kind (Amphibia), *Dendrerpeton Acadianum*, etc., were discovered by Dawson and Lyell in what had been the hollow stump of a tree in the coal-growth of Carboniferous times, at the South Joggins, Nova Scotia (Quart. Journ. Geol. Soc. vols. ix and x, "Acadian Geology," p. 362, etc., and "Air-breathers of the Coal-period," pp. 17–31, pl. iii). Other congeneric forms also were found under similar conditions in the same locality.

The first announcement of the discovery of fossil Insects in America was that by Hartt of the finding of four kinds of insect wings in the "Fern Ledges" of the Little-River Group of the Devonian (Erian) strata at St. John, New Brunswick, in 1862 ("Canadian Naturalist," new series, vol. iii, 1867, p. 205).

Insects had previously been found in the Carboniferous strata of Europe, and have since been traced back to the Silurian of France (*Palæoblattina*, Brong.).

A valuable digest of the Fossil Insects of North America, so far as then known, was communicated in 1868 by Mr. Scudder to the Geological Magazine, Vol. V, pp. 172–177, and pp. 216–222; and his well-known "Fossil Insects of North America, with Notes on some European species," was reviewed in the Geol. Mag. Dec. III, Vol. VIII, pp. 280–282, and Vol. IX, pp. 128–132.

The earliest known Carboniferous Millipede is the *Xylobius sigillariæ*, discovered by Sir W. Dawson in Nova Scotia in 1858; see Quart. Journ. Geol. Soc. vol. xvi, p. 271. Numerous other species of Millipedes have been found in the Devonian and Carboniferous of Europe and America.

Of the Arachnidans, both spiders and scorpions, or animals related to them, have been found in the Palæozoic strata of Europe and America. The scorpions are the most ancient group of the Arachnida, being represented in the Silurian rocks of Gotland and Scotland (*Palæophonus*) and North America (*Proscorpius*).

The first known (Carboniferous) Land-shell was discovered by Dr. Wyman and Sir C. Lyell in 1851 (Quart. Journ. Geol. Soc. vol. ix, 1852, p. 60, pl. iv), among the contents of one of the fossil tree-stumps, with *Dendrerpeton* from the South Joggins. Land-shells have been met with also in the Devonian plant-beds of New Brunswick (St. John), and in some coal-regions of America.

Thus in Canada have been discovered of Palæozoic air-breathers:—

1. Vertebrata, 26 species; all Amphibia.
2. Arthropoda, 33 species; Insects, Scorpions, Myriapods.
3. Mollusca, 5 species; Pulmonate Snails.

Of all the above the author gives a systematic account, with references to memoirs and books, and with the geological stages and the localities. Of group No. 1 there are nine genera of recognizable Microsaurian *Amphibia*; namely, *Hylonomus, Smilerpeton* (gen. nov.), *Hylerpeton, Fritschia* (gen. nov.), *Amblyodon, Sparodus, Dendrerpeton, Baphetes, Platystegos* (gen. nov.). Also *Eosaurus*, of uncertain alliance; and two genera known from foot-prints only, *Sauropus* and *Hylopus.*

Of group No. 2 there are *Græophonus*, a pedipalp; *Mazonia* and *Palæophonus*, belonging to the Eoscorpioidæ; and *Eurypterella, Amphipeltis*, and another, of uncertain position. *Xylobius, Archiulus, Amynilyspes*, and *Euphoberia* are Myriapods; and *Palæocampa, Eileticus*, and *Ilyodes* are more or less related to them. The Insects comprise *Archimylacris, Mylacris, Petroblattina, Platephemera, Lithentomum, Homothetus, Xenoneura, Haplophlebium, Gerephemera, Dyscritus*, and *Archæoscolex.*

Of group No. 3 there are *Pupa* (*Dendropupa*), *Strophia* (*Strophella*), and *Zonites* (*Conulus*).

The author adds an interesting account of two fossiliferous tree-stumps lately observed by Mr. P. W. McNaughton at the Joggins coal-mine (pp. 84, 85); also a Note on the Devonian plant-beds at St. John, New Brunswick; and he gives some very useful suggestions for collectors.

II.—Granites and Greenstones. A series of Tables and Notes for Students of Petrology. By Frank Rutley, F.G.S.

Mr. Rutley has done very good service by publishing this unpretentious little volume, a compendium of petrology, containing a very great amount of useful information in small bulk and convenient form. A glance at the interior of the book, with its long list of species and varieties of rocks, and compact table of minerals, will at once dispel any qualms which the associations of the title may not improbably stir, for it is at once evident that Mr. Rutley has no desire to recur to the period when everything was either a granite or a greenstone. He, however, thinks, and quite rightly, that the use of such terms by geologists in the field would often save errors which creep in when more exact determination is attempted without microscopic aid.

After indexing the symbols to be employed, the author at once gives us a table of rocks, which is clearly intended to be exhaustive, and to contain all the most important rock types. We notice a few omissions, such as some terms recently employed by Brögger, which seem to be of equal importance with others admitted to the table; nor is it quite clear why borolanite is placed with the dyke rocks rather than with the nepheline-syenites. The table depends on chemical composition, mineral constitution, structure, and to some extent on genetic relationship, and is probably as clear as in the present state of our knowledge it could be made.

Definitions of rock structures follow, but, unfortunately, they are not arranged even alphabetically, a defect to some extent atoned for by an index. Then the rocks themselves are defined, the unaltered rocks being placed by themselves and followed by the altered rocks; the felsites are considered in each division, while the porphyrites, diabases, and picrite-porphyrites are placed only in the latter. Explanatory notes on the mineralogical tables succeed, and these contain a good many useful hints on the determination of some microscopical characters and the application of optical tests.

Finally come the determinative tables, arranged under such heads as the Felspars, Micas, Silicates and Oxides, Zeolites, Iron-ores, Alteration products, and the like, reference being made easy by a separate index of minerals.

The work is likely to be very useful to the beginner from the simplicity of its arrangement and the avoiding of all controversial matter, while even to the advanced student it will furnish a most valuable aid to memory, which will save the trouble of reference to larger works at the same time that it will make such reference more easy.

REPORTS AND PROCEEDINGS.

Geological Society of Glasgow: May 9, 1895.

The "Shelly Clays" and the Great Ice Age.—Mr. Dugald Bell, F.G.S., read a paper "On the High-level Shelly Deposits, and their bearing on the question of Submergence; with special reference to the recent edition of Dr. James Geikie's *Great Ice Age.*" Dr. Geikie had intimated that he no longer believed in a "great submergence" of about 1400 feet during the Glacial period, which had been inferred from such high-level shelly "drifts" as those of Moel Tryfaen, in Wales. These, he admitted, were most probably transported to their present position by an ice-sheet. He still, however, believed in a submergence of from 500 to 600 feet, the evidence for which rests on one or two instances of high-level shelly clay in the west and north of Scotland. Indeed, it may be said to rest on only one instance; for the Aberdeenshire "beds," it was tolerably clear, could not be accepted as proofs of submergence; and another and, till lately, leading instance was in this edition "conspicuous by its absence." Chapelhall, near Airdrie, which had figured so largely in connection with this subject for forty years, and on which great stress was formerly laid by Dr. Geikie, is now entirely omitted, without a word of explanation! It seemed unusual to allow one's favourite facts thus to sink out of sight, without some brief *In Memoriam* being inserted where they once figured so largely. But Chapelhall being thus summarily discarded, Clava, near Inverness, which had become known since the last edition, might be said to be the single instance on which Dr. Geikie had to rest his proof of a submergence of about 500 feet. It was, so to speak, the "a'e button," which had to bear a great "responsibility." Accordingly, in this edition, much is made of Clava. A minority of the investigating committee were inclined to think that the shelly deposit there may have been transported by ice to an elevation of 500 feet, just as that of Moel Tryfaen had been to an elevation of 1400 feet. But Dr. Geikie will have none of this. Moel Tryfaen he admits, but Clava, he thinks, would be a "freak" of the ice, and a "remarkable performance." The argument that if there had been a submergence to the extent of 500 feet, we should find traces of it in innumerable localities up to that level—though formerly it appeared to himself unanswerable (second edition, p. 390)—Dr. Geikie now dismisses by saying "it does not necessarily follow." The submergence, he supposes, may have been sudden and of short duration; or marine life may have been scanty; or all traces of it may have been removed by a subsequent glaciation. With all deference, these appear to be greater "freaks" and more "remarkable performances" than any imagined on the other side; and they include not only the ice but also the sea and the solid land. The last supposition, which is the most plausible, has been dealt with elsewhere,[1] and can be refuted in Dr. Geikie's own words (pp. 108, 109, 112, etc.). With regard to Clava, it can be maintained that there is nothing in the deposit that necessitates having recourse to a submergence; but much, in addition to the absence of traces of it at a similar level elsewhere, that is inconsistent with it. Dr. Geikie spoke of the shelly clay having been "dragged forward underneath an ice-sheet" for a distance of ten or twelve miles; but he can hardly insist on this particular mode of transport, seeing he informs us that "stones or boulders, once imbedded in the ice, might travel for hundreds of miles without suffering abrasion" (p. 204). Even the apparent extent of the deposit—which appeared to be Dr. Geikie's principal, if not sole, difficulty—if granted as proved, did not seem to be an insuperable objection to the ice-theory. Numerous instances were known in which large masses of clay and sand, and thin slabs of chalk, etc., had been transported uninjured by the ice. But whatever weight attached to this objection depended entirely upon the assumption that the deposit had all been transported by the ice at once, or *en masse*; which, to use Dr. Geikie's words, "does not necessarily follow." It may have been transported very gradually, and accumulated in an extra-glacial lake, formed at this part by the ice-sheet passing across a bend in that range of hills along whose base its course lay. An examination of the locality showed the extreme probability of this suggestion, which was submitted as at least preferable to sudden and transient submergences of 500 feet—seas with scarcely any marine life—and glaciers that cleared away all traces of a former sea-bed, over only part of which they could have passed. It not merely removed the objection referred to, but also accounted in some degree for several features of the deposit which, on the theory of a submergence, seemed inexplicable—such as the absence of all traces of currents in the clay, yet the worn and rounded stones imbedded in the heart of it; the sharp line of distinction between it and the other parts of the section; its wide difference from these in composition, etc. Reference was then made to the frequent elevations and depressions which Dr. Geikie still favoured during the Glacial period; their want of harmony with what had been observed in other parts of the northern hemisphere; their improbability in themselves, and especially in the repeated

[1] Trans. Geol. Soc. Glas. vol. ix, pp. 109, 110.

conjunction, according to his scheme, of submergence with severe conditions of climate (pp. 312–3, 324–5, etc.). So far as could be seen, submergence, by diminishing the extent of high land and more freely admitting the ocean-currents, must have been favourable to milder climatal conditions, as Lord Kelvin, in his paper on "Geological Climate," had shown. Mr. Bell concluded by expressing his high respect for Dr. Geikie, though obliged on these points to differ from him. A discussion followed.

Geological Society of London.

I.—April 3rd, 1895.—Dr. Henry Woodward, F.R.S., President, in the Chair. The following communications were read:—

1. "Physical Features and Geology of Mauritius." By Major H. de Haga Haig, R.E., F.G.S.

The greater part of the surface of Mauritius is composed of a volcanic breccia; here and there lava-streams occur in the sections exposed in ravines, and sometimes on the surface. The commonest lavas are dolerites.

In at least two places sedimentary rocks occur at considerable elevations; in the Black River Mountains at a height of about 1200 feet a clay-slate is found, and near Midlands in the Grand Port group of mountains a chloritic schist is found at an elevation of about 1700 feet, forming the hill of La Selle; the schist is much contorted, but seems to have a general dip to the south or south-east.

Evidence of recent elevation of the island is furnished by masses of coral-reef and beach coral-rock standing at heights of 40 feet above sea-level in the south, 12 feet in the north, and 7 feet on the islands situated on the bank extending to the north-east.

The author gives full details of the physical geography of the island, including the nature and composition of the mountain-ranges, the depth of the ravines, the occurrence of caverns in the lavas, and the character of the coral-reef surrounding the island. Information is furnished concerning the neighbouring islands, and reference made to the possible former existence of an extensive tract of land at no great distance from Mauritius.

2. "On a Comparison of the Permian Fresh-water Lamellibranchiata from Russia with those from the Karoo Formation of Africa." By Dr. Wladimir Amalitsky, Professor of Geology in Warsaw University. (Communicated by Dr. H. Woodward, F.R.S., Pres. Geol. Soc.)

The fresh-water shells from the Russian Permian deposits belonging to the genus *Palæomutela* are also known from the Karoo Beds of South and Central Africa, as pointed out by the author in 1892. He has recently had the opportunity of studying the actual specimens from the Karoo Beds, and finds in them species of the groups *Palæomutela Inostranzewi*, *P. Keyserlingi*, *P. Verneuilii*, and *P. Murchisoni*; also of a new genus, the forms of which he had previously referred to *Naiadites*, Dawson. All these groups are found also in Russia, and he gives a list of species found in the upper horizons (A, B, and C) of the Permian beds of Russia, and in the Karoo Beds. These upper beds of Russia have been determined by the author as the fresh-water equivalents of the Zechstein; consequently the Beaufort Beds of the Karoo series, if considered as the homotaxial equivalent of the European strata referred to above, should be regarded as Upper Permian. The Upper Permian group of fresh-water lamellibranchiata of Russia, which bears traces of genetic relationship with the Carboniferous Anthracosidæ, and which was already well represented in Permo-Carboniferous and Lower Permian times, is, according to the author, much older than the African fauna of the Beaufort Beds. These may be concluded to have migrated from Russia, the Gondwána Beds of India having probably been the connecting-link between all these deposits.

The author gives a description of the fossils of the Karoo series which he has examined, including a diagnosis of the new genus, in which he places the fossils already alluded to as having been previously referred to the genus *Naiadites*.

3. "Ice-plough Furrows of a Glacial Period." By W. S. Gresley, Esq., F.G.S.

The furrows described in the paper occur in the Coal-measures of north-west Leicestershire. The author considers that they were formed about the time of the Glacial period by floating ice.

II.—April 24th, 1895.—Dr. Henry Woodward, F.R.S., President, in the Chair. The following communications were read:—

1. "On the Shingle Beds of Eastern East Anglia." By Sir Henry H. Howorth, K.C.I.E., M.P., F.R.S., F.G.S.

The author has carefully examined the country around Southwold, where the beds known as Westleton Beds (which might well have been associated with the name of Southwold) are developed. He alludes briefly to the recent shingle, whose pebbles are derived from the ancient shingles of the cliffs; the formation of this shingle, he maintains, may belong to a time not far removed from our own day.

Turning to the Westleton Beds, he notices that they are essentially "drifts," the component pebbles not having been shaped on the spot, but brought as pebbles from elsewhere; and he gives reasons for supposing that they were derived from pebbly beds in the Lower London Tertiary group and in the Red Crag. He also maintains that the shells of the Westleton Beds and Bure Valley Beds are derived from Crag deposits. Reasons are given in the paper for supposing that the pebbles of the Westleton shingle of East Anglia came from the west, and that this moved eastward from the plateau of Suffolk towards the sea. It is considered that these beds can only be explained by a tumultuous diluvial movement.

2. "Supplementary Notes on the Systematic Position of the Trilobites." By H. M. Bernard, Esq., M.A., F.L.S., F.Z.S. (Communicated by the President.)

Since the publication of a paper by the author in the Quarterly

Journal of the Geological Society for 1894, two important papers by Dr. Beecher have appeared, giving details as to the structure and appendages of *Triarthrus.*

In the present paper the author discusses in detail the more recent discoveries in the light of the affinity between *Apus* and the trilobites, and endeavours to show how the results obtained by Dr. Beecher bear on the larger question as to the suggested origin of both of these animals from a chætopod annelid modified in adaptation to a new manner of feeding.

3. "An Experiment to illustrate the Mode of Flow of a Viscous Fluid." By Prof. W. J. Sollas, D.Sc., LL.D., F.R.S., F.G.S.

The author, recognizing that it is by a knowledge of the laws of viscous flow that we must seek to extend our information concerning the movements of flowing ice, conducted an experiment, the details of which are described in the paper, with a model of a glacier composed of the modification of pitch usually known as "cobbler's wax." In the model the pitch moved under its own weight over the horizontal floor of a trough, which was crossed by a barrier to represent an opposing mountain or the rising end of a lake. The results of the experiment showed that the movement of the pitch-glacier was not confined to that portion of it which rose above the barrier, but extended throughout its mass, and that an upward as well as forward movement took place as the barrier was approached. Thus the transport of stones by glaciers from lower to higher levels was by no means an incredible phenomenon, but a necessary concomitant of such simple conditions as those assumed in the experiment.

III.—May 8th, 1895.—Dr. Henry Woodward, F.R.S., President, in the Chair. The following communications were read :—

1. "The Stirling Dolerite." By Horace W. Monckton, Esq., F.L.S., F.G.S.

The rock described in the paper forms a mass about eight miles in length, with an average width of about a mile; it is intruded into the lower part of the Carboniferous Limestone series. There is little doubt that the Abbey Craig rock, north of the Forth, is connected with the Stirling rock; and there is reason to think that the igneous rocks of Cowden Hill and of the hills around Kilsyth are outlying portions of the Stirling rock, being connected with it underground.

All these patches, as well as the main mass, are for the most part composed of a more or less coarse-grained dolerite, the marginal part always becoming finer-grained, whilst the actual edge has apparently been a tachylyte now devitrified.

The author gives the results of his macroscopic and microscopic examination of the rocks from various parts of the mass. He describes rocks from the centre, and also towards the bottom and top of the main mass, including actual contact-specimens from the bottom at Sauchie Craig and from the top at Sauchieburn as well as contact-specimens from minor sheets; and he infers that the sequence is somewhat as follows (beginning from the centre :—

(i) Coarse-grained ophitic dolerite, forming the greater part of the mass.
(ii) Fine-grained ophitic dolerite, say 10 to 20 feet from the margin.
(iii) Basalt with *very little* augite, and with rods of iron-oxide.
(iv) Basalt with porphyritic plagioclase-crystals in a groundmass of microliths of plagioclase and hairs and rods of iron-oxide, having *no* augite. This occurs as near as $\frac{1}{2}$ an inch to the junction, and as far as 5 inches away from it.
(v) Basalt with porphyritic plagioclase in a gray groundmass, say $\frac{1}{10}$ to 1 inch from the margin.
(vi) Basalt with porphyritic plagioclase in a groundmass which is sometimes spherulitic; about $\frac{1}{10}$ inch thick on the average.

2. "Notes on some Railway Cuttings near Keswick." By J. Postlethwaite, Esq., F.G.S.

Several cuttings have recently been made on the Cockermouth, Keswick, and Penrith Railway, chiefly through drift, though some occur in the Skiddaw Slates, and in one case a diabase dyke (much decomposed) was met with.

The author describes the drift as blue clay beneath, and brown clay above, and considers that these two clays were produced during two separate periods of glaciation, with no long interval between. In some places near Keswick water-borne gravel may be seen surmounted by blue clay; this gravel is considered by the author to be of fluviatile origin.

The author has searched both blue and brown clays diligently for shells, but hitherto without success.

3. "The Shelly Clays and Gravels of Aberdeenshire considered in Relation to the question of Submergence." By Dugald Bell, Esq., F.G.S.

The drifts of this region have been described by Mr. Jamieson, and also in the publications of the Geological Survey. The two authorities agree that the Lower (gray) Boulder-clay of the district was produced by a local glaciation. The Geological Surveyors, however, maintain that the intervening sands and gravels with marine shells were produced during a submergence of 500 feet or upwards, whilst the Upper (red) Boulder-clay was formed by an ice-sheet from the south. Mr. Jamieson, on the other hand, assigns a purely glacial origin to the Middle Sands and Gravels, and considers that the Red Clay (which contains a few fragments of marine shells) indicates a submergence.

The author discusses these views, and maintains that submergence is not proved in the case of either Middle Gravels or Red Clay, but that the former are, as Mr. Jamieson maintained, truly glacial, whilst he advocates the existence of extra-morainic lakes to explain the latter.

CORRESPONDENCE.

SCOTTISH INTER-GLACIAL BEDS.

Sir,—Kindly allow me a few lines in reply to Mr. Clement Reid's statements in the last number of this Magazine. Mr. Reid doubts the inter-Glacial age of certain deposits which have been described as occurring between Lower and Upper Boulder-clays at Cowden Glen, in Lanarkshire, and at Hailes Quarry and Redhall Quarry, near Edinburgh, brief reference to which is made at p. 99 of my "Great Ice Age." third edition. I shall take the cases seriatim.

1. *Cowden Glen.*—Mr. Reid has not visited this locality, and the section has been obliterated for some years. He objects to the fossiliferous beds being classed as inter-Glacial, for two reasons: (1) because in some material sent to him for examination he detected two seeds of the garden poppy, and (2) because the whole assemblage of plants and the state of preservation of the animal remains suggest to him an extremely recent date for the deposits. Now, had Mr. Reid perused a paper read by Mr. Bennie to the Geological Society of Glasgow in 1889, he would probably have expressed himself less decidedly. The material examined by Mr. Reid was washed from the peaty silt by Mr. Bennie in 1868 and 1869, and had lain aside for twenty years before it was submitted to Mr. Reid's inspection. Among this material, some obtained from another observer was included by Mr. Bennie. It is not unlikely, therefore, as Mr. Bennie admits, that the two poppy seeds might have found their way accidentally into the collection during the long time it lay in his possession. It is even not impossible that they might have been accidentally dropped into the packet by Mr. Reid himself. The latter is quite sure they are poppy-seeds, but, under the circumstances, it might have been as well had he got some botanist to confirm the determination. So much then for Mr. Reid's first objection. Now for his second. I am afraid that his inference from the fresh appearance of the organic remains does not go for much. Mr. Bennie, whose greater experience gives weight to his opinion, says that the remains are no fresher than might have been expected. Mr. Reid, having apparently made up his mind that Scottish inter-Glacial beds should not contain a temperate flora, seems to think that this preconceived notion of his should be accepted as an argument against the inter-Glacial age of the Cowden Glen beds, in which the relics of such a flora were certainly found. He must excuse me if I decline to accept his dictum as to what the organic contents of an inter-Glacial bed should be. Upon the whole, I think I am justified in putting more trust in the evidence of my own eyes, and in the corroborative testimony of my former colleagues on the Geological Survey and others, than in his not very remarkable discovery of two supposed poppy-seeds in a collection of washed materials which had been lying past for twenty years before it came into his hands.

2. *Hailes Quarry.*—Here Mr. Reid has succeeded in finding a

mare's nest. He says that he saw no Boulder-clay resting upon the Arctic-plant beds. I should have been surprised if he had. If, before venturing on his criticism, he had troubled to read my reference to these beds ("Great Ice Age," p. 303) he would have found that I described them, along with the Corstorphine Arctic-plant beds, as occupying hollows in the surface of the Upper Boulder-clay. They are clearly younger than any Boulder-clay in the Scottish Lowlands. The inter-Glacial beds, formerly so well exposed underneath the Upper Boulder-clay in the quarry at Hailes, and described by me in "Prehistoric Europe," p. 256, are no longer visible. If Mr. Reid had asked Mr. Bennie he would have escaped falling into error, and would have learned that the inter-Glacial peat described by me and the Arctic-plant beds discovered by Mr. Bennie occurred on two separate and distinct horizons. I may add that no material obtained from the Hailes inter-Glacial beds has ever passed into Mr. Reid's hands.

3. *Redhall Quarry.*—This section was described and figured by Mr. John Henderson twenty years ago (Trans. Edin. Geol. Soc., vol. ii, p. 391). Mr. Henderson is a very careful and experienced observer, and knows the geology of the district well, and I have been content to rely upon his evidence. But I may mention that many other members of the Edinburgh Geological Society visited the quarry when it was first opened, and no one ever doubted that the glacial deposits occupied their original position. I did not myself see the section until long afterwards, by which time it had become more or less obscured, but nothing observed by me tended to throw any doubt upon the accuracy of Mr. Henderson's description. The situation of the quarry was familiar to me before the ground had been broken into for quarrying purposes. It was a slight depression lying between gentle slopes, from which no slips or slides of Boulder-clay could possibly have taken place. Mr. Henderson confirms my recollection of the facts, and informs me that at the time the quarry was opened undisturbed Boulder-clay extended continuously over the whole area. It was only when this Boulder-clay had been dug through that the inter-Glacial peat was disclosed. If it were the case that the plants recorded by Mr. Reid as having come from this place and Cowden Glen could not possibly have lived in Scotland during inter-Glacial times, I should be compelled to come to one of two conclusions—either (*a*) that Mr. Reid's unconfirmed botanical determinations are not necessarily infallible, or (*b*) that he has inadvertently mixed his samples or confused his localities, or both.

I have not noticed all Mr. Reid's statements and expressions of opinion which lay themselves open to animadversion, but have probably said enough to show that his attempt to discredit observations made by myself and others has not been quite successful.

EDINBURGH, *3rd May*, 1895. JAMES GEIKIE.

OBITUARY.

JAMES DWIGHT DANA.

BORN FEBRUARY 12TH, 1813. DIED APRIL 14TH, 1895.

THE announcement of the death of this eminent geologist and zoologist will be received with deep regret by the readers of the GEOLOGICAL MAGAZINE. Dana was born at Utica, New York, and entered Yale College, graduating in 1833. On leaving Yale, he entered the service of the United States Navy as teacher of mathematics to midshipmen. In this capacity he visited on board the "Delaware" and the "United States" a number of the seaports of France, Italy, Greece, and Turkey, the cruise lasting fifteen months.

In 1836 he became assistant to Prof. Benjamin Silliman, the mineralogist. In 1837 he published his "System of Mineralogy," a work which obtained a worldwide reputation, and which ran through numerous editions, of which the last was issued in 1892. Dana was next appointed Geologist to the Wilkes Exploring Expedition, which sailed in 1838 and returned in 1842. "The expedition consisted of five ships, the route pursued being briefly as follows:—First to Madeira, then to Rio Janeiro, down the coast and through the Straits of Magellan, after passing which, while on board the 'Relief,' he nearly suffered shipwreck off Noir Island, the ship remaining for three days and nights in extreme peril: in the same storm one of the smaller accompanying vessels was lost. Then to Chili, Peru, and across to the Paumotus, to Tahiti, and the Navigator Islands; then to New South Wales, where the Naturalists remained while Commodore Wilkes went into the Antarctic; then to New Zealand, the Fiji Islands, where two of the officers were murdered by the natives; to the Sandwich Islands, the Kingsmill group, the Caroline Islands, and thence north to the coast of Oregon. Here, near the mouth of the Columbia river, the 'Peacock,' the ship to which Dana had been assigned, was wrecked, entailing the loss of all his personal effects, as well as many of his collections. He was, then, one of the party that crossed the mountains near Mount Shasta, and made their way down the Sacramento River to San Francisco. In his report of the expedition he states that the geological features indicated the probable presence of gold. This was six years before the discovery of gold in California, and rich mines have since been discovered in the region over which the party went. At San Francisco they were taken on board the 'Vincennes,' and the homeward voyage was made by way of the Sandwich Islands, Singapore, the Cape of Good Hope, and St. Helena, arriving in New York in June, 1842." As a result of his connection with the expedition he published the Reports on Geology, Crustacea, and Zoophyta, and spent in all thirteen years editing and superintending the printed reports resulting from these voyages. In 1855 he succeeded to the Chair of Mineralogy at Yale, a position he held till 1894, when he resigned. His "Manual of Geology" appeared in 1863, a fourth edition having been issued only this year. He was part editor of the American Journal of Science from 1846, and continued his interest in it up to the last.

Dana received the Copley Medal from the Royal Society in 1877, and the Wollaston Medal from the Geological Society in 1872; he was a member of the Academy of Sciences, Paris, and of the Academies of Berlin and Munich, and was elected a Foreign Member of the Royal Society in 1884 and of the Geological Society in 1851.

His publications amount to nearly 400 in number, and when one considers that these include such colossal works as his "Mineralogy" and his "Manual" and "Text-Book of Geology," one is astonished at Prof. Dana's wonderful power of work, and are not surprised to learn that his health broke down upon several occasions owing to his excessive mental labours. It is wonderful and touching to read of Prof. Dana working on at the new edition of his "Manual of Geology" at the age of eighty-two, and being actively assisted in all his literary labours by his life-long companion with never-failing and watchful care to the end.

It is impossible to do justice to this distinguished man and personal friend in so short a notice, but we feel that, with our American brethren, we have also lost one of the greatest figures in geology of our time.

THE MARQUIS OF SAPORTA.

Born 1823. Died January 26th, 1895.

By the death of the Marquis of Saporta the sciences of Geology and Botany have suffered a severe loss. A wide botanical knowledge, combined with a vigorous enthusiasm and an untiring energy, enabled Saporta to add a rich store of facts to palæontological literature. Born at Saint-Zacharie (Var) in 1823, he spent some time in a Jesuit college at Fribourg, and in 1861, in conjunction with M. Matheron, published his first paper on a palæobotanical subject.[1] From that date up to the time of his death, Saporta devoted himself as a keen student to the problems of his chosen science.

His earlier works dealt especially with the Tertiary vegetation of the South-east of France; the floras of Aix, Manosque, Sézanne, and other localities have formed the subjects of elaborate monographs, in which he has not merely recorded lists of fossil species, but has dealt with the facts from a broad and philosophic standpoint. Between the years 1872–91 there appeared the splendid series of volumes on the Jurassic Flora of France; this comprehensive work, with its numerous illustrations and exhaustive text, forms an indispensable handbook to students of Mesozoic Botany. Saporta's most recent work, on Upper Jurassic and Lower Cretaceous Plants, appeared a few months before his death[2]; it contains a detailed geological and botanical analysis of an exceedingly interesting flora, and supplies fresh facts of considerable importance towards a more complete knowledge of the early history of dicotyledonous plants.

[1] Examen analytique des flores tertiaires de Provence.

[2] Flore fossile du Portugal (Direction des travaux géologiques du Portugal), Lisbon, 1894.

In addition to his numerous papers on palæobotany, Saporta has left such works as "Le monde des plantes avant l'apparition de l'homme,"[1] "Origine paléontologique des arbres cultivés ou utilisés par l'homme,"[2] and, in collaboration with Professor Marion, "L'évolution du règne végétal"[3]: these form fitting memorials of his wide knowledge as a palæobotanist, and of his zealous advocacy of the importance of fossil forms to the student of plant evolution. By some readers Saporta is perhaps best known as the too eager upholder of the claims of certain structureless casts and impressions to be included among fossil algæ. The valuable contributions to this subject by Nathorst have clearly shown how little weight must be attached to any speculations as to the development of plant life based on Saporta's "Algues fossiles"[4] or his "Organismes problématiques."[5]

As a contributor to Tertiary and Mesozoic Botany, Saporta's name will always be associated with that of Heer and Ettingshausen; and the younger generation of workers in this branch of palæontology may well look upon him as a worthy pupil of Adolphe Brongniart, whose philosophic spirit and scientific handling of facts are reflected in the writings of his younger countryman. The writer of a recent obituary notice in a French scientific journal has thus happily expressed Saporta's unfailing industry: "'A des travaux considérables succédaient des entreprises plus considérables encore, et l'on oubliait l'âge en voyant l'œuvre s'augmenter et les horizons s'étendre toujours."

A. C. S.

THE REV. NORMAN GLASS.

Born December 4th, 1832. Died December 2nd, 1893.

The death of the Rev. Norman Glass on the 2nd December, 1893, at his residence, 26, Lower King Street, Blackpool, has, we regret to say, hitherto escaped the attention of geologists. From local sources we learn that Mr. Glass was educated at the Western Congregational College, Plymouth, where, after distinguishing himself in logic and rhetoric, he entered upon a ministerial career, holding, in rotation, pastorates at Cardiff, London, Basingstoke, Rothwell, Wolverhampton, and Bilston. Soon after obtaining his last appointment he was obliged to retire from the ministry on account of failing health. He then removed to Manchester, and for a time occupied the post of Curator at the Queen's Park Museum.

From an early period Mr. Glass was keenly devoted to geology, and appears to have been on friendly terms with both Murchison and Owen, the former recognizing him as the discoverer of a patch of Silurian rocks (Wenlock Limestone) rising up through the Old Red Sandstone at Pen-y-lan, near Cardiff. He was also fortunate in finding in the Upper Chalk of Charlton, Kent, a new

[1] Paris, 1879.
[2] Paris, 1888.
[3] Paris, 1881–1885 (3 vols.)
[4] 'A propos des algues fossiles, 1882.
[5] Les organismes problématiques des anciennes mers, 1884.

genus of echinoid, which the late Dr. S. P. Woodward described and figured under the name of *Echinothuria floris* ("Geologist," 1863, pl. xviii, fig. B, pp. 327–330). But it was in his association with the late Dr. Thomas Davidson that Mr. Glass will be more particularly remembered by palæontologists. He had devised a method whereby the delicate calcareous internal structures of many of the Palæozoic Brachiopod shells could be exposed for examination, and although this was effected by a somewhat simple process through the agency of a knife, hydrochloric acid, and running water, it required the greatest patience, and no small amount of skill, before satisfactory results could be attained. These investigations naturally led to most important discoveries, and required Davidson to amend much of his earlier work. In the following terms Davidson thus alludes to the valuable assistance rendered him by Mr. Glass: "Prominent in this difficult study [the spiral-bearing Brachiopoda] has been the Rev. Norman Glass, to whose indefatigable perseverance and consummate skill I am indebted for the possibility of laying before my readers a large amount of positive and most valuable information. I can find no words sufficiently expressive to convey the gratitude I feel towards him for the unrelaxing energy he has displayed during upwards of three years in this difficult kind of investigation" [quotation from Davidson's Monograph]. Some forms of spiral-bearing Brachiopods had previously been subjected to development by Young and Neilson of Glasgow, Zugmayer of Vienna, and Whitfield of America, but the success attained by Mr. Glass seems to have eclipsed that of all others in this special branch of palæontological work. His specimens were generously presented to Dr. Davidson, who elaborately figured and described them in his great monograph on the "British Fossil Brachiopoda," published by the Palæontographical Society between 1880 and 1884, subsequently bequeathing them to the British Museum, where they are now exhibited among the type specimens of the "Davidson Collection."

As a further proof of his appreciation of these signal services to his subject, Davidson founded the generic name of *Glassia* to include such forms as *Atrypa obovata*, J. de C. Sowerby, the spiral structure of which, after exposure by Mr. Glass, was proved to be essentially different from that of any previously known genus.

In 1882 the Council of the Geological Society of London awarded him a moiety of the "Lyell Donation Fund" for "valuable aid and services rendered in elucidating the history and internal structure of the British and foreign Brachiopoda." Mr. Glass has contributed the following papers to geological science:—

(1) Silurian Strata near Cardiff. *Geologist*, 1861, vol. iv, p. 168.

(2) On the Development of the Spirals and their Connections in the Palæozoic Brachiopoda, in Davidson's "Monograph of British Fossil Brachiopoda," *Palæontographical Society*, 1882, vol. v, pp. 86–91.

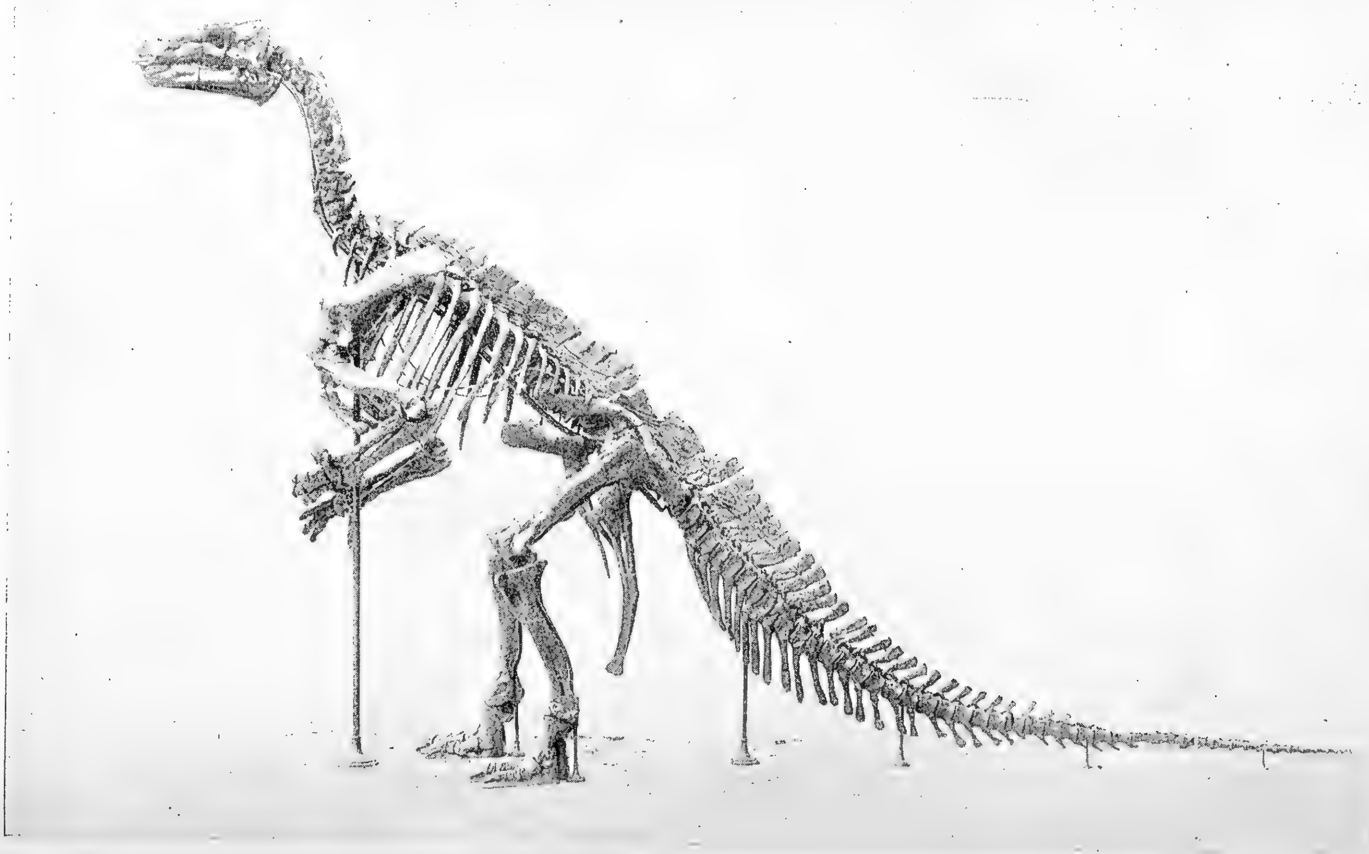
(3) On a new form of Spiral in *Spirifera glabra*. GEOLOGICAL MAGAZINE, 1890, pp. 461–463.

(4) On *Athyris læviuscula*, Sow., sp., with the full disclosure of its loop, etc. *Ibid.* 1891, pp. 495–498.

(5) The Rocks on the Blackpool Coast. *Blackpool Times* (undated).

(6) The Local Geology of Blackpool. *Ibid.* 1893.

R. B. N.



Skeleton of the Iguanodon from Bernissart, Belgium, lately set up in the British Museum (Nat. Hist.). Height 15 feet; length 30 feet.

THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE IV. VOL. II.

No. VII.—JULY, 1895.

ORIGINAL ARTICLES.

I.—Note on the Reconstruction of *Iguanodon* in the British Museum (Natural History), Cromwell Road.

By Henry Woodward, LL.D., F.R.S., Pres.G.S.

(PLATE X.)

BY the kind assistance of Monsieur E. Dupont, the Director of the Royal Museum of Natural History in Brussels, a coloured reproduction of the entire skeleton of *Iguanodon Bernissartensis* has lately been acquired for the British Museum (Natural History), and may now be seen admirably set up in the Reptile Gallery of the Geological Department.

Remains of *Iguanodon* had long been known from deposits of Wealden age in this country, the first notice being that by Dr. G. A. Mantell in 1825 (see Phil. Trans., p. 184). All the English accounts were founded upon teeth and detached bones of various individuals, mostly from Hastings, Sussex, from Maidstone, Kent, and from the Isle of Wight; but no complete specimen was ever obtained in this country. Many species have been established upon these very imperfect remains, but originally they were all referred to a single species, for which the names *I. anglicum*, F. Holl (1829), and *I. Mantelli*,[1] H. von Meyer (1832), were proposed. The latter, having been defined by Owen in 1851, is the species generally recognized in this country.

How imperfect was our acquaintance with the entire animal may be seen from the restoration set up about forty years ago by Waterhouse Hawkins (after Owen's suggestions) in the grounds of the Crystal Palace, Sydenham. At length our knowledge of this very remarkable reptile was destined to be perfected by the discovery, in 1878, of no fewer than twenty-three more or less complete skeletons of *Iguanodon* at Bernissart in Belgium, where heretofore no Wealden strata bad been known to exist.

At this village, between Mons and Tournay, near the French frontier, coal-mining had been carried on for years by M. Fages, Director-General of the Society of Bernissart. A trial gallery, made in order to discover the continuation of a missing seam of coal, led to the finding of an ancient river-gorge, excavated by a stream in

[1] For an account and restored figure of Mantell's *Iguanodon* see Geol. Mag. 1885, Dec. III, Vol. II, pp. 10–15, Pl. I, by H. Woodward.

the Jurassic period through several hundred feet of Coal-measures, but since filled up and all trace of its existence obliterated on the surface. On the discovery of the fossils M. Gustave Arnould, the principal engineer of the coal-pit, immediately informed M. Dupont, Director of the Brussels Museum, who at once sent M. Depauw, the Chief Superintendent of the Modellers' Department, to undertake the extraction of the bones, which were numerous and of gigantic size.

They are preserved in a blackish clay, which filled the valley to a great extent, and was no doubt of fluviatile origin. The associated fossil-remains tell us of an old land-surface covered with cycads, arborescent ferns, and other semi-tropical plants of the Wealden period.

The river must have been well stocked with fishes, especially those of the genus *Lepidotus*, having thick enamelled scales, reminding one of the American bony pike, but with a very different form of head, and with rounded crushing palatal teeth. The banks of the stream formed the home of lizards, crocodiles, water-tortoises, and the huge *Iguanodon*. Thick vegetation of ferns and giant Equisetaceæ clothed the margins of the river, and we can easily realize that in times of flood, which were not infrequent, the *Iguanodon*—and the plants they fed upon—together with crocodiles, water-tortoises, and the fishes of the stream, were all entombed in one common grave and covered up by deposits of fine mud left behind by the river-flood. Evidence of no fewer than four of these freshets was observed by M. Dupont in the course of these explorations.[1]

The exhumation and removal from the mine of these ponderous remains occupied two years. The subsequent development and setting up of the five individuals exhibited in the Brussels Museum was a far longer and still more critical labour. The work of description, commenced in 1881 by Mr. G. A. Boulenger, was continued by M. L. Dollo, in great detail, with admirable figures (see Bull Mus. Roy. Hist. Nat. Belge 1881–82).

Although three entire wall-cases and two table-cases are devoted to the exhibition in the British Museum (Natural History) of the remains of the *Iguanodon* from British localities, they nevertheless fail to impress one with the same degree of interest which is felt in the presence of the huge skeleton which now forms so conspicuous an object in the central floor-space of the Reptile Gallery.

The specimen set up is a coloured reproduction by M. Depauw of one of the five entire skeletons exhibited in the Royal Museum of Natural History in Brussels, which he has worked out and reconstructed with such consummate skill. The skeleton measures 15 feet in height, and 30 feet from the head to the extremity of the tail. It is set up in the position in which it is believed the animal commonly walked.

The *Iguanodon* was a vegetable-feeding reptile, and its cheek-teeth, which exceed 80 in number, were well adapted for chewing

[1] Bull. Acad. Roy. de Belgique, 2nd Serie, Tome 46, 1878, pp. 387–408.

the leaves and shoots of the Cycadaceous and other plants which formed its diet. It had no front teeth, but its jaws were provided with a horny beak, like that of a turtle, covering the border of the premaxilla and of the predentary bone.

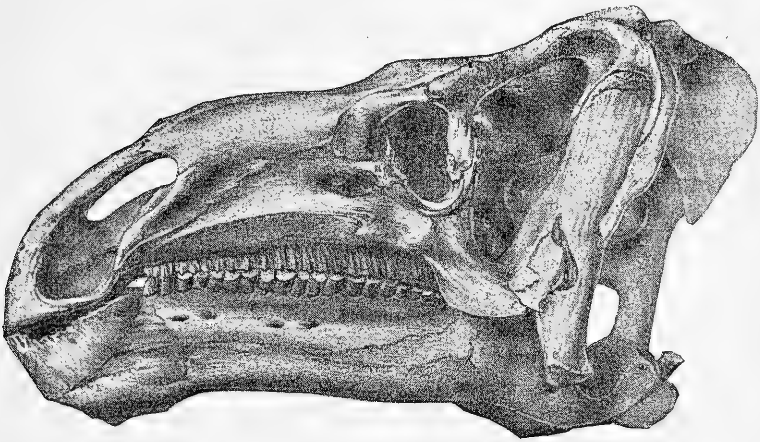


Fig. 1.

Left lateral aspect of skull of *Iguanodon Bernissartensis* (Boulenger); from the Wealden of Bernissart, Belgium (much reduced). The anterior aperture in the skull is the nares (nostril), the middle one the orbit, and the large posterior one the infratemporal fossa. The predentary bone is seen at the extremity of the mandible (after Dollo).

The fore-limbs are shorter than the hind ones, the former being six feet in length and the latter nine feet long. The hands had each five digits with nails, the thumbs being armed with strong, sharp-pointed, conical spurs. They appear to have been but ill-adapted for progression on the ground, though doubtless when browsing on lowly herbaceous plants the *Iguanodon* assumed the same quadrupedal attitude as does the living kangaroo.

The hind-limbs were large and powerful, and had three toes on each foot, with the same number of phalanges as in a bird's foot, namely, three to the inner toe, four to the middle toe, and five to the outer toe. The three metatarsal bones remain separate and distinct as in the foot of a young ratite bird, not anchylosed together as in adult modern birds. The bones of the pelvis (ilium, ischium, and pubis) resemble in many respects those of a large running bird, such as the emeu.

The ponderous tail, as well as the neural spines of the dorsal vertebræ, were strengthened and knit together by numerous stout bony fibres, no doubt giving great additional support to the animal when standing in an erect position; the length of these spinous processes also must have given the tail great depth, and suggests that probably the *Iguanodon* was a good swimmer, using its tail as a rigid, powerful, oar-like propeller by moving it from side to side.

Numerous three-toed footprints of the *Iguanodon* were discovered by Dr. Mantell, Mr. S. H. Beckles and others, preserved on the surfaces of the slabs of Hastings sandstone. These always show a single bipedal track, and may therefore be considered as good evidence that the *Iguanodon* ordinarily walked in an erect position.

Several of these footprints may be seen exhibited in the wall-case on the east side of Gallery No. xi.

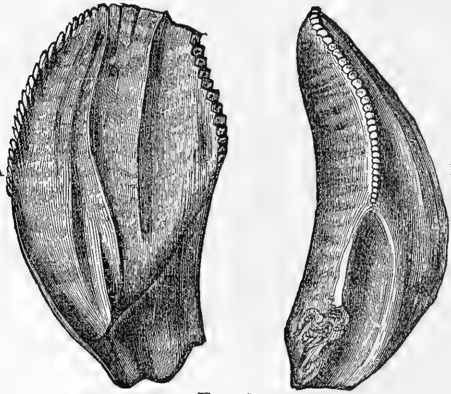


Fig. 2.

(A), Outer view; (B), profile of tooth of *Iguanodon* (natural size), Wealden, Isle of Wight.

In Wall-cases 4*a* and 6, and in Table-cases Nos. 8 and 9, may be seen many examples of portions of the maxillæ and mandibular rami with the worn and unworn teeth of *Iguanodon in situ*, showing their curious curved and leaf-shaped pattern, with the edges elegantly serrated in a manner peculiar to the vegetable-feeding dinosaurs.

In a separate case placed in the centre of the floor near the skeleton, is exhibited a restored reproduction of the skull, of which we give a figure showing the remarkable length of the row of cheek-teeth, reminding one, superficially, of the jaw of the horse, but the mode of suspension of the mandible by the large quadrate bone is unlike that seen in the mammalia. The great horse-shoe shaped predentary bone can also be clearly seen in this specimen.

II.—On the Mode of Occurrence of Eozoon Canadense at Côte St. Pierre.

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

The question of the origin of Eozoon Canadense has been recently revived in an important and most interesting paper on a similar structure in blocks of limestone ejected from Vesuvius.[1] The

[1] Eozoonal structure of the ejected blocks of Monte Somma. By Prof. H. J. Johnston-Lavis, M.D., and J. W. Gregory, D.Sc. Trans. Roy. Dubl. Soc., ser. ii, vol. v, p. 259. Sir J. W. Dawson's views are very fully stated in two sections of his work "Salient points in the Science of the Earth" (1893). [June 12. This paper was finished before a type-written copy of his paper, printed in the last Number of this Magazine (p. 271), reached me. To this I could not refer, because I did not know where, or in what form, it would be published.—T. G. B.]

writers, however, of that paper evidently found that more information existed as to the microscopic structure of the Canadian Eozoon than as to its mode of occurrence, so that a few notes on this subject may be of some use as a contribution to the discussion. I visited one of the most noted localities for Eozoon—Côte St. Pierre—in 1884, when I had the inestimable advantage of being conducted by Sir J. W. Dawson, to whose unwearied kindness and hospitality I was so often indebted during my stay in Canada. I made careful notes and rough sketches of what I saw, collected a fair suite of specimens, and paid especial attention to the relation of the structure to other parts of the rock-masses. Upon the question of the origin of Eozoon I do not purpose to enter: I shall restrict myself to stating facts of which, as it seems to me, account must be taken in all attempts to interpret this extraordinary structure.

Côte St. Pierre is a scattered settlement—one can hardly call it a hamlet—as far as I remember, about twelve miles from Papineauville, on the railway between Montreal and Ottawa. At the station a shallow cutting exhibits an interesting section[1] of Laurentian rocks—marble, calc-mica schist, and biotite-hornblende schist, with a vein of pegmatite—all coarsely crystalline, between two masses of gneiss, the higher of which is finer in grain than the lower. The road to Côte St. Pierre traverses an undulating or slightly hilly district, consisting of gneisses belonging to the upper group, which are often masked by a thin covering of sands and clays (Pleistocene). There are still very considerable tracts of uncleared forest. The crystalline rock, in general character (I did not attempt a minute study), was a distinctly foliated, moderately fine-grained reddish gneiss. This, at the time reminded me of some from the Central Highlands of Scotland, which I had recently examined for Dr. Hicks, and to which he assigned a fairly low place in his succession.[2] The rock is moderately schistose, but in general is strong and not friable.

We kept along the upper series of gneisses, as I was informed, till we arrived at Côte St. Pierre. The cottages are scattered about a rather open and shallow valley, perhaps a quarter of a mile wide; the bed, except where there is a large pool, being nowhere quite flat. On the western, or right, bank is a forest-clad flattish ridge, formed by the lower group of gneisses; on the eastern a similar ridge, consisting of the upper group. The limestone, according to Sir J. W. Dawson, occupies the whole of the valley, and its thickness was estimated by Sir W. Logan as about 500 feet.[3] We spent some hours in examining sundry outcrops of the crystalline limestone (all, I believe, which are of importance), traced the lower gneiss for some distance downwards, and just glanced at the upper gneiss. My description will be, I hope, more intelligible if I follow the apparent stratigraphical order and not that in which the notes were made.

The lowest rock visited was a rather dark, somewhat streaky,

[1] Described briefly in Presidential Address to the Geological Society, 1886, vol. xlii Proc., p. 82.

[2] Quart. Journ. Geol. Soc. (1883), vol. xxxix, p. 159.

[3] This is a minimum. It may be much more. He gives it in places 1500 feet.

biotite or biotite-hornblende gneiss, moderately fine-grained, over which comes a band of no great thickness, of a whitish quartzose rock, of which a more minute description will be given below. It is one of the so-called Laurentian quartzites. Above this comes a very considerable thickness of darkish gneiss, rather variable in character. Sometimes it is coarser, sometimes finer; sometimes there is a fair proportion of quartz, sometimes little; sometimes hornblende dominates over the biotite, sometimes the rock is distinctly banded, with more and less felspathic layers.[1] The highest rock seen was a dark, rather micaceous gneiss, of moderate-sized grain.

A short interval of covered ground separated the last-named rock from a mass of nearly pure pyroxene rock consisting of a coarsely crystalline greyish-buff pyroxene[2] with some interstitial pale-reddish garnet and light-coloured mica (associated), a little calcite, etc. In this rock are veins of an asbestiform mineral which has been worked for "rock cotton," and above this comes the crystalline limestone. The last nowhere affords a continuous section, but occurs in a number of irregular and separate outcrops on the slope and floor of the valley. As the exact relation of these is not easily determined, it will be better to deal with the principal masses.

The first is on the western slope of the valley, in immediate sequence with the rocks mentioned above. A number of shallow pits have been opened in a wood, and the limestone can be traced down to the road leading into the "hamlet." In one of these pits the dip was about 70° to a point 10° or 15° S. of E. The rock varies considerably in character. Sometimes it is nearly pure calcite (or dolomite),[3] sometimes it contains grains, more or less abundantly, of pyroxene or serpentine, which occur either in fairly marked bands or merely scattered. Pyroxenite (greyish) or serpentine (lightish-green) occurs locally in irregular nodular masses or interrupted layers, like chert in a limestone. Well-defined Eozoon is not abundant; indeed, regarding the mass as a whole, it is the exception rather than the rule. This structure commonly forms a kind of band, which is founded upon (if the phrase be permissible) a layer of green serpentine (resembling that in the well-known Connemara ophicalcite) usually not exceeding half an inch in thickness, under which comes a whitish pyroxene, but sometimes the one mineral, sometimes the other, is apparently absent. In the neighbourhood of the "foundation" the layers of calcite and serpentine in the Eozoon are often slightly thicker and less regular than in the outer part. The whole band exhibiting the structure generally varies in thickness from about two to four inches; it appears to pass, rather rapidly, but not always with a sharp boundary, into an

[1] One of my specimens, taken as a sample of about the coarsest type, might be called a quartz-diorite; hornblende is abundant in crystals about a quarter of an inch in length.

[2] The pyroxene is always light-coloured, apparently either malacolite or a closely allied variety, but occasionally it might be tremolite (*i.e.* a variety of hornblende).

[3] Some of my slices show that a little dolomite is present, but, so far as I can tell, calcite is the dominant mineral.

ordinary crystalline limestone, containing, usually, numerous granules of serpentine, which sometimes exhibit a very distinct banding resembling a stratification. Thus the structure may form an "aureole" round a nodular mass of serpentine or pyroxene, but it may also occur upon a mere band or irregular seam of serpentine. In the latter case the structure may take a very irregular curved shape, but whether this was original or due to subsequent bending I could

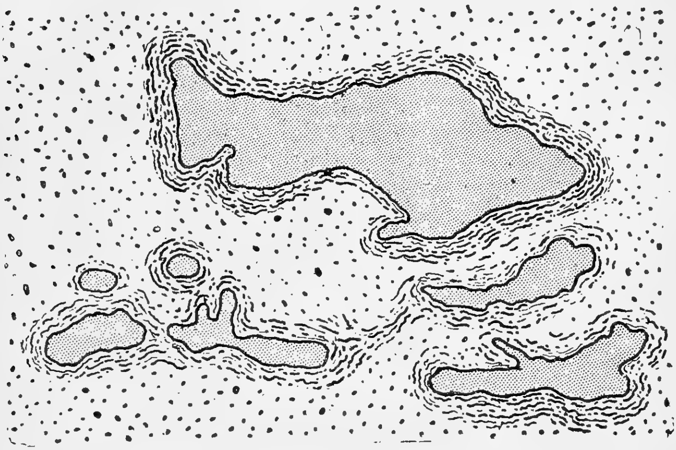


FIG. 1.—Diagram of Eozoonal Rock at Côte St. Pierre.

The closely dotted part is pyroxene or serpentine; the top mass being about 2 feet 3 inches long. The zones of "Eozoon" are indicated by the broken wavy lines, generally surrounding these masses. The remainder of the rock is white crystalline limestone, spotted with granular serpentine.

This figure appeared in my book entitled "The Story of our Planet," and I am indebted to the liberality of the publishers and proprietors, Messrs. Cassell and Co., for the cliché of the block to illustrate this paper.

not determine. The smaller masses, as Sir J. W. Dawson has more than once pointed out, bear a general resemblance to one of the Stromatoporids. A thinnish band of gneiss is intercalated in this limestone, which crops out in the wood near the road, but, as it happened, I did not see it.

The next mass occurs in the bed of the valley, and rather further up it, on a farm belonging to a Mr. Levine. It forms a small rugged knoll, which has been quarried. Here also the limestone varies a little in coarseness, and one of the more finely crystalline varieties contains grains of a nearly black mineral, which will be noticed presently. Eozoonal structure is not generally well developed here, but occasionally it may be seen. It exhibits the same relation to pyroxene and serpentine, the same nodular habit, and the same association with calcite containing granules of these minerals, as we have already described. Now and then, especially in the part where the pyroxene was most abundant, a little white mica occurred, sometimes in plates as much as half an inch in diameter, and in one place the Eozoon was cut by a vein of about the same width filled with this mineral. In another case a micaceous band lay parallel with the surface of the Eozoon, separated from it by a zone of irregularly mixed calcite and serpentine (rather decomposed), about an inch in thickness. The pyroxene, in one part of the knoll, formed a mass, and contained an acicular tremolite, probably occurring as a vein (but this was not quite clear); and on the more northern flank was a rather coarsely crystalline rock, chiefly consisting of felspar; this probably was a vein-product, and may be connected with an intercalation of gneiss.[1]

The general strike of the apparent bedding suggests that this second mass is considerably higher in the group than the former one, but Sir J. W. Dawson expressed the opinion that the two were approximately on the same horizon, and that a flexure or thrusting towards the east had occurred. So far as one could judge from the outline of the country, the underlying mass of coarse gneisses, already described, was at about the same distance as before, so that this probably is the correct interpretation.

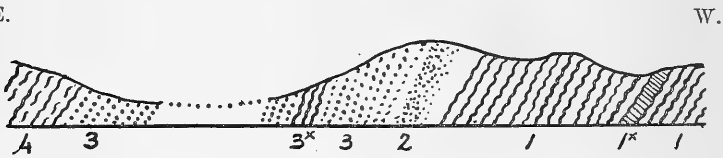


Fig. 2.—Probable succession at Côte St. Pierre.

1. Lower Gneiss.
1^x. Quartzite.
2. Pyroxenite.
3. Crystalline Limestone (Eozoonal).
3^x. Intercalated Gneiss.
4. Upper Gneiss.

The third mass is rather further up the valley, and also on the lower ground.[2] This is a rugged knoll of crystalline limestone, in which pits have been dug, one of them to obtain apatite. The hole was full of water, but I found some specimens. The mineral assumed two forms: (1) well-defined crystals of a greenish-grey colour, from a quarter to half an inch long, in calcite; (2) less regularly crystallized and of light cobalt-blue colour, with the same mineral and pyroxene. The apatite apparently occurred as a vein-product. A short distance from this was a good development of the Eozoonal structure, associated with pyroxene; the latter in masses of concretionary aspect, very irregular in outline and mode of occurrence. As before, the Eozoon formed an enclosing zone, up to a thickness of about four inches, and then passed rapidly into a crystalline limestone, containing granules of pyroxene or serpentine. In one part of this knoll the limestone is distinctly micaceous, and the following succession is exposed in ascending order, beginning

[1] This rock is a normal but perhaps rather fine-grained gneiss, inclined to be "platy" in structure. I do not remember that there was anything to suggest that it was intrusive; it seemed to pass rather rapidly into the limestone, but more as one sedimentary rock passes into another.

[2] The name of the owner was either Lavère or Laval; the farm was No. 10.

with the western side: (1) pyroxenite, about four feet; (2) patches of serpentine in calcite, about three feet; (3) crystalline micaceous limestone, about twelve feet; this is spotted with grains of pyroxene in the lowest part, and more distinctly banded with mica in the upper part.

One outcrop only of the upper gneiss, on the left bank of the valley, was examined. It agreed in general character with that seen on the road from Papineauville, being a distinctly foliated, rather fine-grained biotite gneiss, with alternating bands of more or less micaceous rock. Possibly there were also some indications of an intrusive granite, with but little mica.

The so-called Laurentian quartzite, under the microscope, does not exhibit the slightest trace of a fragmental origin. It consists of quartz, felspar (including microcline), mica (probably a bleached biotite), with a little, rather minute, chlorite, some grains of iron oxide (probably magnetite), and a few microlithic minerals, among them possibly zircon. It exhibits the structure which I have more than once described as very usual in primeval "gneisses," and only differs from them in being exceptionally rich in quartz. Into the microscopic details of the "Eozoonal" rocks I abstain from entering, as they have been so frequently described, and content myself with remarking that the peculiar structures, to which appeal has been made in the controversy, are exhibited by my specimens, in some cases very well. I will only add that the malacolite occasionally, the serpentine perhaps rather oftener, in the supposed "chambers" is stained by a black or brownish mineral, and that in one case[1] the darkish grains included in the calcite prove to be in some cases barely translucent, in others fairly so. The mineral then is of an umber-brown colour, which is doubly refracting, and occasionally becomes fibrous near the edge, but otherwise seems to have neither definite structure nor cleavage. I have not been able to satisfy myself as to its nature, but it bears some resemblance to one of the hydrocarbon group. Possibly, however, it is the loganite examined by Dr. T. Sterry Hunt. A like mineral occasionally forms a border to clear grains of serpentine. The calcite often has a "dusty" aspect, due apparently to the presence of a brown or black powder.

The Rev. J. F. Blake has expressed the opinion[2] that the granular magnesian mineral in these Eozoonal rocks is frequently olivine. It undoubtedly often resembles the latter mineral, and there is no *à priori* reason why this should not be present, especially such a variety (or species) as monticellite. Olivine, however, is commonly associated with igneous rocks, so that a little scepticism is justifiable, and some varieties of pyroxene (such as malacolite) appear to be readily converted into serpentine. The reasons also given by Mr. Blake in favour of his view appear to me inconclusive. Malacolite often exhibits high polarization tints and a similar texture to olivine, and is not seldom, when the grains are rather small, without cleavage. In my own specimens I find it impossible to distinguish, either by

[1] The specimen mentioned above as collected on Levine's Farm.
[2] Quoted by Messrs. Johnston-Lavis and Gregory, *loc. cit.*, p. 274.

texture, polarization tints, or general aspect, grains occurring in the cores or bands, which can be proved by cleavages and extinction angles to be monoclinic pyroxene (malacolite), from the separate uncleaved grains in the calcite or the fragment-like granules in the grains or masses of serpentine. Accordingly, while I admit the *possibility* of olivine being present, I think that this is not as yet proved by any valid evidence.

The observations described above indicate, I think, that the Eozoon often occurs in close relation, on the one hand with a fundamental mass of almost pure pyroxene or serpentine (the latter being, in many cases at least, an alteration product of the former); on the other hand, with a fairly large mass of crystalline limestone containing, sometimes in bands resembling stratification, more or less numerous grains of pyroxene or serpentine; the change in either direction being rather abrupt.

The concretionary habit, mentioned above, would accord either with a structure purely mineral, or with an organism which grew in irregular "cakes" or small reef-like masses like some Stromatoporids, but in the latter interpretation there are three difficulties: (1) We must assume that the organism has been infiltrated, very commonly, if not always, by a pyroxene (malacolite), and this, so far as we know, is not one of the silicates which usually discharges this function. (2) We must account for the grains of malacolite or serpentine in the external crystalline limestone. They might be regarded as detached casts of "chamberlets" of the organism; but this explanation presents some serious difficulties, which will be obvious to a petrologist, while the rock undoubtedly presents a close resemblance to an ordinary granular pyroxene-marble. (3) We must assume that as a rule the interior of the organism perished as the exterior grew, because the centre so commonly is a lump of practically pure silicate.

Whatever may be the origin of Eozoon, nothing which I saw in the field suggested the probability of the specimens being "blocks included in either a volcanic or plutonic mass." If the structure be not a fossil organism, it is at any rate as much a part of the whole rock as chert is of a limestone. There seems no reason for doubting that the valley is excavated in a thick mass of crystalline limestone included between two groups of gneiss, both of which exhibit a very rudely stratified arrangement, and differ in lithological characteristics. The larger masses of pyroxenite did not resemble any igneous rock known to me, but as to their origin I forbear at present to speculate. The felspathic vein did not resemble an igneous rock, nor did the intercalated gneiss. The latter might, of course, be an intrusive sill, modified by pressure; but of this I saw no evidence, and the adjacent limestone, if it has been crushed, has not retained any indication of this action. To the associations of the rock-masses I paid especial attention; because, before I visited Côte St. Pierre, it had occurred to me that possibly the Eozoonal limestone was a rock of later date folded or faulted into an older group. But everything that I saw led me to believe that the rocks formed a true sequence.

The gneisses, of course, may have had an igneous origin, but they certainly are not ordinary intrusive masses, and in any case I believe that the crystalline limestone belongs substantially to the same epoch. In other words there is nothing, so far as I can see, to differentiate the rock in which Eozoon occurs (except this peculiarity) from those other masses of crystalline limestone which are found elsewhere intercalated in gneisses and coarsely crystalline schists. How such rocks were produced is a question which is highly controversial, and upon which, as I have already expressed an opinion, I do not intend to enter. In this paper I have sought nothing more than to state certain facts of which account must be taken in framing any theory as to the origin of Eozoon. I will simply add that, to my mind, they offer a choice between two interpretations only; the structure is either a record of an organism, or a very peculiar and exceptional condition of a pyroxene-marble of Laurentian age, which is not a result of contact metamorphism in the ordinary sense of the term.

III.—Physiographical Studies in Lakeland.

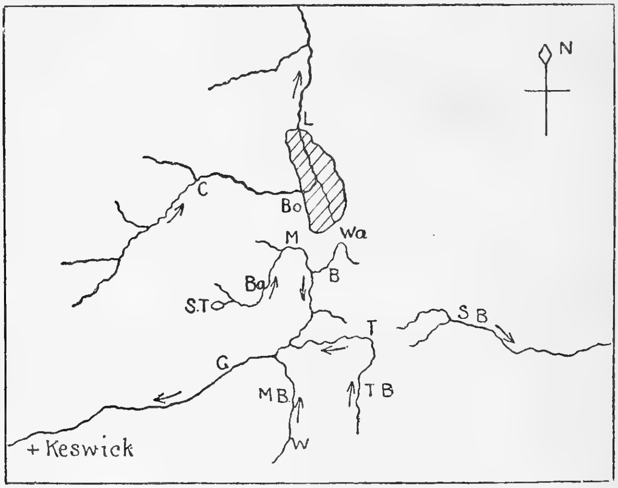
By J. E. Marr, M.A., F.R.S., Sec.G.S.

3. The Rivers Caldew and Glenderamackin.

A TRAVELLER alighting at Troutbeck station (T of Figure), at the summit level of the Keswick and Penrith Railway, finds himself standing at the north-east corner of a moorland plateau (Matterdale Common), having a mean height of over 1000 feet, and sloping gradually down to the River Glenderamackin (G), which bounds it on the north. The moorland is thickly covered with drift, and rock exposures are scarce, except here and there in the tributaries of the Glenderamackin, which run in a northerly direction from the Helvellyn Range, the principal being Troutbeck (T B) and Mosedale Beck (M B); (the latter is one of many of the same name in the district). That the stones in the drift were mainly brought from the Helvellyn Range is easily seen after a very slight examination; the boulders consist mainly of the more altered ashes and lavas derived from the Borrowdale series of the Helvellyn Range, with occasional boulders of the type of quartz-felsite dyke which penetrate the rocks of Helvellyn and its minor ridges (the best known being the familiar "Armboth and Helvellyn Dyke"); whilst the "Eycott" type of volcanic rock, occurring north of the main outcrop of Skiddaw Slates and having its nearest exposure within a mile of Troutbeck station, is entirely unrepresented. At the north-east corner of the moorland, close to Troutbeck station, a few boulders of mountain limestone indicate the point where the erratics from Helvellyn are beginning to be replaced by others brought from the eastward. The drifts of this moorland and of the region to the north have caused the interesting changes in the drainage of the area which it is the main object of this paper to describe.

(a) Shifting of the Drainage of the Troutbeck.

The Troutbeck (T B) rises on Matterdale Common, about three miles S.S.W. of Troutbeck station; it runs in a general N.N.E. direction until close to the station, when it turns sharply to the west, and passes through a rocky gorge of insignificant size, cut through the Skiddaw slates. In direct continuation with the upper part of the stream is a swampy depression, just south of the station and continued into Tarn Moss, from the eastern side of which (situated about $\frac{5}{6}$ of a mile E.N.E. of the station) a small beck (Swinescales Beck, S B) takes its rise, and eventually drains into the Eden, whilst the waters of Troutbeck find their way to the Derwent. The rise from the angle of the Troutbeck to Tarn Moss is almost inappreciable, and the watershed is not twenty feet above this angle where the Troutbeck turns sharply westward. The conformation of the ground shows clearly that the Troutbeck originally ran by way of Swinescales Beck into the Eden basin; and



Map of the Upper Waters of the Glenderamackin and Caldew.

Scale: 4 miles = 1 inch. Old lake marked by diagonal lines.

the part of the old valley now occupied by Tarn Moss and the ground immediately west of it having been filled by drift, this part of the course of the beck was blocked and the beck forced to turn westward, with the formation of a small lakelet which has now been filled up, but which must have existed recently as indicated by the name applied to the moss. It is here that the drift gives indications of the mingling of boulders brought from the east and south respectively, pointing to the accumulation of a specially thick deposit at the meeting of the Helvellyn and Eden Valley ice-lobes.[1]

[1] The extension of the Eden Valley ice to considerable heights on the west side of Edenside is not discussed here, but see Physiographical Studies, No. 2, "Swindale," GEOL. MAG., Dec. IV, Vol. I (1894), p. 539.

(*b*) *The Upper Waters of the Glenderamackin and Caldew.*

The Glenderamackin (G) rises on the eastern face of Saddleback, one of its feeders issuing from Scales Tarn (S T), to be referred to later. It flows through Bannerdale (Ba) to Mungrisdale (M), a village lying four miles north-east of Scales Tarn in a direct line, though the distance is greater along the course of the winding stream. Here it comes out of the comparatively narrow valley of Bannerdale into a broad, nearly flat-bottomed valley, extending in a general north-and-south direction from the junction of the Glenderamackin and Troutbeck streams to the eastern side of Carrock Fell. On reaching this wide valley, the Glenderamackin stream turns sharply south, flows in that direction for two miles, and then turns towards the west and flows past Keswick (as the Greta), to join the Derwent.

After walking from Mungrisdale in a northerly direction for one mile, and noticing an apparently flat bottom to the wide valley above mentioned, extending from Barrow Beck (B) for a distance of three miles to Linewath (L), one is surprised to find the Caldew (C) at Bowscale (Bo) issuing from a narrow valley nearly parallel to that of the upper part of the Glenderamackin, and on reaching the wide valley turning *northwards* to fall eventually into the Eden at Carlisle, instead of southwards to join the Glenderamackin.

It is very apparent that at one time this wide valley was occupied by one river, and that the upper waters of the Caldew were afterwards deflected into the drainage area of the Eden, or the upper waters of the Glenderamackin were turned into the Derwent from the Eden drainage area. It is not a difficult task to discover which of these occurred.

Barrow Beck (B) cuts through drift containing abundant boulders from the Helvellyn Range (I readily found one of a Helvellyn quartz-felsite), so that at one time the Helvellyn ice extended as far as Barrow Beck; at this time the valley northwards seems to have been free of ice, for the moraine of the Bannerdale glacier descending from Saddleback is deposited at the mouth of Bannerdale (the village of Mungrisdale is situated on it, and the Glenderamackin has cut through it, south of the village, showing a series of river terraces at successive levels), and it does not extend across the main north-and-south valley. If the waters of the Caldew originally ran south, they would be blocked by the terminal moraine of the Helvellyn ice-lobe, and ponded back giving rise to a lake. That such a lake existed is indicated by the alluvial flat extending for three miles from White Moss just north of Barrow Beck to Linewath Farm. The position of this lake is indicated by the diagonally shaded part of the Figure. The terminal moraine of the Helvellyn ice-lobe is only a few feet above the alluvial flat, and now forms the watershed (Wa) between the Caldew and Glenderamackin. The old course of the Caldew is indicated to the south of this watershed by the lower part of Barrow Beck, and to the north by a nameless stream (shown traversing the southern part of what was once the lake).

At the northern end of the old lake, the Caldew cuts through a narrow gorge hollowed out of the Eycott volcanic rocks to a depth of about twenty feet. *The top of this gorge is somewhat lower than the top of the drift bar at the south end of the old lake.*

It seems clear that in pre-Glacial times a low watershed, between what are now the upper waters of the Caldew and the present lower (and principal) part of the river, existed at Linewath, and that the present upper waters of the Caldew then drained into the Glenderamackin; that during the Glacial period the terminal moraine of the Helvellyn ice-lobe blocked the present upper part of the Caldew, separating it from the Glenderamackin and forming the lake, and that this lake has been destroyed, partly by silting up and giving rise to Mosedale,[1] Bowscale, and White Mosses on its site, and partly by the cutting down of the stream at the outlet of the lake, forming the little gorge at Linewath. The diversion of the river would add an additional ten miles to the length of the Caldew.

(c) *Minor Moraines in the Glenderamackin Drainage Area.*

At the south end of Bannerdale Crags, and almost half-a-mile south-east of Bannerdale lead mine, a small crescentic moraine occurs at the bottom of a "comb." A stream section shows the moraine-stuff to consist of gravelly clay, with numerous subangular striated blocks of Skiddaw Slate. A similar moraine is seen at the foot of Scales Tarn (S T). The stream from the tarn has cut a section in a very stiff clay with many scratched boulders of Skiddaw Slate. It is clear that this moraine has caused the formation of Scales Tarn, which is neither a rock basin nor due to blocking by snow-slope screes. At the time of my visit this year, on April 7th, the tarn was still frozen over.

A very pretty crescentic moraine noticed by Clifton Ward occurs beneath Wolf Crags (W) at the north end of the Helvellyn Range. It is known as Barberry Rigg, and its two ends are a little more than half-a-mile apart in a straight line.[2] In places it is about 40 feet high, and must at one time have given rise to a tarn, now occupied by a peat moss. A gorge about 30 feet deep, cut through it, shows that it is a true moraine, in which a few scratched stones occur amongst the subangular blocks which fill it, though, owing to the nature of the rocks, one cannot expect many scratches to be preserved. Before the formation of the gorge the tarn must have been over 20 feet deep, and probably considerably deeper, as a good deal of deposit has taken place in it. Mr. Clifton Ward alludes to it in the Geological Survey Memoir "On the Northern part of the English Lake District," pp. 90 and 98. He remarks, on p. 98, that "the glaciers crept down to the level of the sea, sometimes forming moraines just at the sea-margin, as was the case beneath Wolf Crag, Matterdale Common, when the land stood 1,400 feet below its present level." He gives no reasons for the view that this moraine was formed at the sea-level, and though I devoted a considerable

[1] Yet another Mosedale.

[2] See 6-inch map, geologically coloured.

amount of time to examining this special point, I could find none. Be this as it may, it is the prettiest exhibition of the terminal moraine of a small comb-glacier which I have seen in this or any other district, and it is well worth taking the somewhat uninteresting walk which is necessary to reach it.

IV.—The Volcano of Tardree, County Antrim.

By Grenville A. J. Cole, M.R.I.A., F.G.S.,
Professor of Geology in the Royal College of Science for Ireland.

I PROPOSE in the autumn of the present year to lay certain detailed observations on the rhyolites of County Antrim before the Royal Dublin Society; but meanwhile it may be of interest to give some account of the mode of occurrence of these rocks in their most central locality, the neighbourhood of Carnearney and Tardree.

Mr. A. McHenry, F.G.S., some four years ago, while preparing a series of specimens for exhibition in the Museum of Science and Art, Dublin, called my attention to some of the little known varieties of rhyolite from Sandy Braes; and I subsequently visited Hungary, in order to become familiar with the typical highly silicated lava-flows studied by Beudant, Von Richthofen, Judd, Szabó, and others. Since then, in various visits to County Antrim, I became impressed with the unique character of the Tardree volcano, as far as our islands are concerned, and with the comparative neglect in which its beautiful products have been suffered to remain.

The general characters of the district have been described in the Memoirs of the Geological Survey of Ireland, and I shall hope to discuss the question of the geological horizon of the rhyolites when dealing with a wider area. It may be sufficient to remark here that evidence as to the true relations of the rhyolites and the basalts around Tardree is sadly wanting in the field. This has been fairly recognised by those who have ventured to draw sections across the district; and neither the intrusion of the Tardree mass as a dome amid the older basalts, nor its burial by the later basalts, can be regarded as absolutely proved.

For some reason or other, the rhyolites of County Antrim have been almost constantly styled "trachytes," although that name has, for some thirty years, been restricted to another class of lavas. Von Lasaulx's[1] well-known examination of the Tardree rock is to some extent responsible for this; but he styled it a "quarzsanidintrachyt" in his descriptive paper, and a "quarzsanidinrhyolit" in his more popular volume.[2]

In the present state of nomenclature, the term "trachyte" can no longer be used in connection with the Tardree volcano, nor, as far as I am aware, with any post-Cretaceous rock in County Antrim.

The main exposures of rhyolite in the Tardree area, as we go from south to north, are met with as follows:—a cutting in a farm-road

[1] "Petrographische Skizzen aus Irland," Tschermak's Min. u. Petr. Mittheilungen, Bd. i (1878), p. 418.

[2] "Aus Irland" (1878), p. 167.

which descends northward from Scolboa Hill; jutting rocks flanking the notch which runs east and west across Carnearney Hill; two small quarries in the north-west angle of the cross-roads before we reach Tardree Cottage; the well-known quarries of Tardree Mountain itself; sections on the steep ascent to Sandy Braes, beyond the road from Parkgate to Kells; and a number of small excavations on the high moor of Sandy Braes.

The Tardree mass, as now denuded, forms a beautifully regular dome, and presents all the characters of a volcanic core. Its division by vertical joint-planes reminds one of the structure of the phonolite necks of northern Bohemia; while its outline recalls the Grand Sarcouy of Auvergne. The compactness and uniform character of the rock, the abundance of porphyritic crystals, and the absence of fluidal structure, all point to its having formed a continuous mass, probably in the centre of the volcano.

But these characters are rapidly lost as we proceed north or south from Tardree Mountain. The Tardree type of rhyolite, grey, or pale pink, or yellow-brown, crops out here and there; but the larger exposures now show it to possess a distinctly laminated structure. Nothing can be well made out at the cross-roads south of Tardree Cottage, and the brilliant red staining of the rhyolites in the quarries at this point results from irregular alteration, and not from the association of lava-flows of different compositions. On the rise towards Carnearney the compact type is also seen; but in the notch south of the new plantation two kinds of rhyolite are visible. A small cliff faces the plantation, its upper part being formed of compact but fissile rhyolite. There is no obvious flow-structure to account for the parallel and gently dipping planes of division in this rock; but beneath it, the plane of junction being parallel to those of fissility in the upper rhyolites, lies a handsome spherulitic obsidian, preserving all its character as a grey glass, traversed by perlitic cracks. These rocks recall the cliff of Skleno, near Selmeczbánya, with its variety of compact and glassy lavas, poured out as flows one upon another.

The humble exposure at Scolboa merely shows pink, compact, and porphyritic rhyolite, somehow underlying a handsome olivine-basalt. Similarly, the dip of the rhyolites on the north end of Carnearney would bring them under the basalt-flows of the south end and of the summit of the hill. Sir A. Geikie[1] has stated that he knew of no case in which acid lavas of Cainozoic times reached the surface in our islands, save at the Scuir of Eigg; but his omission of the rocks of Sandy Braes from his account of the Cainozoic pitchstones[2] shows that the compact rhyolites of Tardree were the predominant type present to his mind. The exposure on Carnearney looks suspiciously like a section at the junction of two lava-flows, and there is nothing surprising in its occurrence on the south flank of the denuded volcano of Tardree.

[1] "The History of Volcanic Action during the Tertiary Period in the British Isles," Trans. Roy. Soc. Edin., vol. xxxv (1888), p. 145.
[2] *Ibid.*, p. 146.

But the northern side of that volcano shows a far more striking assemblage of rhyolites, among them being the exquisitely perlitic glass recently dealt with by Mr. W. W. Watts.[1] This is the "pitchstone porphyry" and "pearlstone porphyry" of Sandy Braes, noted by Berger,[2] Portlock,[3] and other older authors.

It is surprising how the spread of petrography on the Continent has sent us to Hungary or Lipari for our specimens of rhyolite, while the rich variety of material on Sandy Braes has been scarcely known to the collector.

Von Lasaulx was acquainted with the glassy type of the rhyolites of County Antrim merely from specimens that were shown to him in Dublin; and few of the eminent geologists who have visited the quarries of Tardree appear to have climbed thence to the plateau of Sandy Braes. This upland is traversed by a bold mountain-road, commanding superb views, and running from Doagh to Connor; and a steep lane rises up to it just east of the inn on the north side of Tardree Mountain. The name Sandy Braes does not occur on the 1-inch Ordnance Map, but is easily found upon the 6-inch sheet; it has a real meaning to the local farmers, who quarry the decomposing rhyolites for sand.

On the steep cross-road referred to, there is a little quarry, which is visible from the Tardree inn; the rock is a pink and well-banded rhyolite, its planes of flow being distinctly visible at a distance. Above this, the surface of the moorland is strewn with boulders, large and small, consisting of grey, black, and greenish obsidian, sometimes perlitic, rarely spherulitic, and always containing porphyritic quartz and felspars. This rock breaks up easily under the hammer, and its numerous joint-planes and its partial decomposition cause it to weather down into a yellowish sand. This is the material excavated for use on the paths of local demesnes, and it can be seen in the casual little diggings that are made from time to time. These diggings do not go farther down than the first hard rock, so that their walls show merely lumps of glassy rhyolite embedded in soft sand; but their floors consist of surfaces of decomposing glass, or of compacter and firmer rhyolite, like that of the quarry on the ascent. From the crest of this ascent, across the Doagh road, and away to Sandy Braes, the rock below the surface of the grass or heather is almost pure obsidian. It is probable that the flat dome-like summit forming the southern extension of the braes originated mainly in the surface of a single lava-flow, which was formerly connected with the central mass at Tardree Mountain.

Compact rhyolites occur as we push across to Sandy Braes, and serve to show how the crust of the obsidian, which is now mostly broken up into boulders, is in reality only two or three feet in thickness. At the east end of the braes there is a red compact

[1] "The Occurrence of Perlitic Cracks in Quartz," Q.J.G.S. vol. l (1894), p. 368.

[2] "On the Geological Features of the North-eastern Counties of Ireland," Trans. Geol. Soc., ser. i, vol. iii (1816), p. 190.

[3] "Report on the Geology of Londonderry, etc.," 1843, p. 212.

rhyolite, with banded structure, comparable in type to the "mill-stone-porphyry" of Hliník in Hungary, but of somewhat coarser character. At the west end, on the airy summit of the moor, rhyolite of the Tardree type crops out; and in between, near a hollow of the road, its glassy representatives abound. The banded and fluidal pitchstones of Skleno are here beautifully repeated; and dull-brown spherulitic aggregations also occur, their cracks and hollows being filled, as in Hungary, with chalcedony and common opal.[1] No continuous mass of glass is visible, and in one pit the obsidian boulders resemble blocks that became included in a more crystalline flow, the latter having now decomposed to form a sand. A resisting layer of pale pink rhyolite occurs a few yards farther north, and no doubt extends down into the hill; and above it, and in contact with it, is an agglomerate of glassy and dark hemi-crystalline fragments of rhyolite, embedded in a firm yellowish ground. This can hardly be anything but a true tuff; and many of the sands containing obsidian boulders in this district may have been formed by the breaking up of similar layers. The exposure is a small one, and this interesting relic may disappear under a few weeks' quarrying. It became revealed, however, between two successive visits made in 1894 and 1895; and at any time further evidence of explosive action may be met with in the surface-diggings of Sandy Braes.

Nothing short of deeper trenches or more serious quarrying can show us the real wealth of the material on the heights north of Tardree Mountain; but I trust I have said enough to sustain my main contention. I regard the Tardree dome as the neck formed by the upwelling of a viscid rhyolite, which occasionally flowed out over the Chalk, and perhaps over some of the earlier basalts, round about it. A considerable volcano was in time built up, its flanks formed of true lava-flows and even of tuffs; glassy crusts were developed freely by the rapid cooling of these flows, and various types of obsidian were spread out over some four square miles. The lava-flows have been much reduced by denudation, and are now obviously crumbling away on the high moor of Sandy Braes; but both here and under the later basalt of Carnearney we have evidence of the former complexity and variety of the rhyolitic volcano of Tardree.

V.—Preliminary Notes on the late Connection and Separation of the Pacific Ocean and Gulf of Mexico.

By Prof. J. W. Spencer, M.A., Ph.D., B.A.Sc., F.G.S.

HAVING recently returned from another season's work in the West Indies and Mexico, where I was collecting additional data bearing upon the stupendous changes of level of land and sea which have lately affected the American continent, I find the review of the "Reconstruction of the Antillean Continent" by Mr. Jukes-Browne in the Geological Magazine, April 1895, p. 173, a few points of which may be further explained at the same time

[1] Compare Berger, *op. cit.*, p. 190.

that I furnish some advance notes concerning recently observed phenomena which greatly strengthen the theory of stupendous changes of level in the Pleistocene period. Many months must elapse before I shall be able to complete the studies for publication, so that my papers on Cuba, Jamaica, and Mexico shall be published.

It may be said that the date of the recent continental elevations are based on the extent of the erosion of the Miocene and later deposits. In the south-eastern states but little of the Upper Miocene (American equivalent) has been preserved from erosion. In Cuba and Jamaica the Miocene limestones have suffered enormous degradation, so that probably only the lower strata remain, yet these are of immense thickness, although they are often completely incised by great valleys. The same phenomena hold good for regions south of the Mexican Gulf. The determination of the ages of the beds is based upon palæontological as well as stratigraphical and lithological evidence. The lists of fossils will be submitted in forthcoming papers. In the southern states these deposits are not disturbed to any great extent, but beyond they are everywhere upturned and often occur at high angles. Overlying and occupying portions of the great valleys, there are the widespread loams and gravels of the Lafayette formation of the southern states, which extend also over the coastal plains of Mexico. On the islands, apparently, the same formation occurs, but in part represented by marls, with some included gravel (the Matanzas formation), and these contain fossils of mostly modern species. With the oscillations of land and sea, the perfect synchronism between the eastern and western beds is not claimed, but only the general equivalency, as the continental movements passed from east to west and back again. These Lafayette and Matanzas beds have a remarkably wide distribution, and present a wonderful degree of uniformity, so that the geology of the vast region is greatly simplified. These formations have been provisionally regarded as belonging to about the close of the Pliocene period, and whether a little earlier or a little later is of no material difference. It is the sequence of events which forms the importance of the study, for the palæontological boundaries are somewhat ill defined at present. The surfaces of these Lafayette and Matanzas accumulations have been greatly denuded, so that in many places they are found only in fragments, which have nevertheless been most important in the investigations concerning the "Reconstruction of the Antillean Continent." In these valleys, again, we find later mid-Pleistocene formations which have been traced to the regions of northern drift accumulations. The great continental elevation reached its culmination in the post-Lafayette or early Pleistocene epoch, so far as the eastern part of America is concerned. But at that time I have recently found upon the Tehuantepec isthmus, where the drainage of the eastern plateau was hypothesized to have passed to the Pacific Ocean, that the country was so low as not to permit the formation of deep valleys such as were being formed to the east, and are now drowned beneath the sea or buried along the Atlantic or Gulf coast.

The edges of the Mexican table-lands (a term more correct than elevated valleys) show the counterparts of the submerged valleys to the east—an analogy not found in the valleys of the eastern part of the continent—for the now unsubmerged portions of the continent were too far from their margins to have been incised by the growing *cañons* of the period of great elevation. Yet these Mexican examples represent a shorter duration of time than the drowned Antillean valleys.

In Mexico youthful terraces occur to an elevation of 6,500 feet above the sea, and base planes of erosion upon the margins of the Mesas to an elevation of 8,000 feet. With this enormous elevation the terrace materials in the older valleys have not been removed by denudation except in part, and the youthful *cañons* have not yet reached far into the plains. Thus it appears that Mexico has risen to this great altitude in very recent times, and, when we correlate the geological foundations, it would appear that Mexico and Central America have risen to almost as great an elevation as the late altitude of the Antilles and eastern part of America, while the floor of the Mexican Gulf has been sinking.

Across the floor of the divide between the Atlantic and the Pacific, in the Isthmus of Tehuantepec, there were recent shallow straits, succeeded by natural canals covered with level gravel floors continuous with the terraces on the Atlantic side. The importance lies in the admittance to the Gulf of the sparsely-distributed Pacific littoral types of molluscs. But the gravel floors of the channels over the divides form a most important analogy. Such floors over the watersheds of the Great Lakes of North America have been regarded by some glacialists as evidence *per se* of glacial dams confining the waters of the lake basins at high altitudes. Against this view there are many considerations, but now that the same phenomenon is found within a few degrees of the Equator, and at low elevations, the value of this test for glacial dams disappears.

While no phenomena observed in the Antillean region have weakened the hypothesis of the great changes of land and sea in recent times, yet there is much detailed evidence supporting the theories set forth in the "Reconstruction of the Antillean Continent," of which the points mentioned have a most important bearing, as filling important gaps in the chain of evidence, concerning which we had not the direct observations before the present time.

VI.—Second Note on the Expansion Theory of Mountain Evolution.

By Charles Davison, M.A., F.G.S.,
Mathematical Master at King Edward's High School, Birmingham.

In a note published four years ago,[1] I pointed out a fundamental objection to the principle of the expansion theory. That objection has been clearly expressed as follows by Prof. Leconte,[2] who, like myself, considers it fatal to the theory: "Sedimentation

[1] Geol. Mag., Vol. VIII, 1891, p. 210.
[2] Journ. of Geol., vol. i, 1893, pp. 570–571.

cannot, of course, increase the sum of heat in the earth. Therefore the increased heat of the sediments by rise of isogeotherms, *must be taken from somewhere else.* Is it taken from below? Then the radius [or rather crust] below must contract as much as the sediments expand, and therefore there will be no elevation. Is it taken from the containing sides? Then the sides must lose as much as the sediments gain, and therefore must contract and make room for the lateral expansion, and therefore there would be no folding and no elevation."

It appeared to me possible, however, that the sediment, owing to a less conductivity, might check the transmission of heat through it more than the surrounding crust, and that there might consequently be some, though certainly a small, relative elevation due to the cause invoked. This I now believe to be an error, for I was not then aware how greatly the presence of water can increase the conductivity of sand and rocks. That it does so is evident from the experiments of Professors Herschel and Lebour.[1] They find, for instance, that the conductivity of quartzose sand is ·00105 when dry and ·00820 when wet, that of New Red Sandstone is increased from ·00250 when dry to ·00600 when wet, and that of clay from ·00250 to ·00350. Now, considering that the average conductivity of crystalline and volcanic rocks is ·00519, of schistose and slate rocks ·00531, of different kinds of sandstone ·00734 and ·00323, of limestones ·00561, and of argillaceous strata ·00242, it is evident that I was wrong in supposing that the conductivity of *saturated* sediment might be small enough for it to act as a relative check on the passage of heat from the interior. I conclude, therefore, that the force of the objection, great as it was before, is increased by this additional consideration.

VII.—On the Formation at Low Temperatures of certain Fluorides, Silicates, Oxides, etc., in the Pipernoid Tuff of the Campania.

By Prof. H. J. Johnston-Lavis, M.D., F.G.S., etc.

With a Note on the Determination of some of the Species.

By Prof. Pasquale Franco, M.D., etc.

When such minerals as mica, pyroxene, nepheline, fluorite, and hematite are mentioned to us, we can hardly avoid associating their genesis with very high temperatures, and if amphibole be added we are equally bound to imagine also the existence of high pressure. So deeply rooted is this, I might almost say, superstition that few petrographers, when they find such minerals lining the fissures or cavities in rocks, fail to immediately conclude that great heat, and sometimes pressure, is indicated by such an occurrence. No doubt that in the vast majority of cases they would be right, yet I hope to show in these notes that such minerals have occasionally been produced under little or no pressure

[1] Brit. Assoc. Rep. 1881, pp. 130–135; quoted by Prestwich, "Controverted Questions of Geology," pp. 240–241.

at a temperature so low as to be insufficient to carbonize or even discolour the organic matter of bone, that is at a temperature considerably below that of an ordinary baking oven.

A. Scacchi was the first to draw attention to certain enclosures in the grey tuffs of the Campania, which I have shown to be the representatives of that enigmatical rock the *piperno* of Pianura, and to hold chronologically and stratigraphically the same relative position. To denote the peculiar structure due to the enclosures of different texture of these as well as rocks from different parts of the world, I have proposed the adjective pipernoid, and references to this clastic volcanic rock in several of my papers is denoted as pipernoid tuff.

A. Scacchi supposed this tuff to be the result of mud streams that issued from a wreath of volcanic vents scattered all along the edge of the Campanian plain, where limited by the limestone hills; and the metamorphosed limestone enclosures he considered as true ejected blocks, or, as Prof. Lacroix calls them, *enclaves.* I have been able to refute these views, for the following reasons, as concisely summarized below [1]:—

(1) The pipernoid tuff is a typical andesitic or trachytic scoria, pumice, and dust deposit, and bears no relationship whatever to the clays of mud volcanoes.

(2) To have produced such deposit of it, dozens of months would have been required, not only where A. Scacchi locates them but over hundreds of square miles, and often at the tops and shelves of calcareous mountains, unless we were to admit the mud to have flowed uphill.

(3) The metamorphosed limestone fragments only occur in the pipernoid tuff where this forms a talus against a limestone hill, and are distributed in the tuff in curved wedge-shaped bands just as any fragments are arranged in a talus by the law of angles of repose.

(4) The greater thickness of the tuffs at the foot of the limestone hills is simply due to the talus formed at their feet by the washing down of the mantle of fragmentary material that covered them after their fall from the air at the time of the eruption.

(5) That the same arguments as apply to the number of volcanic vents also apply to the existence of fluoriferous fumaroles or springs, as suggested by A. Scacchi.

It is evident, therefore, that in such a tuff, after its journey through the air, its fall on the surface of the country, and its subsequent transport to lower levels by water, that no heat above that of the surrounding atmosphere could remain, of what existed at the volcano from which the ejecta had been derived, to act upon any inclusions in such a tuff. If any doubts on this point existed, the uncarbonized, unroasted bones included in the tuff would finally dispose of them.

The bone in question I easily recognized as the upper part of a tibia, probably of *Cervus*, and this diagnosis was subsequently

[1] See H. J. Johnston-Lavis: British Association Reports for 1888–89–90–92, and Notes on Pipernoid Structure of Igneous Rocks, "Natural Science," vol. iii, No. 19, September, 1893, pp. 218–221.

confirmed by Professors Bassani and Trinchese. The bone is not entire, but no doubt was so in the tuff, part having been broken off in quarrying operations. It occupied a somewhat larger space than requisite in its matrix, as if part of the flesh were still adherent to it at the time of its burial, or, more likely, the effervescence set up by the acid contained in the dust that enveloped it attacked it and produced sufficient gas to distend the cavity around it. That such was more probably the case is shown by enclosures of limestone which have likewise effervesced, and so now occupy cavities of larger volume than that of the original fragment of limestone. The bone in question is fissured and cracked as if it had shrunk, due no doubt to the removal of some of its organic or earthy constituents, or the chemical replacement of some of them by others of less volume. This bone is covered by a coffee-brown crust up to a tenth or more of a millimetre thick, and consists of the following minerals, according to A. Scacchi and Prof. P. Franco, of augite, hornblende, and biaxial mica, and I have since detected on a small detached fragment of another bone some imperfect yellowish hexagonal prisms quite identical with those on the limestone enclosures, which prisms, though very impure, give the microchemical reactions of nepheline. This second bone was found only a few yards from the tibia, and therefore could not have been exposed to any important difference of temperature. It is true that it contains no organic matter, but that may be due to its being an old weathered bone before its envelopment in the tuff. The same argument applies, though with less force, to the ovine vertebræ from the neighbouring quarry of Fossa Lupara, which contains crystals of hematite in the cavities. With such spongy bones the organic matter disappears much more quickly than in one of the densest parts of the skeleton, such as the main leg bone.

To return to the tibia—the layer of silicates crusts over both the outside surface and that of the marrow cavity and, what is important, the sides of the fissures, which shows that the deposition of such minerals must have been some time later than the fissuring. This fissuring was posterior to the envelopment of the bone in the tuff, for so fragile is it in consequence of their formation that nothing less than a miracle would have preserved it entire.

The composition of this bone is very instructive. A. Scacchi found that it contained :—

Calcium orthophosphate	88·32
Calcium fluoride	6·20
Organic matter	5·48

From the researches of Heintz, Recklinghausen, Zalesky, Hoppe-Seyler, and others, the following is the mineral constitution of bone :—

Calcium phosphate	83·889
Calcium carbonate	13·032
Calcium as fluorides, chlorides, etc.	0·352
Fluorine	0·229
Chlorine	0·183

Different bones of the same animal vary in composition, as do the same bones of different animals. The tibia is one of the densest bones of the body, and the part analysed by Scacchi was the shaft portion and therefore the densest part of that bone. Still, it will be seen that the calcic phosphate is very high—over 93 per cent. of the inorganic constituents: whether this be due to a conversion of some of the original calcic carbonate into phosphate is not easy to say. What, however, is strikingly evident is the conversion of a large part of the calcic carbonate into calcic fluoride so as to constitute over 6 per cent. Fluorine does occur in bones, but in very minute proportions. If we consider the other 6 or 7 per cent. of carbonate to have become phosphate we could then explain the high proportion of this latter compound in Scacchi's analysis.

The organic matter in the Faiano specimen amounts to 5·48 per cent., and Scacchi, in making his analysis, was struck by the fact that in heating the creamy-white bone it blackened and gave off an odour of burnt horn. He did not appreciate the valuable bearing of such a fact on mineral genesis, *for it proves incontrovertibly that the minerals associated with this bone could not have been produced at a temperature sufficiently high to even discolour it, much less to carbonize its organic matter.* Not only this, it likewise shows that the other minerals formed at the expense of the limestone fragments in its immediate neighbourhood must likewise have taken place at a low temperature.

Dried bones afford about 11·40 per cent. of nitrogeneous organic matter and 15·75 per cent. of fat. If we suppose all the fat to have disappeared we even then find the quantity of ossein far below the normal. This could hardly be more than we should expect—it is astonishing rather that such a quantity of organic matter has remained, and its existence points to no very great antiquity of the tuff, which certainly is anterior to the last 660 metres in height of Monte Somma, previous to its great prehistoric truncation, which truncation must be anterior to the last 3000 years. The vertebræ obtained by Scacchi from the neighbouring quarry had lost their organic matter—a state of things to be expected in such porous spongy bones, but they likewise had all their calcic carbonate converted into fluorite.

In the Faiano and Fossa Lupara quarries, numbers of fragments of limestone have been enveloped in the tuff and have undergone most marked changes. All the blocks up to the size of a cocoa-nut have been entirely converted into a mass of beautiful brown mica crystals, which form a shell having the original shape of the enclosure. Within this shell is a hollow space with elegant groups of hyaline globules or radiating bunches of fluorite associated with delicate fibres and needles of nocerite. Besides the mica are crystals of augite, hornblende, and a mineral of the nepheline group, but very impure from enclosures.

Where large blocks of limestone occur, they are in some cases covered with a solidified froth of fluorite, or their surfaces are converted for the depth of several centimetres into mixture of the silicates and fluorides above mentioned, whilst farther in arragonite has been formed at the expense of the calcite of the limestone. This arragonite would seem to indicate some slight warmth to have existed for its formation, but whether of original volcanic heat of the tuff itself or dependent upon heat liberated in the chemical decomposition going on, it is not easy to determine.

The quantity of fluorine must have been very considerable, because the amount of fluorides formed constitute the major part of the products of metamorphism.

The whole of these changes, therefore, was due to some fluorine compound in the original volcanic material, which A. Scacchi shows would most likely be hydro-fluosilicic acid.

Fluorine and minute quantities of fluorides have often been found in volcanic emanations, but the quantity that must have accompanied the dust and scoria of the eruptions to which we owe the pipernoid tuff was exceptionally great. Where these and other constituents of the tuff have been reacted upon slowly with calcite in any form, either organic or inorganic, certain minerals have resulted which are supposed to require very high temperatures, and in some cases high pressures, for their genesis. Of course the mode of formation of hornblende under such conditions is of interest in considering the case where this mineral occupies vesicles or fissures in a cooling lava, but does not in any way militate against the fact of its individualization from a vitreous base being still regarded as indicative of high temperature and pressure.[1]

Finally this is one more confirmation of the fact of the great importance we must attach to fluorine as a mineralizing agent.

I must thank my friend and colleague Prof. P. Franco for kindly clearing up by careful measurements some doubts about the minerals epigenized upon the bone.

Minerals Formed on the Fossil Bones of the Tufa of Faiano near Nocera.

It is a known fact that in the volcanic tuffs of the Campania bones of ruminants occur with minerals superposed on their surfaces and in their cavities. A. Scacchi[2] described a tibia found by and contained in the valuable collection of Prof. Johnston-Lavis as well as a vertebra in the collection of the University Museum in Naples. On these bones he recognized hematite and amphibole. A. Scacchi adds that there are minute brownish-yellow crystals of indeterminable form, but which, under the microscope, appeared by the distribution of some of the faces to be rectangular; he likewise mentions some thin white crystals, that are not mica.

Dr. Johnston-Lavis has courteously allowed me to examine the specimen described by Scacchi. I have been able to recognize on it a pyroxene (augite), mica, and I have determined the form of the amphibole crystals, which was not done by Scacchi.

[1] H. J. Johnston-Lavis, "Relationship of the Structure of Igneous Rocks to the Conditions of their Formation," Scientific Proc. Royal Dublin Soc., vol. v, n.s., pp. 112–156; also Q.J.G.S., vol. xli, pp. 103-106.

[2] A. Scacchi, "Sulle ossa fossile trovate nel tufo dei vulcani fluoriferi della Campania," Atti dell' Acc. delle Scienze di Napoli 1888, p. 6; and also "La Regione vulcanica fluorifera della Campania," Mem. del R. Comitato Geoligico Ital., 2nd ediz., Firenze, 1890, p. 34.

Amphibole (*Hornblende*).

Observed forms (110), (010), (100), (001), ($\bar{1}$11). The faces are very small (0·2 mm.) and feebly reflecting; the observed average inclinations differ by about half a degree from the calculated inclinations. The crystals have a black colour, resinous lustre, and are opaque.

Pyroxene (*Augite*).

Observed forms (110), (010), (100), ($\bar{1}$11).[1]

Average of observed angles.		Number of observations.	Calculated angles.
110 ∧ 010	43° 10′	3	43° 35′
110 ∧ 100	46° 45′	3	46° 25′
$\bar{1}$11 ∧ 010	60° 0′	1	60° 24′

The crystals elongated in the axis C are extremely small, but have brilliant faces, vary in colour from greenish to brownish-yellow, vitreous lustre, are translucent, and exhibit marked chromatic polarization. On the bigger crystals are implanted obliquely smaller ones, in both of which when digested in H Cl. no alteration could be observed, except slight discolouration.

Mica occurs in hexagonal laminæ, very small in size, and very thin. Very rarely with a strong lens can the faces of the zone (001) be distinguished. The colour is brownish, more or less dull, the lustre between adamantine and pearly, and the laminæ are translucent. In some cases the mica is altered, opaque, and has a submetallic lustre. Under the microscope the more coloured laminæ show distinct dichroism, and are distinctly biaxial, normal to the base; but on account of their extreme thinness they do not give in convergent polarized light very distinct curves. In a large proportion of the crystals phenomena of reabsorption with the production of ferrite have taken place, and some are completely transformed into a mass of this mineral.

VIII.—Note on a Contact-Rock from Shap.

By W. Maynard Hutchings, F.G.S.

ONE of the contact-rocks from Shap, which I collected a few years ago, has always presented some points of special interest; and in view of a recent careful re-examination of it, microscopical and chemical, I think a few remarks upon it may not be out of place.

It occurs on the slope of Wasdale Pike, high up above the farm-house of Wasdale Head, and appears to be, in the main, the same as the rocks which are described by Harker and Marr in their paper on the district (Quart. Journ. Geol. Soc., vol. xlvii, 1891), and of which they say (p. 308) that they "have a very distinct lamination, and give in the field a suggestion of crystalline schists, or even of gneisses." This description applies fully to the specimens collected by me from a point about 15 feet from the actual contact.

I first examined the rock a year before I had the pleasure and advantage of going over the ground with Mr. Marr, when I had no

[1] The formula of the faces are those of Miller, and the calculated angles are those in Dana's Mineralogy.

knowledge whatever of the district round the granite; and from its character, macroscopic and microscopic, I set it down as an altered sedimentary, probably a slate, with little or no quartz. Mr. Marr, however, informed me that it is an altered ash, and it was subsequently so described by him and Mr. Harker.

It is so highly altered and completely regenerated that not a particle of original material is left, and so far as *microscopic examination* went, it was mainly on the strength of the presence of certain new minerals, usually connected with altered sedimentary rocks, that the erroneous inference was drawn which was corrected by Mr. Marr's minute knowledge of the field-relationships of the beds.

The most striking point in the mineralogical constitution of the rock is that it contains a considerable amount of both sillimanite and andalusite, the specimens in question being the only ones collected, either by Harker and Marr or by myself, which show the presence of either of these minerals in an altered rock at Shap.

There is nothing of note about the abundant andalusite, but the sillimanite, in addition to bundles of very slender needles and fibres, forms some rather unusually fine prismatic crystals.

As has been previously pointed out, this is the only recorded instance of the formation of sillimanite and andalusite in altered volcanic material, and it is so far deserving of notice as being an additional proof that the *chemical* composition of the rocks invaded, and not their mode of origin or their *mineralogical* constitution, influences the nature of the new minerals formed under the effects of contact-action.

Other minerals present are magnetite, apatite, a good deal of perfectly colourless garnet, in rounded and irregular grains without any crystal faces, a little white mica, and a still smaller amount of biotite, both of the latter irregularly diffused in small patches.

By far the main portion of the rock is made up of felspar, in a mosaic of very varying degrees of development as to size of grain and distinctness of individuals. It is beyond all question completely a *new* formation, and among all the slides of contact-rocks which I have studied I have never seen so complete and striking a development of the mineral, due entirely to contact-action, as in this case.

A large part of it is very fine-grained and acts as a sort of groundmass. In this occur many larger individual grains of the felspar, easily identified as such, and several patches in each slide made up of a mosaic of interlocking grains of strikingly larger dimensions.

Quartz is either absent or very sparingly represented. If present, it is only in the most fine-grained part of the mosaics, as it cannot be identified in the coarser parts.

Many of the felspar-grains, especially in very thin slides, show a very fine lamination or striation, best seen in polarized light. In smaller grains it makes more the effect of the minute striation which has been recognized as frequently characterizing contact-felspar, but in the larger grains of the rock it is often developed in a very much higher degree, there being also various intermediate stages. Taking the larger grains only, this lamellation in polarized light may be seen passing down to a degree of fineness which is only just capable of definition with moderately high powers and good illumination, and there are, again, grains in which it is not seen at all. The same is true of the grains of more moderate size, and among these some few of them which are not striated are single twins, extinguishing quite parallel and safely referable to orthoclase.

Among the larger grains a good number have cleavage distinctly developed, and by patiently searching among these, cases may be found in which there is emergence of a positive bisectrix nearly central, with an extinction-angle, measured against the well-marked cleavage, of 10° to 12°—very often 12° exactly.

These characteristics—the minute lamellation passing down into such a degree of fineness that it cannot any longer be made out, and the extinction-angle of about 12° on *m* flakes—seem to indicate that we are dealing with a felspar similar in nature to that which occurs in pegmatitic veins at Frederiksvärn, in connection with the so-called soda-orthoclase, with which it appears to be intimately related by passages from one to the other, with a similar chemical composition in both cases.

Brögger has concluded that this lamellar felspar at Frederiksvärn is a microscopic intergrowth of orthoclase and albite—a micro-perthite—passing down into a sub-microscopic degree of intergrowth which cannot be resolved by the microscope, and which he designates as cryptoperthite.

The analysis of the felspar from Frederiksvärn shows about 7·5 per cent. of potash to 7 per cent. of soda, and Rosenbusch points out that the extinction-angle of 12° corresponds approximately to the medium angle between orthoclase on the one hand and albite on the other.

As a further test of the probable nature of this felspar in the Shap rock, I have recently carefully analysed an average sample of a large hand-specimen, with the following result:—

	per cent.	
Silica	53·10	
Alumina	23·60	
Ferric oxide	8·50	*Ferrous* oxide not determined.
Lime	3·16	
Magnesia	1·62	
Potash	4·67	
Soda	4·05	
Water	0·55	
	99·25	

It will be seen that the relative proportions of potash and soda do not vary appreciably from those in the Frederiksvärn felspar, and as the alkali-bearing minerals present in this rock, other than felspar, are quite insignificant in amount (merely the very small proportion of micas) we may look on all this alkali as practically representing the felspar. This makes the resemblance to the Frederiksvärn mineral satisfactorily complete, and it is an interesting thing to observe its occurrence, as a new formation, in a rock altered by contact-action. The case is of all the more interest because it does not seem unreasonable to believe that the fine striation seen in the felspars of so many contact-rocks is really due to the same thing, though it is not possible, in most cases, to obtain such good evidence, microscopical and chemical, as this special rock has afforded.

If we further glance at the analysis we see that it gives a striking proof of the incorrectness of the supposition, sometimes made, that high percentage of alkalies tends to exclude the formation of sillimanite and andalusite. Both minerals are abundant in this rock, and yet the alkali-percentage is certainly high.

If the alkalies are calculated all as orthoclase and albite they correspond to 61·72 per cent. of felspars, and we may take this as approximately the amount of those minerals present in the rock.

The high percentage of alumina is rather puzzling in a rock which is an altered ash. Indeed, taking the analysis as a whole, had I made it at the time when I looked on the rock as being an altered slate, I should have regarded the chemical composition as strongly confirming this view, as the analysis harmonizes better with this than with any other supposition. Indeed, with the exception of the fact that the alkali-total is rather high, and the relative proportions of potash and soda are different, the figures are not strikingly unlike those of some of the analyses I gave, in a former paper, of Carboniferous clays. And the resemblance is still closer to some Lower Carboniferous shales which I have analysed more recently, in which the alkalies range from 7 per cent. to over 8 per cent.[1]

Of course the exact determination of the nature of this bed by Harker and Marr, from detailed study of the field evidence, is quite conclusive; and so this rock possesses one more useful point of interest, as it affords an instructive example of the danger and little value which may attach to conclusions drawn from laboratory studies of specimens, without due regard to careful investigation on the ground.

IX.—On Glauconite from Woodburn, Carrickfergus, Co. Antrim.

By A. Percy Hoskins, F.I.C., F.C.S.

GLAUCONITE may be described as essentially a hydrous silicate of iron and potash, but of very variable composition, and generally containing varying proportions of other bodies, such as alumina, lime, and magnesia. It is found at different horizons in the whole geological series of rocks from the Cambrian up to the most recent Tertiary layers, and, indeed, is particularly interesting in being one of the very few silicates which are in actual process of formation on the sea-bed at the present time. The physical characteristics of glauconite grains are practically the same throughout the series, the normal colour being dark green, but sometimes

[1] See also an analysis by me of one of the altered Silurian "flags" at Shap (Geol. Mag., January and February, 1894), in which the total alkali is close on 8 per cent.

being yellowish, greyish, or even almost red. These variations of colour, however, mean at least the commencement of decomposition. The size of the grains is usually about one millimetre in diameter, and although much larger masses are sometimes found these are merely agglomerations of the smaller grains. Under the microscope the grains appear quite homogeneous unless some foreign body is enclosed, or, as sometimes occurs, the commencement of decomposition gives a more or less zonary appearance to them.

The following details have been given me by Miss S. M. Thompson, who kindly forwarded me the specimen used for analysis: "The glauconite grains occur in a cliff of the so-called 'chloritic sandstone' division of the Upper Greensand. The Woodburn River has cut through the Cretaceous rocks in the Knockagh Mountains, and has exposed this face of highly fossiliferous greensand." The specimens were collected from a calcareous sandstone, below the zone of *Inoceramus Crispi.*

The method adopted by Miss Thompson for obtaining the grains was this: The rock was pulverized and washed in a muslin bag until the water ran off tolerably clear; the powder was dried and sifted through coarse muslin, and then, with the help of a lens of low magnifying power, the grains of glauconite were picked up by means of a very fine sable-brush moistened in a tiny vessel of distilled water, into which the collected grains were dropped from the brush. The field of the lens was large enough to admit of this little vessel of water and a tray of glossy brown paper (upon which pinches of the powdered rock were shaken) at the same time, so that no time was lost in dropping the glauconite into the water as quickly as it was gathered. Great care was taken to have the grains as uniform as possible in size and colour. The sample received for analysis weighed a little over one gramme. It consisted of dark green granules of rather less than one millimetre in diameter, very homogeneous and of a rounded contour, intermixed with a few white particles. The grains were soft and readily powdered. The powder was treated with cold dilute hydrochloric acid,[1] to remove any residue of calcium carbonate, was well washed, and dried at 90° C. in an air-bath, and the resulting green powder was taken for analysis.

0·3575 grm. was decomposed with moderately concentrated sulphuric acid, the silica separated in the ordinary way, and the solution used for the determination of total iron, alumina, lime, magnesia, potash, and soda by the usual methods. 0·1975 grm. was ignited for combined water and organic water. 0·2780 grm. was decomposed by heating in a current of CO_2 with moderately concentrated sulphuric acid, and triturated with standard permanganate of potash for ferrous oxide. The results obtained are given in Column I.

[1] Careful subsequent investigations show that any decomposition which may occur during this preliminary treatment with dilute acid has an inappreciable effect upon the figures of the final analysis. Prolonged treatment with dilute acid tends, however, to remove iron, etc., and to heighten the percentage of silica in the residue. Thus a cold solution containing only 0·5 per cent. hydrochloric acid, acting for 39½ hours, extracted 25 per cent. by weight of the constituents of the glauconite.

Remembering what has been already said upon the variable composition of glauconite, it is not surprising to find that this example shows some deviations from the figures given for other glauconites, although in some particulars these differences are noteworthy. To illustrate this, and also to show how other glauconites vary among themselves, two summaries of analyses are appended. Column II shows the mean of analyses by Sipöcz of four samples of marine glauconite from the "Deep Sea Deposit" volume of the "Challenger" Report.[1] These were all taken at a depth of 410 fathoms, and in lat. 34° 13′ S. and long. 151° 38′ E.; yet, taken as they were from practically the same spot, the variations are most pronounced, especially in the essential constituents, silica, ferric oxide, potash, and water. Our Woodburn glauconite shows, however, many differences from all these "Challenger" analyses, and we may note among the essentials that the silica is over 13 per cent. lower than the mean of the four, and more than ten per cent. lower than the least of these; the ferric oxide, though higher than the lowest, is still more than four per cent. less than the mean; the potash is nearly double the highest figure given by the four, while the water is somewhere about the mean. One great difference observable is in the ferrous oxide, where, against a maximum of 1·95 per cent. in the modern marine glauconite, the Woodburn sample shows 16·81 per cent.

Below I have given a *résumé* of twelve analyses of glauconite from rocks which may be regarded as fairly similar to ours, and which are published in Dr. C. Hintze's "Handbuch der Mineralogie."[2] In their selection I have been aided by Prof. Cole. Here again, though we might fairly expect a closer correspondence with our own than in the case of the modern glauconite, we find in comparing them with each other, and with our Woodburn mineral, the same discrepancies in nearly every particular, the silica, for instance, varying from 58 per cent. to a little over 43 per cent., which figure is, however, still somewhat higher than ours. It will be noticed, however, that the ferrous oxide, which is so low in the modern glauconite of Table 1, gives us in Table 2 figures much more nearly agreeing with the glauconite of Woodburn.

The one point which does seem to come out clearly in this comparison is the relative poverty in silica of the Woodburn specimen, though even that is not much below the lowest in value in the mineral analyses quoted. In this connection it is worth noting that in the "Challenger" results the percentage of silica is lowest, and that of potash is highest in those cases in which the green, and especially the dark-green, casts predominate, casts agreeing in appearance with those composing the whole of our Woodburn specimen. Whether this is merely a coincidence, or has a definite significance, is not as yet certain. The fact that where the dark-green casts are most numerous the mineral particles and

[1] Report on scientific results of the voyage of H.M.S. "Challenger"; "Deep Sea Deposits" (1891), pp. 458–460.

[2] Hintze, "Handbuch der Mineralogie," p. 850. Analyses I, II, IV–XI, XIII, and XIV.

siliceous organisms are few, probably accounts, to a large extent, for the variation in silica.

It is just possible that at Woodburn the alkalies may be introduced into minerals capable of retaining them in combination, through the percolation of waters from the large salt deposits of Carrickfergus.

It may be interesting here to notice the figures given in Column III, from the volume of the "Challenger" Report referred to above, for a reddened glauconite in which the silica is exceptionally low. To this analysis the following remark is attached: "The high percentage of ferric oxide and water points to a decomposition of this mineral, which has been transformed into limonite, as is often the case in glauconite from the geological strata, with loss of silicic acid and potash, but this explanation can hardly be given for this specimen, which consists of casts from a coral sand." But no alternative suggestion is made, and neither will the suggestion hold in the case of our own glauconite; for, while the silica is low, neither the ferric oxide nor the water is particularly high, while the potash is seemingly higher than usual. Moreover, the casts are green, and show no signs whatever of decomposition into limonite. Professor Cole has suggested that possibly in the course of ages silica has actually been abstracted in solution; but in this case, since the silica must have been in combination when present in the mineral the grains should show some signs of the decomposition which must have taken place, and no such signs are visible. The only conclusion to be arrived at in the present state of our information is that the glauconite from Woodburn, when originally formed, was a variety containing an unusually small percentage of silica.

I trust I may have a further opportunity of examining specimens of glauconite from this locality, with a view to determining whether the material is constant in composition in different zones.

In conclusion I wish to express my sincere thanks for the kind assistance I have received from Miss S. M. Thompson, of Macedon, Belfast, and Professor Grenville A. J. Cole, of the Royal College of Science, Dublin, in the preparation of this note.

	I.	II.	III.
	Glauconite of Woodburn, Co. Antrim (A. P. Hoskins).	Mean of four analyses of glauconite given in the "'Challenger' Report on Deep Sea Deposits" (Sipöcz).	Reddened glauconite, 155 fms.; lat. 11° 38′ 15″ S., long. 143° 59′ 38″ E.; "'Challenger' Report on Deep Sea Deposits," p. 460 (Sipöcz).
SiO_2	40·00	53·61	27·74
Al_2O_3	13·00	9·56	13·02
Fe_2O_3	16·81	21·46	39·93
FeO	10·17	1·58	1·76
CaO	1·97	1·39	1·19
MgO	1·97	2·87	4·62
K_2O	8·21	3·49	0·95
Na_2O	2·16	0·42	0·62
H_2O	6·19	5·96	10·85
Total	100·48	100·34	100·68

Résumé of twelve analyses of glauconite selected from those quoted by Dr. C. Hintze, "Handbuch der Mineralogie," p. 850 (1892).

	Mean.	Max.	Min.	Remarks.
SiO_2	50·27	58·17	43·60	
Fe_2O_3	17·94	32·80	Nil.	Not stated in three analyses.
Al_2O_3	5·69	10·09	1·50	
FeO	8·16	21·78	2·64	
CaO	0·78	3·21	Nil.	Absent in eight analyses.
MgO	2·29	6·21	Nil.	Absent in four analyses.
K_2O	6·12	8·79	3·10	
Na_2O	?	0·91	0·21	Only occurs in two analyses.
H_2O	8·23	14·70	4·71	
	99·48			

X.—Notes on "The Great Ice Age" in Relation to the Question of Submergence.

By Dugald Bell, F.G.S.

THE new edition of Dr. Geikie's esteemed work has already been noticed at some length in this Magazine.[1] The present writer desires to add some notes—freely, but with all respect to the author—on a special part of the subject, viz. that relating to the "high-level shelly deposits," and their bearing on the question of submergence during the Glacial epoch.

I.

In his "Fragments of Earth-Lore," published about two years ago, Dr. Geikie intimated that he no longer believed in a "great submergence," during which the British Isles were "largely" sunk under the sea. "The marine shells," he said, "in the high-level drift deposits of our islands are 'erratics' carried by the ice-sheet which occupied the basin of the Irish Sea. That the low grounds were submerged to some extent before the advent of that ice-sheet, there seems to be little doubt; but the amount of the submergence has not been ascertained,—probably it did not exceed a few hundred feet."[2]

This announcement was extremely gratifying to those who for some years past had been calling in question any "great submergence," and pointing out the striking lack of evidence in its favour.

It turns out, however, that though Dr. Geikie thus abandoned a "great submergence" of about 1400 feet, which was thought to be proved by "fragments of marine deposits" in Wales and Ireland, he still holds by one of from 500 to 600 feet, which he seems not to consider "great" (though demonstrably it would have placed the British Isles very "largely" under water), and the proof of which depends on one or two instances of "high-level shelly clay" found in the west and north of Scotland. Indeed, we may say it now depends on only *one* instance, for the other is in this edition "conspicuous by its absence."

[1] See January, 1895.
[2] *Op. cit.* p. 173.

Chapelhall.—We allude to Chapelhall, near Airdrie, which for some forty years has been the "stock" instance to prove a submergence in Scotland of about 500 feet. In the preceding edition of this work, Dr. Geikie made much of this instance, referring to it repeatedly as clearly proving submergence. "Evidently," he said, "this shelly clay marks an old sea-bottom, when the sea rose not less (indeed certainly more) than 526 feet above its present level." And he proceeded to point out the great series of changes to which the section bore witness: (1) "a time when the great central valley of Scotland brimmed with glacier ice"; (2) a time when "a free ocean flowed over the site of the district in question"; and (3) a time when "another mighty ice-sheet again overflowed the land."[1]

This Chapelhall section was thus of capital importance to Dr. Geikie in working out the details of the Glacial period; and, as we have seen, he made much of it. What does he say about it in the present edition? Absolutely nothing! It is dropped out of view entirely, without a word of explanation!

We submit this is apt to be extremely puzzling to his former readers. They will naturally wonder *why* Chapelhall is now so completely set aside and ignored. Of course, if they have any curiosity in the matter, they may learn from other sources—but why not also here?—the simple facts. The meagreness of the evidence on which this instance rested having been pointed out, and doubts having been expressed as to whether, in any case, the "deposit" was "in place," a re-examination of the locality was made by a committee appointed for the purpose. The result was entirely *negative*; no trace of the "shelly clay" could be found![2] This accounts for its total disappearance from Dr. Geikie's book. Still, as we say, its absence might have been alluded to, and a brief *In Memoriam* inserted where it once figured so largely. It seems scarcely becoming to let one's favourite facts thus sink out of sight—

"Without the meed of some melodious tear!"

But, "fortunately" (as another eminent writer used to say when facts were found to suit his theory)—"fortunately," since his last edition was published, another instance has emerged on which, now that Chapelhall has "collapsed," Dr. Geikie can still take his stand in maintaining a submergence of about 500 feet. That instance is Clava, in the valley of the Nairn, near Inverness, which now takes the place of Chapelhall superseded or defunct. Dr. Geikie makes up for his reticence regarding Chapelhall by a full and particular account of Clava. If we may adapt a well-known Scotch story, it is now the "a'e button," which has to bear a quite enormous "responsibility." It must therefore be looked to with some degree of care.

Clava.—This shelly clay was described by Mr. J. Fraser some years ago[3] as occurring underneath Boulder-clay at a height of

[1] Second edition, pp. 175–6.
[2] See Trans. Geol. Soc. Glas., vol. ix. Reports Brit. Assoc., 1894.
[3] Trans. Edin. Geol. Soc., vol. iv.

503 feet above the sea, and indicating a submergence of at least that amount "prior to the accumulation of the overlying Boulder-clay." Dr. Geikie continues—"Doubt having been expressed as to whether the shelly clay was really *in situ*, a committee appointed by the British Association duly investigated the beds. . . . The majority of the committee . . . . are of opinion that the shell-bed is *in situ*. . . . . The minority . . . . incline to the view that the shelly clay is not *in situ*, but has been dragged or pushed into its present position by a *mer de glace* . . . . from the basin of Loch Ness." It is admitted that "the stones in the overlying Boulder-clay, and the trend of the glaciation of the neighbourhood, indicate an ice-movement from south-west."[1]

Dr. Geikie, not content with merely stating the facts, takes side strongly with the majority on this question, and indulges in some mild pleasantry at the "remarkable performance" which the minority ascribe to the glacier-ice. Well, it is very much a choice of difficulties; but we shall perhaps see immediately that *more* remarkable performances are required by Dr. Geikie's explanations of the phenomena, and on his own showing, not only for the ice, but also for the sea and for the solid land!

We are told that the minority "appear to have adopted this peculiar explanation of the evidence because they cannot find elsewhere any proofs of a submergence of the land during Glacial times" [*i.e.* to anything like the same extent, or beyond "100 feet or thereabouts"]. "They think that if Scotland had ever been depressed to the extent of 500 feet, the sea would have left abundant evidence of its former presence." Precisely; and in this Dr. Geikie might have been expected to agree with them. Referring to the "Till" of Northern Europe, he writes—"No evidence of marine action in the formation of the stony clay is forthcoming—not a trace of any sea-beach has been detected. And yet, if these clays had been laid down in the sea . . . . surely such evidence as I have indicated ought to be met with."[2] Why, then, is he so severe upon the minority for thinking that if Scotland had been submerged to the extent of 500 feet "the sea would have left abundant evidence of its former presence"?

And why is the minority's explanation "peculiar"? It cannot be so in itself, as the numerous instances of shells and shelly clay imbedded in "Till," to which reference is made in this volume, abundantly show. Besides, it is distinctly adopted by the author himself to account for deposits of "marine drift" at an elevation of 1400 feet in North Wales.[3] The uplifting of these deposits to such a height by the ice is surely a much more "remarkable performance" than the transport of those at Clava to only 500 feet. Indeed, it is not easy to see on what principle, having admitted the transport by ice of marine remains to a height of 1400 feet, one can make a stand against admitting their transport by the same agency to a height of 500 feet. In this case, surely the greater includes the less, and

[1] "Great Ice Age," pp. 139–141.
[2] p. 433. [3] pp. 160, 281, 371.

makes the less not only probable, but in many cases perfectly certain.

But perhaps it is meant that there is something "peculiar" in the Clava deposit itself, which forbids this explanation being applied to it. Its "extent" is referred to, and its "maintaining a horizontal position, and exhibiting no trace of deformation or disturbance." These are points, however, on which the evidence, as given in the Report, does not appear to be at all conclusive; on one or two of them, indeed, it inclines quite the other way.[1] We believe it can be shown, keeping to what is *proved* in the Report, that whatever difficulties the features of the deposit present on the one hand to the ice-transport theory they present still greater difficulties on the other to the theory of a marine deposit *in situ.* But to this we shall return.

Meantime we may note, in passing, that Dr. Geikie unduly heightens the case against the ice-transport theory by representing its purport to be that the shelly clay was "pushed or dragged forward under the ice-sheet" for so many miles. The minority, however, did not express it in these terms, nor did they define the precise mode in any terms; and they may very properly object to Dr. Geikie doing it for them. Certainly, by his own account, this mode does not "necessarily follow." We are elsewhere told of stones or boulders which, "once imbedded in the ice," may have been carried for "a hundred miles without suffering abrasion.[2] It seems hard on the shelly deposits that they could not in some instances (as frozen masses, perhaps) be transported in the same gentle fashion, for ten or twelve miles!

But Dr. Geikie proceeds to discuss the case on more general grounds, into which we must now shortly follow him.

II.

The first part of the more general ground which Dr. Geikie takes up in arguing for a submergence during Glacial times of over 500 feet, has reference to the non-fossiliferous character of the "Upper Boulder-clay." The statement that "had such a degree of submergence ever taken place prior to the advance of a general ice-sheet, we should surely find the ground-moraine of that ice-sheet more or less abundantly charged with relics of marine life," he meets by saying, "this does not necessarily follow."[3]

The author has evidently got some new light on the subject since the date of his previous edition. He then alluded to this absence of marine organisms in the Upper Boulder-clay as an almost insuperable difficulty against the theory of a submergence. "Why," he wrote, "we may ask, does not the Upper Boulder-clay of the Central Lowlands (a great proportion of which must have been submerged before the last ice-sheet overflowed Scotland) contain broken shells, and afford other indications of the latest confluent glaciers having usurped the bed of the sea? That is a very hard question to answer, and I fear we must wait some time yet for an

[1] Brit. Assoc. Report, 1893. [2] p. 204. [3] p. 141.

adequate solution of the difficulty."[1] But now he announces with easy *nonchalance* that the difficulty does not exist—"it does not necessarily follow!"

We may remark, in passing, that there are many things which do not "necessarily follow," but which yet are the only probable things we can accept or reason upon. That a submergence of 500 feet or 600 feet should leave traces of itself in the shape of relics of marine life, more or less abundant, in the Boulder-clay of the succeeding glaciation, seems to us as nearly a necessary consequence as anything we know of in geology; at all events, as in many ways, and by many degrees, more probable than that such traces should all have been removed or destroyed. But let us look at Dr. Geikie's reasons for now making so light of the difficulty which formerly oppressed him.

(1) He says, "a depression of 500 feet or 600 feet would drown only a narrow belt of coast-land, and a relatively small area in the midland of Scotland."

With a recollection of Lyell's old sketch-map, showing the change that would be produced on the contour and extent of the British Isles by a subsidence of 600 feet,[2] we read this statement with considerable astonishment. Let the reader look at any good "Orographical Map" of Scotland, such as that prefixed, for example, to the volume already mentioned, "Fragments of Earth-Lore." There he will see clearly the broad tracts that would be submerged by a depression of 500 feet—in Caithness, around the Moray Firth, in Aberdeenshire, in Strathmore, in Fife, in the Forth and Clyde valley, in Berwickshire, Dumfries, Kirkcudbright, Wigton, Ayr; in all cases running far up into the river valleys; not to speak of innumerable detached areas and winding belts, in some cases of considerable size, all along the western coast. Why, a depression of 500 to 600 feet would drown nearly all the arable land of the country, all the "broad lowland tracts," straths, and "carses," described so graphically in the volume referred to. This as regards Scotland; while in England and Ireland the area submerged would be relatively still more extensive—in fact, the greater part of the country. We may take it, then, that the extent of the area gives emphasis to the question,—If it were all submerged prior to the last glaciation, why does its Upper Boulder-clay not contain fragments of shells, and afford other indications of the former presence of the sea?

Dr. Geikie adds (2) that "the submergence may not have been long-continued," and (3) that "the conditions may not have favoured the abundant development of marine life." But these seem to be purely imaginary suppositions, thrown in without a word in their favour. We need not, therefore, discuss them.

(4) We pass on to notice the last and apparently chief reason given by the author to account for the absence of marine organisms in the Upper, or supposed post-submergence, Boulder-clay. It is,

[1] Second edition, p. 390.

[2] "Antiquity of Man," third edition, p. 278.

that while the submergence may have been short, the succeeding glaciation may have been—or rather, he seems to say, must have been—long; and as it continued, and "sub-glacial erosion" was carried on, "the supply of shelly deposits at and below the level of 600 feet would tend to become exhausted, and the Boulder-clay continually passing outwards from the land would eventually contain no shells."[1] This is our old friend, the theory of the "complete sweeping-out by the second glaciation," which we humbly thought had been disposed of some time ago,[2] but of which, as it now comes up again under the wing of Dr. Geikie, it is necessary anew to take some cognizance. We think we can demonstrate (with Dr. Geikie's help) the impossibility of the ice performing what is thus ascribed to it.

(*To be continued.*)

REVIEWS.

I.—Crystallography, a Treatise on the Morphology of Crystals. By N. Story-Maskelyne, M.A., F.R.S. Octavo, 512 pp., 398 figs., and 8 plates. Oxford, Clarendon Press, 1895.

In one of his scientific aphorisms Goethe pronounces criticism upon Crystallography; this science, he says, has about it something of the Monk and the Old Bachelor: it exists for itself alone, it has no applications, it leads to no results; and yet, he adds, it has by some means captivated and retained its hold upon some of the acutest intellects; this fact is due, he supposes, to the extent and the complexity of its details, which supply almost inexhaustible material for the active mind.

The criticism is no longer true. When Goethe wrote these words the geometrical principles of Crystallography, now known to be remarkably simple and definite, had not been fully established; outside pure Mineralogy its applications at that date were indeed few. But now the Monk has called upon his neighbours, and the Old Bachelor flirts with the spinster sciences—with Geology and Chemistry in particular the most friendly relations have been established, and Petrology, the result of the former liaison, is a young science fast growing to robust maturity.

Whether they wish it or no, a large proportion of modern geologists must acquire some knowledge of Crystallography, without which the study of rocks is almost impossible. Maskelyne's "Morphology of Crystals" will not, it is true, satisfy all their requirements, because it does not deal with the optical and other physical characters, but it is, and must long remain, the standard book to which the geologist must turn for information about the geometry of the subject.

Beginning with the later portions of the book, the reader will find in chapter viii an account of the manner in which crystals are measured; the preceding chapter contains a detailed account of the

[1] p. 142. [2] Trans. Geol. Soc. Glasgow, vol. ix, pp. 109, 110.

various systems and their subdivisions, illustrated with numerous figures and examples; while the second to the sixth chapters discuss the relation between a series of crystal faces, the properties of zones and axes, and the nature of crystal symmetry.

By inverting the order of the chapters, we have here indicated what may be regarded as an objection to the present plan of the book from the point of view of a general reader; the first six chapters contain much that might with advantage have been postponed to later pages. Subsidiary theorems on stereographic projection, on the transformation of axes, and on tautozonal planes, are not calculated to encourage a beginner, and might well have been deferred to a chapter preceding that on crystal calculation. The chapter on crystalloid symmetry, the most original and interesting in the book, might have been introduced almost at the outset. As it is, the first chapter, on the general characters of crystals, is in parts almost unintelligible to a reader who possesses no knowledge of crystal physics.

Let the student, however, boldly begin with chapter v, returning to the preceding pages when necessary, and proceed with all possible speed to chapter vii; and he will find the book a veritable mine of wealth, and one which will repay careful study.

In fact, having stated our objections to the general plan of the book, we may hasten to make reparation by asserting that it is one which if read at all should be read thoroughly; for example, the great theoretical importance of the equations obtained on page 96 will scarcely be appreciated until pp. 112–117 have been mastered. These and the other more difficult parts of the book we may safely commend to the more mathematical reader, to whom they will afford considerable pleasure.

In most subjects three or four good English text-books exist, and it is sometimes difficult to choose between them. In the science of Crystallography there is no such embarrassment. To Professor Maskelyne's book both teacher and student can confidently be referred for two very good reasons: because it has no rival in the English language, and because it is a thoroughly sound and excellent book. A second volume, dealing with the physical properties of crystals, is promised, and will doubtless be expected with interest by geologists, to whom it should be even more useful than the present volume.

II.—Thirteenth Annual Report for the Year 1893 of the State Geologist. Vol. II: Palæontology. Transmitted to the Legislature of New York, March 1, 1894. One Vol. pp. 338. Plates 23–54. With Part II of an illustrated "Handbook of the Brachiopoda." By James Hall, assisted by John M. Clarke. (James B. Lyon, State Printer, Albany, 1894.)

This volume, just received, opens with an instructive summary of the "Evolution of the Genera of the Palæozoic Brachiopoda," a tabular classification into families, and descriptions of new species. These form extracts from the Final Text of vol. viii, part ii, of the

"Palæontology of New York," and are first issued in this Report on account of the continued delay in printing the volume of quarto plates which should have accompanied the conclusion of Professor James Hall's and Mr. John M. Clarke's labours on the Brachiopoda.

A Memoir by Mr. W. H. Sherzer on "Platycnemic Man in New York" follows. The prehistoric remains of this type of humanity are of frequent occurrence on the American continent, ranging from Peru to Mexico, Florida to Wisconsin, from Ohio to New Jersey and Massachusetts. It has been also recognized and described from Oceania and from the Grand Canary Islands, and discussed by Busk, Falconer, Broca, Guillemard, and others. The New York specimens were obtained from Canandaigua lake, and are characterized by the perforation of the humerus, the flattening of the tibia, with curvature of its shaft and head, and compression of the femur, all "*simian* characters departing from the normal human skeleton." These characters, Mr. Sherzer considers, were not caused by "rickets," as by some maintained, that they can no longer be regarded as a sexual distinction, for "they are now known to occur in both sexes." He believes them to have been brought about by corresponding similarities in life habits. The one common habit capable of sufficiently reacting upon the skeleton of both early Man and the Apes "could have been none other than that of tree-climbing, after the fashion of our modern Apes, with the soles of the feet firmly pressed against the tree and the body held off at arm's length." He notes further that the percentage of platycnemism is greater among the most ancient remains found, and diminishes gradually towards modern times, and concludes that arboreal habits would be of necessity more resorted to in primitive times, when man's powers of offence and defence were most limited. Thus the tree-climbing and propensities of the youthful scions of civilized races are satisfactorily accounted for. They are merely recapitulary instincts repeating that period in the history of the development of the race when man lived among green trees, still the most restful and consequently the natural colour for the eyes.

Mr. George B. Simpson next discusses, with the aid of numerous illustrations, the "Different Genera of Fenestellidæ," and supplies a very useful "Glossary and explanations of specific names of Bryozoa and Corals," previously described and figured in vol. vi of the "Palæontology of New York" and preceding "Annual Reports."

The remainder of the Thirteenth Report is devoted to Part II of "An Introduction to the Study of the Brachiopoda," by James Hall and John M. Clarke, forming the concluding portion of that excellent students' "Handbook of the Brachiopoda," of which Part I was issued in 1894 (see Geol. Mag., Dec. IV, Vol. I, No. 360, p. 279, 1894). This treats of the Spiriferoids, Atrypoids, Rhynchonelloids, and Terebratuloids, gives concise descriptions of genera new and old, accompanied with numerous woodcuts, many of which are original productions and represent the results of long-continued and patient research. The thirty-one plates of generic illustrations which complete the handbook are especially welcome, as we get here the first figures of many new genera founded by the authors among the articulated Brachiopoda in the course of their successful labours. We heartily congratulate them on the results, and can only express the hope that the publication of the quarto edition of the Plates needed to complete their great work will not be again delayed by "malign influences" and lack of fiscal support.

An alphabetical index to genera and subgenera is appended, in which we note Mr. W. D. Mathews' siphonotretoid genus *Trematobolus* is not included among the synonyms, although it is omitted from the generic list classified into families in the "Systematic Classification" with which this most useful and interesting handbook concludes, and to the main features of which, through the courtesy of the authors, we have already referred (see GEOL. MAG., March 1895).

With regard to systematic classification, however, and the vexed questions of genetic relationships and affinities, the last word has by no means been said. There is still room here for diversity of opinion, more especially in connection with the relationships of the primitive forms which present such a mixture of characters. Mr. Charles Schuchert, we learn, has nearly completed a "Catalogue of Brachiopoda," which, we feel sure, will further illuminate this most difficult subject. New genera and species are almost daily described throughout the world. Dr. W. H. Dall has a paper in the press defining seven new recent forms from the Pacific Ocean, one belonging to a new subgenus of the Rhynchonellidæ of a very interesting type.[1] The full history of that widespread deep-water discinoid, the so-called *Discinisca Atlantica,* still remains unwritten. A grand opportunity awaits a well-trained embryologist who would turn his attention to the developmental history of the living British Cranoids and Discinoids. Such an investigation, if successfully carried out, might throw much light on obscure points in the early history of these ancient stocks. Will no British student do for our Cranoids and Discinoids what Morse, Dall, Brooks, Beyer, and Beecher have done for the Terebratuloids and Linguloids of the American shores? Palæontologists would owe him a debt of gratitude, and science be greatly advanced thereby. AGNES CRANE.

III.—SUR L'ORIGINE DE LA DOLOMIE DANS LES FORMATIONS SÉDIMENTAIRES. Par M. C. KLEMENT. Bull. d. l. Société Belge d. Geol., etc. Tome IX (1895), pp. 3–23.

AFTER reviewing the very extensive literature relating to the mode of occurrence and origin of dolomite, the author describes a series of experiments in which a solution of sulphate of magnesium and chloride of sodium is made to act at various temperatures on arragonite and calcite. He finds that in the presence of a saturated solution of common salt at a temperature of 91° C. sulphate of magnesium will act on the powder of

[1] *Frieleia Halli*, Dall, a smooth Pacific species allied to *Hemithyris* (?) *lucida*, Gould, from Japanese waters.

arragonite in such a way as to give rise to a product containing 42 per cent. of carbonate of magnesium. Below 60° C. the action is very slight, but between 60° and 91° there appears to be for each temperature a certain maximum amount of replacement possible. When the solution is not concentrated with common salt the sulphate of magnesium acts much less energetically. The powder of iceland spar, unlike that of arragonite, is scarcely acted upon at all under similar circumstances. The powder of corals, on the other hand, is affected in the same way as that of arragonite. Thus *Madrepora humilis* from the island of St. Thomas yielded a product containing 41·9 per cent. of carbonate of magnesium after treatment for 47 hours at 90° C.

The author shows that the product formed in his experiments is not dolomite, but a mixture of the two carbonates. He considers, however, that true dolomite may be formed from such a mixture by secondary processes.

The author finally discusses the question as to whether the conditions of his experiments can be realised in nature on a large scale. Chloride of sodium and sulphate of magnesium are both present in sea-water, which may be concentrated in the closed lagoons of certain atolls. The débris of corals composed of arragonite is present, and the rays of the sun in tropical regions are capable of raising the temperature of such closed basins far above 60° C. He concludes, therefore, that "dolomite is formed by the action of sea-water, concentrated in closed basins and heated by the solar rays, on the arragonite deposited by organisms, in such a way that a mixture of the carbonates of calcium and magnesium is first produced, and subsequently converted into dolomite."

J. J. H. T.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—May 22, 1895.—Dr. Henry Woodward, F.R.S., President, in the Chair. The following communications were read:—

1. "On a Human Skull and Limb-bones found in the Palæolithic Terrace-Gravels at Galley Hill, Kent." By E. T. Newton, Esq., F.R.S., F.G.S.

A human skull with lower jaw and parts of the limb-bones were obtained by Mr. R. Elliott from the high-terrace gravels at Galley Hill, in which numerous Palæolithic implements have been found.

The skull is extremely long and narrow, its breadth-index being about 64; it is hyperdolichocephalic; it is likewise much depressed, having a height-index of about 67. The small extent of the cranium in both height and width shows that it has undergone little or no post-mortem compression, although it has become somewhat twisted in drying. The supraciliary ridges are large, the forehead somewhat receding, the probole prominent, and the occiput flattened below. All the chief sutures are obliterated. Three lower molars and two premolars are in place and are well worn, the three molars being as nearly as possible equal in size. The limb-bones indicate an individual about 5 feet 1 inch in height.

These remains are compared with the fossil human relics which have been found in Britain and on the Continent of Europe, as well as with the dolichocephalic races now living, and their relations to the 'Spy,' 'River-bed,' 'Long-barrow,' 'Eskimo,' and other types are pointed out.

The gravels, in which these human bones were found, overlie the Chalk at a height of about 90 feet above the Thames, and are about 10 feet thick. They form part of the high-terrace gravels extending from Dartford Heath to Northfleet, and their Palæolithic age is shown by the numerous implements which have been found in them, as well as by the mammalian remains which have been met with in similar beds near by, although not at Galley Hill. The human bones were seen *in situ* by Mr. R. Elliott and Mr. Matthew Heys, both of whom, in letters, speak positively as to the undisturbed condition of the 8 feet of gravel which overlay the bones when discovered.

2. "Geological Notes of a Journey round the Coast of Norway and into Northern Russia." By G. S. Boulger, Esq., F.L.S., F.G.S.

The author accompanied the Jackson-Harmsworth Polar Expedition as far as Archangel, and returned by way of the River Dvina. His observations relate mainly to four points: the origin of the foliation of the Norwegian gneiss; the question of raised beaches on the north-western coast of Norway; the boulders and boulder-formation of Northern Russia; and the Trias of the Dvina valley.

Between Christiansund and Tromsö the author was struck with the wide-sweeping folds of the foliation-planes of the gneissose rocks, which appeared to him more readily explicable on a theory of dynamo-metamorphism of rocks originally in part igneous, than by any process of diagenesis. He notes that the terraces observed in the transverse fjords would be perfectly explained by the formation of ice-dammed lakes, though the terraces of the Gulf of Onega seemed less dubious raised beaches than those of the north-west of Norway. He confirms the views of previous writers that many of the boulders of the boulder-formation of Northern Russia are of Scandinavian origin. The beds on the Dvina consist of sands and loams, often coloured red, with bands of alabaster and anhydrite. The strata are horizontal or inclined at a low angle. North of Ustyug Veliki the strata are marked as Permian on the Russian maps, and those to the south as Trias, but the author saw no perceptible break in the succession.

3. "On some Foraminifera of Rhætic Age, from Wedmore in Somerset." By Frederick Chapman, Esq., F.R.M.S. (Communicated by Prof. T. Rupert Jones, F.R.S., F.G.S.)

(1) The author has examined six examples of clays and limestones from different horizons; these were collected by Mr. W. A. Sanford, F.G.S., from a quarry south-east of the village of Wedmore, which has yielded Megalosaurian remains. The rocks in this quarry are

regularly stratified, and characteristic Rhætic fossils have been obtained from them by Mr. Sanford.

(2) The microscopical details of the various clay-washings are given, and the great abundance of some forms of the acervuline foraminifer *Stacheia* is noticed, included amongst which are forms that have been previously described under the name of "*Psammosiphon*" by Vine, and "Plaques de Rayonnés" and "*Asteracanthion*" by MM. Terquem and Berthelin; the former occurring in Silurian strata, and the latter in the Lias. The Rhætic examples of the genus *Stacheia* have numerous aggregated crystals of zeolites (?), of which, however, only impressions remain, included in the material of the tests.

(3) In a comparison made with the foraminiferal faunæ of the older and younger rocks respectively, the Rhætic fauna shows marked affinities with both the Upper Palæozoic and the Liassic facies.

The bathymetrical aspect of the foraminifera from Wedmore is, generally speaking, that of a shallow-water deposit. The genus *Stacheia* is represented so abundantly in some of these Rhætic rocks that the fossils constitute distinct layers in the beds of clay in which they are found. *Stacheia* appears to resemble *Polytrema* in reference to its habitat, and also in the microscopical structure of its test, with the exception that *Stacheia* includes in the test-wall minute sand-grains and other foreign material.

(4) Twenty-six species of foraminifera, chiefly of arenaceous types, are described, nine of which are new forms, viz.: *Haplophragmium Rhæticum, Ammodiscus auriculus, A. fusiformis, Nodosinella Wedmoriensis, Stacheia intermedia, S. triradiata, S. dispansa, S. cuspidata,* and *Truncatulina stelligera.*

II.—June 5, 1895.—W. H. Hudleston, Esq., M.A., F.R.S., F.L.S., Vice-President, in the Chair. The following communications were read:—

1. "On a well-marked Horizon of Radiolarian Rocks in the Lower Culm Measures of Devon, Cornwall, and West Somerset." By George Jennings Hinde, Ph.D., F.G.S., and Howard Fox, Esq., F.G.S.

In the Lower Culm Measures the basal *Posidonomya* Beds and the Waddon Barton Beds with *Goniatites spiralis* consist of fine shales with thin limestones, and above these are the beds which form the subject of the present paper. The Upper Culm Measures consist of conglomerates, grits, sandstones, and shales, with occasional beds of culm. There is evidence of the partial denudation of the Radiolarian rocks during the accumulation of the Upper Culm Beds, as indicated by the presence of pebbles of the former in the latter.

The Radiolarian Beds consist of a series of organic siliceous rocks—some of a very hard cherty character, others platy, and yet others of soft incoherent shales. They are spoken of as the Codden Hill Beds—a name applied to them by previous writers, though the authors do not include in this series all the beds which have been referred to it by others. The term "Grits," which has been used in connection with these beds, is a misnomer; there are beds which are superficially like fine grits, but they are found to be Radiolarian deposits.

The Codden Hill Beds occur along a comparatively narrow belt of country, a short distance within the northern and southern boundaries between the Carboniferous and Devonian systems. Starting with the northern exposures, the authors give a description of the beds as developed in various localities from the neighbourhood of Barnstaple (Codden Hill itself, situated 3 miles S.E. of Barnstaple, being a convenient starting-point), past Dulverton, to Ashbrittle in West Somerset. On the south the beds are traceable from Boscastle to the neighbourhood of Tavistock, and on the east side of the Dartmoor granite they are found near Chudleigh and Bovey Tracey.

At present there are not sufficient data for estimating the thickness of the Radiolarian deposits; but they are probably some hundreds of feet thick, though the whole does not consist of beds of organic origin. In a quarry in the Launceston district 50 feet of Radiolarian cherty rock are seen without admixture of shale.

A detailed description of the lithological characters of the rocks of the series is given, and analyses by Mr. J. Hort Player; a marked feature of their composition is the very general absence of carbonate of lime. The microscopic characters of the rocks are also described, and the small amount of detrital matter in the beds of the series is noted.

Forms belonging to 23 genera of Radiolaria have been recognized, included in the orders *Beloidea*, *Sphæroidea*, *Prunoidea*, *Discoidea*, and *Cyrtoidea*; in addition a scanty but significant fauna of corals, trilobites, brachiopods, and cephalopods is present in some thin shaly beds near Barnstaple. Nearly all the forms are diminutive. The trilobites are described by Dr. H. Woodward, the brachiopods by Mr. F. A. Bather, and the cephalopods by Mr. G. C. Crick. Of the 25 species of fossils other than Radiolaria which have been determined, several are only known elsewhere from the Lower Culm of Germany, while others are common to the Carboniferous Limestone of the British Isles and Belgium.

These fossils tend to confirm the view that the Lower Culm Measures are the deep-water equivalents of the Carboniferous Limestone in other parts of the British Isles, and not shallow-water representatives of deeper beds occurring to the north, as was formerly supposed. In connection with this it is worthy of note that the deep-sea character of the Lower Culm of Germany, which corresponds with our Lower Culm Measures, was maintained by Dr. Holzapfel even before the discovery of Radiolaria in the beds of Kieselschiefer furnished such strong evidence in support of this view.

2. "The Geology of Mount Ruwenzori and some Adjoining Regions of Equatorial Africa." By G. F. Scott-Elliott, Esq., M.A., B.Sc., F.L.S., and J. W. Gregory, D.Sc., F.G.S.

Ruwenzori is a mountain between the Albert and Albert Edward Nyanzas. Topographically it is a narrow ridge which extends for about 50 miles in a direction from N.N.E. to S.S.W. Its summit attains a height of 16,500 feet. The western slope is at an angle of 22°; the eastern slope at about one of 4°. The authors describe sections across the ridge at right angles to its trend. These show that Ruwenzori is not volcanic, nor is it a simple *massif* of diorite. Epidiorite occurs only as banded sheets in the schists on the flanks of the mountain, and is not the central rock of the ridge. The strike of the flanking schists seems to run concentrically round the ridge as though the central rock were intrusive into them. The highest rock collected, a coarse-grained granite or granitoid gneiss, may be an intrusive igneous rock, but it may be part of the old Archæan series faulted up; there is nothing in its microscopical characters to separate it from the Archæan rocks, and the authors think it probable that this rock was raised into its present position by faulting. In this case Ruwenzori is simply composed of an orographic block or "scholl," which was at one time probably part of a wide plateau of Archæan rocks.

There is abundant evidence of volcanic action around Ruwenzori, for the plains, especially to the east and south-east, are studded with small volcanic cones, arranged on lines which radiate from Ruwenzori.

It is affirmed that evidence points to the former occupation of the Nyamwamba, Mubuka, and Batagu valleys by glaciers, *roches moutonnées* of typical character having been noted in the two former valleys.

The country round Ruwenzori consists of rocks which may be conveniently grouped into two series—one composed of gneisses and schists, and the other of non-foliated sediments. The former (the Archæan series) are of the type that has an enormous extension in Equatorial Africa, and forms the main plateau on which all the sediments and volcanic rocks have been deposited.

The sedimentary rocks are probably Palæozoic, possibly pre-Carboniferous, but in the absence of fossils it would be unsafe to go beyond this statement.

3. "On Overthrusts of Tertiary Date in Dorset." By A. Strahan, Esq., M.A., F.G.S. (Communicated by permission of the Director-General of the Geological Survey.)

The results given in this paper were obtained during a re-survey of South Dorset on the 6-inch scale. The disturbances can be divided into two groups,—the one being mainly of Miocene date, and the other of intra-Cretaceous (between Wealden and Gault) age. The former includes the Isle of Purbeck fold (which is the continuation of the Isle of Wight disturbance), the Ringstead fold, the Chaldon and Ridgeway disturbances, and the Litton Cheney fault. In the latter are placed the anticline of Osmington Mill, the syncline of Upton, and a part of the anticline of Chaldon; farther west the Broadway anticline and Upway syncline, a fault at Abbotsbury, and many other folds come into the same group. These earlier movements led to the well-known unconformity at the base of the Upper Cretaceous rocks.

The Isle of Purbeck fold is accompanied by a large thrust-fault, by which the uppermost zones of the Chalk have been pushed in a vertical position under gently inclined lower zones. On the same line of disturbance at Lulworth Cove, the squeezing-out of plastic strata from a part of the fold where compression has been great, and the folding and packing away of such strata in a part where there was a tendency to gape, is described. Farther west the same disturbance is accompanied by inversion of a great thickness of beds, great compression, with vertical crush-planes and nearly horizontal slide-planes. The latter slope southwards, and the roof has moved northwards and upwards over the floor; these slide-planes have accompanied the phenomena of inversion.

The Ridgeway fold and fault resemble those of the Isle of Purbeck, but for some distance the thrust-plane has split, a part of it cutting into the Oolitic floor on which the Upper Cretaceous rocks were laid down, and causing a wedge of Oxford Clay, Cornbrash, and Forest Marble to be thrust over Wealden, Purbeck, Portlandian, and Kimmeridge Clay.

The Litton Cheney fault is connected with an anticline in the Chalk and Greensand which has been superimposed upon a syncline in Kimmeridge Clay and Corallian.

The intra-Cretaceous disturbances have been distinguished by the fact that Upper Cretaceous rocks rest undisturbed upon them, the difference in inclination amounting sometimes to 40°. This movement may have commenced before the Lower Greensand was laid down, but took place principally between the deposition of that formation and the Gault.

The features produced by the earlier movements were planed down before the Gault was deposited, and have had no share in producing the existing physical geography. The later movements, on the other hand, have determined the lines of drainage and the great physical features of the region.

CORRESPONDENCE.

DR. CALLAWAY AND METASOMATOSIS.

Sir,—My friend Dr. Callaway has been kind enough to send me a copy of a short paper of his in the Geological Magazine, in which he says that in my note on his views I have made "the astonishing error" of attributing to him an opposite opinion to that expressed by the words, "a mere gradation between two kinds of rock proves nothing as to the genetic connection between them," and that I have thereby misunderstood and misrepresented him; yet on the very next page he says of such gradation, without mentioning anything else, that it justifies certain conclusions about this connection. Is not this also the opposite to the above opinion?

But to try to be plain. I do not suppose that Dr. Callaway holds the general proposition—"If one rock passes into another in the field, one of them must be derived from the other," but I do think he argues on the basis of the following: "The character of the stages by which one rock passes into another in the field *may* suffice by itself to prove that one of them is derived from the other." This also may be assented to; but the case when one rock is diorite and the other a quartz-schist, will, for few minds, be included amongst those in which such evidence *does* suffice.

Dr. Callaway illustrates his meaning by a piece of underdone beef, as though the matter were one of simple contact or thermo-metamorphism; but when he can show us how, by slicing, rolling, squeezing, or roasting, to convert a piece of lean meat into fat, or *vice versâ*, he will introduce a novelty into the kitchen, and experimentally illustrate what he wishes us to believe in the case of rocks.

Port Said, 12*th June*, 1895. J. F. Blake.

PHOSPHATIC CHALK AT TAPLOW, BERKS.

Sir,—I hear from Mr. Lodge, estate agent to W. H. Grenfell, Esq., Taplow Court, that phosphatic chalk has been met with at a point 870 yards N.E. by E. from the pit which I described in the Quart. Journ. Geol. Soc., vol. xlvii, p. 356 (1891). The section in the new excavation is given by Mr. Lodge as follows:—

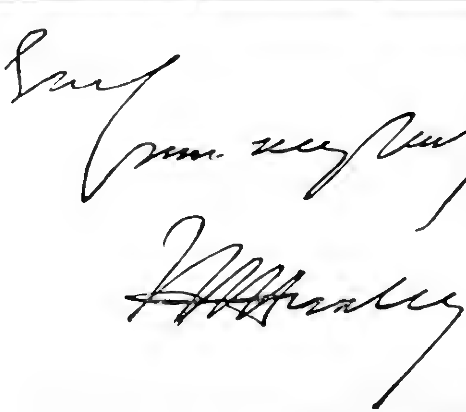
		ft.	in.
Reading Beds	Clay with a layer of greensand and flints at its base	11	0
Upper Chalk	Chalk	8	0
	Phosphatic Chalk	2	0
	Hard white Chalk		
		21	0

It differs from the section at the pit in the phosphatic chalk being eight feet below the base of the Tertiaries instead of twenty feet, and in the phosphatic layer being apparently only two feet thick instead of eleven feet. There are no differences distinguishable under the microscope between the phosphatic beds of the two localities.

28, Jermyn Street, S.W. A. Strahan.

MISCELLANEOUS.

Mr. Thomas William Newton, the Assistant Librarian of the Museum of Practical Geology, Jermyn Street, after a service of nearly thirty-five years, has retired from office under the Treasury Order relating to age. Mr. Newton was joint compiler with the late Mr. Henry White of "A Catalogue of the Library of the Museum of Practical Geology and Geological Survey," published in 1878. This work contains references to about 28,000 volumes, and although a partial dismemberment of the library took place in more recent years, it is still considered a most important compendium to geological literature and other subjects of the natural sciences.



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THE

GEOLOGICAL MAGAZINE.

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No. VIII.—AUGUST, 1895.

AN UNCROWNED KING IN SCIENCE.

IN MEMORIAM.

THOMAS HENRY HUXLEY, P.C., D.C.L. (OXON),

LL.D. (CANTAB, EDIN., ET DUBL.), M.D. (WÜRZB.), PH.D. (BRESLAU), F.R.C.S., F.R.S., F.L.S., F.G.S., F.Z.S., TRUSTEE BRIT. MUS., ETC.

BORN MAY 4TH, 1825. DIED JUNE 29TH, 1895.

(With a Portrait.)

BY the death of Professor Huxley another illustrious name must now be inscribed on the walls of our Valhalla, while the world of science mourns the loss of one of its most distinguished leaders, who shares with Owen and Darwin the reputation of having done more to advance the study of biology than any other of the naturalists who have appeared within the present century.

Though he won his grandest triumphs as a zoologist, there were not many departments of Natural History which he did not cultivate; indeed, it has been truly said of him, by Haeckel, that he was one of the few investigators who had thoroughly mastered the whole range of biology, and might claim to be the first zoologist in this country. Although capable of specializing in any group of animals or plants, he never lost sight of the broader biological problems which are so often overlooked by the less broad-minded systematist, so that he was able to enter the more limited field of classification, and give those who devoted their whole time to any one group a lesson on their own subject. He may well be regarded as our greatest naturalist.

Thomas Henry Huxley was born at Ealing on May 4th, 1825, and was for some years educated at the school in his native place, where his father was one of the masters. This preparatory course was followed by assiduous private reading, including German scientific literature, and instruction in medicine received from a brother-in-law who was a physician. He afterwards attended lectures at the Medical School of the Charing Cross Hospital.

In 1845 he passed the first examination for the degree of M.B. at the University of London, taking honours in physiology. In 1846 he was appointed Assistant-Surgeon to H.M.S. "Victory," for service at Haslar Hospital, and seven months later he was gazetted as

Assistant-Surgeon to H.M.S. "Rattlesnake," under the command of Captain Owen Stanley (brother of the late Dean Stanley), commissioned to survey the intricate passage within the Barrier Reef skirting the eastern shores of Australia, and to explore the sea lying between the northern end of that reef and New Guinea. It was the best apprenticeship to what was eventually to be the work of Huxley's life, the solution of biological problems and the indication of their far-reaching significance.

Two of his warmest friends, Darwin and Hooker, had passed through a like curriculum, the former as Naturalist to the "Beagle" on her voyage round the world in 1831, and the latter as Assistant-Surgeon on board the "Erebus" on her Antarctic expedition in 1839. Eventually the three stood shoulder to shoulder when the battle against the immutability of species was fought.

The voyage lasted from 1847 to 1850, and was the initiation of Huxley's scientific career. Some of the results of the studies in Natural History, for which the cruise afforded facilities, were transmitted to the Linnean and Royal Societies, and were in due course published in their Transactions.

Returning to England in 1850, Mr. Huxley was, in the following year, elected a Fellow of the Royal Society, and in 1852 he was presented with one of the Royal Medals annually awarded by the Society. In 1854 he received the appointment of Professor of Natural History, including Palæontology, in the Royal School of Mines and Curator of the fossil Collections in the Museum of Geology, Jermyn Street; and in the same year that of Fullerian Professor of Physiology and Comparative Anatomy to the University of London.

In 1856 he accompanied his friend Professor Tyndall in his first visit to the glaciers of the Alps, and with him read a joint paper on Glacial Phenomena, published in the Philosophical Transactions in 1857. In 1858 he was appointed Croonian Lecturer to the Royal Society, when he took for his subject "The Theory of the Vertebrate Skull." In 1859 his monograph on "The Ocean Hydrozoa, a description of the Calycophoridæ and Physophoridæ observed during the voyage of H.M.S. 'Rattlesnake,'" was published by the Ray Society. In 1860 Prof. Huxley delivered a course of lectures to working-men, in Jermyn Street, on "The Relation of Man to the Lower Animals." The questions arising out of this topic became the subject of warm controversy at the meeting of the British Association at Oxford between Bishop Wilberforce and Professor Huxley, and was taken up by others in that and subsequent years. The whole discussion appeared in the work entitled "Evidence of Man's place in Nature" (1863), and excited great popular interest both in this country and abroad. Mr. Darwin's views on the origin of species formed Professor Huxley's subject for his lectures to working-men in 1862, subsequently published under the title, "On our knowledge of the Causes of the Phenomena of Organic Nature." His other lectures were on the "Elements of Comparative Anatomy" and on the "Classification of Animals and the Vertebrate Skull."

In 1862, while serving as one of the Secretaries of the Geological Society, he was called upon, in the absence of Mr. Leonard Horner, the President, to deliver the Annual Address. Again, in 1869 and 1870, whilst filling the Presidential Chair of that Society, he delivered two other addresses. That in 1862 dealt with the subject of *Homotaxis* as opposed to the use of the term *synchronism*; in 1869 with the limitation of geological time; in 1870 with the evolution of the vertebrata and their geographical distribution. He presided over Section D at the meeting of the British Association at Cambridge (1862), and as President of the Association at Liverpool in 1870, delivering appropriate addresses on both occasions.

From 1863–70 he held the office of Hunterian Professor of Comparative Anatomy in the Royal College of Surgeons, and in 1869–70 was President of the Ethnological Society. He filled the office of Secretary to the Royal Society for ten years, 1871–80, and of President from 1883 to 1885. In 1883 he was appointed Rede Lecturer at Cambridge.

During the absence of Prof. Wyville Thomson on the "Challenger" Expedition, he divided with Dr. Carus, of Leipzig, the duty of acting as his substitute, delivering the lectures in the summer sessions of 1875 and 1876 at the University of Edinburgh. In 1876 Prof. Huxley visited America, when he delivered an Address at the opening of the Johns Hopkins University at Baltimore, on September 12th, and three lectures in New York, on September 18, 20, and 22, before crowded audiences. In the same year Huxley received the Wollaston Medal from the Geological Society of London.

He was elected a member of the London School Board in 1870, and took a leading part in opposing denominational teaching; but was compelled by ill-health to retire from the Board in January, 1872. In December, 1872, he was elected Lord Rector of Aberdeen University for three years, and installed February 27th, 1874. He was a Fellow and Governor for some years of Eton College. He was an elected Trustee of the British Museum, and a member of the Senate of the University of London. He served on many Government and Royal Commissions, notably on Science, on Fisheries, on Contagious Diseases, on Vivisection, on the Scottish Universities, etc. From 1881 to 1885 he held the office of Inspector of Salmon Fisheries. The only post he continued to hold up to the time of his death was that of Dean and Honorary Professor of Biology in the Royal College of Science, South Kensington.

In 1892 he was admitted a member of the Privy Council, having previously refused the honour of knighthood.

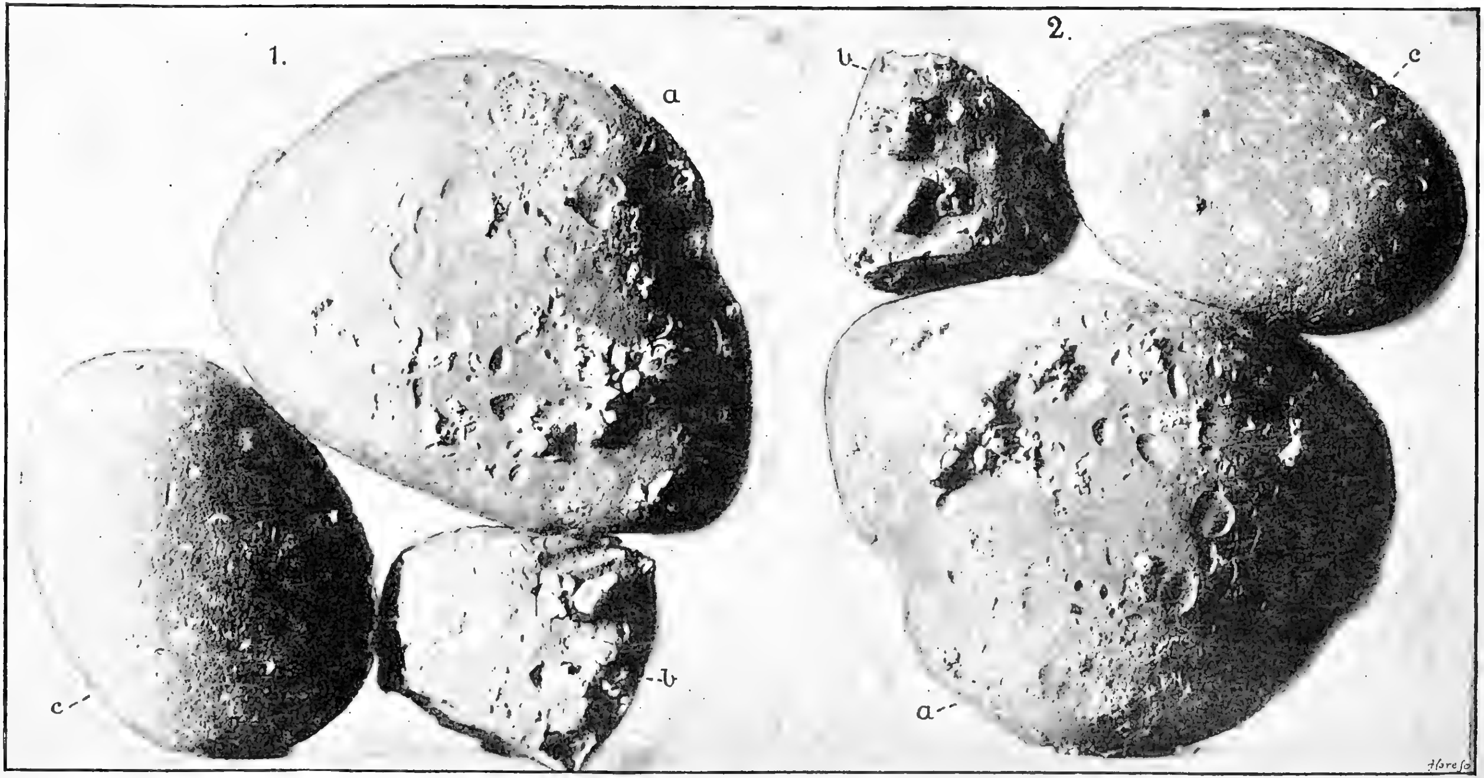
It is impossible to enumerate here the many honours conferred upon Professor Huxley. He was made a Doctor of the Universities of Edinburgh, Dublin, Cambridge, Oxford, Breslau, and Würzburg. The Academies of Brussels, Stockholm, Copenhagen, Cairo, Berlin, Göttingen, Haarlem, St. Petersburg, Lisbon, Rome, Munich, Philadelphia, and many others, conferred on him their Diplomas. He was made an Honorary Fellow of the Royal Society of Edinburgh;

a Member of the Royal Irish Academy; of the American Academy of Science; and (in 1879) a Corresponding Member of the Institute of France (Section Anatomy and Zoology, in place of Von Baer). He was also a Riddare of the Pole Star of Sweden.

Turning to his published works, we may refer to his "Oceanic Hydrozoa"; his Lectures on Comparative Anatomy and Physiology; Lessons in Elementary Physiology (1866), and many subsequent editions; An Introduction to the Classification of Animals (1869); "Lay Sermons, Addresses, and Reviews" (1870). His textbooks on the Anatomy (I) of the Vertebrata (1871), and (II) of the Invertebrata; his Practical Biology; "Man's Place in Nature"; on the Cray-fish, and on Physiography, well illustrate the wide extent and versatility of his powers, both as a naturalist and author; but it was by his lectures and addresses that he displayed the most marvellous of his intellectual gifts, and produced the greatest effect upon the science of his time. He had that wonderful power of carrying his audience along with him, and the happy facility of bringing his knowledge within the mental grasp of his hearers.

Of the 144 papers attributed to Prof. Huxley in the Royal Society's list of scientific papers extending from 1847 to 1884, the following may be mentioned as directly connected with our own science:—

On the Method of Palæontology (Annals, 1856). *Pygocephalus Cooperi*, a Coal-measure Crustacean (Q.J.G.S. 1857). On the genus *Pteraspis* (Brit. Assoc. Rep. 1858); On *Cephalaspis* and *Pteraspis* (Q.J.G.S. 1858); On *Plesiosaurus Etheridgei* (Q.J.G.S. 1858). On Persistent Types of Animal Life (Roy. Inst. Proc. 1858-62). On Species and Races and their Origin (Roy. Inst. Proc. 1860). On *Stagonolepis Robertsoni* (Q.J.G.S. 1859); On some Amphibian and Reptilian Remains from South Africa and Australia (Q.J.G.S. 1859); On *Dicynodon Murrayi*, South Africa, and on Skulls of Dicynodonts (Q.J.G.S. 1859); On *Rhamphorhynchus Bucklandi*, a Pterosaurian from Stonesfield (Q.J.G.S. 1859); On a Fossil Bird and a Fossil Cetacean from New Zealand (Q.J.G.S. 1859); On Dermal Armour of *Crocodilus Hastingsiæ* (Q.J.G.S. 1859); On the Anatomy of *Pterygotus* (Geol. Surv. Mem. 1859); On *Dasyceps Bucklandi* (Geol. Surv. Mem. 1859); On the Lower Jaw of a Labyrinthodont (Geol. Surv. Mem. 1859). On *Macrauchenia Boliviensis* (Q.J.G.S. 1861); On *Pteraspis Dunensis* (Q.J.G.S. 1861); Systematic Arrangement of Devonian Fishes (Geol. Surv. Mem. 1861). New Labyrinthodonts from Edinburgh Coal-field (Q.J.G.S. 1862); On a Stalk-eyed Crustacean from Coal-measures, Paisley (Q.J.G.S. 1862); On the Premolar Teeth of *Diprotodon* (Q.J.G.S. 1862). On a New Species of *Glyptodon* (Roy. Soc. Proc. 1862–63). *Anthracosaurus Russelli*, Coal-field Lanark (Q.J.G.S. 1863). On Cetacean Fossils termed "Ziphius," Cuvier, from the Red Crag (Q.J.G.S. 1864). Osteology of *Glyptodon* (Phil. Trans. 1865). Vertebrate Remains from Jarrow Colliery, Kilkenny, Ireland (Geol. Mag. 1866). Dinosaurian Reptiles from South Africa (Q.J.G.S. 1867); On *Acanthopholis horridus*, a new Reptile from the Chalk Marl (Geol. Mag. 1867); New specimen of *Telerpeton Elginense* (Q.J.G.S. 1867). Animals intermediate between Birds and Reptiles (Geol. Mag. 1868); Two new Fossil Lacertilians from South Africa (Geol. Mag. 1868, pp. 201-205); On *Archæopteryx lithographica* (Roy. Soc. Proc. 1868). On *Hyperodapedon* (Q.J.G.S. 1869); On a new Labyrinthodont, *Pholiderpeton scutigerum*, from Bradford (Q.J.G.S. 1869); On the Upper Jaw of *Megalosaurus* (Q.J.G.S. 1869); Principles and Methods of Palæontology (Smithsonian Reports, 1869). The Milk-dentition of *Palæotherium magnum* (Geol. Mag. 1870); On *Hypsilophodon Foxii*, a new Dinosaurian from the Wealden, Isle of Wight (Q.J.G.S. 1870); Further evidence of the Affinity between the Dinosaurian Reptiles and Birds (Q.J.G.S. 1870); On the Classification of the Dinosauria, with Observations on the Dinosauria of the Trias (Q.J.G.S. 1870); Triassic Dinosauria (*Nature*, 1870, p. 23); On the Maxillæ of *Megalosaurus* (Phil. Mag. 1870). (With Dr. E. P. Wright) On the Fossil Vertebrata from the Jarrow Colliery,



Pitted Pebbles from the Bunter Conglomerate, Cannock Chase.

Kilkenny, Ireland (Irish Acad. Trans. 1871). On *Stagonolepis Robertsoni*, etc. (Q.J.G.S. 1875). On the evidence as to the Origin of existing Vertebrate Animals (lectures, *Nature*, 1876). The Rise and Progress of Palæontology (*Nature*, No. 24, 1881). The Coming-of-age of the "Origin of Species" (1880, Roy. Inst. Proc. 9, 1882).—It will be seen that Professor Huxley was a frequent contributor to the pages of the Geological Magazine, and was one of its constant supporters since its commencement in 1864.

His last paper to the Geological Society was "Further Observations upon *Hyperodapedon Gordoni*," read May 11, 1887: see Q.J.G.S., vol. xliii, p. 675, pls. xxvi and xxvii. His latest work (published in conjunction with Dr. Pelsener) is on *Spirula* ("Challenger" Reports), 1895.

"Four kings laboured to build a mighty hall, the Hall of a Hundred Columns, at Karnak. In a century they built it, and they died; but the hall remains. Four men [Darwin, Tyndall, Huxley, Spencer], more than all others, have raised up within this century an edifice which is the crowning glory of British science; and before the century closes three of them are dead. But the edifice stands, and will stand, as a lasting monument to the power of truth and fearless investigation."—*Pall Mall Gazette.*

For further details see also "Men and Women of the Time," *The Times, Athenæum, The Standard, Daily Chronicle, Daily News*, etc., July 1st. H. W.

ORIGINAL ARTICLES.

I.—Pitted Pebbles in the Bunter Conglomerate of Cannock Chase.

By T. Mellard Reade, C.E., F.G.S., F.R.I.B.A.

(PLATE XI.)

In a letter to this Magazine of May, 1895, headed "The Indentation of the Bunter Pebbles," Mr. W. S. Gresley criticizes the summing-up of my views, given in the 'Annals of British Geology' (1892, p. 52), that "The indentation of the pebbles he considers to be the result of contact-solution, the water being retained at these spots by capillary attraction." It would have been more satisfactory if Mr. Gresley could have read my original paper[1] before penning his letter, as he would then not have assumed that I "adduce no evidence in support of the chemical theory."

Perhaps I may be permitted in the pages of this Journal to re-state, and if necessary expand, my reasons for thinking that the "indentations" were not mechanically impressed, as the term rather assumes, but were simply due to solution at the points of contact. In the absence of specimens of the pebbles themselves, to thoroughly understand the question a good photograph is required, and this I have endeavoured to supply, so that my statements can be literally followed.

These are my points—

First.—If the pittings or depressions were due to mechanical pressure, the material of the pebble which was "indented" would

[1] The Trias of Cannock Chase, Proc. Liverpool Geol. Soc., Session 1891–2.

show signs of distortion. This it never does in any of the examples I have examined. A reference to the photograph will show this clearly; the depressions are perfectly sharp at the edges, and the pebble retains its external shape. The material formerly occupying the depression has been *removed*, not displaced.

Second.—The pebble that is "indented" is often harder than the pebble which indents. The "indenting" pebble is never distorted, but is frequently fractured.

Third.—Out of six indented pebbles now before me, separately collected by myself, Mr. Henry Beasley, and Mr. Edmund Dickson, when our observations were made at Cannock Chase in 1891, only one shows signs of fracture—this is *b* shown in the photograph. It is quite evident that the "fractures" are simply joints, such as may be found in many pebbles, having no indentations upon them. This pebble is a purple ferruginous sandstone or grit, almost as hard as quartzite, but not having a lustrous fracture. The interior of the "indents" is in most cases light grey, the purple colour having been discharged—another evidence of solution. There are also four quartzite pebbles from the Bunter of other localities sent me by Mr. Beasley, one of which, measuring $2\frac{1}{4}'' \times 1\frac{3}{8}''$, has been fractured and recemented by a deposit of silica which closes up about one inch in length of the crack, and is consequently subsequent to it.

Fourth.—Fractures are a sign that the material of the pebble is rigid, and that it cannot be squeezed out of shape. Their existence is to a certain extent evidence against the mechanical theory. I think no geologist will contend that the pebbles have been hardened and indurated since they became pebbles; their smooth worn surfaces show that the rock they were formed from was in the same condition as the pebbles are now.

Fifth.—The indenting pebbles *perfectly fit* the indents of the pebbles. If the indents were the result of mechanical movement this would not be likely to happen in all cases. The "indents" in the ten pebbles before me vary from $1\frac{1}{4}$ inches long by $\frac{3}{4}$ inch in width, shallow and pear-shaped, to circular pits only $\frac{1}{16}$ inch in diameter. They are of all shapes, a saucer-like shape predominating. Some of the pebbles are cemented into their places by a deposit of silica. When the indenting pebbles are removed the cup or depression is seen to be smooth, frequently having a deposit of silica over the surface, sometimes one of carbonate of iron. This deposit of silica in the case of the real quartzites is so hard that a knife will not pierce it.

Sixth.—The pittings are, in the more marked cases before me, principally confined to one side and the edges of the pebbles. The opposite side often has adherent somewhat loosely cemented sand and small pebbles. I take this, which is on the flattest side, to be the bed of the pebbles, and the pitted surface to be the top surface. Why should this be the case on the mechanical assumption? There is not much evidence of lateral pressure in the stratum in which the pebbles occur, and statical pressure one would expect to be equally effective top and bottom.

Seventh.—Let us try what the maximum statical pressure at any time on these Bunter rocks may have been. If we assume that a mile in thickness of rock at one time existed over the Bunter Conglomerate of Cannock Chase, I think it will not be above the mark. At 15 cubic feet to the ton, a column of rock a mile high would give 352 tons to the square foot. The crushing weight of granite cubes is about 720 tons per square foot on the average. Quartzite is harder.[1] If the whole pressure of the column of rock were equably distributed, it would necessarily neither crush nor disturb the quartzite. If, on the other hand, the pressure was increased by being concentrated on certain points, fracture, not distortion, would be the result, from the other parts of the pebble being unsupported. The smaller the indenting pebble the more cogent is this argument.

It is quite remarkable how numerous minute pebbles leave their marks on the very hard sandstones. Pressure applied to them in such a way as to tend to stamp them into the boulder would inevitably crush them, for it is a condition of indentation by pressure that the pressure cannot be applied in a manner to prevent crushing. There seems to be little relation between the hardness of the pebbles and the existence of the indentation. One small pebble, a specially light sandstone showing casts of fossils, has two well-formed pittings in it, and evinces no sign either of fracture or crushing.

Eighth.—But we have positive evidence that at the points of contact of the pebbles solution and deposit have been going on. In most of the depressions there is a deposit of silica which smooths the surface of the depression and unites the grains of rock. In some cases, when a joint or crack traverses the depression, this silica fills it up. The grains of silica, where they are seen in the depression of true quartzite pebbles, show like a mosaic, and appear to be flattened or cut off on their upper surface. I think it extremely probable that solution and deposit have gone on alternately. That solution of the silica has taken place, there is evidence on all hands, including the adherent sand and gravel, for solution must precede deposit. Solvent action would concentrate itself on the continually damp spots, and these are the points of contact of the pebbles, especially on the upper surface of the larger pebbles. The Bunter is a water-bearing rock, and water has a free circulation through it. Referring to the figure given by Mr. Gresley, I would respectfully submit that the branch fractures from the depression are not a proof that the depression was due to the same cause as the fracture. One pebble could not be driven into another without distortion of one or both, as already explained; and the fractures are a proof of the pebble giving way and breaking up without distortion. Also the fractures are not shown to cross the depression or indent. In none of my examples are there any radiating fractures.

[1] Quartz-rock, Holyhead, is given by Mallet as 1641·6 tons per square foot across laminations, and 900 tons parallel to laminations.—Manual of Rocks, Tables, etc., D. K. Clark, p. 631.

The following is an analysis of one of the Cannock Chase pebbles given in my original paper, and made by Mr. P. Holland, F.C.S., a member of the Liverpool Geological Society :—

Analysis of an indented pebble from Stile Cop Gravel Pit, near Rugeley.

$Si\,O_2$	79·26
$Al_2\,O_3 + Ti\,O_2$	9·60
$Fe_2\,O_3$	4·80
$Mn\,O$	0·08
$Ca\,O$	0·22
$Mg\,O$	0·97
$K_2\,O$	2·23
$Na_2\,O$	0·19
Combined water	2·79
	100·14

As further illustrating solvent action at the points of contact, I may refer to a pebble of hard compact grey limestone (probably Carboniferous), 3 inches in diameter, $1\frac{1}{4}$ inches thick, rounded and disc-like in form, from the Bunter Conglomerate near Wolsley Bridge. There are two well-marked dish-like depressions in the stone respectively 1 inch and $\frac{3}{4}$ inch in diameter, which are coated with a thin deposit of carbonate of lime. There is also a good deal of adherent quartzose sand cemented together with carbonate of lime. Here the pebble is of *limestone*, not quartzite or sandstone; yet the same kind of action has gone on, namely, solution of the limestone at points of contact and re-deposit of the carbonate of lime. There is not the slightest sign of fracture to be seen.

EXPLANATION OF PLATE XI.

Fig. 1.—Photograph of three boulders or pebbles from the Bunter Conglomerate of Cannock Chase.

a. Very hard, fine close-grained grit, boulder, or pebble, $7\frac{3}{4}$ in. × 6 in. × 4 in., well rounded and worn. It is covered with "pittings"; the prominent circular saucer-like depression which shows in this, and more plainly in Fig. 2, is $\frac{5}{8}$ inch across. There is a shallow depression $1\frac{1}{4}$ inches long on the upper part of the pebble which is not seen. These pittings are found as small as $\frac{1}{16}$ inch in diameter, but embedded grains of quartz have been found only $\frac{1}{50}$ inch in diameter. The pebbles, where entirely clear of adherent sand, are quite sharp at the edges, as may be seen on examining the plate with a lens. The surface of the pittings is mostly granular, but in some cases has a deposit of silica upon it. The projections above the general surface of the boulders are either whole pebbles, broken or decayed pebbles, or groups of pebbles with sand between cemented thereto. The cemented sand sometimes makes a rim round the depression. Most of these small pebbles, with which the large one is roughened, are counter-sunk or embedded in the boulder, and if removed would disclose pittings. They are generally very firmly cemented into the depressions with silica, and fit them exactly. The opposite side of the boulder has a good deal of adherent sand and gravel, but not many "pittings," which are principally confined to the surface shown in the photograph and to the edges. (Stile Cop.)

b. Hard, fine-grained, purple-brown coloured grit boulder, or pebble, full of joint planes, along three of which it has split; these broken joint surfaces are covered with ferric oxide. The "pittings" are very numerous, and are of a lighter colour than the surface of the pebble, which is well water-worn. One of the pittings is canoe-shaped, $1\frac{1}{4}$ inches long by $\frac{1}{4}$ inch wide. There are small pebbles adherent and imbedded; in this and most other respects the description of boulder *a* applies to boulder *b*. (Stile Cop.)

c. Purple-coloured quartzite boulder or pebble, $5\frac{3}{4}$ in. × $4\frac{1}{4}$ in. × 3 in., a flattened oval in form, covered with depressions of a less decided type than *a* or *b*. The surface of the depressions are white from a deposit of silica therein. There is only one small adherent bit of gravel. The opposite side to that shown in the photograph has no "pittings," but a good many small adherent patches of sand about $\frac{1}{8}$ inch in diameter, apparently indicating the points of contact of small pebbles or gravel, now removed. There are depressions on the edges. (Stile Cop.)

Fig. 2.—The boulders shown are the same as in Fig. 1, but arranged in a way to get the light from another direction to show up some of the features not properly developed in Fig. 1.

II.—Two Occurrences of Radiolarians in English Cretaceous Rocks.

By George E. Grimes, B.Sc., A.R.S.M., A.R.C.S., F.G.S.

THE opinion that fossil Radiolarians were entirely limited to Tertiary strata prevailed until a comparatively late period. Prof. Ernst Haeckel, in his monograph on the Radiolaria, published in 1862, says "that the Radiolarians made their appearance for the first time during the Tertiary period"; and Ehrenberg, as late as 1875,[1] defined all the Polycystina-bearing rocks as Tertiary.

For a long time the Cretaceous rocks yielded but few remains of Radiolarians, and even as late as 1885 Dr. Rüst remarked on the poverty of Radiolarian remains in Cretaceous strata.[2] Since that date, however, chiefly owing to the patient and laborious researches of Dr. Rüst, a large number of species have been obtained from various rocks on the Continent, principally from the Lower Cretaceous.[3]

Prof. Sollas was the first to notice Radiolaria in the Cretaceous rocks of this country, and in his paper "On Greensand Sponges and Foraminifera"[4] he says: "Polycystina of various genera also occur; forms resembling *Haliomma* may be noticed of somewhat frequent occurrence." Prof. Sollas promised a full description of these forms later, but I believe it has not yet appeared.[5]

In 1888 Dr. Rüst[6] described two species—*Dictyomitra anglica* (Rüst) and *Dictyospyris chlamyden* (Rüst)—from flints of Senonian or Turonian age from England; but the locality is not given.

The object of this paper is to describe two fresh occurrences of Radiolaria in our Cretaceous rocks.

One is in the Fuller's Earth Rock Bed in the Lower Greensand, between Redhill and Nutfield, Surrey. This bed lies directly on

[1] Fortsetzung der mikrogeologischen Studien: Abhandl. der k. Akad. der Wissen. Berlin, 1875.

[2] Beiträge zur Kenntniss der fossilen Radiolarien aus Gesteinen des Sura: Palaeontographica, vol. xxxi.

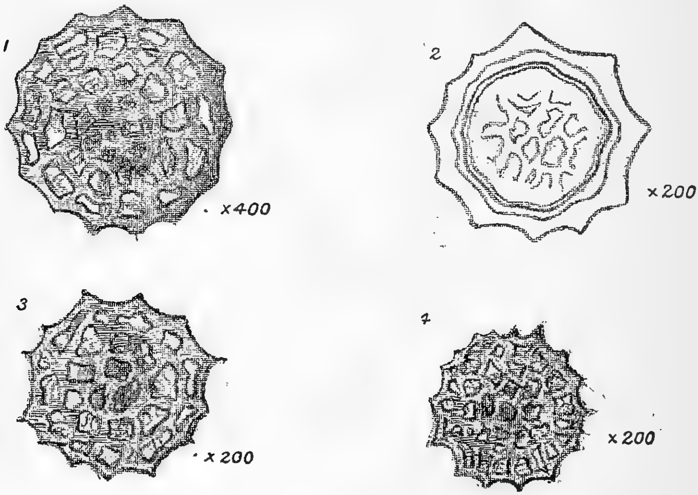
[3] Beiträge zur Kenntniss der fossilen Radiolarien aus Gesteinen der Kreide: Palaeontographica, vol. xxxv.

[4] Geol. Mag., Vol. X, 1873.

[5] It should also be mentioned that Dr. Wallich recorded the occurrence of several genera of Radiolaria in the interior of Chalk flints in 1883 (Ann. and Mag. Nat. Hist., July 1883, p. 52).—Edit. Geol. Mag.

[6] Beiträge zur Kenntniss der fossilen Radiolarien aus Gesteinen der Kreide: Palaeontographica, vol. xxxv.

top of the Fuller's Earth, and is mapped by the Geological Survey as equivalent to the Sandgate Beds of East Kent; but this is disputed by some geologists. As the rock forms the surface of the dip slope of the Lower Greensand at this place it has been considerably denuded, so that its thickness varies from 0 to about 27 feet. When examined in thin sections with the microscope the rock is found to be composed chiefly of broken sponge spicules, and with these Foraminifera (mostly infilled with glauconite and in many cases having the original test), glauconite grains and casts, fragments of tests of Echinodermata, some grains of quartz, and more or less iron oxide. In a few slides globate spicules of *Geodites* were also noticed. The silica in the sponge spicules mostly assumes in a greater or less degree the globular form, which was first noticed by Dr. G. J. Hinde in his paper "On Beds of Sponge Remains in the Lower and Upper Greensand."[1]



Radiolarians from the Greensand of Redhill and Reigate.

Fig. 1.—*Carposphæra Neocomiensis*, sp.n. From the Fuller's Earth Rock Bed, Lower Greensand, Redhill, Surrey. × 400.
Fig. 2.—*Haliomma* sp.? From the Fuller's Earth Rock Bed, Lower Greensand, Redhill. × 200.
Fig. 3.—*Carposphæra*, sp. From the Upper Hearthstone, Upper Greensand, Reigate Hill, Surrey. × 200.
Fig. 4.—*Carposphæra*, sp. From the Lower Hearthstone, Upper Greensand, Reigate Hill. × 200.

Radiolaria were most numerous in the rock from the pit at the top of Redstone Hill and on the south side of the road between Redhill and Nutfield, where there were as many as seven or eight in a section of a little over a square inch in area. The Radiolarians in this bed mostly belong to the genus *Carposphæra*, Haeckel, with

[1] Phil. Trans. Royal Soc., part ii, 1885, p. 427.

two concentric spherical lattice shells (outer cortical and inner medullary). As the lattice shells are now more or less infilled with foreign material the lattice structure of the inner one is not always visible. One of the best defined of these forms is represented in Fig. 1, and as it appears to be new I propose to name it *Carposphæra Neocomiensis*. The diameter of the cortical shell is ·07 mm. (Fig. 1), and the breadth of the medullary shell ·032 mm. There appear to have been originally eight or nine rays connecting the two shells. The lattice mesh of both shells is irregularly polygonal.

Haliomma species? Fig. 2.—As seen in section the boundary is irregularly circular, with numerous cusps, probably the bases of spines. The inner border, as seen in figure, was probably the boundary of the inner test. In the central area there are some faint indications of lattice structure. This organism was found on the thin edge of the rock section. Diameter ·139 mm.

The second occurrence of Radiolaria is in the Upper Greensand at Colley Farm, Reigate. The section at present visible in the pits is, in descending order—

Chalk Marl.	ft.	in.
Greenish Sand (equivalent to chloritic marl)	7	6
Chert	0	6
Soft Hearthstone	6	0
Chert	0	6
Hard Hearthstone	5 to 6 feet.	
Fire and Building Stone	6	0

The Radiolaria were found both in the Upper and Lower beds of Hearthstone. These beds in thin sections under the microscope exhibit a similar composition to that of the Fuller's Earth rock previously described, but the constituent fragments are smaller in size. The beds are made up of broken sponge spicules, grains of quartz, glauconite grains and casts, Foraminifera mostly infilled with glauconite and flakes of mica. The globular form of silica is, however, more developed than in the Fuller's Earth rock, and when sections are examined with the $\frac{1}{4}$ inch objective the globules are seen to make up a large proportion of the slide. The Radiolaria in these beds are not so well preserved as those in the Fuller's Earth rock, but they appear to belong to the same genus—*Carposphæra.*

Fig. 3 represents one of these from the Upper Hearthstone; the diameter of the cortical shell is ·145 mm. Fig. 4 represents a form from the Lower Hearthstone; the diameter of the cortical shell is ·1 mm.

I have to thank Mr. F. Chapman, F.R.M.S., for advice and assistance in the preparation of this paper, and for the excellent figures which accompany it. I wish also to thank Dr. G. J. Hinde, F.G.S., for examining the specimens and advising me on some difficult points; also Professor Judd, F.R.S., for kind advice and facilities for making some of the preparations.

III.—Notes on "The Great Ice Age" in Relation to the Question of Submergence.

By Dugald Bell, F.G.S.

(*Continued from p.* 326.)

III. The Second Glaciation.

"Even if marine life had been prolific, and the old sea-bottom more or less well covered with sedimentary deposits, it does not follow," says Dr. Geikie, "that the Boulder-clay of the succeeding *mer de glace* should now contain any shells" (p. 141).

This is what we have now to consider—that the marine deposits of the submergence, however abundant, may have been swept away by the succeeding glaciation so completely as to leave no trace in the Upper, or post-submergence, Boulder-clay.

Now, we may assume that, in the gradual subsidence and re-emergence of the land ("leaps and bounds" being discarded), the sea would for some time occupy all possible levels up to the supposed maximum limit, and would, on the premises now granted, leave traces of its presence, and of its "prolific" organic life, more or less abundantly at them all. Indeed, such traces would, so to speak, have a double chance of being left—first, during the submergence, and again, during the re-emergence. Further, at every successive level the sea would go into innumerable bights and bays, ravines and sheltered hollows of the land where, from their very nature, subsequent ice-sheets could not follow it.[1] This is obvious enough in itself, but we are glad to have it also on Dr. Geikie's authority. Speaking of the beds of silt, sand, and gravel which in many places are intercalated in the "Till"—indicating a time when the great ice-fields had receded "so far at least as to uncover the lowland tracts and valleys"—he shows that "during the Glacial period the ice-sheet, which followed the lines of the principal valleys, must frequently have crossed the lateral and tributary valleys nearly at right angles. In the main valleys," he continues, "the glacier would exert its full influence, but it would not be able to do so in the narrow lateral valleys and ravines; the ice and Till would merely topple into the glens referred to, and gradually choke them up, and the main mass of the glacier would then pass over the whole .... In such narrow glens, then, any silt, sand, or gravel that had gathered during the absence of the ice-sheet would not be so likely to be ploughed out" (pp. 108–9).

Accordingly, in many hundreds of such little tributary glens all over the country, and at many different levels in them all, marine deposits, if the sea had ever been there, would have a good chance of being preserved.

And that chance, we have to add, would be considerably increased by the very circumstance of these deposits being mainly spread out over the low grounds, where the erosive power of ice-sheets is least, and where, instead of "sweeping out," they tend rather to

[1] See Trans. Geol. Soc. Glasgow, vol. ix, pp. 109, 110.

accumulate débris. Thus Dr. Geikie goes on to say—"I do not believe it was necessary for the preservation of intercalated deposits that they should always have occupied a hollow or depression sheltered from the full sweep of the ice-flow. The great thickness attained by the Till in broad open lowland districts" [this is different from the "narrow belt of coast-land" formerly spoken of] "shows that over such areas there was a tendency for the Till to accumulate, probably owing to a diminished rate of ice-flow. . . . Wherever the flow of the ice-sheet slackened, there would necessarily be less erosive action, and therefore a good chance of pre-Glacial and inter-Glacial beds being preserved" (p. 112; see also pp. 74–5).

We leave Dr. Geikie to reconcile these clear and distinct statements with his arguments for the complete erosion and removal of the marine sediments by the "second glaciation." How could the ice-sheets of that period, while thus largely sparing the "Lower Till" and the overlying fresh-water deposits, pick out and carry away so completely, and from all the low-lying and most sheltered positions in the country, every trace of the marine deposits, "prolific" in organic remains, which must have been there had the sea reached the level, or anything like it, which he contends for? Does he not require far more of the ice than we do? *We* suggested that it may have transported some portions of marine clay and sand a few miles inland from the sea; *he* supposes that it may have removed hundreds of square miles of the same materials into the sea, sometimes over great distances and across every inequality of ground, and left scarcely "a wrack behind"! Truly we may say, "glacier-ice has played many strange freaks, but one may be excused for doubting whether it is equal to this remarkable performance" (p. 141).

Indeed, we do not require to go beyond this individual section at Clava to show how untenable Dr. Geikie's position is. Here, in this upland valley of the Nairn—where, be it noted, there is every evidence that the action of the ice was *along* the valley, and not *across* it,[1]—here are some 36 feet of partly stratified deposits overlaid by a great thickness of Boulder-clay. The "second glaciation" must evidently have been in great force here, to have laid down more than 40 feet of this "Upper Till." Yet it did not wholly "clear out" or "sweep away" the previously existing beds of "fine sand" and "blue clay"; it merely covered them up—at least 36 feet of them—and passed on! What ground is there for saying that it would do otherwise in hundreds of similar, or far more sheltered, localities all over the country?

But if we wish another instance to confirm the view which we are now maintaining, it is furnished to our hand in that immediately afterwards referred to by Dr. Geikie (p. 142), viz.—

The Strathendrick Shelly Till, which was described by Mr. Jack, of the Geological Survey, a good many years ago, as occurring

[1] "The River Nairn runs in a north-easterly direction, and the ice-markings on the floor of the valley indicate that the later ice-flow adhered pretty closely to the direction in which the river now flows" (Trans. Inverness Sci. Soc., vol. ii).

in the lower part of the Endrick valley, a few miles beyond the south-east end of Lochlomond, and at various elevations from 80 to 320 feet above the sea.[1] This shelly Till or Boulder-clay Mr. Jack attributed to the action of a glacier which occupied the bed of Lochlomond after a moderate submergence had converted it, for a time, into an arm of the sea. We say "a moderate submergence," for a little over 20 feet would suffice, as Mr. Jack himself pointed out. But as a laminated clay containing some marine shells and a fragment of a deer's horn was discovered in the same neighbourhood at a height of 108 feet, and assumed to be "in place" (which we think is open to question), Mr. Jack inferred a "minimum submergence" of that amount, 108 feet. This, however, he took care to say, was not to be confounded with the greater submergence in which he then believed, and which he assigned to a later date. After the minor or "minimum" submergence referred to, Mr. Jack's view was that "a large glacier filled up the lake, covered the islands, and climbed the rising ground beyond to the height of at least 320 feet," carrying up with it, from the bottom of the lake, this shelly Till.

Now, this instance evidently tells forcibly against the theory of the total demolition and disappearance of marine remains as a certain result of the "second glaciation." Accordingly, Dr. Geikie suggests that this Strathendrick Till "belongs to a later date than any of the shelly Boulder-clays" he had been referring to; and that it "appears to have been deposited by a local glacier." As to *time*, this is quite opposed to Mr. Jack's view, which was that this shelly Till preceded the "great submergence." It differs from Mr. Jack's view, also, as regards the *means* or *agency*. What is meant by a "local glacier"? We naturally think of one of the smaller ice-sheets which continued to linger in the upland valleys and glens, around the borders of the mountain districts and their gradually diminishing snow-fields, after the extreme period of glaciation had passed away. But Lochlomond is not in any such upland glen or valley; the bottom of it is in great part under sea-level, in parts as much as 500 to 600 feet. The valley is, moreover, 24 miles, or, with its continuation to the head of Glen Falloch, some 36 miles, in length; and there is no point nearer than the head of that glen, or still farther away up Strath Fillan, among the group of high mountains there, which can be indicated with any probability as the place of origin of its glacier. All the striations that have been observed in the district lead to that quarter. If, then, a glacier 40 or 50 miles in length, and a good deal over 1000 feet in thickness,—for such it must have been to have filled up the lake and carried its shelly Till to an elevation of 320 feet above it,—if such a glacier be called "local," it can only be in the sense of not being part of a "general" ice-sheet, though apparently very near it. For, when such a glacier existed in Lochlomond, we may safely say that every arm of the sea all around our coasts would have its glacier of corresponding dimensions, each separated

[1] Trans. Geol. Soc. Glasgow, vol. v.

from its neighbours (where it was separated) by only very narrow ridges of land.

Mr. Jack, at least, believed that "the shelly Till was produced by a glacier which had its gathering ground partly in the region drained by the Fillan"; because "a glacier nourished solely in the Lochlomond valley could not have climbed the rising ground between the Leven and the Endrick to the height (320 feet) to which the shells have been traced." This seems undeniable.

We ask, then—If this second glaciation did not utterly destroy and carry away out of sight the marine shells taken up from the comparatively limited area of Lochlomond, but left abundant traces of them within a few miles of the loch, what reason is there for holding that it—or any similar glaciation—would make a "clean sweep" of all relics of marine life from every bay and inlet, ravine and valley all over the country, that would be occupied by the sea during the supposed submergence of over 500 feet?

We accordingly claim this Strathendrick shelly Till as a strong corroboration, and indeed a practical proof, of our contention that had there been such a submergence, the "Upper Boulder-clay," held to be due to a succeeding glaciation, would undoubtedly, as a rule, be charged more or less abundantly with marine organic remains—Q. E. D.

IV. The Clava "Shell-Bed."

From what has been said, it appears that the absence of all traces of the sea at a similar level, and at many approximate levels, all round the country, and the absence of relics of marine life, more or less abundant, in the Upper (or supposed post-submergence) Boulder-clay, are insuperable difficulties against accepting the alleged submergence of 500 to 600 feet—that is to say, difficulties which have resisted all attempts to explain them away.

The difficulties against the ice-transport theory, on the other hand, must be shown to be greater than those against the submergence theory, before we can be asked to accept the latter as in any degree a satisfactory account of the phenomena.

Now let us take this special instance of *Clava*. There are several points connected with it which seem to require careful consideration. It may conduce to clearness if we here repeat the section—

Above Sea.		Feet.
566 feet.	Surface soil and upper light-brown Boulder-clay; many of the stones striated	43
523 feet.	Fine yellowish-brown sand, very compact; a few very small stones	20
503 feet.	Dark-blue or grey shelly clay, slightly bedded, very little sand or gravel; almost free from stones, except in lower part	16
487 feet.	Coarse gravel and sand, and brown stony clay. (Lower Till, partially reassorted?)	36½
450 feet.	Rock, gritty Old Red Sandstone	

We quote the following summary from the carefully written "Note" of the minority:—

"The ice-transport theory, therefore (whatever difficulty may attach to it), has at least this point in its favour, that the deposit is quite in the track of ice which would almost certainly pass over part of a former sea-bed in its progress. It has also this other point, that the shelly clay consists almost wholly of materials derived from some distance, differing from those in the immediate neighbourhood, and from the Boulder-clay and gravel above and below it. Further, though the clay itself suggests deposition in deep and comparatively still water, the shells and other organisms it contains are almost entirely of littoral species; and though the stones in it are in general rounded and water-worn, some distinctly striated are associated with them, and all occur promiscuously imbedded in this fine unstratified clay, without, as a rule, even a streak of accompanying sand or gravel. Mere submergence seems inadequate to account for these facts. And we venture to say that to assume, first, a submergence of over 500 feet, then a re-elevation to about the old level, with a return of glacial conditions much the same as before, is to hang an immense series of changes upon the (as regards interpretation) more or less doubtful evidence before us." (Report, p. 31.)

Let us now look at some of the difficulties advanced on the other side. One is the well-preserved condition of many of the shells. Numbers of them, it is admitted, are crushed and broken; but many of them, it is pointed out, are whole, some having the epidermis entire, and none, so far as observed, showing any trace of ice-markings or abrasion. All this, however, is paralleled by numerous known instances in which even delicate shells have been transported uninjured by ice, so that it cannot be said to be at all conclusive.

Other points that are urged against the ice-transport theory are the "extent" of the bed, its "horizontality," and its exhibiting "no trace of deformation or disturbance" ("Great Ice Age," p. 141). But in regard to these points opinions will differ as to the clearness or decisiveness with which they are proved by the Report. Take, first, the "extent." We admit, of course, the fact that a "blue sandy clay" was found at 30 yards east and 160 yards west of the main pit, and also in bores at other two points between. Nor are we disposed to make much of the accompanying fact that only one of the bores showed any traces of shells. We are willing to grant that it was probably the same clay, and probably continuous. We remark, however, as very likely having some bearing on its mode of formation, that it seemed to thin out very unevenly on both sides of the main pit, and at a certain distance on either side it ceased altogether. At the main pit it was 16 feet in thickness; at 30 yards to the east it was but 2½ feet; and at 61 yards in the same direction it was not found. Again, at 160 yards west, it was only 15 inches in thickness; at 197 yards it was not found. It thus appears to be a very irregular mass, and restricted within certain definite limits. Certainly it is not "horizontal," the difference in level between its two extremes being about 20 feet. And as certainly it has been subjected to great compression and crushing—whether during its deposition, or since, is a question.

Now (1) we might ask whether the known instances in which masses of clay and fragile slabs of Chalk, etc., of considerable dimensions (some upwards of 180 yards in length) have been transported uninjured by the ice, are not sufficient in some degree to neutralise, or lighten, any objection resting on the apparent or "proved" extent of the "bed"? [1]

[1] See Mellard Reade on "Masses of Chalk imbedded in the Drift of Cromer" (Q.J.G.S., vol. xxxviii, 1882). Also "Great Ice Age," p. 338.

(2) But if any think otherwise, we revert to what we have already urged as to the *limits* of the deposit (which have been proved with at least equal clearness) being a far greater objection to the theory of a submergence.

(3) We would also repeat that the objection drawn from the extent of the "bed" proceeds upon an assumption to which we are by no means restricted, that the deposit was all transported by the ice at once or *en masse*.

At this stage we wish briefly to emphasize one of the points alluded to in the minority's Note, viz.: the striking difference between the composition of the shelly clay, and that of the "rough gravel" below and the Boulder-clay above it.

Be it remembered that the whole section rests on that belt of Old Red Sandstone which sweeps along the southern shore of the Moray Firth, from Loch Ness to Fochabers and Buckie. It is surely a remarkable fact that while the stony materials of the deposits between which the shelly clay occurs, consist of from 70 to 80 per cent. of Old Red Sandstone, and only 20 to 30 per cent. of the more ancient rocks (schists, gneisses, etc.) of the neighbourhood; in the clay itself the proportions are nearly exactly reversed—70 to 80 per cent. of the more ancient rocks, and only about 20 per cent. of the Old Red Sandstone! The materials forming the clay have thus been mainly derived from a greater distance than those forming the rough gravel, or "Till," on either side of it. The difference extends even to the sand taken from these separate parts of the deposit. The sand above the shelly clay, and that washed from the coarse gravel below it, is light in colour, consisting mainly of "well-rounded particles of quartz derived apparently from the adjacent Old Red Sandstone." But the sand contained in the shelly clay itself is "dark or dark-grey in colour, and contains much black mica apparently derived from the disintegration of gneissose rocks" (Report, p. 21).

On the theory of a submergence, it seems impossible to explain the sharp intercalation of a deposit of this kind, so thoroughly different from its immediate surroundings.

It has been suggested, indeed, by an esteemed member of Committee, that as the submergence increased the Red Sandstone of the district was all brought under water, and that then the "blue shelly clay," resulting from the waste of the schistose and gneissose rocks that remained exposed, was deposited. This, however, as far as we can see, will not hold good. The bottom of the shelly clay is 487 feet, and its top 503 feet above the sea; whereas the sandstone in the immediate neighbourhood reaches a height of 700 to 1000 feet, and further to the south-west it ascends to 1500 feet. And from that direction the principal flow of sediment into the supposed ocean basin would undoubtedly take place. Therefore, long before the sandstone was completely submerged,—of which, by the way, there is not the slightest independent evidence,—there would be such a depth at Clava as is inconsistent with the prevailing littoral character of the shells. Indeed, the limited extent of shallow shore there could at any time be at Clava, is a difficulty in this respect. Further, on this theory the transition ought to be gradual; as the area of the sandstone narrowed a smaller and smaller proportion of sandstones should appear, till at length the schists predominated. But here the change is sudden and complete at the very bottom of the clay. As the Report says, "The boundary line between the shelly clay and underlying gravel is clearly defined. There is no intermingling of the two deposits" (p. 4). Similarly, the line of junction between the shelly clay and the overlying sand is "clearly defined" (p. 3). There seems thus to have been a sudden and complete change of conditions during the deposition of the shelly clay, not to be accounted for by submergence—not even by a "rapid and brief" submergence, overlooking for a moment the intrinsic improbabilities of such a supposition, and its contrariety to the other facts of the case. For, as Mr. David Robertson remarks in his valuable Report, "the clay seems to indicate deposition in still water, showing no traces of strong currents." There was very little sand in it; 90 per cent. being fine mud or silt. This is not consistent with the theory of a "rapid and brief" submergence. But how, in any case, could there be "still water" and no strong currents here if this were then a shore of the northern sea, and immediately adjacent to, nay, actually swept by, the strong tides and currents that must then have flowed to and fro through the Great Glen? We can scarcely imagine a locality where, during the supposed submergence, there would be less likelihood of "still water" than at Clava.

Thus, the more it is considered the more do difficulties accumulate round the theory of a submergence to this extent, which, besides, there is absolutely no independent evidence to support. And all these difficulties and objections, if real and well founded, are so many arguments in favour of the ice-transport theory, which (as Professor Ramsay admitted with regard to the analogous cases of Holderness, etc.) is the only alternative.[1]

We think we may now claim to have shown that the ice-transport theory, as applied to this Clava deposit, is, on the whole, much more probable than the theory of submergence. This is all that is required to vindicate the position of the minority. They did not undertake to say what was the precise mode in which the deposit was conveyed or accumulated; they merely expressed their opinion, "with all deference," that the submergence theory was not satisfactory, and that the Committee had "not yet reached a solution of the difficulties" connected with the deposit.

Here, therefore, our remarks might end. But the present writer is now prepared, on his own account, to offer a further suggestion which may perhaps lighten the difficulties still felt, in some respects, to exist. We have said that, if transported by the ice, it does not "necessarily follow" that the whole of this deposit was conveyed simultaneously, or *en masse*. Briefly, our idea is that it may have

[1] Phys. Geol. and Geog. of Great Britain, p. 157 (3rd edition).

been conveyed very gradually, and deposited in an *extra-glacial* lake, formed at this point along the side of the ice-sheet, into which part of the materials being carried by the latter (fine mud, rounded stones, shells, etc.) dropped and were accumulated. The great ice-sheet which issued from Loch Ness, and turned eastward along the base of the Monadhliath hills (as it was compelled to do by the blocked condition of the Moray Firth and the North Sea beyond) would not always, or at all points, cling closely to the base of these hills. There are bends and curves, and small lateral valleys, which it would pass straight across, blocking the drainage, under certain conditions, and so forming lakes of the nature indicated.

The physical configuration of the valley at this point bears out the suggestion. Clava is situated right in front of such a bay or recess in the hills as we have spoken of, which may very probably have been barred by the ice-sheet and converted for a long time into such an "area of deposition" as described. This will be seen quite clearly by examining the contour lines of the locality, in any Ordnance Map.

Several of the puzzling features of the deposit may thus be more or less clearly explained. The complete change which would take place when the lake was formed, and while it was being gradually filled up; the accumulations of this thick mass of fine unstratified silt or mud; the rounded and striated stones dropped into the heart of it with scarcely any trace of sand or gravel; the shells, also, of mixed kinds, but chiefly of shore species, occurring in it with a like absence of the ordinary shore débris; the basin-like form of the clay itself, so far as ascertained; the overlying bed of fine sand, indicating a gentle, steady current, or movement of the water, when an outflow was established;[1] and finally, the Upper Boulder-clay, showing a subsequent extension, or change of direction, of the ice-sheet covering up the whole;—the various parts of the section seem to fall into order, and become in some degree intelligible. Various confirmatory particulars might be adduced, on which, however, we cannot at present enter. Meantime we may say with the old Latin poet—

> Si quid novisti rectius istis,
> Candidus imperti; si non, his utere mecum.

We have only to add that, while thus maintaining our ground against such powerful odds, we trust we have written nothing inconsistent with the respect which we have always felt towards Dr. Geikie for his long and eminent services in this department of Geology.

[1] "A velocity of 6 in. per second will lift fine sand, 8 in. will move sand as coarse as linseed, 12 in. will sweep along fine gravel," etc.—Sir J. Lubbock.

IV.—On the Effect of the Glacial Period in Changing the Underground Temperature Gradient.

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In his recent work on "Controverted Questions of Geology" (p. 159), Professor Prestwich remarks that the intense cold of the Glacial period may still be perceptible in the underground temperature gradient; that "to a certain depth the rate of cooling is now abnormally slow, owing to the excessive refrigeration the crust then underwent." The suggestion is a valuable one, and I propose to test it in the present paper by estimating roughly the change which the temperature gradient may have experienced since the close of the Glacial period.

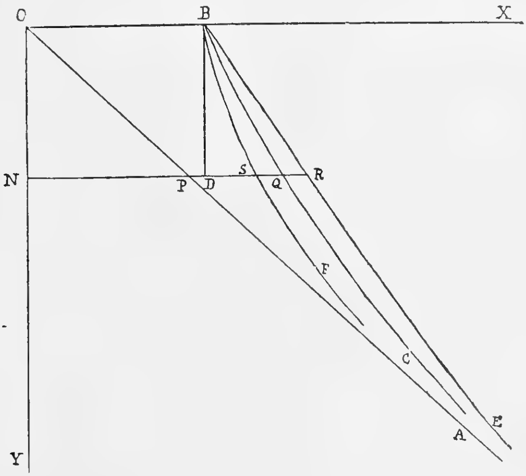
In order to avoid confusion, it may be well to state precisely the meaning which is here attached to the term "temperature gradient." If the temperature increase 1° F. for every 50 feet of vertical descent, the gradient is taken to be 1° per 50 feet or $\frac{1}{50}$° per foot, but not 50 feet per degree. If the gradient in course of time were to change to 1° in 60 feet, it will be said to have decreased, whereas in the latter case it would be said to have increased.

The first point to be determined is the rise of mean annual temperature which has taken place since the Glacial period. The present value of the mean annual temperature in England varies between 45°·6 (Dartmoor), and 51°·9 (Helston), the average over the whole country being 49°·5 F.[1] With regard to the Glacial period, we are concerned, not so much with the mean annual temperature of the air at that time, as, in glaciated districts, with that at the base of the ice-sheet; and this, it is probable, underwent but little change during the whole time the ice-sheet lasted, however intense the cold at its surface may have been. For, if the thickness of the ice exceeded a certain limit, the temperature at the bottom, owing to the rise of the isogeotherms, would be maintained at the melting-point corresponding to the pressure of the overlying ice. With a mean temperature of 0° F. at the upper surface of the ice, and a gradient in the rock below of one degree in 60 feet, Mr. Fisher finds this limiting thickness to be 714 feet.[2] With a gradient of one degree in 50 feet, the limit would be 596 feet. This may, however, be an under estimate, for it does not take the depth of the "surface of invariable temperature" into account. Moreover, while the temperature at the depth of this surface is in rock the mean annual temperature of the locality, it may be less in the case of an ice-sheet whose temperature can never rise above the melting-point, and is therefore incapable of following the oscillations of the external temperature above that point. The effect of the omissions is not, however, very serious, involving indeed in some cases an increase in the above estimate, though not, it may be, a great one.

[1] This is the average of the annual means at 57 stations given by Dr. A. Buchan in his great work on "Atmospheric Circulation," "Challenger" Reports, Physics Chemistry, vol. ii, pp. 196–199.

[2] Phil. Mag., vol. vii, 1879, p. 385.

Considering the low mean temperature assumed to exist at the surface, there is probably no occasion to alter the above estimate of the limiting thickness. But if we double it, and take it at 1200 feet, we shall be well on the safe side; and there is no doubt that for a very long period the ice-sheet in many places attained a greater thickness than this. Now the melting-point of ice is lowered 1° F. by the pressure of every 2730 feet in the vertical thickness of overlying ice, so that the temperature at the base of the ice-sheet may have been as low as 30° or even 29°, but can never under any circumstances have risen higher than 32°. We cannot err very greatly, therefore, in supposing the surface of the ice-covered ground during the whole Glacial period to have remained at a uniform temperature of 30°·5. The subsequent rise of temperature may thus be estimated at 19° F.



All geologists are agreed in attributing a duration of several, or many, thousand years to the Glacial period. If this be correct, the temperature at its close must for some miles have increased almost uniformly with the depth. Thus, if in the accompanying figure O represent a point on the earth's surface, O X a horizontal, and O Y a vertical line, the temperature-curve O P A near the surface must have been almost a straight line, N P representing the temperature at the depth represented by O N, or, rather, the excess of temperature above 30°·5. If O N were taken to represent one foot, then N P would represent the temperature gradient.

Now let us suppose that, at the end of the Glacial period, the mean annual temperature at the surface rose *suddenly* by 19°; and let the line O B represent this amount. Then, at some subsequent time, the temperature-curve would be of the form B Q C, where N Q represents the temperature at the depth O N, the lines O P A, B Q C joining at the point where the change of temperature ceases at the particular time to be sensible. The excess of temperature at the depth O N above that at the surface is represented by D Q, which is obviously less than N P, so that the temperature gradient is diminished at all points to which the heating has become perceptible.

With a further lapse of time the heating effects will have penetrated to a greater depth, and the temperature-curve will have assumed the form B R E. Here, the excess of temperature at the depth O N above that of the surface has increased (D R being greater than D Q); consequently the temperature gradient has also increased, and, continuing to do so, will in time attain a value not differing very greatly from that which it had just before either the close or the commencement of the Glacial period.

Before proceeding further it should be remarked that the inaccuracy of the assumption of a *sudden* change of surface temperature must of course affect all the numerical results hereafter obtained. But, as we do not know the law according to which the rise of temperature took place after the disappearance of the ice-sheet, it seems to me allowable to make the assumption, especially as the provision of *exact* numerical results is not the purpose of this paper. Moreover, if the change were gradual but continually in one direction, the temperature-curve would be of the form B S F, and this would result in a still further decrease of the gradient, so that the change of gradient would in reality exceed that found on the assumption of a sudden rise of surface temperature.

The last element required, and that about which the greatest uncertainty exists, is the time that has elapsed since the close of the Glacial period. On account of the small amount of denudation accomplished, the tendency of opinion has recently been to reduce the estimates of the length of this interval. Prof. Prestwich even puts it at only eight or ten thousand years. The maximum figure is probably that given by Croll of about eighty thousand years.

Under the circumstances, it seems best to calculate the change of temperature gradient for a series of different intervals. In order to give definiteness to the results, I have taken the present gradient at one degree in 50 feet, and, in Table I, have expressed the value the gradient must have had at the close of the Glacial period on the assumptions stated above, for different estimates of post-Glacial time from 5000 to 40,000 years, and for different changes of the mean annual temperature from 16° to 22°.[1]

Thus, if the rise of mean temperature since the Glacial period be 19°, and if the interval since its close be only 9,400 years, the

[1] The calculations are performed as follows:—If b be the rise of mean annual temperature at the surface in degrees, κ the conductivity of rock expressed in terms of its own capacity for heat, t the number of years since the change of temperature took place, then the change of gradient is $b \div \sqrt{\pi\kappa t}$ (Rev. O. Fisher, Phil. Mag., vol. xxxiv, 1892, p. 339). This value, it should be remarked, is independent of the previous gradient. Taking Lord Kelvin's value for κ, namely 400, the above formula becomes $\cdot 02821\, b \div \sqrt{t}$. If $b=20$ and $t=10000$, $b \div \sqrt{t} = \frac{1}{5}$, and the change of gradient is ·00564 degree per foot. But the gradient now is taken to be ·02 degree per foot, so that, at the end of the Glacial period, it must have been ·02564 degree per foot, or one degree in 39 feet.

gradient just before that close must have been one degree in 39 feet; if the interval be 15,000 years, one degree in 41 feet; and if 27,000 years, one degree in 43 feet. Or, again, at the bottom of a mine half-a-mile below the "surface of invariable temperature," *i.e.* about 2700 feet deep, the temperature would be 53° above that at the surface with a gradient of one degree in 50 feet, 68° above with a gradient of one degree in 39 feet, 65° with one of one degree in 41 feet, and 61° with one of one degree in 43 feet. In any case, it follows that the gradient now differs very sensibly from the value it had at the close of the Glacial period.

TABLE I.

Showing Number of Feet of Vertical Descent corresponding to a rise of 1° F. in underground temperature at the close of the Glacial period.

Number of Years since end of Glacial period.	Assumed Increase of Mean Annual Temperature at the Surface.						
	16°	17°	18°	19°	20°	21°	22°
5000	37·9	37·3	36·8	36·3	35·7	35·2	34·8
10000	40·8	40·3	39·9	39·4	39·0	38·6	38·2
15000	42·2	41·8	41·4	41·0	40·6	40·2	39·9
20000	43·1	42·7	42·4	42·0	41·7	41·3	41·0
25000	43·8	43·4	43·1	42·8	42·4	42·1	41·8
30000	44·2	43·9	43·6	43·3	43·0	42·7	42·4
35000	44·6	44·3	44·0	43·7	43·5	43·2	42·9
40000	44·9	44·7	44·4	44·1	43·8	43·6	43·3

The question whether the present gradient retains any traces of the Ice Age depends upon several conditions, such as the mean annual temperature existing before the Glacial period, and the relative lengths of the Glacial period and the subsequent interval. Obviously, this is a question to which it is difficult, perhaps impossible at present, to furnish any decisive answer. If the pre-Glacial mean temperature were the same as it is now, if the glacial conditions commenced and ended abruptly, and if, moreover, the Glacial and post-Glacial periods were of equal duration, then the gradient now would be the same as it was before the Glacial period, that is assuming the normal gradient[1] to have undergone no sensible change during the interval. Supposing the first two of the above conditions satisfied, however, it may be worth while giving a few numerical estimates of the change of gradient depending on different assumptions as to the lengths of Glacial and post-Glacial times. These will be found in Table II, which supposes that the present gradient is one degree in 50 feet, and that the mean annual temperatures were constant during both periods and differed by 19°.

As the general opinion seems to be that the duration of the Glacial period was much greater that that of the succeeding interval, it is therefore possible that some relics of the Ice Age are still to be found in the present temperature gradient.

[1] The gradient due to the temperature of solidification, the surface temperature having remained constant ever since.

A few practical applications of these results may be mentioned in conclusion.

(1) The usual method of finding the average temperature gradient over large areas may be incorrect, unless it is known that all the stations have not recently experienced the effects of a considerable change of mean annual temperature. For instance, the change of gradient in Scotland and the north of England since the Glacial period may be different from that which has taken place in France or Cornwall, and the average of the best determined gradients in these districts is probably not the correct average for the present epoch due simply to the original temperature of solidification.

TABLE II.

Duration in years of		Gradient before Glacial period.
Glacial period.	Post-Glacial period.	
20000	10000	One degree in 46·8 feet
40000	10000	,, 44·1 ,,
40000	20000	,, 46·9 ,,
60000	20000	,, 45·9 ,,
80000	20000	,, 45·3 ,,

(2) Estimates of the earth's age founded on Lord Kelvin's solution and conditions, if derived from a temperature gradient in a recently glaciated district, will err by being too great. For instance, if the duration of post-Glacial time be 10,000 years and if that of the Glacial period were four times as great, the normal temperature gradient at the present time would be nearly one degree in 44·1 feet, instead of one degree in 50 feet. The corresponding value of the earth's age would be about 75 million, instead of about 100 million, years.

(3) Lastly, supposing it in our power to make very accurate observations of underground temperature, it would be possible, by comparing gradients in glaciated districts in the two hemispheres, to determine roughly whether their respective Glacial periods ended nearly simultaneously or at widely different epochs; and thus to obtain some suggestion of the direction, cosmical or terrestrial, in which to look for the origin of the glacial cold.

V.—On the Chalk of the London Basin in regard to Water Supply.

By W. Whitaker, B.A., F.R.S., F.G.S., Assoc. Inst. C.E.

[Reprinted from the Report of the Royal Commission on Metropolitan Water Supply, Appendices to Minutes of Evidence, pp. 433–5 (1893).]

1. Thickness of the Chalk.

Over the area in question the total thickness of the Chalk (where it can be measured from top to bottom, or nearly so) varies from 623 feet at Streatham to 1146 feet at Norwich, and in the latter case the topmost beds are absent; so that the full thickness, in some parts of Norfolk, may be 1200 feet or more. This figure, however, is exceptional, the nearest to it recorded being 890 at Harwich [this should probably be 895, the Glauconitic basal bed having been called Upper Greensand]. At East Horsley, in Surrey, a thickness of 817 feet has been proved, but generally speaking we find less, and over a large area 700 feet is not reached. It seems that the Chalk thins toward London (where 650 feet may be taken as about the usual thickness), not only from north and south but also from east and west. [It may be well to add the thicknesses proved by other borings outside London. These are as follows, where the borings have passed through the whole formation, from the overlying Tertiary beds to the underlying Upper Greensand or Gault:—Loughton 651 feet, Richmond 670, Cheshunt 681, Chatham and the neighbourhood 680–684, and Winkfield, near Windsor, 725. In sundry places where the topmost beds are missing we have the following:—Bushey (Herts) 686, Chartham (Kent) 735, and Coombs (Suffolk) 817, which last-mentioned should probably be over 820, for the same reason as given above, for increase at Harwich.]

2. Divisions of the Chalk.

Of old the Chalk was usually divided simply into Upper and Lower, the former being also known as the Chalk with flints [but the occurrence of flints is not always a safe guide]. Of late years, however, a further division has been made by the splitting up of the old Lower Chalk into Middle and Lower. This last, too, is often again divisible, by the separation of its lower member, the Chalk Marl.

Besides these divisions certain zones have been marked off, but chiefly from the more or less common occurrence of certain fossils in them. These zones, however, need not be noticed now; it is enough to note the divisions that are based on structural features and that occur over large tracts.

The *Upper Chalk* of this great district is marked by the general prevalence of flints, mostly as separate nodules, in layers or scattered; but also in continuous sheets. Often, however, we find a considerable thickness in which flints are very rare. No other peculiar structure is notable in this division; the beds are sometimes thick, sometimes comparatively thin, and usually there are more or less marked planes of jointing.

The *Middle Chalk* is, on the whole, without flints; but sometimes a few flints are found in it toward the middle part. It is thick-bedded and jointed. Its top is generally shown by the presence of hard beds, consisting of cream-coloured crystalline limestone where well developed, and with green-coated nodules. This is known as the Chalk Rock, and is often to be seen in Hants, Wilts, Berks, Oxon, Bucks, Beds, and Herts. It is less clear in Essex and Cambridgeshire, has not been noticed in Suffolk, and but one section is known in Norfolk. In Surrey and Kent, though no bed with the distinct lithological character of the Chalk Rock has been seen, yet microscopic investigation proves that it is represented. The bottom of the Middle Chalk, again, is defined by beds of hard chalk, known as the Melbourn Rock, of a more distinctly bedded character than the chalk above, and having usually a nodular structure and sometimes a brecciated one. As far as our work in dividing the Chalk has yet gone, this bed is proved to be of constant occurrence, though varying in its amount of distinctness. [Since this paper was written, it has been found that the Melbourn Rock is absent in the far west, in Devonshire.]

The *Lower Chalk* is distinguishable from the Middle Chalk by the much thinner character of its beds, the planes of bedding being sometimes emphasized by marly partings [especially in the Belemnite Marl, which next underlies the Melbourn Rock]. It is often slightly clayey, and the Chalk Marl is sometimes particularly so. This lowest member is in places separated fairly sharply from the rest by a third hard bed, the Totternhoe Stone, a gritty, brownish-grey, firm bed. There are no flints in the Lower Chalk of the London Basin.

Any attempt to divide the Chalk into White Chalk and Grey Chalk is, I think, inconvenient. Colour is generally a very bad guide in making stratigraphic divisions, and the greyness of chalk sometimes depends on its dampness rather than on any inherent colouring. Moreover, the term Grey Chalk has been used in so varying a way as to have become confusing. Sometimes it has been limited to the Chalk Marl; sometimes it has been used for the whole of the Lower Chalk; now Prof. Dawkins seems inclined to include the Middle Chalk also under this head. In the first two cases the term is simply a synonym, and therefore useless; in the last it joins together two divisions which are distinctly separable, and is therefore worse than useless.

As the divisions, Upper, Middle, and Lower Chalk, have been mapped, more or less completely, by the Geological Survey, in the London Basin, from Hants and Wilts through Berks, Oxon, Bucks, Beds, Herts, Essex, Cambridgeshire, and Norfolk (partly), and also outside the London Basin, in parts of [Devon], Somerset, Dorset, Wilts, and Hants, and all through Sussex, I think that they may be accepted as practical.

3. Flow of Water in the Chalk.

The passage of water through the Chalk occurs in three ways.

(1) Through the pores of the rock. As these are very small, sometimes indeed practically closed, this is of course a slow process, and results, in underground work, merely in the weeping or oozing out of water from the cut surfaces. Nevertheless, there may be exceptional cases where, from greater openness in the rock, a greater quantity of water may pass through.

(2) Along planes of bedding, or the originally horizontal layers of which the Chalk is built up. Sometimes the passage of water along these planes is insignificant, but sometimes it is very marked, and this naturally occurs where the bedding is more definite or somewhat open, as along layers of flints. Where, too, marly layers occur, their more impermeable character, as compared with the rest

of the Chalk, is likely to cause a flow of water; so also may an alternation of more open with more compact rock.

(3) The chief means of water-communication through the Chalk is by the more or less vertical fissures that occur, either along planes of jointing (structural planes produced after solidification, and not connected with bedding), or more rarely, along faults or cracks. Joint-planes are universal in the Chalk and mostly very plentiful, though often they are so closed as to allow the passage of but little water. They can readily be seen in pits, and it is generally found that the chief ones have a more or less definite direction over large tracts, a good example of this being given by the highest Chalk of East Kent, in which the chief joint-planes run in a north-westerly and south-easterly direction, as is the case also near Grays, in Essex. The planes of master-jointing are connected by other planes running across them.

In underground work it is sometimes found that the chalk is affected by a great number of these joint-planes, none being open, and each giving passage to only a small quantity of water, though the result of the whole may be very satisfactory. In other cases a long extent of chalk may be passed through with but very slight result as regards water-yielding fissures, and then a large fissure may be suddenly struck and a great quantity of water found.

It is very likely that in many of the swallow-holes (which will be described in a separate paper) the water enters the Chalk at a fissure or crack, in fact along a plane of weakness.

The above remarks refer to the ways in which water gets downward into the body of the Chalk; it may be well to consider its more horizontal course toward the parts where it finds an outflow in springs.

The fissures alluded to naturally form a means of communication, not only more or less vertically downward, but also lengthwise along their course, from the higher to the lower grounds.

The same, too, would be the case with planes of bedding, where they are fairly marked; but it has occurred to me that sometimes too much may have been credited to bedding-planes in this matter. From the fact that the Chalk dips inward, from its generally lofty escarpment to the lower ground formed by the margin of the Tertiary Basin, and that therefore the dip-slopes of the Chalk form by far the broadest parts of the outcrop, it follows that the water in the Chalk would have a general flow in that direction, or inward to the central part of the Basin. This flow in the direction of the dip is, of course, subject to lateral change, where valleys are cut through the Chalk to some depth, and an outlet for water is made.

When, however, we examine other smaller tracts, where the slope of the surface does not go with the dip of the beds, we find a wholly different state of things. The one constant and recognized exception is the face of the great escarpment, that is the outward and generally abrupt slope of the Chalk; the crest of the escarpment forms a watershed, and the underground water flows outward, in the direction of the slope, which is the reverse of the dip. The many springs that occur at or near the foot of the escarpment are proof of this flow.

In the more exceptional cases where the escarpment is not a simple ridge, but a double one, the two ranges some way apart (as near Luton), there is a greater area subject to this flow against the dip, and still more so is this the case where, instead of the usual bold abrupt ridge, we have a more gentle and therefore a broader slope (as in Norfolk); so that over a tract some miles in width the plane of saturation will slope in a direction opposite to the dip.

Another marked exception is given by a range of sea-cliffs, where this runs along the dip, or at no very great angle with the direction of the dip, as on the coast near Dover, in which case the water finds a ready outlet along the free margin formed by the cliffs, and takes a shorter course more or less across the dip, instead of a longer one following the dip.

In short, the underground flow depends generally on the surface-contour; the water can generally flow across the bedding when it can more speedily reach an outlet by such a course.

4. Relation of the Structure and Position of the Chalk to Water Supply.

Turning now to the bearing of the different divisions and of the various structures of the Chalk on the question of water supply, we find, in the first place, that the greater part of the area of outcrop is formed by the Upper Chalk, which, rising up from beneath the Tertiary beds, reaches right on to the top of the great escarpment, or bounding-ridge, except where cut through by valleys, which lay open lower beds. Where the escarpment is all in one, as is commonly the case, and is abrupt, it follows that the outcrop of the lower divisions is narrow, very narrow as compared with the broad tract of Upper Chalk inward from the escarpment. This division, too, is the thickest of the three.

The Upper Chalk, therefore, must be the great gathering ground for water; and, as the water sinks downward to low levels, to the boundary of the Tertiary beds, so that the plane of saturation comes near to, and sometimes up to, the surface of the ground, it follows that, as a general rule, this division must be the great water-yielding one, and that works for vast supplies, over most of the area in question, must be established near the outcrop from beneath the Tertiary beds, where the plane of saturation, though near the surface, is at a low level, so that underground water tends to flow down to such works and to replace that pumped out from them.

It seems to me that the place taken by the Upper Chalk as the great water-bearing bed may, perhaps, be owing to its favourable *position* rather than to its structure. There is nothing, as a rule, to prevent water sinking down through the Upper into the Middle Chalk, and we find that at high levels, toward the escarpment, the former is dry, its base being above the plane of saturation, which sometimes may be very far down in the latter. In its frequent layers of flints the Upper Chalk may have some advantage over the Middle Chalk, in regard to the flow of water inward from the higher grounds; but probably these also sometimes act as a hindrance to the downward sinking of water in the rock. In the matter of fissures there may be little difference between the two divisions, and the Middle Chalk suffers from having mostly a far greater mass of other beds over it, which would tend to close its fissures.

The Chalk Rock, which forms the top surface of the Middle Chalk, where well developed, is favourable to the passage of water along it, being usually markedly jointed, and so, *when below the level of saturation,* is often a water-yielding bed; but when above that level, there is nothing to stop its being dry.

Where the escarpment forms a long gentle slope, as in Cambridgeshire and Norfolk, the outcrop of the Middle Chalk is fairly broad, and much water must sink through the rock and find its way out in the springs on the westward slope.

Where, too, the outcrop of the Middle Chalk, though usually much less in width, is cut back by valleys that breach the upper part of the great escarpment, as is the case with the valleys of the Lea (in Beds), of the Gade and of the Bulbourn (in Herts), of the Misbourn and of the Loudwater (in Bucks), of the Thames itself and of the Lambourn and of the Kennet (in Berks and Wilts), there, again, much water is collected by this division, and many springs issue from it, and feed the Thames by its various tributaries.

The Melbourn Rock, at the base of the Middle Chalk, is sometimes water-bearing, by reason of the bed next below (known as the Belemnite Marl) being mostly of a rather clayey character; so that, under favourable conditions, it may delay the downward passage of water.

The Lower Chalk, being generally more clayey than the upper two divisions, is less free to the passage of water. Moreover, its outcrop is mostly narrow, and it is not laid open along valleys as the Middle Chalk often is. Circumstances, therefore, are clearly against this division in the matter of water.

There are, however, places where, from favourable conditions arising, much water occurs in the Lower Chalk, and three special cases may be noticed, the more so as they have largely to do with the lowest and usually the most clayey part of the division, the Chalk Marl.

(1) In Bucks, Beds, Herts, and Cambridgeshire, there is, at the top of the Chalk Marl, a marked hard bed, of a somewhat gritty character, known as the Totternhoe Stone, which is permeable. As the water sinking into this, either directly or through the overlying chalk, is stopped in its downward course by the more clayey beds below, springs are of frequent occurrence along the line of outcrop of the stone.

(2) In Bucks there is sometimes a hard permeable bed in the Chalk Marl, which also gives rise to springs.

(3) In Western Norfolk the Chalk Marl loses its clayey character, and passes northward into hard jointed chalk. The Lower Chalk as a whole, too, is harder than usual, and more permeable. The result is that powerful springs occur either at the very base of the Chalk or some little way above it, and are probably the best source of local water supply.

A case in point is the supply of Wisbech, together with many villages in the Fens, from a spring that breaks out at the edge of the Fen in the valley of the Nar, at Marham, some seven miles south-eastward of Lynn.

Of fairly large supplies got from beds below the Upper Chalk, in the Basin of the Thames, Luton and the Chiltern Hills Waterworks (near Tring) may be mentioned. Several smaller towns, too, depend on the same beds, along the northern outcrop of the Chalk. On the south the outcrop of the lower beds is narrower, but various wells have been carried through the Upper Chalk to these beds, as in the case of the Kenley and Caterham Waterworks. Maidstone gets a great part of its supply from Lower Chalk springs, and Folkestone gets the whole.

As a general rule there is more or less communication downward through the Upper and Middle into the Lower Chalk, so that the water in the Chalk may usually be treated as a whole. Nevertheless there are cases where, from the occurrence of less permeable beds in the Chalk over certain tracts, there may be independent supplies at various depths, and cases in point have been alluded to above, with regard to the Melbourn Rock being underlain by clayey beds, and to the Totternhoe Stone as a local water-bearing bed. There seem, too, to be cases, even in the midst of the Upper Chalk, where, from the occurrence of more compact beds at certain depths, there is some division in the water; and again, where strongly marked joint-planes are of rare occurrence, but fairly open where they occur, we may have lateral division in the water flowing through the Chalk, and this water may therefore take the form of more or less defined and separate underground streams.

In conclusion, I would point out that though there are *general* rules as to water in the Chalk, these must not be taken as *universal*: we must be ready for exceptions, and sometimes for great ones. To give what may be called a political illustration—whilst there are imperial laws regulating the conduct of water in the Chalk kingdom, yet the various provinces of which that kingdom is composed need special legislation of their own: rules that hold in one province may not accord with the manners and customs of another [and the same holds for still smaller districts]. In short, it is a case not only for Imperial but also for Local Government.

NOTICES OF MEMOIRS.

Geological Society of South Africa.

I.—Inaugural Address by the President, Dr. Hugh Exton, F.G.S.

After some congratulatory remarks on the installation and progress of the Society, Dr. Exton referred to the interesting studies to be made in various branches of Natural Science, including particularly Anthropology and Geology. The pioneers of Geology in Africa, Mr. A. G. Bain, Mr. Wylie, and Mr. Stow, had opened the way to the solving of many interesting problems, such as the origin of the great bed of breccia crossing the continent, known as the Ecca, or Dwyka Conglomerate, and the formation of the great valleys dividing the wide areas of Karoo strata, some of the latter comprising rich Diamond-fields and valuable Coal-fields. Still further, the consideration of the nature and origin of the backbone of the Cape country and the Transvaal, whether granitic or quartzitic, often highly auriferous, offer grand opportunities for geological explanation and discussion. Nothing in the known world approaches the banket reef of Witwatersrand, either in the area of country through which it extends, or the average uniformity in its mineral richness. If we consider that within the past twelve months there has been an output of gold to the value of seven millions sterling, and when we see from the working of new companies, and from the more scientific methods of treating the ores, that this output is steadily increasing, we may feel confident that these gold-fields form a centre to which the whole civilized world is looking with profound admiration and eager expectation.

"But there is another factor in connection with the gold-mining industry which we accept too readily as a matter of course, and that is the coal supply, not considering the utter impossibility of working the mines without the steam-power generated by coal; since the supply of wood for fuel (which was used in the early days of the Rand) not only failed to keep pace with the growing demand, but by its great expense stopped the development of the poorer mines, and threatened to render the cost of production in the richer mines greater than the value of the gold obtained. So far back as 1854 Dr. Sutherland directed attention to the existence of coal in Natal. Mr. Dunn's observations, made on behalf of the Colonial Government, were published in 1879, the chief results of which consisted in establishing the relation of the Ecca beds and Karoo series to the coal-seams of the Cape Colony. Indeed, up to 1883, so little had been done by way of proving the existence of workable coal-seams that Professor Green, in his Report to the Colonial Government, recommended that 'suitable rewards should be offered for the discovery of coal as likely to be attended with useful results.' Active search has resulted in discovering the existence of coal at various points over a wide extent of country. It is, of course, of the highest importance that coal should be free-burning and have the property of giving out heat; and these qualities are acknowledged to have been deficient in the coal obtained from seams first opened out in the colony. Professor Rupert Jones has summarized the reports of Mr. Dunn, Mr. North, Professor A. H. Green, and others, who all agree in attributing the deposits of coal to vegetable matter subsiding in fresh-water lakes. The absence of marine fossils was also noted by each observer. Subsequent flooding of such lakes by currents bearing sand and mud would account for the shales with which the coal is so plentifully interstratified. Evidence of the coal having been formed from drift vegetation lies in the absence of an underclay beneath the coal-seams, such as is generally found below European and American coal-beds, and in which the roots of *Stigmariæ* and other plants are to be found. According to the observations of Mr. Draper, the coal now being worked at Vereeniging, by Messrs. Lewis and Marks, has a soft layer of whitish clay underlying the coal; but, as if to prove the futility of applying general theory to each particular case in South African geology, this underlying clay is apparently a decomposed sheet of dolerite, which had intruded below the coal, and, in many parts, penetrated into it, changing the coal into coke in the neighbourhood of the intrusion, and giving it more the nature of anthracite throughout its area. The endeavour to establish a geological horizon for the coal-beds in South Africa has not hitherto led to much practical result. We have Professor Seeley's recent opinion that coal must not be looked for below the strata containing the remarkable characteristic fossil reptilia. Further, we have Mr. Stow's original deduction that coal would be found from 70 to 150 feet below the silicified tree-stems which he traced over a large area in the north of the Cape Colony, and over a still greater extent in the Free State, and which he termed the forest zone. . . . . . Mr. Stow's prediction that the coal would be found to crop out on the north-west of his forest zone has since been abundantly verified at the Vaal River. Nothing like a true Carboniferous system has yet been made out for South Africa; and though ferns, such as *Glossopteris*, have been found, this and some others are looked upon as survivals of Carboniferous plants into Jurassic times."

After some observations on the Coal-beds in the Stormberg and at Lake Nyassa, of the same Karoo series, Dr. Exton concluded with an exhortation to geologists to lose no opportunity in elucidating the many interesting and, indeed, most important problems lying at their feet in the subterranean strata, and before their eyes in the many and varied escarpments of hills and mountains around them.

II.—Glacial Progress. By Captain Marshall Hall, F.C.S., F.G.S.

[From the "Alpine Journal," No. 128, May, 1895.]

SINCE the appointment of the Sub-Committee upon Glacier Observations[1] sufficient time has not yet elapsed for many exact data to have come to hand, with one very brilliant exception—that of New Zealand.

Amongst the explorers of the Southern Alps are men not only mountaineers, but who are also greatly interested in these problems, shrewd observers and efficient officers of the New Zealand Survey. We have the novelty of new excursions, combined with the determination of a series of positions upon which to found future measurements, and all this in mountain ranges till recently scarcely known. The writer will give a summary of this work (with great conciseness, the result of instructions he has received). In the

[1] Geol. Mag., 1895, March Number, p. 144.

absence of key maps, he omits tables, which would not be understood without diagrams of the various localities.

In the year 1892 an exploration was made in the hopes of finding some practicable route for a road from the west coast, Middle Island, New Zealand, across the main range to "The Hermitage." Although this object was not completely attained, materials for a survey of the country were collected, and a map by Mr. C. E. Douglas, explorer, Westland, is published in the Report for 1893 of the New Zealand Surveyor-General, as also a sketch of the geological formation of Copland District and sundry inspiring views of glaciers and peaks. Messrs. Douglas and Cuttance describe the Copland, Lyttle, Strauchon, and Cuttance glaciers amongst other features of the scenery.

In the Report for 1894 Mr. Douglas gives an account of a survey of the Westland Alps, with the assistance of Mr. A. P. Harper, from November, 1893, to April, 1894. On this expedition a satisfactory triangulation was carried up several glaciers. In the case of Franz-Joseph Glacier, points in its neighbourhood and on the ice itself were determined in sufficient number to afford data for estimating its future movements and bulk. This will serve as a typical glacier on the north-west side of the range. Its "snout," 692 feet only above the sea, is but four miles distant from the beach, in lat. 43° 25′ 30″ S., and long. 170° 10′ 58″ E. It has made great winter advance and summer retreat. Débris from lateral ranges have lodged in crevasses of the higher layers of ice, which further down have become the lower layers, the upper ice pushing over the lower,—as is exemplified in photographs to be found in the library of the Alpine Club—showing itself in alternate clear and dirty ice. The upper ice overlaps and breaks off at the terminal face, as also shown in the photographs. Other illustrations and maps will be seen in the Survey Report for 1894, together with a text full of interest. Over one matter the writer has been much exercised. Mr. A. P. Harper gives, at page 77, a table of rates of ice movement during his stay. An average of his figures at different stations gives the daily rate as 154·2 inches. But five other entries are so different, being 5″, 30″, 53″, 23·6″, and 7·28″, that to strike a mean of these figures would evidently mislead. They refer to distances from the sides of the glacier. At page 73 Mr. Douglas makes a statement of considerable interest to students of ancient glaciers. He says: "In valleys containing large glaciers I have always found four tiers of terraces, or old ice-lines, as if there had been four distinct periods. These lines keep a wonderfully regular distance from each other, and their inclination is very uniform, from, say, 4000 feet to 600 feet or 700 feet. . . . . The larger the valley the more gentle the slope."

Mr. T. N. Brodrick, C.E., sent a paper, accompanied with four maps, to the writer. The most important part of Mr. Brodrick's work is a triangulation and survey carried up the Mueller glacier, during which were determined, not only the position of stones on the ice relatively to stations on the huge lateral moraines, but the distance and bearings of many such blocks *from each other.* These positions were first fixed on March 29, 1889, re-determined November 14, 1890, and again December 3, 1893. The measurements so far showed (what has been found elsewhere) that the sides move more slowly than the centre; that the ice moves more slowly as it approaches the terminal face; that the current is varied by surrounding circumstances, such as bends of the glacier and, probably, the unevenness of its bed.

Its daily rate is not constant; a comparison of the rate for 1889–90 with that for 1890–93 shows a decrease of speed during the latter period. Here we ask, how as to *bulk* in those years? Fluctuations of the terminal faces of the Tasman and Mueller glaciers have been constantly remarked, but changes have not lasted sufficiently long to show if the ice be retreating or advancing. Captain Hutton, F.R.S., President of the New Zealand Alpine Club, states that about 1882 the Mueller glacier reached over the Hooker River to the side of Mount Cook, and sheep were taken over on the ice. Traverses were made of the terminal faces of the Tasman in November, 1890, and of the Mueller in March, 1889, and November, 1890. Mr. Brodrick says that the Hooker River so modifies the contour of the Mueller that the experiment has failed to demonstrate short changes satisfactorily, though these traverses will no doubt be of interest in the future. During a recent period all the Canterbury glaciers appear to have been in retreat, but latterly, and for a number of years, to have been stationary.

There is no evidence of ploughing up the earth and leaving it in ridges, and falling stones are in great measure stopped by lateral moraines, and do not reach the ice. Mr. Brodrick gives tables of rates of motion, and one of the areas of six glaciers, together with that of the sources of supply, as regards *névé*.

REVIEWS.

THE SEISMOLOGICAL JOURNAL OF JAPAN. Vol. IV, 1895 (corresponding to vol. xx of the "Transactions of the Seismological Society): Edited by Prof. J. MILNE. pp. xxi + 367.

Contents: A Catalogue of 8331 Earthquakes recorded in Japan between 1885 and 1892, by Prof. John Milne, F.R.S., F.G.S.

MANY of the preceding volumes of this well-known series may have possessed a wider interest, but few, if any, are of greater value, or will more profoundly influence the progress of seismology, than that which is now before us. This evidently is a work which is neither to be "tasted" nor "swallowed," nor even to be "chewed and digested." It is intended for those who make books, not for those who read them. It will be the parent of many papers. For in these somewhat unattractive-looking pages are gathered materials for the harmonic analyzer and facts for the student of terrestrial evolution. Only the labour is required, and that will soon be forthcoming, and we shall know something about the laws which govern the distribution of earthquakes in space and time, at any rate in the country where they have been most widely and successfully studied.

More than nine-tenths of the volume is occupied with two great catalogues. In the first of these we find the time of occurrence of every earthquake, the extent of *land*-area shaken, and figures which by reference to an index-map give the approximate position of the epicentre and the boundary of the disturbed area; in the second, the lengths of the axes of the disturbed area (thus giving the *total* area), the distance of the epicentre from the shore when submarine, and the seismic district to which the earthquake belongs. The importance of the catalogues will be evident from this brief summary.

In the prefatory pages, Prof. Milne gives an account of some of the first results which have been derived from a study of these materials. Mr. Omori has investigated the distribution of after-shocks in space and time, and has already published an important memoir on the subject (see "Natural Science" for June). On a reduced index-map, the distribution of seismic centres in Japan is clearly exhibited. From this we learn that the central portions of the country are remarkably free from earthquakes, and it is interesting to notice that these are the very districts where mountains and active volcanoes are prevalent. The greater number of earthquakes originate along the eastern coast of the empire, from the face of the steep monoclinal slope which Japan presents towards the Pacific Ocean. The chief anticlinal axis of the island runs N.N.W. and S S.E., and, from the southerly prolongation of this axis, earthquakes from time to time originate. Again, along lines of great slope (1 in 20 to 1 in 30) earthquakes are frequent, while they are rare where the slope is gentle; and they are numerous in those districts where there are evidences of secular elevation or depression. A map has also been drawn, though not published, which shows the distribution of earthquakes accompanied by sound. Generally, it appears, sound is heard in rocky mountainous districts, while on the alluvial plains it is but rarely observed.

Several of the Japanese earthquakes have been propagated as far as Europe, and have been recorded by horizontal pendulums. Dr. E. von Rebeur-Paschwitz, who has studied the records of these instruments with great ability and success, contributes a list of 301 seismic disturbances recorded by them in different parts of Europe and at Teneriffe. At least seven of these disturbances were due to Japanese earthquakes. The preliminary tremors are estimated to travel with a surface-velocity of 12 km. (about 8 miles) per second, while the larger oscillations follow at a much slower rate. What is the true nature of these remarkable movements, how they travel—whether in straight or in curved lines, whether along the surface or right through the interior of the earth,—these are the new problems which are set before seismologists to solve, and to which their attention is now being closely directed. C. Davison.

REPORTS AND PROCEEDINGS.

Geological Society of London.

June 19th, 1895.—Dr. Henry Woodward, F.R.S., President, in the Chair.

Mr. Whitaker called attention to the two new Survey maps of the Bournemouth district. In the map without Drift it would be observed that the boundary-lines were more detailed. In the map with Drift much new work had been incorporated—in fact, the Drift-lines were wholly new. The work had been done by Mr. C. Reid.

The following communications were read:—

1. "On the Occurrence of Radiolaria in Chalk." By W. Hill, Esq., F.G.S., and A. J. Jukes-Browne, Esq., B.A., F.G.S.[1]

The authors notice the rarity of records of Cretaceous Radiolaria, and allude to those which have been made, including those by Rüst and Sollas. They have recently discovered spherical bodies resembling in form and general appearance certain calcified and partially destroyed radiolarian tests from some of the Barbadian rocks; microscopic examination of these has proved that many of them, at any rate, are Radiolaria. They occur in the nodules of the lower beds of the Melbourn Rock, at Melbourn, Royston, near Hitchin, Leagrave near Luton, Pitstone and Tring, Watlington, the Richmond boring, the lower part of the "Grit Bed" at Dover, Sutton Waldron and Burcombe (Dorset), and in a nodular chalk which may be considered as the equivalent of the Melbourn Rock from Bindon Cliffs, near Axmouth, Devon. Similar organisms have recently been found in the Chalk Marl of Lincolnshire, Yorkshire, and Norfolk, but have not been noticed in any other parts of the Chalk. It is suggested that they occurred in many portions of the Chalk-ooze, but were usually rapidly and completely dissolved, and contributed to that solution of silica which furnished the substance of flint-nodules; and the authors conclude that the preservation of traces of the Radiolaria in the nodules of the Melbourn Rock is due to some specially favourable conditions.

A description of the changes undergone by Barbadian Radiolaria is given to illustrate the instability of radiolarian tests. Here all stages are traceable, from the perfect siliceous test to a structureless ball or disc filled with calcareous matter, or a mere patch of clear crystalline material.

A description of forms recognized in the nodules of the Melbourn Rock is given.

2. "The Crush-Conglomerates of the Isle of Man." By G. W. Lamplugh, Esq., F.G.S.; with an Appendix by W. W. Watts, Esq., M.A., F.G.S. (Communicated by permission of the Director-General of the Geological Survey.)

The Skiddaw Slates of the Isle of Man have everywhere undergone intense shearing, and on the north-west side of the main stratigraphical axis actual disruption of the bedding with the resultant formation of breccia or crush-conglomerate on a large

[1] See also paper by Mr. G. E. Grimes on Radiolarians in the English Chalk, *ante*, p. 345.

scale has taken place. This structure attains its widest development on the north side of the central valley, though it is noted on a more limited scale in a few localities farther south. It is well exposed in the cliffs three miles north of Peel, but the finest sections are in the interior in Sulby Glen, where the structure has a thickness of some hundreds of feet, and runs continuously about north-north-east for five miles, with a probable extension southward for three miles farther, and also eastward for other four miles. It is usually flanked by gritty flags on one side, and by dark clay-slates on the other. It is affected by a strain-slip cleavage later than the brecciation, and several igneous dykes which intersect it are affected by the same cleavage, though not by the brecciation-movement.

East of Sulby Glen the structure extends towards Ramsey, at first in a horizontal spread over a mile in width, and afterwards in a series of comparatively narrow subparallel bands; and it is suggested that we are dealing here with the emergence of a deformed plane. The structure is continued eastward into the hill overlooking Ramsey, beyond which it is cut off by the sea. In this locality, as elsewhere, the sections show the gradual smashing into fragments of highly contorted strata until every trace of the original bedding is lost, and a "crush-conglomerate" with lenticular and partly rounded inclusions is formed.

The rocks described in Mr. Watts' Appendix are grouped in four classes. Firstly, the grits and slates which have been crushed but have not been converted into crush-conglomerates; secondly, the crush-conglomerates themselves, and the fragments which they contain; thirdly, the dykes of decomposed dolerite (greenstone) and fresh later dolerite which penetrate the conglomerate; fourthly, a portion of the crush-conglomerate metamorphosed by these intrusions.

The chief point of interest is brought out by the examination of the fragments in the conglomerate. All stages of crushing may be traced, until the grit-fragments have a structure which is a mere miniature of the crush-conglomerate itself; that is to say, if the crush-conglomerate be regarded as made of "fragments" of hard rocks enclosed in crushed "matrix" of soft rocks, a host of intermediate varieties with varying resistances will occur. Whether any particular one of these varieties shall pass into "fragments" or "matrix" under the crushing will depend upon the amount of the crushing force and upon the association (paragenesis) of the material brought together to be crushed.

3. "The Chalky Clay of the Fenland and its Borders: its Constitution, Origin, Distribution, and Age." By Sir Henry H. Howorth, K.C.I.E., M.P., F.R.S., F.G.S.

The distribution of the Clay (so often termed Chalky *Boulder*-clay) is noticed, and it is stated that it is surrounded on all sides by country occupied by different deposits, being mainly separated from the sea on the east and north-east by sandy and pebbly materials, while on every other side it is clearly and sharply defined. The paucity of foreign stones is noted as compared with natives, and the similarity of the matrix of the Chalky Clay to the material of the older deposits of the neighbourhood. The author maintains that the contents of the Clay indicate movement of material from west to east in some places, as shown by Jurassic fossils in the East Anglian Chalky Clay, and from east to west in others: in fact, that movement took place in sporadic lines diverging from the Wash and the Fens. He appeals to the amount of disintegration that has taken place to furnish the material for the Clay, the shape of the stones in the Clay, and the distribution of the Clay itself, as evidence against the action of land-ice or icebergs, maintaining that there is no evidence of submergence at the time the Clay was formed; and criticizes the attempts made to explain the formation of the Clay by water produced by the melting of ice.

The author believes that the denudation of the Fen country which produced the great mass of the Chalk Clay with most of its boulders was coincident with and caused by the bending and folding of the Chalk of Eastern England, which took place after the deposition of the Crag beds, and that during the period of folding a great depression was formed round the Wash, into which the water rushed from the North carrying débris and mixing it with clays; this, rushing into what was virtually a *cul-de-sac*, dispersed and scattered its load in all directions.

4. "On the Occurrence of *Spirorbis*-Limestone and thin Coals in the so-called Permian Rocks of Wyre Forest; with considerations as to the Systematic Position of the 'Permians' of Salopian type." By T. Crosbee Cantrill, Esq., B.Sc. Lond. (Communicated by Walcot Gibson, Esq., F.G.S.)

In South Staffordshire a thick series of red rocks—the so-called Lower Permian—overlies the ordinary yellow and gray Coal-measures, and underlies the Triassic rocks. They consist of sandstones, marls, calcareous conglomerates, and breccias, having a general red or purplish-red colour.

Since Jukes' work was published, fresh sinkings have shown that these red rocks must be regarded as of Upper Coal-measure age, because their included fossils have an Upper Coal-measure *facies*. The rocks contain bands of limestone characterized by the presence of *Spirorbis pusillus*: those parts of the series which have not yielded Coal-measure fossils are apparently similar lithologically to those which have yielded them; there is no stratigraphical break between the fossiliferous and unfossiliferous parts of the red series, and the only marked breaks are at the base and summit of the series, the break at the base being locally great but elsewhere practically imperceptible.

The evidence furnished by the deposits of the Forest of Wyre (= Enville) district also leads the author to regard the red rocks associated with *Spirorbis*-limestone and coals as Upper Coal-measures, exhibiting a gradual passing away of Coal-measure conditions and the in-coming of those of New Red Sandstone times; and these passage-beds must be regarded as much nearer the Coal-measure than the Permo-Triassic end of the transitional period.

So far as our present knowledge goes, the so-called Permian rocks of Anglesey, Denbighshire, Lebotwood, Shrewsbury, Coalbrookdale, Wyre Forest, South Staffordshire, Warwickshire, Leicestershire, and North Staffordshire are all essentially similar; and observers are urged to look out for Coal-seams, plant-remains, and *Spirorbis*-limestones.

[The next Meeting of the Society will be held on Wednesday, November 6th, 1895.]

CORRESPONDENCE.

NATURE AND ART.

Sir,—It has been suggested (and the belief is held by many) that the asserted flint implements of the Chalk Plateau of Kent may be divided into two groups—one (A) in which the presumed work is referred to the *agency of nature*, and is therefore non-existent so far as human agency is concerned; and the other (B) of which the work is admitted, but is asserted to be that of Palæolithic Man, and not therefore belonging to a still older race of Man, to which on geological grounds I have assigned them.

B.—It may be admitted as not improbable that some of the more highly finished implements found on the plateau (if not made by the more skilful workman of Eolithic Man) may have been the work of Palæolithic Man. But the mere circumstance of their being found on the same surface with the plateau implements proves nothing, as flint implements of undoubted Neolithic age are likewise found frequently associated with the older plateau as well as with Palæolithic implements on the same surfaces. Further, in a pit dug for the Committee of the British Association by Mr. Harrison, several plateau implements were found in a bed of clay and flints at the depth of six feet from the surface, but no implements of the Palæolithic type were met with there. We may presume, therefore, that the association of implements of different ages on the surface is accidental, and does not always prove that they are contemporaneous.

With respect to the other question (A), I am at forced issue with those who would ascribe any of the forms of the rude plateau flints to any natural agency, such as, for example, as has been suggested in explanation of one form—that of the action of the waves on the shore, or of river-action; and there can be no other. Angular pieces of limestone put into a mill come out rounded marbles. In like manner the sharp angular fragments of flint exposed to the beating of the waves soon lose their sharp angles and become gradually more and more worn, until eventually they are transformed into rounded shingle, such as that which may be seen on Blackheath Common and at Bickley station. No other result is possible. This fact must have been brought home to many who have lounged pleasantly on the sea-beach at Brighton or Dover, but who would not find a bank of plateau flints with their sharp angles and many points, so well fitted for that purpose. Had it been possible for sea- or river-action to have produced such forms as those I have figured in plates v to ix of "Collected Papers," they should be found in all such shingle of whatsoever age. None are forthcoming.

If the waves had possessed that power, we should not need to go beyond our beach-girt southern shores or our numerous river-gravels. Challenged long ago to produce an implement of the true plateau type from a recent beach, the only specimen that has been put forward as such is one from the beach at Aldborough. I have examined this specimen carefully. It is a *naturally* split pebble of the Westleton pebble beds, of which there are millions, *entire* and *split*, on the adjacent shore. These, in fact, constitute a very large proportion of the beach itself, and those of them which happened to be split have had their edges chipped and blunted by the pounding they have undergone on the shore, so that to that extent they resemble the one plateau specimen figured, fig. 4, pl. ii, in the work before mentioned, with the essential exception that whereas the latter often retain the sharp edges which adapted them for scraping, in the former the edges, which are also worn and blunt, were never suited for that purpose. It is, in fact, one of those natural flints which *simulate* in general outline a worked flint, and in this case I am willing to admit that the simulation of this one simple form of the plateau flint is very good and very deceptive. Scores of such natural forms, imitating even the well-defined shapes of the lance-head Palæolithic implements, have been found in gravel beds.

However, to put the matter to another test, I again repeat the former challenge, and am ready to exchange the two volumes of my "Geology" with any young (or old) dissentient, for half a dozen shore flints (not derived) of any of the plateau types figured in the five plates above named.

I have noticed with regret that in discussing the minor points, the essential and important fact of the plateau implements being possibly the work of the earliest known members of the human stock, has been too much overlooked. While anthropologists have sought for and described the stone implements of modern savages, from the poles to the equator, and speculated on their uses, they have with a few rare exceptions shown an unaccountable indifference, not only in the plateau specimens themselves as specimens, but also an unwillingness to give the subject that attention which alone could settle the question. Here is a problem of high importance with respect to the habits, mode of life, and characters of primitive man, as exhibited in a wonderful profusion of their rude tools, and which is nevertheless neglected and rejected, not from personal investigation, but on an assumed impossibility and by an abnegation of personal responsibility. Surely the subject is deserving of further investigation. I wait without anxiety the results of my challenge.

Shoreham, Kent, *July* 15, 1895. Joseph Prestwich.

DR. CALLAWAY AND METASOMATOSIS.

Sir,—The letter of the Rev. J. F. Blake in last month's Geological Magazine does not call for lengthened comment.

He makes it quite clear that in his criticisms of my work at Malvern he had employed the theological, rather than the scientific, method. I had often said that a gradation between two kinds of rock at Malvern proved the derivation of the one from the other; but then I had previously explained, by an accumulation of details, what I meant by a Malvern gradation. Mr. Blake forgot the details, and suggested that I believe any kind of gradation would prove my case. It is possible to involve any author in apparently contrary opinions, if his sentences may thus be detached from their context.

But Mr. Blake goes on to admit that he does not really suppose me to hold the opinion that "if one rock passes into another, one of them is derived from the other," but he does think I argue on the basis of the following: "The character of the stages by which one rock passes into another in the field *may* suffice of itself to prove that one of them is derived from the other." This is quite another thing, and should have been said at first.

Mr. Blake's use of my illustration of the beef cooking before the fire is rather misleading. The roasting meat undergoes a change, and so do the Malvern rocks during metamorphism. The cook is able to observe the change, and so can the geologist at Malvern. These two points exhaust the analogy as I limited it, and to expand it to cover a special theory of metamorphism is to commit a fallacy in logic.

My critic—perhaps I may say "critics," for Mr. Blake follows in the wake of others—appears to think that no amount of microscopic or outdoor evidence will suffice to prove the conversion of a diorite into a quartzose gneiss (not "quartz-schist," as Mr. Blake inaccurately writes). If this opinion be right, we are shut up in eternal darkness on this question, for no other proof is available. Surely, our ignorance of the chemistry of high temperatures and great pressures ought not to be erected into an insuperable bar against the reception of good field-evidence. Are my critics going to wait until earth-forces can be introduced into the laboratory?

Wellington, Salop. C. Callaway.

BOULDERS IN A COPROLITE BED AT STANBBIDGE.

Sir,—A bed of "coprolites" is now being worked near Stanbridge, in South Bedfordshire, at a spot about half a mile west of the church, just in the angle formed by the roads from Leighton Buzzard and Billington. The bed resembles in many respects the Cambridge Greensand; its thickness varies within short distances, the maximum being about one foot. Fossils are not abundant, but those found belong to species which occur in the Cambridge Greensand. Mr. Jukes-Browne made a fresh survey of the district some ten or eleven years ago, and determined that the bed, which was at that time exposed in some other pits in the neighbourhood, occurred at the base of the Upper Gault, which in this district is very marly, yielding over 50 per cent. of carbonate of lime.

Two boulders of quartzite have recently been found in the

Stanbridge pit, and were presented to the Woodwardian Museum by Mr. H. Coningsby; they are angular blocks, 10 × 6 × 6 and 7 × 7 × 6 inches in size, and weigh 16 lbs. and 13 lbs. respectively. Attached to their surface are numerous specimens of *Plicatula sigillina*, Woodw., and *Spondylus striatus* (Sow.), and small concretions of iron pyrites. The quartzite is rather coarse-grained, and was originally a quartz-conglomerate. H. Woods.

NOTE ON THE ERRATIC BLOCKS OF POLARIS BAY AND OTHER LOCALITIES IN NORTH GREENLAND.

Sir,—I should like to place upon record a statement I ought to have published years ago, but which at the time the subject was fresh I thought of too little moment to record. Since then I notice that what I believe to be an erroneous deduction, has been cited by authors of eminence as a fact, without any qualification. The late Dr. Emil Bessels, when in Hall Land, North Greenland, with the "Polaris" Expedition, noticed that the land in the vicinity of the "Polaris" winter quarters was strewn up to elevations of over 1,000 feet with erratic ice-borne boulders, entirely distinct in character from the rocks *in situ*. Bessels, who was a man of high attainments, and a good observer, misled, I believe, by many of these erratics having a superficial resemblance in composition to rocks found in South Greenland, made the sweeping assertion[1] that these erratics came from South Greenland; and that the current and ice-drift in Smith Sound and Robeson Channel, at a former period when these erratics were dispersed, had been from south to north, and not from north to south as is the case to-day. When I sojourned in Grinnell Land, during 1875–76, I was aware of Bessels' opinion, and made many observations on the boulders we met with, and on their distribution. I found them as Bessels described, even on the higher altitudes uncovered by snow, notably on Dean Mount, near the winter quarters of the "Alert," in 82° 27′ N., at an altitude of 1,200 feet. I observed, however, what Bessels seems to have overlooked, that boulders of the same character were strewn over hill-sides and in the valleys down to the present sea-level, and that on some ancient sea-beach at a hundred feet of altitude the stranded boulders were lying under precisely the same conditions as the boulders that now rest on the seashore of to-day, and which have been recently stranded. Grinnell Land is an area of very rapid elevation, and it is only reasonable to argue that the agent that strands the ice-worn boulder to-day on the fore-shore of Grinnell Land is the same as placed the boulders at an altitude of 1,200 feet when that point stood at sea-level. The agent that grounds the erratic of to-day is the ice-raft of the palæocrystic sea, and Bessels was certainly mistaken when he ascribed the origin of these rocks to South Greenland, and to clench his argument had to invoke a change in oceanic circulation to account for the presence of the boulders on the shores of the Polar Ocean. Bessels made a strong point that

[1] Bull. de la Soc. Geog. Paris, p. 298, March, 1875. U.S. Naval Report, 1873, p. 548. Arctic Manual, p. 553, 1875.

one of the most marked characteristics of some of these boulders was their containing large garnets, similar to those in a rock found in the neighbourhood of Fiskernäs, in South Greenland. It is perfectly correct that some of the boulders I met with in Grinnell Land were of garnetiferous gneiss, and the difference between them and the blue Silurian limestone or dark Azoic slate, the rock *in situ*, on which they were lying, could hardly fail to attract attention. From Lady Franklin Bay, on the west side of Robeson Channel, as far north as Cape Joseph Henry, I did not meet with this garnetiferous gneiss as a rock of the country. It does not occur as such in Hall Land, neither do I think it can be found *in situ* along the lands visited by Aldrich in his journey along the north shore of Grant Land, nor on the northern shores of Greenland traversed by Beaumont, Lockwood, Brainard, Peary, and Astrup, for this rock is of such a striking character that such intelligent observers as I have mentioned could not well have passed over it without remarking its garnetiferous structure. There was a fine example of an ice-rounded boulder of this remarkable rock lying stranded a little above high-water line, not far from the "Alert's" winter quarters, in 82° 27′ N. Fortunately I brought away with me fragments of this boulder, which are now in the British Museum; I am informed that the fragment is a "coarse-grained aggregate of large garnets, orthoclase, cordierite, fibrolite, and quartz, with a little biotite. A peculiar feature of the rock is the enclosure of rounded quartz crystals in the felspar. It is probably a garnetiferous cordierite-fibrolite gneiss, but the fragment is too small to show the foliation."

The conclusion I arrive at is, that this erratic boulder and its fellows, scattered over the shores of Grinnell Land and North Greenland, cannot by any possibility have been derived from South Greenland, and floated up through Davis Strait, Baffins Bay, Smith Sound, and Robeson Channel, to the Polar Sea. Such a supposition is as much at variance with fact, as to cast a bladder into the sea at Cape Clear, and assure us that it reached the West Indies; and I cannot understand how a man of Bessels' ability could formulate such a theory. It is far more reasonable to presume that these erratics are derived from some land within the unknown region of the Polar area. If so, the land that produces them must support glaciers, for these ice-worn boulders have passed through the mill of a glacier, to give them their present shape and wear. There can be little doubt that the drift-wood stranded on the shores of the Polar Ocean, along the coast of Grinnell Land, is derived from the great rivers of Siberia, and the same drift and current that transports it is equally capable of drifting ice-borne erratics from unknown Polar lands.

H. W. Feilden, Colonel R.A.

West House, Wells, Norfolk.

EXPANSION THEORY OF MOUNTAIN EVOLUTION.

Sir,—Mr. Davison, in a "Second Note on the Expansion Theory of Mountain Evolution," quoting Prof. Le Conte, restates what he thinks to be a fundamental objection to the expansion theory.

He does not, however, allude to, and therefore possibly has never taken the trouble to read, the several direct replies I have given to this very objection when made by people who had failed completely to understand what my theory, as originally published in 1886, really is. One such complete refutation is contained in a paper in this Magazine in May, 1894, entitled, "On the Result of Unsymmetrical Cooling and Redistribution of Temperature in a Shrinking Globe as applied to the Origin of Mountain Ranges," in which I have dealt broadly with the whole subject, and have shown that the effect of sedimentation is to check the Earth's cooling in the area in which the sediments are being laid down. The form in which the case is stated, both by Le Conte and Davison, shows an entire misapprehension of the whole problem. It is not that the sediments abstract heat from the portion of the Earth's crust upon which they lie or with which they are in contact, but that they simply prevent the outflow and consequent loss of that heat from the nucleus which would otherwise be dissipated into space, and this heat thus retained expands them. I have shown in the paper referred to that it is to the *redistribution* of heat in the crust, and the consequent alteration of stresses and strains, that we are to look for the effective cause of mountain folding and upheaval. To say, therefore, that the "*increased heat must be taken from somewhere else*" is an obvious truism which conceals the implied fallacy that sedimentation at a certain point will cause a greater loss of heat at that point than at the surrounding points whereon no sedimentation has taken place, and this is not true—it is exactly the reverse—less heat will be lost at that point.

Mr. Davison, thinking to strengthen his objections to the expansion theory, now quotes Herschel and Lebour to show that wet rock is a better conductor than dry rock. This was well known to me, through their admirable researches, before I penned a line of the "Origin of Mountain Ranges." Doubtless superficial layers of wet sediment may be better conductors of heat than the average earth-crust, but consolidated sediments miles thick are not likely to be in the moist condition common to surface-rocks. Herschel and Lebour's investigation, so far from supporting Mr. Davison's contentions, are on the whole distinctly in favour of my views. Indeed, I cannot do better than reproduce here some of their extremely acute observations on the results of their experiments, which have so far not received from geologists and physicists the attention they deserve—"In the first place, it seems to be proved by our experiments that the conducting-power of different rocks varies strictly according to their lithological character. Very crystalline rocks, such as granite and serpentine and statuary marble, allowed heat to pass rapidly through them; slate-plates, with their uncrystalline compact structure, had a still higher degree of conductivity. The crystalline nature of a rock alone is not, therefore, the lithological test of its conductivity. The lowest powers of conductivity were found to belong, among the specimens experimented on, to shale; the black shale, which was lower than the grey, is softer and more argillaceous than it, the grey shale having a considerable admixture of arenaceous matter and mica. The difference, however, between these two was so slight that, in the present preliminary researches, when much must be allowed to error, it may be left out of consideration altogether. It would appear, then, from these facts, that a certain compactness, accompanied by cleavage, is favourable to the passage of heat through rocks; and if it be admitted that what is true for small thicknesses is also true for great ones, we may be justified in supposing that the vast masses of clay-slate, and perhaps to a still greater extent their more metamorphosed and crystallized schists (which we know to extend to great depths), are so many points of weakness which must have their influence in the secular cooling of the earth. On the other hand, points of resistance may be assumed to exist, and to be formed by the great sedimentary accumulations of shale, and probably also of clay and other argillaceous unaltered rocks. In a column, therefore, composed in part of cleaved clay-slate and in part of shale, the easy passage of the internal heat outward through the first would be checked through the other in the ratio, roughly speaking, of five to eight. This becomes a stupendous difference when we apply it to the thicknesses we are acquainted with. If we imagine a thick covering of shale or clay or some other rock with a very *low* conductivity which has arrested in its course the heat passing up to it through underlying rocks with a high degree of conductivity—if we imagine such a surface-covering removed (as we know that they frequently have been) by denudation, it is evident that the equilibrium of the heat-resisting covering of the earth will be altered, not only at this particular spot but also wherever the material removed is being redeposited."[1]

It is obvious that the drying and consolidation of sediment goes on concurrently with its increasing depth, and it is probable that the piles of horizontal sediment miles thick which are laid down as the materials out of which future mountain-ranges are built possess a lower conductivity than the substratum of the crust, largely crystalline, upon which they rest.

But whether these sediments are better or worse conductors of heat than the average crust does not in the least affect the principle of their action as intercepters and accumulators of the heat outflowing from the nucleus; and if Mr. Davison had correctly apprehended this fact, instead of confusing the issue by the repetition of a fundamental misstatement, we might not have been favoured with No. 2 note on the "Expansion Theory of Mountain Evolution."

T. Mellard Reade, C.E., F.G.S.

Park Corner,
Blundellsands, Liverpool.

[1] British Assoc. Report, 1873, Appendix p. 226: "Notes on the Conducting-power of certain Rocks," by Herschel and Lebour.

OBITUARY.

VALENTINE BALL, C.B., M.A., AND LL.D. (DUBLIN), F.R.S., F.G.S., M.R.I.A.

Born July 14th, 1843. Died June 15th, 1895.

Few men of science were more widely known or more cordially esteemed than Dr. Valentine Ball, the distinguished Director of the Dublin Museum of Science and Art, whose premature loss we have to deplore.

Valentine Ball was born in Dublin July 14th, 1843, and was the second son of the well-known Naturalist, Robert Ball, LL.D., who died in 1857. He was educated at Dr. Brindley's, Chester, subsequently at Dr. Henry's and Dr. Benson's private schools in Dublin, and at Trinity College, Dublin. He graduated in the University of Dublin, B.A., 1864; M.A., 1872; LL.D. (*honoris causâ*), 1889. He was elected a Fellow of the Geological Society of London in 1874; Fellow of the Calcutta University (*honoris causâ*) in 1875, and Fellow of the Royal Society of London in 1882. He was elected President of the Royal Geological Society of Ireland in 1882. He was appointed Clerk in the Receiver Master's Office, Dublin, 1860–64; and joined the Staff of the Geological Survey of India in 1864, and served till 1881. On his return to Ireland he was appointed Professor of Geology and Mineralogy in the University of Dublin, and held office from 1881 to 1883, when he became Director of the Science and Art Museum in Dublin, which office he held until his death. Dr. Ball was also Honorary Secretary of the Royal Zoological Society of Ireland, and a Member of the Council of the Alexandra (Ladies) College, and of that of the Royal Irish Academy.

His published works are—"Jungle Life in India, or the Journeys and Journals of an Indian Geologist," 1880; "The Diamonds, Coal, and Gold of India," 1881; "The Economic Geology of India," 1881; an English Translation of "Travernier's Travels in India," with Notes and Appendices, etc., 1889. Besides numerous contributions to learned societies, he published several Memoirs on the Geology of extensive tracts in India, and accounts of his visits to and explorations in Afghanistan and Beluchistan, the Andaman and Nicobar Islands, the Himalayas, etc. As a collateral result of his explorations in the wild and then little-known central regions of the Peninsula of India, where he first discovered several coal-fields, he was enabled to suggest to the Government the most desirable line of route for a direct railway between Calcutta and Bombay. This route has now been adopted, after several years spent in surveys of the various alternative routes. Several of his more important recent contributions to societies are upon the "Identification of the Animals, Plants, and Minerals of India which were known to the Ancients." In the year 1884 he presented a Report to the Science and Art Department on the Museums of America; it was subsequently published in the Department's Annual Report. He contributed three articles to the Geological Magazine on the "Volcanoes of the Bay of Bengal," 1879, p. 16, Pl. I; 1888, p. 404; and 1893, p. 289, Pl. XIII; and "On the Mode of Occurrence of Precious Stones in India," 1884, p. 516; "On Eroded Agate Pebbles," 1888, p. 231; "On the Transport of Granite found in the Carboniferous Limestone, Dublin," 1888, p. 232. He filled the office of President at the late meeting of the Museums Association in Dublin in 1894. With most of the scientific societies of Dublin Dr. V. Ball was in intimate association, especially with the Royal Geological Society, of which he was the arduous Secretary for so many years.

In 1869 Dr. Ball married the eldest daughter of the late John Stewart Moore, of Moyarget, county Antrim. He leaves a family of four children. For some years Dr. Ball's health had been failing. About ten days previous to his death serious symptoms were manifested, and he passed away on the afternoon of Saturday, June 15th, at his residence, 28, Waterloo Road, Dublin.

PROFESSOR WILLIAM C. WILLIAMSON, LL.D., F.R.S.

BORN NOVEMBER 24TH, 1816. DIED JUNE 23RD, 1895.

BY the death of Professor W. C. Williamson, Palæobotany has lost one of its most earnest and energetic investigators and exponents, whose memoirs will long remain a record of persevering labour combined with remarkable genius and originality of thought.

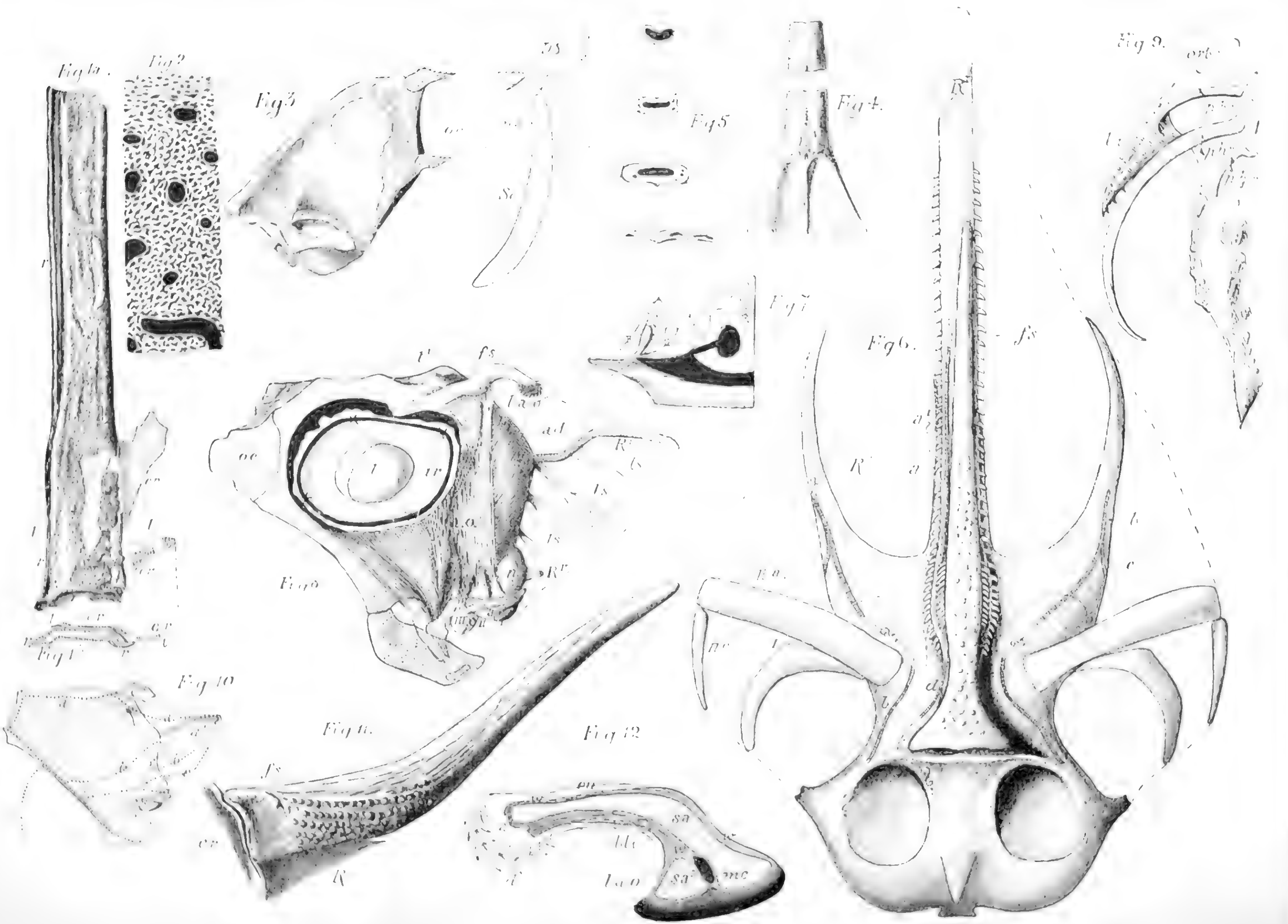
William Crawford Williamson was born at Scarborough on November 24th, 1816. His father was for some time head gardener to the then Earl of Mulgrave, at Lyth Castle, near Whitby, where, having laboured indefatigably in exploring the geology and zoology of the coast of Yorkshire, and made a rich collection of its fossils and recent shells, he was, in 1828, appointed Curator of the well-known Museum of the Literary and Philosophical Society of Scarborough, amongst the collections of which much of his son's early youth was beneficially spent. Young Williamson was destined for the medical profession, but, in 1835, accepted the curatorship of the Museum of the Manchester Natural History Society. Whilst at Scarborough he contributed to the Geological Society of London the first of three memoirs on the "Vertical Distribution of the Organic Remains in the Strata of the Yorkshire Coast," and one to the Zoological Society of London on the "Birds of the Yorkshire Coast," as well as published a description of the well-known tumulus and its contents then recently opened on Gristhorpe Cliff. On reaching Manchester his attention was at once directed to the local geology, and soon resulted in the publication, in the Philosophical Magazine, of a memoir on the "Remarkable Limestones of Ardwick," which form the uppermost part of the Carboniferous strata in that neighbourhood.

In 1838 he resumed his medical studies, first in the Manchester Medical School, Pine Street, and afterwards in University College, London; and in January, 1841, he commenced as a medical practitioner in Manchester. Soon after that he began a series of investigations amongst the recent Foraminifera, the results of which were a succession of memoirs on their minute organization, culminating, in 1848, in the publication, by the Ray Society, of his "Monograph on the Recent Foraminifera of Great Britain," and in a memoir on the minute organisms found in the marine mud of the Levant. This latter memoir contained the first announcement of the existence in some of the deeper seas of what is now known as the Foraminiferal Ooze. The study of some histological features of human bones and teeth led to an examination of the scales and bones of recent and fossil fishes. Two memoirs on these subjects were published in the Philosophical Transactions of the Royal Society, in which he announced his conclusion that the scales and dermal teeth of fishes were the homologues of the oral teeth of the mammalia, the latter being but the relics of the dermal system so extensively developed in fishes. The publication of these two memoirs led to his election as a F.R.S. in 1854. In 1851 the Owens College of Manchester began its career, when Mr. Williamson was elected its first Professor of Biology and Geology. As the institution expanded, this too-comprehensive chair was divided, and for many years past his academic labours had been confined to the Professorship of Botany. Circumstances then drew his attention to the Carboniferous plants of Lancashire and Yorkshire. The result of these later studies has been the publication, in the Philosophical Transactions, of seventeen memoirs "On the Organization of the Fossil Plants of the Coal-measures." On receiving the sixth of this series, the Royal Society recognized them by awarding him their Royal Medal. The Wollaston Gold Medal of the Geological Society was awarded to Dr. Williamson in 1890. Dr. Williamson was President, and subsequently senior Vice-President, of the Literary and Philosophical Society of Manchester. The University of Edinburgh conferred upon him the degree of LL.D. The Göttingen Academy of Sciences elected him one of its foreign members, and the Royal Society of Sweden elected him to the place left vacant by the death of Professor Asa Gray.

In the Royal Society's Catalogue of Scientific Papers from 1834 to 1873 is a list of 57 papers, principally upon microscopic organisms, Foraminifera, Radiolaria, etc.; on the microscopic structure of the scales, bones, and teeth of Fossil Fishes and Reptiles, and a most important series on the structure of coal-plants, *Calamites, Stigmaria, Sigillaria, Lepidodendron*, etc., with which his name will for ever remain honourably associated.

Prof. Williamson had retired from the Owens College, Manchester, for some time before his death, and had been residing at Clapham, where he had occupied himself with Dr. D. H. Scott, F.R.S., Hon. Keeper of the Jodrell Laboratory, Kew, in carrying on his researches in the microscopic structure of Fossil Plants, to illustrate which he had accumulated an immense and valuable series of microscopical sections and specimens.

Prof. Williamson having passed so many years of his life in Manchester had never become a Fellow of the Geological Society of London, although he was the recipient of its Wollaston Medal in 1890. He died at the age of 78 years, having been actively engaged up to a short time before his death.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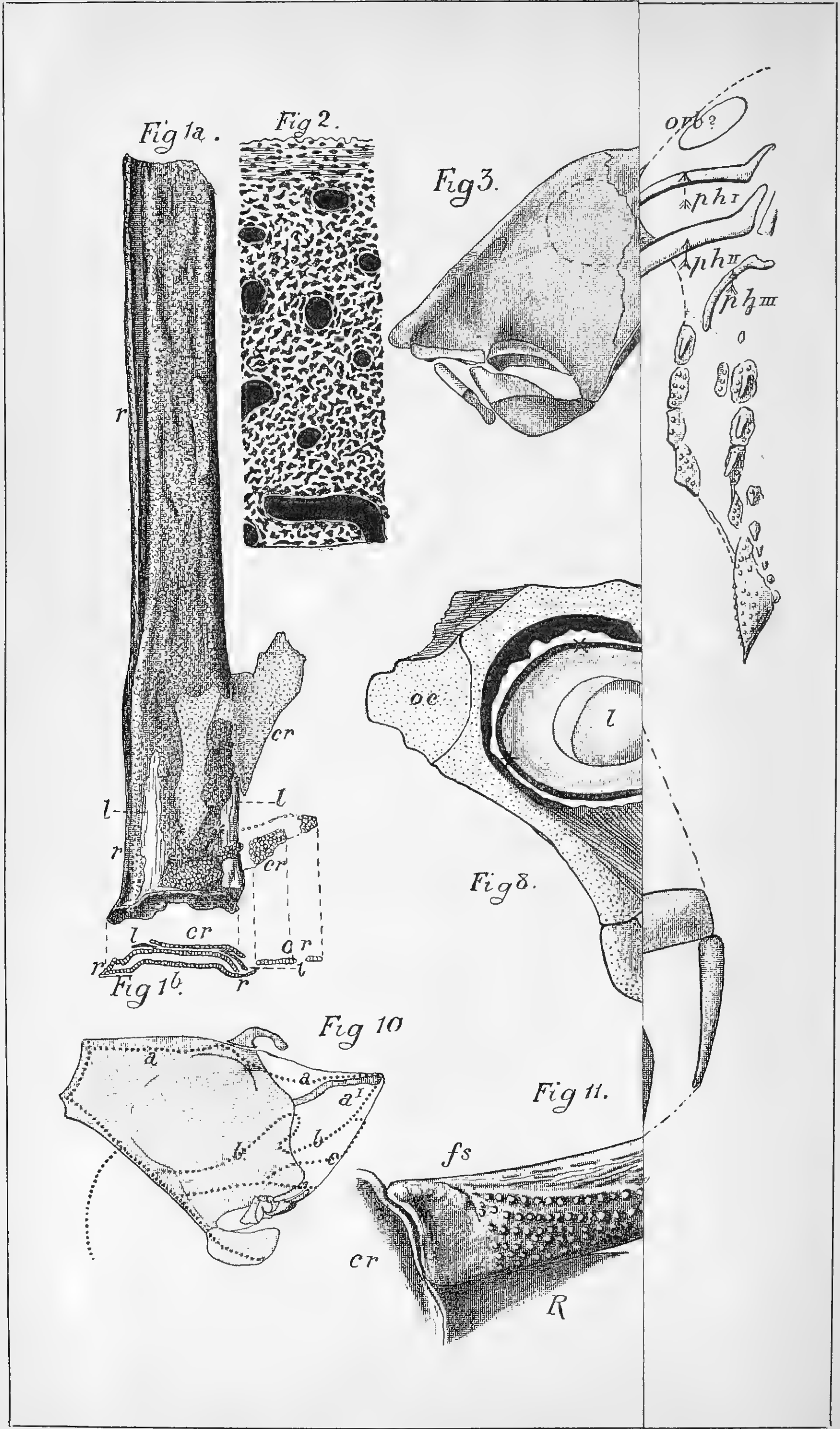
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ORIGINAL ARTICLES.

I.—On the Structure of the Frontal Spine and the Rostro-labial Cartilages of *Squaloraja* and *Chimæra*.

By Otto M. Reis, Ph.D.;
Assistant in the Oberbergamt, Munich.

(PLATE XII.)

THE remarkable frontal spine of *Squaloraja* has always been described as a dermal structure by those who have referred to it, and has been classed with the shagreen-granules and dentition. After the systematic position of the genus had been determined,[1] its frontal spine was rightly recognized as identical with the spine-like frontal process in *Chimæra* and fossil Holocephala, with which it was formerly compared by W. Davies[2] and A. S. Woodward.[3] Both these processes were regarded as dermal structures by von Zittel,[4] Jaekel,[5] and A. S. Woodward,[6] and treated as true ichthyodorulites, *i.e.* as if consisting of dentine or vasodentine. In 1890 the present writer briefly pointed out[7] that the frontal spine of the Jurassic Chimæroid, *Ischyodus avita,* consisted of extremely calcified fibro-cartilage, resembling that of the so-called "claspers" of all male Elasmobranchs. The microscopical structure of these parts differs conspicuously from that of the calcified granules in the common (hyaline) cartilage of the internal skeleton, and its ontogenetic development is different.

It is necessary to describe these differences in detail, because O. Jaekel[8] refers to the frontal spine as having the same structure as the rostral prolongation. With regard to the rostrum he says—"It consists of a hollow calcified tube, the peripheral parts of which consist of little fused cones on which separate star-shaped dentine-scales are fixed."[9] The following pages will show that this statement cannot be based upon accurate observations. They relate to two

1 A. S. Woodward, Cat. Foss. Fishes Brit. Mus., pt. ii, p. 40 (1891).
2 W. Davies, Geol. Mag., Vol. IX, p. 145, pl. iv (1872).
3 A. S. Woodward, Proc. Zool. Soc. 1886, p. 527.
4 K. A. von Zittel, Handb. Palæont., vol. iii, p. 95.
5 O. Jaekel, Sitzungsb. Gesell. naturf. Freunde, Berlin, 1890, pp. 120, 127.
6 A. S. Woodward, *op. cit.* 1891, p. 40.
7 O. Reis, Geognostische Jahreshefte, 1890, p. 8.
8 O. Jaekel, Die Selachier vom Monte Bolca (Berlin, 1894).
9 "Es besteht aus einer hohlen Kalkröhre deren peripherische Teile aus zusammengeschmolzenen Kügelchen bestehen, worauf vereinzelt sternförmige Dentinschuppen sitzen" (*op. cit.*, p. 65).

interesting fragments of the frontal spine and rostrum of *Squaloraja*, duplicate specimens from the British Museum, kindly lent to the present writer for study by Dr. Henry Woodward, Keeper of the Geological Department.

The fragment of a frontal spine shown from the ventral aspect in Pl. XII, Fig. 4, exhibits at the proximal end some interesting features, which were revealed on extrication from the enveloping matrix. The expanded proximal end is small, of triangular shape, and slightly excavated on the ventral side, this excavation being subdivided by a little median crest. As long ago supposed by W. Davies, this feature indicates the insertion of two muscles, one on either side of the median crest. He pointed out that most probably the coarsely fibrous structure of the crest on the dorsal surface of the spine proved the attachment of muscular tissue, "which connected it with and served to elevate the spine above." On a male specimen of the living *Chimæra* (Pl. XII, Fig. 8) I have observed that the highest tendons of the superficial portion of the adductor mandibularis (Levator anguli oris—term)[1] are attached not only on the anterior surface of the free, upwardly-curved, proximal portion of the spine-like process, but also that the fibres of its deeper portion are connected with the whole ventral surface so far as there is space for their insertion. A branch of the tendon is attached also to the under surface of the skin covering the spine. These muscles tend to depress the spine, but there is none to elevate it. The round free process, quite separate from the cranium, is held in place by two dorsal tendon-like ligaments instead of muscles, and these reach from the dorsal surface of the proximal expansion of the spine to the prominent supra-orbital roof of the cranium (Pl. XII, Fig. 8). These tendons and the bundles of muscular fibres on the other side in *Squaloraja* could only have served to fix the spine when pressed in attack, which explains why free tubercles of the integument are confined to the lateral and dorsal side of the proximal portion of the spine.

As regards the internal structure of the frontal spine, we must remark first that it is hollow (Pl. XII, Fig. 5), but becomes more and more compact proximally. As in *Chimæra* (Pl. XII, Fig. 12), the dorsal wall of the cavity is much thinner than the ventral wall. In transverse section (Fig. 5) we may observe with a lens a number of capillary canals in the thick calcified wall; and two smaller main canals can be seen perforating the whole length of the spine, one on either side.

The microscopical structure of the spine is quite the same as in *Ischyodus* and *Chimæra*. A number of vascular canals are to be seen, and between these there are large cells. The elongated form of the cells is observed especially in the longitudinal section, and they differ usually from the cells in the prismatic granules of the calcified hyaline cartilage of the internal skeleton of Elasmobranchs, especially from those of the Holocephala. They are irregularly arranged, and the intercellular tissue is fibrous, but this never

[1] B. Vetter, Jena Zeitschr. f. Naturw., vol. xii, p. 441.

exhibits the irregular peripheral lamellation which is often observable in the lines along which the cells of calcified hyaline cartilage are disposed.[1] This microscopical structure is identical with that of the claspers of fossil and living Plagiostomes and Holocephala,[2] in which the vascular canals are only seldom wanting. The microscopical structure of the middle cone of Selachian vertebræ and of the calcified gill-filaments in the Teleostomous fishes, is also similar. The structure is, indeed, to be defined as fibrous cartilage, or, more technically speaking, as a prochondral differentiation of the mesoderm, of which the intercellular substance ("Bindesubstanz") has not yet undergone the change into the later hyaline stage.

The fibrous cartilages of the male appendicular skeleton are produced in the corium by scleroblasts of a kind which never form hyaline cartilage in fishes. They are developed in dermal folds, originally unconnected with the endo-skeleton of the pelvic fin, and only joined secondarily with the latter.[3] The frontal spine of Chimæroids is similarly quite separate from the cranium, and essentially a part of the fibrous and vascular layer of the cutis.

The cells of these calcifications, which we must now term "cutaneous," are not only irregularly elongated, but are also much more numerous than in the cartilages of the endo-skeleton. I have already pointed out[4] that there is a remarkable difference in the number of cells exhibited by fossilized fibrous cartilage and hyaline cartilage; the cells very frequently disappear entirely in the latter, and are only rarely seen in certain parts of its calcifications. I have observed the same phenomenon in the superficial granules of the endo-skeleton in the living *Chimæra*, which agrees with the fossil *Ischyodus*, *Chimæropsis*, and even with *Squaloraja*. The difference may be observed in the fibrous and hyaline cartilage of one and the same specimen.

The second British Museum specimen under consideration (Pl. XII, Fig. 1) exhibits the great median rostral prolongation. Its dorsal and ventral layers of calcareous prismatic granules are slightly displaced at the ends. On the surface are scattered several of the little hooked dentine tubercles, lying with their radiated bases upon the prismatic granules of the calcified hyaline cartilage; and these seem to be in a perfectly natural position. Near the lateral border of the proximal end of the rostrum, there is also a noteworthy lamellar deposit of bone-like substance. The bony aspect and yellowish-grey colour of this are suggestive of the proximal end of the male spine, of which the deposit may perhaps be a few splints. A microscopical section of the substance confirms this idea, and clearly shows calcified cutaneous fibrillar cartilage. The specimen may thus be either (i) the dorsal aspect of the rostrum of a male with rudiments of a spine, or (ii) the ventral aspect of such a rostrum showing paired ventral spines, or (iii) the dorsal aspect of the rostrum of a female. The latter supposition seems most probable, and I regard the specimen

[1] W. C. Williamson, Phil. Trans. 1851, pl. xxx, fig. 30.
[2] J. Riess, Palæontogr., vol. xxxiv, pl. ii, fig. 12 (clasper of *Chimæra*).
[3] Petri Zeitschr. f. wiss. Zool., xxx, 1878, p. 325.
[4] O. Reis, Mikroscop. Archiv., vol. xli, p. 569.

as proving that the spine consists primitively of paired elements, a conclusion also suggested by the bilaterally symmetrical disposition of the blood-vessels in the wall of the spine of the adult male *Chimæra* and *Squaloraja*.

This result is interesting in view of the present writer's former expression of belief that the three pairs of parietal spines of *Menaspis* (Fig. 9, ph_{I}, ph_{II}, ph_{III}) are the paired serial homologues of the azygous frontal spine of the male Holocephala. Jaekel[1] has referred these horn-like spines to the vasodentine skeleton, at the same time including the frontal spine of Holocephala among vasodentine ichthyodorulites.

The disposition of the dermal vasodentine plates in *Menaspis* as compared with the parietal horns, agrees with that of the paired plates of the Myriacanthidæ (e.g. *Chimæropsis*, Fig. 3) as compared with their frontal spine. A Myriacanthid spine with overlying tubercles is shown in Fig. 11, and may be compared with Fig. 9, which exhibits the left half of the cranium and trunk in *Menaspis*, with the three parietal (male) horns, the lateral spine, and the flat conical plates behind. Jaekel may have been led to identify vasodentine in the parietal horns of *Menaspis* (if he has had occasion to study satisfactory microscopical sections of splints of them) by the abundant occurrence of canals for blood-vessels, which are also observable in the male frontal spine of *Chimæra*, *Ischyodus*, and *Squaloraja*.

We come now to the consideration and restoration of the rostrolabial appendages of *Squaloraja*. Before having established the systematic position of the genus, A. S. Woodward described its great rostral prolongation as an "intertrabecular cartilage." Now we must regard it as identical with the corresponding cartilage in *Chimæra* (Fig. 8), and the lateral cartilages, which A. S. Woodward terms "prepalatine," will also be seen to be the same as in the last-mentioned genus. The rostrum of the Selachian *Rhinobatus maronita*, however, is nearly identical with that of *Squaloraja*.[2]

Finally, there are the labial cartilages of *Squaloraja*, of which A. S. Woodward recognizes two pairs (Fig. 6, *a*, *b*), comparing them with the rods which form the axes of the oral barbels in the Myxinoids. According to the new view, it is now necessary to compare them with the labials of *Chimæra*.

These appendages of *Chimæra* are insufficiently described by Hubrecht,[3] and it is therefore necessary to treat of them more in detail. Three segments of cartilages may be distinguished in the labial complex. The first segment (I) is a single cartilage ("nasal wing cartilage" of Hubrecht), fixed in the common rostro-labial connective tissue, which also supports the great median cartilage of the second segment. The latter consists of three cartilages, of which the great median piece II*a* is covered throughout its whole length by the *labialis anterior* muscle,[4] and thus cannot be a "Schnauzen-

[1] O. Jaekel, Sitzungsb. Gesell. naturf. Freunde, Berlin, 1890, pp. 119–131.
[2] See Catal. Foss. Fishes Brit. Mus., pt. i, pl. iii, fig. 4.
[3] A. A. W. Hubrecht, Niederländ. Archiv., vol. iii, pp. 255–272 (1876).
[4] B. Vetter, Jena Zeitschr. f. Naturw., vol. xii, p. 443 (1878).

knorpel" (Hubrecht), but can only be interpreted as part of the great upper labial cartilage L_1 of the Selachians, segmented because the *labialis* is removed from the internasal crest and attached only to the labial cartilage (II*a*-II*b*) itself. The first segment is homologous with the anterior upper labial L_1, while the lower labial cartilage of the Selachian is represented in *Chimæra* by III*a* and III*b*. Hubrecht describes the latter as hinder upper labials, retaining the symphysial cartilages of the mandible as lower labials; but, in the present writer's opinion, the latter are homologous with the "submental" cartilages in *Scyllium* and *Pristiurus*,[1] and therefore Vetter is right (*loc. cit.*) in determining III*a* and III*b* as lower labials. If one extends transversely the folded lip of *Chimæra* (Pl. XII, Fig. 7) by raising the skin at the corners of the mouth, the internal aditus of the mouth in these corners is found to curve in the direction of the arrow in Fig. 7. As a consequence the cartilages III lie in the ventral and hinder half of the labial skin-fold, shown in perspective from the anterior or inferior aspect in Fig. 7. Moreover, the attachment of the cartilages III is really on the outer surface of the mandible. The separation of the inner cartilaginous segments II and III is also indicated externally by a little infolding of the skin, which arises from a certain point of the outline of the upper lip and extends to the articulation of II and III. A recurved cartilage II*b* extends from the cartilage II*a* to this point of the outline (termed by Hubrecht the whole "anterior labial"), to support the great curtain-like lip. On its connection with II*a* is to be observed II*c* in articulation with III.

In determining the homologies of these parts in *Squaloraja*, it is necessary to remember that we are dealing with a depressed skull instead of one that is laterally compressed. Thus we recognize in the great transverse cartilage II*a* the homologue of the largest cartilage in the labial complex of *Chimæra*. Further, there may be observed at its distal end the cartilage II*c*, reflected backwards to the mouth-opening, and possibly the distal support of a similar curtain-like naso-labial fold. With regard to the third cartilage in this region in *Squaloraja*, we know that it is attached to the hinder side of the two first-mentioned labials, curved in a similar manner and probably situated in nearly the same plane as these. Hence this element can only represent the anterior labial I of *Chimæra*, lying behind the labials II in *Squaloraja* and approaching the mouth-opening on the ventral side, situated behind the labials I and the teeth. The nasal capsules, I suppose, lie between the rostral cartilage and the proximal ends of these labials, opening ventrally.

These cartilages of *Squaloraja*, therefore, cannot be regarded as cirri-like outgrowths of the hinder labials, but represent, in fact, the upper anterior and posterior labials themselves, lying apparently in the interior of a naso-labial fold. Their great development corresponds, indeed, with that of the rostrum and of the rostral spine.

With reference to the spine, A. S. Woodward observes that "we are concerned with an admirable illustration of the principle, that

[1] C. Gegenbaur, Untersuch. vergl. Anat. Wirb., pt. iii, p. 206.

the contours of superficial structures appended to the cranium are frequently determined in the main by the shape of the fundamental cartilage to which they are attached." The application of this principle is well exhibited in the vasodentine dermal skeleton of Elasmobranchs in general, when there is no direct attachment or relationship to the muscles. But the illustration of the frontal spine is especially interesting. It is long when adapted to a long and strong rostrum (*Squaloraja* and *Myriacanthus*), short when adapted to a weak or reduced rostrum (*Ischyodus* and *Chimæra*); laterally compressed when on a laterally-compressed rostrum, vertically compressed when on a skull like that of *Squaloraja*.

EXPLANATION OF PLATE.

FIG. 1.—*Squaloraja polyspondyla*, Agass.: median rostral cartilage, probably of female, from above (*a*) and in transverse section at proximal end (*b*). *cr.* fragments of cranium; *l.* fibrochondral lamellæ. [British Museum.]

FIG. 2.—Ditto: transverse section of frontal spine, enlarged about 80 diameters, showing enclosed cells and blood-vessels, the upper edge representing the inner border resting against the soft cartilaginous axis.

FIG. 3.—*Chimæropsis paradoxa*, Zittel: cranium of female, about one-sixth nat. size; contour restored in dotted lines. [Palæontological Museum, Munich.]

FIG. 4.—*Squaloraja polyspondyla*, Agass.: frontal spine, inferior aspect, showing grooves for adductor muscles.

FIG. 5.—Ditto: transverse sections of spine, showing inner cavity and the bilaterally symmetrical arrangement of blood-vessels.

FIG. 6.—Ditto: dorsal aspect of head, restored after figures by Agassiz, W. Davies, and A. S. Woodward. *a, b,* calcified rings of "lateral line"; I, II*a*, II*c*, labial cartilages; R_1, median rostral cartilage; R_{11}, lateral ditto.

FIG. 7.—*Chimæra monstrosa*, Linn.: right half of anterior side of mouth and nasal opening, from below. The corner of the mouth and lip are raised to show arrangement of labial cartilages, and the arrow divides the labial complex into that of the upper and that of the lower lip.

FIG. 8.—Ditto: right side of head of male, a little from above, the skin removed as far as the eye, and displaying the lens (*l.*), iris (*ir.*), and the deep cutaneous or sclerotic fold (*x.*) round the iris. The dotted surface indicates the rostral, cranial, labial, and mandibular cartilages. The tendon (*t.*) of the hinder attachment of the frontal spine connecting it with the cranial roof above the orbit is unshaded on the right side, and indicated by t_1 on the left side. The uppermost and hindermost fibres of the *adductor mandibularis* are attached to these tendons and to the broad inferior surface of the frontal spine itself (*f.s.*). The tendons of the *levator anguli oris* (*l.a.o.*) are attached on the upper anterior surface of the base of the spine. The tendons proceeding from the internasal cranial crest and the median rostrum itself (R_1) are the ligamental supports of the rostral sensory apparatus: the right lateral rostral cartilage (R_{11}) is seen in front of the nasal capsule (*n.*).

FIG. 9.—*Menaspis armata*, Ewald: left half of cranium and anterior portion of trunk, from above (after Jaekel), showing the probably male parietal horn-like (? chondrodermal) appendages (ph_1, ph_{11}, ph_{111}) and the true dentodermal lateral spine (*l.i.*) corresponding in form, attachment, and superficial ornamentation to the armature of the trunk, but differing in these and other macroscopical characters from the appendages *ph.*, probably chondrodermal calcifications like the frontal appendages of *Chimæra*, *Myriacanthus*, and *Squaloraja* (Figs. 6, 8, 11).

FIG. 10.—*Chimæra monstrosa*, Linn.: arrangement of "lateral line" in respect to the cranial, labial, and rostral cartilages below (*cf.* Fig. 6, *Squaloraja*).

FIG. 11.—*Myriacanthus granulatus*, Egert.: frontal spine showing lateral muscular grooves on proximal end. *cr.* cranium; R_1, median rostral prolongation.

FIG. 12.—*Chimæra monstrosa*, Linn.: longitudinal section (not quite median) of frontal spine, magnified. The soft cartilaginous (pro-fibrochondral) axis (*sa.*) is represented by the light shading; the calcified wall (*w.*) with the blood-vessels (*bl.v.*) is shaded darker. The black inferior surface of the spine serves for the attachment of a great part of the fibres of the *adductor mandibularis*; *l.a.o.* marks the attachment of the *levator anguli oris*. The median canal (*m.c.*), before subdividing into two lateral branches of blood-vessels, has a calcified surrounding wall, separating the soft axis into an anterior (sa_1) and a posterior (*sa.*) mass. The cutis (*cu.*) with the denticles (*d.*) is uncoloured.

II.—A Short Account of the Ammonites and their Allies, as Exhibited in the Cephalopod Gallery at the British Museum (Natural History).

By Arthur H. Foord, F.G.S.,
Of the Royal Dublin Society, Dublin.

THE great group of the Ammonites (using that term in its general acceptation) is distinguished from all other kinds of chambered shells of the Cephalopod type by the complicated foliations of the margins (*sutures*) of the partition walls or *septa* into which such shells are subdivided. Though typically coiled, much in the manner of the flat pond-snail, *Planorbis*, there are straight and variously curved Ammonites; but all have the common character of a highly foliated "suture-line."

The derivation of the Ammonites from the Goniatites has been clearly made out in certain groups by means of this suture-line, the development of which from its earliest stages of growth has furnished the key in such investigations.

The following sixteen families or sections of the Ammonites are the result of the most recent researches in this large and difficult group of fossils:—(1) Arcestidæ; (2) Tropitidæ; (3) Ceratitidæ; (4) Cladiscitidæ; (5) Pinacoceratidæ; (6) Phylloceratidæ; (7) Lytoceratidæ; (8) Ptychitidæ; (9) Amaltheidæ; (10) Arietidæ; (11) Ægoceratidæ; (12) Polymorphidæ; (13) Harpoceratidæ; (14) Pulchellidæ; (15) Haploceratidæ; (16) Stephanoceratidæ.

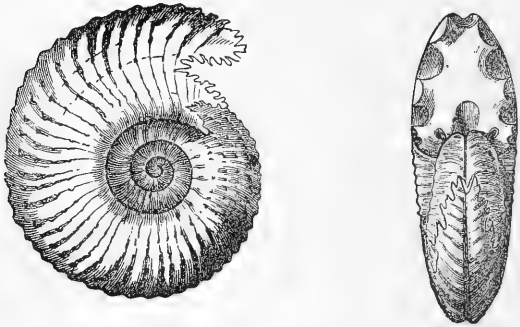
These sections will be found amply represented in the gallery set apart for their display.

Omitting certain forms of doubtful relationship, to be subsequently dealt with, a brief account of the above groups may here be given. The first four families are found chiefly in the Permian rocks of Sicily and of India, and in the Triassic rocks of the Alps (Alpine Trias). Among the Arcestidæ may be noticed the singular Triassic genus *Arcestes*, with its deeply embracing whorls and contracted aperture. In the Ceratitidæ the well-known Muschelkalk species, *Ceratites nodosus*, with its peculiar suture-line (Fig. 2), and the richly ornamented shell of *Trachyceras Aon* (Fig. 1), are met with.

Three very peculiar shells also deserve notice. They are: *Choristoceras, Cochloceras*, and *Rhabdoceras*. In *Choristoceras*, the last whorl becomes separated from the preceding ones, in the manner of *Crioceras*. *Cochloceras* is turreted like a Gasteropod, and may be compared with *Turrilites* in this respect. *Rhabdoceras* is straight, like *Baculites.* All are from the Alpine Trias.

The PINACOCERATIDÆ contain the large species known as *Pinacoceras Metternichi*, from the Keuper of Hallstadt, in Upper Austria. (Wall-case 12.)

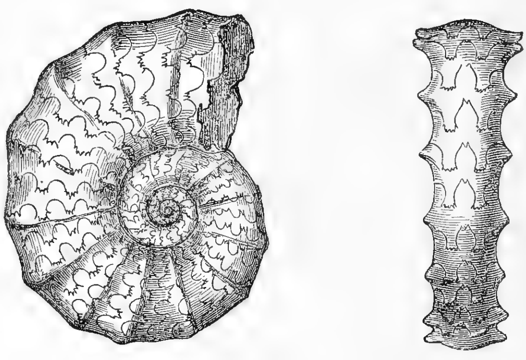
FIG. 1.



Trachyceras Aon, Münst. (Alpine Trias.)

The extreme delicacy of the ramifications of the sutures in this species excels that of any other Ammonite known. The leaf-like terminations of the sutures in the PHYLLOCERATIDÆ are the distinguishing feature in this group; they are well seen in the typical species *Phylloceras heterophyllum,* Fig. 3. (Wall-case 11.) This family began in the Trias, but it extended through the Jurassic into the Cretaceous.

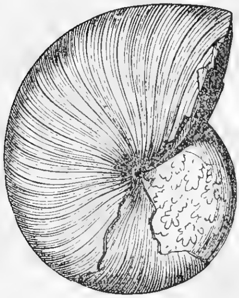
FIG. 2.



Ceratites nodosus, De Haan. (Muschelkalk.)

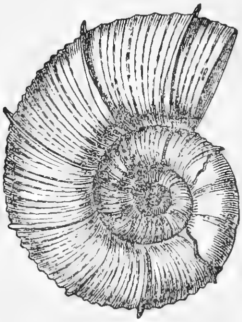
The suture-line is again the most important feature in the family next in order, viz. the LYTOCERATIDÆ, for it supplies the justification for connecting together an assemblage of genera differing widely in external shape. The family begins in the Trias, and is largely represented in the Jurassic and Cretaceous rocks. One of the most beautiful species of this group is *Lytoceras fimbriatum*, whose regular, wavy lines running across the shell make it very attractive to the eye; the effect being heightened by the bold, sharp, transverse ridges encircling the shell at frequent intervals, representing the former "lips" of the shell, Fig. 4. (Wall-case 11.) In *Macroscaphites* (Wall-case 3, Table-case 61) the shell is for about four convolutions

FIG. 3.



Phylloceras heterophyllum, Sow.
(Upper Lias.)

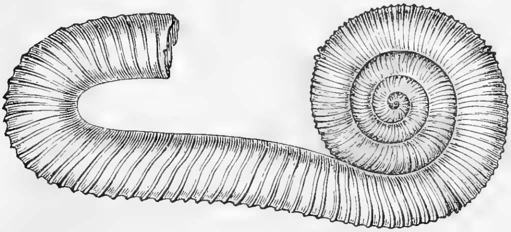
FIG. 4.



Lytoceras fimbriatum, Sow.
(Middle Lias.)

or whorls exactly similar in shape to a *Lytoceras*, when it suddenly takes a direction tangential to the coiled part, and after pursuing a nearly straight course for a short distance it bends back in a hook-like termination (Fig. 5). In *Hamites* the shell is bent at both ends, the apical or smaller (initial) end being again bent: thus the shell has three curvatures. Owing to its slenderness the apical part

FIG. 5.

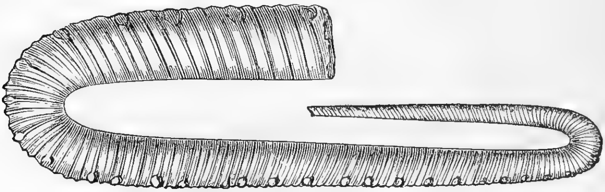


Macroscaphites Ivanii, d'Orb. (Lower Cretaceous.)

of the shell is rarely obtained (Fig. 6). (Table-case 60.) *Hamites* attains its greatest development in the Gault. In *Hamulina* and *Ptychoceras* (Neocomian and Gault) there is but one sharp bend in the shell, the straight limbs in *Ptychoceras* being actually in contact at, and in the region of, the aperture.

A still further departure from the typical form of the Cephalopod shell is encountered in the singular genus *Turrilites*, which takes the form of a Gasteropod shell (Fig. 7). The mouth or aperture is, however, turned towards the left-hand side, or, in other words, the shell is "sinistral." *Turrilites* is found exclusively in Cretaceous rocks. (Wall-case 3, Table-case 60.) *Helicoceras* is coiled like *Turrilites*, but the whorls are disconnected. In *Heteroceras* the last

Fig. 6.

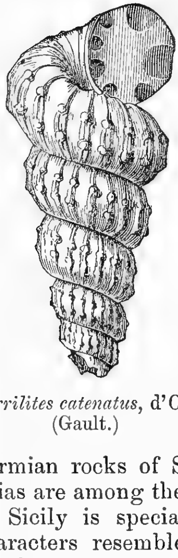


Hamites elegans, d'Orb. (Cretaceous.)

whorl is detached (Fig. 8). Both are Cretaceous genera. (Table-case 57.) In *Baculites* (Cretaceous) the shell is perfectly straight, except in the earliest or embryonic stage of its development, in which it is coiled. It occurs in vast numbers in the Danian (Upper Continental Chalk) of the North of France, whence the name *Baculite* Limestone given to those beds (Fig. 9). (Wall-case 3, Table-case 60.)

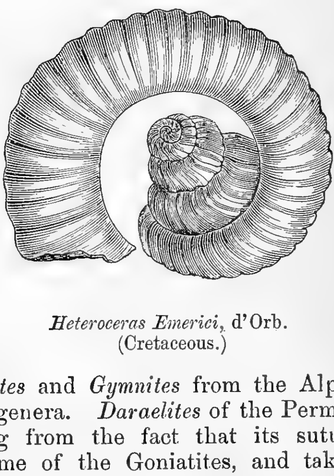
The next group, Ptychitidæ, consists for the most part of Triassic genera, but its earliest representatives come from the

Fig. 7.



Turrilites catenatus, d'Orb. (Gault.)

Fig. 8.

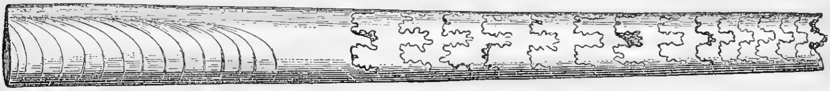


Heteroceras Emerici, d'Orb. (Cretaceous.)

Permian rocks of Sicily. *Ptychites* and *Gymnites* from the Alpine Trias are among the best known genera. *Daraelites* of the Permian of Sicily is specially interesting from the fact that its sutural characters resemble those of some of the Goniatites, and taking the Ptychitidæ as a whole it is considered that they present a gradational series connecting the Goniatites with the Ammonites. (Table-case 69.)

The principal feature observable in the AMALTHEIDÆ is the *keel* or projecting edge of the outer border (periphery) of the shell, which is prolonged beyond the margin of the aperture in the form of a long narrow process. In *Amaltheus margaritatus* (Middle Lias) the keel is prominent and beautifully sculptured, resembling the

FIG. 9.

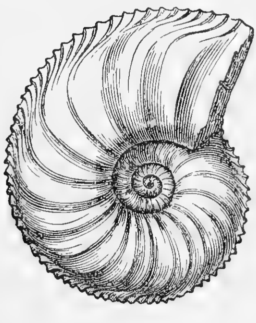


Baculites anceps, Lam. (Upper Cretaceous.)

strands of a miniature rope. *Cardioceras cordatum* (Oxford Clay) is one of the most highly ornamented of Ammonites, having a series of numerous sharp ribs upon the sides of the shell, which, in passing over the periphery, form a series of fine crenulations (Fig. 10). *Schloenbachia varians* (Lower Chalk) has strong and knotted ribs. (Wall-cases 5, 9, 11; Table-cases 62–69.)

The family of the ARIETIDÆ embraces a large number of Ammonites which at first sight appear to be only remotely related, nevertheless a careful study of their development has led to their

FIG. 10.



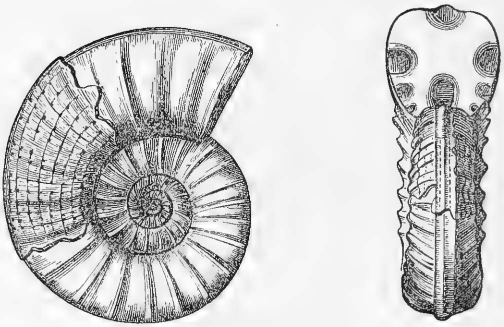
Cardioceras cordatum, Sow. (Oxford Clay.)

being grouped together. Among the most familiar members of this large group are the following, viz.: *Psiloceras planorbe*, which gives its name to the "zone of *Ammonites planorbis*" of the Lower Lias, and at the same time marks the first occurrence of Ammonites in British rocks; *Arietites Bucklandi* (*A. Bucklandi* zone); *Arietites obtusus*, Fig. 11 (*A. obtusus* zone); and *Oxynoticeras oxynotum* (*A. oxynotus* zone).

The shells in this group are flattened in form, and the whorls usually only slightly embracing, and generally numerous (see *Psiloceras planorbe*, e.g.). *Oxynoticeras oxynotum* is remarkable for the extremely attenuated and trenchant form of the adult shell. In this species the whorls are deeply embracing, so that very little is seen of the inner volutions. (Table-case 68, Wall-case 12.)

The ÆGOCERATIDÆ are restricted to one genus, *Ægoceras,* of the Lias. *Ægoceras capricornus,* Fig. 12 (*A. capricornus* zone of the

FIG. 11.

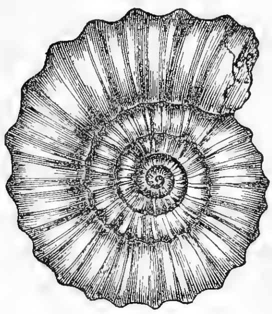


Arietites obtusus, Sow. (Lower Lias.)

Lower Lias), *Æ. Davæi* (Fig. 13), and *Æ. armatum* of the Lower Lias are some of the most characteristic species. The last-named species is conspicuous for the long spiny processes projecting from the sides of the shell. (Wall-case 12.)

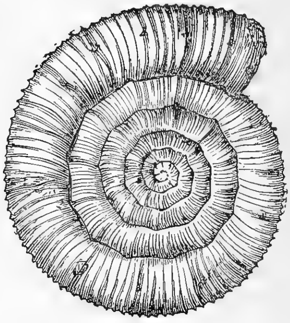
The family POLYMORPHIDÆ has been constituted to contain certain genera which have been separated from the ÆGOCERATIDÆ on the

FIG. 12.



Ægoceras capricornus, Schloth. (Lower Lias.)

FIG. 13.

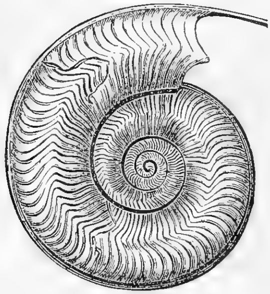


Ægoceras Davæi, Sow. (Lower Lias.)

one hand and from the HARPOCERATIDÆ on the other. It is notable for the variations undergone by the shell in passing from the young to the adult stage of growth. *Liparoceras Bechei* (Middle Lias) is a well-known species with a highly ornate shell. *Hammatoceras Sowerbyi* (Lower Oolite) has a keeled margin in the young shell which it loses in the adult, while the umbilicus, at first narrow, becomes ultimately wide. (Wall-case 10.)

The HARPOCERATIDÆ are derived from the ARIETIDÆ. The oldest forms begin in the Middle Lias, and they extend into the Inferior Oolite. The shells are flattened and keeled, and have falciform or sickle-shaped ribs, or striæ. *Hildoceras bifrons*, from the Upper Lias of Whitby, shows this kind of ornamentation very distinctly.

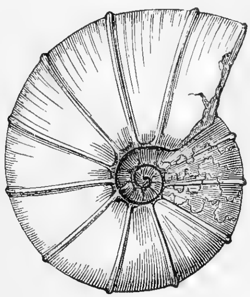
FIG. 14.



Grammoceras serpentinus, Schloth. (Upper Lias.)

Leioceras opalinum (Lower Lias) is another characteristic species, the aperture with ear-shaped lateral processes. *Grammoceras serpentinus* (Fig. 14) characterizes the "*Serpentinus* zone," or Jet Rock, which has yielded some of the finest and best preserved Ammonites of the Yorkshire Lias. Of Inferior Oolite species *Ludwigia Murchisonæ*, Sow., and *Oppelia subradiata*, Sow., may be mentioned. (Wall-case 10.)

FIG. 15.



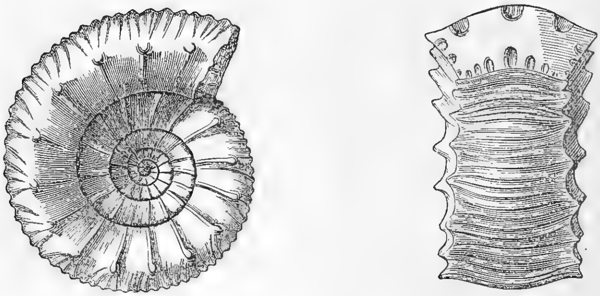
Desmoceras ligatum, d'Orb. (Neocomian.)

The PULCHELLIDÆ (Cretaceous) are remarkable for the simplicity of their suture-line, some resembling Goniatites, others Ceratites, in this respect. They are considered to be true Ammonites, descendants of the Jurassic HARPOCERATIDÆ, but in a state of degeneracy. *Pulchellia compressissima* (Lower Cretaceous) and *Neolobites Vibrayeanus*

(Upper Cretaceous) may be cited as examples of this small group. (Table-cases 63, 64.)

The HAPLOCERATIDÆ, ranging from the Inferior Oolite to the Middle Chalk, differ in many respects from the HARPOCERATIDÆ, from which they branch off. The shell is generally thick, sometimes remarkably so, as in *Pachydiscus peramplus* of the Middle Chalk; there are also periodic constrictions or grooves upon the

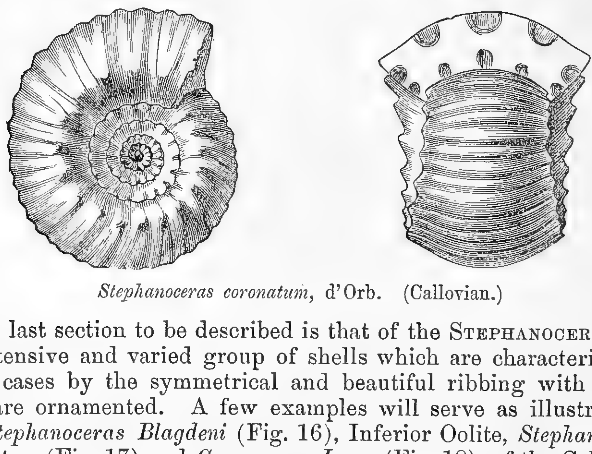
FIG. 16.



Stephanoceras Blagdeni, Sow. (Inferior Oolite.)

surface, which gave rise to the old group-name *Ligati*. Finally, the contour of the edge or periphery of the shell is uninterrupted, there being no keel such as is met with in the HARPOCERATIDÆ. There is an aptychus in a few forms. Of the flatter kinds of shells of the present family, *Desmoceras ligatum* (Fig. 15) of the Neocomian and *Desmoceras planulatum* of the Gault may be referred to as examples. (Table-case 64.)

FIG. 17.



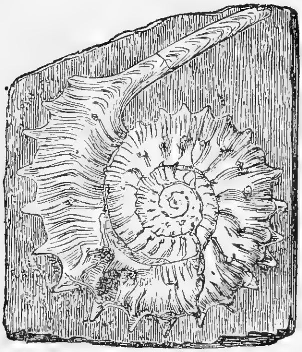
Stephanoceras coronatum, d'Orb. (Callovian.)

The last section to be described is that of the STEPHANOCERATIDÆ, an extensive and varied group of shells which are characterized in many cases by the symmetrical and beautiful ribbing with which they are ornamented. A few examples will serve as illustrations, viz. *Stephanoceras Blagdeni* (Fig. 16), Inferior Oolite, *Stephanoceras coronatum* (Fig. 17) and *Cosmoceras Jason* (Fig. 18), of the Callovian or Oxford Clay, and *Hoplites radiatus* (Fig. 19), of the Neocomian. (Wall-cases 5, 9, 10; Table-cases 62–68.)

Another characteristic shell of this group is the *Acanthoceras Rhotomagense* of the Lower Chalk. (Table-case 62.)

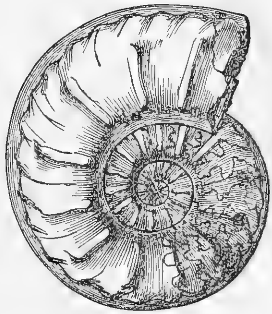
A small group of forms still remains to be considered whose structure (external and internal) has led to their being regarded as

FIG. 18.



Cosmoceras Jason, Rein. (Callovian.)

FIG. 19.

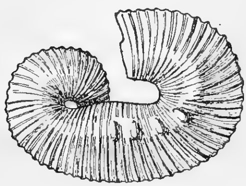


Hoplites radiatus, Brug. (Neocomian.)

offshoots from the STEPHANOCERATIDÆ. They may be divided into two sections—the first, consisting of shells partly uncoiled; the second, in which the shells are completely coiled, with deeply embracing whorls.

Section I.—The form of *Scaphites* immediately recalls that of *Macroscaphites*, but it differs in several particulars: it is much more closely coiled, that is, the inner coils of the shell are not seen,

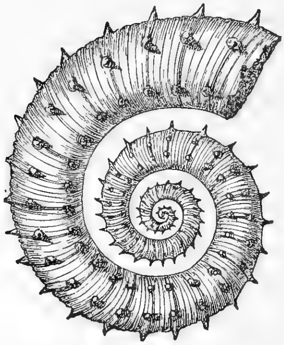
FIG. 20.



Scaphites Hugardianus, d'Orb. (Cretaceous.)

being covered up by the succeeding ones; and further, the uncoiled part is much shorter and its outline more rounded, while it bends over so as to almost reach the coiled part. *Scaphites* is abundant in the Middle and Upper Cretaceous. (Table-case 61.) *Crioceras* has the form and curvature of an Ammonite, but the whorls are not in contact (Fig. 21). It was formerly supposed that this genus was wrongly founded upon broken shells of *Ancyloceras* (*q. v.*); but the discovery of the aperture has dispelled this error. There is no doubt, however, that *Toxoceras* is nothing more than a fragment of *Crioceras*. *Ancyloceras* begins like *Crioceras*, but at the last whorl the shell is straightened out at a tangent to the coiled part, and after attaining

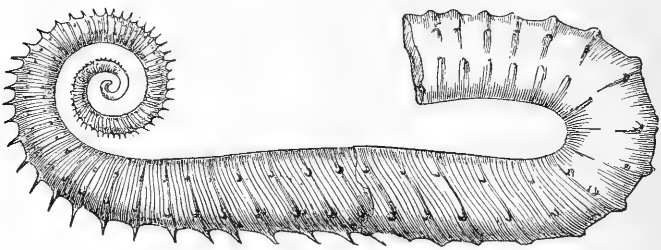
Fig. 21.



Crioceras Emerici, Léveillé. (Neocomian.)

a considerable length in a straight course it bends over abruptly in the direction of the coiled part, as in *Scaphites*. *Crioceras* and *Ancyloceras* are variously and elegantly ornamented with ribbing, spines, and tubercles. *Crioceras* extends from the Neocomian to the Upper Greensand; *Ancyloceras* from the Inferior Oolite to the Chalk.

Fig. 22.



Ancyloceras Matheronianum, d'Orb. (Neocomian.)

Section II.—This section includes Ammonites of flat, disc-like form, with *Ceratites*-like sutures and deeply embracing whorls. *Sphenodiscus* and *Buchiceras* (Upper Cretaceous) are characteristic genera. *Placenticeras* (Cretaceous) includes such species as *P. Largillertianum* and *P. Orbignyanum*.

An hour spent in this gallery will well repay the student interested in the study of the fossil Cephalopoda.

III.—A Description of *Ceramurus macrocephalus*, a small Fossil Fish from the Purbeck Beds of Wiltshire.

By Arthur Smith Woodward, F.L.S., F.G.S.,
Of the British Museum (Natural History).

SINCE the publication of some notes on the English Purbeckian Fishes a few months ago,[1] the writer has been favoured by the Rev. P. B. Brodie, M.A., F.G.S., with the opportunity of re-investigating and comparing the original specimen of the small problematical fish *Ceramurus macrocephalus*, briefly described by Egerton[2] from the Purbeck Beds of the Vale of Wardour. Most of the early descriptions of fossil fishes are inadequate for present needs; and no genus and species could be less satisfactorily characterized than that just referred to. A new attempt to elucidate the fossil, in the light of modern knowledge, is thus very desirable, more especially as no other specimens of the same fish have hitherto been recognized.

Egerton's original description, accompanying Brodie's figure, is merely a brief note. He remarks that this little fish "presents the nearest affinity to the remarkable genus *Megalurus*, but differs in its slender form and the large proportional size of the head. The vertebræ seem to be fewer in number, and of smaller diameter. The most characteristic feature is the tail, which is strengthened above and below by broad, elongated, fulcral scales. This interesting specimen may be designated by the name of *Ceramurus*, or tile-tail, from the character of the fulcral scales supporting the lobes of the caudal fin. The species may be called *macrocephalus*." Such is the complete quotation, and no further particulars as to the genus and species have hitherto been published.

The fish in question is preserved in counterpart, but the head and caudal fin are imperfect, while a vein of calcite crosses it obliquely at the hinder end of the abdominal region. There is also some displacement at the back of the branchial region. The length of the head with opercular apparatus must have been about twice as great as the maximum depth of the trunk, while it would probably be contained four times in the total length of the fish. No feature worthy of note can be observed in the fragments of the head. The vertebral centra are delicate rings, which appear to have been disposed in a spaced series so that in their crushed condition they are exposed mostly in end-view. It is not possible to count them. The neural arches in the abdominal region are much shorter than their appended spines, which are loosely apposed apparently by a forked base. The ribs are short, and especially delicate. The neural and hæmal spines in the caudal region are fused with their respective arches, and these also probably with the vertebral centra. The axis is much turned upwards at the base of the caudal fin, and the hæmal spines are thickened as usual. There are no traces of

[1] "A Contribution to Knowledge of the Fossil Fish Fauna of the English Purbeck Beds," Geol. Mag., Dec. IV, Vol. II, p. 370 (April 1895).

[2] In P. B. Brodie's "Fossil Insects," p. 17, pl. i, fig. 2 (1845).

intermuscular bones. The fins consist of long slender rays, with distant articulations, and apparently never forked more than once at the distal end. Each is fringed by three or four very long and slender fulcra, which are conspicuous by their enamelled surface. The slender pectoral arch of one side is displaced backwards, and the imperfect pectoral fins, with the characteristic fulcra, are shown. One of the hour-glass-shaped pelvic fin-supports is exhibited, and some of the delicate pelvic fin-rays adpressed to the trunk reach as far as the origin of the anal fin. The dorsal fin is short-based, arising near the middle of the back and opposite to the pelvic pair. Nine supports, of which the anterior ones are stouter than the rest and somewhat winged, can be counted in front of the disturbing vein of calcite; and the long dorsal rays are pressed down upon the back so that their distal ends appear behind this vein. The anal fin arises behind the posterior end of the dorsal, and comprises about eight rays, which when adpressed reach nearly to the base of the caudal fin. The latter fin is imperfect and distorted, and it is impossible to determine whether or not it was forked. Delicate scales may have covered the trunk, but there is no clear evidence of them. Robust ganoid ridge-scales, however, are observable on both borders in the hinder half of the caudal region; and those of the dorsal border are shown to be remarkably acuminate, the apex of each scale being especially produced into a long point at the base of the upper caudal lobe.

In short, so far as can be determined from this unique specimen, *Ceramurus* does not exhibit any special feature of resemblance to *Megalurus*. The fins bear large fulcra, while those of *Megalurus* are non-fulcrated; the form of the caudal fin is unknown; the dorsal fin is remarkably short; the vertebral centra are merely spaced rings. On the whole, the fish appears to the present writer to be most closely related to *Pholidophorus*, and it will probably prove to have a forked tail. The axial skeleton of the trunk, the fins, and the caudal ridge-scales are especially suggestive of *Pholidophorus*; but *Ceramurus* differs in the large size and fewness of the slender fin-fulcra, in the unusual development and serried arrangement of the dorsal ridge-scales of the tail, and in the *apparent* absence of scales on the flanks. The fish may, therefore, be provisionally assigned to the Pholidophoridæ, under the generic and specific name which Egerton proposed for it.

IV.—Notes on "The Great Ice Age" in Relation to the Question of Submergence.

By Dugald Bell, F.G.S.

(*Continued from p.* 355.)

V. Changes of Level in Relation to Climate.

LEAVING those local matters, there is a point of some general interest, suggested by several passages of Dr. Geikie's work, which we should like briefly to notice before laying it aside. It is in regard to those repeated depressions and re-elevations of the land which he still favours in connection with the Glacial epoch. Dr. Geikie's latest "scheme" of that epoch seems to include at least *five* Glacial and *four* inter-Glacial periods, accompanied by submergences and re-elevations to the extent of between 500 and 600 feet—the maximum being for the present restricted to that amount.[1] Frankly, we confess ourselves unable to see the proofs for so many Glacial and inter-Glacial periods, of which, if they did occur, it would apparently be impossible—on the author's own premises as to glacial erosion—now to discover any traces. Apart from this, we might remark on the inherent improbability of such extensive oscillations of the earth's crust having happened in recent geological times, without leaving more distinct evidence of themselves than the very scanty and doubtful deposits which we have been considering.

Let us look, however, for a little at such alleged movements in one aspect only—their relation to glacial conditions. We think it may be taken as a certain *datum*, to begin with, that in itself a high elevation of the land tends to bring about colder conditions; and on the other hand, a depression or submergence of the land is distinctly favourable to milder conditions of climate. In this country, for example, an elevation of a few hundred feet would bring a considerable extent of our mountainous regions within the limits of perpetual snow. It would also ward off to a greater distance the warmer currents of the sea, and in these and other more indirect ways it would obviously lower the general temperature of the country. On the other hand, a submergence of a few hundred feet, by lowering and diminishing the high lands, and by admitting more freely the ocean currents—the great distributors of heat and equalizers of temperature—would certainly go far to bring about milder and more genial climatic conditions. So that, as Lord Kelvin has pointed out, with a far more moderate submergence than many are in the habit of imagining, in the northern hemisphere, there would in all likelihood be no snow or ice at all till some point far up within the Arctic circle, and perhaps not much even there.[2]

Sometimes impossible currents are invoked from unknown regions, to perform tasks that are plainly beyond them. So long as the earth has revolved on its present axis, and the great continents of its surface have occupied their present position, so long, it would seem, must the general system of aerial and ocean currents have been the same. Our belief in the general similarity of conditions in these respects during the Glacial period, and at present, is confirmed by the fact—admitted by Dr. Geikie—that alike in Europe, Asia, and America, the areas of maximum precipitation during the Glacial period corresponded to the areas of maximum precipitation still. "The former distribution of snow and ice was in strict accord with existing conditions: . . . . there can be no doubt that the conditions

[1] See "Great Ice Age," pp. 323–325, 421 and 422. Also "Fragments of Earth Lore," pp. 319–321.

[2] "On Geological Climate," Trans. Geol. Soc. Glasgow, vol. v.

of Glacial times bore an intimate relation to those that now obtain" ("Great Ice Age," p. 777). We cannot see, then, how it could possibly be otherwise than that elevation and colder conditions, submergence and warmer conditions, must have gone together. This cardinal principle, we submit, should be borne in mind in the construction of any scheme of events for the Glacial period.

Now, from this point of view, we can make nothing of Dr. Geikie's "succession of events" during that period; the physical changes and climatal conditions set forth seem to be utterly disconnected, and indeed at variance with each other. Thus, to take a few instances, we read—

"The climate certainly must have become cold and ungenial as the depression continued" (p. 312).

"Scotland submerged . . . . The climate had deteriorated" (*ibid.*).

"The land gained on the sea until the latter had retreated considerably beyond its present limits. The climate at the same time became more genial" (p. 313).

"Submergence next ensued, the climate at the same time passing from temperate to Arctic" (p. 323).

"Re-elevation of the land, or retreat of the sea, and a gradual amelioration of climate" (p. 325).

"Submergence once more ensued . . . . and the climate at the same time became colder" (*ibid.*).

From these and other passages which might be quoted it would seem that the author regards elevation as somehow productive of more genial conditions, and submergence as associated with colder and more severe conditions of climate.

We hold the opposite view so strongly that when shells of distinctly Arctic species are found (as in some instances they have been) at a considerable elevation, that very circumstance, to our mind, casts "ominous conjecture" on their being really in place.

We may remark, in closing, that these numerous distinct Glacial periods, accompanied by repeated depressions and re-elevations, are not borne out by the observations of geologists in other countries. Unless cause be shown to the contrary, the probability surely is that the conditions prevailing here during the Ice Age were similar to those prevailing in other parts of the Northern hemisphere. We have already quoted Dr. Geikie to the effect that "no evidence of marine action has been detected in the formation of the stony clays" which cover "the low grounds of Northern Europe" ("Great Ice Age," pp. 432–3). "Nowhere do German geologists find any evidence of marine action"—that is, in the Boulder-clay. The overlying so-called "inter-Glacial" deposits within the Baltic area, as a rule only attain a very moderate elevation (pp. 448–50). In Sweden, two Boulder-clays are recognized, a lower and an upper; but Törnebohm says they have "both been formed in the same way, and are true *moraines de fond*, and that in the interval between them, marked by a partial retreat of the ice, "the land was not submerged." In short, "the majority of geologists on the Continent believe that there have been only two Glacial epochs, separated by an inter-Glacial epoch of more genial conditions" (pp. 445–6).

This corresponds very well with the results arrived at generally by the American geologists: they recognize three stages—the *early* Glacial epoch, characterized by ice-accumulation to its maximum extent; the *middle* Glacial epoch, or that of the first retreat of the ice; and the *later* Glacial epoch, or that of the final retreat (Dana; see also Chamberlin, in "Great Ice Age," p. 773).

But some prefer to regard the whole as really *one* epoch, though varying from time to time in intensity and local extent.

While not unaware of local difficulties, we respectfully submit that Dr. Geikie's complicated system of so many Glacial and inter-Glacial periods, and so many submergences and re-emergences, from 500 or 600 feet downwards—with their varying and apparently inscrutable effects upon climate—tends on the whole to increase these difficulties, and should therefore be "reformed altogether."

V.—A Note on the Torbay Raised Beaches and on the Detached Blocks trawled in the English Channel.

By A. R. Hunt, M.A.

In Professor Prestwich's important paper on the Raised Beaches of the South of England[1] the following passage occurs: "In Torbay there are small portions of a Raised Beach near Paignton. . . ." As on the strength of this statement the line of Raised Beaches is carried in the map round the extreme present limits of Torbay, and the hitherto universally accepted doctrine, that Raised Beaches do not occur in the softer parts of the coast-line, is thus controverted, the assertion is one of considerable importance.

In my own paper on the Raised Beaches I wrote, in 1888[2]—"The stage of the erosion indicated by the Northern Torbay Raised Beaches is that when the east and west coast-line had not passed the line of Torbay, and Torbay itself was but in an early stage of formation." A Raised Beach at Paignton would subvert this conclusion, and the numerous facts on which it was based.

Desirous as I necessarily was to investigate the reputed Paignton beach, Professor Prestwich in the most generous way offered me every facility. The authorities relied on were Messrs. Pengelly and Ussher. As it happened, Messrs. Pengelly and Ussher, and myself, had all written independent papers on the few hundred yards of coast in question; so there was no lack of literature to fall back on.

My first impression was that Mr. Pengelly might have described as a beach an eroded bed of conglomerate very like a Raised Beach in the sandstone of Roundham Head, which bed he used to point to as an instance of contemporaneous erosion of Triassic age, and possibly a Raised Beach, though one in no way connected with the Quaternary beaches. This deposit, however, does not seem to be noticed in any of his papers. Referring the question to Mr. Ussher,

[1] Quart. Journ. Geol. Soc., vol. xlviii, p. 279.
[2] Trans. Devon Assoc., vol. xx, p. 250.

he reminded me of a gravel bed between Paignton and Torquay, described in his paper mentioned above, wherein Mr. Ussher writes—"We have in the alluvial deposits of the Goodrington and Paignton flats, and in the blown sands extending from Roundham Head to the north part of Preston Sands, and in the present sea-beaches, the latest evidences of Pleistocene deposition. Of these three phenomena the gravels near the gasworks are probably the oldest. . . . . All these events transpired within that most recent part of the Pleistocene period which succeeded the formation and elevation of the old beaches of Hope's Nose and other places."[1] We see clearly that Mr. Ussher here knows of no "old beach" at Paignton, as, his subject being "The Geology of Paignton," he goes to Hope's Nose for an example of such deposits. Mr. Pengelly, writing of precisely the same locality, observes—"A glance at the existing beach at the foot of the cliff, a study of the Raised Beaches *almost in sight*," etc.[2] (italics mine). The Raised Beaches "almost in sight" are again those at Hope's Nose and Brixham; the one obscured from view by Daddy Hole Point, the other nearly five miles distant across the bay.

Mr. Pengelly clearly, though writing of Paignton Quaternary Geology, knew of no Raised Beach there. It may, I think, be accepted as a fact that no Raised Beach at Paignton has been known to any local geologist. But as both Mr. Pengelly and Mr. Ussher spoke of Raised Beaches in connection with the geology of Paignton, a reader might easily remain under the impression that Raised Beaches occurred in the immediate neighbourhood. "Beaches almost in sight" might very well be round the next headland instead of the nearest being three miles distant.

A Raised Beach at Paignton would snap a very pretty chain, or set of chains, of evidence, reconstructing the ancient coast-line. There is an immense amount of work still awaiting the right man in the sands and pebbles of the ancient beaches. Never was I more struck by geological evidence than I was by two pebbles at Brixham—one absolutely indistinguishable in form from the spheroidal chert of Chesil; the other a characteristic igneous rock from the Teignmouth conglomerates, found, I believe, nowhere else. These stones must have travelled across the mouth of Torbay, about 20 feet or so above the level of present high-water. Such a fact signifies volumes! By no possibility could these pebbles have travelled round such a bay as Torbay is now. These stones alone suffice to forbid the possibility of a Raised Beach at Paignton, at any rate one contemporaneous with the rest.

In Professor Prestwich's paper referred to, the author, while mentioning my work in the kindest manner, cites me as an authority in favour of the view that blocks trawled in the English Channel were ice-borne, *e.g.*, "Mr. Hunt dismisses the hypothesis of adjacent land-ice, owing to the absence of similar blocks between Dartmoor and the sea, and concludes that they were brought there by floating

[1] Trans. Devon Assoc., vol. x, p. 203.
[2] *Loc. cit.*, p. 200.

ice."[1] This is not quite so. I wrote as follows: "If, on the other hand, they [the blocks] were brought by floating ice from distant regions, it remains to be explained why they should be found collected together in a limited area of the English Channel." I meant that no such explanation was forthcoming; and continued subsequently—"The stone itself may be considered *primâ facie* evidence that the large detached stones in the sea off Salcombe are really granite, and that the ground on which they lie is granite too."[2] This was in 1879. Many varieties have occurred in addition to granite since then. My very last words on these stones, in 1889, were—"However, it is clearly impossible to prove that some of them may not have been ice-borne. Let those who maintain that theory show cause for their belief."[3] The evidence is strangely conflicting. About seven years ago I was staggered by a suggestion which reached me from an influential quarter that it might be doubtful whether there was anything further to be written on the subject of the detached blocks trawled in the English Channel. As a matter of fact, the necessary work is no more than commenced; and there is no prospect of it ever being resumed.[4] Let me dwell for a moment on one single point—Let us assume that the crystalline blocks are ice-borne: we are at once confronted with the fact that they occur in an area of sands and gravels partly derived from crystalline rocks, which sands and gravels are certainly not ice-borne. In such an inquiry it is not safe to take anything for granted. It seemed safe to assume, as was assumed, that the Channel granites were connected with Dartmoor; whereas they have proved themselves perfectly distinct. So, before taking for granted a connection between the Channel blocks and the Sussex boulders, it will be necessary to compare them in detail, and minutely. It will also be necessary to do the same by the Channel crystalline gravels, to ascertain whether they are related to England or to France; to both, or to neither. The coming man should have his steam yacht, enthusiasm, patience, the acuteness of a Sherlock Holmes, be a good practical micro-petrologist, and prepared to follow where the clue leads instead of where he thinks it ought to lead. Before the days of the microscope and steam, analogous work was done by such men as Mr. Godwin-Austen, and it is to their successors we must look in the future. To any such worker Professor Prestwich's paper must prove of the greatest value, suggesting as it does innumerable subjects for detailed research, as well as problems to be solved and theories to be tested.

[1] Quart. Journ. Geol. Soc., vol. xlviii, p. 297.

[2] Trans. Devon Assoc., vol. xi, p. 316.

[3] *Ibid.*, vol. xxi, p. 485.

[4] The difficulty lies in interesting the fishermen sufficiently to preserve hand specimens, and to take notes as to bearings. I was fortunate enough to interest a most intelligent and trustworthy crew, on whom I could place all reliance, and whose zeal was stimulated by half-a-crown for each large block, of which a fragment was preserved and whose position was ascertained. Their vessel changed hands long since, and her crew was dispersed. Thanks to my friend Professor Hughes all their carefully collected specimens are preserved in the Woodwardian Museum.

In conclusion, I may refer to a paper read by my esteemed colleague, Mr. D. Pidgeon, to the Geological Society in 1890, in which, on the evidence of the shells and beach materials sent to him, he disputed the genuineness of the Raised Beaches of Hope's Nose and the Thatcher Rock.[1] Mr. Pidgeon, with his accustomed keen eye for important detail, has pointed out certain very significant facts previously unnoticed, and still unexplained; but the proof of the genuineness of the beaches lies in evidence quite independent of the minute structure of the beach-material, organic or inorganic. Had my friend been able to visit the beaches, I feel assured he would never have questioned their genuineness; and think it highly probable he would have found some very satisfactory explanation for the angularity of certain of the inorganic, and for the fractured state of certain of the organic, components of the deposits in question. During the many years over which my own investigations extended, I never gave these two points a thought; and since Mr. Pidgeon's paper was published have not set foot on the Thatcher Rock.

VI.—The Viscous Flow of Glacier-Ice.

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

ALTHOUGH, ever since the classical researches of J. D. Forbes on the phenomena presented by the Swiss glaciers were published, it has been recognized that glacier-ice behaves like a viscous liquid, and flows from high to low levels much in the same way as does a river of water, it is apparent that many who have interested themselves in the subject of glacier-flow, and have written rather dogmatically on the subject, have not clearly realized the nature of the phenomenon. Very contradictory and erroneous conclusions have consequently been arrived at, with the result that it is now somewhat difficult for those who have not made a special study of the subject to distinguish what may be fairly regarded as ascertained fact from that which is purely matter of opinion.

I will, therefore, venture to state as clearly as possible the laws of viscous flow (as I understand them) as deduced from experiment, and then inquire to what extent the motion of a glacier approximates to the conditions of such flow.

Our knowledge of the subject is by no means due to recent discovery. The viscous flow of liquids—and glacier-ice behaves as a very viscous liquid—was worked out by Poiseuille and Coulomb. Later, we have Helmholtz, O. E. Meyer, Graham, Clerk Maxwell, and Osborne Reynolds. The discoveries of these workers are quite sufficient to enable us to work out the more important phenomena presented by glacier-flow from first principles. Indeed, had sound physical theory been adhered to by all writers on the subject of glacier erosion and transport, the mistakes so many have fallen into might have been avoided. Fortunately such investigators as Prof. James Geikie have been able to keep the balance of opinion from inclining in the wrong direction.

[1] Quart. Journ. Geol. Soc., vol. xlvi, p. 438.

In treating of viscosity we are at the outset met by a verbal difficulty. Viscosity and plasticity have both been used to denote the same physical property. Some writers speak of ice and pitch as being plastic as well as viscous. It is better, however, to follow Maxwell,[1] who defines a viscous body as one which undergoes continuous change of form under stresses, however small. All viscous substances are on this view true liquids. A plastic substance, on the other hand, only undergoes continuous change of form when the stress exceeds a certain value. When the stress required to cause continuous distortion is small, the substance is called a *soft solid.* Until this limiting stress is reached the substance is elastic, and the stress at which what is known as perfect elasticity ceases to be obtained, and the substance undergoes permanent deformation, is called the *limit of perfect elasticity.*

We must also recognize that there are *hard solids.* In them, when the stress exceeds the limit of perfect elasticity, the substance begins to yield more or less steadily as the stress increases. In some cases after this limit is reached the solid suffers a sudden permanent elongation. It afterwards regains its strength, and then only yields further with increasing stress.

The point at which the material gives way is called the *yield point,* and as it coincides very nearly with the limit of perfect elasticity, and is easily detected, it is now always noted by practical engineers. But the distortion of a *hard solid* is not produced under the conditions which give rise to viscous flow. Indeed, the action of the stress often appears to produce an allotropic change in the material. The whole subject is a most difficult one, and has by no means been completely worked out. There is no real boundary separating a hard from a soft solid. The soft solid under a sufficiently great stress yields much as a viscous fluid does; whilst the hard solid often fractures, and definite shear planes or faults are formed.

The difference between plasticity and viscosity is one of fundamental importance to the engineer, for as long as the stress put upon a foundation does not exceed the *yield point* the structure raised upon it is permanently stable. It is quite otherwise with a viscous material. No possible foundation can be stable upon such a substance unless it be made to float like a ship upon water; for, however large the area upon which the stress acts, the foundation will yield continuously.

With increase of temperature the yield point and limit of perfect elasticity grow smaller and smaller in many instances; and a soft solid or plastic material may, with rise of temperature, become a viscous liquid.

By many the difference between the plastic and viscous condition is not properly appreciated. We have our softer rocks spoken of as though they were viscous, and various theories of soil-cap motion propounded to explain phenomena resulting from other agencies.

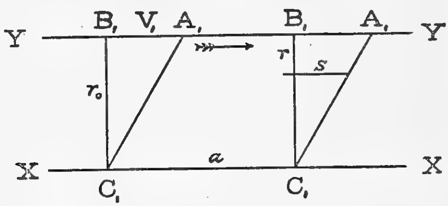
[1] "Theory of Heat," 1894 edition, p. 303.

When saturated with water many sands, clays, and loams do become very plastic, and flow almost like viscous fluids. Excellent instances of such flow may be seen at the base of the Cromer cliffs.

We must regard the solid crust of our earth as being hard, truly plastic, or plastic under great pressure, not viscous. Except as the result of denudation, or from the action of internal forces, which occasionally bring the stresses above the limit of perfect elasticity, our mountain ranges are stable and not tending to level up as they would do if composed of even a much more viscous substance than pitch. To quote Maxwell,[1] "A tallow candle is much softer than a stick of sealing-wax; but if the candle and the stick of sealing-wax are laid horizontally between two supports the sealing-wax will in a few weeks in summer bend with its own weight, while the candle remains straight. The candle is, therefore, a soft solid, and the sealing-wax a very viscous liquid."

The term viscosity, however, has been used to indicate a property of solids of quite another kind. That it should have been used in such a way is unfortunate, for the property known as *solid viscosity* is quite different from that of a liquid. To make this quite clear the phenomenon presented by a solid substance under the action of a stress will be considered before treating in detail the conditions of liquid flow.

Fig. 1.



The space between two planes, Fig. 1, one of which YY is free and the other XX fixed, we will regard as being occupied by a solid substance. Under a given stress, acting along the plane YY in the direction of the arrow, the solid undergoes an elastic shear equal, we will say, to the displacement of B_1 to A_1. But, the stress remaining constant, it will be found that with the lapse of time this displacement slowly increases in amount, especially if the solid be set in vibration, and only reaches a maximum after a very considerable interval has elapsed. On removing the stress the plane returns at once to almost its original position. But the last traces of distortion only disappear after the lapse of many hours. Indeed, in many instances the original configuration is never regained, the behaviour of the material as it were depending upon its previous history.

We will now consider the conditions of flow of a thin stratum of a viscous liquid placed between the planes XX and YY, the

[1] "Theory of Heat," 1894 edition, p. 303.

upper one of which is moving at a uniform speed in the direction of the arrow. Observation shows that in such a case, owing to the resistance offered by the liquid to shear, the stress is transmitted from layer to layer of the liquid, and each portion of the fluid moves at a velocity which increases uniformly as we recede from XX and approach YY. Of course the motion of the fluid is regarded as having reached a steady state; inertia-effects consequently do not show themselves. Hence the particles originally forming the lines $B_1 C_1$ in the figure after a certain interval of time have positions on the lines $A_1 C_1$. As these lines are on the same base and between the same parallels, the inclosed space retains its original area. Distortion only has been produced, each horizontal layer having moved over the one below it. It must be clearly understood that to produce these conditions of motion the stress must not act with equal force on each particle of the fluid, but solely along the plane YY, and be transmitted from particle to particle owing to the viscosity of the fluid.

With a solid between the surfaces, if the planes be relatively fixed whilst the material is under stress, the stress persists. On the other hand, in the case of a liquid the stresses very soon die away. The time required for this to take place, Maxwell called the "time of relaxation." For highly viscous liquids it may be measured by hours, or even days; for ordinary liquids a fraction of a second suffices; whilst for a gas such as air, Maxwell estimated the stress as lasting about the fifty-thousand millionth of a second.

The force R required to produce such continuous relative motion is a shearing stress, and it is measured by the stress per unit area of either of the planes, in which a is the length and b is the breadth of the area over which the force acts; and we may write

$$R = F\,a\,b \quad . \quad . \quad . \qquad (1)$$

In Fig. 1 we have a mass of liquid $B_1 C_1$, $B_1 C_1$ for our purpose being regarded as free from the action of gravity, occupying the space between two horizontal parallel planes, XX and YY. The plane YY is moving under the action of a force, R. Let the distance between the planes be denoted by r_0 and the speed at which the plane YY is moving by V_1. Then the rate of distortion may be written—

$$\frac{V_1}{r_0} \quad . \quad . \quad . \quad . \qquad (2)$$

Making s the velocity of any plane, at the distance r from YY we have

$$\frac{s}{r_0 - r} = \frac{V_1}{r_0} \quad . \quad . \qquad (3)$$

which expresses the fact that the rate of distortion is uniform across the section.

To maintain this rate of distortion a shearing stress F, acting parallel with the planes, is required. The ratio of this force to the rate of distortion, the temperature and pressure being unaltered, is a constant for each particular liquid. It is denoted by μ, and is called the coefficient of viscosity. We may consequently make

$$F = \mu \frac{V_1}{r_0} \quad . \quad . \quad . \quad . \quad (4)$$

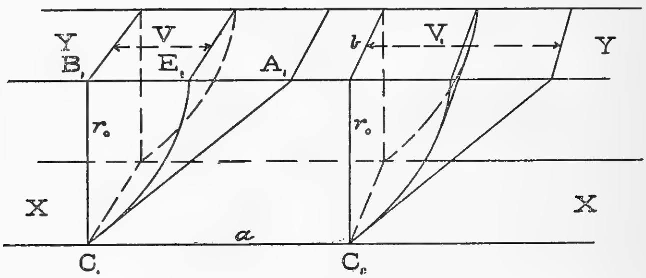
and

$$\mu = F \frac{r_0}{V_1} \quad . \quad . \quad . \quad . \quad (5)$$

It will be seen that as long as V_1 and r_0 retain the same relative proportions, *i.e.* as long as the rate of distortion is unaltered, the shearing stress F has the same value at all planes parallel to XX and YY.

In these illustrations no slip at the boundaries has been regarded as taking place.[1] In the case of such fluids as have had their viscosities determined by their rate of flow through capillary tubes, slipping at the boundaries, if it took place at all, must have been less than a thousandth of the mean flow, although the tangential force at the boundary was as much as 6 lbs. per square foot at a speed of 1·23 feet per second. Considering that the skin-resistance of a steamer going at 25 knots is not 6 lbs. per square foot, it is clear that slipping at the boundaries does not take place in practice, unless in very exceptional cases. The resistance to slipping at the

Fig. 2.



boundaries is in most cases probably greater than is the resistance to local shear of the liquid itself. In the case of ice the conditions are usually very different. Below the freezing point the ice may adhere to the boundary walls, and under such circumstances there is no slipping. But above the freezing point ice is always separated from other substances by a film of water, and as the viscosity of water is very much less than that of ice, slipping at the boundary readily takes place. Two surfaces of ice under the same conditions cohere strongly. This makes it impossible under such conditions for one portion of ice to flow over another portion resting in a hollow without imparting motion to it, for regelation takes place and the stresses are transmitted by the viscous resistance. It is

[1] "Dynamical Theory of Incompressible Fluids," by Osborne Reynolds, Phil. Trans. 1895, p. 123.

quite possible that the coefficient of viscosity μ is not a constant for glacier-ice, as such ice varies much in structure at different points, and its viscosity appears to be rather a molar than a molecular phenomenon. At present we do not appear to have any complete theory of viscosity; consequently it would be premature to declare that glacier-ice is not truly viscous. Before we can safely go so far we must be able to show that the same theory will not apply, for example, to both ice and water.

In Fig. 1 we have regarded the flow as resulting from the action of a stress applied at a plane surface parallel to the direction of flow, the viscosity of the fluid setting in motion the whole mass in such a way that the rate of distortion is everywhere the same.

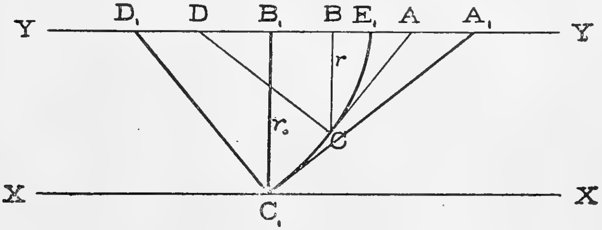
In Fig. 2 the viscous liquid is supposed to be flowing over a plane surface under the action of a uniform pressure acting upon a surface at right angles to the direction of flow. Here in place of a force F acting on unit area of YY parallel to the direction of motion, we have a pressure P, acting on unit area of the surface $b\,r_0$ normal to the direction of flow. This may be due either to the pressure of a liquid column, or it may be regarded as the effect of gravity acting with an equal force on each particle of the liquid, the lower plane being inclined so as to give uniform conditions of flow between the parallel planes XX and YY. In either case the nature of the flow is the same.

At the bounding plane XX the whole pressure on $b\,r_0$ is acting to distort the liquid, and the rate of distortion

$$\frac{V_1}{r_0}$$

is the same as before for the same total force acting on the liquid. However, at any given distance r from the surface YY the shearing stress is obviously proportional to the area acted on by the pressure, divided by the length of the line over which the shearing stress acts, *i.e.* to $\frac{b\,r}{b}$ or simply to r.

Fig. 3.



In Fig. 3, $BC = r$, and $\frac{AB}{BC}$ = rate of distortion at the point C; $\frac{AB}{BC}$ is, therefore, proportional to BC.

But by drawing CD, $C_1 D_1$ perpendicular to CA, $C_1 A_1$ we have by similar triangles

$$\frac{AB}{BC} = \frac{BC}{BD} \quad . \quad . \quad . \quad . \quad (6)$$

therefore $\frac{BC}{BD}$ is proportional to BC, and BD must be a constant, which is a characteristic property of the parabola. Hence the curve $C_1 C E_1$ is a parabola whose axis is YY.

So we find that when a viscous substance is flowing under the action of gravity, or is propelled by a pressure uniformly distributed over a section normal to the direction of flow, the shearing stress is always greatest at the boundary. This is so even when the moving mass passes over a hollow with gently sloping sides. In Fig. 2 we may suppose that we are dealing with the flow of a very broad glacier moving down an incline. Every particle of it is being urged along in the direction of the inclination of the upper surface with a force depending upon the mean slope of the surface area immediately above it. The slope of the surface upon which it rests is only of secondary importance. The motive power wholly results from the inclination of the upper surface. If it were due to the slope of the lower surface a mass of ice in a basin-shaped hollow would form a vortex ring, and we should have a case of perpetual motion. Indeed, we must regard a glacier as moving just as a river does when the slope is very small (insufficient to make sinuous motion take the place of direct motion), but owing to its greater viscosity as moving at a much slower speed.

At each cross-section the volume passing must be the same, provided no ice is melted at the surfaces. Where the ice is thickest the slope of the upper surface is least, and where thinnest the slope is greatest. That this is so can be seen from the simple equations applicable where inertia does not influence the result.

Writing R as the total force on the liquid we have, Fig. 2,

$$R = P r_0 b \quad . \quad . \quad . \quad . \quad (7)$$

At the bounding plane XX, and making P the pressure on unit area, we have from equations (1) and (4)

$$R = \mu a b \frac{V_1}{r_0} \quad . \quad . \quad . \quad (8)$$

$$\therefore V_1 = \frac{R r_0}{\mu a b} \quad . \quad . \quad . \quad (9)$$

Making V the maximum velocity, as the curve of distortion is a parabola, we have $V = \frac{1}{2} V_1$, and from (9) and (7)

$$V = \frac{R r_0}{2 \mu a b} \quad . \quad . \quad . \quad (10)$$

$$= \frac{P r_0^2}{2 a \mu} \quad . \quad . \quad . \quad (11)$$

Also the volume V_1 swept through by any cross-section in unit of time

$$= \frac{2}{3} V b r_0$$

$$= \frac{2}{3} \cdot \frac{P r^2}{2 a \mu} \cdot b r_0$$

$$= \frac{P r_0^3 b}{3 a \mu} \quad . \quad . \quad . \quad (12)$$

So the volume passed is directly proportional to the pressure P, and to the cube of the thickness r_0 in the case of the central portion of a very wide glacier.

If the bed be semicircular we obtain in a similar way

$$V_1 = \frac{\pi}{16} \cdot \frac{P r^4}{a \mu} \quad . \quad . \quad . \quad (13)$$

No account is taken of the volume passed owing to slipping at the boundary. It, however, is only a fraction of that passed owing to the viscosity of the ice.

Experiments employed to ascertain the conditions of motion of existing glaciers have proved that velocity curves drawn across the glacier are parabolas, distorted somewhat where the ice-river is caused to make a bend, much in the same way as are the curves illustrating the flow of a river by the momentum of the water.

Above Montanvert the Mer-de-Glace is fractured across at one point, and into the crevasses so formed the surface moraine falls and forms imbedded strings of stone and mud. Lower down the melting of the ice at the surface again exposes the débris. But instead of running as straight lines across the glacier, the lines of débris sweep across as great parabolic curves having their apices pointing down-stream. No finer illustration of the fact that glacier-flow is a strictly viscous phenomenon could be conceived than is here presented. Proofs have also been given that a glacier moves more rapidly at the surface than it does at the bottom.

We also find that the rate of distortion at the bounding surface, where it rests upon rock, is greater than at any other point, and that there the abrading action is most energetic. Indeed, at the bottom of a hollow which might form the bed of a lake, even if the motion of the ice be slow, the pressure is very great, the ice going down into it at one end and rising from it at the other. Even at the bottom of such a hollow the maximum rate of distortion is located and a powerful grinding action maintained.

Throughout its course a glacier is urged along, not by a pressure from above but by gravity acting upon each molecule of ice during its whole course from the cold snow-fields above to the point where it melts in the warm valley below. No doubt *thrust* does play some part in the movement, just as does the momentum of the water in the flow of a river; but it is quite a subordinate feature and only produces local effects.

I am much indebted to Mr. C. E. Wolff, B.Sc., for the assistance he has rendered in the mathematical treatment of the subject.

VII.—On the Pitch Lake of Trinidad.[1]

By S. F. Peckham.

After a recent visit to Trinidad I am led to add my testimony to that of the numerous observers, who for more than a hundred years have written concerning this remarkable phenomenon.

The earliest account of a visit to Trinidad, accessible to English readers, was published in the Transactions of the Royal Society of London in 1789, by Alexander Anderson.[2] He describes Point La Brea as a promontory fifty feet high jutting into the Gulf of Paria. Ascending to the lake he describes it as three miles in circumference, divided into "areola" resembling those upon a turtle's back, the surface of each being "horizontal and smooth." He was there in the rainy season, and concluded that evaporation on the clear afternoons removed the torrents of water that fell during other parts of the day, as there was no other outlet. He further states that the soil around La Brea consists of cinders and burnt earth, being evidently the product of subterranean fires, as there were hot springs in the neighbouring woods.

The next visitor is Dr. Nicholas Nugent, who published an account of a visit made in October, 1807.[3] He landed on the south side of La Brea Point, which he describes as consisting of a bluff of porcelain jasper, "generally of a red colour." Ascending to the lake he perceived a strong sulphurous and pitchy smell, like that of burning coal, and soon after had a view of the lake, which at first sight appeared to be an expanse of still water, frequently interrupted by clumps of trees and shrubs, but on a nearer approach it was found to be a plain of mineral pitch with frequent crevices filled with water. "The surface of the lake was not polished or smooth so as to be slippery; the consistence was such as to bear any weight, and it was not adhesive; though it partially received the impression of the foot, it bore us without any tremulous motion whatever, and several head of cattle were browsing on it in perfect security. The interstices or chasms are very numerous, and, being filled with water, present the only obstacle to walking over the surface. The arrangement of the chasms is very singular: the sides are invariably shelving from the surface, so as to nearly meet at the bottom, but there they bulge out towards each other with a considerable degree of convexity. These crevices are known occasionally to close up entirely, and we saw many marks or seams from this cause. The lake contains many islets covered with long grass and shrubs. It is not easy to state precisely the extent of this great collection of pitch; the line between it and the neighbouring soil is not always well defined. The main body may perhaps be estimated at three miles in circumference; the depth cannot be ascertained, and no subjacent rock or soil can be discovered. The negro houses in the vicinage, built by driving posts into the earth, frequently are

[1] From the Amer. Journ. Sci.—Third Series, vol. L, No. 295, July 1895.
[2] Philosophical Transactions, lxxix, 65, 1789.
[3] Transactions of the Geological Society of London, i, 63, 1811.

twisted or sunk on one side. In many places it seems to have actually overflowed like lava, and presents the wrinkled appearance which a sluggish substance would exhibit in motion. In some parts it is black, with a splintery or conchoidal fracture; in other parts so much softer, as to allow one to cut out a piece in any form with a spade or hatchet, and in the interior it is vesicular or oily; this is the character of by far the greater portion of the whole mass: in one place it bubbles up in a perfectly fluid state, so that you may take it up in a cup."

"In the south-eastern part of the island there is a similar collection of this bitumen, though of less extent, and many small detached spots of it are to be met with in the woods; it is even said that an evident line of communication may thus be traced between the two great receptacles."

Dr. Nugent devotes considerable space to a discussion of the geology and origin of the bitumen. As his opinions are based on theories no longer accepted by geologists, I will only remark *en passant* that he associates the mud volcanoes of Cedros Point with the agencies that have been active in bringing the bitumen to the surface.

The next notice that appeared was written in September, 1832, by Capt. J. E. Alexander, 42nd Royal Highlanders.[1] He says: "At the small hamlet of La Braye a considerable extent of coast is covered with the pitch, which runs a long way out to sea, and forms a bank under the water. The Pitch Lake is situated on the side of a hill; a gradual ascent leads to it, which is covered with pitch in a hardened state, and trees and vegetation flourish upon it. The pitch at the sides of the lake is perfectly hard and cold, but as one walks off towards the middle with shoes off, in order to wade through the water, the heat gradually increases, the pitch becomes softer and softer, until at last it is seen boiling up in a liquid state, and the soles of the feet become offensively warm. During the rainy season it is possible to walk over the whole lake, nearly, but in the hot season a greater part is not to be approached. The lake is about a mile and one-half in circumference; and not the least extraordinary circumstance is, that it should contain eight or ten small islands, on which trees are growing close to the boiling pitch. In standing for some time on the lake near the center, the surface gradually sinks until it forms a great bowl, as it were; and when the shoulders are level with the general surface of the lake, it is high time to get out. The flow of pitch from the lake has been immense, the whole country round, except near the Bay of Guapo, being covered with it; and it seems singular that no eruption has taken place within the memory of man, although the principle of motion still exists in the center of the lake."

Speaking of Point Cedros, he says: "What renders this point so interesting to the stranger is an assemblage of mud volcanoes, of which the largest may be about one hundred and fifty feet in diameter. At times the old craters cease to act, but when that

[1] Journal of the Franklin Institute, 1833, xv, 337. New Edinburgh Philos. Magazine.

is the case new ones invariably appear in the vicinity. The mud is fathomless, yet does not overflow, but remains within the circumference of the crater. From what I recollect of the Crimea, I should say that there is a remarkable similarity between it and Trinidad—geologically speaking: in both there are mud volcanoes, in both there are bituminous lakes, and both have been frequently visited with earthquakes."

The next observer was Mr. N. S. Manross, who visited the lake in 1855, and has been widely quoted. He says: "The village of La Brea stands on a projecting tongue of land which owes its preservation from the inroads of the sea to the fact that it consists entirely of hardened pitch, which withstands the waves far better than the loose materials of the accompanying formations. The shore for miles, both north and south, consists mainly of the same material, and juts boldly out into the sea wherever it is thus pitch-bound. A road leads up from the landing to some sugar estates beyond the lake. It ascends a gentle slope of hardened pitch, which, where left to itself, is covered with a dense growth of reeds and bushes. The road itself is a fine illustration of the adaptation of pitch to the purpose of paving. Where too much mixed with earth it has become pulverized to a depth of a few inches, but in many places it is still so pure and solid that the wheels of heavily loaded sugar wagons and the hoofs of horses make but a slight, and even that a transient, impression. In no part of the ascent to the shore of the lake does the stream of pitch appear to be covered by more than one or two feet of soil, while in most places it is entirely bare. In places where the surface is not protected by vegetation it becomes so far softened by the sun as to be still making progress downward.

"On nearing the lake the ascent becomes steeper. Here the pitch is bare, or but slightly covered with grass. Its appearance is not that of a sudden simultaneous overflow in a single smooth stream, but that of a great number of streams each but a few yards or rods in breadth. Their surfaces are drawn out into all manner of contortions, and where the edges meet, small ridges have been thrown up and the pitch broken into fragments not unlike the scoriæ of lava currents. These fragments of pitch were on fire in several places, having been kindled by a fire that ran through the 'bush' a few weeks before."

"On ascending the last slope of this pitchy glacier a singular scene meets the eye. A black and circular plain of pitch one-half mile in diameter lies flush with the edge of the stream. It is surrounded by a dense wall of forest, in which various species of tall palm are most conspicuous. The lake itself is entirely bare of vegetation, except about twenty small clumps of trees which are arranged in a sort of broken circle about one-half way from the center to the circumference."

"The entire surface of this circular plain is seen to be interspersed by a network of water channels. Its appearance is exactly that of marbled paper. The pitch is divided into flat or slightly convex areas, mostly polygonal but sometimes circular. They vary from one to eight rods in diameter. The intervening spaces are full of water. These channels (or spaces) have heretofore been described as crevices or cracks in the pitch. This description, however, is incorrect, for the material, though apparently almost as hard as stone, is yet far too plastic to admit of anything like a fissure remaining open in it. The channels are produced and maintained by the following singular process. Each of the many areas into which the lake is divided possesses an independent revolving motion in this wise: at the center of the area the pitch is constantly rising up, not breaking out in streams, but rising *en masse.* It is thus constantly displacing that which previously occupied the center, and forcing it towards the circumference. The surface becomes covered with concentric wrinkles and the interior structure somewhat laminated. When the edge of such an expanding area meets that of the adjoining one the pitch rolls under, to be thrown up again at the center at some future period. The material is nearly soft enough to meet and form a close joint at the top, but descends with a rounded edge and at a considerable angle. The conclusion, then, to which a close observation leads us in regard to the present condition of this singular lake is, not that it has suddenly cooled down from a boiling state, as heretofore described, but that, as the material is, it is still boiling, although with an infinitely slow motion. As the descent of the glacier may be considered the slowest instance of flowing in nature, so the revolutions of the scarcely less solid bitumen of this lake may be set down as the slowest example of ebullition."

"Towards the center of the lake several detached areas are met with, the surfaces of which yield under the foot. On standing ten or fifteen minutes one may find himself ankle deep. A person standing long enough would undoubtedly sink and perhaps disappear in it; but in no place was it possible to form those bowl-like depressions around the observer as described by former travellers."

"The water which filled the crevices of the pitch is clear and very pure. It is the favourite resort of all the washerwomen for miles around. As the water is flowing now, the pitch has formerly flowed from the lake in all directions. The entire surface covered by it is estimated at 3000 acres. The pores of the pitch are full of water, which oozes out on the slightest pressure, and by moistening the skin prevents adhesion. Streams of gas issue, sometimes rising through the water, but more frequently from small openings in the pitch above water-level."

"In one of the star-shaped pools of water, a column of pitch had been forced up from the bottom, expanding into a sort of center-table about four feet in diameter. Pieces torn from the edge of this table sank readily, showing that it had been raised by pressure and not by buoyancy."

"About a mile and one-half south of the lake I observed numerous beds of indurated clay filled with the remains of leaves and vegetation. A little further on appears a bed of brown coal and lignite, about twelve feet thick. It has such a dip and direction that, if continuous, it would pass under the lake at a great depth. At about a mile to the north-west of the lake another bed of brown coal crops out upon the shore. It is about twenty feet thick. From the occurrence of such considerable accumulations of vegetable matter, so situated as apparently to pass under the lake, it seems reasonable to regard them as the source of the pitchy matter. Indeed, many pieces of wood may be observed in the beds of brown coal, which differ in no respect in their appearance from many of the pieces thrown up in the lake itself."

Mr. Manross[1] is completely at sea in his points of the compass.

The observations upon which the descriptions of this lake, from which I have made careful abstracts, were based, were made from forty to one hundred and sixty years ago. I have been able to verify them in almost every particular, and these descriptions clearly portray the appearance and condition of the lake at the time I visited it in March, 1895. In addition to these descriptions, other observations quite different in character and purpose have been made concerning the island of Trinidad, and incidentally of the Pitch Lake, during the last thirty-five years. In 1860 Messrs. Wall and Sawkins published quite an extended report upon the geology of Trinidad, including observations upon the occurrence of bitumen throughout the island.[2]

Dr. Nugent remarked in the article above quoted: "and it must be remembered that geological enquiries are not conducted here with that facility with which they are in some other parts of the world; the soil is almost universally covered with the thickest and most luxuriant vegetation, and the stranger is soon exhausted and overcome by the scorching rays of the vertical sun."[3] These observations exactly express the conditions under which these gentlemen performed their undertaking. It is, therefore, not surprising that errors should have been found in their conclusions and corrected by later observers.

Mr. J. R. Lechmere Guppy, in 1892, thus stated the conclusions that he had reached in reference to Trinidad Geology[4]:—

"It appears from the evidence derived from the nature of the Naparima rocks, their fossil contents, and the movements which

[1] American Journal of Science, part ii, vol. xx, p. 153, 1855.

[2] Report on the Geology of Trinidad, by order of the Lords Commissioners of Her Majesty's Treasury, London, 1860.

[3] *Loc. cit.*, p. 70.

[4] Quart. Journ. Geol. Soc. 1892, vol. xlviii, pp. 519–536. *Ibid.*, vol. xxii, 571; *ibid.*, vol. xxiv, p. 11; *ibid.*, vol. xxvi, p. 413; *ibid.*, vol. xlviii, p. 221.

The "Naparima rocks" consist of an anticlical that, abutting in a bluff near San Fernando, on the Gulf of Paria, extends across the island almost to the east coast. They also appear on the mainland of Venezuela near the Bay of Cumana. The lowest strata are Cretaceous, and are called, together with the Eocene above them, the "Older Parian." The "Newer Parian" above is Miocene, and contains lignites and bitumen. Here orbitoides and nummulites are found in a mass of rock projecting into the Gulf of Paria, supposed to be Miocene. In the Western Hemisphere orbitoides are supposed to characterize the Eocene. In the Eastern Hemisphere nummulites are characteristic of the same formation. The deposit that here contains them both lies between other Miocene deposits.

have effected them and other formations of Trinidad, that during the Cretaceous and Eocene periods there was a sea having a considerable but variable depth of water, say up to one thousand fathoms and more. It is probable that this sea extended on the north to the base of the northern range of hills, a distance of some twenty or twenty-five miles from the northern limit of the Naparima deposits. During the Cretaceo-Eocene period the northern mountains probably formed an unbroken chain with the littoral cordillera of Venezuela. This chain may be called the 'Parian Range.' According to abundantly clear evidence given by me in 1877,[1] the great chasms between Trinidad and Venezuela called the Bocas del Drago were produced by subsidence. Previous to this the 'Parian Range' probably formed the southern boundary of the Caribbean continent, and was a barrier through which no large river found its way. The 'Parian Range' may be regarded as one of those 'stable areas' which has never been submerged since Palæozoic times."

"To the westward the Cretaceo-Eocene sea probably extended as far as the present low-lying alluvial plains of Venezuela. In this direction it was no doubt bounded by the high lands now forming the Pico de Cumanacoa and the Cerro del Bergantin, ranges at present twice as high as any in Trinidad. Its southern extension went presumably near to the granitic and gneissic ranges and plateaux of Guiana."

"After the close of the Miocene period there was probably in the region south of the 'Parian Range' a slow and gradual upheaval which brought the oceanic deposits above the level of the sea, during which process they suffered great denudation. The Gulf of Paria was then land, and Trinidad was then united to the mainland. At that time the river Guarapiche probably flowed across Trinidad from Venezuela, while the Orinoco continued to pour its waters into the ocean at some distance southward. The disruption of the 'Parian Range' and the formation of the Bocas and the Gulf of Paria followed. There are palæontological reasons for believing that this submergence did not take place until a late geological epoch."

From this conclusion it is manifest that the Miocene period was one of frequent alternation of elevation and submergence, during which there were long periods when the different members of the formation were covered with tropical swamps having luxuriant vegetation, that are now represented by the great swamp at the east end of the island. The buried vegetation of these swamps has been converted into coal through Pliocene and recent times, which has been distilled at low temperatures, probably initiated by fermentation within the mass of the coal itself, assisted by the water of thermal springs.

Messrs. Wall and Sawkins discuss at length the phenomena peculiar to the lake, and disagree with previous observers to such an extent that, after a careful examination of their paper, I am forced to the conclusion that their study of the subject was

[1] Proc. Sci. Assoc. Trinidad, December 1877, p. 1C3.

extremely superficial. In illustration: they say of the "areas," "the surface is frequently marked with ridges, especially near the edges: these are due to the constant expansion and contraction which is supposed to occur." A most singular explanation, resting on *supposed* phenomena that were neither observed nor proved theoretically. Although they quote Bischoff,[1] it is only to prove a possible origin for the asphaltum by direct conversion from woody fibre, leaving entirely out of consideration the conclusions of this eminent author in reference to the production of hydrogen sulphide, to which further reference will be made. It is, however, just to these authors to remark that the general knowledge of the world concerning bitumens and their origin has been vastly increased during the thirty-five years that have elapsed since they issued their report.

1.

Diagram-map of the Island of Trinidad.

Charles Kingsley and some others have written descriptions of the lake since 1860, but no new facts are stated by them.[2]

During 1892 the Hon. W. P. Pierce, then United States Consul at Port of Spain, at the request of the department, made a very full and able report upon the asphalt of Trinidad.[3] The fulness with which all sources of information are made to lend their quota towards a general conclusion in regard to all possible aspects of this question, is of itself the best guarantee, to any unprejudiced reader, of the eminent fairness of this report. Its appearance was almost immediately followed by another report made by Mr. Clifford Richardson, at that time Inspector of Asphalt and Cement for the District of Columbia.[4]

[1] Bischoff, Chem. and Phys. Geol. (Cav. Soc. Ed.), vol. i, pp. 288, 290, 291.

[2] "A Christmas in the West Indies." London, 1879.

[3] Consular Reports, No. 145, Oct. 1892.

[4] Reports of the operation of the Engineer Department of the District of Columbia, for the fiscal year ending June 30th, 1892. Washington, 1893.

This report of Mr. Richardson, while seemingly emanating from a wholly disinterested source, presents statements and conclusions in many respects quite different from those reached by Consul Pierce and previous observers. It was for the purpose of satisfying myself as to the facts, and also of studying the occurrence of bitumen in Trinidad in the light of such observations as I had made in California and elsewhere, that I lately made a trip to Trinidad and the Pitch Lake.

On approaching Point La Brea from the north-west, the reef of asphaltum that forms a barrier around the point and against the sea is plainly visible. Upon the point itself and jutting into the sea are what appear like low ledges of rock, which a nearer inspection proved to be masses of asphalt taken from village lots, that had been piled for shipment, but had been so long left in the tropical sun that they had melted and flowed into a solid homogeneous mass, that looked at a short distance off like ledges of slate. The piles,

2.

Topography of the immediate area of the Pitch Lake of Trinidad.

which were originally about twenty-five feet in height, were not more than three feet thick. Near these masses were other piles of the same material, from which lighters were being loaded, and which had not remained in the sun long enough to melt. Many hundreds of tons were included in these masses, the original pieces of which had so far coalesced that the asphalt had to be again broken with a pick before removal. Passing on shore beyond these piles, the plant of the Pitch-lake Concessionaires was encountered, in which the operation of boiling a mixture of so-called land asphalt, the ordinary lake asphalt, and the soft pitch from the centre of the lake was going forward. The operation is conducted in kettles, resembling open sugar kettles, and is very crude and simple in character. Passing eastward I next encountered a wide area covered with asphalt, that had melted in the sun to a level surface, perhaps two feet in depth. I was told that this asphalt was dug from a village lot, the ownership of which was in dispute; that originally the piles were at least twenty feet in height, but while the owners disputed the piles melted in the sun.

Farther on I struck the road to the lake, which appeared to me exactly as Mr. Manross had described it forty years ago. The houses in the village were in the same condition described by Dr. Nugent in 1807. The slope leading up to the lake was in exactly the condition in which all previous observers had described it, as resembling a lava-flow—a black glacier. The several points at which asphalt had been and was being excavated, showed in the most admirable manner that the movement of the asphalt down the slope and towards the sea is still in progress. Every excavation was in a short time partially refilled by a movement of the asphalt up from the bottom and in from the sides, the cavity in time becoming filled full to the level of the surrounding area. One illustration of this fact was the spot from which the noted cargo of the Teneriffe was taken, every trace of former excavation having completely disappeared.[1]

The Trinidad Bituminous Asphalt Company were excavating a lot near the road, and had also recently uncovered a lot that had become almost completely refilled in a few months, after the removal of several thousand tons of asphalt. Farther up the slope the Trinidad Asphalt Company were taking out asphalt from lots on the Belle Vue estate. These lots, like most of the others, were covered with a dense tropical jungle, consisting of palms, sedges, canna, and other plants, from three to ten feet in height. It did not need the testimony of Mr. Manross to show that in all probability fire had more than once consumed this mass of vegetation, producing a terrific heat, that had melted and converted into so-called "iron-pitch" much of the surface of the pitch. The "iron-pitch" is present in greater or less quantity, both within and without the boundaries of the lake, wherever fire has consumed the vegetation, and consists simply of melted pitch which has been heated so hot as to deprive it of its water and more volatile constituents, causing it to flow in streams, often to considerable distances. Below these melted masses the pitch lies in its normal and unaltered condition.

It must, however, be constantly borne in mind, while reading the statements of different observers made on different occasions, that the lake and its principal overflow have presented different phenomena at different periods. While it was evident at the time I visited the overflow that fire had swept over its surface, it was equally evident that it had for a long time been free from any such visitation. I have seen similar flood-plains of asphalt in California that had been on fire for months, and others that had been burned some time previous to my visit to them. I can imagine that after such a fire the resemblance of the overflow of the lake to a "black glacier" would be much more pronounced than when covered with a rank growth of vegetation, as it now is. It is not, however, the surface that flows, covered as it is by masses of coke, iron-pitch, vegetation, and rubbish. The houses in La Brea now all rest on

[1] I was told by those who witnessed the digging of this cargo, that apparently no care was exercised in its selection. One gentleman declared that it was the dirtiest cargo of pitch ever sent from the island.

blocks. In this position they are much more stable than on posts, although anything resting upon the overflow is unstable. It is the cheese-pitch, full of water, and containing more or less gas, buried beneath these surface accidents, that has flowed and still flows.

Although a large amount of clay and vegetable débris fills the interstitial spaces of the rough surface of the asphalt, the vegetation is not confined to such surfaces, but seems to flourish equally well upon the bare pitch, the roots penetrating the pitch without the slightest difficulty, except where it had been converted by melting into iron-pitch. There is also considerable coke where the fires have been hottest. All of these impurities are carefully excluded from the pitch that is mined, both for boiling and for shipment in the crude state, by all of the men employed by the different companies in extracting it. This selection is not difficult, as the appearance of the iron-pitch is very different, and the amount very small, as compared with the pure or cheese-pitch.

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

REVIEWS.

I.—The Cretaceous Series of the Upper Missouri; and the Chalk of North America and its Foraminifera.

SEVERAL interesting and instructive reports are published in the Iowa Geological Survey, vol. iii. Second Annual Report, 1893, with accompanying papers: 501 pages, with numerous maps, plates, cuts, and photographs. Large 8vo, Des Moines, 1895. There are: 1. Cretaceous deposits of the Sioux Valley; by H. F. Bain. 2. Certain Devonian and Carboniferous outliers in Eastern Iowa; by W. H. Norton. 3. Geological section along Middle River in Central Iowa; by J. L. Tilton. 4. Glacial scorings in Iowa; by C. R. Keyes. 5. Thickness of the Palæozoic strata of North-eastern Iowa; by W. H. Norton. 6. Composition of the Iowa Chalk; by S. Calvin. 7. Buried River-channels in South-eastern Iowa; by C. H. Gordon. 8. Gypsum deposits of Iowa; by C. R. Keyes. 9. Geology of Lee County; by C. R. Keyes. 10. Geology of Des Moines County; by C. R. Keyes.

I. At pages 101–114 Mr. Bain details the features and measurements of the Cretaceous series as seen along the Sioux River, a tributary of the Upper Missouri, forming the northern third of the western boundary of Iowa. Beneath a thick coating of drift and loess, he notes the occurrence (downwards) of—(1) the Pierre shale; (2) Niobrara chalks and soft limestone (locally unconformable on the Sioux quartzite); (3) Benton shale; and (4) Dakota sandstones and shales. These formations vary in their thicknesses over this part of America; and here are apparently some 300 or 400 feet thick. They correspond with the description given of this and neighbouring districts by Meek and Hayden (1853–1873), except that the topmost part of the series, namely, that of the Fox Hills (sandstones and arenaceous shales), is not shown on the Sioux River. Mr. Bain points out that the recognized eastward extension of the upper members of the group renders it probable that the Mesozoic seas spread further eastward than has hitherto been commonly supposed.

II. At pages 211–236 Dr. Samuel Calvin, State Geologist, shows that the old idea of the geological structure of North America being destitute of "Chalk" is quite unfounded, as readers of the American Journal of Science, Canadian Naturalist, Bulletin of the American Geological Society, Science, the Reports of several Geological Surveys, and well-known works by Ehrenberg and F. Römer, might well know. He states that true "Chalk," soft and white, made up of Foraminifera and Coccoliths, and without the admixture of mechanical sediments, has a thickness of at least 25 feet on the Sioux River in Iowa; and is 50 feet thick at Ponca in Nebraska; at Saint Helena, further up the Missouri, 90 feet; at Yankton in South Dakota, 130 feet; and probably 200 feet at the mouth of the Niobrara. Near the mouth of the Sioux it is represented by (from top)—(1) Chalk, 12 feet; (2) soft Inoceramus-limestone, 12 feet; (3) Chalk, 12 feet. (See Mr. Bain's memoir, p. 111.)

Dr. Calvin (p. 115), having described the mode of occurrence of the foraminiferal shells as being quite similar to that in the English Chalk, proceeds to enumerate and discuss the various published notices that have indicated a rising and increasing knowledge of this view, founded on the recognition of microscopic fossils in the Cretaceous strata from various parts of North America. Thus Prof. J. W. Bailey, in 1841, described some "prairie chalk" from the North-west (see also Hitchcock's "Elementary Geology," new edition, 1860, p. 382); Dr. Ch. G. Ehrenberg figured some Foraminifera from the Chalk of Missouri and Mississippi, 1843, and Bailey in 1844; Dr. F. Römer some from Texas, 1852, and T. A. Conrad in 1857; F. B. Meek and F. V. Hayden described the Cretaceous strata along the Missouri River, in 1859–61; Dr. C. A. White the Inoceramus-limestone of Iowa, in 1870; Dr. G. M. Dawson the Chalk of Nebraska and Manitoba, 1874; Prof. R. T. Hill, in 1888, 1889, and 1890, definitely gave the name of "Chalk" to the soft calcareous beds of the Lower and Upper Cretaceous series in Texas and Arkansas; and Prof. S. W. Williston treated of the Kansas Chalk in 1890.

The more common of the Foraminifera of the North-American Chalk, as figured by the various observers above referred to, appear to be—

1. *Textilaria pygmæa*, d'Orbigny. G. M. Dawson, Canadian Naturalist, vol. vii, 1874, p. 253, fig. *b*; S. Calvin, Iowa Geol. Survey, vol. iii, 1895, p. 226, pl. xix, fig. 7. This is rather common in the Cretaceous and Tertiary deposits, and in existing seas.

2. *Textilaria globulosa*, Ehrenberg. Bailey, Amer. Journ. Sci. and Arts, vol. xli, 1841, p. 401, fig. 2; Calvin, Iowa Geol. Survey, vol. iii, 1895, p. 225, pl. xix, fig. 5. This species, first described by Ehrenberg, has a wide geographical range, chiefly in the Cretaceous series. The localities whence the specimens figured by Ehrenberg were obtained are—Cretaceous: Egypt, Syria, Arabia (?), France,

England, Islands of Möen and Rügen in the Baltic, Bohemia, Russia, and Missouri; Eocene: Egypt, and Bavaria; also from volcanic mud in the Eastern Archipelago, and from wind-dust at Malta, Lyons, and Silesia or Austria. Dr. H. B. Brady has recorded it as occurring in a brackish tidal pond at Westport, Ireland. It is a common Cretaceous fossil, being recorded from the Chalk of Swanscombe (zone of *Micraster cor-testudinarium*), from the Chalk of Taplow (zone of *Belemnitella quadrata*); from the Chalk of Westphalia, by Reuss, under the name *T. globifera*; also by Andreae, from the Oligocene of Elsass, under the name *T. gracillima*; and by Millett from the Pliocene of St. Erth. One specimen has been met with in the Chillesford Beds of Aldeby, near Beccles.

3. *Textilaria gibbosa*, d'Orbigny. Bailey, Amer. Journ. Sci. and Arts, vol. xli, 1841, p. 401, fig. 1 (?); Woodward and Thomas, 13th Geol. Rep. Minnesota, 1885, p. 166, pl. iii, figs. 1–5 (as "*T. globulosa*"); Calvin, Iowa Geol. Survey, vol. iii, 1895, p. 225 (as a small broad variety of *T. globulosa* widening rapidly in its growth, and, indeed, zoologically there is very little difference between these forms), pl. xix, fig. 6. This is a common *Textilaria*, both recent and fossil.

4. *Textilaria striata*, Ehrenberg. G. M. Dawson, Canad. Nat., vol. vii, 1874, p. 253, fig. *a* (given as "*T. globulosa*"). This is a variety of *T. gibbosa*. Among the figures of this form given by Woodward and Thomas in the Thirteenth Report of the Geological Survey of Minnesota, 1885, p. 166, pl. iii, figs. 1–5 (there termed "*T. globulosa*"), one *partially striated* individual is shown by fig. 5. This is more especially an American species.

5. *Spiroplecta Americana*, Ehrenberg. Mentioned by Bailey, Amer. Journ. Sci. and Arts, vol. xlvi, 1844, p. 308; but the figure in the footnote is possibly a *Textilaria*, not a *Spiroplecta*. Woodward and Thomas, Thirteenth Report Geol. Surv. Minnesota, 1885, p. 168, pl. iii, fig. 9. This species was at first regarded by Ehrenberg as a *Textilaria*; but its name was changed by him to *Heterohelix* in 1841; and in his "Mikrogeologie," 1854, he referred to it as *Spiroplecta Americana* from the Chalk of Missouri and Mississippi. Equivalent forms, not always arenaceous, are found in the European Chalk and Tertiaries, and in existing seas.

6. *Bolivina punctata*, d'Orbigny. A well-known subtypical form of *Bulimina*, under which generic appellation it appears in the Iowa Geol. Survey, vol. iii, 1895, p. 229, pl. xix, fig. 8. This is cosmopolitan in the oceans, from shallow to abyssal waters; and it is common in the Chalk and Tertiaries.

7. *Dentalina communis*, d'Orbigny. Calvin, Iowa Geol. Survey, vol. iii, 1895, p. 229 ("Nodosarian forms"), pl. xix, figs. 11, 12, 13. Such Nodosarines occur in the Permian and Jurassic strata, and are extremely common in European Chalk, in the Tertiaries, and in many seas, from shallow to abyssal depths.

8. *Nodosaria ambigua*, Neugeboren. *Nodosaria Texana*, Conrad, Geol. Reports U.S. and Mexican Boundary Survey, vol. i, pt. 2 (4to, Washington, 1857), "Description of Cretaceous and Tertiary Fossils,"

p. 159, pl. xiv, figs. 4 *a, b, c,* corresponds very closely indeed with Neugeboren's *Nodosaria ambigua,* Denkschrift. k. Akad. Wiss. Wien, vol. xii, 1856, p. 71, pl. i, figs. 13–16, from the Chalk of Upper Lapugy in Transylvania. It occurs also in some Tertiary beds, and in the North Pacific Ocean.

9. *Frondicularia.* A fragment of *Fr. Verneuiliana* (?), d'Orbigny, is given by Dr. Calvin in pl. xix, fig. 14, p. 229, Iowa Geol. Survey, vol. iii. It is known from the Chalk of France and England.

10. *Cristellaria.* Calvin, Iowa Geol. Survey, vol. iii, 1895, p. 229, pl. xix, fig. 9, is either one of the poor varieties of *Cr. rotulata,* such as are met with in the European Chalk, or the initial part of one of the many *Marginulinæ* of the Chalk. This is similar also to others of both kinds met with in older and younger strata.

11. *Globigerina cretacea,* d'Orbigny. Bailey, Amer. Journ. Sci. and Arts, vol. xli, 1841, p. 401, fig. 4; G M. Dawson, Canad. Nat., vol. vii, 1874, p. 253, fig. *c* ("*Discorbina globularis,*" possibly an immature *Globigerina digitata*); Woodward and Thomas, Geol. Surv. Minnesota, 1885, p. 171, pl. iii, figs. 13 (?), 14–16; pl. iv, fig. 19, and edge-views, figs. 23 and 24 (?); Calvin, Iowa Geol. Survey, vol. iii, 1895, pp. 216, 228, pl. xix, figs. 1, 2, 4. The appearance of limbate borders in these last and in most of the other figures on this plate is probably due to the translucent edges of these shells, as seen when mounted in balsam. Specimens of real *Globigerina marginata* (Reuss), such as are known in the European Chalk, were figured by Woodward and Thomas in the Geol. Survey, Minnesota, 1885, p. 174, pl. iv, figs. 20–22, from the Boulder-clay containing Cretaceous Foraminifera. *Globigerina cretacea* is a characteristic microzoon of the Chalk. It has near relatives in other deposits and in the existing seas.

12. *Globigerina digitata,* Brady. Calvin, Iowa Geol. Survey, vol. iii, 1895, p. 228, pl. xix, fig. 3. This interesting species has not been previously observed in the Chalk, but only in the present oceans. G. M. Dawson's fig. *c,* however, above mentioned, with its elongate ultimate chamber, may be a proximate variety, or a young form.

13. *Anomalina ammonoides* (Reuss), G. M. Dawson, Canad. Nat., vol. vii, 1874, p. 253, fig. *d* ("*Planorbulina Ariminensis*"), is one of the neat and almost symmetrical forms belonging to *Planorbulina*; it is very common in the European Chalk, and lives in the sea now at depths varying from 37 to 1350 fathoms. It is figured by Dr. Calvin, Iowa Geol. Survey, vol. iii, 1895, p. 235, pl. xix, fig. 10, as "*Truncatulina,*" to which it is generically allied, but more symmetrically formed.

14. *Orbitolina* or *Patellina lenticularis* (Blumenbach) is probably the foraminifer, from Texas, figured and described by Dr. Ferdinand Römer as *Orbitulites Texanus* in the "Kreidebildung von Texas," etc. (4to, Bonn, 1852), p. 86, pl. x, figs. 7 *a–d.* He first mentioned it in his "Texas" (Bonn, 1849), p. 392.

For the occurrence of this little Cenomanian fossil in Europe, see the Catalogue of the Fossil Foraminifera in the British Museum

(Natural-History Branch), 1882, pp. 10, 17, and 19; and for its synonomy and relationships, pages 84, 85.

At pages 228, 229, Dr. Calvin offers some suggestive remarks on the probable conditions of that part of the Cretaceous sea now replaced by North America, especially in the Iowa region, as to the relative depth and clearness in some parts, and its shallower state near the old shore-line eastward. Judging from the relatively large growth, or the contrary, of some *Textilariæ* and other forms, he indicates the area of deep and clear water, and that of shallow and littoral with its mechanical sediments. We cannot, however, agree with his notion that the *Globigerina digitata* is an "abnormal" form, taking on an extra growth in consequence of being "restricted" or otherwise on the deep sea-bottom.

The successive formation of the several members of the Cretaceous series in this region, and the probable physical conditions under which they were deposited, is carefully described. The local subsidence was greatest when the Niobrara Chalk was being formed, with its abundant Foraminifera, whether pelagic or abyssal, and with the associated Coccoliths and Rhabdoliths as in Manitoba. Then a gradual elevation of the sea-bottom began; and this in time brought about the formation of the shales and sandstones of the Pierre and succeeding stages.

The wide range of these Foraminifera in the two Hemispheres is a subject of interest not lost sight of by Dr. Calvin; and their long continuous and persistent existence, or great range in time, has been often noticed by naturalists. T. R. J.

II.—Grundzüge der Palæontologie (Palæozoologie). Von Karl A. von Zittel, Professor an der Universität zu München. 972 Textseiten, mit 2048 in den Text gedruckten Abbildungen. München u. Leipzig. (Oldenbourg, 1895.) London: Dulau and Co., 37, Soho Square, W. Price 25*s*., post free.

It is not more than two years since that Prof. von Zittel brought to a successful conclusion the "Handbuch der Palæontologie," which, on a scale not before attempted, included in its scope a description of all the leading genera of fossils, as well as references to those of subordinate importance. In the preparation of this immense work, nearly twenty years ran by; and, as is well known, in this interval our knowledge of fossils advanced in nearly every department, with the result that by the time the concluding volume of the "Handbuch" appeared, the earlier portion of the work, treating of the lower groups of the Invertebrata, was already in part out of date. In place, however, of re-writing the first volume of the "Handbuch" as an instalment of a new edition, Von Zittel has prepared the present "Grundzüge," in which a brief but comprehensive representation of the more important facts of palæontology, both vertebrate and invertebrate, have been brought within the compass of a single volume. The same method of arrangement has been adopted in this, as in the larger work; but to keep it within the necessary limits, a selection of the specially typical forms had to be made for description, while others are referred to by name only. The author has endeavoured to carry out, what should be the leading aim of palæontology, a natural system corresponding to morphological and phylogenetical facts. Fossils are regarded chiefly in their relations as members of the animal kingdom, rather than from the geological standpoint as furnishing evidence of the comparative age of the beds in which they are inclosed; but their significance in this latter respect has by no means been neglected, and the geologist will find the characteristically leading fossils of the different rock formations amply described and figured.

A special feature of this volume is the unusual number and excellence of the illustrations, which adorn nearly every page; not only has full use been made of the clichés of the remarkably clear woodcuts of the "Handbuch," but there are in addition numerous fresh figures, so that a typical form of nearly every fossil genus of importance has been represented.

In an introductory chapter, after an explanation of the conception and object of the science of Palæontology, reference is made to the chemical and mechanical changes which take place in organic remains in the process of fossilization, and this is followed by an instructive and spirited exposition of the relations of Palæontology to each of the sister sciences of Biology, Geology, Physical Geography, Embryology, and Phylogeny, and the essential importance and value of the facts contributed by Palæontology to these respective sciences is very forcibly elucidated.

It would lead beyond the bounds of our space to refer in any detail to the numerous alterations and additions which have been introduced in the systematic portion of the present work, in comparison with that of the "Handbuch": these mainly concern, as might be supposed, the division of the Invertebrata. It will suffice to state, however, that the results of the most recent investigations of specialists and others in the various groups of fossils have been critically noted and incorporated in this book, thus rendering it valuable as a reference to the experienced palæontologist as well as to the student-beginner in the science.

As additional recommendations, the letterpress is clear, the book is strongly bound, and it is brought out by the publishers at a very moderate price.

III.—Observations on the Structure of some Diprionidæ. By St. Leonk. Törnquist. Trans. Roy. Swedish Physiographical Soc., 1892–93.

The author in this paper describes the structure of *Climacograptus scalaris* (Lin.), *C. internexus* (Törnq.), *Diplograptus palmeus* (Barr.), *D. bellulus* (Törnq.), and *Cephalograptus cometa* (Geinitz). His method of preparation consists in grinding down specimens preserved in iron pyrites until the required section is obtained. For purposes of description he divides the thecæ of the polypary into two series: (*a*) primordial, containing the first theca; (*b*) second series.

He believes that the polypary of *Climacograptus scalaris* is built up in the following way: The conical sicula is on the side of the second thecal series, and the apex coincides with the axis of the polypary. It sends out the connecting canal on the side facing the primordial series, and this runs along the lower portion of the sicula and opens into the proximal part of the biserial chamber. This chamber he defines as that part of the common canal below the median septum; it gives rise to two thecæ on each side, the rest of the cavity of the rhabdosoma being divided by a median septum into two uniserial canals originating in a common chamber.

Climacograptus internexus is similarly developed, but is characterized by the free prolongation of the lower lamina of each thecal partition, which extends downwards over the aperture in a manner resembling *M. priodon* (Bronn). The median septum is undulated.

Diplograptus palmeus.—The septum is incomplete, and thecal series therefore originate from one biserial canal.

D. bellulus.—This species is characterized by the long proximal prolongation of the virgula. There is no trace of a median septum, and the common canal is very narrow.

Cephalograptus cometa.—The connecting canal is almost at the base of the sicula, and is directed somewhat outwards. It opens into the common biserial canal, which does not send out the first theca of the second series until far beyond the pointed end of the sicula. The median septum is incomplete.

The author concludes with the observation that the central cavity of the rhabdosoma may consist of two uniserial canals, separated by a more or less complete median septum, and originating from a short biserial chamber, or a single biserial canal.

G. L. E. and E. M. R. W.

IV.—"Ueber Diplograptidæ," Lapw., and "Ueber *Monograptus*," Geinitz. By Carl Wisman. Bull. Geol. Instit. of the Univ. of Upsala. Vol I, No. 2. 1893.

The author has been able to make very complete researches on the structure of the proximal part of the polypary in the Diplograptidæ and in *Monograptus*, owing to the method of preservation of his specimens. The polypary was embedded in limestone, and was isolated and stained by means of acid and Schulze's macerating fluid.

As regards the Diplograptidæ, Wisman lays stress on the following points: The sicula consists of two parts, the proximal and distal, differing in their form and external sculpture. This gives rise, on the right-hand side, to only *one* bud, so that the Diplograptidæ are Monoprionidian. This bud gives rise to a theca, and each subsequent theca develops from the one next below it, but on the opposite side and not from a common canal. The polypary, together with the virgula, develop at first both proximally and distally, but at a later period the distal growth alone persists. The sicula does not lie embedded between two branches grown together along their dorsal surfaces, as was formerly supposed to be the case, but is at first free and is only later enclosed in the periderm. The virgula is single, and is not continuous throughout the whole length of the polypary, since it undergoes two different phases of formation. The proximal part develops as a spine from the apertural part of the sicula, whilst the distal portion is a prolongation of the apex of the sicula. The virgula is united to the bases of the partition walls between the thecæ in some cases, but it is frequently free for a great part of its length. There is no double longitudinal septum in the polypary.

As regards *Monograptus*, the structure closely resembles that of the Diplograptidæ. In *Monograptus*, however, there is only one row of thecæ, which develop on the same side as the first theca. Unlike *Diplograptus* the thecæ develop only in a distal direction. The distal portion of the sicula grows simultaneously with the thecæ lying at the same level. The virgula is somewhat triangular in shape and lies on the inner side of, and occasionally in, the periderm itself, not in a groove on the outer edge. No lumen to the virgula has been observed either in *Monograptus* or in the Diplograptidæ, but it is the opinion of the author that such existed and that it was filled with a living substance.

E. M. R. W. and G. L. E.

CORRESPONDENCE.

INTERESTING CONTACT-METAMORPHISM.

Sir,—I have read with much pleasure Mr. W. M. Hutchings' article on "An Interesting Contact-Metamorphism," in the Geological Magazine for last March. There is one thing, however, which I cannot understand anywise. It is the word "anthrophyllite."[1] It seems to me to be a name applied to a mineral produced by the contact-metamorphism. I know the mineral "anthophyllite," but not "anthrophyllite."[1] I have met with this term for the first time. I inquired into nearly all mineralogical and lithological books our University possesses, but all in vain. Would you, sir, kindly describe it to me, or tell the literature, if any? I beg this of you, or of Mr. Hutchings himself.

Geological Institute, Science College, Imperial University, Tokyo, Japan. 1st *July*, 1895. — H. Ishihara.

METAMORPHISM AT MALVERN.

Sir,—Would you permit me to add three words to the letter which you kindly inserted in this month's Geological Magazine? In stating an analogy between the roasting of meat and the process of metamorphism at Malvern, I wrote, or, at any rate, meant to write, "The cook is able to observe *the cause of* the change, and so can the geologist at Malvern." In the letter as printed, the words in *italics* do not appear. The omission is a vital one.

Wellington, Salop, *August*, 1895. — C. Callaway.

[1] No doubt Mr. Ishihara is correct: the *r* was an error in printing and should have been deleted.—Edit. Geol. Mag.

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No. X.—OCTOBER, 1895.

ORIGINAL ARTICLES.

I.—On *Didymograptus*, *Tetragraptus*, and *Phyllograptus*.

By Dr. Gerhard Holm,
Palæontologist to the Geological Survey of Sweden, Stockholm.

Translated from the original in Geol. Fören. i Stockholm Förhandl., Bd. XVII, Häft iii, No. 164, 1895, pp. 319–359. By G. L. Elles and E. M. R. Wood, Newnham College, Cambridge.

(PLATES XIII AND XIV.)[1]

THE knowledge of the internal structure and development of the different forms of Graptolites is very incomplete, owing to the unfavourable method of their preservation, Graptolites, in almost all cases, being found embedded in shale.

For more than ten years, however, I have been acquainted with Graptolites which, exceptional though it may be, are embedded in pure limestone, and are usually preserved in full relief; not unfrequently also the chitinous substance is so well preserved, that the polypary can be set free by dissolving the limestone with acid.

The first Graptolites which, by this means, have been isolated and studied by me, were *Climacograptus Kuckersianus*, nov. sp., Holm, from a specimen collected by G. Linnarsson, near Kuckers, in Estland, and now the property of the Geological Institution at Upsala, and *Retiolites Geinitzianus*, Barr., in a limestone nodule from Motala. I have since described the internal structure of the latter, principally with the aid of the above-mentioned specimen.[2] In the same paper I have given an account of an improved method of dissolving the matrix, by means of which, for example, such fragile objects as the connecting parts of the reticulate polypary of *Dictyonema cervicorne*, Holm, and the fork-shaped, apertural spines of the thecæ, can be isolated.

Since the above-mentioned time, I have constantly collected as much material as I could obtain suitable for treatment by this method, for the purpose of a closer study of the structure, development, and affinities of Graptolites; and I have now isolated many thousands of specimens belonging to a great many forms of different groups of Graptolites.

[1] The plates and page-illustration will appear with the second part of this paper next month.

[2] Bihang K. Vet. Akad. Handl., Bd. 16, Afd. iv, No. 7, 1890.

In this paper an account is given of the development and structure of the polypary in the genera *Didymograptus*, *Tetragraptus*, and *Phyllograptus*. This is based exclusively on the excellent material, which I have succeeded in collecting during many years, from the grey glauconitic Vaginatenkalk of various localities in N. Öland. This limestone contains but few Graptolites, but they are in a condition well fitted for isolation.

According to the general current opinion, which seems to have been founded on Lapworth's description of the development of the graptolitic polypary in "On an Improved Classification of the Rhabdophora," the development in the bilateral and the diprionidian forms takes place from two buds, which arise directly on the two sides of the sicula. Certainly Lapworth himself has since changed his former opinion, and with his usual penetration, on the ground of the structure of the genus *Dimorphograptus*, has stated as theoretically more probable that the sicula in all the "Graptoloidea" gives rise to only one bud: this opinion, however, has been disregarded. Quite recently, first Törnquist and then almost simultaneously Wiman, who had at their disposal far better material than Lapworth, conclusively showed that in the Diplograptidæ only one bud is developed from the sicula, and that both rows of thecæ are derived from this.

In the following pages it will be shown that, in the main, a complete conformity exists in the first stages of development of the polypary, both in the genera *Didymograptus*, *Tetragraptus*, and *Phyllograptus* and in the family Diplograptidæ. It may, therefore, be considered as in the highest degree probable that the earlier development of the proximal part (the three first thecæ) in all the bilateral or diprionidian forms of Graptolites is, in the main, the same, and has taken place through the formation of only one bud on one side of the sicula—or first theca, as I believe it is—which side is always the same in relation to the later development of the polypary. From this bud thereafter is developed partly the second theca; partly the canal—"connecting canal"—which connects both halves of the polypary and which in the first place gives origin to the third theca (=first theca on opposite side of sicula); and partly also the common canal, which connects the second theca with the succeeding ones.

In the family of the Monograptidæ, which must be considered as degenerate from the Diplograptidæ, the "connecting" canal, which otherwise bends over to the opposite side of the sicula, and from which the thecal row of that side ought to come, is not developed, but is entirely absent. From the bud on the sicula, therefore, only the second theca is developed, together with the common canal for the single or main branch of the polypary. From the sameness of the structure of the proximal part arises the intimate relationship between the Graptolite forms, separated in time from one another; and this also determines how the younger forms arise from the older through a gradually increasing simplification at first of the distal part, and then, as in the Monograptidæ, of the proximal part of the polypary.

General review of the structure of the proximal part of the polypary (Terminology).—For the sake of conciseness and clearness in description, and an easier comparison between different forms, and also for greater precision in the terms employed, many of which have been only lately introduced, there follows here a general description of the proximal end in the genera described below. The terms have been adapted as far as possible so that they can be also used for the other groups of Graptolites which are provided with a sicula.

The *sicula*, which has a cone-like form, is defined by Lapworth[1] as "The chitinous covering of the free zooid 'germ' or embryo in the Graptoloidea." As Wiman has shown in *Diplograptus*, sp., and in *M. dubius*, Suess, the sicula is composed of two essentially different parts, the proximal and the distal, distinguished by the different nature of the periderm. In the proximal or more pointed end of the sicula, or, as it may perhaps be better termed, the *initial part*, the periderm-wall is very thin and pellucid, and provided with longitudinal branching and anastomosing swellings or striæ, which disappear near the boundary with the distal part, but which, uniting together at the apex of the sicula, form the projecting virgula. In the wider or distal (or perhaps better termed *apertural*) portion of the sicula, the periderm is thicker and less pellucid, and it is provided with lines of growth like those of the rest of the polypary. In opposition to Wiman, I believe that the more pointed end of the sicula, which has no growth-lines, exactly corresponds to the original "chitinous covering of the free zooid germ or embryo," and thus is the "initial part" from which the "*apertural part*" is developed which everywhere shows normal lines of growth.

The *apertural part* of the sicula, as far as can be judged, has the same function as a theca, and might therefore be justly considered as the first theca of the polypary (see fig. 1). The old name "sicula" is nevertheless a convenient and significant one, and is here retained. Even if there be some doubt whether the whole apertural part of the sicula should be regarded as the first theca, it cannot at least be extended to that part of the same which lies below the passage opening into the second theca. It is evident from the direction of the lines of growth at this spot in *Diplograptus*, sp., and *M. dubius*, Suess, that this connection with the growth of the sicula first appears as a notch in the apertural margin, which afterwards by further outward growth of the edge of the sicula is changed into a foramen closed all round. The common canal, by which all the cells of the polypary are connected with one another—whether the different individuals have been developed by budding from the cœnosarc, or whether they are developed from and connected with the one immediately preceding—(the common canal) must therefore be considered to begin already in the sicula, even if it has been convenient, for the sake of description, to distinguish one part as the "connecting" canal. There does not exist any important morphological difference whatever between the part of the sicula lying below the passage opening to the second theca and the remaining thecæ.

[1] Quart. Journ. Geol. Soc., vol. xxxi, 1875, p. 639.

In the bilateral and diprionidian forms the sicula always occupies a side position, more or less oblique to a median plane between the second and third thecæ, dividing the polypary symmetrically into two similar halves. This arises in consequence of the fact that the "connecting" canal between the second and third thecæ, and thus between the two side halves of the polypary, proceeds along one side of the sicula, and more or less completely embraces it. The sicula occupies, therefore, on one side of the polypary a more or less superficial position, so that it is here exposed, either completely, as in *Didymograptus, Tetragraptus,* and *Phyllograptus,* or for a longer or shorter space nearest the aperture, whilst the rest of it is embedded in the polypary, as in *Diplograptus* and *Climacograptus.*

This side of the polypary is called in the sequel the *sicula side*; the opposite side, which is occupied by the "connecting" canal between the two halves of the polypary (second and third thecæ) is the *anti-sicula side.*

The sicula here is either completely obscured—for example, in *Diplograptus, Climacograptus,* and *Phyllograptus,* or visible only near the aperture and mucro, as in such bilaterally developed monoprionidian forms as *Didymograptus* and *Tetragraptus.* In the former the sicula on this side is completely embedded in the polypary, and is concealed not only by the "connecting" canal but also by the oldest theca and the common canal. In the latter, again, the connecting canal forms only a broader or narrower band across the sicula.

The sicula side in descriptions is termed the *anterior,* that is the side turned towards the spectator, which, when pointing out the different position of the parts, is the usual position of the polypary. For the same reason the anti-sicula side is termed *posterior.* In this I agree with Törnquist—"Structure of Diprionidæ"—who uses the terms "obverse aspect" and "reverse aspect" in the same sense.

The *second* or *left theca,* as it may be called from its position, or more correctly the bud from which it is afterwards formed, always grows out from the left side, and lies along this near the aperture of the sicula (*Didymograptus* and *Tetragraptus*) or ends against it, in which latter case it makes a bend to the left (*Diplograptus* and *Phyllograptus*). The apertures of the sicula and left theca are always turned in opposite directions—that of the sicula to the right, and in the same direction as the thecæ of the rows or branches lying on the right of the sicula; the left-hand theca towards the left, and in the same direction as the remaining thecæ on the left half of the polypary. The direction of the boundary between the sicula and left theca determines, therefore, the direction of the polypary.

The position of the passage opening from the sicula, and thus the place from which the bud grows out, varies. In *Phyllograptus* it is situated quite close to the apex of the sicula, in *Tetragraptus Bigsbyi,* Hall, probably slightly lower down, in *Didymograptus minutus,* Törnq., somewhat below the middle of the sicula, in *Didymograptus gracilis,* Törnq. Mut., still nearer the aperture; but in *Didymograptus gibberulus,* Nich., the position is almost the same as in *Phyllograptus*, if one disregards the long thread-like initial part of the sicula.

The connecting canal.—From the bud developed on the sicula, there arises almost simultaneously with the left theca the common canal for the left half of the polypary and the connecting canal, which crosses the dorsal side of the sicula and gives origin to the third (or, better, the right) theca lying on the right side of the polypary, and also the common canal for the right half of the polypary. This is particularly clear and conspicuous in *D. minutus*, Törnq. Mut., and the same thing also occurs in *Tetragraptus* and *Phyllograptus* (see Figures). By the connecting canal, therefore, we understand in the sequel the canal surrounded on the outside by a special wall, which crosses the sicula on the dorsal side of the polypary, and forms the connection between the two halves of it.

By the development of the three thecæ just described, namely the sicula, the left and right thecæ (primordial thecæ), there originates the primitive form, from which by bifurcation and growth in different directions a further increase of the polypary takes place. This is, in its general characters, in complete agreement in the representative Graptolites referred to, and therefore probably similar in all Graptolites where degeneracy has not taken place.

The genus *Didymograptus*, from the left theca of which there arises only one left branch, and similarly from the right only one right branch, constitutes a further stage of growth of the primitive form. This primitive form or state of development we can therefore term the *Didymograptus*-stage. If no other facts of a different nature are known, it is impossible to assign an individual to its proper genus when it is only known in this or in an earlier stage of development. This is shown in Figures 13–16, Pl. XIV, which represents a young form of *Tetragraptus Bigsbyi*, Hall, in the *Didymograptus*-stage. An account of the further bifurcation belongs to the description of the different genera.

The virgula.—The virgula is wanting in the genera here described; it has, moreover, never been observed by me in any forms belonging to the family Dichograptidæ. On grounds which will be shown later on, a virgula corresponding to that in *Diplograptus* and *Monograptus* cannot occur in the Dichograptidæ. The same is the case in the Dictyograptidæ, Tullb., in forms of Nemagraptidæ, and in the genus *Dicellograptus* of family Dicranograptidæ. A virgula seems never to have been described or figured in any allied form. In the family Diplograptidæ a virgula has been observed in a great many cases, and probably therefore occurs generally (or always?). In the family Monograptidæ it at least is often found, and in many cases has been figured. I have not yet had an opportunity of observing whether both the chitinous threads, which in the Retiolitidæ (*Retiolites* and *Stomatograptus*) have been called the straight and zigzag virgulas, correspond with and have the same mode of origin as the virgula in *Diplograptus*. That a virgula corresponding to that in *Diplograptus* and *Monograptus* cannot occur in the families and genera first enumerated, results from the mode of origin of the same, as a prolongation of the initial part of the sicula.

Törnquist (Siljansområdets Grapt., i, p. 16) has already pointed out, in the descriptions of *Didymograptus minutus*, Törnq., that the thread-like prolongation of the sicula most nearly corresponds with the virgula in the genera *Diplograptus* and *Monograptus*. That this must be the case is evident from Wiman's description of the origin of the virgula from the sicula in *Diplograptus*. Whilst it has been previously supposed that the virgula extended lengthways along one side of the sicula, and therefore in the developed polypary often formed a free, thread-like prolongation of the proximal as well as the distal end of the same, Wiman has shown that the virgula of the sicula, in the sense which he, in conformity with former authors, gives to it, is not continuous, but consists of two separate parts. The one of these, which forms the beginning of the true virgula, stretching throughout the whole of the polypary, originates first near the apex of the sicula as a prolongation of the same, and in *Diplograptus* is embraced and comprised within it by reason of the direction of the development of the polypary. It is this, which corresponds to the thread-like prolongation of the apex of the sicula mentioned above, which occurs in certain species of *Didymograptus*, e.g. *D. gibberulus*, Nich., where it extends beyond the length of the branches.

Since the apex of the sicula is free, as is the case in the above-cited Graptolite forms, a virgula cannot consequently occur embedded in the dorsal side of the branches. It may be observed that in genera in which the sicula is embedded in the polypary a virgula need not of necessity be present.

The presence or the absence of a virgula depends on whether the initial end of the sicula is protracted or not. Thus, for example, the virgula is absent in *Phyllograptus*, and such has hitherto never been observed in any allied species; and in more than a hundred of my isolated or otherwise prepared examples of *Phyllograptus angustifolius*, Hall, in which the internal structure can be studied, no trace of a virgula has ever been observed.

The second of the forms referred to the virgula by Wiman consists of a cylindrical chitinous thread, which originates as a result of growth within the apertural end of the sicula, at some distance from the initial portion. This later structure stands evidently in no relation whatever to the real virgula, but may be regarded as an apertural spine.

The presence of a virgula has, curiously enough, hitherto been considered as the main character of Graptolites. Thus, for example, Lapworth[1] characterizes the sub-order Rhabdophora as follows: "Hydroida in which the polypary is strengthened by a chitinous filiform virgula." Zittel[2] also emphasizes the presence of a virgula in the sub-order Graptoloidea, and says: "Through the possession of a virgula, Graptolites differ from all other Hydroida." The generally

[1] Geol. Mag., Vol. X, 1873, p. 555.
[2] Handb. der Pal., p. 293.

accepted opinion concerning the presence or absence of a virgula in all Graptolites, although such was never described or expressly mentioned, except in the groups Diplograptidæ, Monograptidæ, and Retiolitidæ, might be explained by the two following circumstances:—One of these is that Barrande only knew of forms with a virgula, with the exception of *Retiolites,* in which genus he certainly had observed the chitinous filament named by later authors "a straight virgula," but referred it to the outer network. He began his chapter on the virgula (solid axis) thus: "Graptolites are always provided with a virgula."[1] Through his authority he might so have influenced later authors that his representations concerning the virgula became a creed. The other circumstance might be that broken branches of Dichograptidæ have long been confused with species of *Monograptus* in which the virgula is really present, hence the absence of the virgula in the former has never been questioned.

How strongly the idea of the presence of a virgula in all true Graptolites has taken root is best shown by the fact that so keen and critical an observer as Brögger[2] was disposed to admit the presence of a virgula in *Dictyonema* and *Bryograptus,* although he had never observed it in these forms.

Genus Didymograptus, M'Coy. Pl. XIV, Figs. 1–3, 7, 8.

Concerning the structure of the proximal part of *Didymograptus,* one finds hardly anything mentioned in literature, and in the figures of its species the proximal part is in the greater number of cases so inconspicuously or indefinitely indicated, and figured only from one side, that no definite conclusions can be drawn as to its structure. One exception is Moberg's description of *Didymograptus gibberulus,* Nich.—"Nyagrapt. från Skåne," p. 339, pl. viii—for which, however, Moberg, in ignorance of the true structure of the *Didymograptus* polypary, and misinterpreting the characters in the incomplete material at his disposal, founded a new genus, *Isograptus.* As will be seen below after the description of the *Didymograptus* polypary, Moberg's description and figures, properly interpreted, show clearly that the proximal part of *Isograptus gibberulus* completely agrees with that of the genus *Didymograptus.* Some observations about the *Didymograptus* polypary are mentioned further by Törnquist (Siljansområdets Grapt., i, p. 15). Concerning the sicula, Törnquist remarks that it seems sometimes as if it "had been divided first by an oblique wall into two parts, and as if each part sent out a separate branch." The figures of the proximal part—figs. 8, 12, and 14—which all show the sicula side, indicate that it is the sicula and left theca joined, together with the walls between them, which are referred to by Törnquist. Törnquist states further that the sicula "keeps its triangular form, and by a conspicuous wall is separated from both stipes," which always arise "at different levels from the sides of the sicula, and seem to have originated by a kind of budding."

[1] Grapt. de Bohême (1850), p. 4.
[2] Die Silur. Etagen, 2 u 3, 1882, p. 37.

This also points to conclusions drawn exclusively from the sicula side. As above mentioned, Törnquist also has observed the thread-like process sometimes arising from the apex of the sicula, and has rightly indicated that the nearest correspondence to this in the genera *Diplograptus* and *Monograptus* is the virgula. The two species of *Didymograptus* which are here described, are both from the grey glauconitic Vaginatenkalk at Hälludden, near Torp in Böda parish, in Öland.

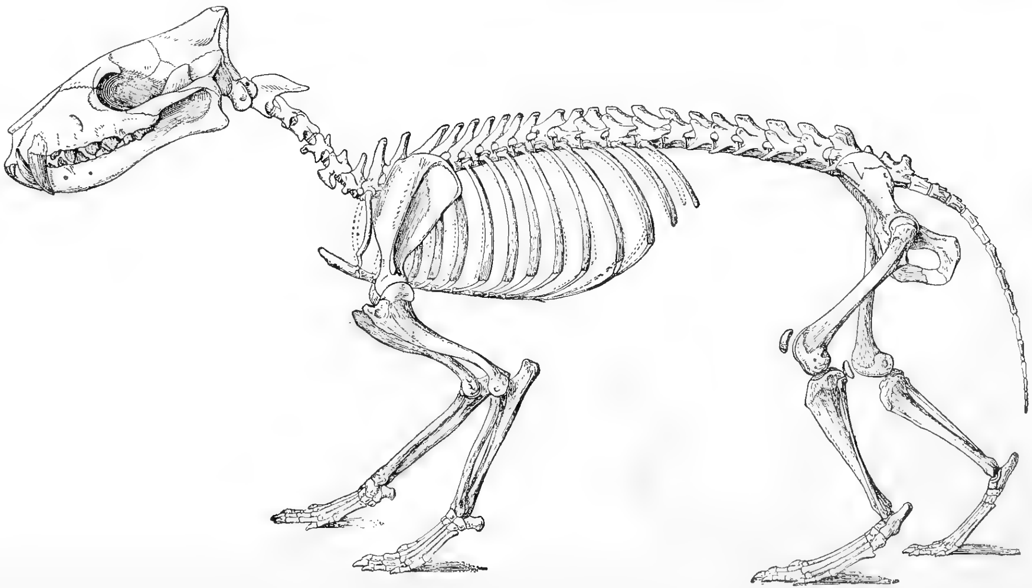
Didymograptus minutus, Törnq. Mut. Pl. XIII, Figs. 1-3.

The three figures give, even at the first glance, a far clearer picture of the external and internal structure of the proximal part than any description. Fig. 1 shows a cast of the sicula side, with the partitions appearing as dark lines on the rock surface; Figs. 2 and 3 show the anti-sicula side in reflected and transmitted light, so that the internal walls and growth-lines of the periderm become visible, and also a simultaneous picture of the external shape, the course of the growth-lines, the internal divisions, and the connection between all these thus obtained.

The apex (initial part) of the sicula is broken off. All over the remaining part, and the polypary besides, conspicuous and regular lines of growth can be seen. The passage opening for the canal arising from the sicula is in this case situated nearer the apertural margin. This appears in Figs. 1 and 3 as a discontinuity in the wall of the sicula. The canal arising from the sicula exhibits on the anti-sicula side (Fig. 3) a peculiar characteristic and instructive arrangement of growth-lines, showing how from the bud in the left wall, by development in different directions, there is formed simultaneously partly the "connecting" canal, which lies on the dorsal side of the sicula, and partly also the common canal of the left stipe. Again, the left theca seems here to be completely separated from the common canal by a wall which runs with the sicula wall, and, without a break, stretches to the aperture of the theca (interthecal wall between left theca and the succeeding theca). This is confirmed by the lines of growth, which, on different sides of the wall, do not stand in any relation to one another.

On the sicula side (Fig. 1), on the contrary, matters are seen from the cast to be quite different. The canal arising from the sicula is here in free and open connection with the left theca, in that the interthecal wall, mentioned on the anti-sicula side, takes its origin at first nearer the middle of the left theca. From this it follows that, simultaneously with the two above-mentioned canals, the left theca is also developed from the bud on the sicula, but that the development of the same proceeded from the sicula side, where the connection exists.

The interthecal wall between the left theca and succeeding theca —the proximal part of the common canal is therefore formed falsely (*skeft*) as well as obliquely—ends on the anti-sicula side, and opens towards the common canal on the sicula side. The left theca, in consequence of this, as shown by its outlines (Figs. 2 and 3), has



A restoration of *Hyænodon cruentus*, Leidy. One-seventh natural size, from the White River (Oligocene) Beds of South Dakota.

a narrow and sack-shaped termination on the anti-sicula side. From all this it follows that the left branch near its proximal part is not "bilaterally symmetrical," in opposition to what Moberg believed was the case in the genus *Didymograptus* (Nyagrapt. från Skåne, p. 346). The development of the following thecæ on the left branch seems to be regular. The "connecting" canal, from which, on the opposite side of the sicula (right side), the right theca and common canal of the right branch arise, crosses the sicula somewhat obliquely, so that the right branch comes to originate somewhat nearer the aperture of the sicula than does the left branch. The lines of growth on the connecting canal are quite continuous with those on the right branch. It appears from Fig. 3 that the connecting canal is really separate from the sicula. At different foci under the microscope the growth-lines of both can be seen crossing one another. In the broken and ragged part of the connecting canal the growth-lines of the sicula alone are shown. Also in the forms preserved in relief of the anti-sicula side (Fig. 2) the "connecting" canal appears, and its passage into the canal from the sicula and common canal of both branches is very conspicuous. The aperture of the sicula is always bent to the same quarter as the apertures of the thecæ of the right branch.

Didymograptus gracilis, Törnq. Mut. Pl. XIII, Figs. 7, 8.

This specimen has not been found transparent, but the same position of relief as in *Didymograptus minutus*, Mut., is shown on both sides. Fig. 7, sicula side; Fig. 8, anti-sicula side. The "connecting" canal is here conspicuous; the proximal end of the sicula shows a fine initial apex.

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

II.—A Restoration of *Hyænodon.*

By Prof. W. B. Scott, F.G.S.

(PLATE XIIa.)

HYÆNODON is one of the genera of fossil mammals which has been for a long time imperfectly known. Excellently preserved skulls have been described and figured by Leidy and Filhol, and some of the limb-bones and vertebræ by De Blainville and Schlosser. Material was, however, lacking for a satisfactory restoration of any of the species, and the specific reference of the scattered bones found has always remained more or less uncertain. In the season of 1894 Mr. Hatcher had the good fortune to discover in the White River beds (Oligocene) of South Dakota a number of remarkably fine specimens pertaining to several species of *Hyænodon*, which at length enable us to gain an idea of the appearance of this most remarkable animal.

The accompanying figure (Plate XIIa) must at once strike everyone as altogether grotesque and improbable, and were it not so largely drawn from the remains of a single individual found together in one block of matrix, I should not venture to publish it. To this individual belong the skull, neck; nine thoracic, four lumbar, two sacral, and two caudal vertebræ; the scapula, ulna, radius, and part of the carpus; the femur, tibia, fibula, and part of the pes. The missing vertebræ were restored from a second specimen which had the skull, all the presacral vertebræ, tibia, fibula, and hind foot. This is a young animal, still retaining the milk dentition, and is very probably referable to the same species (*H. cruentus*, Leidy) as the first. Another adult specimen of the same species, slightly larger than the first, consists of the mandible, axis, humerus, ulna, pelvis, and femur, and allows the proper proportions to be accurately observed. Other more or less fragmentary skeletons, representing various species, lead to similar results, though it yet remains to be determined how far the European species, which exhibit certain constant differences from the American, were characterized by the same remarkable appearance.

As compared with any of the recent Carnivora, the head of *Hyænodon* seems large out of all proportion to the body and limbs, the neck short, the back, especially the lumbar region, quite long, the tail short, the limbs short and slender, and the feet weak.

The characteristic and peculiar physiognomy of the head is already familiar and needs no further description. The neck seems very short and slender to carry the weight of the large head, its length being hardly more than two-thirds that of the skull. The axis is the only cervical vertebra which is strongly developed, possessing a large spine; the others are weak.

The thorax is small, when compared with the skull, but measured by any other standard is quite large and capacious. The vertebral spines are developed much as in the Carnivora, and the transverse processes and rib-tubercles are very conspicuous. The lumbar region is quite long and powerful, the vertebræ having massive centra, long and heavy spines, transverse processes, etc. These features are most marked in *H. horridus*; the smaller species have much less massive loins and evidently feebler muscles. The whole back, from the neck to the sacrum, is strongly axled upward, and its parts are articulated together with unusual flexibility and strength. The tail is rather short and slender, and has about the same relative length as in the raccoons.

The scapula is small and, though with many peculiarities (especially the shape of the acromion), has a shape not unlike that found in the dogs. The humerus is short and slender, and the fore-arm bones still more so, though the ulna is relatively little reduced and has, as in nearly all creodonts, a very prominent olecranon. The manus is small, short, and broad, with five spreading digits and short phalanges, terminated by heavy claws.

The pelvis is decidedly large, even when compared with the overgrown skull, and has an expanded, flattened ilium, more carnivorous than creodont in appearance. The femur considerably exceeds the humerus in length, but is light and slender and has nearly lost the third trochanter. The tibia is short, though much longer than the radius, and the fibula is stout, with expanded ends.

The pes is pentadactyl, and the gait was probably semiplantigrade, like that of many of the recent viverrines. The remarkable peculiarities of *Hyænodon* may, as Filhol has suggested, perhaps find their explanation in the aquatic habits of the animal.

The structure of the European species of this genus is not nearly so completely known as is that of the American. In dentition and skull structure the two groups of species are nearly identical, and probably the characters of the rest of the skeleton corresponded as closely. In two points, however, the European forms, so far as they are known, deviate from the American: (1) in the presence of an alisphenoid canal, and (2) in the formation of a scapho-lunar bone in the carpus by the coalescence of the scaphoid, lunar, and central, which in the American species remain permanently separate.

This is hardly the place to enter upon a discussion of the relationships and phylogenetic descent of *Hyænodon*. It may be mentioned, however, that the problem is much modified by the discovery of *Hyænodon* in the American Upper Eocene (Uinta beds), recently announced by Osborn and Wortman.

Geological Museum of Princeton University.
August 12*th*, 1895.

III.—Review of the Evidence for the Animal Nature of Eozoön Canadense.

By Sir William Dawson, K.C.M.G., LL.D., F.R.S., etc.

I. Historical and Stratigraphical.

The writer of these notes had hoped to have been able long ago to let the vexed questions respecting Eozoön repose in peace in so far as he was concerned, and he is now induced to offer a short summary of the evidence in the case only with the view of correcting some misapprehensions that seem to have arisen in regard to points well established, and which, independently of any question as to the nature of Eozoön, belong to the certain data of geology. These misapprehensions lead to the confounding of the structures originally discovered by Logan with things in no way related to them, and from which they had been clearly distinguished by my own original studies, and by those of Hunt, Carpenter, and Rupert Jones. New facts relating to pre-Cambrian life have also been coming to light from time to time, and many of these are connected, either directly or indirectly, with the evidence respecting Eozoön.

As early as 1858, Sir William Logan had begun to suspect that the Stromatoporoid forms collected from the great Laurentian limestones in different parts of Canada must be of organic origin, and he ventured to mention them as possibly of this nature at the meeting of the American Association in 1859, and in his General Report on the Geology of Canada in 1863. The evidence on which he relied was their occurrence only in the limestones, their similarity in form and general structure to the Stromatoporæ, or "Layer-Corals" of the Palæozoic, and the circumstance that, while the forms and structures seemed to be identical, they were mineralized by Serpentine, Loganite, Pyroxene, and Dolomite, an indication that a similar mould had been filled by diverse minerals.

At that time the little leisure I could spare for original work was occupied with Carboniferous and Pleistocene geology, and I had no ambition to invade the great and difficult pre-Cambrian districts of Northern Canada any farther than might be necessary to my work as a teacher of geology. In the interest of that work, however, I had gone over considerable portions of the Laurentian and Huronian districts surveyed by Logan and Murray, with the aid of their maps and reports, and had satisfied myself of the great accuracy of their work, which led in my judgment to the following results:—

(1) That the upper part of the Lower Laurentian of Logan, since called the Grenville Series,[1] consisted of truly stratified metamorphic rocks, including great and extensive deposits of limestone, quartzite, iron-ore, and other rocks, evidently of aqueous origin, and that the condition and crystalline and chemical characters of these rocks were not essentially different from those of the altered Palæozoic beds with which I was familiar in Nova Scotia and New England.

(2) That the Huronian, a less disturbed, less altered, and in the main evidently a clastic series, rested unconformably on the Laurentian, and was in part composed of its materials.

(3) That the "Upper Copper-bearing series" of Lake Superior, since known as Kewenian, was newer than the Huronian, but older than the oldest fossiliferous Cambrian rocks then known in Canada.

(4) That, while the Kewenian and Huronian rocks, and those designated by Logan as Upper Laurentian, indicated by the presence of igneous masses, and, in the case of the two former, by the prevalence of coarse, clastic material, littoral conditions and much volcanic disturbance, the still older Grenville Series was of a character more indicative of long-continued quiescence, accompanied by the accumulation of great calcareous deposits, possibly of organic origin.

These conclusions were noticed in papers contributed to local societies, in published lecture-notes, and in class-teaching, and were frequently discussed with Logan and Hunt. Accordingly, when, in 1863, at the urgent request of Logan, I undertook the microscopic examination of large series of his supposed Laurentian fossils and the containing limestones, as well as of other crystalline limestones of various ages, slices of which he had caused to be made, I was not unprepared to find the curious and beautiful structures which developed themselves in his Stromatoporoid forms, and in portions of the limestone in which they were contained, but which appeared to resemble those of Foraminifera rather than those of Corals.

The results thus attained, in 1864, were not fully published until after Logan was prepared to sustain them by detailed maps and sections of the district on the Ottawa containing Eozoön, a work extending over many years of arduous and skilful labour; and until Dr. W. B. Carpenter and Prof. Rupert Jones had studied the original specimens and others prepared for themselves, along with

[1] By Dr. Sterry Hunt.

my notes, and camera drawings prepared by the artist of the Geological Survey. Dr. Sterry Hunt had also examined chemically the serpentine and other minerals associated with the supposed fossils, and various hydrous silicates mineralizing organic remains in Silurian and other limestones, as terms of comparison. The whole was then communicated to the Geological Society of London, and appeared in the somewhat elaborate joint paper published in 1865.

[But a preliminary account entitled "On the occurrence of Organic Remains in the Laurentian Rocks of Canada," by Sir W. E. Logan, F.R.S., F.G.S., with communications on the structure by J. W. Dawson, LL.D., F.R.S., and on the Mineralogy of the same remains by T. Sterry Hunt, F.R.S., had, however, been communicated to the British Association at Bath, Sept. 15–21, 1864, and was subsequently published in the GEOLOGICAL MAGAZINE, Vol. I, for November 1864, pp. 225–227.]

I confess that in the intervening time I have seen no good reason to induce me to doubt the essential validity of the work embodied in this paper of 1865, or to modify to any considerable extent the conclusions therein stated. On the other hand, many new and confirmatory facts have been disclosed, and after careful and, I trust, candid study of the objections raised, down to those which have recently appeared in the Dublin Transactions, I believe that they largely depend on want of knowledge of the character of the Grenville formation, and on misapprehension as to the form and structure of Eozoön and its mode of occurrence.

It is true that in those members of the Laurentian system of Logan which are below and above the Grenville Series, later observations have not only failed to detect fossils, but have shown valid reasons adverse to the probability of their occurrence, at least in the portions of those formations hitherto open to our study.[1]

The lowest Laurentian gneiss of Logan (Trembling Mountain gneiss, Ottawa gneiss, fundamental gneiss), which occupies a vast area in Northern Canada,[2] and is the only part of the system known to many geologists, consists, so far as known, wholly of foliated or massive orthoclase gneiss, with bands of hornblendic schist (amphibolite), and of hornblendo-micaceous schist. While in some places it appears to have a truly bedded structure, especially where different varieties of gneiss, amphibolite, and biotitic schist alternate, in others its foliation is obscure, or seems to have been induced by heat and pressure. Dr. F. D. Adams, who has given much study both to its characters on the large scale, and to the microscopic structure of the rocks, in his latest publication on the subject[3] characterizes it as a complicated series of rocks of unknown origin,

[1] See GEOLOGICAL MAGAZINE, June, 1895.

[2] According to the geological map of Northern Canada prepared by Dr. G. M. Dawson for the Geological Survey, the area of Laurentian rocks exceeds two millions of square miles. Of this, so far as is known, the older or fundamental gneiss occupies by far the larger portion.

[3] American Journal of Geology, vol. i, No. 4, 1893.

but comprising a considerable amount of intrusive material. He regards it as either the remains of a primitive crust penetrated by much igneous matter, or as a series of altered rocks older than the Grenville Series, and formed under different conditions. In any case it seems to want the evidences of ordinary aqueous deposition presented by the limestones, ironstones, quartzites, and schists of the Grenville Series. Similar views were advocated in my address on the "Geological History of the Atlantic," before the British Association, in 1886.[1]

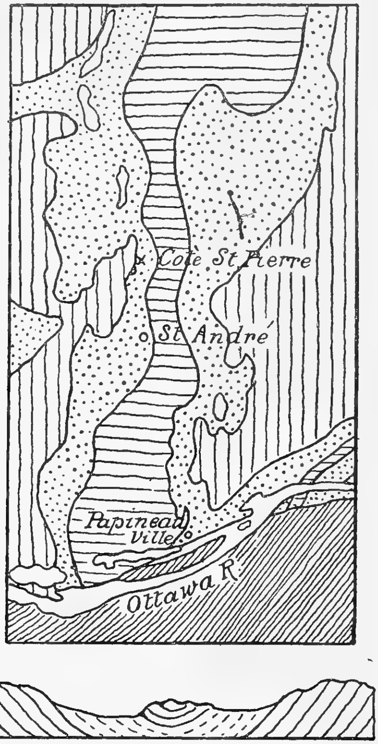


Fig. 1.—Distribution of Grenville Limestone in the district north of Papineauville, with section showing arrangement of the beds. Scale of map 7 miles to an inch. (See also Dr. Bonney's paper, Geol. Mag., July 1895, p. 295.)
Dotted area: Limestone.
Horizontal lines: Upper gneiss (fourth gneiss of Logan).
Vertical lines: Lower gneiss (third gneiss of Logan).
Diagonal lines: Overlying Cambrian and Cambro-Silurian (Ordovician).

The Upper Laurentian of Logan (Labradorite, Anorthosite, or Norian Series), supposed by him to overlie the Grenville Series unconformably, is now stated by Adams to consist of eruptive

[1] See also Museum Memoir on Eozoön, pp. 2, 3. Montreal, 1888.

matter, mainly composed of triclinic or lime felspars, and to which the name Anorthosite[1] may properly be applied. These rocks, cutting the Grenville Series, and apparently in some places interbedded with it, are not now regarded as a distinct series of beds, but as indicating local outbursts of igneous action dating about the close of the Grenville period. What aqueous rocks may have been contemporaneous with them, or may have filled the interval between the Grenville Series and the Huronian, we do not at present certainly know, though possibly some of the rocks associated with the upper part of the Laurentian, or the lower part of the Huronian in the interior, and in the eastern part of Canada, may come into this place.[2]

It is to be observed that in 1865 these facts respecting the fundamental gneiss and the Upper Laurentian of Logan, were not distinctly before our minds, though in subsequent papers I thought it best to consider the Grenville group as a distinct series under the name "Middle Laurentian." It is quite possible, however, that our referring in the first instance to the Laurentian as a whole, may have led to erroneous impressions.

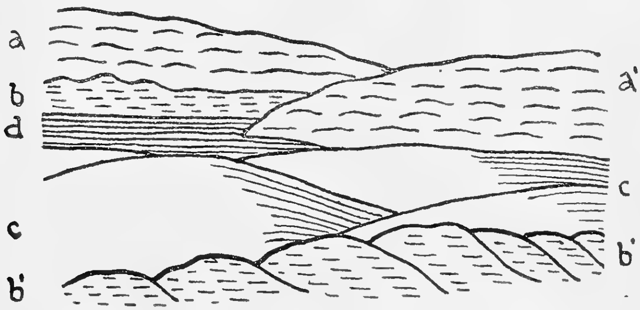


Fig. 2.—Topography at Côte St. Pierre, from the N.E. (For section see Dr. Bonney's paper, Geol. Mag., July 1895, p. 296.)

(*a*) Lower gneiss. (*a'*) The same brought forward by fold.
(*b*) Limestone (Lorne's Quarry). (*b'*) The same, exposure on La Vigne's farm.
(*c*) Limestone, mostly covered with soil.
(*d*) Pond or small lake.

For the purpose of these notes, therefore, it will be best and most accurate to confine ourselves to the Grenville Series, which has been carefully explored and mapped by the officers of the Geological Survey in the country lying north of the Ottawa River, and also in some parts of the areas between that river and the St. Lawrence. In these regions Logan recognized a thickness of 17,250 feet of deposits, of which no less than 4,750 feet consisted of limestone, principally in three great bands, though with intercalated gneissose

[1] Proposed by Hunt.
[2] Some of these beds are regarded by Von Hise (Amer. Journ. of Geology, vol. i) as a lower member of the Huronian. They may also be identical in part with the "Kewatin" group of Lawson.

layers. The Grenville Series may thus be regarded as one of the great calcareous systems, comparable with those of the Palæozoic period, which it also rivals in its association with carbonaceous and ferruginous deposits. Though minute globular forms, probably

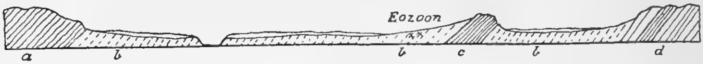


Fig. 3.—Arrangement of beds in valley of Calumet River—(*a*) Upper gneiss; (*b*) Limestone partly covered with soil; (*c*) Included bed of gneiss; (*d*) Lower gneiss.

organic, have been found in the Middle Limestone, that of Long Lake, Eozoön proper is confined, so far as known, to the Upper Limestone, known specially as the Grenville Band. This band and its accompaniments I have myself studied in the region north of

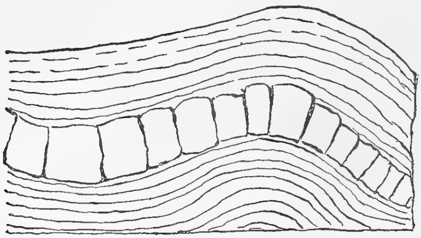


Fig. 4.

the Ottawa, at the Augmentation of Grenville, near the Calumet, in the quarries opposite Lachute, at Côte St. Pierre, at Montebello, at Buckingham, and Templeton, as well as in some of the districts west of the Ottawa, where the same limestone is supposed to recur.

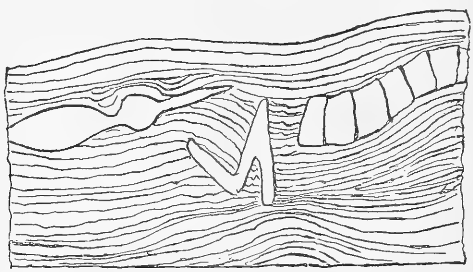


Fig. 5.

Figs. 4 and 5.—Bent and dislocated Quartzite, in contorted schists interstratified with Grenville Limestone, near Montebello. The quartzites have been broken and displaced, while the schists have been bent and twisted. In the immediate vicinity the same beds may be seen slightly inclined and undisturbed.

Everywhere it is a large and regular bed, sometimes with even strike and dip, but at intervals thrown into violent contortions along with the enclosing beds, in the manner usually seen in disturbed strata of later age, where it is common to find portions little affected by plication alternating with strongly folded beds having the harder ones dislocated; others are merely bent or folded (Figs. 4 and 5). It presents subordinate beds of different qualities, dolomitic, serpentinous, or graphitic, and is immediately associated with thin-bedded, fine-grained gneisses, quartzite, and biotitic and hornblendic schists. In some beds it has disseminated crystals of minerals usually found in metamorphic limestones, while in others there are concretionary masses, nodules, and grains of serpentine and pyroxene. Eozoön in masses occurs only in certain layers, most frequently in those which are serpentinous, but a careful examination detects in many layers, not showing perfect examples of Eozoön, small fragments or patches having its characteristic structures, or detached chamberlets or groups of these. The occurrence of these fragments I regard as an important fact, and as showing that what may be termed "Eozoön sand" enters largely into the composition of the limestone.

In illustration of this part of my subject, I present a rough map of the district near the Petite Nation River, in rear of Papineauville, referred to by Dr. Bonney in his valuable paper in the July Number of this Magazine, and in addition to the section given in his paper, one showing the order of succession in the valley of the Calumet, a little stream some distance to the eastward. I also give examples of the manner in which the associated gneiss, though often very regular, is along certain lines contorted, and the manner in which, in these contorted spots, the quartzite bands are cracked and broken, exactly as may be observed in the shales and sandstones of the Quebec group on the Lower St. Lawrence.

I may add here that Dr. Adams has found that in certain localities the rocks of the Grenville Series become almost horizontal, though even in this case they show evidence of having been subjected to much alteration and to lateral pressure.

The summary of facts above given should, I think, be sufficient to show that in the case of the Grenville limestone we have phenomena which cannot be explained by mere pressure acting on massive rocks, or by segregation of calcite from igneous rocks, or by vein structures, or by any contact structures arising at the junction of igneous and aqueous deposits. We have, on the contrary, to deal with a formation which indicates that in the early period to which it belongs regular sedimentation was already in full operation. The more precise vital and chemical agencies which prevailed in the ocean of the Laurentian period we must notice later.

I have merely to add here that the characters assigned above to the Grenville Series have not only been fully corroborated by the recent work of Adams and Ells in Canada,[1] but also by the surveys of Kemp and Smyth in the more disturbed and elevated district of the Adirondack Mountains in New York.[2]

We have thus paved the way for the consideration of evidence of a structural and chemical character.

(*To be continued.*)

[1] American Journal of Geology, 1893, No. 4. Also Reports Geol. Surv. of Canada.
[2] Bulletin Geol. Soc. of America, March 1895.

IV.—The Glacial Deposits of Aberdeenshire.

By Prof. Edward Hull, M.A., LL.D., F.R.S.

Mr. DUGALD BELL, F.G.S., has been so good as to send me a copy of his paper on the "Shelly Clays and Gravels of Aberdeenshire,"[1] on which I beg leave to offer a few observations, as it deals with a subject in which I take much interest, namely, the origin and mode of formation of such deposits. His paper is mainly based upon one by Mr. T. F. Jamieson, of Ellon, also published in the same journal,[2] and on a recent memoir by the Geological Survey of Scotland.[3] There is no difference amongst these authors of any importance as regards the structure and composition of these post-Tertiary deposits, which are found adjoining the coast of Aberdeenshire; and they may be briefly described as follows, in descending order[4]:—

1. Upper Red Clay with boulders, and a few marine forms, 1 to 15 ft.
2. Gravel and Sand with waterworn pebbles and shells, 40 to 60 ft.
3. Lower Boulder-clay ("Grey rubbish"), 5 to 10 ft.

As regards No. 3, there is no difference of opinion. All are agreed that it is the product of the great ice-sheet—the *moraine profonde*—of the epoch of intensest glaciation. It is when we come to deal with Nos. 2 and 1 in the above series, that we find divergence of opinion amongst the authorities quoted. Thus, Mr. Jamieson considers the gravel and sand (No. 2) to be a sort of "moraine," though in some way not clearly explained, "washed" or reconstructed under water, owing to which the pebbles have lost their glaciated surfaces; in fact, the pebbles are remarkable for the absence of glacial striæ, which one would have supposed was strongly indicative of aqueous action. The bedding is generally rude and irregular, but current-bedding occurs occasionally, and the marine shells are almost always fragmental. Notwithstanding all these indications of deposition under water, Mr. Jamieson does not consider that the beds indicate submergence. Mr. Bell concurs, and regards the No. 2 series as the product of land glaciation only (p. 475). On the other hand, the writer of the Survey Memoir considers this deposit as "evidence of inter-Glacial submergence."

I may here pause to enquire in the first place why, if No. 2 deposit has an identical, or similar, origin with No. 3 (the Lower Boulder-clay), there should be so marked a distinction between them? It certainly requires some very clear demonstration to induce one to believe that one ice-sheet will give rise to a stiff unstratified clay with glaciated stones and boulders; and another, to a rudely stratified gravel and sand in which the pebbles are subangular or rounded and destitute of glacial striæ. Even Mr. Jamieson sees the

[1] Quart. Journ. Geol. Soc., Aug. 1895.

[2] *Ibid.*, vol. xxxviii.

[3] This I regret to say I have not seen; but rely upon Mr. Bell's quotations therefrom, which I doubt not are correct.

[4] Very clearly represented in Mr. Jamieson's Coast-section, *ibid.* p. 151.

difficulty, and suggests the washing and rounding process above referred to; but if this were carried on under the waters of the sea it involves the recognition of submergence, a view borne out by the presence of sea-shells.

Next we have to consider the mode of formation of the Upper Red Clay (No. 1) which is found overlying the gravel and sand deposit (No. 2). Mr. Jamieson considers this to be undoubtedly the product of submergence to a depth of some 300 feet; but Mr. Bell regards it as of purely glacial (or land-ice) origin. It is not surprising that as Mr. Bell regards No. 2 as the product of land glaciation, he should take a similar view with regard to the Upper Red Clay with boulders. But again I ask—why, if all these three deposits are the products of similar physical agencies, should they assume such diversified forms as to be capable of, not only definition under different terms, but of illustration along the line of a sea-cliff under very different modes of representation, as Mr. Jamieson has shown? If they have originated from one and the same agency, why should they not have been found as represented by a solid mass of Boulder-clay from top to bottom? The same or similar conditions would, we may suppose, have produced similar results. Instead of three deposits superimposed and each differing from the other, we might have expected one solid ground-moraine formation throughout. Then, in order to maintain the purely land-glacial origin of No. 1, according to Mr. Bell, we have to explain in some way (to myself unintelligible) the presence of marine forms, enumerated by Mr. Jamieson,[1] consisting of shells, such as *Astarte borealis. Cyprina islandica, Saxicava sulcata*, etc.; remains of fishes, swimming birds (eider-duck), seals, starfishes (*Ophiura*). These forms were not found, it should be observed, on or near the surface, but sometimes imbedded deep in the clayey mass. No doubt Mr. Bell would reply that their presence is to be accounted for by supposing that these forms were carried from the sea to the land by the glacier.[2] But if this be the explanation, I would observe that the ice of the North Sea, whether derived from Scandinavia or Scotland itself, was only forced over the land while the North Sea was blocked by ice, in which there were neither shells, starfishes, nor probably seals. On the whole it would seem that Mr. Jamieson has on this point the preponderance of the evidence; and if so, considering the sub-glacial conditions under which the Upper Boulder-clay was clearly deposited, it does not seem surprising that in the waters "marine life was far from abundant."

It seems to me that the confusion which has arisen amongst the neo-glacialists regarding the glacial phenomena of the British Isles is largely due to the practice of confounding aqueous with glacial deposits. As long as deposits, such as No. 2 above, consisting of

[1] *Supra cit.*, p. 166.

[2] If it be the intention of Mr. Bell to represent this by his map, I may observe that on comparing the lines of the ice movement with the arrows given by Prof. James Geikie in his map in the "Great Ice Age," they are almost always at right angles: both cannot be correct.

beds of sand, gravel, and laminated loam or clay, are looked upon as the production of land-ice, so long will these enthusiastic glacialists fail to arrive at intelligible conclusions regarding the physical conditions of the Glacial period. Is it not much more rational to suppose that three superimposed deposits, differing in composition and structure from each other, should have been formed under three different sets of conditions rather than under one and the same or similar? And in the case of the Aberdeenshire deposits surely we have a very evident succession of conditions, such as, in brief: 1st, general land glaciation; 2nd, submergence in sea-waters, during which the rivers brought down sand and gravel from the adjoining emergent lands to be taken up and distributed over the sea-bed; and 3rd, continued submergence, with the recurrence of cold conditions, owing to which the snows and glaciers again occupied the higher elevations, and the streams charged with glacier mud entered the sea and gave rise to a Red Clay formation. The Aberdeenshire deposits do not stand alone; they have their equivalents in Lancashire and Cheshire and in Ireland. The fine section on the banks of the Ribble above Preston is identical (*mutatis mutandis*) with that on the coast of Scotland, and indicates similar widespread conditions in the Glacial period. Mr. Bell denies submergence; but I am tempted to quote a passage from a letter recently received from Prof. Prestwich on this subject, which may possibly have some weight with the neo-glacialists.[1] He says: "I quite agree with you as to the important submergence in Glacial times which has left such clear evidence in the Cotteswold Hills[2] and Welsh Mountains. It is surprising to me that the ice-ploughing hypothesis could ever be entertained. Some half century ago it was my good fortune to come across some fossiliferous gravels in the hills (1,120 feet) between Chesterfield and Buxton. Why the simple explanation should ever have been pushed aside in favour of the more fanciful view I cannot understand, unless it be the innate love of change." Neither can the writer.

V.—On the Pitch Lake of Trinidad.

By S. F. Peckham.

(*Continued from the September Number*, p. 425.)

Near the crest of the ascent to the lake the road divides: one branch passing to the left and south ascends over the rim of the basin of the lake, and skirting the lake for about a quarter of its circumference passes over the hill to the south-west, as described by Mr. Manross. The right-hand branch follows the flow of the pitch and enters upon the lake simply by a change of grade from a sharp ascent to a very slight inclination upwards towards the centre of the lake. I was particularly impressed with this fact, and took pains

[1] Dated 25th July, 1895.

[2] On the Jurassic table-land of the Cotteswolds we find round quartzite pebbles, washed out of the New Red Conglomerate of the Midlands, scattered over the surface up to a level of about 600 feet—a real "Northern drift."

to verify my first impression upon a second visit, as it proved conclusively that, notwithstanding the vast quantities of pitch that had been removed from the lake, there is still a movement out of the lake, glacier-like, down the slope to the sea.

My first impression as I looked over the expanse of the lake was a surprise. I had expected a scene of desolation. Nothing could be further from the reality. In the centre were the islets so often described. Within and around them a dark area resembled the muddy bottom of a pond from which the water had been drawn off, with here and there patches and intervening streams of water remaining. From the border of this dark centre, the vegetation arose higher and higher around almost the entire circumference of the lake, until it reached a border of palm trees from thirty to fifty feet high. As I looked over the lake I beheld on a vast scale the appearance of asphalt beds that I had many times seen in California.

An examination of the borders of the lake showed that it occupied a bowl-like depression in a truncated cone that rested against the side of a hill that rises above the lake to the south-west. Along the line of ascent that I had followed, the slope towards the north-east to the sea is very gradual. In other directions the ascent is abrupt, sometimes steep, especially toward the south. These slopes are covered with tropical jungles consisting of palms of various species, sedges, canna, and wild vines. The border of this depression presents upon the inside for the most part an escarpment of sand and clay, that has evidently been built up and afterwards broken down in many places by water. Wherever excavations have been made in the cone or the escarpment they show that the cone consists of both asphalt and earth. At a point on the south side, near where the road leaves the lake, the appearance of the surface indicates that the drainage of water from the lake was frequently in that direction to a considerable amount, notwithstanding numerous artificial drains lead out of the circumference of the lake and the wide natural outlet down the slope to the sea. To the north-west towards the sea, a heavy stream of asphalt has overflowed to the sea, forming a barrier reef for a considerable distance. Asphalt has also overflowed to the south, and the general appearance of the escarpment seemed to indicate that at some remote period the basin now occupied by the lake had been filled some three feet higher than the present level of the lake. I looked in vain for any evidence that the mass within the lake had been recently depleted; but I am aware that observations at considerable intervals of time would be necessary to establish that fact, by referring the mean level of the lake to some fixed point by means of a very careful trigonometrical survey.

A very careful study of the present appearance of the lake and its boundaries led me to believe that the suggestion of Mr. Richardson, that the lake occupies the crater of an old mud volcano, is correct, and that it has been built up of very unstable material, through contact of water issuing in large quantity from subterranean springs which has come in contact with strata identical with or resembling those described by Mr. Guppy.[1] Into this ascending current, resembling a quicksand, was projected bitumen, at intervals in very large amounts, so that irruptions of mud have coincided with and alternated with irruptions of bitumen, the whole building up the cone and at times overflowing it, while the basin has gradually filled with bitumen to the exclusion of mud.

It is, however, equally evident that for an indefinite period there has been an outflow of bitumen from the crater towards the sea, at La Brea, not over its rim, but through a crevice in its side—in fact, through its broken-down side; and that, notwithstanding the vast quantities of asphalt now being taken from the lake by the Concessionaires, the movement is still out of the lake.

Capt. Alexander, in 1832, spoke of the flow out of the lake as "immense." Manross, in 1855, says, "this stream of pitch has been dug through in several places, averaging from 15 to 18 feet in depth." A well dug at one point on the slope of the overflow was abandoned still in asphalt, at the depth of forty feet. Several village lots have been excavated to a depth of twenty feet, still in asphalt. The invariable reply of the negroes to the question, "Have you ever dug through the asphalt?" was, "No, sir." The conclusion that I reached on the ground is, that the asphalt flowing down the slope to the sea fills a ravine excavated by water, and that it is slowly moving out of the lake with the pressure of the asphalt in the lake behind it. This conclusion is in harmony with the testimony of all the observers above quoted for the last hundred years.

Concerning the condition and appearance of the pitch within the lake, I think it is quite certain from all the observations above quoted that the pitch has gradually become harder and more stable during the last 106 years. I do not think that later observers have any right to question the veracity of those who have preceded them. Dr. Nugent says that in 1807 the centre was so soft that it could be dipped up with a cup. Alexander describes it in 1832 as so unstable that the weight of a man produced a bowl-like depression to the depth of one's shoulders, and that the heat gradually increases as one walks off towards the middle with his shoes off. Manross, 23 years later, says, "It may be that the material has become much harder since the first accounts of it were written; but it is difficult to understand how the weight of a man can have displaced a mass of pitch equal to a 'great bowl' as deep as the shoulders." Kingsley, 24 years later, is practically of the same opinion. At the time of my visit, a man was loading a cart near the centre of the lake, and while they did not remain in one place long enough to secure a large load, there was no apparent danger of their being engulfed.

[1] Guppy says (Quart. Journ. Geol. Soc., xlviii, 527, note): "When a piece of the foraminiferal rock is placed in water, it absorbs it rapidly and falls asunder, and the water which enters into union with it is given up only to evaporation. . . . From these properties it follows that the natural soil roads passing over these rocks become in the wet season the worst quagmires it is possible to imagine." Of another bed, "In the presence of water this rock is the most incoherent of any I have ever met with. . . . It falls into powder at the mere contact of water."

Yet it must not be assumed that the cosmical agencies that produced this deposit of bitumen have ceased to be active, or are even simply quiescent. Abundant evidence is to be found in the neighbourhood, and even within the lake itself, that such forces are still active. A few miles to the south-west of the lake, at Guapo, large springs of maltha or "liquid asphaltum" are now flowing, and within the boundaries of the lake near the power station of the tramway, and within only a few rods of the edge of the cone, I observed what the workmen called (and very properly) a "blow-hole." This was a circular hole, about six inches in diameter, from which bitumen, more nearly fluid than any I saw elsewhere upon the island, had been ejected to the amount of perhaps a barrel. It was so soft as to flow readily, of a brilliant black colour, and appeared to contain little, if any, mineral matter. I was told by a workman that such holes occurred quite frequently and so far apart as apparently to have no connection with each other.

Asphalt beds occur in California that are the product of the hardening of maltha, or mineral tar, which escapes over a considerable area. Sometimes it flows continuously from a central orifice, but oftener the flow through the hot summer seems to be arrested by the lower, winter temperature, when the orifice through which the flow took place becomes plugged. The succeeding season the maltha issues along a line of less resistance and flows through the summer, when it in turn becomes plugged. These plugged orifices are often several rods apart for successive seasons, and present the appearance of a cicatrix. I have no doubt that more extended observations than I was able to give would reveal a similar condition of outflow at and in the vicinity of the lake.

I carefully studied these phenomena as likely to offer some suggestion concerning the origin of the deposit. As a description of the observed facts, I can add nothing to that of Mr. Manross. I do not understand why Messrs. Wall and Sawkins observed nothing of the sort described by him, or thought it not "very obvious to what force or what influence this is attributable." These "areola" are very irregular in shape. I think their form may be, to some extent, determined by the weight of water pressing against their sides. The surface of each one is slightly rounded from the centre to the edge of the water; they then round off at a very sharp angle, finally descending almost perpendicularly. These areas consist of pitch inflated with gas to such an extent, that when broken into the structure exactly resembles an over-fermented cheese—hence the term "cheese-pitch." The cavities are from one to three or more inches in dimensions. The gas that they contain is constantly rising to the surface, where it bubbles out and bursts, thus forcing the centre up, and causing a slow but irresistible movement from the centre towards the circumference, where the pitch continually rolls under exactly as Manross has described it. His suggestions concerning the ebullition of the mass within the lake were confirmed to the very letter.

This action is explained in this wise: Mr. Richardson's analysis of asphalt water shows it to be very rich in sulphates. As has been elsewhere shown, sulphates, especially those of the alkalies, when in solution are decomposed, when the water containing them flows through strata impregnated with organic matter, into hydrogen sulphide, and a carbonate of the oxide present. When hydrogen sulphide infiltrates strata containing carbonate of lime, gypsum is formed and sulphur deposited, or converted into free sulphuric acid.[1]

The Miocene bituminous strata of Southern California are full of sulphur springs and numberless deposits of sulphur. One such deposit in the southern part of Kern County is supposed to contain several thousand tons of sulphur.

The reaction between sulphates present in the lake water and the bitumen or other organic material of the formation furnishes a ready explanation of the presence of hydrogen sulphide; but I must confess that the odour of that gas was much less apparent about the lake than I had been led to expect. Analysis will alone show what the gases are that inflate the asphalt, but of their presence in enormous volume there can be no question. At a rough estimate, I should say that from one-third to one-half the volume of the mass as it exists in the centre of the lake is gas. I also hazard the opinion that this gas makes the *mass* specifically lighter than water, else the tables described by Manross and Kingsley would not rise and spread on the surface of the water, and further the masses of asphalt would coalesce, and the water would float upon the asphalt. Moreover, it is without any doubt that through this motion or ebullition which is produced, not by escape of vapour generated by heat, but by gases forced upward by their own specific gravity through a yielding mass, that the asphalt and mineral matter which forms the floors and sides of the crater are mixed together until the asphalt is saturated; *i.e.* it reaches such a condition of plasticity and viscosity, that it will no longer absorb any more mineral matter in presence of water. I cannot account for the almost uniform character of the mixture of water, bitumen, and mineral matter on any other hypothesis.[2]

Asphalt is very inert to changes of temperature. It is a very poor conductor of heat, and even under a tropical sun the daily surface changes of temperature and consequent expansions and contractions are wholly inadequate to produce conditions affecting such enormous masses of material as the crater contains.

The frequent use of the term "volcanic" in connection with the supposed origin of this mass of bitumen is, in my judgment,

[1] Proc. Amer. Philos. Soc., vol. x, p. 445. Bischoff, Chem. and Phys. Geol. (Cav. Soc. Ed.), ii, p. 28; *ibid.*, vol. i, pp. 15, 340. T. S. Hunt, Chem. and Geol. Essays, pp. 23, 87, 99, 111.

[2] Mr. Richardson asserts that 90 per cent. of the 80 per cent. of insoluble mineral matter in the pitch is silica. As a possible explanation of the presence of so much silica, I would suggest that the hot water that distilled the bitumen might have held silica in *solution*, which has been precipitated within the pitch as it has cooled. The fact, if it be a fact, that so much silica exists in the pitch as hydrate, may account for the large amount of water held in the pitch.

misleading. With the term volcanic is usually associated streams of melted lava, scoria, and pumice. The masses of porcellanite and jasper mentioned by all observers as found in the neighbourhood of the lake, do not require for their origin any "subterranean fires." It only requires that hot water, holding silica in solution under high pressure, shall percolate a bed of clay. The distillation of beds of lignite requires nothing more. In one case the product is red or yellow jasper, in the other a deposit of bitumen. The less the pressure the more dense will be the bitumen. Water will inevitably bring the bitumen to the surface, unless it is held down by impervious strata. If the water, accompanied by bitumen, encountered in its upward passage such strata as have been described by Mr. Guppy, a mud volcano yielding bitumen would be the inevitable result. It appears to me that all of these conditions are present in and about the pitch lake. They are exactly the conditions that have produced enormous tar springs and asphalt beds in California, excepting that there the strata necessary to produce mud volcanoes are wanting, but the porcellanites, the hot springs, the sulphur springs, and the bitumen, are all there, and in some localities on a scale that vies with Trinidad.

I looked in vain for specimens of wood in process of transformation into asphalt. I enquired of many intelligent men, and others connected with mining the pitch, if they had ever seen such specimens; they invariably answered "no." Two or three remarked that the wood never decayed in the pitch, that it came out as it went in. One man replied that "if it went in rotten it came out rotten." I saw in several excavations along the tramway masses of vegetable matter that appeared to have been converted into humus, and was told by the workmen that in time these masses would become incorporated with the pitch. Such masses account for the organic matter in solution in the lake water, and also for the amorphous organic matter not bitumen, observed by Mr. Richardson.

The Concessionaires of the lake have recently put in operation a tramway and pier by which the pitch can be very rapidly and easily removed from the lake to vessels lying at the pier. The tramway forms a loop, which in a general way may be said to pass just outside the circle of islets. (See map.) In building the tramway much of the vegetation on these islets has been destroyed. The laying of the tramway presented some peculiar engineering difficulties, that have been fully overcome. The islands float on the pitch, and I believe that they represent portions of the edge of the crater broken off during violent irruptions, and placed in and maintained in their relative positions through their relations to the various centres of ebullition into which the surface of the lake is divided. These islets, which largely consist of vegetable matter, float, while logs of wood and palm-tree ties sink in the pitch; it therefore occurred to Mr. Freeman, the engineer in charge of the work, to support his tramway on palm leaves, of which many specimens are twenty-five feet in length. This expedient has proved a complete success, not only upon the summits of the "areola," but in crossing the crevices that separate them. The tramway furnishes a succession of admirable points from which to view the lake, as no difficulty is experienced in walking upon the ties around the entire loop. The cars are run in groups of four, which, when loaded, have a gross weight of about six thousand pounds. I carefully watched the passage of successive groups of these cars and could not observe any change of level in the road bed as they passed along; yet I am quite certain if a group had been allowed to stand for several hours, that both tramway and cars would have sunk in the pitch.

The pitch is excavated along this tramway upon the summits of the "areola." Wherever the surface of the pitch is broken, the vesicles are uniformly smaller as the pitch is taken from points removed from the centre of the lake. As the water dries out the vesicles collapse, and the colour changes from brown to bluish-black. If left long enough in the sun, any of the pitch, no matter from what spot it may be taken, will first melt upon the surface, and finally flow into a more or less compact mass. The pitch being dug by the Trinidad Asphalt Company, both within and without the lake, was brown when freshly dug, changing to black on exposure. The same might be said of that dug farther down the slope from village lots by the Trinidad Bituminous Asphalt Company. It was quite evident that as the pitch was taken from points farther and farther from the centre of the lake it had been subjected to more and more pressure, the gas being forced out as a consequence, the vesicles made smaller, and the specific gravity thereby increased. There are enormous masses of pitch within the lake that could not, in my opinion, be distinguished by the eye from the pitch taken from the village lots by either of the companies before mentioned. I am therefore quite at a loss to determine why Mr. Richardson alleges such a specific distinction between what he pleased to term "lake" and "land" asphalt. It appears to me to be a distinction without a difference.

For further facts concerning the commercial and economic relations of Trinidad Asphalt, the reader is referred to the report of Consul Pierce, which I believe to be one of the most complete and impartial of all the valuable consular reports issued by the State Department.

It was my intention to include in this paper some statistics regarding the enormous amount of asphaltum of different varieties shipped from La Brea since January 1st, 1890. When a friend applied to the custom house in Port of Spain for an official statement, he reported that such information had been refused, on the ground that such a statement would make public private interests, inasmuch as the Trinidad Asphalt Company had shipped several cargoes of "land pitch" to the United States since that date.

By referring to the maps the reader can clearly distinguish the relative positions of the lake and the adjacent portion of the island.

University of Michigan, Ann Arbour, Michigan,
April 15*th*, 1895.

NOTICES OF MEMOIRS.

I.—British Association for the Advancement of Science. Sixty-fifth Annual Meeting, held at Ipswich, Sept. 11–18, 1895.

List of Papers read in Section (C), Geology.

William Whitaker, B.A., F.R.S., F.G.S., President.

The President's Address. (See p. 461.)

F. W. Harmer.—The Southern Character of the Molluscan Fauna of the Coralline Crag tested by an Analysis of its Abundant and Characteristic Shells.

F. W. Harmer.—The Derivative Shells of the Red Crag.

H. W. Burrows.—Notes on the Stratigraphy of the Crag, with especial reference to the Distribution of the Foraminifera.

H. B. Woodward.—Note on a Section at the North Cliff, Southwold.

John Spiller.—Recent Coast-Erosion at Southwold and Covehithe.

Rev. E. Hill.—Observations on East Anglian Boulder-clay.

Rev. E. Hill.—Indications of Ice-raft Action through Glacial Times.

Rev. E. Hill.—On Traces of an Ancient Watercourse in West Suffolk.

Clement Reid and *H. N. Ridley.*—Further Notes on the Arctic and Palæolithic Deposits at Hoxne.

W. Whitaker.—Some Suffolk Well-sections.

Prof. W. J. Sollas.—Pitch Glaciers or Poissiers, and Illustrations of Glacier Movements.

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A. Gobert.—The Gobert Freezing Process for Shaft-sinking and Tunnelling under Rivers.

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B. Harrison.—Report on Plateau Flints of North Kent.

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Dr. Conwentz.—On English Amber, with Exhibition of Specimens.
Dr. J. G. Garson.—A Palæolithic Skeleton from the Thames Valley.

II.—British Association for the Advancement of Science, Ipswich, 1895.—Underground in Suffolk and its Borders: Address to the Geological Section. By W. Whitaker, B.A., F.R.S., F.G.S., President of the Section.

When the British Association revisits a town it is not unusual for the Sectional Presidents to refer to the addresses of their local predecessors, and to allude to the advance of their science since the former meeting. I have at all events tried to follow this course, with the sad result of having to chronicle a falling back rather than an advance in our methods of procedure; for at the meeting of 1851 all the Sectional Presidents had the wisdom not to give an address, and of all the inventions of later years I look upon the presidential address as perhaps the worst.

Had I the courage of my opinion I should not now trouble you; but an official life of over thirty-eight years has led me to do what I am told to do, and to suppress my own ideas of what is right. After all it is the fault of the Sections themselves that they should suffer the evil of addresses. They could disestablish the institution without difficulty.

On these occasions it is not usual to allude to the personal losses our science has had in the past year; but there are times when the lack of a familiar presence can hardly be passed over, and since we last met we have lost one of our most constant friends, who had served us long and well, and had been our Secretary for a far longer time than any other holder of that office. When we were at Oxford last summer none of us could have thought that it was our last meeting with William Topley.

I do not now mean to say anything on the origin or on the classification of the various divisions of the Crag and of the Drift that occur so plentifully around us, and form the staple interest of East Anglian geology. These subjects, which are the more interesting from being controversial, I leave to my brother-hammerers, and without claiming the credit of magnanimity in so doing, having said what I had to say on them in sundry Geological Survey memoirs. The object of this address is to carry you below the surface, and to point out how much our knowledge of the geology of the county in which we meet has been advanced by workers in another field, by engineers and others in their search for water. As far as possible allusion will be made only to work in Suffolk; but we must occasionally invade the neighbouring counties.

This kind of evidence has chiefly accumulated since the meeting of the Association at Ipswich in 1851; for of the 476 Suffolk wells of which an account, with some geologic information, has been published, only 68 were noticed before that year, all but two of these being in a single paper. The notes on all these wells are now to be found in twelve Geological Survey memoirs that refer to the county. Number alone, however, is not the only point, and many of the later records are marked by a precision and a detail rarely approached in the older ones. It should be stated that in the above and in the following numbers strict accuracy is not professed, nor is it material. A slight error in the number of wells, one way or the other, would make practically no difference to the general conclusions.

Now let us see how these records affect our knowledge of the various geologic formations, beginning with the newest and working downward.

The Drift.—Under this head, as a matter of convenience for the present purpose, we will include everything above the Chillesford Clay. There is no need for refinement of classification, and the thin beds that come in between that clay and the Drift in some parts do not affect the evidence we have to deal with.

As a matter of fact, it is only from wells that we can tell the thickness of the Drift over most of the great plateau that this formation chiefly forms; open sections through a great thickness of Drift, to its base, are rare, except on the coast.

There is often some doubt in classifying the beds, the division between Drift and Crag being sometimes hard to make in sections of wells and borings; but from an examination of the records of these Suffolk sections that pass through any part of the Drift Series (as defined above) we find that no less than 173 show a thickness of 50 feet and upward, whilst of these 34 prove no less than 100 feet of Drift, many reaching to much more. Of the two that are said to show a thickness of over 200 feet and the one said to be more than 300 feet deep in Drift, we can hardly feel certain; but such amounts have been recorded with certainty as occurring in the neighbouring county of Essex.

These great thicknesses (chiefly consisting of Boulder-clay) show the importance of the Drift, and the impossibility of mapping the formations beneath with any approach to accuracy, on the supposition that the Drift is stripped off, as is the case in the ordinary geologic map. The records also show the varying thickness of the Drift, and how difficult it often is therefore to estimate the thickness at a given spot. Sometimes the sections seem to point to the existence of channels filled with Drift, such as are found also in Essex and in Norfolk; and it may be noted that in the northern inland part of the former county, one of these channels has been traced, though of course not continuously, for some eleven miles along the valley of the Cam, and at one place to the depth of 340 feet (or nearly 140 below sea-level), the bottom of the Drift moreover not having been reached even then. A channel of this sort seems to occur close to us, in the midst of the town of Ipswich, where, by St. Peter's, one boring has pierced 70 feet of Drift, and another 127, in ground but little above the sea-level.

As the Drift sands and gravels, that in many places occur below the Boulder-clay, often yield a fair amount of water, the proof of their occurrence and of the thickness of the overlying clay is of some practical good.

The Crag.—On this geologic division we have a less amount of information, as would be expected from the fact that it is not nearly so widespread as the Drift, and this information is confined to the Upper or Red Crag, the Lower or Coralline Crag occurring only over a very small area, and no evidence of its underground extension being given by wells.

What we learn of the Red Crag, however, is of interest, several wells having proved that it is far thicker underground than would have been supposed from what is seen where its base crops out. One characteristic, indeed, of this sandy deposit, in the many parts where it can be seen from top to bottom, is its thinness, as in such places it rarely reaches a thickness of 40 feet. But, on the other hand, wells at Hoxne seem to prove more than 60 feet of Crag, whilst at Saxmundham the formation is 100 feet thick, and at Leiston and Southwold over 140. Further north, just within the border of Suffolk, there is, at Beccles, a thickness of 80 feet of sand, or, with the overlying Chillesford Clay, a total of 95. Our underground information has, then, trebled the known thickness of the Upper Crag of Suffolk.

It has also shown that at some depth underground the colour-name is a misnomer, the shelly sands being light-coloured and not red. This is the case, too, with some other deposits, which owe their reddish-brown colour at the surface to peroxide of iron. Presumably the iron-salt is in a lower state of oxidation until it comes within reach of surface actions. This seems to point to the risk of taking colour as the mark of a geologic formation.

Eocene Tertiaries.—Below the Crag there is a great gap in the geologic series, and we come to some of the lower of the Tertiary formations, about which little had been published, as regards Suffolk, before the work of the Geological Survey in the county. It seems as if the special interest in the more local Crag had led observers to neglect these beds, which had been amply noticed in other parts.

We have records of more than forty wells in Suffolk that are partly in these deposits, and of these thirty-six reach down to the Chalk, twenty giving good sections from the London Clay to the Chalk. The thickness of the Lower London Tertiaries (between those formations) thus proved varies from 30 to 79½ feet, the higher figure being much greater than anything shown at the outcrop. The greatest recorded thickness is at Leiston, where, moreover, the top 26 feet of the 79½ may belong to the uppermost and most local of the three divisions of the series, the Oldhaven Beds, of very rare occurrence in the county. The next greatest thickness is at Southwold, where the whole has been classed as Reading Beds (the persistent division), though here and elsewhere it is possible that the underlying Thanet Beds are thinly represented. It is noteworthy that at both these places, where the Lower London Tertiaries are thick, they are also at a great depth, beginning at 252½ and 218 feet respectively, which looks as if, like the Crag, they thickened in their underground course away from the outcrop.

The important evidence given by these wells, however, is not as regards thickness; it is to show the underground extent of the older Tertiary beds, beneath the great sheet of Crag and Drift that prevents them from coming to the surface north-eastward from the neighbourhood of Woodbridge. It is clear that over this large tract we can know nothing of the beds beneath the Crag otherwise than from wells and borings; and, until these were made, our older geologic maps cut off the older Tertiary beds far south of the parts to which we now know that they reach, though hidden from our sight. No one, for instance, would have imagined many years ago that at Southwold the Chalk would not be touched till a boring had reached the depth of 323 feet, or some 280 below sea-level, nor that at Leiston those figures would have been about 297 and 240.

It is from calculations based on the levels of the junction of the Chalk and the Tertiary beds in many wells that the line engraved on the Geological Survey map as the probable boundary of the latter beds under the Crag and Drift has been drawn. From what has gone before, however, as to the great irregularity in the thickness of the Drift, it is clear that this line must be taken only as approximate, and open to correction as further evidence is got; albeit the junction of the Chalk and the Tertiary beds is found to be here, as elsewhere, fairly even, along an inclined plane that sinks towards the coast.

Cretaceous Beds.—Though the *Chalk* is reached by very many wells, yet we get less information about it, by reason of its great thickness. Moreover, the great amount of overlying beds in many cases is a bar to deep exploration.

Of our Suffolk wells there are forty which go through 100 feet or more of Chalk. Of these twenty go through 200 feet or more, half of these to 300 or more, and again half of the ten to 400 or more, a very exact piece of geometric progression, or more strictly, retrogression. Although two wells pass through the great thickness of more than 800 feet of Chalk, yet neither of them gives us the full thickness of the formation; for the 816 feet at Landguard Fort do not reach to the base, whilst the 843 (or 817) feet at Combs, near Stowmarket, do not begin at the top.

As in no case yet recorded has the Chalk been pierced from top to bottom in Suffolk (a defect that will be supplied during this meeting by the description of the Stutton boring), that is to say, no boring has gone from the overlying older Tertiary beds to the underlying Gault, we must now, therefore, cross the border of the county to get full information as to the thickness of the Chalk; and we have not far to go, for the well-known Harwich boring passes through the whole of the Chalk, proving a thickness of 890 feet. It is almost certain, indeed, that this should be given as a few feet more, for the 22 feet next beneath, which have been described as Gault mixed with Greensand, is probably in part the green clayey glauconitic base of the Chalk Marl. We may fairly add for this another 5 feet (as also in the case of the Combs boring), and may say that, in round numbers, the Chalk reaches a thickness of about 900 feet in the south-eastern part of Suffolk. Toward the northern border of the county it is probably more, as the deep boring at Norwich passes through nearly 1,160 feet of Chalk, and that without beginning at the top of the formation.

Of our recorded Suffolk wells only three reach the base of the Chalk, at Mildenhall, Culford, and Combs; consequently we have little knowledge of the divisions of the Chalk. These divisions, indeed, are of comparatively late invention, having been evolved since the publication of many of the deep sections that have been referred to.

If the Upper Chalk at Harwich goes as far down as the flints, then we must allow it to be 690 feet thick, leaving little more than 200 for the Middle and Lower Chalk together. At Landguard Fort, from the same point of view, the Upper Chalk would certainly be 500 feet thick, and one cannot say how much more.

At Combs, on the other hand, flints have been recorded as present only in the top 27 feet of the Chalk; but whilst this may have been owing in part to the boring having passed between fairly scattered nodules, and in part perhaps to insufficient care in observation, at Harwich it is possible that some flints may have been carried down in the process of boring.

What evidence we have tends to show, however, that the Upper Chalk forms a good deal more than half, and perhaps about two-thirds, of the formation, the Middle and Lower Chalk being rather thin. This agrees with what is found in other parts where the Chalk is thick, extra thickness being chiefly due to the highest division. The glauconitic marly bed at the base seems to be well developed and to be underlain by the Gault clay; so that we have no good evidence of the occurrence of the Upper Greensand. This division may be thinly represented at Mildenhall, but it is difficult to classify some of the beds passed through in the old boring there.

As far as the *Gault* is concerned little of course is known; but that little points to this formation being unusually thin, presumably only 73 feet from top to bottom at Culford, and probably not more than between 50 and 60 at and near Harwich. In the north-western part of the neighbouring county of Norfolk it is well known to be still less, the clay thinning out northward along the outcrop, until at last there is nothing but a few feet of Red Chalk between the carstone of the Lower Greensand and the Chalk. The Gault being of much greater thickness around and under other parts of the London Basin, this thinning in Norfolk and Suffolk is noteworthy. The absence of the more inconstant Upper Greensand is to be expected in most places, and calls for no remark; it may, however, be noted that geologists are coming to the conclusion that these two divisions are really parts of one formation, and one result of this geologic wedding is for the inconstancy of one partner to be greatly compensated by the constancy of the other.

The *Lower Greensand* has been found in one deep boring only, at Culford, in the western part of the county, where it is represented by $32\frac{1}{2}$ feet of somewhat exceptional beds. This slight thickness prepares us for underground thinning, and in the far east of the county the formation is presumably absent, there being no trace of it at Harwich or at Stutton.

With the Cretaceous beds we pass from the regular orderly succession of geologic formations; indeed, it may be said that when we reach the base of the Gault we pass out of the region of facts into the realm of speculation.

We have come then to perhaps the most interesting problem in the geology of the Eastern Counties, to the consideration of the question, What rocks underlie the Cretaceous beds at great depths? In dealing with this I must ask your patience for frequent excursions outside our special district, and sometimes indeed far away from it.

Beyond the outcrop of the lower beds of the Cretaceous Series in Cambridgeshire and Norfolk, we find of course a powerful development of the great Jurassic Series; but the only two recorded deep borings in and near Suffolk that have pierced through the Cretaceous base, at Culford on the north-west and at Harwich on the south-east, show not a trace of anything Jurassic: they pass suddenly from Cretaceous into far older rocks. And here a paper that is to be brought before you must be anticipated, to a slight extent, by adding that the trial-boring at Stutton shows just the same thing—the Gault resting directly on a much older rock, which cannot be classed as of Secondary age.

There is no need now to discuss the literature of the old rocks underground in South-eastern England: that has often been done. We may take the knowledge of what has been shown by the various deep borings as common property, and may use it freely, without troubling to state the source of each piece of information, and I will not therefore burden this address with references. I had indeed thought of supplementing a former account by noticing the later literature of the subject; but decided to spare you from the infliction, and myself from the trouble of inflicting; though it may be convenient to add, in the form of an appendix, a list of the chief papers on the subject that have been published since the question was discussed at length in 1889, in an official memoir on the geology of London, and to supply some omissions in that work. Nor do I propose to make any special criticism of papers on the subject that have appeared of late years; this is hardly the occasion for controversy, which may well be put off to a more convenient season. Some general remarks, however, I shall have to make after putting the facts before you.

There are 10 deep borings reaching to old rocks in the London Basin, of which accounts have been published. We find that in

4 of these (Meux's, Streatham, Richmond, and Dover) Jurassic beds separate those rocks from the Cretaceous beds; so that there are 6 in which these last rest direct on old rocks (Ware, Cheshunt, Kentish Town, Crossness, Culford, and Harwich). Stutton, of course, make a seventh. The Jurassic rocks occur only in the southern borings, either in London or still further southward, and in one case only (Dover) is there any considerable thickness of these: in the other 3 they are from $38\frac{1}{2}$ to $87\frac{1}{2}$ feet thick. As far as regards Suffolk and its borders we may therefore disregard them, except in the far west, near their outcrop, and we may pass on to consider the older rocks that have been found.

So far the occurrence, next beneath the Cretaceous or Jurassic beds, of Silurian, Devonian, and Carboniferous rocks has been proved, whilst in some cases we are still doubtful as to the age of the old rocks found. In 5 cases distinctive fossils have been found (Ware, Cheshunt, Meux's, Dover, and Harwich), but in 5 others they have not (Kentish Town, Crossness, Richmond, Streatham, and Culford), and it is in the latter group, too, that the character of the beds leaves their age in doubt. So far another must be added to these, as no fossil has yet been found in the old rocks at Stutton.

Of the above 10 deep borings in the London Basin (using that term in the widest sense, as including the Chalk tract that everywhere surrounds the Tertiary beds) we owe 9 to endeavours to get water from deep-seated rocks, and in addition to these 9 we have several other deep borings, which, though not carried through to the base of the Secondary rocks, yet give us much information concerning those beds (at Holkham, Norwich, Combs, Winkfield, London, Loughton, Chatham, and Dover). In one case only, that of Dover, has the work been done for the purpose of exploration, but now, after a few years' interval, a second trial has been made at Stutton.

Now both of these borings were started for a much more definite object than merely to prove the depth to older rocks, or the thickness of the Cretaceous and Jurassic Series. There is one particular division of those older rocks that has a distinct fascination for others than geologists. We, happily, are content to find anything and to increase our knowledge in any direction, but naturally those who are not geologists, as well as many who are, like to find something of immediate practical value. As already shown, we owe much knowledge of the underground extension of formations to explorations for water; it has now become the turn of geologists to help those who would like to find that much less general, though nearly as needful and certainly more valuable thing, *coal.*

The first place to suggest itself to those geologists who had worked at this question, as a good site for trial, was the neighbourhood of Dover, and for various good reasons. The trial has been made, and successfully, several hundred feet of Coal-measures having been found, without reaching their base, but with several beds of workable coal.

Beyond that neighbourhood, however, geologists are not in such accord, and generally speaking, fairly good reasons can be given both for and against the selection of many tracts for trial, except in and near London, where no geologists would recommend it, from the evidence in our hands.

Let us then shortly review the evidence that we have on the underground extension of the older rocks in South-eastern England, with a view of considering the question of the possibility of finding Coal-measures in any of the folds into which those rocks have probably, nay almost certainly, been thrown.

The area within which the borings that reach older rocks in the London Basin is enclosed is an irregular pentagon, from near Dover, on the south-east, to Richmond on the west, thence to Ware, thence to Culford on the north, thence to Harwich, and thence southward to Dover, the greatest distance between any borings being from Dover to Culford, about eighty-six miles. It is therefore over a large tract, extending, of course, beyond the boundaries sketched above, that we have good reason to infer that older rocks are within reasonable distance of the surface, nowhere probably as much as 1,600 feet, and mostly a good deal less.

We must now consider some evidence outside the tract hitherto dealt with. Southward of the central and eastern parts of the London Basin we have evidence that the Lower Cretaceous beds thicken greatly, from what is seen over their broad outcrop between the North and South Downs. We know also, from the Dover and Chatham borings, that the Upper and Middle Jurassic beds come in to the south-east, whilst the Sub-Wealden Exploration, near Battle, proves that those divisions thicken greatly southward, the latter not having been bottomed at the depth of over 1,900 feet at that trial-boring.

Westward, however, near Burford in Oxfordshire, and some miles northward of the nearest part of the London Basin, Carboniferous rocks have been found at the depth of about 1,180 feet, these being separated from the thick Jurassic beds (including therein the Liassic and Rhætic) by perhaps 420 of Trias. They consist of Coal-measures, which were pierced to the depth of about 230 feet.

In and near Northampton, north-eastward of the last site, and still further from the northern edge of the London Basin, the like occurs; but the beds found are older than the Coal-measures, and the Trias is thin, not reaching indeed to 90 feet in thickness, and being absent in one case. At one place, too, the Carboniferous beds have been pierced through, with a thickness of only 222 feet, when Old Red Sandstone was found, and in another place still older rock seems to have been found next beneath the Trias. The depth to the rocks older than the Trias, where they were reached, was 677, 738, and 790 feet, or respectively 395, 460, and 316 below sea-level. Some of these figures must be taken as somewhat approximate, though they are near enough to the truth for practical purposes.

A boring at Bletchley, to the south, reached granitic rocks at the depths of 378½ and 401 feet; but these rocks seem to be only boulders in a Jurassic clay: their occurrence, however, is suggestive of the presence of older rocks at the surface no great way off, in Middle Jurassic times.

Much further northward, at Scarle, south-west of Lincoln, the older rocks have been reached at the depth of about 1,500 feet, all but 141 of which are Trias, and they begin with the Permian (which crops out some eighteen miles westward), the Carboniferous occurring after another 400 feet, and having been pierced to 130.

We have then evidence that over a large part of South-eastern England, reaching northward and westward of the London Basin, though the older rocks are hidden by a thick mantle of Jurassic, Cretaceous, and Tertiary beds, yet they seem to be rarely at a depth that would be called very great by the coal-miner. They are distinctly within workable depths wherever they have been reached.

There is no area of old rocks at the surface in our island, south of the Forth, in which Coal-measures are not a constituent formation. Truly, further north, in the great tract of Central and Northern Scotland there are no Carboniferous rocks; but we can hardly say that none ever occurred, at all events in the more southern parts. We know, though, that on the west and north Jurassic and Triassic beds rest on formations older than the Carboniferous.

It is not, however, to this more northern and distant tract that we should look for analogy to our underground plain of old rocks; rather should we look to more southern parts, to Wales and to Central and Northern England, where Coal-measures are of frequent occurrence. On the principle of reasoning from the known to the unknown, I cannot see why we should expect anything but a like occurrence of Coal-measures, in detached basins, in our vast underground tract of old rocks.

What, then, is the evident conclusion from what we know and from what we may reasonably infer? Surely that trials should be made to see if such hidden coal-basins can be found.

One trial has been made, and it has succeeded: the Dover boring has proved the presence of coal underground in Eastern Kent, along the line between the coal-fields of South Wales and of Bristol on the west, and those of Northern France and of Belgium on the east.

The long gap between the distant outcrops of the Coal-measures near Bristol and Calais has been lessened very slightly by the working of coal under the Triassic and Jurassic beds near the former place, but much more by our brethren across the narrow sea, the extent of the Coal-measures beneath the Jurassic and Cretaceous beds, having not only been proved by the French and the Belgians along their borders, but the coal having been largely worked. At last, we too have still further decreased the gap, by the Dover boring, a work that I trust is to be followed by other work along the same line.

But is this the only line along which we are to search? Are we to conclude that the only coal-fields under our great tract of

Cretaceous beds (where these are either at the surface or covered by Tertiary beds) are in Kent, Surrey, and other counties to the west? Have we no coal-fields but those of Bristol and of South Wales? The bounds of our midland and northern coal-fields have been extended by exploration beneath the New Red Series: are we to stop here and to assume that there can be no further underground extension of the Coal-measures south-eastward? This seems hardly a wise course, and is certainly a very unenterprising one. It seems to me rather that the right thing to be done is to try to find out the real state of things, by means of borings.

There are, of course, objectors in this as in other matters. Some may say that it is silly to try in Suffolk, and that Essex gives a better chance of success. Others, again, may prefer Norfolk. And yet others may argue that there is no chance of finding Coal-measures in any of those three counties. But I must confess my inability to understand this line of reasoning; the fact is, that the data we have are few and far between, and that we want more. It is really of little use to bandy words, and I do not now mean to take up the matter in detail. We cannot get at the truth except by actual work; justification by faith will not hold in this case, still less justification by unfaith.

Let us hark back a little and call to mind what has happened in the past. I remember the time when certain geologists disbelieved in the possibility of the occurrence of Coal-measures anywhere in South-eastern England, it being argued that the formation thinned out before it could get so far eastward. Then this view was somewhat varied, and it was inferred, from certain observed facts, that even if Coal-measures did reach underground into these benighted parts, they would be without workable coal, and so practically useless.

Now for some years nothing occurred to upset the prophets of evil, that is to say, no fact came to light. There were not wanting inferences to the contrary, but it remained practically a matter of opinion. One day, however, the needful fact came, and the first boring made specially to test the question (at Dover) disproved both the above negative theories by finding Coal-measures with workable coal. Let us hope that a like result may happen in East Anglia, and that the pessimists may again be in the wrong.

We should not, however, fall into the opposite error, that of optimism. We must not expect an immediate success like that at Dover. We are here much further from any known coal-field. Advertisements of various wares sometimes tell us that "one trial will suffice," but it is not so in this case. We should not be content until many borings have been made, and we should not be despondent if, after sites have been selected to the best of our judgment, we begin with a set of borings that are unsuccessful in finding coal.

At the time of writing I cannot say that the Stutton boring is a success or a failure as far as coal is concerned, but I am quite ready to accept the latter without being discouraged. Whatever it is you may know during our meeting; it is certainly a success in the matter of reaching the old rocks at a depth of less than 1,000 feet. We should remember that every boring is almost certain to give us some knowledge that may help in future work.

There is a further point, however, to be taken into account. A boring that may at first seem to be a failure, from striking beds older than the Coal-measures, may some day turn out otherwise. The coal-field along the borders of France and Belgium is sometimes affected by powerful and peculiar disturbances, by faults of comparatively gentle inclination (far removed from the usual more or less vertical displacements) which have thrown Coal-measures beneath older beds in large tracts. This is no mere theory, though advanced as such at first by some Continental geologists, who have had the great satisfaction of seeing their theory adopted by practical men, and proved to be true, much coal being worked below the older beds that have been pushed above the Coal-measures by overthrust faults.

Our trial work, of course, does not yet lead us to consider such disturbances as those alluded to. We have at first to assume a normal succession of formations, and not to carry on explorations in beds that can be proved to be older than the Coal-measures; but the time may come when it will be otherwise.

Another matter to which attention has been drawn by our foreign friends is an apparent general persistence of disturbances along certain lines, or, in other words, the recurrence of disturbances in newer beds in those parts where earlier movements had affected older beds; so that, reasoning backward, where we see marked signs of disturbance for long distances in beds at or near the surface, there we may expect to find pre-existing disturbances of the older beds beneath. This, however, is a somewhat controversial question, and much remains to be done on it; but should it be proved as a general rule it may have much effect on our underground coal.

Finally, the question of the possibility of finding and of working coal in various parts of South-eastern England is not merely of local interest; it is of national importance. The time must come when the coal-fields that we have worked for years will be more or less exhausted, and we ought certainly to look out ahead for others, so as to be ready for the lessening yield of those that have served us so well. It is on our coal that our national prosperity largely, one may say chiefly, depends, and, as far as we can see, will depend. Let us not neglect any of the bounteous gifts of nature, but let us show rather that we are ready to search for the treasures that may be hidden under our feet, and the finding of which will result in the continued welfare of our native land.

Abstracts of Papers read at the British Association Meeting, Ipswich, September 1895.

III.—Some remarks on the Stereornithes, a Group of Extinct Birds of Patagonia. By C. W. Andrews, B.A., B.Sc., F.G.S., Assistant in the British Museum.

THE history of the discovery of the extinct birds of Patagonia is briefly given, and the more important of the opinions that have been expressed as to their affinities are noticed.

The age of the deposits in which the remains occur is probably much later than the Eocene, to which they are usually referred, and may perhaps be taken as Miocene.

The structure of the skull and skeleton of *Phororhacos*, as described by Ameghino in his recent valuable and interesting paper, is discussed and compared with that of some other birds. In the absence of actual specimens it is impossible to arrive at any very definite results, but it may be suggested that some, at least, of the Stereornithes may be related to the Geniformes, particularly to the Dicholophi. Others of the group are imperfectly known, but some of them appear to differ considerably from *Phororhacos*. It therefore seems probable that the "Stereornithes" may include a somewhat heterogeneous collection of birds which have lost their power of flight in consequence of some local conditions affecting their mode of life, and in correlation with the reduction of their wings attained a greatly increased size. A similar instance is to be found in the extinct birds of New Zealand, where the Dinornithid *Apteryx*, *Cnemiornis*, *Aptornis*, etc., all flightless, and for the most part of great size, formerly coexisted. In most cases, as soon as the peculiar conditions to which they are adapted pass away, such specialized forms become extinct, and this appears to have happened to the Stereornithes.

There seems no reason why such groups of flightless birds should not arise at any period and in any region, providing the conditions of life are favourable; indeed, the Gastornithidæ, in the Eocene of Europe, and the Stereornithes, in somewhat later deposits in South America, may be taken as instances of this.

In the Stereornithes the keel of the sternum was no doubt reduced or absent, so that they were "Ratites" in the narrowest sense of the word; but on the other hand, they can hardly be referred to the sub-class Ratitæ as usually understood, the members of which possess numerous primitive characters which point to the conclusion that they are the survivors of a group, or perhaps several groups, not necessarily contemporaneous, of ancient and generalized birds in which the power of flight had been lost, perhaps even in the Secondary period. Unfortunately, the want of any means of distinguishing truly primitive characters from those which Fürbringer calls "pseudo-primitive," which are acquired in the course of retrogression (*rückbildung*), makes it impossible to determine the exact relation of the "Ratitæ" to other flightless birds, and until a long series of remains from different horizons is available, this uncertainty must remain. It seems very doubtful whether *Gastornis* is at all related to the South American forms.

IV.—The Cladodonts of the Upper Devonian of Ohio. By Professor E. W. Claypole, D.Sc. (Lond.).

NUMEROUS specimens of the Cladodonts of the Cleveland Shale in Ohio have been found by Dr. William Clark. They for the first time reveal to us the general form of the fishes to which belonged the teeth that have alone so long represented the genus *Cladodus*. The fossils are in very fair preservation, but their state of pyritization has obscured many of the details of their structure. So far as regards their form, however, we now know that they were long, slender fishes, resembling in their character the sharks of the present day; that they possessed well-developed and powerful pectoral and caudal, with weak ventral fins, the dorsals being unknown; that they were for the most part, or altogether, spineless; that at least one species possessed cladodont teeth of more than one pattern; and that they had near the hind end of the body a peculiar flat expansion or membrane of rudely semicircular form, which gave to the caudal extremity when seen from above the outline of a sharp-pointed shovel.

The largest whole specimen yet found shows a fish of about 6 feet in length, but detached teeth and other fragments indicate others of double this size, and supply abundant proof that in late Devonian times, and in the North American area, the elasmobranch fishes had attained very great proportions and a high stage of development.

Hitherto the Cladodonts have been regarded as, in the main, characterizing the Lower Carboniferous rocks, but we now find them abounding in the earlier Devonian strata, and, as shown by the contents of their stomachs, preying—in some cases at least—on the smaller placoderms of the same area.

From the evidence of the new specimens it appears most likely that the species already defined from single and isolated teeth can no longer be maintained.

For details see the papers in the "American Geologist" for 1893–4–5.

V.—The Great Devonian Placoderms of Ohio, with Specimens. By Professor E. W. Claypole, D.Sc. (Lond.).

THE Upper Devonian Shales of Ohio have recently afforded a remarkable series of fossil fishes rivalling in size and interest those found many years ago in the Old Red Sandstones of similar age in Scotland, and described by Agassiz and Hugh Miller. The earliest of these, *Dinichthys*, was closely studied, and its structure was well explained by the late Dr. Newberry. It was an immense armour-clad fish, whose head measured from 2 to 3 feet in length. *Titanichthys*, the second of the group, though less massive, was of yet larger size. *Gorgonichthys*, the third, was described by the present writer in 1893, and, so far as is yet known, was the most formidable of all, possessing jaws of enormous size and thickness, above 24 inches long, ending in teeth or points from 6 to 9 inches in length. The fourth and last, *Brontichthys*, of which a description was also published by the writer in the "American Geologist" for 1894, is equally heavy and of equal size, but differs from all the rest in possessing very massive symphysial portions in the mandibles with sockets apparently for the reception of teeth, as in *Titanichthys.*

Of the two last-named genera only the jaws are yet known with exactness. Other portions have been found of *Gorgonichthys,* but are still embedded in the matrix. So far as can at present be determined, all the four are closely allied to *Coccosteus,* and belong to the same family.

The set of casts exhibited in illustration of the fossils has been prepared by their discoverer, Dr. William Clark, and faithfully represents the originals, of many of which only single specimens are yet known. The labour of extricating them from the pyritous shale has proved very heavy, and much yet remains to be done in this direction.

VI.—Zonal Division of the Carboniferous System. By E. J. Garwood, M.A., F.G.S., and J. E. Marr, M.A., F.R.S.

THE authors call attention to previous attempts which have been made to divide the Carboniferous rocks into zones, noting the zonal divisions of the Lower Carboniferous rocks of North England established by De Koninck and Lohest, and the view expressed by Waagen that fuller work will enable geologists to define a series of zones in the Carboniferous as in older and newer strata.

The detailed work of one of the authors (Mr. Garwood) leads them to suppose that the following zones occur in the Lower Carboniferous beds of the northern part of the Pennine Chain and adjoining regions:—

Zone of Productus *cf.* Edelburgensis.
„ P. latissimus.
„ P. giganteus.
„ Chonetes papilionacea.
„ Spirifera octoplicata.

Mr. Garwood has traced the zone of *Productus latissimus* occupying the same relative position to that of *P. giganteus,* from Settle, in Yorkshire, to the Northumbrian coast, near Howick Burn.

The authors believe that brachiopods and goniatites will furnish good results, if a detailed study of their distribution be made; and they suggest that a committee be appointed to inquire into the possibility of dividing the Carboniferous rocks into zones, to call the attention of local observers to the desirability of collecting fossils with this view, and, if possible, to retain the services of eminent specialists, to whom these fossils may be submitted.

VII.—Probable Extension of the Seas during Upper Tertiary Times in Western Europe. By G. F. Dollfus.

TAKING into consideration the position and nature of all the outliers of Upper Tertiary age, the author is led to the following conclusions as to the extension of the Neogenic seas in Western Europe. During Miocene times England was united to France, and we have proof of the existence of two seas in the western part of Europe: one on the east extended over part of Belgium (Bolderian system), Holland, and north of Germany—probably this sea was not very far off the eastern coast of England; the other sea, the Western, or old Atlantic Sea, was off Ireland, penetrating in various gulfs into France, as in some part of Contentin, Brittany, in the Loire valley, in the gulf of the Gironde, but there was no way of communication with the Mediterranean basin crossing France. In North Spain there are no Miocene deposits, in Portugal Miocene beds are purely littoral.

The communication with the Mediterranean Sea was certainly by the valley of the Guadalquivir. The Gibraltar Strait had not exactly its present place. The fauna of these Miocene coasts was warm and very similar to the existing fauna of Senegal and Guinea.

We can divide Pliocene time into three periods, but the situations of the seas were not very different. England was always in direct continental communication with France; the English Channel was not open at all. All the Pliocene deposits of Belgium, North France, or England, even the Lenham beds, are on the side of the North-eastern Sea; we find all these patches on the northern side of the great anticlinal line of the Artois, Boulonnais, and Weald. The fauna is different from the Miocene, and colder—it even turns more and more cold during the progress of Pliocene time. On the western or Atlantic side we have little gulfs leading the sea into the land, but not so frequently and not so far as during Miocene times. The Cornwall deposits, Contentin beds, and the Brittany patches are very limited; the basin of the Gironde contains no trace of Pliocene beds, and we have no trace of recent marine beds at the foot of the Pyrenees. In the north of Spain there is also no trace of Pliocene beds. The continent seems to have been higher, and the Atlantic tolerably distant. All the Portuguese sands recently discovered are littoral, and only on the Algarve coast and south of Spain do we find proof of the probable communication with the Mediterranean. The Gibraltar Strait was not always in the same place during Pliocene time; in the beginning probably the Guadalquivir valley to Murcia continued to be the strait, but later the rock of Gibraltar was separated from Africa and a new road was open; this way was certainly deeper than the former one, and as deep as the existing strait. By this depression the cold fauna of the depths of the Atlantic penetrated into the Mediterranean Sea as far as Sicily and Italy with *Cyprina islandica*.

The geology of Morocco is unknown, but we have plenty of information on Algeria. We have there great Miocene deposits raised along the Atlas Chain up to a great altitude, and a little lower a good and very long band of Pliocene beds of marine and continental origin. Quaternary deposits, similarly continental and littoral, occur lying along the actual coast, pointing out the south side of the Mediterranean connection.

In a few words, the English Channel has been opened very recently, and no sea occupied its place before. No sea has crossed France or Central Spain, and we are obliged to seek for an outlet for the Eastern Sea during Miocene time by way of Germany, Galicia, and South Russia, or by the north of Scotland.

During the existence of the Pliocene seas there was no other communication for the Crag seas than the northern one, for the western, the southern, and eastern sides were undoubtedly shut in by land.

VIII.—On the Importance of Extending the Work of the Geological Survey of Great Britain to the Deep-seated Rocks, by Means of Boring. By F. W. Harmer, F.G.S.

THE systematic exploration of the subterranean geology of these islands is equally important from a scientific and a practical point of view. At present our knowledge of the structure of the rocks which form the foundation of our island home is due either to isolated and occasional borings, such as that of the Ipswich Syndicate in search of coal, or to deep wells sunk by mercantile firms; but the latter do not reach further than is necessary to obtain a supply of water, and the work is generally suspended just where it becomes geologically most interesting. But such a Survey is important practically, because unsuspected sources of wealth may be hidden under our very feet.

It is a mistake to suppose that a discovery such as that of a new coal-field would enrich only the landowners of the district, because whenever any appreciation of real property takes place, the State at once claims its share of the increased value, both for imperial and local purposes. The average for the whole country of the rates raised by local taxation alone was, for 1891, 3*s.* 8*d.* in the pound, to which must be added imperial taxes and the tithe. It may be stated roughly, that for every £100 of yearly 'unearned increment' the State is benefited in one way or another by £25, or one-fourth of the amount. The discovery of a new coal-field would cause increased prosperity in the district in which it occurred, and from this the State, through taxation, would derive great though indirect advantage.

The growing difficulty of finding employment for the ever-increasing population of these islands is a strong reason why this Survey should be undertaken.

Part of the cost might be borne by the landowners under whose property any minerals were discovered. Certain districts should be selected with the consent of the Local Authorities, and Parliamentary power taken to charge a royalty on any minerals obtained below a certain depth. Landowners would probably welcome proposals to make borings on their estates on such conditions. In the first instance, however, the Survey should map out accurately the subterranean limits of existing coal-fields, or mineral-bearing rocks, but trial borings should be put down in different localities, and each new boring would help to show more plainly the direction in which further investigations should be made. Much light would be thrown by such a Survey on the circulation of underground waters, a matter of great practical importance.

The expense of boring would be much reduced if undertaken on a large scale, as machinery and apparatus would be available again and again. The Survey would employ its own workmen, who would become increasingly efficient and economical.

REVIEWS.

Open-air Studies: an Introduction to Geology out-of-doors. By Grenville A. J. Cole, M.R.I.A., F.G.S., Professor of Geology in the Royal College of Science for Ireland, Dublin. London: Charles Griffin and Co. (Limited), Exeter Street, Strand, 1895. 8vo, pp. xii and 322, with Eleven full-page Illustrations, and Thirty-three Illustrations in text.

PROFESSOR COLE has done excellent service to our science if only by pointing out to his readers that geology is a study for the *open air*, and can no more be acquired satisfactorily in a museum or a laboratory than can the study of biology. We are reminded of a story told of the Swedish Botanist Solander, who had looked for so long a time at plants in the Museum *Herbarium*, that when a green living plant was brought to him by a lady to be named, he studied it attentively and then said: "Madam, if you shall take this plant home and put it between paper and shall sit upon it for a week, I shall tell you its name."

It is by a visit to a quarry by the roadside, or to the cliffs on the seashore, that boys may be stimulated to become geologists; and it is doubtless due to the inveterate love of bird's-nesting among country schoolboys (and all schools ought to be in the country) that we owe the passion for ornithology which has so long prevailed amongst us, and is still a dearly-loved pursuit of Englishmen.

While, however, the love for Natural History and the passion for enquiry are usually born, and must always be nurtured in the field, yet we are compelled to admit that no progress can be made without the aid of books and teachers; and that those who seek not only to acquire, but to advance, knowledge relating to rocks or fossils, must now-a-days prepare themselves by a course of study in a petrological or biological laboratory. Such training is as needful to the geologist as it is to the engineer or the surgeon.

We would not deter those living in the country, who have no means of special training, from giving attention to geology. Regarding it as a recreative science they may do useful work in collecting fossils and recording sections of the strata; but one chief lesson which all of us have to learn is how far our own knowledge can be relied upon, and when to depend upon others for the identification of minerals, rocks, and fossils. Wonder and interest may be aroused by personal observation among the rocks; but the lessons which can be learnt in the field will not be fruitful without close attention to the literature of the subject and to present methods of research.

Professor Cole recognizes the need of all this, and although he explains as many technical terms as he can in the field, he gives us a severe introductory chapter on the materials which form the earth's crust, before he asks us to accompany him out-of-doors. In a work dealing with so complex a subject as geology it is impossible to explain every term that is used; but this account of rocks and minerals, and elements, will show the student the kind of fundamental knowledge he must acquire. This very chapter is one that may repel a general reader whose enthusiasm has not already been kindled, and who desires only to know the leading objects and conclusions of geological enquiry; but as no sound knowledge can be acquired without application, the earnest student will do well to master this preliminary lesson (with the aid of specimens) before he engages in the more inviting open-air studies.

Once in the field the student is led on to "a mountain hollow" to witness the work of glaciers, and "down the valley" to examine the work of springs and rivers. He is taken more or less rapidly from one country to another "along the seashore" and "across the plains." He passes from the "dead volcanoes" of Auvergne and other regions to "a granite highland," and then to the volcanic mountains of Skye. He is given a rapid and consequently meagre account of "the Annals of the Earth," of its main epochs, and their rocks and fossils. Then "the Surrey Hills" are visited, and many particulars are given of the Cretaceous rocks, as a sample of what might be said with respect to other strata and their fossils.

The author introduces a table showing the foreign divisions with which some of our English formations are correlated; but such names as *Urgonian* for Atherfield Clay, and *Cenomanian* for Upper Greensand and Lower Chalk, if used at all in this country, are for the Museum and not for the Field. In their broad usage they apply to minor epochs of time rather than to formations; and the author rightly employs the local stratigraphical terms in his field-lessons. But why separate Gault from Upper Greensand in so marked a way as to put the former into Lower and the latter into Upper Cretaceous?

A study of the Weald leads on to a study of "the folds of mountains," and to lessons on the results of earth-movements and attendant phenomena.

The nine chapters dealing with open-air studies thus cover a good deal of ground, and form a fitting introduction to the principles of geology. Writing in a pleasant and familiar style, that reminds us not a little of "The Gamekeeper at Home," the author shows himself so enthusiastic a lover of Nature that his work cannot fail to arouse keen interest in geology. We would commend it to all beginners, and to the "Home Reading Union," for although there may be a little too much of detail, here and there, to please everybody, yet the explanations are lucid, and the narrative is for the most part attractive enough, even if it be discursive. We would commend it also to advanced students and teachers, for they would surely freshen up their knowledge on many a subject, whether it be on salt-lakes or volcanic phenomena, chalk-flints, or pressure-metamorphism. The beginner, let us hope, after reading this book, will be tempted to proceed to more systematic works, and although in the fuller records he will find the facts not embedded in quite so picturesque a matrix, yet the fascinating Open-air Studies of Prof. Cole will have given the subject a glow of animation, which will be fostered and developed by actual work in the field.

OBITUARY.

THOMAS JAMES SLATTER, F.G.S.

BORN 1834. DIED AUGUST 1ST, 1895.

THOMAS JAMES SLATTER, F.G.S., whose decease we have now to report, died at his house, The Drift, Evesham, on the 1st of August. He was a geologist whose knowledge of the locality in which he lived and worked was most intimate and reliable. He was born in Gloucester in 1834, but his family was for many years located at Stratton, near Cirencester. He was the cousin and intimate friend of John Jones, of Gloucester, whose contributions to pages of the earlier numbers of this MAGAZINE, and to the Proceedings of the Cotteswold Naturalists Club, were well known. Mr. Slatter commenced his business life as quite a young man in the Gloucestershire Bank, and then took up his abode in Evesham. He became successively manager of the Moreton-in-Marsh, Redditch, and Evesham branches of the Bank, but retired into private life a few years since, and, having built a new house on Green Hill, near the latter town, removed into it his extensive and most interesting collection of fossils. He was elected a Fellow of the Geological Society of London in 1879, but, to the regret of those who knew how careful he was as an observer, he was never the author of any work on geology, nor even of any contribution to a periodical on the geology of the district he knew so well. His death, by paralysis, took place in the house which he had so lately erected.

R. F. T.

JAMES CARTER, F.R.C.S., F.G.S.

BORN OCTOBER 3RD, 1813. DIED AUGUST 31ST, 1895.

WE regret to record the death of our old and valued friend, and fellow-worker in fossil Crustacea, Mr. James Carter, F.R.C.S., F.G.S., of Cambridge, in his eighty-second year. During the greater part of his life Mr. Carter practised as a surgeon in Cambridge, where his house, in Petty Cury, was for many years the resort of the leading geologists and men of science in the University, who never failed to find in Mr. and Mrs. Carter genial, cultivated, and hospitable hosts.

He was especially interested in palæontology, and devoted much of his time to this and other scientific subjects. He contributed papers to the GEOLOGICAL MAGAZINE and the Quarterly Journal of the Geological Society, the chief being "On a New Species of *Ichthyosaurus* from the Chalk" (1846), "On *Orithopsis Bonneyi*" (1872), "On a Skull of *Bos primigenius* perforated by a Stone Celt" (1874), "On the Decapod Crustaceans of the Oxford Clay" (1886), and "On Fossil Isopods, with a Description of a New Species" (1889).

Mr. Carter was recognized as an authority on the fossil Decapod Crustacea; for some time he has been engaged in collecting materials for a monograph on that group, and has left his manuscript in an advanced state. He retained his interest in his pursuits almost till the last, and was engaged in his scientific work to within a few weeks of his death. He served on the Councils of the

Geological and Palæontographical Societies for some years, and was a local secretary of the latter society. Mr. Carter presented his collection of Cambridge fossils to the Woodwardian Museum some years before his death.—(*H. W.* and *Athenæum.*)

PROFESSOR SVEN LOVÉN,

OF STOCKHOLM.

Born January 6th, 1809. Died September 3rd, 1895.

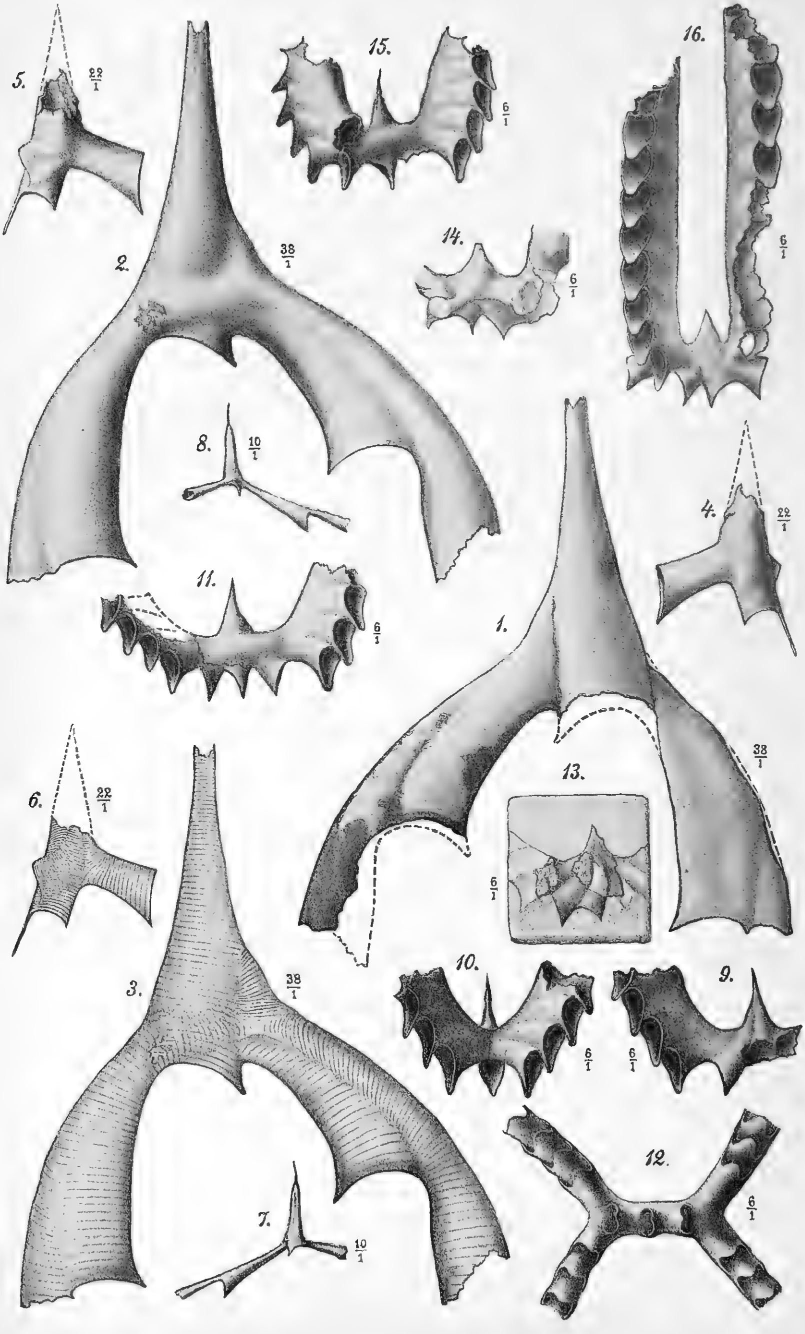
Another distinguished biologist has just passed away, one out of a number of those whose births have made famous the beginning of this century, now so nearly expired. Lovén of Stockholm may well take rank with Owen of London, Milne-Edwards of Paris, Siebold of Munich, and Van Beneden of Louvain, as one of the great pioneers of natural science.

Lovén was born at Stockholm in 1809, and matriculated at Upsala, taking the degree of Doctor of Philosophy in the University of Lund. In 1830 he became a Docent of the University, and, after having attended the lectures of Ehrenberg and Ritter at Berlin, he devoted himself to the study of the marine fauna of the shores of Scandinavia, explored the Baltic and North Seas, and conducted the first scientific expedition to Spitzbergen in 1837. Lovén was elected Professor of Geology and Keeper of the Invertebrata in the Natural History Museum in Stockholm in 1841. In 1868 the University of Lund conferred upon him the degree of M.D. *honoris causa.*

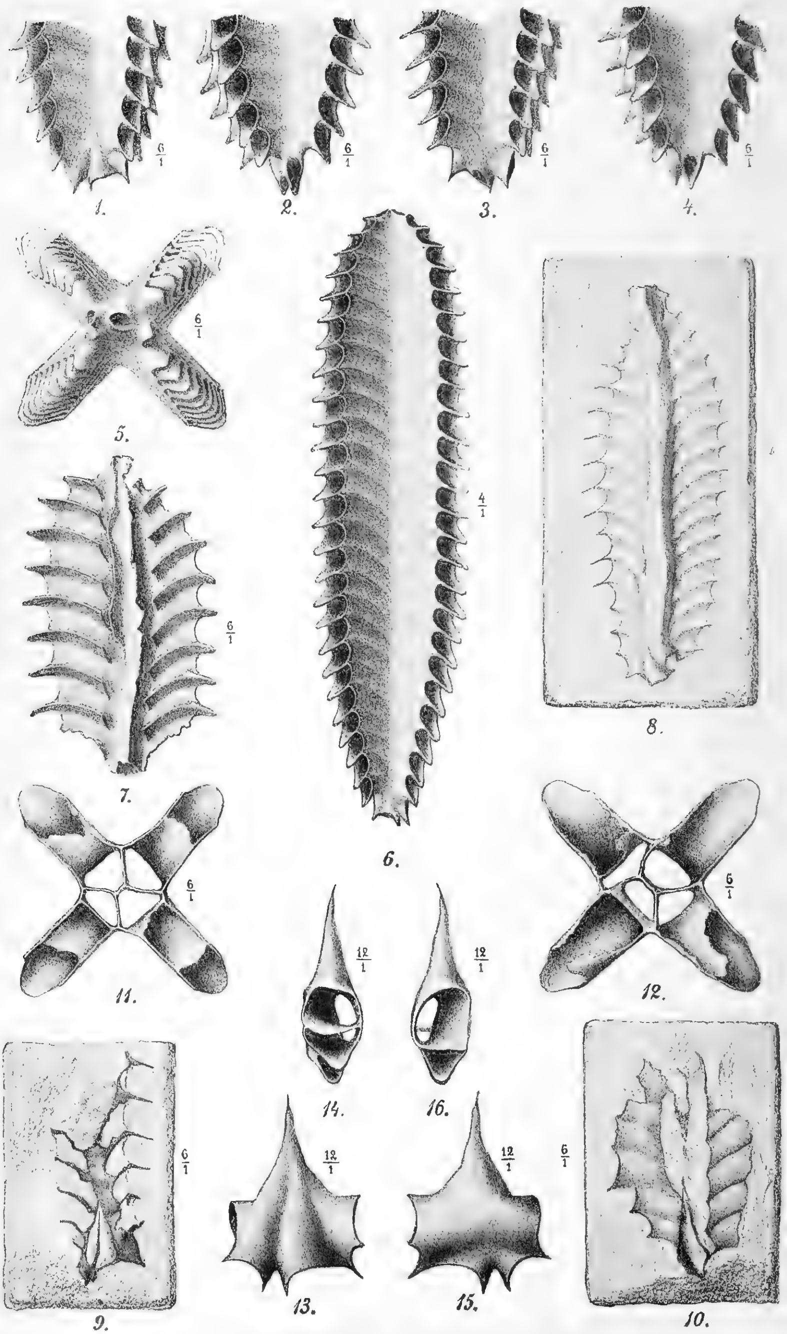
As early as 1835 we find him writing upon the hydroid zoophytes; in 1846 he published an Index of the Mollusca of the Western Shores of Scandinavia, and devoted himself to the study of the development of mollusca. Later on in life he made a minute examination of the structure of Echinoderms, on which he published several beautifully illustrated memoirs.

Writing at first in Swedish or in German, he gave, later on, his results in French, but for the closing years of his laborious life he wrote in English. As the chief of an important department of the Zoological Museum at Stockholm, he brought his exhibited specimens to a high degree of artistic beauty, and it was in virtue of this position, and not because of any connection with a University, that he was, *secundum mores Scaniæ,* known as Professor.

His researches on the anatomy and physiology and the geographical distribution of the marine invertebrata, gained for him election as a Member of the Academy of Stockholm in 1840. He was made a Corresponding Member of the Institute of France in 1872; a Foreign Member of the Geological Society of London in 1882, and of the Royal Society of London in 1885. He resigned his connection with the Museum a few years since, the burden of bodily pains being too great for his advancing years, rendered sad by the early death of a son of great promise. Those, however, who had been brought into personal contact with him felt that so long as Lovén lived they had a real friend. His charming geniality and his remarkable kindness to men much younger than himself made a deep and lasting impression on all who had the pleasure to know him personally.—(In part from the *Athenæum,* Sept. 14th, 1895.)



Ljustryck af Chr. Westphal Stockholm.



Ljustryck af Chr. Westphal Stockholm.

THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE IV. VOL. II.

No. XI.—NOVEMBER, 1895.

ORIGINAL ARTICLES.

I.—On *Didymograptus*, *Tetragraptus*, and *Phyllograptus*.

By Dr. Gerhard Holm,
Palæontologist to the Geological Survey of Sweden, Stockholm.

Translated from the original in Geol. Fören. i Stockholm Förhandl., Bd. XVII, Häft iii, No. 164, 1895, pp. 319–359. By G. L. Elles and E. M. R. Wood, Newnham College, Cambridge.

(PLATES XIII AND XIV.)

(*Continued from the October Number, page* 441.)

Didymograptus gibberulus, Nich.

Moberg, Nya Grapt. från Skåne, p. 345, pl. viii, figs. 3–7.

As has been previously indicated (see p. 439[1]), the conclusion might be drawn from Moberg's description and figures of this species, interpreted by the knowledge of the true structure of the *Didymograptus* polypary, that the structure of the proximal part could in no essential particulars be separated from that just described in *D. minutus*, Mut. Consequently the genus *Isograptus*, which was proposed by Moberg for the species in question, is not authorized—at least, as founded on any of the characters cited by Moberg. The differences between *Isograptus* and *Didymograptus*, to which latter genus the species is referred by Nicholson, ought to be, according to Moberg, that in *Didymograptus* "both stipes arise at somewhat different levels on the sicula," and that "each branch is itself bilaterally symmetrical"; whilst, on the contrary, in *Isograptus* the stipes should "arise bilaterally symmetrical from the sicula," and each branch is not itself bilaterally symmetrical. As we have seen above, in reality in *Didymograptus* the left stipe is not bilaterally symmetrical, and the symmetry in the right stipe is entirely the same as that which is described by Moberg in *Isograptus*, namely, obliquely near the base, because the stipes do not arise from the side of the sicula, but from the "connecting" canal.

No one believes for a moment that the presence of symmetry in stipes is a distinction. The same is also the case as regards the point of origin of the stipes. As has been shown above, the stipe arises in *Didymograptus* from a point on the left side of the sicula, and this is, therefore, the apparent point of origin of the right stipe from the right side of the sicula, as is believed by Moberg, and which, as has been previously shown, lies at a different level to that

[1] The reference in the October Number, p. 439, to Pl. XIV is an error; it should be to Pl. XIII.—Edit. Geol. Mag.

of the left stipe. It follows from Moberg's description that the relation is completely the same in *Isograptus*, as we shall see.

According to Moberg, whose material consisted entirely of much compressed specimens in shale, the impressions in the shale of the two sides of the polypary present "as regards the proximal part" (including the sicula) "a somewhat different appearance." On the one side (dorsal side of Moberg) the "sicula," according to Moberg's interpretation, would be divided longitudinally from the middle, and would form "two similar primordial thecæ grown together along their whole length," except near the apertures. To each side of the "sicula" a theca is attached, and grows with it for the whole of its length. Again, on the opposite side of the polypary (ventral side of Moberg) no such division in the proximal part of the sicula has been observed, and the "sicula" passes up on the dorsal side into two lateral thecæ, between which the divided apertural part of the sicula (primordial thecæ) is visible.

On comparing the figures and descriptions with those of *D. minutus*, Mut., it is clear that figs. 3 and 7*a* represent the sicula side; to fig. 7*b* and the remaining figures there is no reference, but fig. 5, and probably also fig. 4, represent the anti-sicula side with the connecting canal, which Moberg regards as a longitudinally divided sicula ("primordial thecæ") consisting of the sicula and the left theca, which latter, as in *Phyllograptus* and probably also in *Tetragraptus*, arises either at the apex of the sicula or immediately near thereto. It is clear that the partition wall between the true sicula and the left theca has not left any impression on the shale on the anti-sicula side, from the fact that it is concealed by the connecting canal, which forms on this side the proximal part of the primordial thecæ, and passes over on one side into the right theca, and on the other into the theca immediately succeeding the left theca. Although *Didymograptus gibberulus* differs from *D. minutus*, Mut., in the position on the sicula of the point of origin of the left theca, and agrees in this respect with *Phyllograptus angustifolius*, Hall, and *Tetragraptus Bigsbyi*, Hall, this is not a sufficient reason for retaining the genus *Isograptus*, for to judge from Törnquist's figures (Siljansområdets Grapt., I, pl. i, figs. 13, 14) the same would be the case in such a typical *Didymograptus* form as *D. decens*, Törnq. In this connection a question concerning the structure of *D. gibberulus* may be discussed. In the generic diagnosis and afterwards in the descriptions, Moberg characterizes *Isograptus* without reservation as a two-stiped form. In spite of this he seems, as far as I can understand, curiously enough, to contradict himself at the end of his descriptions, and inclined to accept the existence of four branches in the same, where, mentioning that "the apex of the sicula ends in a narrow tubular appendage, also observed in very young individuals, and that this appendage seems at a considerable distance from the sicula gradually to increase not inconsiderably in width," Moberg remarks—"Since this dilatation never takes place much outside the part of the appendage enclosed by the stipe, we should not run any risk in considering the appendage of the sicula as part of a third branch (but which also might cause it to be supposed that still another branch existed, concealed in the rock)."

This appendage of the sicula is, however, quite certainly not a branch, but is formed by the unusually long, thread-like extension of the initial part of the sicula, as shown by an isolated specimen of my own from the grey glauconitic Vaginatenkalk near Hälludden, in Öland. The length of this in the specimens in question is over 7 mm., while the length of the branches is only 3 mm. It tapers gradually for the whole of its length towards the apex.

In connection with the genus *Didymograptus* may be mentioned a singular form of graptolite (Pl. XIII, Figs. 4–6), the figure of which is drawn from a damaged specimen, but subsequently two complete ones were obtained. The structure of the polypary is very simple, as besides the sicula it is formed only of the left theca and the connecting canal. A comparison between the figures of *D. minutus* (Mut.) and the present form, placed side by side and viewed in the same position, shows that in the latter the development of the parts mentioned is completely similar to that in *Didymograptus*, with the exception that from the bud of the sicula is developed besides the connecting canal only a left theca, but no left stipe. The connecting canal ends also near the right side of the sicula, without even giving origin to any right theca in case the connecting canal itself does not function as such. In the figured specimen the free apertural margin of the connecting canal projects slightly at its upper corner from the right side of the sicula. This, however, is not the case with the other two specimens. The sicula is provided with a true apertural spine, which originates in the periderm some distance behind the aperture, in the same way as the spines in *Diplograptus*, sp. (p. 438), and it appears to be of the same nature, but curiously enough, contrary to what is usually the case, it lies on the right side of the theca. The aperture of the left theca is turned straight out, and the lines of growth on the anti-sicula side show the same course as in the common canal—or the proximal part of the second theca on the left branch—in *D. minutus*, Mut. (Figs. 3 and 6).

That, however, the left theca is certainly terminal, and that consequently the left branch cannot develop, is clearly shown by the fact that the course of the growth-lines is everywhere quite regular, and parallel with the apertural margin; therefore no indication whatever of bud formation can be perceived on the proximal part of the left theca, either in this way or in surface relief. To this may be added what we have seen concerning the growth of the left branch in *D. minutus*, Mut.: the formation of the common canal and left theca takes place simultaneously, so that an interthecal wall cannot originate in a completed part of the stipe.

It has been observed in many cases that the same thing occurs at the distal end of the stipe: Pl. XIV, Figs. 6, 13, 14. It follows, therefore, that in the present form no left branch can be supposed to develop from the aperture of the left theca. The development of a right theca, or a right branch, from the connecting canal does not seem to be in any way impossible. It is uncertain whether the Graptolite in question is only a young form or a distinct and fully developed species, the development of which ceased at this stage. How it comes about, I have not yet been able to decide. I have not found with it any species to which it could be referred. If a right branch should really be developed, the form might be referred to the genus *Azygograptus*, Nich. and Lapw., in which only one branch grows out from the free sicula. How and from what side of the sicula the branch arises in *Azygograptus*, does not definitely appear from the descriptions and figures given of the forms placed under it. Probably the present form is a transitional type between *Didymograptus* and *Azygograptus.*

Genus Tetragraptus, Salter.

Hall[1] first described the proximal end in *Tetragraptus*: "In the Graptolites with four stipes the condition appears like that of two individuals of two-stiped forms, conjoined by a straight connecting process of greater or less extent, with the radicle point in the centre, though often obscurely marked. This connecting process is always destitute of cellules, and this with its divisions I have termed the funicle." Upon this statement is founded the presence of a tubular funicle uniting two sides of the polypary in forms with four or more stipes belonging to the Dichograptidæ. Almost all later authors, as, for example, Lapworth and Nicholson, have followed Hall in believing that the funicle is destitute of thecæ. I, however, have described the presence of a theca on each side of the sicula in the funicle in *Trochograptus diffusus*, Holm, whose proximal end is similar to that of *Tetragraptus.*

On these grounds, and in consideration of the many branched Dichograptidæ being embedded in shale, and therefore showing the thecæ of the central part of the polypary only in very exceptionally favourable cases, and as these thecæ are analogous to those in *Didymograptus* and other forms which are better exposed, I draw the conclusion that the funicle in many cases, if not always, was furnished with thecæ.

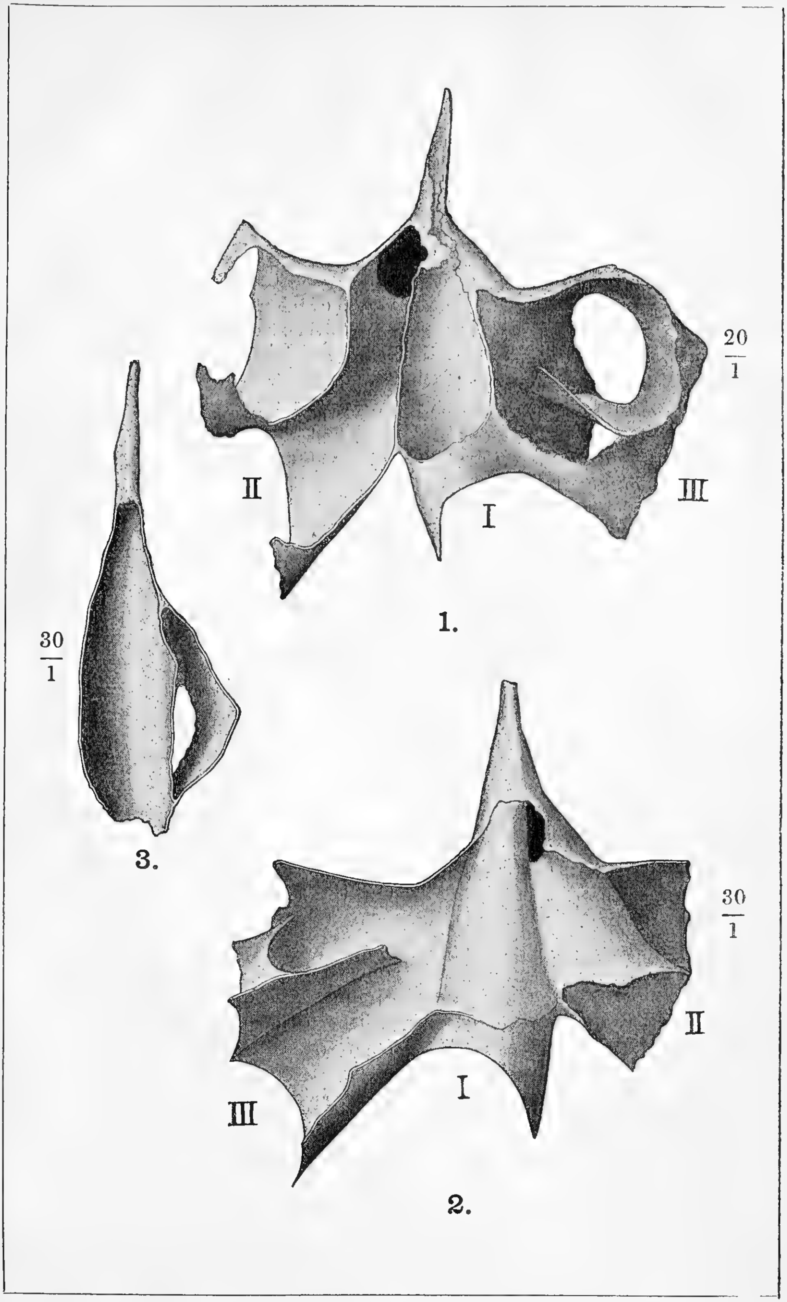
Curiously enough, Törnquist believes (Siljansområdets Grapt., i, p. 15) that "the expanded end of the sicula in Dichograptidæ which have more than two primary branches divides repeatedly into two, and thus without apparent border passes over into the theca-bearing polypary"; and it appears that on account of the supposed difference between *Didymograptus* and the remaining Dichograptidæ, he is inclined to separate the former as the type of a distinct family—Didymograptidæ.

A "funicle" has not been found in any Graptolite.

Tetragraptus Bigsbyi, Hall. Pl. XIII, Figs. 9–16; Pl. XIV, Figs. 13–16; Figs. 1–3, p. 485.

This is the only form of *Tetragraptus* upon which I can offer any remarks.

[1] "Graptolites of the Quebec Group": Geol. Surv. Canada, dec. ii, 1865, p. 19.



Tetragraptus Bigsbyi, Hall.
[Reproduction of Taf. 12 in Dr. Holm's original paper.]

In consequence of the thickness of the periderm, I have not been fortunate enough to make it sufficiently transparent to show the course of the growth-lines. In most cases the specimens have been well preserved, with the exception of the apex of the sicula, which is nearly always crushed.

As I could not sacrifice my best preserved specimen for sectioning, I have not been able to distinguish the connecting opening between the sicula and left theca. Probably it is situated near the initial point, as in *Phyllograptus angustifolius* (Pl. XIV, Fig. 9). The development of the left theca, the connecting canal, the right theca, and the common canals, agrees in all essentials with that of *Didymograptus* (Pl. XIV, Figs. 13–16). These figures very clearly represent the *Didymograptus*-stage of a young specimen, in which the four branches of the second order have not yet begun to be formed.

The differences which are found between the *Didymograptus*-stage of *T. Bigsbyi* and that of *D. minutus*, Mut., may depend on the different angle of divergence of the stipes, and thus might be termed specific. A comparison between the latter and *T. fruticosus*, Hall, in which the angle of divergence is about the same, would certainly show complete correspondence in detail.

The foramen between the left theca and the connecting canal, with the left common canal, is visible from both the sicula and anti-sicula side (see Page-illustration, p. 485; Figs. 1 and 2 show examples). The detailed explanation of the figures gives an exhaustive description of the structure of the proximal part. Here only may be noticed the great width of the connecting canal in *T. Bigsbyi*, and how it forms along the sicula and left theca a raised projection on the anti-sicula side, in consequence of the situation of the foramen near the proximal end of the sicula; these are, therefore, here nearly completely concealed by, and embedded in, the connecting canal, in the interior of which they stand out in relief (see Page-illustration, Fig. 2). On the anti-sicula side, therefore, only the proximal apex and a narrow border of the sicula, and the left theca near its aperture, are visible; similarly, as in *Didymograptus* the connecting canal is somewhat oblique in relation to the long axis of the sicula. In consequence of a direct cleaving of the common canal by a vertical wall, the formation of two branches on each side of the connecting canal occurs, whereby there arise the four stipes of *Tetragraptus.*

Explanation of Page-illustration (see p. 485) printed in the text.

Tetragraptus Bigsbyi, Hall.

Fig. 1.—Proximal part from the sicula side, with the outer walls of the thecæ on this side removed so as to show the interior. The foramen between the sicula and left theca is not visible; that between the left theca and connecting canal is, however, shown on the left side; the anterior left branch is completely cut off, and of the posterior branch only the base remains, which arises from the common canal. On the right side, the right aperture of the connecting canal is indicated by the light, which, behind the sicula, through the foramen of the left theca and connecting canal, jointly falls into the background of the passage between the latter

and the common canal belonging to the right theca and right branch. The edge of the aperture in the right theca is injured, but the interthecal wall, which separates this from the anterior and posterior oldest thecæ of the right branch, is conspicuous. The anterior right branch is completely cleared away, and only a narrow border of the base of the posterior branch remains. The large opening shows the connection (common canal) between the two right branches. The projecting edge of the same is formed by a diaphragm-like intercalated lamella.—Enlarged 20 diameters.

Fig. 2.—The proximal part from the anti-sicula side, with the external walls of the connecting canal and the right theca removed in order to show the interior of the connecting canal and its relation to the common canal. The sicula, the apertural margin of which is perfect, appears in relief within the connecting canal; the same is the case with the left theca, the foramen of which touches the sicula wall. On the right side, the common canal for the left branch arises; on the left, that belonging to the right theca and right branch. Of the distal links interthecal wall of the right theca the further part remains. The posterior right branch is completely removed, and only the base of the anterior remains, showing the curved inner edge of the interthecal wall between the first and second thecæ of the latter branch.—Enlarged 30 diameters.

Fig. 3.—Same specimen as Fig. 9, Pl. XIII. Longitudinal, vertical section of the sicula, on the sicula side of the polypary, showing the interior of a part of the left half of the sicula, and to the right of this a transverse section of the connecting canal. The foramen between the sicula and left theca is not visible, as it lies higher up within the part of the proximal end of the sicula, which has not been cut away.—Enlarged 30 diameters.

I = Sicula. II = Left theca. III = Right theca.

Genus Phyllograptus, Hall.

No description of the structure of the proximal end, founded on actual or certain observations, is known. Hall thus summarizes, in his generic description, what he knows of the proximal end: "The whole supported on a slender radicle or combined in groups"; and he believed that, since the proximal end was provided with a "radicle," the majority were free in the same manner as in *Diplograptus*, whilst others were attached in groups to some support which bore them. In the figures only *P. typus*, Hall, is shown with a long cuneiform diminishing "radicle," which according to the description sometimes approaches half an inch in length. In the remaining three species the radicle is not visible, and it is described in the text as "minute" or "scarcely visible."

Lapworth, although he probably did not possess a good specimen of *Phyllograptus*, and therefore could not observe the development of the polypary, as early as 1873 rightly interpreted the same and the position of the sicula: "Polypary composite, being essentially a quadribrachiate monoprionidian polypary, whose branches coalesce by the whole of their dorsal surfaces; sicula embedded—the major extremity forming the proximal end of the adult polypary." The only observation on the sicula in *Phyllograptus* agreeing with the reality is that given by Törnquist (Siljan. Grapt., i, p. 20), where in *P. densus*, Törnq., he "believes himself to have observed a sicula with a jutting-up apex, between the most proximal thecal circle"; he adds, however, that this requires confirmation.

According to Törnquist, the thecæ should be situated in four circles, and the four rows of thecæ are therefore of equal height. It follows from this that the genus *Phyllograptus* must be considered to have arisen from four branches, like those of a *Tetragraptus*, with their backs to each other, and that, since the sicula in *Tetragraptus* can branch dichotomously, the first thecæ of the branches ought to be of the same height.

We have seen above that the sicula does not branch either in *Tetragraptus* or in *Phyllograptus*, but that without this it gives origin to thecæ which, both in *Didymograptus* and *Diplograptus*, are developed from each other, and therefore occupy a different height in the polypary. Törnquist's supposition of a circular arrangement of the thecæ is therefore incorrect. The figures show that the arrangement changes conspicuously (Pl. XIV). This is due to the fact that the thecæ in different rows are separated by longitudinal septa, and are developed completely independently of each other, and therefore, since the height of the thecæ can change, any very regular arrangement is impossible.

Tullberg has done greater service than any other in emphasizing the near generic relationship between *Tetragraptus* and *Phyllograptus*. In his Classification of Graptolites, mainly based on that of Lapworth, which he justly takes to be the most natural, up-to-date, analytical table of the more important Graptolite genera, he has partially introduced some emendations. One of these is the suppression of the section Tetraprionidæ, originally proposed by Hopkinson for the genus *Phyllograptus* and accepted by Nicholson and Lapworth. Tullberg rightly places *Phyllograptus* with the Dichograptidæ as a close ally of *Tetragraptus*. Törnquist (Siljan. Grapt.) again returns to the old way, and has placed *Phyllograptus* in a separate family, Phyllograptidæ, allied to Dichograptidæ. *Tetragraptus* and *Phyllograptus* are therefore separated from each other by *Didymograptus*, which Törnquist places in the Dichograptidæ.

Phyllograptus angustifolius, Hall. Pl. XIV, Figs. 1–12.

By comparing the figures of *T. Bigsbyi*, Hall, and this species, the close agreement between them is quite evident, both in internal and external structure; with the necessary reservations due to the fact that the cœnosarcal threads of the four branches in the *Tetragraptus* polypary are in *Phyllograptus* disposed near each other, and instead of four independent periderm walls form a single, cruciform, four-winged, longitudinal septum. The oblique position of the sicula and of the proximal end of the left theca in relation to the median plane of the polypary stands out very conspicuously, as it lies completely revealed on the sicula side. Only the apertural edge of the sicula, which is turned, not only to the right side but also to the anti-sicula side, is visible on the latter. The connection between the sicula and the left theca takes place near the proximal end of the sicula: Pl. XIV, Fig. 9. The foramen between the left theca and the connecting canal has the same position as in *Tetragraptus*. From the right end of the connecting canal the right theca arises;

and immediately above, the common canals for both the right stipes of the polypary. Again, from the left end of the connecting canal arises only the common canal for the left stipes.

The three primordial thecæ, representing the *Didymograptus*-stage in *Phyllograptus*, occupy a somewhat oblique position in relation to the diagonals, which in the cross-section of the polypary are parallel with the thecal rows and describe a square: Pl. XIV, Fig. 5.

No trace of a virgula has been observed. The four wings in the longitudinal septum are rarely completely regular, but the form of the cross-section varies somewhat in longitudinal direction in the same specimen, without any definite rule (Pl. XIV, Fig. 8). Usually the wings are united two and two to a connecting lamina (Pl. XIV, Figs. 5, 11, and 12). The winged laminæ sometimes show a curved wrinkling. As an abnormality, there was observed in one specimen, on the anti-sicula side, a small supernumerary independent theca, probably arising from the connecting canal. A deformity observed in another specimen, was the presence of only three stipes. The proximal end of this is not preserved, therefore I cannot determine how the deficiency arose.

EXPLANATION OF PLATE XIII.

Didymograptus minutus, Törnq. Mut.

Figs. 1-3.—Proximal part of the polypary, showing the sicula, broken off near the apex, the left and right thecæ, and the connecting canal between them; also the proximal part of one other theca on each branch.—Enlarged 38 diameters.

Fig. 1.—Sicula side of the specimen, the rest of which is embedded in the rock; the cast with the periderm nearly entirely removed in order to show the walls, which appear as black lines, between the sicula on the one side and the left and right thecæ on the other side; also the incompleteness of the first-mentioned wall, by means of which the connection between the sicula and left theca is effected.

Fig. 2.—Anti-sicula side, isolated by means of acid, in reflected light, showing the roll-shaped connecting canal and the different shape of the left theca on this side to that on the sicula side, from which arises the inequality in the sides of the interthecal wall.

Fig. 3.—The same side, seen in transmitted light, so that the walls and the delicate growth-lines of the periderm are visible, showing also the limits of the thecæ, by the intersecting of the growth-lines at different foci of the microscope, and the connecting canal between the left and right thecæ. The wall of the canal next the right branch is somewhat broken, and here in consequence only the growth-lines of the sicula are seen.

Figs. 4-6.—An unknown Dichograptid, very young? specimen, consisting of only the sicula and left theca and the connecting canal, one corner of which projects beyond the sicula. On account of its small size and fragile nature, the proximal part of the sicula was considerably injured before the drawings were made. Slight fractures of the margins of the sicula and left theca have been restored in the figures.—Enlarged 22 diameters.

Fig. 4.—Sicula side, in direct light.

Fig. 5.—Anti-sicula side, in direct light.

Fig. 6.—Same side, in transmitted light, showing the growth-lines. The half of the periderm belonging to sicula side is ground off.

Didymograptus gracilis, Törnq. Mut.

Figs. 7-8.—Proximal part of a developed specimen.—Enlarged 10 diameters.

Fig. 7.—Sicula side.

Fig. 8.—Anti-sicula side, showing the connecting canal.

TETRAGRAPTUS BIGSBYI, Hall.

FIGS. 9-12.—Proximal part of a specimen obliquely broken across the sicula and right theca—see Fig. 9—by the fracture of the rock. The pieces were cemented with Canada balsam, and both parts of the *Tetragraptus* specimen subsequently isolated.—Enlarged 6 diameters.

FIG. 9.—The more complete part, from the sicula side, showing the proximal part of the sicula, the left theca, the anterior left branch, and the passage between the connecting canal and the right theca.

FIG. 10.—From the left side, showing the left theca seen from the aperture, the proximal part of the sicula, and the anterior and posterior left branches.

FIG. 11.—From the anti-sicula side, showing the connecting canal and the sicula behind, the left and right thecæ, also the posterior left branch and the posterior right branch; in the latter the first theca is complete and the remaining ones show only the apertures.

FIG. 12.—From the proximal end, with the sicula side turned downwards, showing the apertures of the sicula, left and right thecæ, and the thecæ of the four branches.

FIG. 13.—Proximal part of another specimen lying in the rock, partly in relief, partly in impression. From the anti-sicula side. The connecting canal and the wall between that and the sicula have, however, remained in the counterpart, so that the smooth cast of the sicula appears uncovered. The left theca in impression, the right theca complete with fractured surface at the junction of the connecting canal.—Enlarged 6 diameters.

FIG. 14.—Another specimen. Proximal end, also lying in the rock, seen from anti-sicula side, showing the connecting canal. All the branches are broken off near their point of origin.—Enlarged 6 diameters.

FIG. 15.—Young specimen with posterior left branch complete. Anterior right branch injured near the apex, and both the remaining branches broken off near their point of origin. Anti-sicula side seen a little from the left, so that the aperture of the right theca appears, showing sicula, right theca, and connecting canal; the apertural part in the left theca is broken off. Isolated by means of acid.—Enlarged 6 diameters.

FIG. 16.—Isolated. Much injured specimen, showing sicula, left and right thecæ, and both anterior branches. Posterior right branch is missing, and only the first theca of the posterior left branch remains.—Enlarged 6 diameters.

EXPLANATION OF PLATE XIV.

PHYLLOGRAPTUS ANGUSTIFOLIUS, Hall.

FIG. 1.—Sicula side, seen a little from the right, showing the cornet-shaped sicula, visible for the whole of its length, with the apertural margin turned somewhat to the right; to the left of this the left theca, also with its cornet-shaped proximal part lying along the left side of the sicula, but turning the apertural portion and aperture obliquely downwards to the left. To the right of the sicula, the right theca directed obliquely downwards, with the aperture turned to the right. Above this the thecæ lying in the plane of the paper and directed obliquely forwards; to the left the anterior left, and to the right the anterior right, series of thecæ. Behind the latter appears the outline of the posterior right series of thecæ.

FIG. 2.—Right side, seen a little from the left, showing the lowest of the right thecæ with the aperture turned forwards towards the spectator, and above it, to the left, the anterior, to the right the posterior, right series of thecæ. On the left side, behind the former, the apices of the anterior left series of thecæ appear, and behind the right theca the apex of the aperture of the sicula.

FIG. 3.—Anti-sicula side, seen somewhat from the right, showing the aperture of the sicula directed obliquely forwards to the left; to the left of this the right theca in profile, and to the right the left theca. Above this, to the left, the posterior right, and to the right the posterior left, series of thecæ. On the right side we get a glimpse behind of the outlines of the anterior left thecal series.

FIG. 4.—The left side, seen a little from the left. The aperture of the lowest of the left thecæ turned towards the spectator; above, to the right, the anterior, to the left the posterior, left thecal series. On the left side one gets a glimpse behind the left theca of the apertural part of the sicula, and behind the posterior left thecal series of the apices of the posterior right thecal series.

FIG. 5.—From the proximal end, with the sicula side turned upwards, showing in the middle the aperture and the oblique position of the sicula, and on each side of this the apertures of the left and right thecæ. The apertures of these three thecæ occupy almost one and the same plane, which forms an angle of about 40° with the cruciform plane of the thecal series. In this figure all the thecæ visible in the specimen in this position are drawn.—Enlarged 6 diameters.

FIG. 6.—Specimen with the anti-sicula side perfect, seen straight from this side, so that only the two posterior thecal series are visible. The sicula and the left and right thecæ appear in the same position as in Fig. 3. Isolated with acid.—Enlarged 4 diameters.

FIG. 7.—The interior of another incomplete specimen, ground down directly to the level of two thecal series lying in the same plane, and afterwards isolated with acid. It shows the smooth interthecal walls and their straight terminations against the common canal, and also the longitudinal septa. Both the laminæ of the longitudinal septum, which bounds the common canal for the downturned thecal series, which are here not visible, are complete, whilst of the two others only a fragment remains.—Enlarged 6 diameters.

FIG. 8.—Impression of the outer side of two thecal rows lying in the same plane (to the left the anterior right, to the right the posterior left). Between these projects the common canal formed by the longitudinal septa for the thecal series, which are bent downwards and concealed in the rock matrix. The longitudinal septa appear here, as is often the case, to be somewhat irregular, and of a different shape in the longitudinal direction. Transverse sections of the longitudinal septa, therefore, do not maintain the same form throughout the whole length of the polypary. At the proximal end, one side of the sicula embedded in the polypary is free, and its oblique position in relation to the long axis of the polypary is shown. To the right of the sicula the longitudinal septum of the anti-sicula side is perforated by the connecting canal.—Enlarged 4 diameters.

FIG. 9.—Specimen almost completely embedded in the rock, only a small part of the proximal end of the sicula side being free, showing the conical proximal part of the sicula and left theca, the greatest part freed from periderm, so that the partition wall, as well as the connection between the two near the apex, stands out.—Enlarged 6 diameters.

FIG. 10.—A part of a specimen lying in the rock in the same position as the specimen Fig. 8, showing the impression of the proximal part of the anterior right thecal series, and the proximal part of the posterior left series in relief. The substance infilling the sicula has fallen away, except near the apex. To the right of the sicula a trace of the conical elevated part of the left theca, merging into the sicula near the apex.—Enlarged 6 diameters.

FIGS. 11, 12.—Transverse section of two different specimens, isolated with acid, showing the commonest forms of the longitudinal septa, the common canal for each thecal series, and the straight inner edge of the interthecal walls.—Enlarged 6 diameters.

TETRAGRAPTUS BIGSBYI, Hall.

FIGS. 13–16.—A quite uninjured young specimen, representing the *Didymograptus*-stage, showing only the sicula, left and right thecæ, and the connecting canal between them, and at both ends of this its passage into the common canal, which at this stage has the appearance of, and may have functioned as, the distal theca. As in nearly all my specimens of *Tetragraptus*, the apex of the sicula and left theca is somewhat shrivelled. Isolated with acid.—Öland, the cliffs south of Byrum's Sandbay, in the glauconitic grey Vaginatenkalk. Enlarged 12 diameters.

Fig. 13.—From sicula side.

Fig. 14.—From right side. The distal wall of the right theca, not completely developed, forms only a narrow band. Behind the apertural margin of the right theca appears the projection of the sicula. In the interior of the right theca and connecting canal the sicula appears to the left. To the right, on the contrary, the canal is quite open.

Fig. 15.—From anti-sicula side.

Fig. 16.—From left side. The sicula appears here in the interior to the right, the open connecting canal to the left. In the right aperture of the same one gets a glimpse of the undeveloped distal wall of the right theca.

II.—Notes on the Diamond-bearing Rock of Kimberley, South Africa. (I) By Sir J. B. Stone, M.P., F.G.S. (II) By Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., and Miss C. A. Raisin, B.Sc.

[At the end of last year, while on a visit to Sir J. B. Stone, I had the opportunity of seeing a very interesting series of specimens from the Kimberley mines, which he had obtained during a recent tour in South Africa. Among these were two large lumps of the breccia in which the diamond occurs. As these were in a much better condition for microscopic examination than any which I had ever seen, I asked him to let me study one of them. This request he kindly granted, and sent me samples of all that he had collected. As not very much has been written on the subject, at any rate in the English language,[1] the results of the investigation and the conclusions to which it has led may be worth publishing. At my request, Sir J. B. Stone has contributed, notwithstanding his many duties, a prefatory note on the mines and on the opinion which he formed during his visit.—T. G. B.]

(I) The Kimberley Diamond Mines, South Africa.

By Sir J. B. Stone, M.P., F.G.S.

It may be fairly asserted that increased geological interest attaches to the deeper workings of the Kimberley Diamond Mines as they proceed. The remarkable development of underground mining, following upon the amalgamation of interests, which was the outcome of the collapse of the surface workings in 1886, or thereabout, has offered better opportunities for observation, not only of the diamond matrix-material but also of the varying characteristics of the neighbouring rock formations.

The interest created among scientists, upon the first announcement being made that the now famous diamond-bearing "Blue Clay" filled up presumed necks of volcanic craters, has not faded away, nor has the interest in the subject at all lessened. There is, if anything, an increased desire to find out the secret workings of Nature's laboratory, and to learn how the diamonds were formed,

[1] Reasons, in themselves very sad, have hitherto prevented the publication of the elaborate investigations of the late Prof. Carvill Lewis, to which reference has been made below. By a curious coincidence, his manuscripts and all the materials which he had used were entrusted to me by Mrs. Carvill Lewis, just as I had completed my share of the above paper. It is my intention to lose no time in preparing for publication the work of my lamented friend.—T. G. B.

how they came into position, and what is the precise nature of the material in which they are imbedded.

Whilst speculative theories have been propounded, which have added interest to what was already a romantic story, observations have been made at the same time, which are of more exact scientific value and have contributed to a larger knowledge of the subject. Among the facts which have been disclosed are the following: the variation of the character in the diamonds found in the different mines and localities; the varying amount and value of the "stones" from the respective mines, and even from the several parts of the same one; and the variable nature of the "Blue Ground" material.

The diamonds not only occur in all shades of colour, from deep yellow to blue-white, from deep brown to light brown, in green, blue, pink, orange, pure white, and at times even opaque, but also they vary in shape, brilliancy, and size; nevertheless so generally uniform are the particular characteristics of those of any mine, that experts, it is said, can unmistakably distinguish the products of the several workings.

As an illustration, the "stones" from the Jagersfontein Mine are worth thirty or forty per cent. more than those from the De Beers Mine, owing to their purity of colour and brilliancy, though the yield of the latter is evenly about tenfold that of Jagersfontein. Nor is this feature of variation distinguished only in the "stones," for the Blue Clay[1] also varies in its character, it being distinctly different in texture in the several workings; thus, in the De Beers Mine it is so much harder than in the Kimberley Mine, as to take quite twice the length of time to reduce it in the process of disintegration, or, to use a local word, to "pulverize" it, an operation to which all the material is subjected. The yield, too, of diamond wealth is irregular and singularly erratic: the west ends of both the Kimberley and De Beers Mines do not pay to work, whilst the north, south-east, and centres are exceedingly rich, a condition which is even more apparent where the "Blue" lies in close proximity to volcanic rock.

The disintegration of the "Blue" is an interesting process, and throws some light upon the character of the material itself. In past times the same formation, exposed at the surface to the action of the atmosphere, became oxidized and softened, and was always known as Blue Clay, and to-day similar weathering action is relied upon to soften the material which comes from the deep workings in the shape of hard rock. There are thousands of men busily labouring in the labyrinth of galleries below, at varying depths up to 1200 feet, and loads of rock are rapidly sent to the surface, quickly filling long trains of ballast trucks, which are run to the adjacent plains where the wagons are tilted and the precious material is scattered over the ground to undergo the process of weathering; this in the main being all that is needed to disintegrate it, that is if sufficient time is allowed. Violent mechanical means of crushing or breaking up the Blue

[1] This, by the way, is not clay at all when first dislodged in the underground workings, but hard rock, which has had to be "won" by means of drilling and blasting, such as is customary in rock-mining operations.

Ground are necessarily avoided, as it might damage the imbedded diamonds. Therefore weathering action alone is relied upon, subject to the mass being turned over occasionally by "harrowing" it.

The "depositing floors" cover vast areas extending to many square miles of country, which are carefully protected by fences, and the whole vigilantly guarded. The reducing process takes, not merely days or months, but years to bring the material into a condition ready for the work of washing and sorting. At the present time there is a valuable reserve, the worth of which must amount to many years' income; in other words, there are many millions of pounds worth of diamonds stored in these disintegrating areas.[1]

It is not to the purpose here to refer particularly to the process of washing and sorting, or to the thousand and one interesting details that form part of the story of the gigantic and rich enterprises of Kimberley, among which the energy of the De Beers Company takes such a conspicuously leading part, but it is more pertinent to follow the material itself through the series of operations which lead to the final results, and to glean useful geological facts respecting its composition and the history of the diamonds.

The first process of washing carries away all the finer particles of mud, permits the picking out of larger "stones," of easily recognized volcanic rock, or of similar substances, and leaves a mass of granular material from the size of a pin's head to that of a small apple, the several substances amongst it being well and distinctly separated. This is now turned over to the sorters, who proceed to riddle it into classified heaps. Those consisting of the greater particles, amongst which the larger and more valuable stones may be expected to be found, are placed in the hands of confidential and responsible Europeans; the finest, from which the most minute diamonds are extracted, being examined by Kaffirs (all of whom are carefully watched), who go over the fine refuse almost grain by grain.

These granular masses in process of sorting are highly interesting. They are rich in garnets, in olivine, in pyrites, and many other minerals; and they disclose the detailed composition of the breccia of the "Blue Clay."

Among this composite material the diamonds are found in the proportion of about 1 to $1\frac{1}{2}$ carats to the ton, and in size, from the smallest grain to "stones" of the greatest value.[2]

A parcel of diamonds in the rough (such as, for instance, the day's product of one of the mines) is an extremely interesting subject of investigation and study. Such a bowl full of stones, amounting to thousands of pounds in value, fresh from the cleaning process of having been boiled in acids, present in their uncut and unassorted condition a general resemblance to a handful

[1] A better idea of the riches of the mines will be gleaned from the brief statement which has just publicly appeared (July, 1895), that the De Beers Company have sold the output for the year for the sum of three million and a half pounds sterling.

[2] One in the possession of the De Beers Company weighed in the rough state as much as 428 carats.

of saltpetre crystals. A more minute and careful examination discloses the interesting fact that many, if not most of the stones, are fractured, and are but parts of perfect crystals. This indicates that they have been subjected to mechanical forces, explosive or otherwise, and of itself seems to prove that the diamonds were not formed at the spot where they were found.

It should be stated that above the diamond-bearing rocks there are extensive beds of carbonaceous shales, and it has been supposed that chemical action, due to steam generated in the volcanic rock, formed the diamonds.[1] Of course due weight must be given to the facts adduced by those who favour the idea that the diamonds were actually formed at or near the spot where they were found, particularly the one singular fact of the prevailing similarity of stones in localities, which it is admitted remains at present unexplained; but even if the broken diamonds were not sufficient evidence, certainly the schistose surfaces of the "snake" (a hard intrusive porphyritic rock), and the glossy appearance of the crater face lying in contact with the Blue Ground, should be perfectly convincing.

No doubt some such chemical action as indicated did take place and produced the diamonds, but it is more than probable that this occurred far away from their present resting-place, the exuding mud-flow having been propelled forward by earth pressure, or some other dynamical force, and that the diamonds were fractured by extreme pressure in transit.

In conclusion, it is interesting to have to report that the De Beers Company are energetically continuing the work of sinking in the main shaft, which, it may be well to state, is through the adjacent hard rock and within a short distance of the crater funnel of the mine proper. This, to get to the 1200-feet level, has passed through the upper beds of basalt and black shale, through the hard amygdaloidal melaphyre deposit, through some 400 feet of quartzite, and into the lower shale beds.[2]

[1] It may be well here to quote a passage from a letter on this subject received from Mr. W. Moses, the able director of the De Beers Mines, who ventures upon a more elaborate explanation. He says: "I am inclined to stick to my theory of the formation of diamonds and the depositing of them in the present formation of Blue Ground or volcanic mud. To put it as short as possible, the diamonds were produced from carbonic acid gas under extreme pressure and changes of temperature, the oxygen being consumed by the carbon, etc., the result being the diamond. To revert to the present deposits: they were made in the crater of an extinct volcano, into which came thermal springs, which washed away the sides of the soft strata below (the volcanic rocks forming the volcanic mud of the Blue Ground), and the diamonds were introduced from below by the action of the boiling energy of the thermal springs. The blue ground or mud, if you remember, we concluded had not gone under any great heat, as the small particles of shale clearly indicated; in short, the diamonds were separately formed, and were brought into their present position from below." It has also been supposed, and with some show of probability, that with the opportune presence of carbon, under conditions of intense heat and perchance pressure, crystallization took place, the colours of the stones varying as they were affected by the presence of metals or oxides of metals.

[2] A letter recently received from Mr. W. Moses states that "the sinking of our main shaft still continues in the blue metamorphic shale, and no change has yet

(II) On the Rock and other Specimens from the Kimberley Mines.

By Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., and Miss C. A. Raisin, B.Sc.

THE undecomposed rock is obviously a fairly hard breccia, exhibiting a rather irregular fracture and consisting of minerals and rock fragments in a blackish-green, slightly granulated "paste." Some of the minerals, probably fragments, can be readily identified, *e.g.*, olivine, green pyroxene, brown mica, and garnets. The fragments of rock are of various sizes up to about two inches diameter. They are generally rather compact in texture, greenish-grey in colour, sometimes exhibiting a zonal structure near the edges. The specific gravity, determined by a Walker's balance, of a specimen of the breccia measuring about $2\frac{1}{4}'' \times 2'' \times \frac{1}{2}''$ is 2·61; of a piece about one-fourth that volume, 2·66.[1]

Under the microscope the rock is seen to consist of fragments large and small, becoming at last a mere powder, which are set in a serpentinous mineral and a carbonate, these acting as the cementing paste, but the latter mineral being more sporadic in occurrence. Commencing with the larger minerals[2] in the specimen before us, (1) Olivine is the most abundant. Its cleavage in some cases is a little more marked than usual. It occurs generally in rounded grains, partially ringed by serpentine, indeed sometimes completely converted into this mineral. The alteration usually is as follows:—Round each grain is a zone of fibrous serpentine, exhibiting a rather parallel ordering, which acts feebly on polarized light. A zone follows where the fibres are arranged in cones, the apices of which seem to pierce the olivine, as if the cone structure had gradually extended inwards and had affected indirectly that of the whole layer. Here, however, the axes of the cones are more or less parallel. This parallelism seems to depend on some structure in the olivine itself—most probably a cleavage—and not on the form of the grain. In some cases the fibrous mineral seems, from the extinction angle, to be actinolite or tremolite.[3]

(2) Sahlite, or lightish-green augite, occurs in grains often somewhat oblong, commonly with an alteration zone at the exterior, consisting of a fibrous mineral, which has the extinction of actinolite. The olivine and the sahlite often present considerable resemblances in their general microscopic aspect, and the same holds true of their alteration products.

taken place in the appearance of the strata. We have now passed through some 200 feet of this formation, and I am in hopes of getting a change which will be very interesting." Mr. Moses also promises to send a further box of samples when this takes place, which it is needless to say will be of additional interest under the circumstances.

[1] These specimens were given to one of the authors by C. J. Alford, Esq., F.G.S. That brought by Sir J. B. Stone was inconveniently large for weighing.

[2] A number of analyses of minerals are given in the paper by Prof. Maskelyne and Dr. Flight, Quart. Journ. Geol. Soc., vol. xxx, 1874, pp. 408–416. In our specimens, bronzite, which appears to be common in their material, seems to be rare, if not absent.

[3] As was also observed by Prof. Carvill Lewis.

(3) Mica. The flakes are somewhat irregular in outline, of a pale but rather warm brown colour, well cleaved. The pleochroism is from light dull buff to an ochre-brown. Cases of twinning occur; one of the twins sometimes greatly dominating over the other. The mica at its exterior is changed into a mass of a minute, very pale green mineral, which sometimes extends up cleavage cracks. This apparently is the material designated vaalite by Professor Maskelyne.

(4) Garnet: (rare in this specimen) wine-red in colour. In one case this mineral is surrounded by a zone about ·006″ thick (except on one side, where it becomes a mere film). This zone exhibits a radial fibrous crystallization and a banded structure. It varies in colour from a rather light to a very dark umber-brown, and the constituents seem to have a straight extinction. Beyond this, in three directions, is a much broader border, variable in thickness, barely translucent, and a deep umber-brown in colour; but perhaps only a more felted mass of the mineral already mentioned. The more diaphanous part does not appear to be sensibly dichroic, and can hardly be biotite or an altered mica. It might, however, be a mixture of iron oxide with fibrous quartz, as in the so-called crocidolite. In another slice biotite does occur as a decomposition product of a garnet, but here the former mineral eats into the latter in a somewhat irregular manner.

(5) Chromite. Feebly translucent brown grains, occasionally octahedral in form, are doubtless chromite, but other iron oxides are present in the slide.

(6) Pseudobrookite (?). Other brown grains, occurring in a rudely square form or as an association of granules, are anisotropic, and sometimes exhibit, with crossed nicols, specks of rather bright colour, indicative, probably, of aggregate structure. Small crystals, however, of a mineral to be mentioned below (perofskite) are sometimes clustered about these grains and may mask the colour effects. We refer these brown grains to pseudobrookite, though the tint is less rich than usual. This, however, may be due to decomposition.

(7) Rutile. A few small crystals occur, among them a geniculate twin, and in serpentine, as observed by Prof. Carvill Lewis. We doubt, however, whether it is an alteration product.

(8) Perofskite. The grains, usually from ·0002″ to ·0008″, are sometimes hexagonal in outline, often showing a central spot and radial lines, a very faint yellowish tinge with transmitted light, and a whitish or yellowish-grey with reflected. These grains have a habit of clustering, and they sometimes wreathe around fragments of crystals and rocks.

Leaving for a moment the rock fragments, we proceed with the matrix, to which, indeed, the last-named mineral might be referred. Its hardness is barely 3, though among its microscopic constituents is one which scratches glass. When powdered, it effervesces briskly with HCl. Apparently it is composed of the following constituents: (*a*) a clear colourless isotropic serpentine; (*b*) brown mica, in small films, sometimes irregular in outline, having a general resemblance to that described above, but almost certainly of secondary origin. With mica, perhaps, may be included some rather regular hexagonal thin plates, of an apparently colourless mineral, which seem to project into interspaces; (*c*) chlorite (?); (*d*) needles, often radially tufted, clear and colourless, with low polarization tints and probably straight extinction; (*e*) a carbonate, seemingly varying from calcite to dolomite, filling up interspaces; and probably (*f*) a little opal.

As to the rock fragments, our specimen of the breccia has not afforded either granite or pegmatite, rocks which were detected by Prof. Daubrée. Those present, as described above, have a hardness generally a little less than 4, but one large fragment, paler in colour than most of them, is about 2·5. Under the microscope the outermost zone is usually thin, sometimes consisting rather largely of an aggregate of minute chlorite, followed by a second and broader zone containing films of brown mica[1] with ill-defined outlines; the third zone is often rich in minute perofskite. In other cases the external zone is richer in perofskite, and within this comes a greenish zone, which may be followed by another perofskite band, sometimes broad. The inner part of the fragments is rather "patchy" in structure, consisting, in some cases, very largely of a clear colourless isotropic material (? a hydrous glass). In this, scattered in rather varying quantities, are (*a*) clusters of perofskite; (*b*) films of brown mica (biotite) as above, in one or two cases sprouting inwards from the inner zone; (*c*) minute acicular prisms, giving low polarization tints and straight extinction, often forming tufted or radiating groups (occasionally almost spherulitic), which in a few cases seemingly are growing from the ends of the brown mica; (*d*) rude attempts at skeleton crystals, probably magnetite; (*e*) a carbonate (as in the matrix).

Three fragments differ somewhat from the rest. One includes serpentinized olivine surrounded by a material, which exhibits a structure suggestive of a flowing. Another consists of grains and granules of serpentinized olivine, with thin flakes of brown mica and pseudobrookite or chromite. The third with transmitted light looks almost pellucid, but with crossed nicols exhibits an aggregate structure, such as may be seen in a serpentine, though on a very minute scale, the constituents being grouped in lighter and darker parts, as may be sometimes observed in a scoriaceous rock. One corner, however, exhibits a spherulitic structure, which also makes its appearance here and there in other, commonly the outer, parts of the fragment.

The general aspect of these fragments (except for the zones) recalls certain varieties of much decomposed serpentine, and to this rock, though we have never seen any quite identical, we venture to refer it, believing that it is the result of the alteration of either a glassy or a very minutely crystalline peridotite. The zonal banding may be original, as it recalls that exhibited by fragments in some diabase tuffs from Porthdinlleyn,[2] where it is an original

[1] The biotite is variable in amount, and occasionally is wanting.

[2] *Cf.* C. A. Raisin on Variolite . . . . of the Lleyn: Quart. Journ. Geol. Soc., vol xlix, 1893, p. 151.

structure, such as is common in slaggy ejectamenta. Still, like the bands produced in some stained rocks, it might be a result of infiltration; but though the latter may be a modifying cause, we incline to adopting the former explanation.

The "blue clay" or "blue ground," the material obtained in the earlier and shallower workings, is clearly only a decomposed condition of the rock already described,[1] the cementing carbonate having been more or less removed[2]; and the "yellow ground" represents a further stage in the decomposition. We have compared the fine-grained part of the "blue ground" with some crushed and decomposed serpentine from the Lizard, and find a strong likeness between the dominant material in both, so that very probably the dust-like fragments of serpentine (altered peridotite) enter largely into the composition of the diamantiferous rock. The more durable minerals are separated from it by washing. Two packages, given some time ago to one of us by Prof. Boyd Dawkins, are divided into coarser and finer washings: the former often run from about one- to nearly three-eighths of an inch, the latter do not generally exceed one-tenth of an inch in diameter. The materials appear to be similar, though the relative quantities may differ in the two, and among the coarser some rock fragments (in one case a fine-grained peridotite, in another apparently a sedimentary rock) are present. Among the minerals in these samples, and in those brought by Sir J. B. Stone, which are roughly sorted but are of larger size, we find the following:—

(*a*) Garnets; more than one variety being present. The majority are from a wine-red to a purple-lake in colour (almandine); a few are orange-red to reddish resin-brown, when magnified, (? essonite). They appear to be always fragmental; this is very obvious in the case of the clear-coloured specimens, and even those which are more rounded suggest a fragmental origin. Many of the latter seem to be only dull-coloured greenish grains, but on breaking them they are found to consist of a kernel of red garnet, surrounded by an aggregated doubly-refracting substance. This may be merely some incrusting mineral, but it suggests the possibility of a decomposition zone. Some have on the exterior brown mica, perhaps also a chlorite, with another mineral too minute for identification, and if we may found an inference on the ease with which the grains break, the same material probably occupies fissures.

(*b*) The fragments of sahlite are often determined by cleavage planes. The colour is commonly a fairly rich celandine or oil green, but two or three of the well-rolled small grains are a very rich emerald green. These probably contain a considerable amount of chromium, but we should expect that all would afford traces of this base.

[1] The material which Prof. Maskelyne and Dr. Flight were examining was evidently "blue ground," and was taken from depths not exceeding 180 feet.—Q.J.G.S., vol. xxx, 1874, p. 406.

[2] In the museum at Owens College, Manchester, are some large lumps of partially decomposed breccia intermediate between the ordinary "blue ground" and the specimens described in this paper.

(*c*) Fragments of olivine, of a greenish-yellow colour, not very numerous.

(*d*) Iron oxides. Grains of magnetite are very few in number—not one per cent. of the washing; most of the grains are not attracted by the magnet, have a bright metallic lustre, give a brownish streak, and a bead (with borax) of yellowish bottle-green colour. These are clearly ilmenite, as was further indicated by the usual chemical test. We have not found chromite, but, as our search has not been a very close one, it may have escaped us. It can hardly be common. A good many subrotund grains or little flattish cakes of rusty brown colour prove to be limonite.

(*e*) Occasional grains of pyrite and quartz, and flakes of brownish mica.

Two other rock specimens, brought back by Sir J. B. Stone, must also be noticed. One is a somewhat shapeless lump, with rather rounded surfaces, more or less slicken-sided, unctuous to the touch, and of a pale olive-grey colour. The hardness of the exterior is about 1·5, but a portion of the interior exposed by a fracture is a little less than 3. The former, when powdered, does not effervesce with H Cl, and under the microscope resembles a rather decomposed serpentine; the latter effervesces briskly, and appears to be mainly calcite, perhaps slightly dolomitic. We seem, then, to have a nodule of impure calcite, of what origin it is difficult to say, enclosed in a kind of husk of decomposed serpentinous material.

The other specimen is a hard, fine-grained grit or quartzite, almost black in colour, with a thin banded structure, parallel with which it has a tendency to split, especially where a white mica (fragmental) is abundant. A microscopic section shows it to consist mainly of fragments of quartz, fairly angular to subrotund, a few being compound and possibly derived from veins. The majority contain fluid cavities, although the amount of these is variable; bubbles, frequently small, are generally present, and microlithic enclosures may be occasionally noted. Often there is a thin external zone of secondary quartz. A few fragments of felspar, including a plagioclase, and microcline also occur. The grains are set in an earthy matrix, a good deal of which on close scrutiny has a fragmental aspect, and very probably is largely made up of decomposed felspar. This part, with crossed nicols, is brightly speckled, most likely owing to the formation of a secondary micaceous product. We find also ilmenite, partly converted into leucoxene, a few flakes of altered biotite, and sundry microliths. On one side of the slice are one or two bands of variable thickness, where the rock is darker and more fissile, the fragments being smaller, and the amount of mica (chiefly white) being larger; here also are some grains of pyrite. Probably the rock is a member of the Karoo series, though possibly slightly altered.

Our observations accordingly seem to justify the following statements:—

(1) That the diamantiferous rock is a breccia, which in its unweathered condition is cemented together by secondary minerals.

(2) That it contains various rock fragments, some of them, in all probability, having been formerly peridotites.[1]

(3) That it contains a considerable number of minerals of fair size in a more or less fragmental condition (*e.g.*, olivine, augite, biotite, garnet, magnetite, ilmenite).

(4) That these minerals—or at any rate most of them—are not such as are likely to have been formed *in situ*, but more probably have been obtained by the destruction of rather coarse peridotites, pyroxenites, and eclogites.[2]

(5) That while, since the formation of the breccia, changes to a not inconsiderable extent have taken place in the production of serpentine, chlorite, perofskite, etc., these are not such as are suggestive of a very high temperature or of very great pressure.

We are therefore led to the following conclusions:—That the diamond also was not produced *in situ* in the rock which we have been describing, but, like the garnet, etc., had its origin elsewhere, probably at a distinctly greater depth from the surface.[3] We thus agree with Professor Daubrée,[4] and differ from the views expressed by Mr. Hudleston[5] and Prof. Carvill Lewis,[6] both of whom regarded the diamond as produced *in situ*,[7] but we agree with the former that the "pipes" are probably of volcanic origin,[8] and that heated water

[1] In the specimens which we have examined it happens that fragments of shale, which according to Profs. Daubrée and Carvill Lewis are sometimes abundant, are either extremely small and rare or entirely absent. At any rate, they cannot now be identified with any certainty. [Professor A. H. Green, F.R.S., since these words were written, has most kindly lent me a number of specimens of rocks and minerals which he collected when visiting Kimberley in 1882, together with sundry notes and sections, of great interest. His specimens of "blue ground" are not quite so hard as those described above, but are in better preservation than most that I have examined. They contain fragments of black shale, in one case abundantly. One specimen also includes several angular fragments (up to a good half-inch in diameter) of a compact, slightly streaky, greenish-yellow rock, apparently a rotten serpentine (microscopic examination seems hopeless). There are specimens also of other rocks which occur as fragments in the breccia: three of these must have been of large size; two are amygdaloidal, one a compact diabase, the other a reddish porphyrite; the third an olivine basalt with some flakes of brown mica. Of smaller specimens (not more than about an inch in diameter) six are from the Bloemfontein Mine: one is a diorite, very slightly foliated; the other five are particularly interesting, for they represent a fairly coarse rock, chiefly composed of sahlite and a brownish mica, indistinguishable from that described above in the breccia. There are also specimens of the sheets of doleritic or diabasic rocks of the district. Dykes, sheets, etc., of these, according to Professor Green, are very abundant, as described in his paper (Q.J.G.S., xliv, pp. 254, 264). His sections make the "neck"-like character of the diamantiferous rock very clear —T. G. B.]

[2] As described in our paper, Geol. Mag. 1891, p. 412.

[3] We may say that this conclusion was arrived at independently of previous writers, for we did not refresh our memory of the opinions expressed by them till our work was practically concluded.

[4] Comptes Rendus, 1890, vol. cx, p. 18.

[5] Proc. Geol. Assoc., viii, p. 65.

[6] Brit. Assoc. Reports, 1886, p. 667; 1887, p. 720; and Geol. Mag. 1877, pp. 22–24.

[7] Prof. Maskelyne inclines to the opinion that the diamond was produced at or near the contact of a basic igneous rock with a carbonaceous shale, but that since then the whole mass has been affected by mechanical disturbances and thermal waters.—Q.J.G.S., vol. xxx, 1874, pp. 407, 408.

[8] This was Mr. Dunn's opinion, who supposed that the diamond was produced by

has been the principal agent in producing the secondary metamorphism,[1] and we think with the latter that the association of the diamond with a peridotite is not fortuitous, though we believe that this mineral, like the others mentioned above, originated at a much greater depth in the earth's crust. This view, we were glad to find, had already commended itself to Prof. Daubrée, who makes some highly suggestive remarks on the association of diamonds and meteorites.[2]

III.—Review of the Evidence for the Animal Nature of Eozoön Canadense.

By Sir William Dawson, C.M.G., LL.D., F.R.S., etc.

II. Petrological and Chemical.

BEARING in mind the statements made in the previous note, respecting the stratigraphical relations of the Grenville Series, and referring to the excellent account by my friend Dr. Bonney of his observations at Côte St. Pierre, and to some difficulties stated by him which merit attention, we may sum up the evidence so far, under the following statements :—

1. The limestones included in the Grenville Series and their associated quartzites and schists bear so strong a resemblance in mineral character to metamorphosed Palæozoic calcareous beds of organic origin and their associates, as to warrant at least the careful consideration of any forms apparently organic contained in these limestones.

2. The occurrence in these limestones of nodular silicates, of graphite, of pyrite, and of apatite, affords additional reason to suspect their organic origin.

3. The presence of large beds as well as of veins of graphite and of thick deposits of iron ore in the Grenville Series constitutes an additional analogy with Palæozoic formations holding organic remains.[3]

These facts were adduced by Dr. Sterry Hunt and Dr. J. D. Dana in evidence of the probability of life in the Laurentian period, even before the discovery of Eozoön. Certain particulars connected with them, however, now demand somewhat more detailed attention, in connection with that discovery, and with recent objections to the organic nature of Eozoön.

Dolomite or magnesian limestone is a not infrequent associate of Palæozoic fossiliferous limestones; and I have remarked in previous

metamorphism of the carbonaceous material in the shales.—Q.J.G.S., vol. xxx, 1874, p. 54; vol. xxxiii, 1877, p. 879; vol. xxxvii, 1881, p. 609. Prof. Green informs us that his examination led him to the conclusion that the 'pipes' were volcanic necks.

[1] This may have been the last stage in a series of volcanic disturbances, of which the flows noticed by Prof. Green (*loc. cit.*) may have been the earliest.

[2] *Loc. cit.*, pp. 20-24. Prof. Lewis had already called attention to certain points of likeness in the diamantiferous rock and meteorites.

[3] See papers by the author on the Graphite and Phosphates of the Laurentian Rocks, Quart. Journ. Geol. Soc. London, 1869 and 1876.

papers on the similarity of the mode of occurrence of silicified Stromatoporæ in the great dolomite of the Niagara formation with that of Eozoön in the Grenville Limestone, in which dolomite occurs in beds, in thin layers, and in disseminated crystals, in a manner to show that it was an original constituent of the deposit. Dolomite is also one of the most common minerals filling the cavities of Eozoön, and especially the finer tubuli. The mode of its occurrence on the small scale may be seen in the following description of a section of a portion of a bed of limestone from Côte St. Pierre, examined under a lens, after being treated with dilute acid. The specimen comprised about six inches of the thickness of the bed:—

Crystalline limestone with crystals of dolomite, constituting about one half (fragments of Eozoön in calcite portion).[1]

More finely crystalline limestone, with rounded granules of serpentine, some of them apparently moulded in cavities of Archæospherinæ, or of chamberlets of Eozoön.

Limestone with dolomite as above, but including a thin layer of limestone with granules of serpentine.

Limestone and dolomite, with a few grains of serpentine and fragments of Eozoön.

Crystalline dolomite with a few fragments of Eozoön, as limestone, with canals in dolomite.

Limestone with fragments of Eozoön, granules of serpentine, and groups of chamberlets filled with serpentine.

We have thus a bed of limestone in which dolomitic and serpentinous layers appear to alternate, and occasional fragments of Eozoön occur in both, while the smaller forms resembling fossils are, so far as can be observed, limited to the serpentinous layers.

At Aruprion on the Ottawa a portion of the Grenville Limestone presents dark graphitic layers parallel to the bedding, and giving it a banded grey and white appearance which has led to its use as a marble. An analysis by Dr. Harrington shows that the graphitic layers contain 8·32 per cent. of magnesia, the lighter layers only 2·57 per cent., in the state of grains or crystals of dolomite. Associated with the marble there are also beds of brown-weathering dolomite, affording 42·10 of magnesia. The graphite in this marble, under the microscope appears as fibrils and groups of minute clots, and sometimes coats the surfaces of crystals or fragments of calcite, the appearances being not unlike those seen in carbonaceous and bituminous limestones of later date.

In both the above cases the magnesium carbonate is evidently an original ingredient of the bed, and cannot have been introduced by any metamorphic action. It must be explicable by the causes which produce dolomite in more recent limestones.

Dana has thrown light on these by his observations on the occurrence of dolomite in the elevated coral island of Matea in Polynesia,[2] under circumstances which show that it was formed

[1] Distinguished by their fine granular texture and canal-systems.

[2] "Corals and Coral Islands," p. 356, etc.

in the lagoon of an ancient coral atoll, while he finds that coral and coral sands of the same elevated reef contain very little magnesia. He concludes that the introduction of magnesia into the consolidating under-water coral sand or mud has apparently taken place—"(1) In sea-water at the ordinary temperature; and (2) without the agency of any other mineral water except that of the ocean"; but the sand and mud were those of a lagoon in which the saline matter was in process of concentration by evaporation under the solar heat. Klement has more recently taken up this fact in the way of experiment, and finds that, while in the case of ordinary calcite this action is slow and imperfect, with the aragonite which constitutes the calcareous framework of certain corals, and at temperatures of 60° or over, it is very rapid and complete, producing a mixture of calcium and magnesium carbonates, from which a pure dolomite more or less mixed with calcite may subsequently result.[1]

I regard these observations as of the utmost importance in reference to the relations of dolomite with fossiliferous limestones, and especially with those of the Grenville Series. The waters of the Laurentian ocean must have been much richer in salts of magnesium than those of the present seas, and the temperature was probably higher, so that chemical changes now proceeding in limited lagoons might have occurred over much larger areas. If at that time there were, as in later periods, calcareous organisms composed of aragonite, these may have been destroyed by conversion into dolomite, while others more resisting were preserved, just as a modern *Polytrema* or *Balanus* might remain, when a coral to which it might be attached would be dolomitized. This would account for the persistence of Eozoön and its fragments, when other organisms may have perished, and also for the frequent filling of the canals and tubuli with the magnesian carbonate.

The question now arises as to the mineralization of Eozoön with serpentine, and more rarely, especially in the case of its larger and lower chambers, with pyroxene. Connected with this is the alternation, as above described, of serpentinous and dolomitic layers in the limestone, as if in successive times the conditions were alternately favourable to the deposition of magnesium in the form of carbonate and in that of silicate.

We learn from the "Challenger" Reports that under certain circumstances the presence of organic matter in oceanic deposits causes an alkaline condition, tending to the solution of silica and the formation of silicates. We also learn that siliceous matter in a state of fine division (*e.g.* volcanic dust) may afford material for the production of hydrous silicates, either directly or indirectly through the agency of organisms forming siliceous skeletons. The "Challenger" Reports also show that the silicates known under the name of glauconite, and thus deposited, contain several bases to some extent interchangeable. Of these the principal are aluminium, potash, and iron, though magnesia is also present. Some older

[1] Bulletin Geol. Soc. Belgium, vol. ix (1895, p. 3). Also notice in Geol. Mag., July 1895, p. 329.

silicates injecting fossils in the Palæozoic rocks are less complicated, and contain more magnesia; and, as Hunt has shown, there is nothing anomalous in the supposition that in the Laurentian period silicate of magnesium and iron may have acted in this capacity.[1]

It is true that serpentine is now usually regarded as a product of the hydration of olivine and pyroxene; still, even on this supposition, it might be formed from the hydration of fine volcanic dust falling into the sea. Hunt also has shown that the serpentine of the Grenville Limestone differs chemically from those supposed to be of direct igneous origin in its comparative freedom from iron oxide, in its larger proportion of water, and in its lower specific gravity, besides being a more pure silicate of magnesium. That it can be deposited by water is shown by the chrysotile filling veins, and by my own observations, published long ago, on the serpentine replacing and filling cavities of Cambro-Silurian fossils at Melbourne in Canada, and filling the cells of Silurian corals at Lake Chebogamong.[2]

The occurrence of pyroxene in the limestone, and filling some of the chambers of Eozoön, may also be easily explained. Dr. Bonney well remarks that it does not resemble any igneous rock known to him, and it is quite certain from its mode of occurrence that it cannot be directly igneous. Somewhat thick and continuous beds of a coarser pyroxenite occur in some parts of the Grenville Series, *e.g.* at Templeton, and I have described them as probably volcanic ash-beds, while the large pyroxene crystals found in the veins of apatite traversing these beds are probably of thermo-aqueous origin. But the limited and irregular masses and concretions of white pyroxene occurring in the limestones are of different texture and colour, and more purely silicates of lime and magnesia. They may have resulted from local showers of volcanic ashes drifted by currents into hollows of the Eozoön reefs, and sufficiently fine to fill the larger chambers of dead specimens, and when consolidated to form a basis for the growth of new individuals. This is, I think, the only supposition on which they can be explained, and it would also explain the difficulty suggested by Dr. Bonney as to the association of the pyroxene with Eozoön.

There seems, however, to be no good evidence that any portion of the pyroxene has been changed into serpentine; and it is evident that if such a change had occurred after the consolidation of the rock, serious chemical and mechanical difficulties would be involved, whereas if volcanic débris, whether of the nature of olivine or pyroxene, became hydrated while the rock was incoherent and in process of formation, this would tend greatly to promote the infiltration with hydrous silicates of any fossils present in the mass.

Assuming the serpentine and pyroxene to have been deposited as

[1] See Analyses of Glauconites, etc., by Dr. Hunt in "Dawn of Life," p. 126. One tertiary example is silicate of iron and magnesia. See also Hoskins on Glauconite, Geol. Mag., July 1895.

[2] Quart. Journ. Geol. Soc. 1864, p. 69, also 1879, p. 48 *et seq.*, Memoir on Eozoön in Peter Redpath Museum, 1888, p. 48 *et seq.*

above suggested, the remaining objections stated by Dr. Bonney would at once disappear. Specimens of Eozoön or other fossils might be infiltrated or filled with these silicates, and while the latter were superabundant they might form separate concretions or grains which might in some cases envelop the fossils or be attached to them in irregular forms, just as one finds in the case of the flints in chalk or the chert in some other limestones.[1]

It is scarcely necessary to say that no objection to the organic origin of the Eozoön can be founded on the fact that many of the specimens are fractured, crushed, bent, or faulted, by the movement of the containing rock, or on the circumstance that well-preserved specimens should be rare, and found chiefly in beds containing silicates capable of injecting their cavities. On the other hand, the circumstance that fragments of Eozoön are abundant in the limestone is one of the best possible proofs that we are dealing with a calcareous organism. It would be interesting to describe and figure a number of specimens in our collections illustrating these points; but to do so would require an extensive illustrated memoir, for which neither space nor means are at present available.

I observe, in conclusion of this part of the subject, that in any highly crystalline limestone we can hope to find well-preserved fossils only when their cavities and pores have been filled with some enduring siliceous mineral; but, on the other hand, that porous fossils, once so infiltrated, become imperishable. It still remains to consider shortly new facts bearing on the structure of Eozoön and its possible biological affinities.

(*Part III will appear in the December Number.*)

IV.—On the Stratigraphy of the Crag of Suffolk, with especial reference to the Distribution of the Foraminifera.[2]

By H. W. Burrows, A.R.I.B.A., etc.

The successional order of the strata of the Crag of the Eastern Counties, and the grouping and relationship of the several members of this formation, are here described more especially with regard to the Foraminifera obtained from them. These remarks on the distribution of the Microzoa in the Crag are based upon the examination of material collected by myself during the past eight years, with the exception of some from Tattingstone and Gedgrave (zone *g*) kindly supplied by Professor Prestwich. The whole of this material has been worked over by Mr. Richard Holland and myself; and Mr. Frederick Chapman has given us some aid with the Tattingstone Crag. Whilst assisting lately in the production of Part II of the Monograph of the Foraminifera of the

[1] It is a curious coincidence that Dr. Johnston-Lavis has described in the July Number of this Journal, the aqueous deposition at ordinary temperature of crystals of pyroxene and hornblende, in cavities and crevices of bones included in an ash-bed of recent date, and in presence of calcite, apatite, and fluoride of calcium, as in the Grenville Series. This is a modern instance analogous to that suggested above.

[2] Read before Section C of the British Association at Ipswich, Sept. 12th, 1895.

Crag, it has been necessary to re-examine the collections previously made by the late Messrs. S. V. Wood and W. K. Parker, and the work done by them, with Dr. H. B. Brady and Professor T. Rupert Jones; and in view of the desirability of having the latest information in a tangible shape, I have been led to put together some notes on the Crag and the Distribution of its Foraminifera for this Monograph, Part II. An Abstract of my memoir is now offered to the British Association, meeting at Ipswich in the centre of the Crag district.

The relative abundance of the Bryozoan, Molluscan, and other remains, besides the Foraminifera, is necessarily an important element in the classification of the Crag beds, and is taken into careful consideration.

The Pliocene beds of the British Isles have been exhaustively dealt with by Prof. Prestwich (1841–1890), and lately by Clement Reid in his "Pliocene deposits of Britain" (Memoirs Geol. Survey, 1890); and the foreign equivalents are tabulated in G. F. Harris's Appendix to R. B. Newton's "Syst. List of F. E. Edwards's Coll. British Oligocene and Eocene Mollusca, British Museum," 1891.

PLIOCENE FORMATION.

A. Newer Pliocene Beds (Upper Crag).

I. *Beds above the Red Crag* (Norwich Crag, etc.).—From Southwold there were enumerated ten species of Foraminifera in the First Part of the Monograph;

From Thorpe, near Norwich, seven species;

From Bramerton, two species;

From the Chillesford beds, eight species are known.

These are common forms of *Textilaria*, *Bulimina*, *Lagena*, *Nodosaria*, *Polymorphina*, *Truncatulina*, and *Polystomella*; mostly of North-Atlantic habitat.

II. *Red Crag* (Essex and Suffolk).—The coarse quartzose sand and ferruginous condition of the Red Crag were not favourable to the presence and preservation of Foraminifera; but a more extended research in the finer and lighter-coloured sands might prove profitable, although a prolonged search through some of the grey sand, so rich in Mollusca, from Walton-on-the-Naze, has not resulted in any additions to the twenty species recorded in the Monograph, Part I, 1866, Table in Appendix II.

B. Older Pliocene (Lower Crag).

I. *St. Erth Beds.*—At St. Erth, near Marazion, Cornwall, occurs a very small outlier of sands and clays, the Pliocene age of which was definitely established by the late Mr. S. V. Wood, jun. (1885); and a full description of the exposure was given by Messrs. P. F. Kendall and R. G. Bell (1886), and by Mr. C. Reid (1890).

Beneath the vegetable soil and "head" (argillaceous deposit with angular stones), are sand and clay, and then a *fossiliferous* blue clay ($1\frac{1}{2}$ to 3 feet thick), underlaid by a pebble-bed and sands: all are variable, but amount to 12–14 feet in thickness. The Foraminifera have been carefully worked out by Mr. Fortescue W. Millett, of Marazion; and the lists published by him (1885, 1886, 1894) give a total of 163 species and well-marked varieties. Of this number seventy-six are also met with in the Coralline Crag; and the additions now made to the rhizopodal fauna of the latter emphasize the similarity to a considerable degree.

The present notes have special reference to the Crag of the Eastern Counties; and, although the St. Erth beds are of great interest, they are only thus briefly referred to for the purpose of comparison. They contain a very rich assemblage of *Lagenæ* (thirty-six species); while only twenty-three are recorded from the Coralline Crag, of which, however, eighteen are common to the two. One of the most interesting is *Lagena seminuda*, Brady, a species met with at only six stations by the "Challenger," two in the South Atlantic and four in the South Pacific, with a range of depth from 1300 to 2350 fathoms. In the St. Erth clay it is rare; but in the Coralline Crag (zone *f*) it is rather common; so that we have in the Pliocene beds the earlier appearance of a comparatively shallow-water form, which has apparently since migrated to deeper seas. The *Polymorphinæ*, so well represented in the Coralline Crag, appear to be somewhat rare at St. Erth; but of the fifteen recorded species, ten are also found in the former. Taken altogether, the balance of evidence, so far as the Foraminifera are concerned, supports the arguments adduced by Mr. C. Reid for including the St. Erth beds with the Older Pliocene.

II. *Coralline Crag* (termed also the "Suffolk Crag," "White Crag," "Bryozoan or Polyzoan Crag").—Both by Prof. Prestwich (1871), and by Messrs. S. V. Wood, jun., and F. W. Harmer (1872), two main divisions of this Crag were fully recognized. The upper division (zones *h* and *g*), 36 feet thick; and lower division (zones *f* to *a*), 47 feet, altogether 83 feet, according to Prestwich; and the whole (zones 3‴, 3″, and 3′) 60 feet by the other authors.

1. At *Sutton* and *Ramsholt* zones *a*, *b*, *c*, and part of zone *d*, are developed.

The lowest zones were exposed only in long since disused pits. The old pit on Mr. Colchester's farm at Sutton, south side of Sutton Farm Hill, showed in 1860 (Prestwich): Under the surface soil (1 foot); zones *d* and *c*, 17 feet, the latter rich in Foraminifera; zone *b*, 4 feet; zone *a*, phosphatic nodules, mammalian remains, and foreign boulders (Nodule bed), 1 foot, on London Clay. The Ramsholt pit was correlated with part of zone *c*.

2. At *Broom Hill*; zones *d* and *c*. Pit near the Keeper's Lodge, one mile west of Orford Church: Under the surface soil and drift (3 feet); zone *e*, 7 feet; *d*, 15 feet, probably lenticular, not exceeding 10 to 12 feet in thickness in 1894.

Foraminifera are abundant in both zones in this section. In zone *d*, in addition to the forms common to most of the Coralline Crag exposures, *Polystomella crispa* is perhaps the most common, together with fine specimens of *P. macella*. Some of the *Polymorphinæ*, as *P. frondiformis*, *P. complanata*, *P. compressa*, and *P. gibba*, are very large and well grown; and the same remark applies to *Pulvinulina repanda.* *Cassidulina lævigata,* not usually a common form in the Coralline Crag, is also fairly plentiful in this zone. In zone *e* we notice the same abundance of *Polystomella crispa,* large and well developed. Other common species are *Textilaria sagittula, Truncatulina lobatula, T. Haidingeri,* and *Rotalia Beccarii.* On the other hand, *Nonioninæ* are rare and small. Milioline forms are remarkably absent.

3. *Sudbourne Hall.*—Under the surface soil and drift ($1\frac{1}{2}$ feet); zone *d*, $6\frac{1}{2}$ feet.

This pit is referred, somewhat doubtfully, by Prof. Prestwich to the zone *d*; but the Mollusca, especially the band with *Arctica islandica,* in a greenish to buff-coloured Crag, so distinctive of this zone at Broom Hill, Sutton, and elsewhere, together with the Foraminifera, confirm this view. Some of the latter are here very fine; specimens of *Polymorphina frondiformis* 5 mm. long, and of *P. complanata* 4 mm. long, are not uncommon. *Polymorphina variata* is also plentiful and well grown, together with *Textilaria agglutinans* (varieties) and *T. trochus.*

4. *Tattingstone* (*Park Farm*); zone *d.*—Prof. Prestwich kindly supplied some material from the outlier of Coralline Crag occurring in this locality, four and a half miles south-south-west of Ipswich. The section is now much overgrown; but originally, beneath 12 feet of Red Crag, about 8 feet of Coralline Crag were exposed. This was referred with some doubt by Prof. Prestwich to his zone *d*; and the foraminiferal fauna differs somewhat from that referable to this zone in other localities. *Lagenæ* are fairly plentiful; *L. lacunata* and *L. melo,* not often met with elsewhere, being rather common. Excepting some species which range through the entire formation, Foraminifera are rather rare.

5. *Sutton*; zones *e, f,* and *g.*—The pits in this classical locality are now somewhat obscured, weathered, and overgrown. The celebrated Bullock-yard pit, about 250 yards south-west of Pettistree Hall, furnished the late Mr. S. V. Wood with the bulk of his extensive collection of Mollusca from this formation. In 1894 a comparatively fresh excavation, some forty to fifty yards north of the Bullock-yard pit and facing Pettistree Hall, showed: Under the surface-soil (2 feet); zone *g*, 2 to 3 feet; zone *f*, 5 feet; zone *e*, $4\frac{1}{2}$ feet. The strata are in all probability lenticular and unevenly bedded. Here the zones *e* and *f* have yielded a rich foraminiferal fauna. The latter gives *Polymorphina frondiformis, P. variata, P. gibba, P. complanata, P. communis, Textilaria gibbosa, Biloculina ringens,* etc.; while the *Lagenæ,* rarer as individuals, are numerous in species. *Dentalina pauperata,* 6 mm. long, *D. obliqua,* 7 mm. long, *Polymorphina nodosaria,* 4 mm. long, and *Dimorphina tuberosa,* 4 mm. long, are not infrequent. In zone *e* the species common in the same zone at Broom Hill are also plentiful here; and *Nonionina scapha,* rather rare there, is very common here and well developed. *Miliolinæ* are rather common, together with *Planorbulina Mediterranensis* and *Discorbina rosacea.*

It seems probable that the greater number of the species recorded from Sutton in the First Part of the Monograph of the Foraminifera of the Crag (1866) were from zone *f*; but, if that were not so, it is now impossible to separate those found in zone *e*.

6. *Gedgrave.*—Zones *f*, *g*, and *h* are still well shown in the pits at High and Low Gedgrave, one-and-a-half miles west of Orford.

Pit close to *High House, Gedgrave.* Under the surface soil, zone *h*, 2 to 3 feet; zone *g*, for about 17 feet to bottom of the pit; base not seen.

Pit at *Low Farm, Gedgrave*, close to the marshes, showing in part the downward succession of the High House Pit; zone *f*, $6\frac{1}{2}$ to 7 feet (base not seen). A small pit at *Ferry Barn*, half-a-mile to the south-west, also shows a good exposure of this bed, with Foraminifera and small Mollusca.

Zone *f* is rich in Foraminifera, some being large and striking, *e.g.* *Textilaria agglutinans*, *T. gibbosa*, *Polymorphina variata*, *P. frondiformis*, *P. compressa*, *P. complanata*, together with large, but rarer, *Biloculina ringens*, etc. *Spirillina vivipara*, usually a rare species, is somewhat common here. Speaking generally, the Foraminifera are closely allied to those from Sutton, zone *f*.

In zone *g* a striking feature is the comparative abundance of *Lagenæ*, particularly the marginate forms. Other rather common species are—*Nonionina scapha*, *Spirillina vivipara*, *Miliolina oblonga*, *Planorbulina Mediterranensis*, *Textilaria sagittula*, *Bolivina Ænariensis*, and *Rotalia Beccarii*.

Zone *h* has probably been reconstructed from a part of zone *g*.

7. *Aldborough*; zone *g*.—The pits near the Red House, Leiston Road, close to Aldborough, show about eight feet of fine, buff-coloured, rubbly limestone full of Bryozoa, in part decalcified. Mollusca are not abundant, those species of which the tests are formed of aragonite having been removed by percolation of carbonated waters. *Chlamys opercularis* is abundant, however, as the shell consists of calcite. Owing to this decalcification, Foraminifera are somewhat scarce in this locality, only a few much decomposed Porcellaneous forms, such as *Miliolina oblonga*, *M. seminulum*, and *Biloculina ringens*, occurring. The Hyaline forms, although better preserved, are usually in a somewhat decomposed condition, with the chambering obscured. Thus probably the original foraminiferal fauna is by no means fully represented.

8. *Sudbourne.*—Pits to the north-east of Sudbourne Church. The upper beds in this neighbourhood are nearly all referable to zone *g*; they are very ferruginous, and the Foraminifera badly preserved. Eleven species, mostly common elsewhere, have been found; they are plentiful, but obscured with iron-oxide.

III. *Lenham Beds.*—The sands and fossiliferous ironstone found at Lenham, in Kent, by Professor T. Rupert Jones and Mr. W. Harris, were referred in 1858 by Professor Prestwich to the Crag and Diestian Series; and this has been confirmed by further comparison of the fossils with those of Diestian age. These sands do not appear to have been examined for Foraminifera, and probably decalcification would cause a false conception to be taken of the protozoan life.

IV. The *Nodule Bed*; zone *a*, originally exposed at Sutton (see above).—In the exposures now open, as at Foxhall, the mixed and remanié character of the deposit precludes any trustworthy inferences being made from such specimens as might be found.

Note.—Some Foraminifera derived from much older Tertiary beds were found by Mr. Searles V. Wood in the Coralline Crag of Sutton and elsewhere, namely, *Orbitolites, Orbiculina, Alveolina, Peneroplis, Amphistegina, Nummulites*, and *Orbitoides*; mostly unique specimens.

The value of Foraminifera as a means of establishing stratigraphical correlation, with few notable exceptions, such as *Nummulites* and *Fusulina,* has not perhaps been so fully recognized as it might be.

In the Coralline Crag the most strikingly constant Foraminifer is *Polymorphina frondiformis*, and this species appears to be characteristic of this horizon in England. So far as I am aware, it is not met with in the Antwerp Crag. I have collected and examined material from the Casterlian and Scaldisian of the Kattendyk Docks, but have not found this species; nor is it recorded from the Diestian. May this not prove that the Antwerp beds are of somewhat different age to those of England?

The "constancy and determinability" of the zones established by Professor Prestwich for the Coralline Crag were doubted by Messrs. S. V. Wood, jun., and F. W. Harmer; but the foregoing notes tend to prove that there is good ground for accepting his subdivisions. The exact correlation of isolated patches of the Crag is not in all cases easily established; and further research is needed to finally settle the relationship of some of them.

So far as my researches on the Mollusca of the Crag have extended, and I have collected for several years from almost every exposure now open, they confirm the zonal arrangement of the beds. The band with *Arctica islandica* is apparently constant to zone *d*. At Sutton and Gedgrave, points widely separated in the Crag area, zone *f* is characterized by the relative abundance of species which are either absent or rare in other zones; among such may be named *Bullinella acuminata, B. conulus, Adeorbis subcarinatus, A. pulchralis, Trochus obconicus, Raphitoma brachystoma, Turbonilla elegantior, Lima ovata*, and others; while some species, though not so distinctive of this zone, are far more abundant than in any other, such as *Ringicula buccinea, Cæcum mammillatum, Triforis perversa, Astarte Forbesi*, and other species.

NOTICES OF MEMOIRS.

Snow Dust. By Prof. Cleveland Abbe. *Monthly Weather Review*, January, 1895, pp. 15–19. (U.S. Weather Bureau.)

On the night of January 11–12, 1895, a shower of dust in connection with snow fell throughout a large part of Indiana and Kentucky. The dust may have been intermingled with snow in the air, or may have fallen with the wind that preceded a second snowfall. At any rate, it was found afterwards forming a layer of dirty snow, between two clean layers of snow, and it was thus easy to gather it free from the underlying soil. A large number of specimens were collected and were submitted to microscopical and physical examination. The dust was found to be largely made up of silt, mixed with organic matter, and was probably derived from some dried-up lake, pond, or marsh to the north-west. Professor Whitney's mechanical analysis shows that it is almost identical with the loess that covers great areas in Illinois, Nebraska, and other adjoining States, and he gives the following Table showing the percentage by weight of the contents of air-dried samples:—

	Moisture.	Organic matter.	Medium sand, 0·50—0·25 mm.	Fine sand, 0·25—0·10 mm.	Very fine sand, 0·10—0·05 mm.	Silt, 0·05—0·01 mm.	Fine silt, 0·010—0·0005 mm.	Clay, 0·005—0·0001 mm.
Rockville, Ind., black snow	3·17	11·98	0·00	0·00	0·00	69·37	5·80	9·68
Virginia City, Ill., upland loess... ...	...	...	0·00	0·01	7·68	61·85	9·60	15·15
Virginia City, Ill., valley loess	...	...	0·01	0·10	24·84	60·98	2·80	6·15
Nebraska loess formation	5·40	4·96	0·00	0·00	23·14	54·81	2·46	9·45

The different estimates of the amount of dust that fell vary from $12\frac{3}{4}$ to 150 lbs. avoirdupois per acre. C. Davison.

REVIEWS.

I.—Chemical Crystallography. An Introduction to Chemical Crystallography. By Andreas Fock, Ph.D. (Berlin). Translated and edited by William J. Pope. (189 and xvi pages, 8vo.) Clarendon Press, Oxford.

MASKELYNE'S "Morphology of Crystals" has been quickly followed by a companion volume issued from the same Press, and dealing, not with the geometrical form, but with the origin, growth, and chemistry of crystals. In a review of the former book it was stated that Crystallography has now developed relationships with other sciences, by which it is invested with numerous practical applications. Fock's little book should be read by every chemist or geologist who wishes to have a thoroughly lucid and reliable account of the manner in which crystallography dovetails into chemistry, and especially of the remarkable problems which have emerged into prominence during the last few years in the region of physical chemistry. Some of these have come into existence since the date of the German edition, and account for the large amount of additional matter which appears in the English translation.

Osmotic pressure, diffusion, the nature of double salts and isomorphous mixtures, the equilibrium between different substances in a mixed solution—all these are subjects of vital importance to the chemist, and of no less interest to the geologist who occupies himself with the study of igneous magmas. Important above all is the experimental work of Roozeboom upon the last-mentioned problem. About a third of the book is devoted to a sketch of isomorphism, under which these points are ably treated. There is, of course, mixed with established facts much that is hypothetical, and little attempt is made by Dr. Fock to sift the one from the other; but he has, at any rate, given a truthful abstract of work which was previously only to be found dispersed through many books and journals.

Mr. Pope has made an excellent translation, and has done good work in bringing the subject to the notice of English readers. The result of his collaboration with Dr. Fock has been to supply a thoroughly attractive and readable survey of all that is known at the present date about chemical crystallography or crystallographic chemistry.

II.—An Introduction to the Study of Rocks. By L. Fletcher, F.R.S., etc., Mineral Department, British Museum (Natural History). Printed by Order of the Trustees: London. 8vo, pp. 118. Price 6*d*.

THIS Handbook may well be considered alongside of the Guide to the Collections of Rocks and Fossils belonging to the Geological Survey of Ireland.[1] Both in a measure show the difficulties of grouping information which relates to diverse specimens arranged in cases; but the methods adopted in the two works are in many respects widely different. In the Survey Guide, the age, method of formation, and life-history of the rocks are dominant features; in the British Museum Guide, greater prominence is given to their mineral structure and characters.

Commencing with definitions of different kinds of rock and of large mineral masses, the author proceeds to describe their varieties of structure and composition, and the methods of crystalline growth. In reference to characters he uses the term *petrical* for those to be observed in large rock-masses in the field; and *lithical* for the characters manifested by fragments of rocks, such as are preserved in a museum. Then follow concise and excellent explanations of many terms commonly used to describe these various characters.

The variations in rock-masses and the similarities between rocks of different ages are duly noted; and it is pointed out that the same mass may at one age belong to one kind, at another age to a different kind of rock, as a result of metamorphism. Serpentine is cited as an example.

The author then expresses his determination "that rocks should

[1] *Infra*, p. 516.

be distributed into kinds by means of lithical characters alone," and states that these may be grouped in regard to Mineral composition and Structure. He takes thirty different rocks, and seeks to ascertain how they may be classified. Seven preliminary groups are first made, but they lead to assemblages which are more curious than instructive. Thus, among "Rocks essentially composed of material belonging to a single mineral species," we find Rock-salt, Quartz-rock, Limestone, and Serpentine grouped together; and again, among "Rocks which, though really composed of material not belonging to a single definite mineral species, are so far homogeneous in aspect that the essentiality of the compositeness is concealed from the unaided eye," we find Coal, Clay, Obsidian, Phonolite, and Felstone arranged together. We may, indeed, question the value of such temporary assortments. It is as if we arranged the books in a library according to their bindings; and the author himself proceeds to show that any arrangement based on apparent simplicity is unsatisfactory for purposes of classification. He then discusses the modes of origin of the rocks belonging to his seven preliminary groups, and also the processes by which the rocks have attained their present characters. This leads to certain re-arrangements in his groupings, and to a number of separate descriptions of the principal rocks. Hence the student must turn from page to page if he wants to learn all that is said about crystalline schist, gneiss, slate, shale, or any other rock. The index will here prove very serviceable, but we venture to hope that in the future editions of his work the author may find ways of simplifying his groupings and descriptions of rocks. He has devoted great care and pains to his work, he has given us much valuable and precise information, and has pointed out a number of ways in which rocks may be arranged; but we believe the student would have found the path to knowledge easier if one general classification had been given, and if the descriptions of each type of rock had been in sequence.

Like all the British Museum publications, this work is excellently printed, and in respect both to type and paper it sets an example that might well be followed by Her Majesty's Stationery Office. Its price is sixpence.

III.—Petrology for Students: An Introduction to the Study of Rocks under the Microscope. By Alfred Harker, M.A., F.G.S. (Cambridge, at the University Press).

THIS is a book which presents no easy task to the reviewer; it is so full of thorough and useful work and so carefully put together that there is practically nothing in it to correct and little to add, while to endeavour to make an abstract of it would be to make an extract of Liebig or to compress pemmican. Avoiding the long description of the petrological microscope which usually occupies so many of the first pages in a book of this kind, referring to other special works for descriptions of minerals, and laying aside any digression on methods of research other than study in the field, with the lens, and with the microscope, the author plunges at once into his subject and teaches us just exactly what we want to know about the shape, appearance, and general optical characters to be observed in the microscopic study of minerals, and of the rocks which they constitute. Then with a few passing words on classification he begins his description of Plutonic rocks with the Granites.

He divides the igneous rocks into three broad classes, of which the plutonic class needs no explanation; the intrusive rocks are defined as "certain families of rocks" which "are met with almost exclusively in the form of dykes, sills, laccolites of small dimensions, and 'pipes' of old volcanoes"; and the volcanic rocks are those which "have consolidated from fusion under superficial conditions, *i.e.* by comparatively rapid cooling under low pressure."

An uniform mode of description is adopted throughout. After a few preliminary remarks on each great rock-group we are given a list of the constituent minerals and their characters in the rocks in question, an account of the structure of the rocks, of their leading types, and, where necessary, of their special modifications. The leading types, whenever possible, are defined from British examples, but where the British Isles fail to supply the desired information the whole world is laid under contribution. The especial value of this part, and indeed of the entire work, is that the description is written in almost all cases direct from the actual specimens, and the author tells us with reserve of particulars and variations which have not come within the wide range of his own personal observation. Notwithstanding this, very full references are given throughout, and this will make the book especially valuable to the advanced student, as it gives him a mine of bibliographic detail.

A slight slip occurs under the Diorites, where the rocks of Nuneaton are stated to be probably of Carboniferous age. As a matter of fact these diorites, like the Cambrian sediments into which they are intruded, are unconformably overlain by Carboniferous rocks, and are almost certainly not later than Ordovician in point of date. Where similar rocks occur, as at Inchnadamff, the Wrekin, and the Longmynd, they penetrate Cambrian or older rocks only, and have never been found to touch Ordovician strata.

The term Gabbro is not used quite in the sense suggested by Teall, but appears to be confined to rocks possessing the diallagic modification of augite. Two main types of ultrabasic rocks are recognized, the picrites and the peridotites, the former "having usually subordinate plagioclase," the latter being non-felspathic. In dealing with the basic intrusive rocks Mr. Harker departs from the usual, and, as we venture to think, the best, practice of British petrologists in declining to use the term diabase for the altered representatives of the dolerite family, and in applying it to ophitic and granulitic rocks which "are holocrystalline and typically non-porphyritic." Thus the word dolerite is reserved to designate volcanic rocks of basaltic composition in which the distinction between phenocrysts and ground-mass is not well marked. By such use of terms we find the Ordovician sills of Carnarvonshire, the Whin Sill, and the Clee Hill rock named diabases, but when we look for dolerites amongst the volcanic subdivision we find the term not very decisively defined and applied to only two rock-groups, those known as Toadstones in Derbyshire and the ophitic and granulitic rocks of the Inner Hebrides.

It is interesting to notice that the criterion of age is once and for all swept away in naming volcanic rocks, and the author uses such terms as rhyolite, trachyte, and basalt for volcanic rocks of Tertiary and pre-Tertiary ages.

Sedimentary rocks are dealt with in considerable detail under the usual headings, and we would call especial attention to the full and accurate treatment of the calcareous division, which includes an account of the microscopic appearance of the chief organic constituents of these rocks.

The last but by no means least important part of the work is devoted to the consideration of metamorphism, beginning with a masterly account of the minerals developed by thermal action in various kinds of rocks, igneous, sedimentary, and even foliated. Dynamic metamorphism is also ably treated, a distinction being drawn so far as possible between the direct effects of pressure and movement and the secondary effects due to heat liberated by crushing and shearing. A lumber room has still to be provided for the reception of "various crystalline rocks," including schists, gneisses, granulites, and eclogites; some of these are shown to be due to thermal metamorphism, others to dynamic action on sedimentary or igneous material, and the rest are probably original igneous products.

The Pitt Press is to be congratulated on the printing and appearance of the book, and the proof-sheets have evidently been read with extreme care; but it is a great pity that the drawings, on which much labour has clearly been spent, presumably by the author, have not been reproduced by some more satisfactory process, which would have dealt more tenderly with the minuter details in them.

In closing the book we have only two words to add to the student, be he field-worker, petrologist, or mineralogist—*Read it.*

W. W. W.

IV.—Guide to the Collections of Rocks and Fossils belonging to the Geological Survey of Ireland. By A. McHenry, M.R.I.A., and W. W. Watts, M.A., F.G.S. 8vo, pp. 155. (Dublin: Printed for Her Majesty's Stationery Office by Alexander Thom and Co., 1895. Price 9*d.*)

THE collections of rocks and fossils belonging to the Geological Survey of Ireland are deposited in the Science and Art Museum at Dublin. Commenced when Jukes was Director of that Survey, the collections of late years have been much amplified, so that they are well calculated to illustrate the general geology of Ireland. The original collection was fully described in a catalogue prepared by Jukes, and all the facts of importance published therein have been incorporated in the present volume. Moreover, the works of the many geologists (whether connected with the Survey or not) who have made a study of Irish Geology, have been consulted in the preparation of the Guide, so that it aims to give a summary of all the leading facts connected with the subject. That this aim has been fully and most carefully carried out, will be acknowledged by all who peruse the work of Messrs. McHenry and Watts.

At the same time it will be freely conceded, that it is almost impossible to produce a work that will readily serve all the wants of those who have access to the Dublin Collection, and of those who seek only to learn the latest results of enquiry relating to the Geology of Ireland. To get a connected account of each formation we have to look under four headings devoted to each province, and there is no index to facilitate reference. With patience, however, the student will be able to glean what he wants; and the entire work contains such valuable records of fact and so many lucid explanations and suggestions (all for the small sum of ninepence!), that it should be in the hands of every working geologist.

The rocks, stratified and igneous, are described in four great groups, those of Leinster, Connaught, Ulster, and Munster. The following are the formations described:—

Recent	Blown Sands, Alluvium, Peat, etc.
Pleistocene	Glacial Drifts.
Pliocene	("Manure Gravels" of Wexford.)
Eocene or Oligocene	Upper Basalts. Leaf Beds, etc. Lower Basalts.
Cretaceous	Chalk. Upper Greensand.
Jurassic	Lias.
Triassic	Rhætic Beds. Keuper. Bunter.
Permian	
Carboniferous	Coal-measures. Millstone Grit. Yoredale Series. Carboniferous Limestone. Lower Carboniferous (Slate, Sandstone, etc.).
Old Red Sandstone	Upper. Lower (including Dingle Beds).
Upper Silurian	Ludlow Wenlock. Tarannon. Llandovery.
Lower Silurian	Caradoc-Bala. Llandeilo.
Cambrian	
Foliated Crystalline Rocks.	

We observe a certain amount of reticence in assigning any particular age (even a pre-Cambrian age) to the several areas of crystalline schists: and there is justification for caution. While Kinahan, in 1878, remarked that "Rocks older than the Cambrian formation are not known in Ireland"; Hull, in 1891, observed that "Recent investigations have conclusively established the existence, in several detached areas, of representatives of these [Archæan] the most ancient of known rock-groups."

In the present work the authors include under the general heading of "Foliated Crystalline Rocks," granites that in places graduate into gneisses, various schists, micaceous limestones, and grits, all more or less sheared and foliated. Some of the quartz-schists are very like that group known in the Scottish Highlands as "moyne-schist"; but the only area referred to as Archæan is that of Pettigo, in Donegal, where the hornblendic and granulitic gneisses are grouped with the "old gneiss" of the north-west Highlands. While some of the gneisses are foliated granites, others appear to be altered grits; and with regard to age, the fact is that the complex masses of older plutonic and metamorphic rocks have not yet been fully investigated. Limestones yielding forms referred with some doubt to Corals, occur interbedded with the quartzites and schists in Donegal; and certain shales at Fintown, in Ulster, which occur in association with foliated rocks, have yielded markings like Graptolites. Hence it is as yet impossible to say what infoldings of altered sedimentary and fossiliferous strata may occur amid older and perhaps pre-Cambrian crystalline schists.

No traces of the old trilobite-faunas of the Cambrian rocks have yet been discovered. These rocks in Ireland have only yielded few and doubtful fossils; but the problematical forms named *Oldhamia* are regarded as of "probably organic origin."

In the Silurian rocks the task of following out the zones indicated by Graptolites, has borne good fruit, and the results at present attained by the Geological Survey are duly indicated. Palæontological evidence has thus been obtained to enable more definite correlations to be made with the English and Welsh divisions of the Silurian system.

The Dingle Beds and Glengarriff grits are grouped with the Lower division of the Old Red Sandstone, and this is conformable to the Upper Silurian; while the Upper Old Red Sandstone (Yellow Sandstone Series) passes up conformably into the Carboniferous rocks.

In ascertaining what has been done with regard to the Lower Carboniferous rocks, and their relationship with the Upper Devonian, we should have been glad of the names of some of the common and characteristic species. As it is, genera only are mentioned, and the vexed subject of correlation is not discussed.

Of the newer formations but little need here be said; it is interesting, however, to note that the "Manure Gravels" of Wexford are considered to be of Pliocene date, though newer than the St. Erth Beds.

The Igneous rocks are arranged so as to give the student a history of volcanic action in Ireland from the earliest times to the great eruptions of Tertiary date. Particular accounts are given of the contemporaneous or interbedded volcanic rocks that lie amid the Foliated Crystalline rocks, the Lower and Upper Silurian, the Old Red Sandstone, Carboniferous, and Lower Tertiary; and of the intrusive rocks which penetrate all formations up to the Lower Tertiary. A great many eruptive rocks have for the first time been examined in detail and described, while some of them have proved new to Ireland. Contact-metamorphism is illustrated by the effects produced on all types of sediments by the intrusive dolerites of Antrim.

The section on Fossils contains a useful general account of each great division of Plants and Animals, and a summary of the leading fossils of each group of strata. This is followed by a list, with references, of the figured and type specimens of fossils in the Survey Collection. A brief account is also given of drawings, photographs, maps, and sections that are preserved in the Museum; and the work concludes with an index (under numbers) of the places from which the rock-specimens described in the Guide have been collected.

V.—Geological Papers by Edmund Garwood, M.A., F.G.S., in Vols. I and II of "A History of Northumberland," issued under the direction of the Northumberland County History Committee, and Edited by Edward Bateson, B.A. (Newcastle-upon-Tyne and London, 1893–1895.)

I SHOULD like to draw the attention of geologists, and more especially of those among them who are interested in North-Country Geology, to a series of papers by Mr. Edmund Garwood which, unless they are historians and archæologists as well as geologists, they run the risk of missing altogether.

To antiquarians it is well known that a very elaborate History of Northumberland, on a very large scale, is in course of publication by a learned committee having the seat of its operations at Newcastle-upon-Tyne. Of this great work, two superb quarto volumes of the ten or dozen intended have already been issued to subscribers, and it is much to be feared that many who would wish to keep abreast of the progress of British geology may be unaware that, buried in the mass of topographical, chronological, and genealogical details which necessarily make up the bulk of the work, there are a number of valuable geological chapters—much too valuable to be overlooked without loss.

The scheme of this "History" is, unfortunately, such that the chapters in question are not consecutive, and refer each one to a particular parish or group of parishes, sometimes anything but adjacent. This naturally leads to a considerable amount of repetition, the disadvantage of which is perhaps to some extent counterbalanced by a certain convenience for local purposes which may be conceded to the plan. This criticism apart—and Mr. Garwood is in nowise responsible for the lines on which he has been forced to work—nothing but praise can be meted out to these useful and, in several cases, important additions to Northumbrian geology.

The papers are distributed as follows:—

Vol. I. The Geology of Bamburghshire, pp. 3–9; The Geology of Bamburgh Parish, pp. 13–17; The Geology of Belford Chapelry, pp. 357–362. Appendix I. References to Geological Papers, pp. 417, 418.

Vol. II. The Geology of Embleton Parish, pp. 2–8; The Geology of Ellingham Parish, pp. 217–221; The Geology of Howick, Long

Houghton, and Lesbury, pp. 328–336. Appendix I. References to Geological Papers (continued), p. 496. Appendix II. Sections of Coal Workings in the Mountain Limestone Formation, pp. 497, 498. Appendix III. View of Cullernose Bay, showing junction of the Whin Sill and Sedimentary Rocks (an excellent Photographic Plate). Appendix IV. Coloured Plate, giving the details of the Section from Howick to Cullernose Point. Appendix V. Plate of Sections, showing sedimentary rocks associated with the Whin at Ratcheugh, Little Mill, and the Harkess Rocks, (after Tate and Lebour).

It will be seen from the above list that a great deal of ground has been covered by Mr. Garwood, and it should be added that he has spared neither time nor trouble in carefully going over every inch of it. Though thoroughly master of all that had been previously done in the districts described, the author has used his own judgment in all cases, and has added largely to the facts already recorded concerning them. More particularly I would call attention to his interesting discoveries respecting the minerals resulting from contact-metamorphism in connexion with the Great Whin Sill, to what is probably a raised beach noticed by him on the Howick coast, and to his very pertinent and suggestive remarks respecting the Drift deposits that form a marked feature in much of the country referred to. His work is in no sense a compilation, though he has in every instance endeavoured to do full justice to previous observers, but is the result of honest hard work such as any field-geologist would be proud of. Under these circumstances one cannot but regret that the form of its publication should be likely to withdraw it from the recognition which it deserves.

I may perhaps express a hope that when the series of papers is completed they may be issued separately, and thus rendered accessible (which at present they certainly are not) to ordinary geological readers. G. A. Lebour.

VI.—The Rubble-drift and Ossiferous Breccia in the Island of Palmaria, and on the Shores of the Gulf of Spezzia. By Professor Giovanni Capellini. (Mem. R. Accad. Sci. Istit. Bologna; ser. 5, vol. iv, 1895.)

In this memoir reference is first of all made to Professor Prestwich's various papers on the Rubble-drift and Raised Beaches of Southern England and the Northern Coast of France, in the Journal of the Geological Society of London and the Reports of the British Association, in 1861–65. Professor Capellini then alludes to the deductions drawn from a consideration of this particular Drift, especially as seen at Brighton and Sangatte, and given in the Bulletin Soc. Géol. France, 1880; and to the conclusions arrived at by Prestwich, as published in the Philosophical Transactions, in the Journal of the Geological Society, and Proceedings of the Victoria Institute; and of late published in a separate book treating of the "Tradition of the Flood." These are to the effect that at the above-mentioned places, and elsewhere in Western Europe, the peculiar Drift treated of bears direct evidence of a great submergence, followed by an upheaval of the land, at the close of the Glacial period.

Reviewing the observations formerly made by Pareto, De la Marmora, himself, and others at places on the Italian coast and islands, Prof. Capellini gives the result of his visits to the cave called Cala Grande, in Palmaria, meeting with the characteristic Rubble-drift strongly developed. He adds some interesting details of the discoveries made of late years in the breccia at the Grotta dei Colombi, between the headlands of Pittonetto and Capo dell' Isola, in Palmaria.

In 1863 Prof. Capellini had seen this Rubble-drift lying on the local limestone, as a coarse breccia of limestones, jaspers, etc., at Calandrella, between Pertusola and Santa Teresa; but had regarded it as belonging to the Triassic. Also other coarse breccia near Santa Teresa, Pitelli, and Santa Terenzo. These corrections will be made in the explanation of the geological map of the environs of Spezzia.

On the east side of the Gulf of Spezzia he has defined the limits and height of the Rubble-drift, in connection with the small masses of ossiferous breccia of Monte Rocchetta; and he finds that it covers the highest parts of the Isle of Palmaria or southern extremity of the west side of the Gulf. The range on the east side was probably submerged for more than 200 mètres of its present height at the end of the Palæolithic period.

Much is to be expected from a close examination of this Rubble-drift on the Italian coasts and islands, in connection with the numerous caves and bone-bearing breccias. Prof. Capellini fully adopts Prestwich's views as to the nature and origin of the Rubble-drift; and points out that it is probably the same singular deposit of which several geologists have noticed traces on the coasts of the Mediterranean, and of which Professor Issel (treating of the Raised Beach between Arenzano and Cogoleto) has well remarked that "one could include it neither among the alluviums, nor among the marine Quaternary deposits."

VII.—A Geological Enquiry respecting the Water-bearing Strata of the Country around London. By Joseph Prestwich, F.G.S., etc. 8vo. (London: Gurney and Jackson, 1851–1895.)

At the time of the first publication of this work, the Lower Greensand was regarded as underlying London, and as a possible source of water-supply. Subsequently, however, the deep boring by the New River Company at Camden Town proved the contrary. A large plate accompanied a partial issue of this book, but was accidentally destroyed, and the rest of the printed sheets remained on hand. Since that time it has been proved that the Palæozoic ridge beneath London is limited in its extent both eastwards and westwards; and that the outcrop of the Lower Greensand is wide enough to receive sufficient rainfall to allow of its yielding a good water-supply. On the west, favourable localities are near Leatherhead and Windsor, and in the Godalming and Hindhead district as originally stated; and on the east, in the neighbourhood of Shoreham, Strood, Frindsbury, and Loughton. Hence the re-issue of this useful work, with its woodcuts (without the original plate), and with additions by the author, Professor Prestwich, D.C.L., F.R.S., etc.

VIII.—The Climates of the Geological Past and their Relation to the Evolution of the Sun. By Eug. Dubois. 8vo, pp. 167. (London: Swan Sonnenschein and Co., 1895. Price 3*s.* 6*d.*)

THIS interesting and suggestive little volume is worth reading, even though geologists may not be prepared to accept the author's conclusions. Leaving out of account subsidiary questions, his argument is mainly this:—Starting with the accepted hypothesis of a cooling sun, he suggests, from a comparison of the relative number of fixed stars in each class, that there is probably a rapid transition from the "white" or hottest to the "yellow" or second stage, and a more gradual transition to the "red" or coolest stage. He then alludes to the evidence of long-continued genial conditions in the earth's climate, extending apparently with little change from Carboniferous to Cretaceous times. This genial and almost changeless period he correlates with the "white" stage of the sun's history—when the sun was comparable to Sirius or Regulus in the light and heat he gave out. Then, arguing from the scarcity of transition stars between the white and yellow class, he thinks that there came a rapid change to the yellow, or Capella, stage, and a great fall in the heat radiated by the sun; this period of rapid refrigeration being represented by the Tertiary period, with its fast diminishing temperature. At the beginning of Pleistocene times the yellow stage was reached, and a series of Glacial and inter-Glacial epochs set in, corresponding with oscillations of the sun between the "yellow" and the "red" or coolest stage. It is for the astronomer and physicist to criticize these speculations; but to the mere geologist it seems as if the author were hurrying things on rather too fast, if we must accept so vast a change in the condition of the sun as having occurred during the small portion of geological time that extends from the commencement of the Tertiary period to the present day.

For a second edition it would be well to have the proofs examined by an Englishman. The translation is usually well done; but one occasionally comes across German or Dutch idioms which, not having the original by us, are not easy to comprehend. Among the plants mentioned we find "Cornelian" (for Cornel) and "wolfs' claws" (given as a living plant allied to *Lepidodendron*).

IX.—Fauna Fosil de la Sierra de Catorce, San Luis Potosi, por Antonio del Castillo y Jose G. Aguilera. Boletin de la Comision Geológica de México. No. 1. (Mexico, 1895.)

The Fossil Fauna of the Sierra of Catorce, in San Luis Potosi, Mexico. 4to, pp. ix and 55, pls. i–xxiv.

THE Sierra of Catorce is a comparatively isolated ridge, about 10 leagues in length and 2 in breadth, with a plateau-like summit, which is elevated 1200 metres above the plains of San Luis. It is a well-known mining area. The Sierra consists of three principal rock divisions: the lowest is formed of altered shales or phyllites, in which no fossils have as yet been discovered; the second division, which is rich in fossils, is built up of arenaceous and marly shales; whilst the upper division consists of a shaly lower portion, and over this compact gray limestones with nodules and bands of chert or flint. This upper division contains species of *Exogyra*, *Lucina*, *Phylloceras*, and *Schloenbachia*, which are considered by the authors to represent the Aptian and Albian stages of the Lower Cretaceous.

The main purpose of this memoir is the description of the fossils of the second division, which are regarded as in part of Jurassic age, and in part Cretaceous. The authors subdivide the formation into higher and lower groups. The higher, or Cieneguita, is of shales and sandy marls, more or less calcareous, which contain no fewer than nine species and varieties of *Aucella*, together with *Lytoceras*, sp.n., *Placenticeras*, sp.n., *Pulchellia*, sp.n., and *Olcostephanus*, sp.n. The most important and numerous of these fossils are the various species of bivalve mollusca of the genus *Aucella* which are intermingled in the different strata of this subdivision, the thickness of which altogether does not exceed five metres, whilst in Russia five of these same species, according to Lahusen, characterize as many different zones of the Upper and Lower Volgian! As the Mexican Beds contain as well a form of *Olcostephanus*, which is nearly identical with *O. Asterianus*, D'Orbigny, from the Neocomian, and a species of *Pulchellia*, a genus exclusively Lower Cretaceous, the author thinks that the higher group with *Aucella* should be regarded as Neocomian.

The lower subdivision, or the Alamitos group, consists of fine-grained sands and argillaceous shales. It contains *Rhynchonella*, 2 sp., *Terebratula*, 2 sp., *Waldheimia*, sp.n., *Aucella Bronni*, *Cucullæa*, sp.n., *Lucina*, 2 sp.n., *Cyprina*, sp.n., *Cyprimeria*, sp.n., *Goniomya*, sp.n., *Pleuromya*, sp.n., *Vermetus*? sp.n., *Nautilus*, sp.n., *Rhacophyllites*, 3 sp.n., *Haploceras*, 3 sp.n., *Perisphinctes*, 16 species, of which 12 are new, *Olcostephanus*, sp., *Hoplites*, 4 sp.n., *Aspidoceras*, sp.n., *Aptychus*, 2 sp., and *Belemnites*, 2 sp. Reviewing the affinities of the various forms in this group, it is placed as Upper Jurassic, probably on the horizon of the Kimeridge and Portland Beds.

The descriptions of the fossils in this memoir appear to have been carefully drawn up, but the figures are not sufficiently clear to allow of any safe judgment to be formed as to the characters of the species they are intended to represent. This is the more unfortunate since such a large proportion, more particularly of the Ammonites, are described as new. As regards these latter, it may be remarked that in no single instance are the suture-lines figured, and as they are only referred to in one or two cases, it may be supposed that they are not shown in the type-specimens. Again, it would be impossible to discriminate from the figures the various species of *Aucella*, and unless the originals show the specific characters clearer than the figures, not much weight will be placed on the remarkable statements as to the distribution of these forms in the Mexican beds as compared with those in Russia.

This memoir is an important contribution to the Geology of Mexico, and it may be hoped that it is the first of a series which will make known the geological characters of that country in detail.

G. J. H.

CORRESPONDENCE.

REPLY TO PROFESSOR HULL ON THE GLACIAL DEPOSITS OF ABERDEENSHIRE.

SIR,—Anything Prof. Hull writes is sure of respectful attention in many quarters—not least in that part of the West of Scotland where he laboured during an early stage of his geological career, and where he still has some good friends. From the lettered retreat in which he fitly "crowns a youth of labour with an age of ease," the Professor emerges (in your last Number) to rebuke and exhort a "neo-glacialist" for his errors and "fanciful views" regarding non-submergence and the Glacial period. May the heretic be allowed a few words by way of reply?

The Glacial deposits of Aberdeenshire consist, it may be repeated, of the following, in ascending, *i.e.* chronological, order:—

1. Lower Grey Boulder-clay, derived from the rocks of the district.
2. Beds of Gravel and Sand, with water-worn pebbles and fragments of shells.
3. Upper Red Clay, with boulders and a few marine forms.

No. 1 is admitted to be the *moraine profonde* of an ice-sheet which once extended seaward from the mountainous region on the west. The only questions are regarding 2 and 3. Under what conditions were they formed? Do they indicate submergence up to, or somewhat beyond, the highest level at which they are found? Or are they also due—under certain changing conditions—to land-ice? The answers to these questions are various:—

Dr. Jamieson says No. 2 *does not,* but No. 3 *does* indicate submergence.

The Geological Surveyors say No. 2 *does,* but No. 3 *does not.*

Professor Hull says *both do.*

The only other possible view is also held, viz. that *neither* indicates submergence.

Now, as Dandie Dinmont used to observe, "that makes an unco difference"; and in such a divided, not to say disorderly, state of opinion on the subject, it seems hardly fair to say, or imply, that anyone trying to throw additional light upon it is animated by an "innate love of change."

After laying down the grand "rational" rule or principle that "deposits differing in composition and structure from each other should have been formed under different sets of conditions," Prof. Hull goes on to state the "evident succession of conditions" of these three differing superimposed deposits in Aberdeenshire, viz.:

1. "General land glaciation" (admitted).
2. "Submergence in sea-waters" (?).
3. "Continued submergence" (!).

These are the "different sets of conditions" for the "diversified forms" of deposits 2 and 3! Of course, Prof. Hull may explain that other conditions, which may vary, are included under "submergence"; but if so, he must allow glacialists, "neo-" or otherwise, to say the same (with as much, or they may think, *more* reason) of "glaciation."

We shall look at these other conditions immediately. Meantime it seems almost sufficient to remark that Prof. Hull has first of all to settle matters with Dr. Jamieson. That careful observer concluded from his study of the materials of these deposits (2 and 3) that both had been transported by northward-moving land-ice. Prof. Hull seems to overlook entirely the essential facts which led Dr. Jamieson to this conclusion. These are: *first*, the presence in both deposits of stones foreign to the district, and not found even in the Grey Till underneath, but, particularly in No. 3, clearly derived from tracts to the south; *secondly*, striations on rock-surfaces confirming this, showing first a local glaciation from the west, followed by a more general one from the south; and *lastly*, the fact that the shelly fragments in No. 2 were largely of *Crag* species—pre-Glacial forms—which Dr. Jamieson accounted for by inferring that the northward-moving ice had "scoured out" some area of the *Crag* along the coast, and conveyed the materials to some extent northward and inland in its progress. All this Prof. Hull overlooks. The result is striking. A deposit containing fragments of Pliocene or pre-Glacial shells and pieces of "yellow limestone and calcareous shale not now found *in situ* in Aberdeenshire," is supposed to be due simply to an inter-Glacial submergence!—after the country had been swept by a "great ice-sheet," in whose *moraine profonde* no trace of such rocks or organisms can be found!

Thus it becomes evident that the other conditions which Prof. Hull adds to submergence, even if granted, will not account for the deposits in question. "Sand and gravel brought down by rivers from the adjoining emergent lands" could not contain fragments of rocks not found there either *in situ* or in fragments, and of which there is no evidence that they have ever been there. Then Prof. Hull supposes that the "continued submergence" was accompanied by "the recurrence of cold conditions"—rather a violent supposition, for the obvious natural tendency of submergence (in this part of the world, at least) would be in the opposite direction, towards *milder* conditions of climate.[1] But granting the supposition for a moment, it is clear that "glaciers occupying the higher elevations" could not produce a "Red Clay" totally unlike the waste of the rocks of the district (as Dr. Jamieson has pointed out), nor mingle that clay with foreign materials, such as "stones of a volcanic nature unlike the rocks of Aberdeenshire or the North of Scotland,"

[1] See this MAGAZINE for Sept., p. 403.

but resembling the masses of trap which occur in the Old Red of Forfar and Kincardine.

In short it appears that the facts of the case, with singular perversity, resist all Prof. Hull's endeavours to place them under the "saut water!"

Passing from this, the Professor makes the following remarkable statement: "I would observe that the ice of the North Sea . . . was only forced over the land while the North Sea was blocked by ice, in which there were neither shells, star-fishes, nor probably seals." Surely Prof. Hull understands that in all such cases the contention is that the ice has transported materials formed in the sea-bed *before* it was so blocked? If he does not believe in such transport, then he has to settle matters with Sir Arch. Geikie, Dr. James Geikie, Messrs. Peach, Horne, De Rance, Clement Reid, Lamplugh, and many others, before condescending to me! Or are they all "neo-glacialists" together, and alike smitten with "the innate love of change"?

The Professor speaks as one standing on the shore of truth, and looking out over a sea of error, of "the confusion which has arisen among the neo-glacialists regarding the glacial phenomena of the British Isles." It seems very evident that the sect or school of geologists referred to (whoever they may be) did not *make* the confusion, but only *found* it.

As Prof. Hull ends by quoting part of a private note from Dr. Joseph Prestwich, I may also close with a sentence from the same high authority—a sentence which may well be taken as a guiding light in all discussions on this subject. In his standard work on "Geology," speaking of those slow movements of the earth's crust, of which the latest evidences are seen in our "Raised Beaches," that distinguished author sums up as follows:—"Continuous for long periods in the earlier times, and productive of settlements to be measured, in Cambrian and Silurian times, by thousands of feet, they have gradually diminished in intensity and power, until, in the later geological times, those great slow continental movements became limited to hundreds, and in more recent times have become reduced to, so to speak, tens of feet, or to a state of comparatively stable equilibrium."—(Vol. ii, p. 525.)

Glasgow, *9th October.* Dugald Bell.

Postscript.—I have omitted to notice Prof. Hull's remark on the little sketch map in my paper in the *Quarterly Journal* for August. He says—"On comparing the lines of the ice-movement with the arrows given by Prof. James Geikie in the 'Great Ice Age,' they are almost always at right angles: both cannot be correct." This is very astonishing. I wonder what map Prof. Hull has been looking at? Let the reader judge for himself by turning to the map of the "British Isles during the Epoch of Maximum Glaciation" given by Dr. Geikie at p. 69 of the work referred to. There he will see the lines of ice-movement running up along the Aberdeenshire coast, and curving round to N.W. across the Moray Firth, and over the northern part of Caithness, as I have shown them.[1] Of course it is the recent edition of Dr. Geikie's work that is referred to. Can it be that Prof. Hull

[1] Anyone wishing confirmation of this may also turn to Croll's map of the Ice-Sheet in North-western Europe, in "Climate and Time," or to Sir A. Geikie's map of the glaciation in his well-known "Scenery and Geology of Scotland."

has been founding his remark on the *old map*, in the first or second edition of that work, showing only the earlier glaciation on land, and not at all the subsequent ice-movement along the coast? In any case, as Prof. Hull seems to throw doubt on one's accuracy in the matter, it becomes necessary to point out that the mistake is entirely his own, as doubtless he will readily acknowledge.

THE AGE OF THE RHYOLITES OF COUNTY ANTRIM.

SIR, — The "Proceedings of the Geologists' Association" for August, 1895 (vol. xiv, p. 152), contain a communication made by myself to Mr. R. Lloyd Praeger respecting the probable contemporaneity of the rhyolites of county Antrim and the granite of the Mourne Mountains. This statement was based on notes made by me early in the year, and I had learned, from conversation with Mr. W. W. Watts, that similar views were current among the members of the staff of the Geological Survey of Ireland. Hence the form in which Mr. Praeger utilized the information sent to him.

I wrote, however, in June, before I had received my copy of the GEOLOGICAL MAGAZINE for that month, and hence Mr. McHenry's clear statement of his belief,[1] though by that time published, was not directly referred to. As soon as I read his paper, I forwarded an account of it, and a withdrawal of any reference to myself, to Mr. Praeger, who revised the amended sentences on his proofs; but the correction appears to have been overlooked in the press of business connected with a summer excursion of the Association. I make this explanation, since the passage, as published in August, is distinctly unfair to Mr. McHenry's paper, which has thrown such light upon the question. GRENVILLE A. J. COLE.

ROYAL COLLEGE OF SCIENCE FOR IRELAND,
DUBLIN; *October* 13*th*, 1895.

OBITUARY.

ROBERT FITCH, F.S.A., F.G.S.

BORN OCTOBER 21ST, 1802. DIED APRIL 4TH, 1895.

GEOLOGY, like other branches of Natural History, has owed much of its progress to the zeal of collectors. Of these, one of the most painstaking and successful was the late Robert Fitch, who, in addition to a most valuable collection of antiquities, had gathered together a very fine series of fossils from the Crag and Chalk of Norfolk. He was born at Ipswich, on October 21st, 1802, educated at the Grammar School, and apprenticed to a chemist and druggist in the town. Pursuing this occupation he settled in Norwich, in 1827, in partnership with Mr. Sheriff Chambers, and continued until he was over 90 years of age to take an active interest in business. From an early date he took great interest in fossils, and his specimens were always at the service of those engaged in palæontological studies.

He seldom wrote on geological subjects, his chief literary contributions being to the "Transactions of the Norfolk Archæological Society." In 1836, however, he communicated to the Geological Society an account of the discovery of the tooth of a Mastodon in

[1] "On the Age of the Trachytic Rocks of Antrim," GEOL. MAG. 1895, p. 264.

the Crag at Thorpe, near Norwich; and in 1840 he sent to the "Magazine of Natural History" a "Notice of the existence of a distinct Tube within the hollows of the Paramoudra." In later years he announced before the Norwich Geological Society, the finding of Deer's antlers in the re-deposited Chalk at Hartford Bridges, near Norwich; and also the discovery of Flint Implements in the valley of the Little Ouse. His fine collection is placed in a special room in the new Museum-buildings at Norwich Castle. He died on April 4th, 1895, in the 93rd year of his age.

JOHN ELLOR TAYLOR, Ph.D., F.L.S., Etc.

Born September 21st, 1835. Died September 28th, 1895.

As an enthusiastic lover of Nature, and a popular exponent of Geological and Botanical Science, Dr. Taylor did much to arouse in others an interest in Natural History subjects. The son of the foreman of a cotton factory, he was born at Levenshulme, Manchester, and was employed in early years in the railway-works at Crewe. Developing a taste for literature and science, he read largely, cultivated a facile style of writing, and became a contributor to a Manchester paper. His leisure hours were devoted to Geology, and in his first work, "Geological Essays" (1864), he gave a sketch of the geology of Manchester and its neighbourhood. About the year 1862 he settled in Norwich, as a sub-editor of the *Norwich Mercury*, and stirred up much interest in the geology of the country round the old city. He drew attention to the disturbed Chalk at Whitlingham, Swainsthorpe, and other places; he pointed out the differences in the Mollusca preserved in the two shell-beds in the Norwich Crag at Bramerton; and, in conjunction with the late John Gunn, he established the Norwich Geological Society, which is now incorporated with the Norfolk Naturalists' Society. Before these local Societies, and before the British Association, the results of his geological observations were brought; and records of his work are printed in the earlier volumes of the Geological Magazine. In 1866 he published a little introduction to Geology, entitled "Lithographs," and subsequently other popular works on Natural History flowed from his pen. In 1872 he was appointed Curator to the Ipswich Museum, a post from which he retired through ill-health about two years ago. He contributed a capital "Sketch of the Geology of Suffolk" to White's History of the County; and for many years he was Editor of *Science Gossip*. His Science Lectures at Ipswich and elsewhere were widely appreciated, and of late years he was a strong advocate of the search for Coal in East Anglia.

Dr. J. E. Taylor was present in the Geological Section of the British Association at Ipswich in September last, and spoke on the subject of the deep-boring in search of coal at Stutton; and definitely stated his opinion, that though unfavourable to the anticipations and hopes of himself and others, he believed that the boring had brought up a sample of the Yoredale Shales below the real Coal-measures.

Erratum.—On p. 472, October Number Geol. Mag., line 17 from top of pag for Geniformes read *Gruiformes*.—Edit. Geol. Mag.

THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE IV. VOL. II.

No. XII.—DECEMBER, 1895.

ORIGINAL ARTICLES.

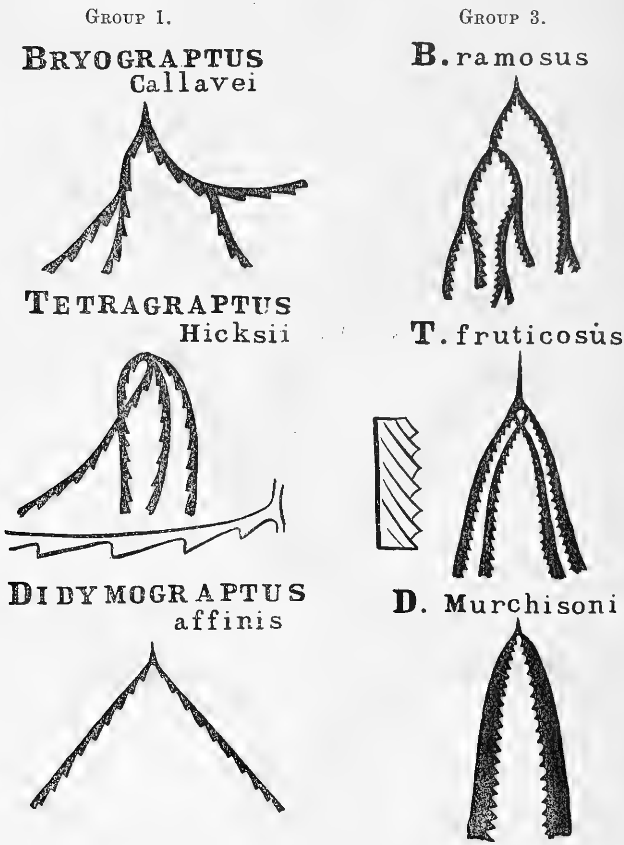
I.—NOTES ON THE PHYLOGENY OF THE GRAPTOLITES.

By Prof. H. A. NICHOLSON, M.D., D.Sc., and J. E. MARR, M.A., F.R.S.

SINCE the remarkable paper by Professor Lapworth "On an Improved Classification of the Rhabdophora" was published in the GEOLOGICAL MAGAZINE for 1873, a great deal of fresh information has been gathered as to these interesting fossils; but the classification given in that paper, though to some extent confessedly artificial, is still generally adhered to. Observations made by the authors in recent years lead them to suppose that that classification will in the future undergo considerable modification; but in the present state of our knowledge it serves a purpose so useful, that it is not our intention to propose any immediate change in it. Our object, on the other hand, is to bring forward certain conclusions which we have independently reached, and which will, we believe, enhance the value of Graptolites to the stratigraphical geologist, and lead to results important to the biologist. Our conclusions are based upon an examination of a large number of forms generally referred to the family Dichograptidæ; but, as we propose very briefly to indicate, they affect the relationships of Graptolites belonging to other families also.

In general, the number of stipes possessed by Graptolites has been looked upon as a character of prime importance; indeed, many of the genera are based essentially on their possession of a certain number of stipes, as for example, *Loganograptus*, *Tetragraptus*, and *Didymograptus*. Again, the "angle of divergence" of the stipes has been considered an important factor in the diagnosis of families. As regards this latter point, however, the existence of a form like *Didymograptus gibberulus*, Nich., in which the angle of divergence is over 180°, whilst the other characters are those of a true *Didymograptus*, shows that this angle is not of primary importance in separating the major divisions of the sub-class Graptolitoidea. On the other hand, we have been led to believe that a character of really essential importance in dealing with the classification of the Graptolites, and one which, in all probability, indicates the true line of descent, is to be found in the shape and structure of the hydrothecæ.

In the more ancient types of Graptolites the hydrothecæ are comparatively simple, differing little from the initial sicula, except in the fact that the proximal aperture gives connection with the cœnosarc.[1] Among these forms there are three more important types of hydrothecæ. In one group, the hydrothecæ are narrow and straight, the neighbouring cells barely overlapping, or not overlapping at all, while the aperture is straight, and is usually at right angles to the back of the stipe. In a second group, the hydrothecæ are also straight, but overlap to a marked extent, while the aperture is straight, and is at right angles to the back of the



stipe or at right angles to the hydrothecæ. In a third group, the hydrothecæ are curved, narrow at their bases and widening towards their mouths, while the aperture is curved, and its upper lip is usually prolonged into a pointed process or spine. In contrast with the comparatively simple hydrothecæ of the older types of Graptolites, we find later types, such as *Dicellograptus*, *Dicranograptus*, and more especially *Monograptus*, generally characterized by

[1] See Holm, Geol. Mag., Dec. IV, Vol. II, p. 435.

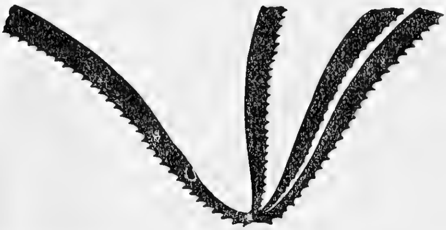
hydrothecæ which are much more complex, and which exhibit very marked modifications of the primitive sicula.

Taking the above facts into consideration, we find reason to conclude that the character of the hydrothecæ is the most important point to retain in view in separating different families of the Graptolitoidea. Taking any group of forms with hydrothecæ of a similar character, we believe that the next most important point to consider as indicating genetic relationship is the "angle of divergence." On the other hand, the number of stipes in the

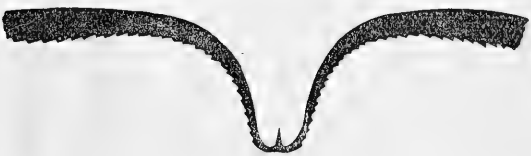
GROUP 2.

BRYOGRAPTUS retroflexus

TETRAGRAPTUS denticulatus



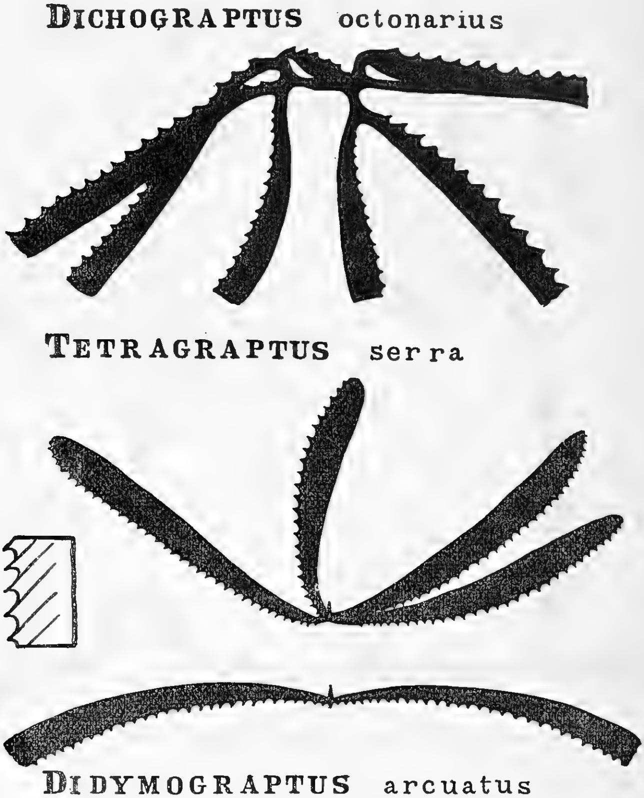
DIDYMOGRAPTUS fasciculatus



polypary is a character of minor importance; since we think it can be shown that, separating Graptolites into groups characterized by their hydrothecæ, the different groups will in many cases exhibit a series of parallel modifications as regards the number of stipes in the polypary, the older forms of the group being the more complex, and the later forms undergoing reduction as regards this particular. Our views may be best illustrated by reference to forms belonging to the "genera" *Bryograptus*, *Dichograptus*, *Tetragraptus*, and *Didymograptus*, the appearance of which in time, in the above sequence, is indicated by stratigraphical observations.

In our illustrations we show nine species of *Tetragraptus*; and we are not acquainted with any others which have with certainty been referred to this genus, except *T. alatus*, Hall, which is only known from examples in very bad preservation. Eight of the *Tetragrapti* are represented by forms of *Didymograptus* which are closely comparable with them as regards the characters of the hydrothecæ and the amount of the angle of divergence; whilst the ninth (*Tetragraptus denticulatus*, Hall) is comparable with *Didymograptus*

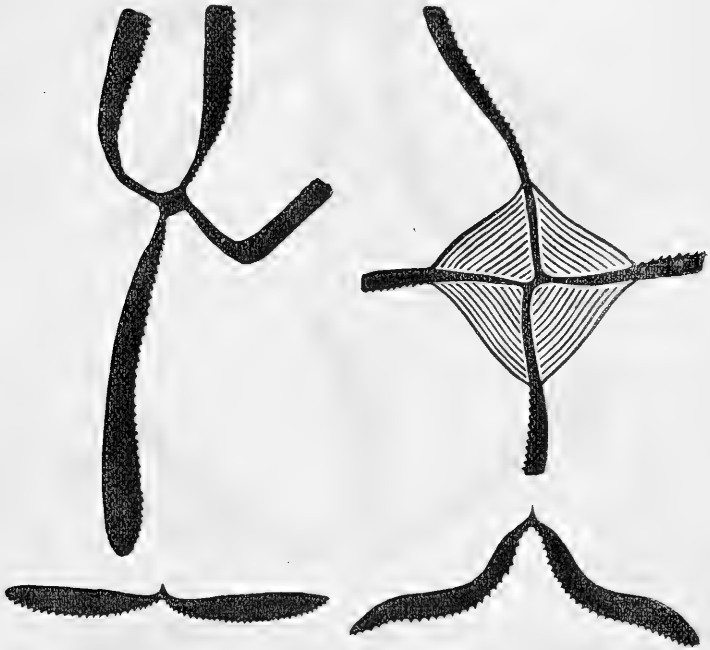
Group 4.



fasciculatus, Nich., as regards the angle of divergence, though the characters of the hydrothecæ of the two differ considerably in minor points. Moreover, four of these four-branched *Tetragrapti* are represented, as regards the characters of the hydrothecæ and the amount of the angle of divergence, by forms of *Dichograptus* or *Bryograptus*, with eight or more branches, and a fifth by a *Bryograptus* which agrees in the amount of the angle of divergence, though the hydrothecæ differ in minor points. Considering the amount of unworked material which we know to be in existence in the case of the "genera" *Dichograptus* and *Bryograptus*, we confidently predict the discovery of forms of these or allied "genera" which will agree with the four remaining *Tetragrapti* as regards the above-mentioned characters.

Taking the series shown in our illustrations in order, we find the following points of agreement in the members of each group of the series, the chief or only points of difference being in the number of stipes in the polypary.

Group 7. TETRAGRAPTUS crucifer — Group 5. TETRAGRAPTUS Headi



DIDYMOGRAPTUS pennatulus — DIDYMOGRAPTUS V-fractus

(1) Group containing *Bryograptus Callavei*, Lapw., *Tetragraptus Hicksii*, Lapw. and Hopk., and *Didymograptus affinis*, Nich. In this group the stipes are narrow, and the hydrothecæ are of the rectangular straight type, and are in contact only or overlap very slightly; while the angle of divergence is about 90°. (This latter feature is not quite clear in the case of *Tetragraptus Hicksii*.) (See p. 530.)

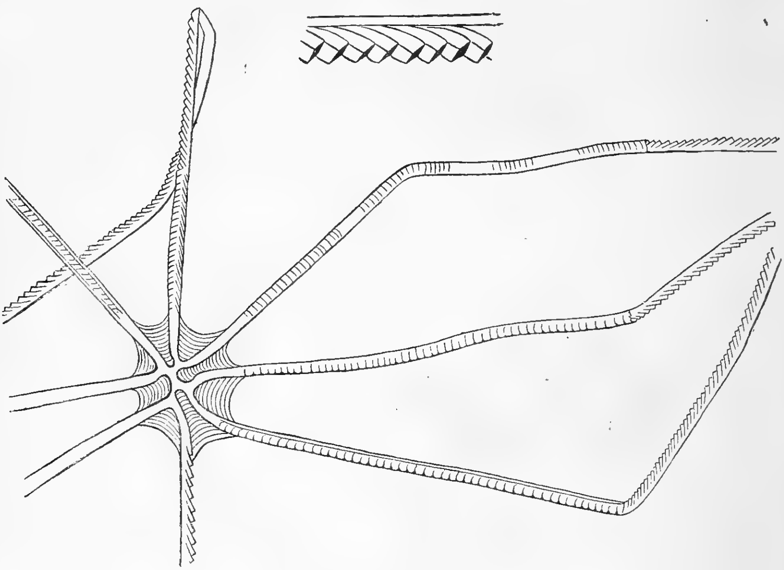
(2) Group containing *Bryograptus retroflexus*, Brögger, *Tetragraptus denticulatus*, Hall, and *Didymograptus fasciculatus*, Nich. In this group the angle of divergence is nearly 180° in the proximal

part of the polypary, the stipes curving backwards and then becoming straighter in the distal portion; while the hydrothecæ overlap, and are variable in form. (See p. 531.)

(3) Group containing *Bryograptus ramosus*, Brögger, *Tetragraptus fruticosus*, Hall, and *Didymograptus Murchisoni*, Boeck. In this group the angle of divergence is less than 45°, the stipes being sub-parallel in the distal portion of their course; while the hydrothecæ are of the straight type, with straight apertures, and overlap one another. (See p. 530.)

(4) Group containing *Dichograptus octonarius*, Hall, *Tetragraptus serra*, Brongn. (=*T. bryonoides*, Hall), and *Didymograptus arcuatus*, Hall. In this group the angle of divergence is over 180°; the stipes are curved, and the hydrothecæ overlap and have curved apertures. (See p. 532.)

Group 5.



Dichograptus octobrachiatus.

(5) Group containing *Dichograptus octobrachiatus*, Hall, and *D. Sedgwickii*, Salt., with *Tetragraptus Headi*, Hall, and *Didymograptus V-fractus*, Salt. In the forms of this group the stipes are very similar in character, all giving indications of the broken V-curve; while the hydrothecæ have straight apertures. (See also p. 533.)

(6) Group containing an unknown *Dichograptus*, *Tetragraptus Bigsbyi*, Hall, and *Didymograptus gibberulus*, Nich. (See p. 535.)

In this group the angle of divergence is over 180°; the stipes are broad and sub-parallel in the distal portion of the polypary; and the hydrothecæ are deep and curved, with curved, mucronate apertures. (See Nicholson, Ann. and Mag. Nat. Hist. 1875, p. 271.)

(7) Group containing an unknown *Dichograptus*, *Tetragraptus crucifer*, Hall, and *Didymograptus pennatulus*, Hall. (See p. 533.)

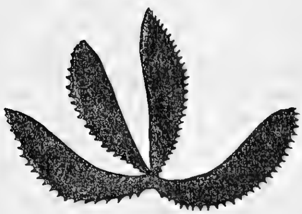
In this group the angle of divergence is at first less than 180°, but the stipes (in each pair of the *Tetragraptus*) are finally placed in the same straight line. The stipes are broad, and the hydrothecæ are inclined at a high angle to the line of the back of the stipe, and overlap one another.

(8) Group containing an unknown *Dichograptus*, *Tetragraptus quadribrachiatus*, Hall, and *Didymograptus extensus*, Hall. (See p. 536.) In this group the angle of divergence is under 180°, the stipes (of each pair in the *Tetragraptus*) are in the same straight line. The hydrothecæ are of the straight type, with straight cell-apertures.

(9) Group containing an unknown *Dichograptus*, *Tetragraptus approximatus*, Nich., and *Didymograptus nitidus*, Hall. (See p. 537.) In this group the angle of divergence is under 180°; the stipes are curved in their proximal portion and afterwards placed in the same straight line (each pair in the case of the *Tetragraptus*). The stipes are narrow, and the hydrothecæ are of the straight type, with straight apertures.

GROUP 6.

TETRAGRAPTUS Bigsbyi



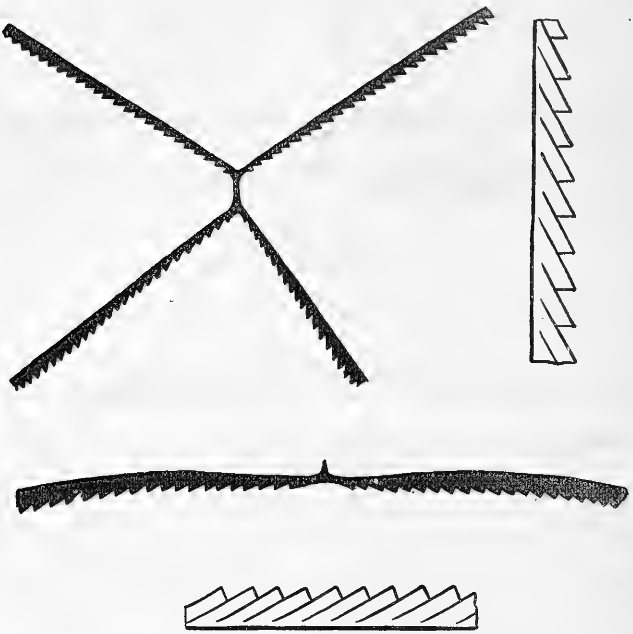
GROUP 6.

DIDYMOGRAPTUS gibberulus

It must not be supposed that in all of the above-mentioned groups the nearest four-branched form to the corresponding eight-branched one, or the nearest two-branched form to the corresponding four-branched one, has been actually selected. For instance, in the case of the second group, the hydrothecæ of *Didymograptus fasciculatus*, Nich., are very different in some respects from those of *Tetragraptus denticulatus*, Hall, and *Bryograptus retroflexus*, Brögger. We believe, however, that in such cases other forms will ultimately be found which will remove this discrepancy. It is probable that a whole group of species sprang from an earlier form which possessed a greater number of branches than its descendants. Thus, the whole series of the "tuning-fork" *Didymograpti*—the *Murchisoni* group—is generally admitted to form one group, and we believe that all the species included in that group have sprung from *Tetragraptus fruticosus*, Hall. Many of the species of this group of *Didymograpti* agree much more closely with *Tetragraptus fruticosus* as regards the characters of the hydrothecæ than does *D. Murchisoni*, and we have figured this latter simply because it is so well known. Again, it is quite conceivable that a *Didymograptus* which from its general shape would be placed in the *Murchisoni* group, might show hydrothecæ entirely different in character from those of *Tetragraptus fruticosus*, and might thus be shown to have descended from an altogether different type of *Tetragraptus*. That the *Didymograpti* were divisible into groups has long been known; and in 1885 Otto Hermann suggested (Die Graptolithenfamilie Dichograptidæ, Lapw.) six such groups, the types of these being respectively *Didymograptus patulus*,

Group 8.

TETRAGRAPTUS quadribrachiatus

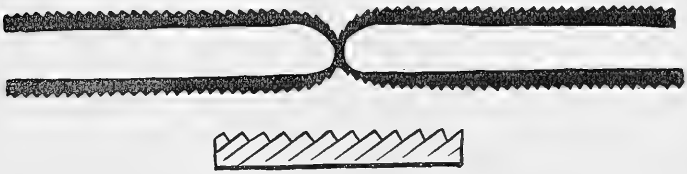


DIDYMOGRAPTUS extensus

Hall, *D. Murchisoni*, Boeck, *D. fasciculatus*, Nich., *D. pennatulus*, Hall, *D. affinis*, Nich., and *D.* V-*fractus*, Salt. Some of these groups, as before remarked in the case of the *Murchisoni* series, are certainly natural, while others will most likely be ultimately re-divided and will undergo a redistribution of their contained species. Each group, however, will probably be found to present close affinities to one particular species of *Tetragraptus*.

It is very difficult to understand how the extraordinary resemblances between the various species of *Tetragraptus* and *Didymograptus* have arisen, if, as usually supposed, all the species of these genera have descended from a common ancestral form for each genus, in the one case four-branched, in the other case two-branched. On the other hand, it is comparatively easy to explain the more or less simultaneous existence of forms possessing the same number of stipes, but otherwise only distantly related, if we imagine them to be the result of the variation of a number of different ancestral types along similar lines. And, indeed, similar phenomena have been shown to exist in other groups of organisms. Thus, in a paper on "The Bajocian of the Mid-Cotteswolds," published in the Quarterly Journal of the Geological Society for August 1895, Mr. Buckman gives reasons for supposing that "genetic observations on Brachiopoda indicate that biplicate *Terebratulæ* are, at any rate in the Jurassic rocks, independent, or heterogenetic, homœomorphous derivatives of non-plicate forms. The method of nomenclature hitherto adopted rather tends, however, to confuse these biplicate forms

GROUP 9.



TETRAGRAPTUS approximatus

DIDYMOGRAPTUS nitidus

together, either as the same species, or as varieties of one another—and they are often difficult to distinguish—and totally overlooks their relationship to the non-plicate forms (from which they appear easily separable), thus ignoring their genetic affinities altogether." The same authority further remarks that "analogous cases of the heterogenetic development of similar but entirely unrelated forms are well known among Ammonites. Mojsisovics has called such cases, between non-contemporaneous Ammonites, 'heterochronous convergence.'" The conclusions which Buckman has reached as regards "species" of Brachiopods and Ammonites appear to us to be applicable to "genera" of Graptolites.

Following our inferences concerning the relative value of the form of the hydrothecæ and the amount of the angle of divergence to their legitimate conclusion, we may observe that when the angle of divergence reaches 360°, so that the stipes of the polypary coalesce by the whole of the dorsal surface, as in the members of the confessedly artificial families Diplograptidæ and Phyllograptidæ, the true relationships of the members of these "families" to one another may be more remote than those to members of some other family. Thus, Hall (Grapt. Quebec Group, pl. xvi, fig. 26) figures a form of *Tetragraptus* which he refers to *T. Bigsbyi*,[1] in which the apices of the stipes are in contact, and remarks that "it is difficult to separate such forms from *Phyllograptus*." In fact, having examined many specimens, we are disposed to suggest that this form is truly intermediate between *Tetragrapti* of the *Bigsbyi* type and *Phyllograptus*.

Furthermore, as the unilateral *Monograpti* are related to the bilateral *Diplograpti* through *Dimorphograptus*, the same reasoning applies to these; and the single genus *Monograptus* may contain descendants of more than one "family." This would account for the great diversity in the character of the Monograptid hydrothecæ. Many *Monograpti* possess hydrothecæ resembling those of pre-existing Diplograptidæ, whilst one well-known species, *M. argutus*, has hydrothecæ closely similar to those of the family Dicranograptidæ.

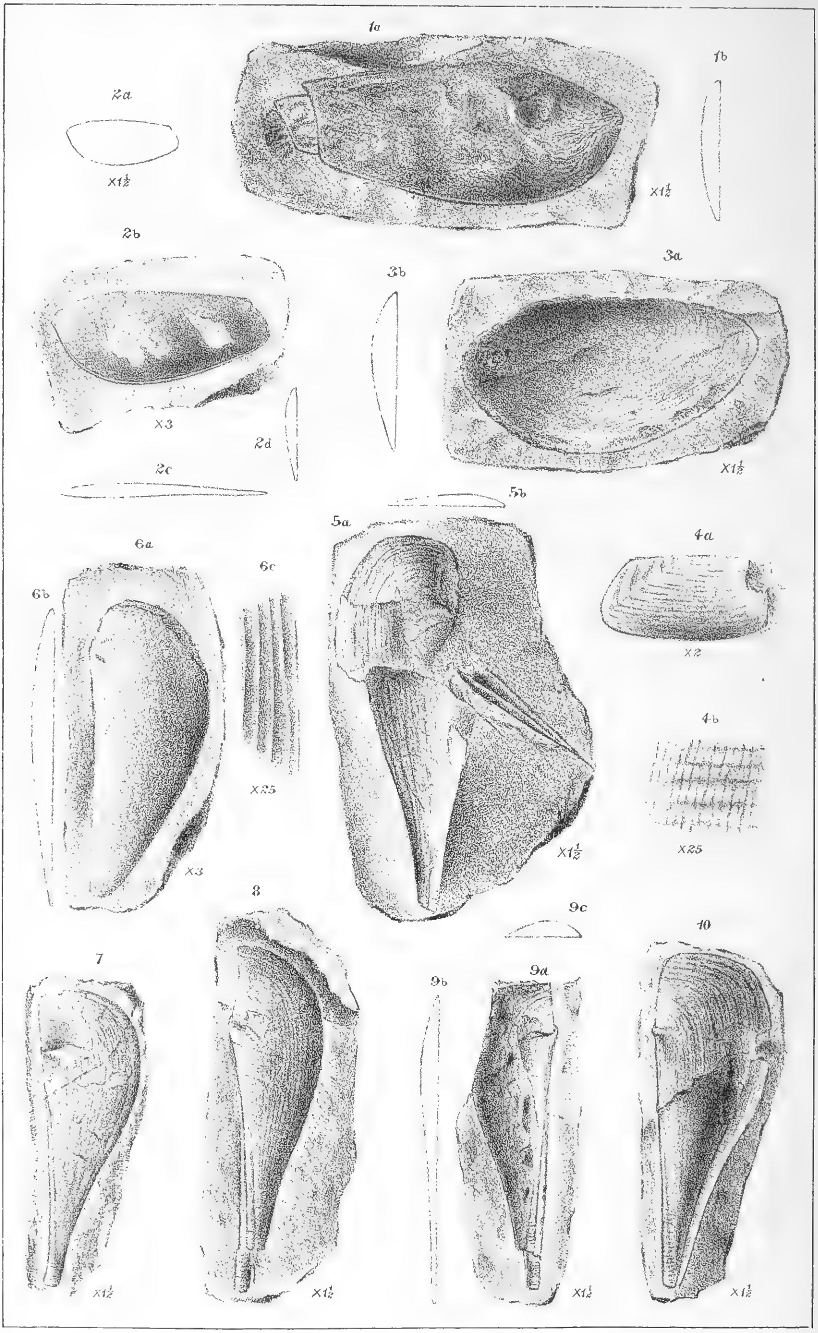
Should our conclusions be correct, the present nomenclature will have to be altered, for it is clear that two species of *Didymograptus*, to take an example, which have descended through different Tetragraptid forms, the one from a *Bryograptus*, the other from a *Dichograptus*, cannot be relegated to the same genus. In the present state of our knowledge we believe it would be not only inconvenient but also unpardonable to alter a classification the working value of which has been made fully apparent, and we propose, therefore, to retain such names as *Monograptus*, *Didymograptus*, and *Tetragraptus* as "generic" names, merely observing that we do not consider the species placed under these various groups to belong to definite genera, in the sense in which the word is used by biologists, but that they constitute cases of what Buckman terms heterogenetic homœmorphy of forms which are only distantly allied to one another.

To a considerable extent these homœomorphic forms are isochronous and not heterochronous, as proved by detailed work in the field; hence their extreme value to the stratigraphical geologist. They may be regarded as constituting a special case of mimicry, the reasons for the existence of which may be very briefly discussed.

We are indebted to Mr. Clement Reid for the first suggestion that the variations in the characters of Graptolites may be connected with the supply of food, and study of the variations inclines us to accept this suggestion as plausible, if not correct.

The earlier Graptolites (such as *Dictyograptus* in the Lingula flags, etc.) consisted of a number of irregularly-branching stipes; but symmetry in the arrangement of the stipes would tend to ensure an equal supply of food to each stipe; hence we soon meet (in the

[1] We have examined a large number of examples of the *Tetragraptus* here alluded to, which have been collected in the Skiddaw Slates of Troutbeck and Outerside, near Keswick, and are of opinion that it is specifically separable from *T. Bigsbyi*, Hall, and ought to receive a new name. Pending a complete description, we may therefore speak of this form as *T. inosculans*. In some of our specimens of this singular form not only are the apices of the stipes in contact, but more or less complete fusion or cohesion has taken place.



Geo. West & Sons del. lith. et imp.

PALÆOZOIC PHYLLOPODS, &c.

Tremadoc rocks) with many-branched forms like *Clonograptus* possessing a symmetrical arrangement: the fewer the branches, however, the greater the supply of food to the entire organism; consequently we find forms with more than eight branches (*Logano-graptus*) rapidly replaced by eight-branched forms (*Dichograptus*), these by four-branched forms (*Tetragraptus*), and these, again, by two-branched forms (*Didymograptus*). Professor Lapworth has privately furnished us with what is doubtless the reason why unilateral forms like *Azygograptus* did not survive, until the genus *Monograptus* became established in the Silurian rocks, but we await the publication of this reason. Four-branched forms descended from one series would be at a disadvantage as compared with two-branched forms of another; therefore, when once a two-branched form of one series was established, any departure from a four-branched to a two-branched form in another series would tend to survive, and the four-branched forms would die out, hence the general isochronism of forms belonging to diverse series possessing the same number of branches.

Again, forms having the series of hydrothecæ facing one another would receive a smaller supply of food than those having the hydrothecæ further apart; consequently the increase in the angle of divergence followed, which attained its maximum of 360° when the backs of the stipes came into contact with *Phyllograptus*, *Diplo-graptus*, and *Climacograptus*.

Lastly, hydrothecæ the openings of which faced downwards and lay in the same plane would be placed at a disadvantage compared with those which faced in different directions, hence the variations in the nature of the hydrothecæ resulting in the curved and sometimes twisted forms met with amongst the later Graptolites. This would also produce its effect upon the angle of divergence.

The above notes are offered as suggestions only, though in our opinion they are plausible. Should they be correct, the value of Graptolites, enormous as it already is to the stratigraphical geologist, will become equally so to the biologist; and we may look forward to the establishment of a complete phylogeny in the case of this remarkable sub-class.

II.—On some Palæozoic Phyllopoda.

By Professor T. Rupert Jones, F.R.S., and Dr. Henry Woodward, F.R.S.

(PLATE XV.)

1. Ceratiocaris reticosa, sp. nov. Plate XV, Figs. 1*a*, 1*b*.

In the Museum of Practical Geology there is a specimen of *Ceratiocaris* (No. 4435), from the vicinity of Ludlow, which was not noticed by us in the "Monograph of British Palæozoic Phyllocarida" (Palæontographical Society), 1888. It is a squeezed carapace, evidently allied to the *Ceratiocaris cassioides* there described and figured, pages 59–61, pl. iii, fig. 9; pl. iv, fig. 7; and pl. vii, figs. 4–6. The specimen appears to have been bivalved.

The contained animal matter has caused an irregular convexity (as seen also in figs. 4–6, pl. vii above mentioned), especially in the anterior third; and here it has been broken down, leaving a small rough cavity in some obscure organic material.

The exposed (right) valve has been damaged by pressure; but, though much excoriated, it retains on the lower part of the front moiety an ornament of numerous raised flexuous striæ (like those seen in fig. 9, pl. iii), trending upwards and forwards to converge at the anterior extremity. Near the postero-dorsal angle, moreover, there is a patch of peculiar reticulate sculpture, with lozenge-shaped meshes. Further trace of this ornament is visible for a little way towards the middle of the valve. In its proportions this specimen comes nearest to fig. 9 in pl. iii of the Monograph, but differs from it considerably; and still more from the other known examples. Thus:—

	Millimètres	
Length and height	29 × 12·50, specimen under notice, from near Ludlow.	Lower Ludlow formation.
,, ,,	26 × 11, the Monograph, pl. iii, fig. 9, p. 60, from Leintwardine, near Ludlow.	
,, ,,	25 × 14, the Monograph, pl. vii, fig. 6, p. 60, from Leintwardine, near Ludlow.	
,, ,,	25 × 12, the Monograph, pl. vii, fig. 5, p. 61, from near Ludlow.	
,, ,,	23 × 12, the Monograph, pl. vii, fig. 4, p. 60, from Tripleton, near Ludlow.	
,, ,,	22 × 12, the Monograph (not figured), p. 60, from Tripleton, near Ludlow.	
,, ,,	22 × 9, the Monograph, pl. iv, fig. 7, p. 60, from near Ludlow.	
(Not figured), the Monograph, p. 60, from Benson Knot, Kendal.		Upper Ludlow formation.

It has not nearly so great a height in its anterior moiety as *C. cassioides*; in consequence of its having a much less convex antero-ventral border. The sinuous striæ are comparable with those on both the front and hinder portions of fig. 9 in pl. iii; but none of the known examples exhibit the neat delicate reticulation, with lozenge-shaped meshes, which this additional example shows on its postero-dorsal area. Unfortunately only a limited patch remains, but the ornament is obscurely continued for a little way forwards towards the middle of the valve.

This peculiar ornamentation suffices to distinguish the species under consideration, even if the larger size and the more elongate or attenuate outline do not constitute a sufficient distinction.

2. Emmelezoe Lindstroemi, sp. nov. Plate XV, Figs. *2a–2d*.

Several specimens, in a soft grey argillaceous limestone, homotaxial with the Wenlock Beds, from Lau, near the south-east coast of Gothland, Sweden, have been communicated by Professor Gustav Lindström, F.M.G.S. On one piece of this marly rock there are indications of at least six carapaces, flattened, and more or less mutilated by pressure, some showing a trace of the underlying valve. Another specimen (shown by Fig. 2) lies alone on another piece of the same rock.

The enclosed animal matter expresses itself in the irregularity of the surface of the valves, especially at the antero-ventral region (as in fig. 9*a* of pl. vii, "Monograph of the Ceratiocaridæ," 1888); also by small raised spots more or less isolated. Among these, however, there is generally one small pustule that seems to be analogous to the little ocular tubercle in *Emmelezoe* ("Monograph Ceratiocaridæ," Pal. Soc. 1888, pp. 69–71, pl. vii, fig. 9, and pl. viii, figs. 1–3). In one specimen (not figured) it is accompanied by a small scutcheon with a wrinkled pattern.

The valves are chitinous, amber-coloured, somewhat iridescent, delicately thin, and brittle. The form is obliquely sub-oblong; somewhat boat-shaped; nearly straight on the back; elliptically and obliquely curved below; broadest (highest) in the anterior moiety, the antero-ventral curve being well developed. The front end has its apex on the median line of the valve; and is more frequently preserved than the posterior, which tapers, and was truncate with an ogee curve.

One specimen measures	13 × 6 mm.
Another specimen measures..................	11 × 4 mm.
Another specimen (Fig. 2) measures	10 × 4 mm.

This form is nearest to *Emmelezoe Maccoyiana* (Monograph, pl. viii, fig. 2); it has a greater antero-ventral curve than *E. elliptica* (fig. 1); and it is relatively longer and less boldly curved on the ventral border than *E. crassistriata* (fig. 3) and *E. tenuistriata* (pl. vii, fig. 9). Moreover, it shows none of the striate ornament seen in all these. The absence of this sculpture and the feebleness of the ocular tubercle weaken its apparent alliance with *Emmelezoe*; but we cannot associate it with *Ceratiocaris solenoides*, *C. inornata*, and their allies (Monograph, pp. 48–54, pls. viii and x).

In the Geological Magazine, Decade IV, Vol. II, p. 170 (April 1895), Dr. G. J. Hinde, in an abstract of a memoir by Prof. G. Lindström, communicated to the Royal Swedish Academy of Sciences in December, 1894, gives an account of the finding of these and other interesting Upper Silurian fossils, including fish-remains (*Cyathaspis*).

3. Lingulocaris lingulæcomes, Salter, 1866. Pl. XV, Figs. 3*a*, 3*b*.

In the "Monograph of the British Palæozoic Phyllocarida" (Palæont. Soc.), 1892, this species is treated of with its Synonymy, at p. 81.

The Rev. G. C. H. Pollen, S.J., F.G.S., of St. Beuno College, St. Asaph, has kindly communicated a specimen of what seems to be this species from Capel Arthog, between Barmouth Junction and Dolgelly, North Wales.

It is the hollow cast of the outside of a right valve, lying on a bed-plane of a bluish slaty rock, with ferruginous stains, belonging to the Lingula-flags (probably the Ffestiniog or Middle Division).

In shape it is obliquely subovate (28 mm. long; 13 mm. high); broad (high) in front, narrower and rounded behind. The anterior extremity of the valve is boldly rounded in advance of the umbo, but has a slight antero-dorsal slope. The hinge-line is straight (17 mm.) from the umbo to the postero-dorsal curve. The umbo is about a fourth of the length of the valve from the front end. Ventral edge elliptically curved; deepest just in front of the middle of the valve. The surface is marked with numerous thin striæ, parallel with the ventral margin, and concentric with the umbo.

This specimen most nearly agrees, as to shape, with Salter's fig. 2, pl. x, "Memoirs Geol. Survey," vol. iii (1866), pp. 253 and 294; and second edition (1881), p. 485, being more ovate than his fig. 1. Its ornament agrees with that of the latter. The variation in outline may possibly be due to sexual difference.

4. Cypricardinia (?), Hall, 1859. Plate XV, Figs. 4*a*, 4*b*.

This fragment of a molluscan valve, from Girvan, when looked at with its broken end downwards, has somewhat of the appearance of a fragmental upper moiety of a *Pinnocaris*, hence it has been figured tentatively in this plate.

Fig. 4*a* shows the outside of the posterior moiety of the right valve of probably a *Cypricardinia*, such as *C. sublamellosa* and *C. concentrica*, Hall, "Palæontology of New York," vol. iii, 1859, pp. 267, 268, pl. L, figs. 1 and 2. It measures 9 × 4 mm. Fig. 4*b* gives an enlarged view of a portion of its ornament.

The specimen is in Mrs. Gray's Collection, in Edinburgh, and was collected by her from the Lower Silurian rocks of Balclatchie, Girvan, Ayrshire.

5. Pinnocaris Lapworthi, R. Etheridge, jun., 1878. Plate XV, Figs. 5–10.

For descriptions and synonymy see "Monograph Silurian Fossils of Girvan," vol. i, 1880, p. 210, pl. xiv, figs. 17–20; and "Monograph British Palæozoic Phyllocarida," 1892, pp. 118, 119, pl. xv, fig. 24.

The only known representative of the peculiar Crustacean genus *Pinnocaris* occurs usually as black, shining, chitinous, flattened carapace-valves (sometimes decomposed); elongate and triangularly-obovate in outline; broadly rounded at one end (anterior); with an umbo; striæ parallel to the ventral margin and concentric with the umbo; and a long, narrow, transversely wrinkled posterior extremity.

In some instances the valves are subconvex; and often are evidently in pairs, containing matrix representing animal matter. In no instance have the two valves presented themselves as lying open or expanded side by side.

The umbo is situated on the straight margin, generally at about a fourth of the length of the valve from the anterior extremity; but in small specimens relatively at a less distance. It appears typically as a small pinched-up fold, hollow within; but it is much modified by pressure in different individuals; remaining sometimes as a triangular ridge between two furrows; or as two small ridges bounding a triangular pit; or otherwise modified.

The straight edge of the long (posterior) portion of the valve has a corded appearance, from a little below the umbo to the extremity. This special margin begins very thin, and widens downwards, the little cross-striæ or wrinkles becoming stronger as it widens; the last eight or ten are much larger and thicker. In some cases (as in Fig. 9, more especially) it is double. Possibly this corded margin has reference to a peculiar dorsal longitudinal plate intermediate to the two valves. This may have been susceptible of being bent when the valves closed; or it may have split along its length. Such an intermediate dorsal plate is regarded by Hall and Clarke as having existed in *Mesothyra* ("Palæont. New York," vol. vii, 1888, p. 187, pl. xxxii, fig. 1); but we do not find it in the allied *Dithyrocaris.* The corded margin has a distant analogy to a lateral moiety of the intermediate and striated plate in *Pholadocaris*, H. Woodward (Geol. Mag., Dec. II, Vol. IX, 1882, p. 388, Pl. IX, Fig. 16). It more closely resembles the much stronger, corded, dorsal edges in *Dithyrocaris tricornis*, H. W. and R. Eth. (Geol. Mag., Vol. X, 1873, pp. 483–6, Pl. XVI, Fig. 3), which does not seem to possess an intermediate dorsal plate. *Pholadocaris* has been met with only in its expanded form; but *Dithyrocaris* has been found both in the expanded and closed state.

The two valves of *Pinnocaris*, if placed side by side, with the straight edge of one in contact with that of the other, would present an analogy to some of the flat open carapaces of *Pholadocaris* and *Aptychopsis*, with the difference that there would be little or no nuchal notch with the two valves of *Pinnocaris* thus arranged, and a very narrow open space below the umbo, not gaping at the end.

Judging from the two outlines of the counterparts of the closed carapace (Pl. XV, Figs. 8 and 9), we may say that when the valves were closed the dorsal edges would lie against each other (with or without a very narrow flanging ligament), whether they formed a straight or a slightly flexuous line, with or without a protruding umbo. Even anteriorly the edges would meet (with a slope), and would not necessarily require an intermediate plate. So a bivalve Mollusc, if laid open, would have angular notches fore and aft, but no intermediate plates.

As far as mere outline is concerned, *Pinnocaris* has a distant resemblance to a figure of *Beecherella subtumida* in E. O. Ulrich's memoir on that genus, "American Geologist," vol. viii, 1890, p. 200, pl. ii, fig. 6; but it is very distinct in other respects. The outline may be said to have a still more remote likeness to *Protozoëa Hilgendorfi*, Dames, "Zeitsch. d. Geol. Ges.," vol. xxxviii, 1886, p. 577, pl. xv, figs. 5–7.

Except one example from the Upper Silurian of Kendal, Westmoreland, all the specimens we have seen are from the Lower Silurian of Girvan, Ayrshire, from which locality Mrs. Gray, of Edinburgh, has made a large collection.

THE SIZES OF COMPLETE SPECIMENS.

No. in Mrs. Gray's Collection.	In millimètres. Length.	Width.	Figures in Pl. XV.	In Monograph Girvan Fossils, 1880, Pl. XIV.
2	34	13		
1	$33\frac{1}{2}$	$12\frac{2}{3}$	Fig. 5.	"Fig. 17."
28	32	9		
10	30	13		
6	30	12		"Fig. 18."
15	30	10	Fig. 10.	
8	30	$8\frac{2}{3}$	Fig. 8.	
7	28	10	Fig. 7.	
14	28	10		
9	28 ?	$7\frac{2}{3}$	Fig. 9.	(Counterpart of Fig. 8, but damaged in its upper moiety.)
11	27	11		
12	25	7		
3	24	7		"Fig. 20."
26	22	7		
13	22	5		
24	14	5	Fig. 6.	
29	14	5		

The Kendal specimen in the Monograph Brit. Foss. Phyllopoda, 1892, p. 118, pl. xv, fig. 24: Length, 25 ? mm.; width, 10 mm.

The apparent size of the specimens is considerably affected by the degree of pressure or amount of distortion they have received.

EXPLANATION OF PLATE XV.

1*a*, right valve; 1*b*, outline of end view.

FIG. 1. *Ceratiocaris reticosa*, sp. nov. From near Ludlow. Museum of Practical Geology, Jermyn Street.

FIG. 2. *Emmelezoe Lindstroemi*, sp. nov. 2*a*, left valve, natural size; 2*b*, the same, magnified 3 diameters; 2*c*, outline of edge view; 2*d*, outline of end view. From Lau, Gothland. Brit. Mus.

FIG. 3. *Lingulocaris lingulæcomes*, Salter. 3*a*, hollow cast of right valve, × $1\frac{1}{2}$ diameters; 3*b*, outline of transverse section. Capel Arthog, North Wales. Collection of Rev. G. C. H. Pollen, F.G.S.

FIG. 4. *Cypricardinia*. 4*a*, imperfect right valve, twice nat. size; 4*b*, portion of the ornament, magnified 25 diameters. From Balclatchie, Girvan. Mrs. Gray's Collection, Edinburgh.

FIG. 5. *Pinnocaris Lapworthi*, R. Etheridge, jun. 5*a*, carapace, one and a half times nat. size. The upper part is convex, and exhibits the outside of the left valve, which is broken across at the umbo, showing a thin layer of brownish matrix between the valves. The inside of the right valve forms the lower part of the figure. The crushed spikes at the side are quite distinct, and must have belonged to some other organism, having no relation to *Pinnocaris*. They seem to consist of a once convex tapering style, now crushed along its middle, and a much smaller, obscure, thin, and simple spike or spine lying below the other and nearly parallel with it. 5*b*, approximate outline of the convexity of the upper (front) end. From Balclatchie, Girvan, Ayrshire. Mrs. Gray's Collection.

FIG. 6. *Pinnocaris Lapworthi*, R. Etheridge, jun. 6*a*, convex cast of the interior of a right valve, 3 times nat. size; 6*b*, outline of the edge view; 6*c*, a small portion of the linear ornament of the test preserved at the antero-ventral curve, enlarged 25 diameters. From Ardmillan Brae, Girvan. Mrs. Gray's Collection.

FIG. 7. *Pinnocaris Lapworthi*, R. Etheridge, jun. A flattened carapace: the upper part shows a portion of the outside of the right valve; the lower part is the slightly hollow inside of the left valve. From Balclatchie, Girvan. Mrs. Gray's Collection.

FIG. 8. *Pinnocaris Lapworthi*, R. Etheridge, jun. Concave mould of the outside of a left valve. From Balclatchie, Girvan. Mrs. Gray's Collection.

FIG. 9. *Pinnocaris Lapworthi*, R. Etheridge, jun. 9*a*, convex cast of the inside of left valve; counterpart of, and fitting into, Fig. 8; but imperfect at top and side of upper moiety. 9*b*, outline of edge view; 9*c*, outline of end view. From Balclatchie, Girvan. Mrs. Gray's Collection.

FIG. 10. *Pinnocaris Lapworthi*, R. Etheridge, jun. Probably a carapace; showing the right valve, of which the upper part retains the usual black shining test; and the lower part is the convex cast of the inside of the posterior moiety of the same. From Ardmillan Brae, Girvan. Mrs. Gray's Collection.

III.—REVIEW OF THE EVIDENCE FOR THE ANIMAL NATURE OF EOZOÖN CANADENSE.

By Sir WILLIAM DAWSON, C.M.G., LL.D., F.R.S., etc.

III. STRUCTURAL AND BIOLOGICAL.

IN recent years I have been disposed to attach more importance than formerly to the general form and macroscopical characters of Eozoön. The earlier examples studied were, for the most part, imbedded in the limestone in such a manner as to give little definite information as to external form; and at a later date, when Sir William Logan employed one of his assistants, Mr. Lowe, to quarry large specimens at Grenville and Côte St. Pierre, the attempt was made to secure the most massive blocks possible, in order to provide large slabs for showing museum specimens. More recently, when collections have been made from the eroded and crumbling surfaces of the limestone in its wider exposures, it was found that specimens of moderate size had been weathered out, and could, either naturally or by treatment with acid, be entirely separated from the matrix. Such specimens sometimes showed, either on the surfaces or on the sides of cavities and tubes penetrating the mass, a confluence of the laminæ, constituting a porous cortex or limiting structure. Specimens of this kind were figured in 1888,[1] and I was enabled to add to the characters of the species that the original and proper form was "broadly turbinate with a depression or cavity above, and occasionally with oscula or pits penetrating the mass." The great flattened masses thus seemed to represent confluent or overgrown individuals, often contorted by the folding of the enclosing beds.

There are also in well-preserved specimens certain constant properties of the old calcite and serpentine lagoons. The former are continuous, and connected at intervals, so that if the siliceous filling of the chambers could be removed, *the calcareous portion* would form a continuous skeleton, while the serpentine filling the chambers, when the calcareous plates are dissolved out by an acid, forms a continuous cast of the animal matter filling the chambers. This cast of the sarcodous material, when thus separated, is very uniformly and beautifully mammillated on the surfaces of the laminæ, and this

[1] GEOLOGICAL MAGAZINE, and Museum Memoir.

tuberculation gradually passes upward into smaller chambers, having amœboid outlines, and finally into rounded chamberlets. It is also a very constant point of structure that the lower laminæ of calcite are thicker than those above, and have the canal-systems larger and coarser. There is thus in the more perfect specimens a definite plan of macroscopical structure.

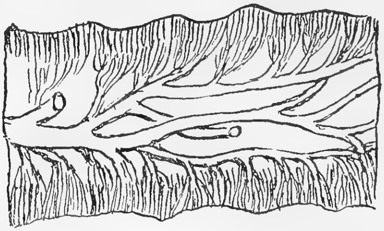


Fig. 6.—Diagram of typical mode of arrangement of canals and tubuli in a lamina of *Eozoön Canadense.* (Magnified.)

The normal mode of mineralization at Côte St. Pierre and Grenville is that the laminæ of the test remain as calcite, while the chambers and larger canals are filled with serpentine of a light green or olive colour, and the finer tubuli are injected with dolomite. It may also be observed that the serpentine in the larger cavities often shows a banded structure, as if it had been deposited in successive coats, and the canals are sometimes lined with a tubular film of serpentine, with a core or axis of dolomite, which also extends into the finer tubuli of the surfaces of the laminæ. This, on the theory of animal origin, is the most perfect state of preservation, and it equals anything I have seen in calcareous organisms of later periods. This state of perfection is, however, naturally of infrequent occurrence. The finer tubuli are rarely perfect or fully infiltrated. Even the coarser canals are not infrequently imperfect, while the laminæ themselves are sometimes crumpled, crushed, faulted, or penetrated with veins of chrysotile or of calcite. In some instances the calcareous laminæ are replaced by dolomite, in which case the canal-systems are always imperfect or obsolete. The laminæ of the test itself are also in some cases replaced by serpentine in a flocculent form. At the opposite extreme are specimens or portions of specimens in which the chambers are obliterated by pressure, or occupied only with calcite. In such cases the general structure is entirely lost to view, and scarcely appears in weathering. It can be detected only by microscopic examination of slices, in parts where the granular structure or the tubulation of the calcite layers has been preserved. All palæontologists who have studied silicified fossils in the older rocks are familiar with such appearances.

It has been alleged by Möbius and others that the canal-systems and tubes present no organic regularity. This difficulty, however, arises solely from imperfect specimens or inattention to the necessary results of slicing any system of ramifying canals. In Eozoön the canals form ramifying groups in the middle planes of the laminæ, and proceed at first almost horizontally, dividing into smaller branches, which ultimately give off brushes of minute tubuli running nearly at right angles to the surfaces of the lamina, and forming the extremely fine tubulation which Dr. Carpenter regarded as the proper wall. In my earlier description I did not distinguish this from the canal-system, with which its tubuli are

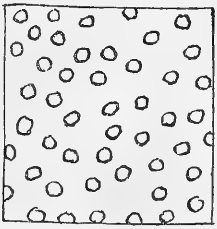


Fig. 7.—Cross section of minute tubuli, about 5 microms. in diameter. (Magnified.)

inwardly continuous; Dr. Carpenter, however, understood this arrangement, and has represented it in his figures[1] (see also Fig. 6). It is evident that in a structure like this a transverse or oblique section will show truncated portions of the larger tubes apparently intermixed with others much finer and not continuous with them,

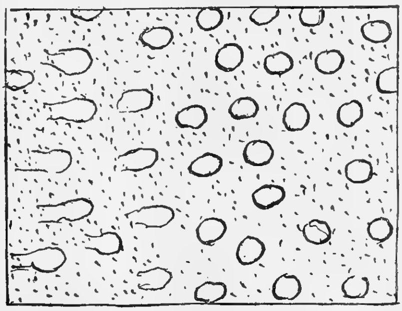


Fig. 8.—Cross section of similar tubuli, more highly magnified, and showing granular character of the test. (From camera tracings.)

except very rarely. Good specimens and many slices and decalcified portions are necessary to understand the arrangement. This consideration alone I think entirely invalidates the criticisms of Möbius, and renders his large and costly figures of little value, though his memoir is, as I have elsewhere shown, liable to other and fatal objections.[2]

It has been pretended that the veins of chrysotile, when parallel to the laminæ, cannot be distinguished from the minute tubuli terminating on the surfaces of the laminæ. I feel confident,

[1] Ann. and Mag. Nat. Hist., ser. 4, xiii, p. 456, figs. 3, 4.
[2] Museum Memoir, pp. 50 *et seq.*

however, that no microscopist who has seen both, under proper conditions of preservation and study, could confound them. The fibres of chrysotile are closely appressed parallel prisms, with the optical properties of serpentine. The best preserved specimens of the "proper wall" contain no serpentine, but are composed of calcite with extremely minute parallel cylinders of dolomite about five to ten microms. in diameter, and separated by spaces greater than their own diameter (see my comparative figure, "Dawn of Life," p. 106; also Figs. 5, 6). In the rare cases where the cylinders are filled with serpentine they are, of course, still more distinct and beautiful. At the same time I do not doubt that observers who have not seen the true tubulation may have been misled by chrysotile veins when these fringe the laminæ. Möbius, for instance, figures the true and false structure as if they were the same.

Protest should here be made against that mode of treating ancient fossils which regards the most obscure or defaced specimens as typical, and those better preserved as mere accidents of mineral structure. In Tertiary Nummulites injected with glauconite, it is rare to find the tubuli perfectly filled, except in tufts here and there, yet no one doubts that these patches represent a continuous structure.

I have remarked on previous occasions that the calcite constituting the laminæ of Eozoön often has a minutely granular appearance, different from that of the surrounding limestone. This is, I presume, the "dusty" appearance referred to by Dr. Bonney. Under a high power it resolves itself into extremely minute dots or flocculi, somewhat uniformly diffused. Whether these dots are particles of carbon, iron, apatite, or siliceous matter, or the remains of a porous structure, I do not know; but similar appearances occur in the calcareous fossils contained in altered limestones of later date. Wherever they occur in crystalline limestones supposed to be organic, the microscopist should examine these with care. I have sometimes by this appearance detected fragments of Eozoön which afterward revealed their canals.

I have not space here to notice late observations on Archæospherinæ and other objects supposed to be organic found in pre-Cambrian rocks in Canada and in Europe. They afford, however, to some extent, corroborative evidence in favour of Eozoön.

Supposing a probability to be established of the animal nature of Eozoön, we should naturally expect to detect links of connection between it and fossils known to us in the succeeding geological formations. We have, however, here to make allowance for the probability that an organism so very ancient may differ materially from any of its successors, and may probably be a synthetic or generalized type, or present embryonic characters. Analogy might also justify the supposition that it might be represented in later times by smaller as well as more specialized forms. In this connection also, the probable warmth and shallowness of the Laurentian ocean, and its abundance in calcium carbonate and in carbonaceous matter, probably organized, should be taken into account. It should also be noted that the formations next in ascending order are of a character little likely to preserve organic marine forms of the "benthos" or ground-living group. We might thus expect a gap in our record between the fauna of the Grenville Series and that of the next fossiliferous formations.

Logan naturally compared his earlier specimens with the Stromatoporæ so abundant in the Ordovician and Silurian Limestones; and in this he was justified, for, whatever may be the ultimate judgment of naturalists as to these problematical fossils, and whether they are referred to Protozoa or to Hydrozoa, or, as seems more likely, are divided between the two, they resemble Eozoön in general structure and mode of accumulation of calcareous matter, and occupied a similar place in nature. My own conclusion, on discussing the microscopic structures of the specimens of Eozoön, was that they were probably those of Protozoa allied to those Foraminifera with thick supplemental skeleton [1] which had been described by Dr. Carpenter. At the same time, I suspected that those Stromatoporoids, like Cœnostroma, which possess thick laminæ penetrated by ramifying tubes, might be allied to the Laurentian fossil. Dr. Carpenter regarded the structures as combining in some respects those of Rotaline and Nummuline Foraminifera, and ably, and as I think conclusively, defended this view when attacked.[2] The Rotaline type of Foraminifera has since that time been traced by Cayeux and Matthew far down into the pre-Cambrian rocks. The Nummuline type is not known so early. As to the canal-bearing Stromatoporoids, none of them show the fine tubulation, though some have radiating and branching canals. Recent students of the Stromatopora seem disposed to refer them to Hydrozoa,[3] a conclusion probable in the case of some of the forms (especially those spinous ones incrusting shells), but doubtful in the case of others, and more particularly the oldest of all, belonging to the genus Cryptozoön of Hall, and Archæozoön of Matthew,[4] the structure of which seems, so far as known, to consist of very thin primary laminæ with a supplemental tubulated skeleton resembling that of the genus *Loftusia*, and which must, I think, be regarded as foraminiferal. In any case, whether these primitive forms are Protozoa or rudimentary Hydroids, they reach back in time nearly as far as Eozoön, and are equally massive and abundant, and may be regarded as analogous to it in magnitude, habitat, mode of growth, and function in nature.

These later discoveries are gradually widening the horizon of palæontologists in the direction of the dawn of life, and the studies of those who trace backward the history of the Invertebrates of the Palæozoic seas are demanding more and more the discovery of earlier forms than those yet known to complete the chain of life.[5] The field is a difficult one to cultivate, and demands both labour and patience, but it holds forth the prospect of great discoveries, and it has already become the duty and interest of palæontologists to

[1] Calcarina, etc. [2] Ann. and Mag. Nat. Hist., *loc. cit.*
[3] Nicholson, Monographs Palæontographical Society.
[4] Bulletin Nat. Hist. Survey of New Brunswick, 1894–5.
[5] See Dr. Woodward's Address as President of the Geological Society, 1895.

extend their inquiries as far back as the Laurentian in the search for Eozoic life.

In this respect the study and discussion of Eozoön have not been without use, in directing attention to the possibility of finding organic remains in the older crystalline rocks, to the danger of confounding them in their peculiar condition with merely mineral structures, to the state of preservation of organic remains in the older formations, and to the origin and significance of the large deposits of limestone, dolomite, hydrous silicates, iron ore, graphite, and apatite, laid up in certain horizons of the Eozoic rocks. Questions of this kind have been greatly advanced toward their satisfactory solution since the discovery of Eozoön in 1858, and in some degree at least in consequence of the interest excited by that discovery. It is hoped that the present notes may tend in the same direction, and that, whether or not they succeed in removing any existing scepticism in respect to Eozoön, they may help to stimulate and guide the search for those beginnings of life, which there are now the best reasons for believing are to be found far below the base of the Cambrian.

[Additional facts and illustrations, and references to previous papers on the subject, will be found in "Specimens of Eozoön Canadense," pp. 106, published by the Peter Redpath Museum (Notes on Specimens, Sept. 1888), which may be obtained on application to the Museum, or through W. Foster Brown, Bookseller, Montreal. See also, for a popular summary, Chapters v and vi of "Some Salient Points in the Science of the Earth," London, 1893.]

[For Parts I and II of this article see Geol. Mag. 1895, Dec. IV, Vol. II, No. X, October, p. 443, and No. XI, November, p. 502.]

Erratum.—November Number, p. 503, line 30, for *Aruprion* read *Arnprior.*

IV.—Zonal Divisions of the Carboniferous System.

By E. J. Garwood, M.A., F.G.S., and J. E. Marr, M.A., F.R.S.

One of us remarked last year in an article in *Science Progress* that "we may expect to find our Carboniferous deposits divisible into zones in a manner comparable with that which holds good among other . . . strata." The same writer called attention to the fact that similar views had been expressed by Waagen (Salt Range Fossils, "Memoirs of the Geological Survey of India, 1891"), who considered that the Carboniferous fossils had not received the same attention as those of other rocks.

In Russia, three important divisions of the Carboniferous have been made out: the stage of *Productus giganteus* and *Spirifera Kleini*, referred to the Lower Carboniferous; and the Moscovian stage, with *Spirifera Mosquensis*, and the Gshellian stage, with *Chonetes Uralica*, to the Upper Carboniferous. The marine type of Upper Carboniferous deposits has now been found widely distributed over Europe, Asia, Africa, and America, though represented by few truly marine beds in Britain; but the Lower Carboniferous strata are admirably represented in our country, and it is the object of this paper to induce local observers to pay greater attention to these beds than they have hitherto done, and also to study such marine beds of the Upper Carboniferous (Millstone Grit and Coal-measures) as are developed in this country.

In 1886, De Koninck and Lohest showed that the Carboniferous Limestone of the north-east of England was divisible into three groups: the lowest, containing a number of corals and certain fish, including *Lophodus lævissimus*, L. Ag., and *Copodus cornutus*, L. Ag.; the middle, with abundance of *Chonetes papilionacea*, Phill.; and the upper, with *Productus giganteus*. Since that time one of us (E. J. G.) has paid considerable attention to the Lower Carboniferous strata of the northern half of the Pennine Chain, and whilst corroborating the views of the Belgian writers as to the relative position of the two Brachiopods above mentioned, has also detected the occurrence of other fossils in a definite order in that district. So far, the following succession has been made out (in descending order):—

Beds with *Productus* cf. *Edelburgensis*	Yoredale Series.
,, *P. latissimus*	
,, *P. giganteus*	Mountain Limestone Series.
,, *Chonetes papilionacea* and *Chætetes septosus*	
,, *Spirifera octoplicata*	

The beds containing *Productus latissimus* have now been traced, occupying the same relative position from the Settle district of Yorkshire into Northumberland.

Starting in the Ingleborough district, a well-marked horizon is found, characterized by very fine specimens of *Productus latissimus*, occurring at the base of the "Yoredale Series" in thin argillaceous limestone (being the limestone next above the top of the "Lower Scar Limestone" in that district = second limestone of Sedgwick: "Description of a Series of longitudinal and transverse sections through a portion of the Carboniferous Chain between Penigent and Kirkby Stephen,"—Trans. Geol. Soc. 1831, vol. iv, pl. vi, fig. 1).

Proceeding northward to Wensleydale, the same fossil is found in a limestone apparently higher in the series, the Hardraw Scar Limestone (see Mem. Geol. Survey Explanation of Q.S. 97 N.W., p. 200). In the Cross Fell escarpment *P. latissimus* occurs in the High Cup Valley in the second limestone above the Lower Scar Limestone (Melmerby Scar Limestone), the latter being characterized at the top by the presence of *Productus giganteus*. On the other (eastern) side of the Pennine watershed, *P. latissimus* is found everywhere in the upper parts of the valleys of the Tyne, Wear, and Tees where the "great" or "main" limestone, in which it is here embedded, occurs. The limestone with *P. latissimus* is, therefore, separated by several intermediate limestones from the Melmerby Scar Limestone.

Still further to the north and east, a thin limestone is found to be crowded with *P. latissimus* on the north-east coast immediately south of Howick Burn, the bed in which it occurs being separated from the Great Limestone (at a lower horizon) by some thickness of mechanically formed sediments.[1]

[1] For further details concerning this section, see Garwood, in "History of Northumberland," by E. Bateson, vol. ii, p. 330.

The reason for the existence of *P. latissimus* at what is apparently a constantly higher horizon as compared with the Lower Scar Limestone, as we proceed northward, we hope to discuss elsewhere; at present we wish to call attention to the fact that, whatever the lithological characters of the strata, the beds with *P. latissimus* occur definitely above those with *P. giganteus.*

The writers hope to obtain further information concerning the minor subdivisions of the Carboniferous rocks of the Northern Pennine region, and in the meantime would urge observers to study the distribution of the Carboniferous fossils in other regions. The Southern Pennine Chain, the neighbourhood of the Bristol Coal-field, and the Carboniferous rocks of North and South Wales would probably repay the labour of a minute study; and local collectors are particularly requested to note the exact horizon of each fossil which they obtain, a task by no means difficult, with the admirable detailed maps of the Geological Survey to serve as a guide. The writers' observations coincide with those of others who have attempted to differentiate minor divisions of the Carboniferous strata, indicating that the Brachiopods are most likely to repay one in carrying out such work; but the remarkable results which have followed from a careful study of the Ammonites would suggest the desirability of careful collection and examination of the *Goniatites*, which are pretty abundantly found in most districts. At the same time, other groups of fossils should not be neglected; corals, especially, will probably yield valuable information in the hands of specialists.

It is daily becoming more apparent that the Carboniferous period was not, as some have supposed, a comparatively brief period, throughout which sediment accumulated with exceptional rapidity. The remarkable discovery by Dr. Hinde and Mr. Howard Fox of thick deposits of Radiolarian cherts in Devon, Cornwall, and Somerset, is of particular interest from this point of view. It can hardly be doubted, therefore, that fossil zones, such as have been defined in strata both older and newer, can also be detected in the beds of Carboniferous age; and if so, it is fully time that the necessary work should be done in strata of such importance. That it has not already been achieved is a probable indication that the task will be a more difficult one than that of separating the Lower Palæozoic or Mesozoic rocks into zones, and may probably be too much for one or two workers. We therefore suggested at the recent meeting of the British Association that a committee might be formed to inquire into the possibility of dividing the Carboniferous strata of Britain into fossil zones; that it should be the duty of the committee to call the attention of local observers to the desirability of collecting Carboniferous fossils, making accurate notes as to the horizon of each, and paying special attention to the Corals, Trilobites, Brachiopods, and Cephalopods; and that the services of eminent specialists who have studied these groups of fossils should, if possible, be retained by the committee, to study the specimens submitted by the local observers.

V.—The Destruction of the Chalk.

By Grenville A. J. Cole, M.R.I.A., F.G.S.,
Professor of Geology in the Royal College of Science for Ireland.

MR. A. C. G. CAMERON, of the Geological Survey of England and Wales, published in 1893 [1] an account of a boulder of chalk so large that the village of Catworth has been built upon it, while springs arise between it and the clays which underlie the mass. Sir A. Geikie [2] now reports the interesting discovery that "a cake or floor of chalk, lying at the base of the Boulder-clay, may be traced over an area of more than twenty square miles in the west and north of Huntingdonshire and in northern Bedfordshire. It crops out more or less continuously along the brow of the hills under the Boulder-clay and rests on the Oxford Clay. It probably consists of many large sheets of chalk which, at the beginning of the deposit of the Boulder-clay, were transported from the chalk hills lying to the east and north-east."

Here we are met by the old question which has so often been discussed in presence of the chalk-masses of Cromer. Have we necessarily to do with glacial action on a large scale, or with processes of disintegration which have broken up the Chalk almost *in situ*? This massive limestone, traversed by continuous vertical joints, is a ready prey, in our cliffs and quarries, to undermining influences, and to the flaking action of frost. The great rock-falls of Dover or of the Dorset coast would furnish very respectable boulders to any "drift" now forming in the Channel. The famous landslip of Axmouth affected the Chalk to a depth of more than 100 feet, and was accompanied by the contortion and upthrust both of the older and more recent strata along the shore. Hence blocks of very various age became mingled together, "invested with sea-weed and corallines, and scattered over with shells and star-fish," [3] representing the existing fauna. Mr. Mellard Reade [4] has elaborated a combined terrestrial and drift-ice origin for the Cromer boulders; and, in the discussion on his most suggestive paper, Prof. Hughes compared the phenomena to those of the landslips near Lyme Regis, in the Isle of Sheppey, and along the river Clwyd.

Chalk resting upon clay along a shore-line is liable to a rapidity of destruction, taking place on an extensive scale, which is nowadays scarcely realized by those who dwell at some distance from the coast. Since catastrophic sea-waves and recurrent deluges have been all but banished from our speculations, it has been the custom to ascribe anything that shows evidence of violence to the glaciers of the Ice Age; and these glaciers have grown in dimensions in proportion to the work ascribed to them. But the storms of the

[1] "Notes on a transported mass of Chalk in the Boulder-clay, at Catworth, in Huntingdonshire": Glacialists' Magazine, vol. i, p. 96. Also Fortieth Report of Department of Science and Art (1893), p. 249.

[2] "Annual Report of the Geological Survey and Museum of Practical Geology for 1894": Forty-second Report of Department of Science and Art, p. 274.

[3] W. D. Conybeare, letter quoted by Lyell, "Principles of Geology," eighth edition, p. 310.

[4] "On the Chalk-masses or Boulders included in the Contorted Drift of Cromer": Quart. Journ. Geol. Soc., vol. xxxviii (1882), p. 222.

winter of 1894–5, and their effects upon the coast of County Antrim, may teach us an important lesson in the destruction of the Chalk by more ordinary natural causes.

The constant landslips at Garron Point and near Glenarm have given rise to a number of masses of chalk, overriding and embedded in the deposits of the present sea, so that the coast, were it upheaved, could with difficulty be differentiated from that of Cromer. The modern sands of the Channel are here mingled with the débris of glacial "drifts," which contain the fragments of shells that marked a colder period. A singular confusion of materials could thus be dredged up close to the land, and blocks brought by floating ice from a distance, such as the eurite of Ailsa Craig, are familiar objects upon the shore. These latter may represent, on the scale of our Antrim illustrations, the Norwegian rocks in the drift of Cromer.

The great storms of the last fortnight of December, 1894, added a large portion of the coast-road to the modern "drift" deposits of the Irish Channel; and they have also provided us, on the north side of County Antrim, with an effective model of the newly discovered floor of Huntingdonshire.

I am indebted to Mr. R. Welch, of Belfast, for a description of the scene in Whitepark Bay, between Carrick-a-rede and the Giants' Causeway. The Chalk and the Greensand here rest characteristically upon the Lower Lias, the clays of the latter series providing the former with an easy gliding-plane. Doubtless the shore for some distance seaward is formed of detached masses of the Cretaceous strata; but the storm-waves have now swept clear from sand an area of, on an average, 1000 feet by 100 feet, its width at the centre being about 250 feet. Mr. Welch has, as usual, made a very successful photographic record of the rocks exposed (No. 5119 in his geological series). The whole area is seen to be covered with blocks of chalk, which are often 10 feet long; they are almost in contact, and are bounded above and below by their planes of stratification, like flakes that have been moved only a short distance from their original position. In the cleft-like intervals between them, the dark surface of the Lias clays is everywhere visible. It is as if a massive bed of chalk had been broken up almost *in situ*; and we probably have here a picture in miniature of many miles of the submarine coast of County Antrim. The spaces between the blocks at Whitepark Bay will, in time, become filled up with modern beach-material; and we only want floating ice in the Channel to embed them in a glacial sand or in a Boulder-clay. Their environment will be a shifting material, liable to compression and even to contortion, as new masses ooze out slowly from the land. Mr. Welch's photograph thus seems to reveal to us what we may call a landslide-phase, rather than a catastrophic landslip-episode, in the destruction of the Chalk. I venture to think that it represents an early phase in the history of the huge chalk-flakes and associated drifts that are being studied in England by Mr. A. C. G. Cameron. The picture is a striking record of the way in which massive chalk may go to pieces, and may be moved outwards on a gentle slope, while yet preserving its stratified aspect and a certain air of continuity.

VI.—Observations on East Anglian Boulder-clay.

By the Rev. E. Hill, F.G.S.[1]

I DESCRIBE some facts which have attracted my attention in my neighbourhood as bearing on the question of the East Anglian Boulder-clays, and I note the directions in which these facts would seem to lead our ideas. For the most part I limit myself to my own observations.

The soil of my neighbourhood is extremely heavy. Boulder-clay is the subsoil, and is often turned up by the plough. The great lumps and clods are dried by the sun into masses almost as hard as brick. But these iron clods, penetrated by the frosts of the severe winters we have lately had, become such that, after the frost has passed away, at the tap of a stick they crumble into a fine powder and almost into dust. If such be the effect of present winters, what may not have been within the power of winters in the great Ice Age. It should be noted also that the matrix of the East Anglian Boulder-clay seems chiefly Kimmeridge clay, while that of the Midlands is, I believe, chiefly Keuper and Lias. These are clays which frost would pulverize, and which occur in the respective regions. There is, then, no need to call in a glacier grinding-mill to make a matrix for the Boulder-clay. These observations seem to point to the land-ice theory being unnecessary.

In the matrix of clay, besides flints, there lie pieces of chalk of every size, from boulders measured by yards down to the pea and the pin's head. I find it difficult to understand how a glacier could grind chalk to anything other than powder. But frost makes the face of a clunch wall or chalk quarry scale off, and showers down pieces of every size. The number of these pieces in the clay is great. I have tried to count the number in a definite area. Counting only pieces of pea size and upwards, I have twice found as many as ninety to the square foot. How come these to be so intimately mingled with the clay-matrix.

Again, how are the clay and chalk brought together at all? The Kimmeridge clay all lies far to the west of Suffolk; I know of none nearer than Ely. On the other hand, chalk occurs as a constituent of Boulder-clays in the Midlands far to the west of all Cretaceous beds. Chalk, then, has been carried westwards, and clay in the opposite direction. What was the agent which could carry east and west at once? Certainly not those glaciers whose course can be mapped by their contents. These observations seem to indicate that the land-ice theory is impossible.

In digging wells many blocks of chalk and limestone brought up are found to be striated or scratched. One such (which was shown), from a well at Felsham, is scratched on one side only; the other side is a mass of fossils, unscratched. It may be a split portion of a larger block, or it may have had one side protected by ice. But in any case clearly it was scratched first and placed in the clay

[1] A paper read at the Ipswich Meeting of the British Association.

afterwards. If the stone and the clay were deposited together, and deposited by water, the appearance is intelligible. The natural explanation is that the Boulder-clay was deposited in water, and that ice, floating over this water, carried stones and dropped them.

The clay is found in West Suffolk up to heights of 340 feet; but none of the neighbouring outcrops of chalk reach 300 feet. I have attempted to trace the contour-line of 300 feet from the Tees to the Thames. The tracing shows that chalky Boulder-clay in East Anglia attains a higher level than any ground northwards up to the Lincolnshire Wolds. Even there, the elevated area of chalk is smaller than the equally elevated area of East Anglian clay. Besides, Mr. Deeley tells us that chalk-drift is found in Leicestershire up to 800 feet, which is far higher than any Northern chalk. It seems, therefore, natural to suppose that much chalk country was then relatively higher than now; accordingly that a tilt of the surface has taken place since Glacial times.[1] This is similar to a conclusion which Prof. Prestwich arrived at, on the independent evidence of his Westleton beds.

Another observation of mine may have a significance. In some brickyards a coarse clay is ground up with water and allowed to settle in shallow pits. A similar material is produced in Cambridgeshire when the mud, washed off from coprolites, has been run into the 'slurries.' When I have seen these pits cut into, their material in its texture has sometimes strongly recalled to me some of the finer varieties of Boulder-clay—for instance, the chocolate-coloured clay of Holderness. This likeness suggests that the deposition of Boulder-clay was a process which went on rapidly. If so, the formation may have taken place in less time than we are accustomed to suppose.

The above observations, then, taken together, suggest the picture of a broad sheet of water surrounded by slopes of clay and scarps of chalk. These are to be broken and pulverized by winter-frosts, and washed down in muddy torrents by spring or summer rains, while stones embedded in ice are also carried down, scratched in the transit, and floated far before they are dropped. But the surface of these waters cannot be still, nor even flowing in a uniform direction. There must be tides, eddies, or varying winds, since something seems required to drift the ice-rafts across the movement of the muddy waters, so as to produce the mixture of materials which we find.

I have confined myself to my own area and my own observations; also I have made no attempt to answer the difficulties which may be raised. There are, however, two obvious objections on which something may be said. It is urged that if the Boulder-clay be of aqueous origin, it ought to contain fossils and be stratified. If my

[1] This argument of course assumes the conclusions previously arrived at. Those who maintain glacier-transport should bear in mind that, unless levels have changed, the ice must have been at a yet higher level above the spot whence it brought the chalk. If this came, for instance, from Speeton, Flamborough Head must then have been buried beneath 500 feet of ice.

suggestion that it was formed rapidly have any truth, fossils need not be expected. Thick muddy waters would probably be quite unfitted for life. I do not think there are fish in the muddy Swiss glacial streams.[1] And the artificial clays I have described sometimes show little or no stratification on a small scale. On a large scale the Boulder-clay *is* stratified. I have seldom gone far without finding traces of this. Often, indeed, it is as clearly stratified as any other clay.

There are doubtless many other difficulties, some of which may be fatal. I offer this paper as an independent contribution to a most controverted, and therefore most attractive, question.

VII.—British Geology in relation to Earth-Folding and Faulting.[2]

By T. Mellard Reade, C.E., F.G.S., F.R.I.B.A.

THE history of every science may be compared to the ascent of lofty and diversified mountains, in which level benches and plateaux alternate with steep and rugged slopes. The first explorers, beginning at the base, toil upwards, hardly knowing which course to take, and having little idea of the country that lies before and above them. But they toil on, gathering information as they go, until, reaching a level resting-place, they can look back and form a more accurate conception of the country they have traversed. Still, they can see but a little way upwards, much less perceive the summit, but ascend they must, gaining an ever-widening view and grander and more just conceptions of the wide world below.

It is thus that the study of geology has progressed. By the combined operation of an army of explorers a vantage-ground has been obtained from which we are enabled to review our position and determine upon the next point of attack.

The history and succession of the rocks have been traced, their position in time and in part, their location in space—but the latter knowledge can never be complete until the whole world has been surveyed, both above and below the waters; now a seemingly impossible task: yet who shall speak for the future?

By the aid of numerous geologists, both great and humble, of all climes and countries, manfully working towards a common end, the order of succession has been outlined, and a fair but very crude knowledge of the earth's history reached. So far as palæontology and stratigraphy can speak, they tell us a good deal, but we cannot realize the meaning of it all without the aid of correct physical conceptions to reveal the processes of the wonderful earth-history which lies buried under our feet.

It is with this object that I ask your indulgence this evening in mentally travelling with me over the British Isles to see what help we can get from known British geology.

[1] In the discussion on this paper it was stated that the Dora Baltea, though thick with glacier mud, contains excellent fish.

[2] Presidential Address to the Liverpool Geological Society, 1895.

Facts of British Geology.

An examination of a good geological map of England and Wales, such as that known as Greenough's, published by the Geological Society, shows at once that the older rocks from the Cambrian to the Carboniferous constitute the bulk of the more essentially mountain areas.

Thus, North Wales is mainly Cambrian and Silurian; Cumberland and Westmoreland are largely composed of equivalent rocks, surrounded with a fringe of Carboniferous, which, more greatly developed in Northumberland, Durham, Yorkshire, and Derbyshire, forms the mountainous district of the Pennine Chain, the so-called backbone of Northern England. Leaving out of consideration for the moment the pre-Cambrian rocks of Anglesey and Shropshire, it is in the Cambrian and Silurian that the greatest deformations and foldings have taken place. Lying conformably upon the Upper Silurian in Herefordshire and Brecknockshire is the great thickness of Old Red Sandstone, more horizontally developed, but yet in the Beacons of Brecon and the Fans of Carmarthen rising as mountains from two to three thousand feet high. These are overlaid conformably by the South Wales Carboniferous rocks. In the North the Carboniferous Limestone lies unconformably upon the Silurian, the Old Red being practically absent. These Carboniferous rocks are in places considerably folded, the Pennine Chain itself being an anticlinal axis, while the Devonian and Carboniferous in Somerset and Devon are folded often at high inclinations in the Quantocks and the Mendips.

Surrounding these anticlinal areas, and in the depression between them, the Permian Limestone breccias and sandstones and the Triassic sandstones and marls lie unconformably upon the Carboniferous rocks, and much of this country is hilly, but cannot be correctly designated mountainous. The whole of the group of rocks, from the Cambrian to the Trias, occupy, roughly speaking, the western half of England, including Wales, but the eastern half of England is constituted of a succession of younger formations, from the Rhætic to the Pliocene. The Rhætic constitutes the passage from the Trias to the Lias, and, though nowhere developed on an extensive scale, is interesting as showing a conformable succession which is unbroken through the Oolites to the Upper Cretaceous. Between the Cretaceous and Eocene is an unconformable break representing a great time interval separating the Cretaceous and Tertiary, which is further confirmed by the complete change in the fauna and flora. The Eocene, Miocene, and Pliocene are conformable, and with them ends what is called the solid geology of the country, the succeeding deposits being Pleistocene, Glacial, and post-Glacial, consisting mostly of clay, sands and gravels, Boulder-clay and alluvium.

It is thus seen that the western half of England, together with Wales, possess the mountainous districts *par excellence*, while the eastern half is distinguished by gently undulating or horizontal strata, with sharp folds located in small areas, as in the Isle of Wight, at Purbeck, and the Yorkshire Chalk at Flamborough Head.

That the Lias had formerly extended over a considerable area of the western half is shown by the preservation of outliers in Shropshire, Staffordshire, and Cumberland, and *prima facie* it is probable that the overlying formations have also at one time in geological history been present. To a student of physical geology a glance at the geological map of England is sufficient to show that the outcrop of the Lias extending from the Severn to the Tees is an escarpment of denudation.

It must not be supposed for a moment that Britain represents the normal physiographic condition of the various formations all over the world, and that the mountain areas are always the oldest. Quite the contrary. In the Alps, Himalayas, and Rockies, in the mountains of the Caucasus and Central Turkestan, it is the younger formations that constitute the highest members of the mountain belts, and it is generally conceded that the bulk of the mountain-making in these chains has been geologically a late event.

Of course in great mountain chains we may have, and generally do have, the older rocks, even to the Archean gneisses and schists thrown up and exposed in their axial folds. This, however, as a rule, only shows that the earth movements to which they owe their birth and growth have been extreme and profound, involving the deep-lying sediments, and even their foundation rocks, in the general movement. We thus see that there is no intimate relationship between the *age* of the rocks of which mountain areas are composed and the existence of the mountains themselves.

The Mountain Areas of England and Wales as related to the thickness of the sedimentary and other deposits of which they are composed.

The Lower Cambrian Rocks of South Wales are estimated to have a thickness of from 3500 to 4000 feet, and are supposed to be over 8000 feet in North Wales. The Upper Cambrian, where well developed, attain a thickness of from 5000 to 6000 feet. The Ordovician, or Lower Silurian of the Survey, is estimated at from 12,000 to 25,000 feet; in Shropshire, according to Murchison, 18,000 feet; and between the Menai Straits and the Berwyns 19,000 feet. The Silurian, or Upper Silurian of Murchison and the Survey, may be 14,000 feet in the north-west of England, and from 3000 to 6000 feet in Wales. The total thickness of British Silurians, Lower and Upper, is stated by Murchison to be from 26,000 to 27,000 feet. Thus, from the base of the Cambrian to the top of the Silurian cannot be less than 35,000 feet.

We thus arrive at the grand aggregate thickness of from six to seven miles of rocks constituting the most mountainous parts of England and Wales. These rocks have suffered more intense deformation than any of the overlying formations, and have, as first lucidly explained by Ramsay, suffered enormous denudation since their folding and upheaval.[1]

[1] "Denudation of South Wales and the adjacent English Counties": Memoirs of the Geological Survey, vol. i.

The only break in the series of any moment occurs between the Ordovician and Silurian. There can be very little doubt that their areal extension was proportionately as great as their thickness. Between the Carboniferous and the Silurian there is a strong unconformity in the north of England and North Wales, but this is bridged over, as already explained, in Shropshire, Herefordshire, and South Wales, by the Old Red Sandstone, estimated at 10,000 feet. The Silurian shades upwards into the Old Red by well-defined passage beds, to be seen in many sections, while the Old Red graduates into the Carboniferous in no less perfect a manner.

The Carboniferous is an extensively developed formation in Britain. The base of Mountain Limestone varies in thickness from 1000 feet in Monmouthshire to 3000 feet in the Mendips in Somerset, while in Derbyshire it is 1600 feet, in the Vale of Eden 2000 feet, and in Llangollen 1200 feet thick. The Millstone Grit reaches a maximum of 5000 feet, the Coal-measures of South Wales 7000 to 8000 feet, and, according to Logan, reaches 10,000 to 12,000 feet in Monmouthshire, Glamorganshire, and Pembroke. In Lancashire the Coal-measures are 6600 feet, though the upper portions have been denuded.[1]

If we add these figures to the Cambrian and Silurian we arrive at a grand total of 55,000 feet, but it is not to be inferred that this occurs in any one place. Ramsay estimates the Silurians, Lower and Upper, the Old Red, and Coal-measures in South Wales at from 20,000 to 33,000 feet (Mem. of Geol. Survey, vol. i, p. 316).

It is of these enormously developed rocks that the typical mountain areas of England and Wales are composed. The question may well suggest itself to us whether there is not here a relation of cause and effect. We have seen that with the exception of the break between the Ordovician and Silurian there has been continuous deposit of sediment from the beginning of the Cambrian to the end of the Silurian, and still further, that in the Old Red Sandstone districts this sedimentation appears to have gone on almost uninterruptedly to the close of the Carboniferous. It is certainly a striking fact that a portion of the earth loaded with sediment to the vertical extent of some five to ten miles should be the very spot where the earth's crust has been elevated not less than four miles, according to Ramsay, and where even now the basal wrecks of these former gigantic elevations should reach 3000 feet above the sea-level. Consider for a moment what five miles of consolidated sediment means. It is equal to a load of 2000 tons per square foot on the normal crust of the earth.

This loading doubtless squeezed and shifted laterally some of the deeply lying and more mobile matter underlying the normal crust, until a balance of stability was attained. Then, by a process of expansion, the effect of a necessary rise of temperature of the old crust and overlying deposits, the conditions were reversed: the

[1] The authorities for these statements are principally Murchison and Ramsay, together with other authorities quoted by H. B. Woodward in the "Geology of England and Wales."

lengthening beds, unable to expand, laterally folded upon themselves, and the whole mass of sediment, by cubical expansion, increased in volume to the extent shown, by the rise of the mountain mass above the sea-level. But we are not to limit this action to the immediate mountain area, for the flanking area, probably largely constituted of more horizontal beds, now covered by newer deposits by successive lateral expansions, added to the folding and heaping up of the mountain masses.

Areas occupied by the Rocks newer than the Carboniferous.

If this relation between extensive and massive sedimentation and mountain-making stood alone it might justly be considered as merely accidental. I have, however, elsewhere shown that such relations may be traced in every known great mountain range; that formations here thinly developed and horizontal are in the Alps and Pyrenees, to go no further afield, extensive, thickly developed, and thrown into immense mountain masses.

In Britain the Permian and Trias, which lie unconformably upon the Carboniferous, reach a thickness of some 6000 feet, but the variation of thickness is very considerable from the overlapping of these formations on the mountain slopes. They are, however, as a rule, more affected by folding and faulting than the succeeding formations, and constitute some considerable hills and escarpments.

The Jurassic and Cretaceous occupy the largest part of the eastern half of England, and may be put down at perhaps 5000 feet, and the Tertiary at say 1500 feet; the total thickness of the British rocks from the Permian to the Tertiary inclusive, working out to about 12,500 feet. It is, however, very questionable whether such an aggregate thickness occurs in any one locality; while in the case of the older rocks, from the base of the Permian down to the base of the Cambrian they are developed in great thickness in direct superposition.

Characteristics of the Folding of the Eastern and Western Areas of England and Wales contrasted.

The rocks already described as occupying the eastern half and south of England are characterized by long low folds breaking into sharp anticlinals and synclinals at a few points only, such as in the Chalk at Flamborough Head and in the Tertiaries of the Isle of Wight, the eroded edges of these long folds forming the characteristic escarpments stretching across the country in a southwesterly and north-easterly direction. Sharply contrasted with these long undulations are the strata forming the mountain nuclei of Wales and Cumberland, where we find the rocks sharply bent and compressed, the remnants of the primitive folds forming by denudation the mountain scenery as now beheld by us. Intermediately we find areas of the Carboniferous and Old Red having a horizontal development, such as is to be seen in the Carboniferous of the neighbourhood of Whernside and Ingleborough, and can be well studied near to Dent, where the much contorted Silurians are in juxtaposition to the less disturbed Carboniferous, the latter being let down by an enormous fault of unascertained throw. Again, in Herefordshire and South Wales we see a considerable extent of horizontal Old Red, which, as it approaches the Silurian mountain folds, becomes itself conformably inclined.

Not less interesting and instructive are the dome-like structures, such as the celebrated dissected Silurian dome of Woolhope, which rises in successive rings through the Old Red, which it carries on its flanks. May Hill is another similar structure, not so perfectly formed and also bisected by faulting against the Trias.

The physical constitution of Herefordshire and Brecknockshire is largely a horizontal plane of Old Red Sandstone, which, where it approaches the folded Silurian areas at the margins or round the enclosed domes, takes on the folds of the older rocks on which it lies.

Silurian and Old Red of the South-east of Scotland.

It will be instructive now to turn our attention to the rocks of a similar age to be seen dissected in the splendid line of cliffs from Berwick-on-Tweed to the far north of St. Abbs Head and Siccar Point. Here the Silurian (Lower Silurian) are intensely folded, and instead of the conformable succession from the Silurian, through the Old Red and Carboniferous which we have just seen obtains in Herefordshire and South Wales we see the Upper Old Red Sandstone conglomerate resting upon the edges of the Lower Silurian in the strongest unconformity. Well may the justly celebrated Hutton have exhibited this phenomenon, as seen at Siccar Point, as one of the best illustrations of the views he developed in the "Theory of the Earth."

So perfectly are the two formations cemented together that it is possible to get hand specimens of the unconformity. It would appear that while the sediments of South Wales were being laid down in quiet waters from the beginning of the Upper Silurian to the close of the Carboniferous, the succession of events was several times broken in Scotland, as shown, not only by the strong unconformity already spoken of between the Upper Old Red and the Lower Silurian, which I have myself seen, but by the unconformity Sir Archibald Geikie shows exists between the Lower Old Red and the Lower Silurian,[1] and even between the Upper and Lower Old Red[2]; and he further states "that the great earth movements which plicated the Highlands and Southern Uplands were probably simultaneous, and took place chiefly during the long series of ages represented by Upper Silurian deposits."[3] As the Upper Silurian in Lanarkshire passes gradually into the overlying Old Red Sandstone,[4] it is probable that the break between the Upper and Lower Silurian we have seen exists in England and Wales also extends to Scotland. The succession of events in the latter country are indeed more

[1] "The Geology of Eastern Berwickshire": Memoirs of Geological Survey, p. 20. "Scenery and Geology of Scotland," second edition, p. 122, also p. 138.

[2] *Ibid.* p. 329. [3] *Ibid.* p. 299. [4] *Ibid.* p. 327.

complex and difficult to trace than in South Britain, but it is sufficient for the present purpose simply to mention them as all pointing towards the immense range of geological time represented by the conformable Upper Silurian Old Red Sandstone and Carboniferous of South-west Britain.

Thickness and Extent of Rock Formations a measure of their plication.

The preceding sketch is little more than the barest outline of geological events recorded in the rocks of our own island, yet attentively studied the following facts stand out prominently:—The sedimentary rocks which were deposited in the greatest volume are those also that subsequently became most plicated. Though they were the earliest laid down they even now constitute the distinctly mountain masses of Britain, and possess actually the highest peaks and the highest average elevation. When it is considered that these mountains have been exposed to the destroying agencies of denudation for an enormous period of geological time, and still stand pre-eminent above those built out of younger formations, we may perhaps picture to ourselves in some slight degree the extent of the original mass. Not only are the Cambrian and Silurian formations here of enormous thickness, but they are of surprising and unknown extent, and they are found whenever denudation has proceeded far enough to bare them to the eye.

Again, the Carboniferous, taken together with the Devonian and Old Red Sandstone, occupying the second place in the mountain structure of the British Isles, consist of great masses of sediment, not indeed rivalling the Silurian in volume, but of great extent and thickness, though much denuded. Some portions are considerably folded, and most are greatly faulted, but as a whole do not show anything like the signs of lateral compression which are seen in the Cambrian and Silurian.

The Permian and Triassic rocks come next in time and, curiously enough, in importance as regards thickness, and the country they occupy, if not mountainous, possesses a more faulted structure than any of the following formations, and is of a more hilly character.

When we ascend to the Lias, Oolites, and Cretaceous, then the beds become more continuous, horizontal, and less faulted. Folds, and sharp ones, are to be met with, but these, as a rule, are local, the lateral pressure to which they were subjected having been less, and concentrated at fewer points. The same peculiarities apply to the Tertiary rocks, perhaps in a stronger degree.

Relation of Orographic Structures to the mass of the sediment composing them.

I trust that I have now said sufficient to show that there is in the British Isles an intimate connection between the depth, extent, and mass of the several great deposits marking the progress of geologically recorded events, and the structures into which they have been severally raised.

The mountain-building and the foldings and the faultings are, roughly speaking, found to be proportionate to the original mass of the deposits out of which they have been fashioned by earth forces. If these facts stood alone they might be considered nothing more than curious coincidences. If, however, we cast our eyes abroad to the great continents we find that similar principles hold good, and that the mountain massives are related the world over to the thickness and volume of the deposits out of which they have been fashioned. Thus, the Alps, the mountains of the Caucasus, the Himalayas, are Tertiary structures; the Appalachians and Urals, Carboniferous; and these mountain chains are constructed of enormous thicknesses and volumes of sedimentary rocks.

Expansion and Contraction the cause of Folding and Faultings.

We may well ask ourselves why this relation between volume of sediment and greatness of disturbance should be so constant, and any theory of mountain genesis must necessarily explain these associated facts. The once favourite hypothesis which accounts for them by a shrinkage of the nucleus of the earth and the closing in of the non-shrinking crust upon it, and consequent folding by tangential pressure, fails to explain the constancy of the connection of great thicknesses of sedimentary rocks with the evolution of mountain ranges.

Neither does the principle of isostacy so insisted upon by American geologists explain the compression, folding, and building up of great masses of sediment into mountain ranges. On the principle of isostacy, it must be obvious to anyone possessing even a rudimentary acquaintance with mechanics that the sinking of the bed of the seas on which great deposits are accumulating, and to some extent a rise of surrounding land, may be explained, but not the lateral compression and elevation of the sediments themselves into mountain ranges.

Where, then, are we to look for the agency constantly associated with the deposit of great volumes of sediment which is capable of eventually upheaving them from below the sea-level, and by lateral compression and folding throwing them into mountain chains?

Again, when after the lapse of lengthened periods of geological time, denudation has cut away and removed into the sea large masses of elevated land, what agency is it that causes it to shrink and become traversed by great lines of faulting?

It appears to me now, even more vividly than it has done in the past, that the only agency with which we are acquainted constantly associated with sedimentation and denudation, and capable of these enormous dynamical effects, is change of temperature: that expansion by increase of heat is the cause of the folding, compression, and upheaval of rocks, while loss of heat and consequent shrinkage is the cause of the earth fractures known as normal faults. This principle I explained fully in 1886 in my "Origin of Mountain Ranges"; since then the theory has been subjected to much criticism, ranging from a questioning of fundamental principles down to a minor examination of small details.

The fundamental position has, I maintain, not been shaken, either by mathematical physics or geological facts. The more the theory is tested by the light of practical geology the more remarkable is the explanation it affords of the associated phenomena of sedimentation and mountain-building; denudation and faulting. Furthermore, no other theory yet brought forward attempts to offer an explanation of more than one set of these phenomena, namely, those of compression. Normal faulting cannot be accounted for by compression, yet the rival theory of tangential pressure on the crust through the shrinkage of the earth's nucleus provides for compression only. Contraction, by which I have shown that normal faults are produced, is not part of the machinery of any other theory than the one associated with my name.

I ask geologists to bring to the consideration of these great problems clearness of vision, for, usually, a single aspect only is examined, the rest being left in an impenetrable haze.

I trust I have now brought sufficient evidence before you to show that a broad examination of the formations of these islands, and their associated physical phenomena, throws a good deal of light on the problems of mountain-building, and that their remarkable relations are well worth more detailed examination than I have been able to give them in this address.

NOTICES OF MEMOIRS.

I.—Notes on some Tarns near Snowdon. By W. W. Watts, M.A., F.G.S.[1]

During a recent visit to North Wales, the writer has taken the opportunity of examining a few of the tarns in the immediate vicinity of Snowdon, including the two small lakes in Cwm Glas, Glaslyn, and Llyn Llydaw.

In the hollow of Cwm Glas there are two tiny tarns named Ffynnon Frech and Ffynnon Felen; both lakes drain over a barrier of rock, but in a rainy season the upper one appears to find a second outlet over the long, low col to the east, so that in this state it has the two outlets depicted on the six-inch map. The upper lake appears to be a portion of a bending valley dammed at both ends by scree and stream-débris, and thus compelled to find an escape over the rocky side. The lower lake is confined in a rock-basin, as rock occurs at its actual outlet and at every point where any former outlet might have been possible. The lake is, however, so shallow that its occurrence in a basin of rock is perhaps of little consequence.

The neighbouring hollow of Cwm Dyli, as is well known, contains three lakes, the highest being Glaslyn, the next Llyn Llydaw, and the lowest Llyn Teyrn. Glaslyn is bounded on all sides by live rock, except at and near its outlet. This exit is over moraine, which, however, is evidently not very deep, for rock makes its appearance just below, and in such a way as to almost compel belief

[1] Read before Section C of the British Association at Ipswich, September, 1895.

in a complete rock bar. Beside the present course of the effluent stream is a parallel strip of moraine running down towards Llyn Llydaw, but living rock soon appears in this in such a way as to show that if there be any old channel in this direction it must be exceedingly narrow and tortuous. If this lake be not contained in a true rock-basin it must be very shallow, or else must have found exit by a gorge quite as narrow as those found at the end of some of the Swiss glaciers.

Immense quantities of moraine material occur on the south-east side of Llyn Llydaw, but a careful examination of the map and the ground shows that only two possible outlets exist, that now used for this purpose, and a second which is occupied by bog resting on moraine, and gives rise to a small stream which is joined lower down by the outlet of Llyn Teyrn. The moraine is, however, only a thin skin on the surface of rock. The present outlet shows live rock 40 or 50 feet below the level of the lake, and the second possible exit at a rather less distance below the same level. If the moraine were stripped off, there is little doubt that this lake, like Glaslyn, would show a basin of rock which would hold water, unless it is very much shallower than is generally supposed to be the case.

II.—On Pitch Glaciers or Poissiers. By Prof. W. J. Sollas, D.Sc., F.R.S.[1]

PITCH and the ice of glaciers strikingly resemble each other in behaving as solids or liquids, according to their manner of treatment. On the sudden application of force they break like brittle material, but behave as fluids when subjected to gradual pull or pressure. Hence it is possible to employ pitch in the construction of working models of glaciers in order to obtain an insight into those internal movements of actual glaciers which are beyond the reach of direct observation. The study of glacial deposits has shown that many erratic boulders were transported, during the Glacial period, from lower to higher levels, and left stranded on the flanks of mountains some hundreds of feet above their source.

This standing difficulty in the way of physical theories of glacier-movement has been explained by the study of pitch models, which show that the lower layers of material on approaching an obstacle are carried up in an ascending current. The inference, which is confirmed by other kinds of observation, is that similar movements take place in actual glaciers. Further, a glacier sometimes over-rides its terminal moraine without disturbing it; and in an experiment this was exemplified, for pitch flowed for several months over a ridge of loose material without carrying a particle of it away. A remark made by Professor Fitzgerald to the effect that viscosity seemed merely to retard, not to alter the nature of, the movement, in the cases described, led the author to experiment with less viscous material, such as Canada balsam and glycerine, with concordant

[1] Read before Section C of the British Association at Ipswich, September, 1895.

results. A trough containing balsam flowing upwards over an obstacle under its own head of pressure was shown by the lantern upon the screen.

A raised model of Ireland had been constructed, and the directions of ice-movement as determined by the Rev. Maxwell Close indicated upon it by arrows; on allowing water streaked with colouring matter to flow over it from two areas supposed to represent the great gathering grounds of snow of the Glacial period, the water had taken paths, as shown by coloured streaks, corresponding to those taken by the ice as shown by the arrows, a concordance in every way remarkable.

REVIEWS.

I.—The Geological Survey.

THE Report for the year 1894 of Sir Archibald Geikie, Director-General of the Geological Survey of the United Kingdom and Director of the Museum of Practical Geology, has reached us somewhat late in the present year. This is the more to be regretted, as the Report contains (in addition to the statistics relating to field-work, museum-work, and publications) a record of the chief scientific results obtained during the year.

Of the entirely new area in course of survey, that of the Isle of Man first calls for notice in the account of work done in England and Wales. There Mr. G. W. Lamplugh has discovered certain conglomerates in the Skiddaw Slate group, which he believes to have been produced by the breaking up of sandy slates and grits under intense shear strain. Unlike ordinary crush-breccias the included fragments often assume the characters of pebbles, rounded by attrition. The subject has been fully brought before the Geological Society, so that further reference here is not needful. No fossiliferous zones have as yet been determined in the Skiddaw Slates. With regard to glacial phenomena, the general march of the ice during the height of glaciation is noted to have been from some point west of north. It is stated that a bed of fine warp or silt in the glacial series of Kirk Michael may prove to be of some economic value: it has been used locally as a fuller's earth.

In areas that are being re-surveyed, those of the South Wales and other coal-fields are, without doubt, the most important. Portions of Glamorganshire, Brecknockshire, and Monmouthshire are being mapped by Messrs. J. R. Dakyns, A. Strahan, and W. Gibson, and in these (as in all other) areas where the Geological Survey is now engaged, the six-inch Ordnance Maps are utilized in the work. It is interesting to learn that, on the eastern border of the great coal-field, the several subdivisions of the Old Red Sandstone at present observed, appear to pass into each other, from the red marls and sandstones with cornstones up to the red sandstones, quartz grits, and conglomerates. The Carboniferous Limestone Series, as is well known, exhibits marked variations in the thickness of its component strata, and it is noticed that in the middle of the main limestone there is, locally, a remarkable band of white oolite 40 feet thick. The chief lithological divisions in the Millstone Grit and in the Coal-measures are separately mapped, so that the structure of the ground may be clearly represented. This is of great practical value as regards the bands of clay-ironstone, the steam-coals, and other economic products.

Much new information has been obtained with regard to the extent of the boulder drift, and to the occurrence of Esker gravels in Monmouthshire and South Wales. Proof that the ice must have existed in considerable bulk has been obtained in the excavations of some new waterworks at Nant-y-bwch, where a hill of sandstone, upwards of 200 yards long, has been found to be a transported mass.

Some commencement has been made with the re-survey of the Leicestershire coal-field by Mr. Fox-Strangways, and of the North Staffordshire coal-field by Mr. De Rance.

It is satisfactory to learn that the results of these and other re-surveys will be published on the new series of the Ordnance one-inch maps, while MS. coloured copies of the six-inch maps are deposited in the Geological Survey Office for public reference.

In Devonshire and Cornwall, Mr. Ussher has been surveying the subdivisions of the Devonian formation and their associated igneous rocks; while in the southern counties Messrs. Whitaker, Reid, Bennett, Blake, Hawkins, and Jukes-Browne have been engaged in mapping the Drifts and re-surveying the Cretaceous and Tertiary rocks. The mapping of the Drifts in Yorkshire and in parts of the Midland counties has been continued by Messrs. Tiddeman and Cameron, who have likewise attended to needful revisions of the previous survey of the older and more "solid" formations.

In Scotland the Lewisian gneiss of the northern part of Raasay was mapped by Mr. Teall. It has been determined that the various crystalline rocks older than the Torridon Sandstone, and comprised under the general designation of Lewisian gneiss, may be divided into five distinct groups. The oldest and chief group is the "fundamental complex" of banded and foliated rocks, and this is considered by Mr. Teall to have decided affinities, both as regards chemical and mineralogical composition, with plutonic igneous products. A scheme devised by him for descriptive purposes, is now published in the Director-General's Report. Based primarily on mineralogical composition, and to a subordinate extent on structure, it shows the nature of the various rocks comprised within this "fundamental complex." In the other groups are included various dykes, gneissose granite, and pegmatite. The observations of Messrs. Peach and Horne prove that in certain areas the "Moine schists" have been produced by the alteration of the lowest Torridonian grits and shales.

Interesting results have been obtained by Mr. Hinxman in Strathspey, and by Mr. Barrow in Deeside, with regard to the relations of the great granitic masses.

The survey of the Island of Arran has been taken in hand by

Mr. Gunn, and he has found in the red sandstones, which extend along the eastern shore, and across the southern half of the island, a contemporaneous volcanic group. It is considered highly probable that these beds are of Permian age.

The older rocks and the Tertiary dykes of the south-east of Skye have been mapped by Mr. Clough, while Mr. H. B. Woodward has been engaged in the survey of the Jurassic rocks along the north-eastern borders of the island. With Mr. Symes in Cantyre, Mr. Wilkinson in Islay, Mr. Hill in the region between Loch Fyne and Loch Awe, Mr. Grant Wilson in Banff and Elgin, and Mr. Greenly (who has since retired) in Sutherland, the Geological Survey has made progress in various parts of Scotland.

In Ireland the work of revision has been carried out in different areas by Messrs. Egan, Kilroe, McHenry, and Sollas. The Croagh Patrick quartzite is now assigned to the Llandovery formation. In the tract of ground between Clifden and Oughterard there is a complex series of rocks which are considered to be equivalents of the Dalradian rocks of other regions. In the district of Pomeroy, in Tyrone, there is a belt of igneous rocks, lying between the Silurian and Old Red Sandstone rocks on the south and the crystalline schists on the north; and it has been found that they include lavas interleaved with cherts and jaspers exactly like those associated with the igneous rocks at the edge of the Highlands. It is surmised that the cherts, and certain overlying shales, etc., may prove to be of Arenig age.

II.—Les Variations périodiques des Glaciers. Discours préliminaire. Par F. A. Forel, President de la Commission Internationale des Glaciers. Archives des sciences physiques et naturelles. Genève. Vol. xxxiv, p. 209.

PROFESSOR FOREL commences by relating the formation of his committee, "sur l'initiative" of the writer of this notice. Each member, he tells us, is to organize—as seems best to him, and after the most useful fashion—historical, present, and future studies of glacier phenomena, and publish such in the periodicals of his own country; and a summary is to appear annually in the Archives des sciences, etc., of Geneva. He then proceeds to the consideration of what the phenomena to be studied consist in. Much of this ground has already been put forward by the writer, but there are points and extensions dwelt upon by Professor Forel which it may be acceptable to touch upon.

He rightly emphasizes the importance of concentrating our energies, more especially at first, upon the observation of actual advance, retreat, increase or diminution in bulk of glaciers, and to the simultaneity or otherwise of their variations in both hemispheres and all latitudes, as also to their relation to meteorological records.

As regards the study of névés, to the extent and quantity of which, of course, much of glacier variation is due, he thinks that, great as is the importance of such observations, we had better for the present not complicate our work, but "occupons-nous seulement des glaciers proprement dits." The writer, though agreeing to a great extent with this, is unable to see how a definite line could profitably be drawn between food-supply and glaciers. However, M. Forel quite admits the importance of such study, and that not only must heat, cold, winds, sunshine, ablation, moisture, and precipitation be the causes of variations, but that the history of past seasons and of the snow reservoirs must bear upon more recent change of mass, all which it is absolutely necessary to carry into account to obtain a reliable budget. It is, however, evidently important that the meteorologists should help in our researches, rather than that we should dissipate our energies by studies specially their trade! Let them bear in mind that, as our author well puts it, "La grandeur relative des glaciers est un indice de la variation du climat." He hopes for light to be thrown upon the question of periodicity of climate by comparative glaciology, and pays a very just tribute to the work of Brückner on Klimaschwankungen. Roughly speaking, Switzerland has witnessed three great oscillations in the century.

A few words as to methods. I. The well-known and elaborate system applied to the Rhône glacier is: In September the *tongue* of that glacier is surveyed, and the superficies of the ground left by its retreat. Simultaneously a levelling is executed of lines, always the same, on the surface of the ice; this gives its variations in volume. Lastly, the annual advance is ascertained of points placed each year on the same profiles, which gives variation in flow.

II. The forest officers in Switzerland adopt a simpler plan. In front of glaciers two fixed marks, one on each side of the containing valley, give a measurable base. From this base the distances of certain principal points on the glacier front are measured at the beginning of September (as in the first case), and their position indicated in abscissæ and ordinates. A sketch upon a convenient scale accompanies the officers' reports, and shows variations in length.

III. Photography, applied by M. Joseph Tairraz, of Chamounix. Each year, at the same date—September—a view of the glacier snout is taken from the same point with the same apparatus. A comparison of successive views gives the required history. A series is very instructive, but the difference from one year to another, in the ice-front, is not easily appreciated, whereas views taken at longer intervals show variations clearly.

IV. To this the writer may add that the possession of a box camera and a prismatic compass with clinometer (or, as he himself has practised, of a Casella's Galton pocket altazimuth) enables a survey and photogram to be made simultaneously, simply by placing the fiducial edge of the clinometer against the side of the camera, on a plane table, plotting the compass bearings, and noting the clinometer. In adding details to maps, *prick out* the station and write notes on the back. Also *spot* glass negatives and *prick* films and prints.

MARSHALL HALL.

III.—The Gold Mines of the Rand, being a Description of the Mining Industry of Witwatersrand, South African Republic. By Frederick H. Hatch and J. A. Chalmers. (London: Macmillan and Co., 1895. Price 17*s.*)

THAT a mining district which produces gold to the value of £6,963,000 sterling per annum, and the market value of whose mines is over £100,000,000, should so long remain without any work descriptive of the nature of the industry and the geological structure of the country, is remarkable.

Messrs. Hatch and Chalmers' book on the "Gold Mines of the Rand" will be found to contain a brief description of the geology of the district and a more extended account of the mines, the method of mining employed, and two useful chapters on the metallurgical treatment of the ore, including the history and application of the cyanide process. The work is copiously illustrated and is accompanied with a geological section, two maps of the chief mining centres of the Southern Transvaal, and several tables showing the monthly output of the mines, dividends paid, etc.

The authors have put together, in a very readable form, a mass of information that has been gradually accumulating on the subject.

The chapters on the geology of the district are confined to a brief account of the geological structure of South Africa, a description of the auriferous conglomerates, and some remarks on the nature of the mineralization, the origin of the ore bodies, and the distribution and value of the gold contents.

The South African formations are broadly grouped together in descending order as follows:

Recent deposits.
Karoo formation.
Cape formation.
South African Primary formation.

The Witwatersrand beds (following Schenck) are assigned to the Cape formation, but no new facts are brought forward to support this view.

Some errors that have appeared in nearly all descriptions of the geological structure of the country are repeated. Thus the quartzites and shales to the immediate north of Johannesburg are represented on the diagram section as having the same dip as the auriferous conglomerates, whereas they are only locally conformable, though the strike of the two groups is coincident from east to west. There is little doubt that the junction of the gold-bearing beds and the quartzite shale group is a faulted one, and that the true sequence remains to be discovered.

The relation of the "Banket beds" to the Primary formation is also not clearly stated, but it is inferred (p. 71) that they rest on the eroded edges of the latter. Near Johannesburg and again near Vredefort there is very clear evidence that the Banket beds are pushed over the ancient metamorphic rocks, while there is no evidence to show that the conglomerate beds were formed by the denudation of the Primary rocks. The metamorphic rocks of the Transvaal consist chiefly of altered igneous rocks, but the conglomerates are composed almost exclusively of quartz-pebbles, without a single specimen of any other kind except sandstones.

It seems certain that the age of the Witwatersrand beds will have to be decided by mineralogical identity. Their relation to the older rocks must not be considered as proved until some mineral that is known to be peculiar to the metamorphic rocks is detected in the matrix of the Banket beds. It is true that in the Zwarteberg Mountains sandstones, with scattered quartz-pebbles similar to those of the "Banket," are folded in with rocks in which Spirifers and Terebratulæ of Carboniferous species are said to occur. But it has been demonstrated again and again how dangerous it is, in a folded district, to argue the age of beds when closely associated or even in actual contact.

The classification of the auriferous conglomerates into a conformable and unconformable set has little geological importance. It is impossible to correlate the conglomerates of outlying districts with those near Johannesburg since there is really no distinctive lithological difference between the various conglomerates. The paltry difference in the size and number of the pebbles is no safe guide. Even if there were a bed or group of beds that could with certainty be recognized throughout the Southern Transvaal as occupying a definite horizon in the auriferous series, it would be extremely difficult, owing to the faulted character of the country and the complexity introduced by the intrusions of igneous masses, to piece together the disjointed fragments that remain.

The igneous rocks are briefly described as basic "greenstones"—diabase, epidiorite, and gabbro being recognized among others.

No attempt is made to classify the faults and dykes according to their relative ages. It is certain that many of the dykes were formed prior to the deformation of the beds, since they have been converted into schistose rocks, while others show no signs of alteration. It is interesting, however, to find that reverse faulting is recognized, which results in some cases in the reduplication of the beds, as instanced on the property of the Witwatersrand Company, where the conglomerates of the Main Reef Series have a double outcrop.

The origin of the gold is left an open question, but no connection is found to exist between the gold contents of the conglomerates and their proximity to igneous masses or dykes.

In the chapter on "Deep Levels" the authors have carefully avoided introducing theory into their descriptions, and make no allowance for the part played by reverse faults in bringing the Main Reef Series nearer to the surface, but it is by no means an impossibility that the members of the Main Reef Series will be found much nearer the surface than any ordinary flattening of the beds could account for.

From the facts brought forward by Messrs. Hatch and Chalmers and other observers, it is certain that in the Rand formation the geological student has an excellent field for studying the incipient stages of dynamo-thermo-metamorphism. In a work primarily intended for mining students and the general public, it is not to be expected that these subjects will be treated of in more than mere outline, but it is to be hoped that a geologist, who is both a good stratigraphist and petrologist, will attempt to unravel the geology of the country. A careful investigation of the district and a conscientious collection of all the available facts will certainly bring to light much that is new and interesting to geological students, and which would in turn be of much practical value.

REPORTS AND PROCEEDINGS.

Geological Society of London.

November 6th, 1895.—Dr. Henry Woodward, F.R.S., President, in the Chair.

The President announced that the Council had temporarily appointed Mr. Clyde H. Black to the post of Assistant-Clerk.

The following communications were read:—

1. "The Serpentine, Gneissoid, and Hornblendic Rocks of the Lizard District." By T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S., Professor of Geology and Mineralogy in University College, London.

After some introductory remarks the author states that in company with the Rev. E. Hill, and in consequence of their work in Sark, he again investigated the question of the genesis of the hornblende-schists at the Lizard, and was able to overcome the difficulties which formerly withheld him from attributing an igneous origin to the schists themselves and their banded structures to fluxional movements during consolidation. Here also, as in Sark, there is some evidence of this banding being the result, at any rate in places, of a mixture of a less and a more basic material. Additional evidence is given as to the genesis of the granulitic group and its relations to the hornblende-schist. Moreover, in consequence of the paper by Messrs. Fox and Teall, published in the Society's Journal (vol. xlix, p. 199), the author has again examined (with Mr. Hill) every section which he could discover to bear on the relations of the serpentine, the hornblende-schist, and the granulitic rock. A number of instances are quoted where the serpentine splits open or rumples the bands of the granulitic rock, or cuts across them. He shows that in the sections at Potstone Point and elsewhere the serpentine is welded to the hornblende-schist, cuts across its banding, and behaves generally as an intrusive rock, while the rare cases of apparent interstratification of the two prove to be the results of the inclusion and occasionally very local melting down of the latter by the former rock. He maintains that the relations of the serpentine to the granulitic and the hornblendic groups are inexplicable on the hypothesis of an igneous complex, so far as he understands the meaning of that term, or of a folding in a solid condition or any other form of dynamo-metamorphism, and he maintains his original opinion that the serpentine (*i.e.* the original peridotite) is intrusive in the other rocks.

The paper also deals with some minor points in the geology of the Lizard; the author supplying some additional particulars about the serpentine at Porthkerris and Porthallow, and explaining that he has found the rocks on the south side of Porthoustock Cove to be only a continuation of those which form the crags south of the opening of the Cove, though they are generally less well preserved: namely, a fine-grained gabbro, intrusive in the ordinary Crousa Down gabbro, and "greenstone" dykes cutting both of these.

2. "The 'Schistes Lustrés' of Mont Jovet (Savoy)." By J. W. Gregory, D.Sc., F.G.S.

The author gives a history of the controversy as to the age of the 'schistes lustrés' of the Western Alps, making special reference to the views of Zaccagna and Bertrand concerning the schists of Mont Jovet. Of these writers, the former maintains that the rocks of the summit of the mountain are old rocks on which the Carboniferous and Triassic strata were deposited unconformably; while, according to the latter author, the rocks forming the top of the mountain were laid down after those which flank it.

In the present paper the author gives the results of an examination of the rocks of Mont Jovet recently made by him. He contends that Lory and Zaccagna were correct in identifying the central rocks of Mont Jovet as 'schistes lustrés,' for this conclusion is supported by their lithological characters and the occurrence of basic igneous rocks of the 'pietre-verdi' type associated with them, and is not opposed to their stratigraphical relations. It is further maintained, as the result of the evidence collected by the author, that the schists in question are older than the Trias; for fragments of the schists occur in the Trias, there is a discordance of strike between the two series, masses of dolomite rest unconformably upon the flanks of the schists, and the Trias has escaped metamorphism which the schists have undergone. The probabilities are in favour of the schists occupying the same relation to the Carboniferous as they do to the Trias; while the close approximation of the schists to the former shows that the schists are not the altered representatives of the neighbouring Carboniferous beds, and it is therefore concluded that the 'schistes lustrés' are pre-Carboniferous, but evidence by which finally to assign them to any exact horizon before this date is still wanting.

CORRESPONDENCE.

ON THE USE OF THE TERM *BOLDÉRIEN*.

SIR,—Will you allow me a few words on the term *Boldérien* as applied in the abstract of the interesting paper of Mr. G. F. Dollfus (GEOL. MAG., October 1895, p. 474) on the seas during Upper

Tertiary times in Western Europe. This name was originated by Dumont for the white sands, without fossils, which appear in the Bolderberg, near Hassalt. We can observe these sands, in places, on the banks of the Rhine, where they contain fossils, and are classed as Upper Oligocene. The Miocene of Belgium is the *Crag noir d'Anvers*, part of the *Diestien* of Dumont, the *Anversien* of Cogels and Van Ertborn.

Lately, M. E. Van den Broeck has endeavoured to demonstrate on the evidence of fossils found in the upper beds of the *Boldérien* at Waenrode, that the *Boldérien* and *Anversien* are *synonymous*, and, consequently, that the term *Anversien*, being newer, must be cancelled. This view, it appears, was adopted by M. Dollfus; but I still maintain that this correlation is by no means well founded, and agree with Cogels and others that our ancient *Boldérien* is Oligocene.

UNIVERSITÉ DE LIÉGE;
October 29th, 1895.

C. DEWALQUE.

OBITUARY.

DR. ERNST VON REBEUR-PASCHWITZ.

BORN AUGUST 9TH, 1861. DIED OCTOBER 1ST, 1895.

DR. ERNST VON REBEUR-PASCHWITZ was born on August 9th, 1861, at Frankfurt a. Oden. In consequence of his father's movements as a Government officer, Von Rebeur's school was often changed, but wherever he went his knowledge of mathematics made him in these studies *facile princeps*. He obtained his doctorate at Berlin, where he became an assistant at the Observatory. At Karlsruhe, where he was 'Erster Assistant,' he commenced, in 1884, to interest himself in Zöllner's pendulum. It was about this time that his health first caused anxiety to his friends. Although he visited Switzerland, Italy, Teneriffe, and other places, returning to his home in apparently good health, it was soon recognized that his recoveries were only temporary. At Halle, where he was Privat Docent, the condition of his throat and chest precluded him from giving lectures. From 1891 until his death, on October 1st, 1895, he was more or less confined to a bed or sofa, often suffering excruciating pain, and never left his room excepting during the summer.

It was during this period of physical incapacity that Von Rebeur produced his most remarkable work, and became the pioneer of a new seismology. Commencing with the endeavour to measure lunar gravitation, he discovered the diurnal wave, that earthquakes could be recorded at stations distant more than a quarter of the earth's circumference from their origin, came in contact with the ubiquitous tremors, and observed many other phenomena connected with the movements of our so-called *terra firma*. These discoveries attracted the attention of other observers, and horizontal pendulums were established at several of the more important observatories in Germany and Russia.

Von Rebeur's last work was an endeavour to obtain co-operation for the observation of these instruments throughout the world, a scheme which, although he has not lived to realize it, will, in all probability, be accomplished in the near future. His ability and energy are testified by the works he leaves behind, and his modesty and kindly nature are spoken of by all who knew him. J. M.

Captain Charles Tyler, F.L.S., F.G.S., whose death on the 2nd November last, in his 70th year, we deeply regret to record, was for very many years an active member of the Council of the Palæontographical Society, and keenly interested in all microscopical research. He also worked assiduously at the Protozoa with the late Dr. Bowerbank, F.R.S.

MISCELLANEOUS.

A most useful "Bibliography of Midland Glaciology" has been contributed by Mr. W. J. Harrison to the Proceedings of the Birmingham Natural History and Philosophical Society (vol. ix, 1895). His record includes the titles of more than one hundred and fifty papers, dating from the year 1811 up to the present time, and written specially on the Drift deposits or glacial phenomena of the Midland counties; and he has added titles of over a hundred other books and papers which have a more general bearing on the subject. Nor has he confined his record to titles, for notes are given on the contents of nearly every article. He remarks that singularly little attention was paid to the Midland Drift by the officers of the Geological Survey when they mapped the region in 1855–60. What is now wanted is a detailed survey of the various accumulations of Boulder-clay, Sand, and Gravel.

"The Onyx Marbles: their origin, composition, and uses, both ancient and modern," is the title of a Memoir by Mr. George P. Merrill (1895. Reprinted from the Report of the United States National Museum). The term onyx marble, as is well known, is applied to varieties of travertine or stalagmite, which exhibit banding and translucency that are often as pronounced as in the true onyx. Used in ancient times for various ornamental purposes, and known as "Oriental alabaster," the marble has been obtained in Persia, Egypt, Algeria, Italy, Mexico, California, Arizona, and other regions; and it is largely used for interior decoration at the present day. Mr. Merrill enters fully into the characters of the several onyx marbles, and to their method of formation by springs in the open and in caverns. His work is illustrated by 18 plates.

Erratum.—In Dr. Gerhard Holm's article, November Number, line 21 from top of page 482: after the word "canal," insert a full stop (.); then for "which," read *What*; and in line 22, for "consisting" read *consists*.

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