

15. *On a RADIOLARIAN CHERT from MULLION ISLAND.* By HOWARD Fox, Esq., F.G.S., and J. J. H. TEALL, Esq., M.A., F.R.S., F.G.S. (Read February 8th, 1893.)

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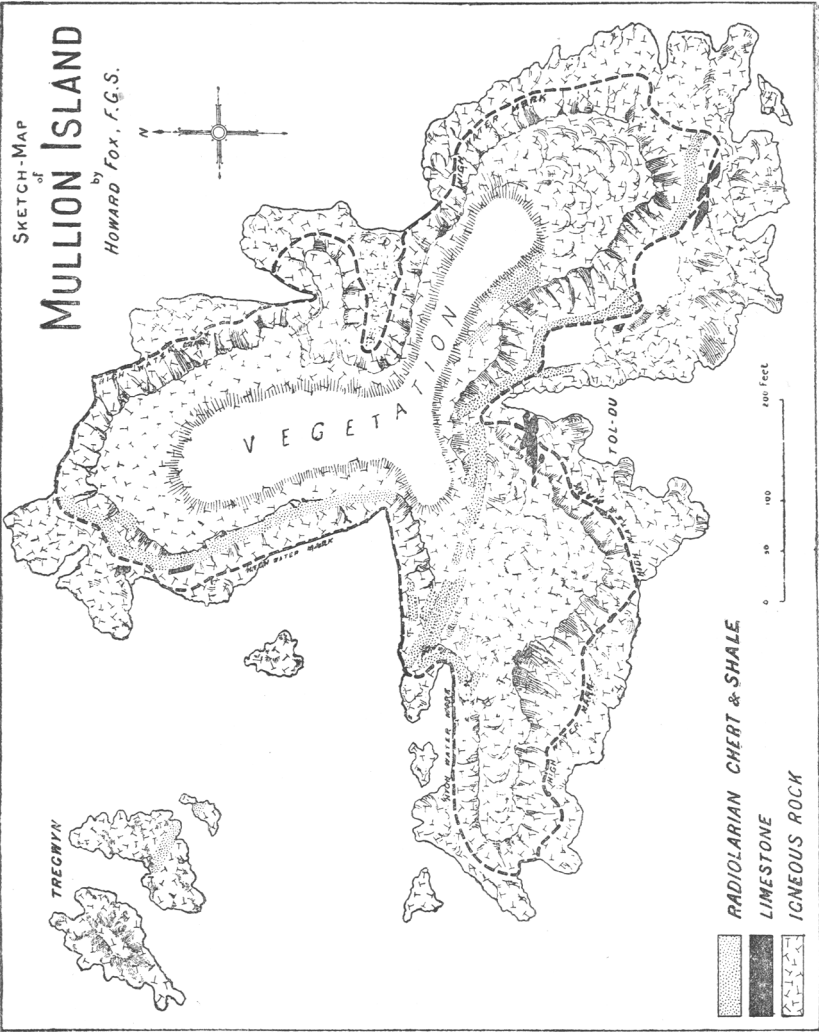
I. DESCRIPTION OF THE ISLAND AND ITS PREDOMINANT ROCKS.

MULLION ISLAND lies off the western coast of the Lizard Peninsula, a little south of Mullion Cove. The channel separating it from the mainland is only about 250 yards wide at its narrowest part, and yet the rocks of which the island is composed are quite distinct from those of the adjacent coast.

The island somewhat resembles in shape the leaf of the trefoil. From the central part three promontories, each 150 yards in length, answering to the three lobes of the leaf, run out into the sea; one towards the north, another towards the west, and a third towards the south-east. The coast-line is almost everywhere backed by cliffs which vary in height from 20 to 100 feet. The culminating point lies at the extreme edge of the western promontory, facing the open sea. The upper portions of the cliffs in this part of the island glow with brilliant orange and yellow tints, owing to the luxuriant growth of the ubiquitous lichen *Parmelia parietina*. The lower part of the island is covered in places with miniature forests of tree-mallow. Sea-beet and other marine plants abound.

The predominant rock is of igneous origin. It is greenish, fine-grained, much jointed, and often highly decomposed. The old term 'greenstone' may be appropriately applied to it. In the mass it is separated into rude rolls by curvilinear joints. These rolls show circular or elliptical outlines in cross-section and measure from a few inches to 2 feet in diameter. Flat surfaces of this rock, such as are exposed in many places at the base of the cliff, remind one somewhat of the appearance of a lava of the *pahoehoe* type. A few spherical amygdaloids are scattered through the mass.

Under the microscope the common type of rock is seen to consist of felspar, augite, iron ores, and secondary products, such as carbonates and chlorite, derived from these minerals. The felspar may occur as porphyritic crystals sparsely scattered through the groundmass, or as long, slender microlites forming a constituent of the groundmass. The augite occurs as small grains and microlites, and is sometimes only represented by secondary minerals. Iron ores are comparatively scarce. In structure the rock is more allied to a lava than to an intrusive mass. Small veins filled with calcite are very common.



One somewhat exceptional variety may be described as a fine-grained, dark greenish-grey dolerite. It is composed of pale brown augite showing a strong tendency to form long, slender prisms, lath-shaped feldspars, and iron ores (scarce).

The stratified rocks, which form only a very small portion of the island, consist of cherts, shales, and limestones. They occur in thin strips which cannot be traced continuously across the island, and are both underlain and overlain by igneous rocks. They are seen at different horizons from the foreshore to the summits of the northern and south-eastern promontories. The chert is the most interesting lithological type, on account of its radiolarian origin. It is interstratified with shale, and occurs in bands which vary from $\frac{1}{4}$ inch to several inches in thickness. As many as thirty bands may occur in a thickness of 3 feet. In some places where movement appears to have taken place before the final consolidation of the cherts, some layers have been pinched out, while others have been thickened into nodules. That these nodules are not of a concretionary character is shown by the presence of radiolaria. The colour varies from black to grey or brown, and very frequently the thinner layers have a central dark band, bordered by lighter-coloured margins. The radiolaria may often be observed with a pocket-lens on the surfaces of cross-joints, but they are most perfectly seen on the upper surfaces of some of the layers where the shale has been removed by the weather. Here they appear as rounded protuberances, often thickly crowded together, and their true nature can be at once determined by placing such a surface under the microscope. The reticulated character of the test can then be often clearly seen. The chert bands are generally traversed by a network of white quartz-veins.

The shale varies in colour from buff or brown to nearly black. We have searched this shale for fossils, but up to the present time only one microscopic form has been detected, and that one has not been identified. The limestones are grey in colour and crystalline in texture. Their precise relations to the series of cherts and shales cannot be very clearly made out. Not unfrequently they occur as more or less isolated lenticles in the greenstone.

An excellent exposure of the rocks of the island is seen in Tol Du, the inlet on the southern side. The foreshore is formed of 'greenstone,' and the exposed surface shows the peculiar appearance above referred to. The more or less distinct rolls exhibit a tendency to elongation in a north-westerly and south-easterly direction, and there are indications of a dip towards the north-east. Small patches of chert and shale may be seen sticking on this surface, and bits of limestone occur between the rolls of igneous material. At the base of the cliff facing south-west is a band of chert and shale measuring a few feet in thickness. It is covered by another mass of rock precisely similar to that which forms the foreshore. As the section is followed round the south-eastern part of the island patches of the chert-shale series are seen at different levels in the igneous rocks.¹

¹ [A subsequent visit has enabled me to obtain evidence that the band of radiolarian chert traverses the third islet of Tregwyn, as well as the two where it is shown on the map facing this page.—H. F., March 21st, 1893.]

The northern promontory also shows an excellent exposure of the igneous and stratified rocks. The latter are here from 8 to 10 feet thick at the base of the cliff, where it faces towards the north-west. The thickness rapidly diminishes as the band is followed towards the south. The cherts are here associated with black shales, which certainly look as if they should yield fossils. The igneous rock possesses the same structure as at Tol Du, with the same rude N.W.-and-S.E. strike in the rolled masses. The cherts and shales are again exposed on the upper surface of the south-eastern arm near the central part of the island, and two bands may also be seen on the western arm. The latter occur in the cliffs facing north, but cannot be traced to the other side of the promontory.

II. RELATION OF THE IGNEOUS AND THE STRATIFIED ROCKS.

An important question arises as to the relation between the igneous and the stratified rocks. Must the 'greenstone' be regarded as intrusive or contemporaneous? The fact that the stratified rocks appear to have been completely enclosed in igneous material, and that there is no trace of a floor over which a lava could have flowed, are points which may be urged in favour of the former view. But there are other facts which are difficult to explain on this hypothesis. Thus the igneous rock is uniformly fine in grain, although developed on a very extensive scale. There are no marked signs of metamorphism in the sedimentary rocks. The ropy structure is quite unlike that of any known intrusive mass of equal size. In these circumstances we are tempted to ask whether the phenomena may not be due to the injection of igneous material between the layers of the stratified series near the surface of the sea-bed, and possibly while deposition was actually going on. In this way thin sheets of deposit might be detached and moved on by the flow of igneous material. The phenomena might be explained by the simple flow of a submarine lava, if such a lava possessed the power of insinuating itself between layers of deposit and tearing them up during its onward march.

III. THE ROCKS OF THE NEIGHBOURING MAINLAND CONTRASTED WITH THOSE OF THE ISLAND.

The rocks of Mullion Island have not been found on any portion of the adjacent coast. The opposite cliffs are formed of hornblende-schist and serpentine. Stratified rocks make their appearance at Polurrian Cove, rather less than a mile N.N.E. of Mullion Island. The junction at this point has been described by Prof. Bonney, in vol. xxxix. of this Journal (1883), p. 10. The change from hornblende-schist to a sedimentary series consisting of dark slates with sandy beds is abrupt, and the fault which fades to the south, so as to carry the sediments beneath the schists, is marked by a breccia. The strike of this breccia, as it is exposed on the coast, points to Mullion Island. We endeavoured to trace the fault inland on the six-inch map, but, as it does not make a feature, and as there are few

exposures, this is by no means an easy task. The first point where the fault can be fixed within a few yards is at La Frowder, and if this point be joined to the exposure on the coast and the line continued, it would pass to the north of the island. The trend of the junction-breccia on the coast, therefore, appears to indicate that the fault curves somewhat towards the south. If this curvature were continued for a short distance, it would carry the boundary-fault between Mullion Island and the mainland, and such is the view we take. We have examined the coast from Polurrian Cove to the cliffs north of Gunwalloe in the hope of finding the rocks of Mullion Island, but without success. They must apparently be looked for in other parts of Western Cornwall.

IV. NOTE on the *RADIOLARIA* in the MULLION ISLAND CHERT.

By GEORGE JENNINGS HINDE, Ph.D., V.P.G.S.

[PLATE IV.]

As already mentioned by the Authors, the radiolaria in this chert are partially weathered out on the surface of some of the beds, and, when examined under a lens or under the microscope, they appear like so many millet-seeds, thickly covering the rock. In this condition they usually show the lattice-like structure of the test, of a light or dark-brown tint; when this has been weathered off, only the solid cast of translucent silica which has filled up the originally hollow test projects above the surface. The majority of the forms thus shown appear to be simple spheres belonging to the genus *Cenosphaera*, Ehrenberg (Pl. IV. fig. 1.), but as only the upper portion of these weathered-out forms can be distinguished, it is quite possible that some of them may be oval instead of spherical.

In thin microscopic sections of the chert, the radiolaria are shown in some portions nearly in contact with each other, while in others they are less thickly distributed. Most of them appear as transparent bodies with circular or oval outlines, only marked off from the enclosing matrix by the clearness of the silica which has filled in their inner cavities. The lattice-structure of the tests in these forms has completely disappeared, and only the chalcedonic casts of the interior remain. Sometimes the tests are shown in section as circular or oval rings of a brownish tint, in which the apertures are indicated by alternate lighter spaces (Pl. IV. figs. 4, 5). In a few rare instances the tests have become stained by an opaque dark material, and these show the structure fairly well; but unfortunately this dark substance has often infilled the interior of the tests, so that only their outlines can now be distinguished. In their general condition of preservation the radiolaria in this Cornish chert strikingly resemble those in the Ordovician¹ chert of Scotland, but they are less favourably preserved in the specimens which have as yet been obtained.

Owing to their imperfect preservation, it is not possible to give

¹ *Ann. & Mag. Nat. Hist.* ser. 6, vol. vi. (1890) p. 40.

more than an approximate determination of the genera to which the radiolaria belong, and in some cases even the generic position is doubtful. The genera recognizable are *Cenosphaera*, Ehrenberg, *Carposphaera*, Haeckel, *Cenellipsis*, Haeckel, *Lithapium*, Haeckel, and *Lithatractus*, Haeckel, belonging to the two sub-orders of the Sphaeroidea and Prunoidea. The commonest forms present are simple, spherical or oval lattice-tests belonging to *Cenosphaera* (Pl. IV. fig. 1) and *Cenellipsis* (Pl. IV. figs. 4-7). The tests range from .16 to .30 mm. in diameter. The genus *Carposphaera*, in which there are two concentric lattice-tests, is represented by a few small forms (Pl. IV. figs. 2 and 3) which may perhaps belong to two species. A specimen with an elliptical lattice-test and a single spine (Pl. IV. fig. 8) is included under *Lithapium*, and other examples with two concentric tests and with a spine at each pole (Pl. IV. fig. 9) belong to *Lithatractus*. Forms with spines are comparatively rarely shown in sections; in the two examples figured (Pl. IV. figs. 10 and 11) only the outlines are seen, and they do not appear to belong to any genus yet described. The recognizable forms belong to simple generic types which are all represented in Palæozoic strata, and with one exception as low as the Silurian, but they do not afford any trustworthy indication of the age of the chert in which they occur.

With the exception of the radiolaria, the only other microscopic organic remains in sections of the chert are some ill-defined spicular bodies, shown only in the dark-stained portion of the rock; some of these may be fragmentary spines of radiolaria, while others are perhaps spicules of siliceous sponges.

The following is a technical description of the forms which can be recognized:—

Sub-order SPHÆROIDEA, Haeckel.

Cenosphaera, sp., Pl. IV. fig. 1.

Spherical tests, ranging from .145 to .305 mm. in diameter, are numerous in the chert, but the lattice-structure is shown only in those weathered out on the surface. The holes in the test appear to be subequal, about .015 mm. in breadth, while the lattice-work is from .005 to .010 mm. wide. In the size and disposition of the apertures of the test, this form resembles *C. gregaria*, Rüst ('Palæontographica,' vol. xxxi. 1885, p. 286, pl. xxvi. fig. 10), which is common alike in Devonian, Jurassic, and Cretaceous strata.

Carposphaera, sp. a, Pl. IV. fig. 2.

The outer test is .145 mm. in diameter and .009 mm. in thickness, and the inner .045 mm. in breadth. The structure is not preserved. There are three rays visible, connecting the inner with the outer test. It resembles in outline *C. pygmaea*, Rüst, from the Lower Carboniferous of the Harz ('Palæontographica,' vol. xxxviii. 1892, p. 135, pl. vi. fig. 13), but it is distinctly larger. The form is rare.

Carposphaera, sp. b, Pl. IV. fig. 3.

The outer test is .095 mm. in diameter and .007 mm. in thickness; the inner, .030 mm. in diameter. There are from seven to eight rays connecting the inner with the outer test. No pores are shown. Rare.

Sub-order PRUNOIDEA, Haeckel.

Cenellipsis, sp. a, Pl. IV. fig. 4.

Test regularly oval, long diameter .220 mm., breadth .185 mm. Surface apparently smooth, the holes circular or oval, about .015 mm. in width, the lattice-work less than the width of the holes. Wall, .020 mm. in thickness.

Cenellipsis, sp. b, Pl. IV. figs. 5, 6.

Test regularly oval; length, .20 mm.; breadth, .165 mm.; thickness of wall, .015 mm. The lattice-structure is not clearly shown. It is smaller, and the wall is thinner than in the preceding species.

Cenellipsis, sp. c, Pl. IV. fig. 7.

Test elongate oval; length, .25 mm.; breadth, .18 mm. The apertures are circular or oval, unequal in size, from .010 to .025 mm. in breadth; the lattice-work is less than the width of the apertures. Fairly common. In form and proportions the specimens agree with *Cenellipsis perovalis*, Rüst ('Palaeontographica,' vol. xxxviii. 1892, p. 151, pl. xvi. fig. 4), from the Lower Carboniferous of the Harz, but the apertures of the test are smaller and less crowded.

Lithapium, sp., Pl. IV. fig. 8.

Test elliptical; length, .18 mm.; breadth, .15 mm. At one end is a short conical spine, .045 mm. in length. Structure very imperfectly shown.

Lithatractus, sp., Pl. IV. fig. 9.

The elliptical outer test is .110 mm. in length and .085 mm. in breadth. The inner test is .040 mm. in diameter; it is connected by four or five rays with the outer test. Only one spine, .050 mm. in length, is preserved, but there are traces of another at the opposite end of the test and of some minute blunted spines (or tubercles) as well. The lattice-structure is not shown.

FORMS UNDETERMINED, Pl. IV. figs. 10, 11.

Fig. 10. Test nearly circular in outline; length, .195 mm.; width, .155 mm.; with three radial spines: the longest preserved is .195 mm. in length. No structure shown.

Fig. 11. Test circular in outline, .2 mm. in diameter, with two long, tapering, radial spines, about .2 mm. in length, and two short secondary spines. No structure shown.

EXPLANATION OF PLATE IV.

- Fig. 1. *Cenosphaera*, sp. Drawn from a specimen weathered out on the surface of a slab of chert. $\times 200$ diameters.
 Fig. 2. *Carposphæra*, sp. *a*. Drawn from a microscopic section. $\times 200$.
 Fig. 3. *Carposphæra*, sp. *b*. $\times 200$.
 Fig. 4. *Cenellipsis*, sp. *a*. Showing the wall in section. $\times 200$.
 Figs. 5, 6. *Cenellipsis*, sp. *b*. One specimen showing the wall in section, and the other showing traces of the lattice-work. A quartz-vein traverses a portion of this latter. $\times 200$.
 Fig. 7. *Cenellipsis*, sp. *c*. A specimen showing the lattice-structure preserved in dark material. $\times 200$.
 Fig. 8. *Lithaptium*, sp. Showing indistinct traces of the lattice-structure. $\times 200$.
 Fig. 9. *Lithatractus*, sp. Showing the form in section. $\times 200$.
 Fig. 10. Outline of undetermined form with three radial spines. $\times 100$.
 Fig. 11. Specimen undetermined, the outline only shown. $\times 100$.
 Fig. 12. A portion of a slab of chert, showing radiolaria partially weathered out on its surface. $\times 50$.
 Fig. 13. Section illustrating the structure of the greenstone associated with the chert of Mullion Island. Two porphyritic crystals of felspar and acicular microlites of the same mineral are clearly recognizable in the figure. $\times 50$.

All the specimens are from the chert at Mullion Island, Cornwall.

DISCUSSION (ON THE TWO PRECEDING PAPERS).

THE PRESIDENT commented on the many difficulties felt by De la Beche which were still unsolved. It was difficult to know whether the serpentine was intrusive in the hornblende-schists, or *vice versa*. At the previous Meeting a similar question was being discussed with regard to the Hebrides, viz. whether there the acid rock was intrusive in the basic or *vice versa*. If he might venture on a surmise, might not the Lizard rocks form an igneous complex, where each observer paid particular attention to those points bearing on his own views? The position had been advanced a point further by the Authors. He suggested that the discovery of organisms in Mullion Island might throw light on the period to which the complex belonged, though it was not clear that the Mullion Island rocks were of the same age as those of the mainland. It seemed that Dr. Hinde could not determine the age of the radiolaria.

Rev. EDWIN HILL spoke of the interest of this paper on Mullion Island. The Lizard serpentine seemed ringed in by other rocks; in this respect it resembled an igneous 'plug,' and such was the impression left on him by the general view of the aggregate of evidence. While these papers on a small area were most valuable, he hoped that the Authors would some day furnish a view of the Lizard as a whole. A harmony of diverse views had been suggested; he doubted if it were desirable to attempt this.

Prof. BONNEY said that the discovery of radiolarian chert at Mullion Island (which he had not visited) was of great interest, but it would never help, as the President seemed to think, in determining the age of the Lizard schists. He believed there was a

volcanic complex at the Lizard; but if the last-named rocks belonged to one, then there were two complexes of different dates.

As regards the case of the granitoid rock and the serpentine, south of the Lion Rock: difficulties were caused in this district by the fact that there was an intrusive granite, which sometimes brought up fragments of an older dark rock, and a granulitic rock, included as large fragments in the serpentine, and the two were often very like one another. Without examining on the ground the instance described by the Authors, he was not prepared to say to which of these rocks he should attribute it; going by the diagram, there were difficulties in either reference. If intrusive granite, then its form and structure were very strange; if caught up in the serpentine, then we must suppose the heat of the latter to have produced a slight plasticity.

He had not examined the particular section of banded schist and serpentine found in the cliffs near Ogo Dour, and it was doubtless a puzzling one. But that the Lizard serpentine at several places was distinctly intrusive in the Hornblendic or the Granulitic Series, he was convinced—for instance, in Ogo Dour Bay (farther north), at Henscarth, Porthalla, Kildown Point, etc. Moreover, he had repeatedly obtained proofs of the intrusive nature of serpentine in other regions, and did not believe the same rock could have two modes of origin. The Norway case he knew as a rock, and believed it was only a 'sill' made schistose by pressure. As regards the case at the Lizard, was the hornblende-rock associated with the serpentine the normal hornblende-schist of the district? Of this he felt doubts. If it were, we might have only a peculiar case of intrusion; if not (as he suspected), then this might be a case of fluxion-banding, the peridotite magma being either exceptionally ill-mixed with a more felspathic one (cases of which did occur), or possibly having locally half-dissolved some fragments of hornblende-schist. There were certainly no signs, in the rocks themselves, that they had been modified by pressure, indications of which at the Lizard were only local. Banded structures caused by fluxional movements in igneous rocks, leading sometimes to an apparent stratification of material with considerable differences, were now becoming familiar. To some of these the speaker referred. The case discussed was a curious and interesting one, and he reserved a final opinion till he had seen it in the field; but it did not alter his view (for he agreed with Mr. Hill's remarks) that the Lizard serpentine was an altered peridotite, intrusive in the hornblendic and granulitic groups.

Dr. Hicks said he was glad that there were some reasons for believing that the radiolarian chert might be of Ordovician age; and he hoped that this important discovery would lead to the detection of similar bands in neighbouring areas, where no doubt could arise as to the geological horizon. He would be inclined to place the beds towards the base of the Ordovician, for many years ago he arrived at the conclusion, as stated in papers read before the Geological Society in 1875 and 1876, that the Arenig and

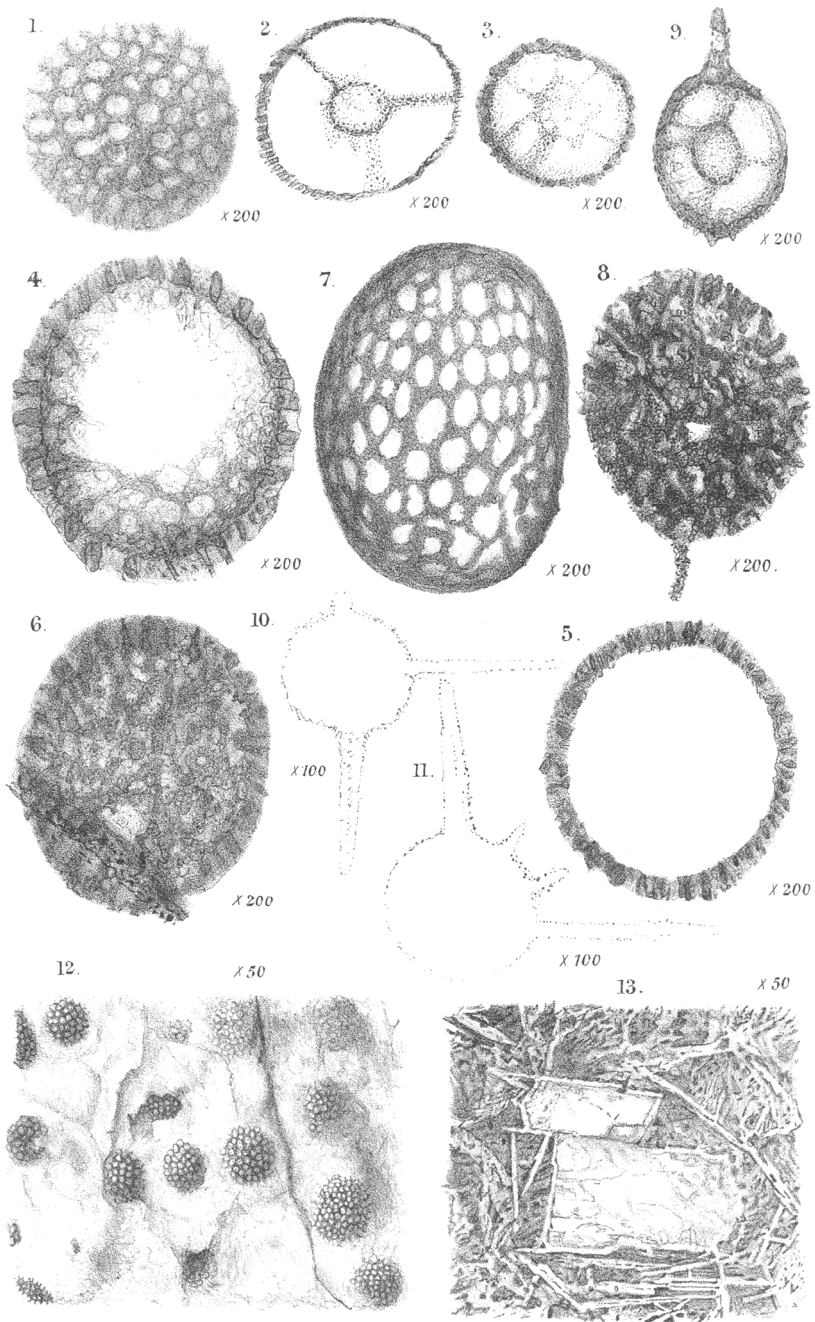
Llandeilo Beds had been deposited in comparatively deep water. His conclusions, however, were then severely attacked by the late Sir Andrew Ramsay and others; but evidence was now accumulating to show that they were correct.

Dr. HINDE also spoke.

Mr. TEALL did not think that a determination of the age of the Mullion Island sediments would throw any light on that of the crystalline schists of the Lizard. The main object of the first paper was to show that certain hornblende-schists were interbanded with foliated serpentine. It must be remembered, however, that the hornblende-schists of the Lizard were certainly not all of the same age. Some of the foliated portions of the dykes in the area under consideration bore the closest resemblance to parts of the hornblende-schist of the South.

He agreed with Prof. Bonney that there were intrusive peridotites, but he thought there were others which formed integral portions of gneissose formations. He commented on certain points of resemblance between the Lizard District and the North-west of Scotland. In both there were foliated crystalline rocks cut by basic dykes, and in both these later dykes passed into schists. He thanked the speakers for the kind way in which they had received the papers.

Mr. HOWARD FOX said it would be gratifying if the discovery of the Mullion Island radiolarian cherts led to that of other beds in England and Wales. Some of the less accessible points and outlying rocks in Cornwall had yet to be examined. Prof. Bonney had kindly informed him that west of Conway marine mud was seen to be partly caught up by Bala lava as the Mullion Island chert and shales appeared to have been, and south of Clermont Ferrand Prof. Bonney had seen a lava-stream with many large lumps of marl picked up by it. The interest of their second paper was largely enhanced by Dr. Hinde's most valuable note.



F. Hollick del. et lith.

Mintern Bros. imp.