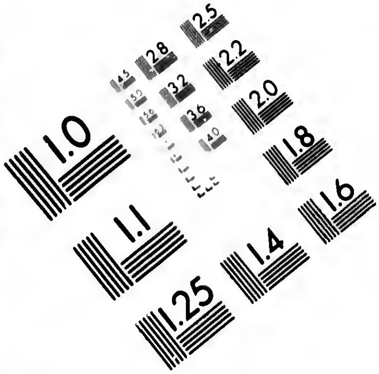

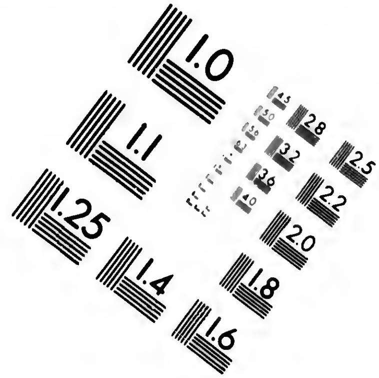

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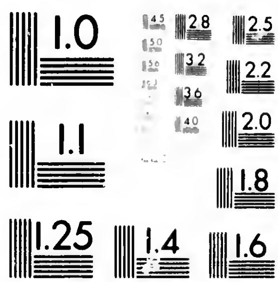

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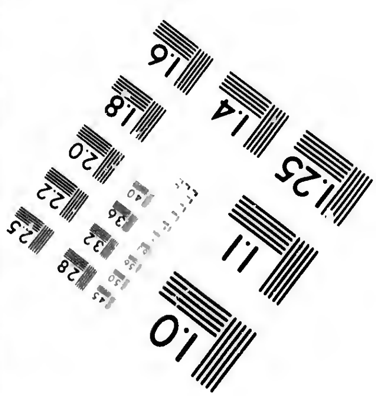

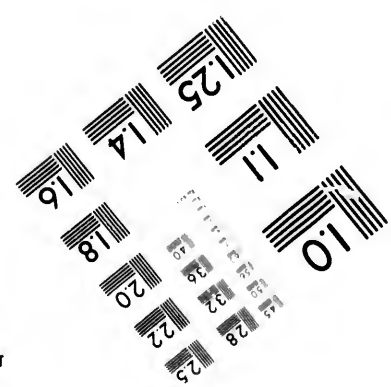

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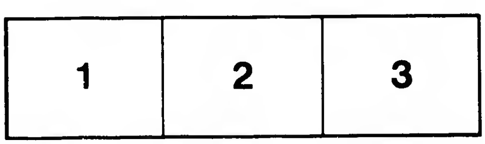
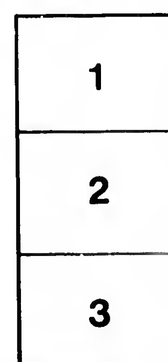
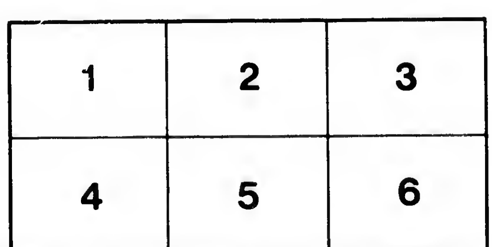


[*From the* QUARTERLY JOURNAL *of the* GEOLOGICAL SOCIETY *for February* 1876.]

# ON THE OCCURRENCE OF *EOZOON CANADENSE* AT CÔTE ST. PIERRE.

# NOTES *on the* OCCURRENCE *of* EOZOON CANADENSE *at* CÔTE ST. PIERRE.

By J. W. DAWSON, LL.D., F.R.S., F.G.S.

[PLATE X.]

CÔTE ST. PIERRE, in the Seigniory of Petite Nation, on the river Ottawa, is the locality whence some of the most instructive specimens of *Eozoon* were obtained by the late Mr. Lowe, whose collections are referred to in papers presented to this Society by Sir W. E. Logan and the writer. Believing that a reexamination of this place would afford a good opportunity for collecting additional specimens, and for the study of the fossil *in situ*, as well as for testing the validity of objections recently raised to the animal nature of *Eozoon*, I made arrangements for visiting it in September last; and, through the kindness of Mr. Selwyn, Mr. T. C. Weston, of the Geological Survey, a skilful collector, and who has had much experience in preparing and examining specimens of *Eozoon*, was permitted to accompany me, and subsequently prepared slices and photographs of some of the specimens obtained.

The Lower Laurentian rocks of this region have been carefully mapped and described in the Reports of the Geological Survey, to which I may refer for their general description. The limestone, which has afforded *Eozoon* at Côte St. Pierre, is a thick bed belonging to the Grenville band of Sir W. E. Logan, and included between the two great belts of orthoclase gneiss (the third and fourth gneiss) which in this region constitute the upper beds of the Lower Laurentian. Its average thickness, according to the measurements of Sir William Logan, is 750 feet; but it varies from 1500 feet to 60 feet. Its outcrop has been traced in the country north of the Ottawa for at least 100 miles, along several anticlinal and synclinal folds*.

At Côte St. Pierre this limestone occurs on the flank of a hill of gneiss and stratified diorite, with a dip to the south-east at angles of 70° to 80°. The dip, however, is very inconstant, owing to the contortions of the beds.

The limestone is white and crystalline, and may be described as thin-bedded, since it presents a great number of layers of no great individual thickness, and differing in the coarseness of the crystallization and in the presence of dolomite, serpentine, and layers of gneissose matter in some of them. The specimens of *Eozoon* were found to be abundant in only one bed, not more than four feet in thickness, though occasional specimens and layers of fragments occur in other parts of the band. The exposures are in part natural weathered surfaces seen on a wooded bank, in part an opening made by Mr. Lowe to extract specimens of *Eozoon*, and a larger opening made, as we were informed, by parties in search of fibrous serpentine, or "rock-cotton," for economic purposes.

* See map in 'Geology of Canada,' 1863.

The sections seen in the artificial exposures may be tabulated as follows, though from the highly inclined position of the beds and the irregularity of the excavations, perfect accuracy was not attainable:—

*Mr. Lowe's Excavation* (order descending).

1. Limestone with serpentine and entire specimens of *Eozoon*—3 feet.
2. Coarse crystalline limestone, with layers containing fragments of *Eozoon*—4 feet.
3. Limestone with concretions and layers of serpentine, and a few specimens of *Eozoon*—several feet, to the bottom of the excavation.

*Fisher's Excavation* (order descending).

1. Laminated limestone with bands of serpentine—6 feet.
2. White laminated limestone traversed by small veins of chrysotile—8 feet.
3. Limestone with concretions and interrupted bands of serpentine and pyroxene, and fragments of *Eozoon*—10 feet. (Crystals and layers of dolomite occur in this and the preceding beds.)
4. Limestone with large concretions of serpentine, and in one layer fine-grained variety of *Eozoon* (var. *minor*)—20 feet.
5. Limestone with serpentine and perfect specimens of *Eozoon*. (This probably corresponds to Lowe's excavation)—12 feet.
6. Coarse-grained limestone and dolomite—several feet.

(After a break of several yards)

7. Limestone with masses of pyroxene and veins of chrysotile and some imperfect *Eozoon*.

(After a break of several yards)

8. Coarse-grained diorite, resting on a thick band of gneiss.

In front of Lowe's excavation, and apparently overlying the limestone exposed in it, is a narrow ledge of fine-grained gneiss; and beyond this other and probably overlying limestone appears, holding pyroxene and mica. The whole vertical thickness of the limestone exposed can scarcely exceed 150 feet; but this is probably only a small part of the development of the band at this place.

In the strike of the limestone to the south it appears to bend abruptly, or to be thrown by a fault, to the south-east, the gneiss and diorite coming forward into a line with it, and the limestone appearing in a little bare knoll in front of these. On the surface of this limestone were found some fine specimens of weathered *Eozoon*.

I examined carefully the relation of the bedded serpentine and the veins of chrysotile or fibrous serpentine to the limestone. The compact serpentine is evidently an original part of the deposit, occurring in layers and lenticular concretions. In some beds it shows no indication of the structure of *Eozoon*; but in others it fills the cavities of the fossils, and there are many regular layers of fragmental *Eozoon* of considerable thickness in which it fills the cells, while in other layers interstratified with these the fossil is associated with dolomite. I satisfied myself on this point not only on the ground, but also by taking away large specimens representing several thin layers, and treating them with dilute acid so as to being out the structure. The following is a section of such a specimen, 5½ inches in vertical thickness, treated with acid and examined with a lens:—

1. Limestone with crystals of dolomite and a few fragments of *Eozoon*.
2. Fine-grained limestone with granules of serpentine—the latter filling the chamberlets of fragments of *Eozoon* and small globigerine Foraminifera.
3. Limestone with dolomite and including a thin layer of serpentine as above.
4. Limestone and dolomite with grains of serpentine and fragments of supplemental skeleton of *Eozoon*.
5. Crystallized dolomite, holding a few fragments of *Eozoon* in the state of calcite.
6. Limestone with disseminated serpentine as above, chamberlets of *Eozoon* and fragments of its supplemental skeleton, also small groups of chamberlets, perhaps globigerine Foraminifera.

In other specimens a like thickness of rock presented a mass of fragments of supplemental skeleton with the canals injected with serpentine, and granules of the same filling the chambers.

The chrysotile veins, which are sometimes an inch or more in thickness, but branch off into the most minute fibres, are evidently altogether subsequent in origin to the bedded limestone and serpentine. They are undoubtedly of aqueous origin, and in their mode of occurrence strongly resemble the veins of fibrous gypsum penetrating the Lower Carboniferous marls of Nova Scotia. They cross the bedding in all directions, and pass through the structure of *Eozoon*, though sometimes running parallel to its laminæ for short distances. They must have been introduced after the *Eozoon* was mineralized, and have evidently no connexion with its structure.

In the diagram (Pl. X. fig. 2) I have attempted to represent this relation; and I have no hesitation in stating that the assertion that these chrysotile veins are identical with or similar to the proper wall of *Eozoon* either in structure or distribution, is wholly without foundation, other than that which may arise from confounding dissimilar structures accidentally associated with each other.

Some slickensided joints lined with a lamellar and fibrous serpentine traverse the beds, and, as the chrysotile veins sometimes terminate in them, may be older than the latter. These also were observed to cross the masses of *Eozoon*.

Few disseminated minerals, other than those already mentioned, were observed in the *Eozoon* limestone. A few detached crystals of mica, pyroxene, and pyrite were found in the fragmental layers, and also a few rounded particles of quartz, probably grains of sand.

The perfect examples of *Eozoon*, at least those rendered evident by mineralization with serpentine, are confined to certain bands of limestone, and notably to one band—that originally opened by Mr. Lowe. In this bed the fossil occurs in patches of various sizes, some of them two feet or more in diameter, and bent or folded by the contortions of the strata; others are much smaller, down to a few inches. On the weathered surfaces the specimens mineralized with serpentine project, and exhibit their lamination in great perfection, resembling very closely the silicified *Stromatoporæ* of the Corniferous Limestone.

None of the specimens of *Eozoon* is of any great vertical thickness. The lower laminæ are generally the best developed and with the thickest supplemental or intermediate skeleton. The upper laminæ become thin-walled, though often very regular; and after about 100 laminæ at most, the superficial portions become acervuline for an inch or so and then terminate. In some specimens only a few regular laminæ are formed, succeeded by acervuline structures. A very fine and regular specimen in my collection has 100 laminæ in a thickness of $3\frac{1}{2}$ inches, giving a little more than a thirtieth of an inch for the average height of each lamina of sarcode and shell-wall.

In order to test the state of preservation of the canal system and nummuline layer, I treated a great number of specimens from different parts of the bed with a dilute acid. The result was, that in all the canal system could be detected in greater or less perfection in the thicker laminæ near the base of the forms, and in some through a great number of the laminæ. The structure of the nummuline layer was not so constantly preserved, its tubuli not being infiltrated in some parts, so that it appears as a structureless band, or fails altogether to be visible. In no instance could it be seen to pass into chrysotile, as recently affirmed by Messrs. Rowney and King*, although chrysotile veins often run very near to or across the walls. The nummuline layer is almost always distinctly limited by parallel surfaces, with its tubes at right angles, or nearly so, to these. The sort of chevron arrangement figured by Rowney and King in fig. 7 of their plate, in the number of the 'Annals of Natural History' for October 1874, I have never observed; and Mr. Weston, who has prepared and examined microscopically hundreds of specimens of *Eozoon*, was struck with the inaccuracy of the representations in this plate, and remarked on it the first time that I met him after he had seen the paper referred to. Figs. 2 and 3, Pl. X., relate to these points, and show the actual nature of the nummuline wall and its relation to the intermediate skeleton and chrysotile veins, as do also the figures recently published by Dr. Carpenter in his paper in the 'Annals'†.

By careful scrutiny of the beds we were enabled to detect two new forms of *Eozoon*, which may eventually prove to be distinct species, but which for the present may be regarded as varietal forms.

One of these, found *in situ* by Mr. Weston, is flat in form and very finely laminated, with thin walls except near the lower part, where there is some supplemental skeleton with finer and more curved canals than usual. The thin walls or laminæ of the ordinary skeleton are connected by very frequent vertical pillars or partitions, and are as numerous as thirty in half an inch, while the whole thickness of the specimen does not exceed an inch. It thus very closely resembles some of the Devonian and Silurian *Stromatoporæ*, especially when seen on the weathered surface. It may be named in the mean time variety *minor*.

The second occurs in more or less oval patches a few inches in diameter, limited by a sort of frame or border of compact serpentine, and presenting under the microscope an aggregation of small acervuline chamberlets, having the proper wall filled with unusually

* Ann. & Mag. of Nat. Hist. May 1874. † *Ibid.* June 1874.

long parallel tubes, and with little development of supplemental or intermediate skeleton. The appearance of parallel tubulation running through and past several successive chamberlets was more conspicuous in these specimens than in the ordinary acervuline *Eozoon*, and the chamberlets themselves more cylindrical and tortuous. These specimens may either be portions of the acervuline superficial part of *Eozoon* broken off and separately preserved, or they may constitute a distinct varietal form. As the latter seems on the whole most probable, I would name this form variety *acervulina*.

These varieties are of much more rare occurrence than the ordinary type of *Eozoon*.

The ordinary specimens of *Eozoon* found at St. Pierre are mineralized with serpentine; but fragments imbedded in the dolomitic limestones have their canals filled with a transparent mineral which, from its optical character, is evidently dolomite, though the quantity obtained was not sufficient for any definite chemical test. Parts of the canals in these specimens were filled with calcite, as shown by its dissolving entirely away in a dilute acid. In one of the serpentinous specimens also I have observed that, while portions of the groups of canals, especially the basal portions, are filled with serpentine, the extremities of the canals and their finer branches present, under polarized light, the aspect of calcite; and that they are filled with this mineral is proved by these portions of the canal-filling being entirely removed when treated with dilute acid. It would thus appear that in these specimens, while the terminal parts of the canals have been filled with calcite, the basal portions have been occupied by serpentine. This is not, however, a new fact, as similar appearances have been already described both by Dr. Carpenter and the writer.

In one specimen I observed a portion of the fossil entirely replaced by serpentine, the walls of the skeleton being represented by a lighter-coloured serpentine than that filling the chambers, and still retaining traces of the canals. The walls thus replaced by serpentine could be clearly traced into connexion with the portions of those still existing as calcite. This shows that the serpentine, like the quartz in silicified shells and corals, has had the power of replacing the calcite of the fossils; and I believe that its partial action in this way accounts for some irregularities observed in the less perfectly preserved specimens. Nor is it improbable, as Dr. Hunt has already suggested, that some of the masses of serpentine and pyroxene on which specimens of *Eozoon* are based, may represent older and more perfectly mineralized masses of the fossil.

In some of the specimens of *Eozoon*, the superficial laminæ are apparently broken and displaced in such a manner as to suggest the idea that partial disintegration by the waves had taken place before they were finally buried. It is also observable that in some of the masses the compression to which they have been subjected has produced a microscopic faulting, which slightly displaces the laminæ.

One of the most interesting features of the St.-Pierre limestone.

not noticed by previous observers, is the occurrence of layers filled with little globose casts of chamberlets, single or attached in groups, and often exactly resembling the casts of *Globigerinæ* in greensand (Pl. X. figs. 4–10). On weathered surfaces they were often especially striking when examined with the lens. In some cases the chamberlets seem to have been merely lined with serpentine, so that they weather into hollow shells. The walls of these chamberlets have had the same tubulated structure as *Eozoon* (fig. 4); so that they are in their essential characters minute acervuline specimens of that species, and similar to those which I described in my paper of 1867* as occurring in the limestones of Long Lake and Wentworth, and also in the loganite filling the chambers of specimens of *Eozoon* from Burgess. Some of them are connected with each other by necks or processes, in the manner of the groups of chamberlets described by Gümbel as occurring in a limestone from Finland, examined by him. That they are organic I cannot doubt, and also that they have been distributed by currents over the surface of the layers along with fragments of *Eozoon*. Whether they are connected with that fossil or are specifically distinct may admit of more doubt. They may be merely minute portions detached from the acervuline surface of *Eozoon*, and possibly of the nature of reproductive buds. On the other hand, they may be distinct organisms growing in the manner of *Globigerina*. As this is at present uncertain, and as it is convenient to have some name for them, I propose to term them *Archæosphærinæ*, understanding by that name minute Foraminiferal organisms, having the form and mode of aggregation of *Globigerina*, but with the proper wall of *Eozoon*.

In slicing one of my specimens from Côte St. Pierre I have recently observed a very interesting peculiarity of structure, which deserves mention. It is an abnormal thickening of the calcareous wall in patches extending across the thickness of four or five lamellæ, the latter becoming slightly bent in approaching the thickened portion. This thickened portion is traversed by regularly placed parallel canals of large size, filled with dolomite, while the intervening calcite presents a very fine dendritic tubulation. The longitudinal axes of the canals lie nearly in the plane of the adjacent laminæ. This structure reminds an observer of the *Cœnostroma* type of *Stromatopora*, and may be either an abnormal growth of *Eozoon*, consequent on some injury, or a parasitic mass of some Stromatoporoid organism finally overgrown by the *Eozoon*. The structure of the dolomite shows that it first incrusted the interior of the canals, and subsequently filled them—an appearance which I have also observed in some of the larger canals filled with serpentine, and which is very instructive as to their true nature.

From the above facts the true nature of *Eozoon* may, I think, be rendered evident to any geologist, however little he may have made the fossil Foraminifera a subject of study. The theories as to its origin may be summed up thus:—

1. The complicated theory of pseudomorphism and replacement,

* Quart. Journ. Geol. Soc. vol. xxiii. p. 260.

advocated by Messrs. Rowney and King, may be dismissed at once. Independently of the insuperable chemical difficulties which have been pointed out by Dr. Hunt*, and which he proposes to discuss more fully in his papers on Chemical Geology, now in the press, we have the further facts that no replacement of serpentine by calcite is indicated by the relations of these minerals to each other, while such replacement as does occur is in the other direction, or the change of calcite into serpentine, as evidenced by the state of preservation of some specimens of *Eozoon*, above referred to. Further, this theory fails to give any explanation of the specimens mineralized by pyroxene, dolomite, and calcite, or to account for the nummuline wall, except by attributing it to the alteration of chrysotile, which is inadmissible, as the veins of this mineral are newer than the walls supposed to have been derived from them.

2. Inasmuch as many apparently concretionary grains and lenticular masses of serpentine exist in the Laurentian limestones, it may be supposed possible that *Eozoon* is merely a modification of these concretionary forms. In this case, the filling of each lamina and chamberlet of *Eozoon* must be regarded as a separate concretion; and even if we could suppose some special cause to give regularity and uniformity to such concretions in some places and not in others, we still have unaccounted for the canals and tubuli, or the delicate threads of serpentine representing them. Further, we have to suppose that a tendency to this regular and complicated arrangement has affected in the same way minerals so diverse as serpentine, loganite, pyroxene, and dolomite.

3. The only remaining theory is that of infiltration by serpentine of cavities previously existing in the calcite. There is no chemical objection to this, inasmuch as we know of the infiltration of fossils in other formations by minerals akin to serpentine; and in these limestones the veins of fibrous serpentine have evidently been introduced by aqueous action subsequently to the production or fossilization of the *Eozoon*. Further, the white pyroxene of the Laurentian limestones, and the loganite and dolomite, are all known to have been produced by aqueous deposition. The only question remaining is, Whence came the original calcite skeleton with laminæ, chambers, canals, and tubuli to be so infiltrated? The answer is given in the comparison with the tests of Foraminifera, originally proposed by the writer, and illustrated in so conclusive a manner by the researches of Dr. Carpenter.

I may add, in conclusion, that had geologists generally the opportunity of studying *Eozoon in situ*, in good exposures, like that at St. Pierre, they would much more fully understand and appreciate the arguments for its organic nature, than when they have had opportunities of examining only polished specimens and slices†. Its

* Trans. Royal Irish Academy, 1871.

† I have been sorry to find, from specimens in the cabinets of my friends, that some London dealers are in the habit of circulating specimens labelled "*Eozoon canadense*" which have no trace of the structures of the fossil, but are either badly preserved acervuline portions or merely ordinary serpentine marble. Such specimens can, of course, only mislead, and may produce much unnecessary scepticism.

Stromatoporoid masses, projecting from the weathered beds of limestone, would at once attract the attention of any collector; and the whole conditions of its occurrence, whether entire or in fragments, are precisely those of fossil corals in the Silurian limestones. Further, the symmetry and uniformity of its habit of growth are much more apparent when they can be studied in large specimens prepared by natural weathering or by treatment with an acid.

[*Note* (Oct. 30).—Messrs. Richardson and Weston, of the Geological Survey, have recently revisited the locality of *Eozoon* at Côte St. Pierre mentioned in the above paper, and have collected some additional specimens. One of these deserves notice, as illustrating the nature of *Archæosphærinæ*. It is a small or young small speci-

Figs. 1–4.—*Small weathered Specimen of* Eozoon *from Petite Nation.*

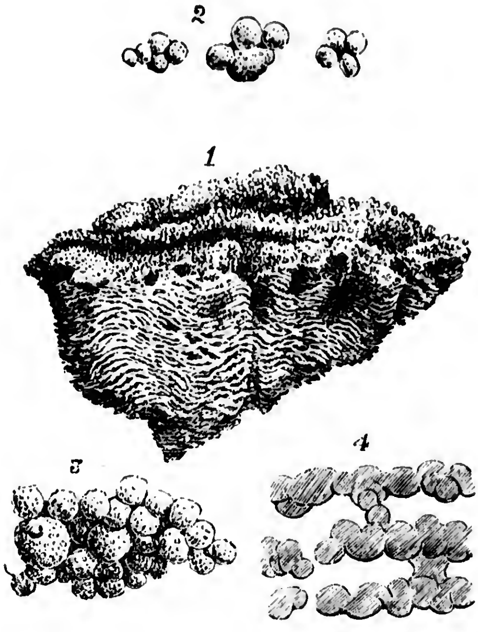



Fig. 1. Natural size; showing general form, and acervuline portion above and laminated portion below.
2. Enlarged casts of cells from upper part.
3. Enlarged casts of cells from the lower part of the acervuline portion.
4. Casts of sarcode layers from the laminated part; enlarged.

men, of a flattened oval form, $2\frac{1}{2}$ inches in its greatest diameter, and of no great thickness (fig. 1). It is a perfect cast in serpentine, and completely weathered out of the matrix, except a small portion of the upper surface, which was covered with limestone which I have carefully removed with a dilute acid. The serpentinous casts of the chambers are in the lower part regularly laminated; but they are remarkable for their finely mammillated appearance, arising from their division into innumerable connected chamberlets resembling those of *Archæosphærina* (fig. 4). In the upper part the structure becomes acervuline, and the chamberlets rise into irregular prominences, which in the recent state must have been extremely friable, and, if broken up and scattered over the surfaces of beds, would not be distinguishable from the ordinary *Archæosphærinæ*. This specimen thus gives further probability to the view that the *Archæosphærinæ* may be for the most part detached chamberlets of *Eozoon*, perhaps dispersed in a living state and capable of acting as germs.]

EXPLANATION OF PLATE X.

Fig. 1. Fragments of skeleton of *Eozoon*, imbedded in dolomite limestone. (*a*) Fragment with canals. (*b*) Fragments not showing canals. (*c*) Dolomite. (Magnified 10 diameters.)

2. Laminated *Eozoon*, with vein of chrysotile. (*a*) Calcareous wall, slightly eroded with acid. (*b*) Serpentine filling chambers. (*c*) Chrysotile vein crossing the structures. (10 diam.)

3. Portion of a speciment similar to that in fig. 2; a very thin slice more highly magnified. (*a*) Intermediate skeleton with portions of two large canals. (*a'*) Proper wall with fine tubulation. (*b*) Serpentine filling chambers. (*c*) Chrysotile vein traversing serpentine. (Magnified 90 diam.)

4. Small *Archæosphærina*, showing tubulated wall. (200 diam.)

5, 6, 7, 8. *Archæosphærinæ*, casts, as opaque objects, of some of the varieties. (75 diam.)

9 and 10. Similar specimens seen in section. (75 diam.)

The specimen represented in fig. 4 is from Long Lake; all the others are from Petite Nation.

DISCUSSION.

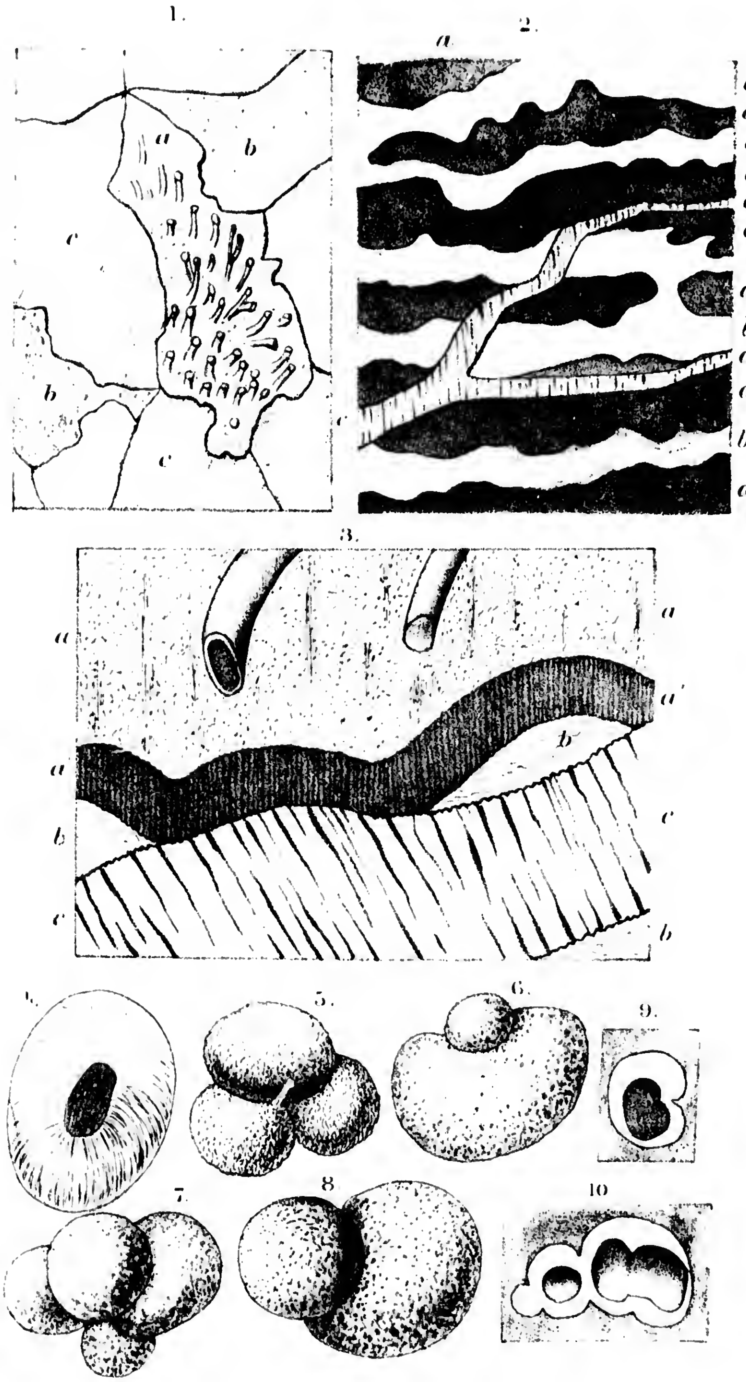
Prof. DUNCAN said that he thought the author had run the mineralogists rather hard. For his own part, when he first examined specimens of *Eozoon* he had come to the conclusion that they were ancient Foraminifera with Nummuline peculiarities; and since he had acquired a more intimate acquaintance with fibrous minerals and serpentines, he found himself more than ever confirmed in this view. The discovery of isolated masses was very interesting, seeing that, whether they were separated fragments or distinct organisms, they still showed the Nummuline structure. Prof. Duncan compared the habit of growth of *Eozoon* to that of the Nullipores, and suggested that it would be more philosophical to refer both the latter and the Foraminifera to Häckel's group "Protista."

Mr. ETHERIDGE remarked upon the singular fact that whilst, as a general rule, we were disappointed in obtaining instructive sections of *Eozoon*, we had only to go to Dr. Carpenter to see sections which seemed to be convincing. He thought the difference of opinion that prevailed as to the nature of *Eozoon* was due mainly to the difficulty that certainly existed of procuring specimens to show the so-called tubuli and stolons. He stated that he had received from Jersey specimens which at the first glance he said were like

*Eozoon*; and on getting sections of these made, organic structure at any rate seemed to be present. He had specimens of *Stromatopora* so like *Eozoon* in external appearance, that Sir W. Logan on seeing them immediately mistook them for the latter.

Prof. RAMSAY said that he was pleased to find that there might be some relation between *Eozoon* and *Stromatopora*. For his own part he did not see how the structure described as *Eozoon* could have been formed, unless it was of organic origin.

Mr. EVANS remarked that, it seemed to him, one of the most interesting points of the paper consisted in the indication (he believed, for the first time) of the occurrence of possibly separate organisms associated with *Eozoon*. They apparently bore a close resemblance to *Globigerina*; and, considering the conditions of fossilization, their presence seemed to confirm the notion of the organic and indeed Foraminiferal origin of *Eozoon*.




... del. lith. Mintern Bros. imp.

EOZOON AND ARCHÆOSPHERINÆ