ART. XXV.—*On new specimens of Eozoön Canadense, with a reply to the objections of Professors King and Rowney; by J. W. DAWSON, LL.D., and notes by W. B. CARPENTER, M.D. Illustrated by two plates.*

[This paper, published in the Quarterly Journal of the Geological Society for August, 1867, is preceded by an article by Sir Wm. E. Logan, from which the following extracts are made by way of introduction.—Eds.]

The most important of these specimens was met with last summer by Mr. G. H. Vennor, one of the assistants on the Canadian Geological Survey, in the township of Tudor and county of Hastings, Ontario, about forty-five miles inland from the north shore of Lake Ontario, west of Kingston. It occurred on the surface of a layer, three inches thick, of dark gray micaceous limestone or calc-schist, near the middle of a great zone of similar rock, which is interstratified with beds of yellowish-brown quartzite, gray close grained siliceous limestone, white coarsely granular limestone, and bands of dark bluish compact limestone and black pyritiferous slates, to the whole of which Mr. Vennor gives a thickness of 1,000 feet. Beneath this zone are gray and pink dolomites, bluish and grayish mica-slates, with conglomerates, diorites, and beds of magnetite, a red orthoclase gneiss lying at the base. The whole series, according to Mr. Vennor's section, which is appended, has a thickness of more than 21,000 feet; but the possible occurrence of more numerous folds than have hitherto been detected, may hereafter render necessary a considerable reduction.

These measures appear to be arranged in the form of a trough, to the eastward of which, and probably beneath them, there are rocks resembling those of Grenville, from which the former differ considerably in lithological character; it is therefore supposed that the Hastings series may be somewhat higher in horizon than that of Grenville. From the village of Madoc, the zone of gray micaceous limestone, which has been particularly alluded to, runs to the eastward on one side of the trough, in a nearly vertical position into Elzivir, and on the other side to the northward, through the township of Madoc into that of Tudor, partially and unconformably overlaid in several places by horizontal beds of Lower Silurian limestone, but gradually spreading, from a diminution of the dip, from a breadth of half a mile to one of four miles. Where it thus spreads out in Tudor it becomes suddenly interrupted for a considerable part of its breadth by an isolated mass of anorthosite rock rising about 150 feet above the general plain, and supposed to belong to the unconformable Upper Laurentian, thus showing that the specimens of *Eozoön* of this neighborhood, like those previously discovered and described, belong to the Lower Laurentian series.

The Tudor limestone is comparatively unaltered; and, in the specimen obtained from it, the general form or skeleton of the fossil (consisting of white carbonate of lime) is imbedded in the limestone, without the presence of serpentine or other silicate, the color of the skeleton contrasting strongly with that of the rock. It does not sink deep into the rock, the form having probably been loose and much abraded on what is now the under part, before being entombed. * * *

In Dr. Dawson's paper mention is made of specimens from Wentworth, and others from Long Lake. In both of these localities the rock yielding them belongs to the Grenville band, which is the uppermost of the three great bands of limestone hitherto described as interstratified in the Lower Laurentian series. That at Long Lake, situated about twenty-five miles north of Côte St. Pierre in the Petite Nation Seigniory, where the best of the previous specimens were obtained, is in the direct run of the limestone there; and like it the Long Lake rock is of a serpentinous character. The locality in Wentworth occurs on Lake Louisa, about sixteen miles north of east from that of the first Grenville specimens, from which Côte St. Pierre is about the same distance north of west, the lines measuring these distances running across several important undulations in the Grenville band in both directions. The Wentworth specimens are imbedded in a portion of the Grenville band, which appears to have escaped any great alteration, and is free from serpentine, though a mixture of serpentine with white crystalline limestone occurs in the band within a mile of the spot. From this gray limestone, which has somewhat the aspect of a conglomerate, specimens have been obtained resembling some of the figures given by Gumbel in his illustrations of the forms met with by him in the Laurentian rocks of Bavaria. * * *

It was the general form on weathered surfaces, and its strong resemblance to *Stromatopora*, which first attracted my attention to *Eozoon*; and the persistence of it in two distinct minerals, pyroxene and loganite, emboldened me, in 1857, to place before the Meeting of the American Association for the Advancement of Science specimens of it as probably a Laurentian fossil. * *

The following is from an ascending section of the Laurentian rocks in the county of Hastings, Ontario, by Mr. H. G. Vennor.

	Feet.
1. Reddish and flesh-colored granitic gneiss	2,000
2. Grayish and flesh-colored gneiss, sometimes hornblendic; mean of several pretty closely agreeing measurements.....	10,400
3. Crystalline limestone, sometimes magnesian, includes in Elzivir a one foot bed of graphite; sometimes very thin, but in other places attains a thickness of 750 feet; estimated as averaging	400
4. Hornblendic and dioritic rocks, massive or schistose, occasionally associated near the base with dark micaceous schists, chloritic and epidotic rocks, including beds of magnetite; average.....	4,200
5. Crystalline and somewhat granular magnesian limestone, occasionally interstratified with diorites, and near the base with siliceous slates and small beds of impure steatite	330
This limestone is metalliferous, holding disseminated copper pyrites, blende, mispickel, and iron pyrites, the latter also sometimes in beds of	

two or three feet. Gold occurs in it at the village of Madoc, associated with argentiferous tetrahedrite and in irregular veins with bitter-spar, quartz, and carbonaceous matter.	Feet.
6. Gray siliceous or fine-grained mica-slates, with an interstratified mass of about sixty feet of yellowish-white dolomite	400
7. Bluish and grayish micaceous slate, interstratified with layers of gneiss, and occasionally holding crystals of magnetite	500
8. Gneissoid micaceous quartzites, banded gray and white, with a few intratified beds of siliceous limestone	1,900
9. Gray micaceous limestone, sometimes plumbaginous, interstratified below with occasional layers of diorite, and layers of a rusty-weathering gneiss	1,000
This division in Tudor is traversed by numerous N.W. and S.E. veins, holding galena in a gangue of calcite and barite. The <i>Eozoon</i> from Tudor, here described, was obtained from about the middle of this calcareous division, which appears to form the summit of the Hastings series.	
Total thickness.....	21,130]

I. SPECIMEN OF EOZON FROM TUDOR, ONTARIO.

This very interesting specimen, submitted to me for examination by Sir W. E. Logan, is, in my opinion, of great importance, as furnishing a conclusive answer to all those objections to the organic nature of *Eozoon* which have been founded on comparisons of its structures with the forms of fibrous, dendritic, or concretionary minerals,—objections which, however plausible in the case of highly crystalline rocks, in which organic remains may be simulated by merely mineral appearances readily confounded with them, are wholly inapplicable to the present specimen.

1. *General appearance*.—The fossil is of a clavate form, six and a half inches in length, and about four inches broad. It is contained in a slab of dark-colored, coarse, laminated limestone, holding sand, scales of mica, and minute grains and fibers of carbonaceous matter. The surface of the slab shows a weathered section of the fossil (Pl. II); and the thickness remaining in the matrix is scarcely two lines, at least in the part exposed. The septa, or plates of the fossil, are in the state of white carbonate of lime, which shows their form and arrangement very distinctly, in contrast to the dark stone filling the chambers. The specimen lies flat in the plane of stratification, and has probably suffered some compression. Its septa are convex toward the broad end, and somewhat undulating. In some places they are continuous half way across the specimen; in other places they divide and re-unite at short distances. A few transverse plates, or connecting columns, are visible; and there are also a number of small veins or cracks passing nearly at right angles to the septa, and filled with carbonate of lime, similar in general appearance to the septa themselves.

On one side, the outline of the fossil is well preserved. The narrow end, which I regard as the basal portion, is rounded. The outline of the side first bends inward, and then outward, forming a graceful double curve, which extends along the greater part of the length. Above this is an abrupt projection, and then a sudden narrowing; and in the middle of the narrow portion, a part has the chambers obliterated by a white patch of carbonate of lime, below which some of the septa are bent downward in the middle. This is probably an effect of mechanical injury, or of the interference of a calc-spar vein.

With the exception of the upper part above referred to, the septa are seen to curve downward rapidly toward the margin, and to coalesce into a lateral wall, which forms the defined edge or limit of the fossil, and in which there are some indications of lateral orifices opening into the chambers. It is worthy of remark that, in this respect, the present specimen corresponds exactly with that which was originally figured by Sir W. E. Logan in the 'Geology of Canada,' p. 49, and which is the only other specimen that has exhibited the lateral limit of the form.

On the side next the matrix, the septa terminate in blunt edges, and do not coalesce; as if the organism had been attached by that surface, or had been broken before being imbedded.

2. *Microscopic characters.*—Under the microscope, with a low power, the margins of the septa appear uneven, as if eroded or tending to an acervuline mode of growth; but occasionally the septa show a distinct and regular margin. For the most part merely traces of structure are presented, consisting of small parts of canals, filled with the dark coloring-matter of the limestone. In a few places (Pl. III, fig. 1), however, these appear as distinct bundles, similar to those in the Grenville specimens, but of fine texture.

[In fig. 2 is represented a portion of the canal-system in a Grenville specimen, in which the canals, which are transparent in one side (being infiltrated with carbonate of lime only) are seen on the other to be partially filled with black matter, probably a carbonaceous residuum of the sarcodæ which they originally contained.—w. B. c.]

In a few rare instances only can I detect, with a higher power, in the margin of some of the septa, traces of the fine tubulation characteristic of the proper chamber-wall of *Eozoon*. For the most part this seems to have been obliterated by the infiltration of the tubuli with colorless carbonate of lime, similar to that of the skeleton.

In comparing the structure of this specimen with that of

those found elsewhere, it would appear that the chambers are more continuous, and wider in proportion to the thickness of the septa, and that the canal-system is more delicate and indistinct than usual. In the two former respects the specimens from the Calumet and from Burgess approach that now under consideration more nearly than do those from Grenville and Petite Nation; but it would be easy, even in the latter, to find occasional instances of a proportion of parts similar to that in the present example. General form is of little value as a character in such organisms; and so far as can be ascertained, this may have been the same in the present specimen and in that originally obtained from the Calumet, while in the specimens from Grenville a massive and aggregative mode of growth seems to have obliterated all distinctness of individual shape. Without additional specimens, and in the case of creatures so variable as the Foraminifera, it would be rash to decide whether the differences above noticed are of specific value, or depend on age, variability, or state of preservation. For this reason I refer the specimen for the present to *Eozoon Canadense*, merely distinguishing it as the Tudor variety.

From the state of preservation of the fossil, there are no crystalline structures present which can mislead any ordinarily skilful microscopist, except the minute veins of calcareous spar traversing the septa, and the cleavage-planes which have been developed in some portions of the latter.

I would remark that, as it seemed desirable not to injure any more than was absolutely necessary a unique and very valuable specimen, my observations of the microscopic structure have been made on a few slices of small size,—and that, as the microscopic structures are nearly the same in kind with those of specimens figured in former papers, I have not thought it necessary to prepare numerous drawings of them; while the admirable photograph executed for Sir W. E. Logan by Mr. Notman illustrates sufficiently the general form and arrangement of parts (see Pl. II).

3. *Concluding remarks*.—In a letter to Dr. Carpenter, quoted by him in the 'Quarterly Journal of the Geological Society' for August, 1866, p. 228, I referred to the occurrence of *Eozoon* preserved simply in carbonate of lime. The specimens which enable me to make that statement were obtained at Madoc, near Tudor, this region being one in which the Laurentian rocks of Canada appear to be less highly metamorphosed than is usual. The specimens from Madoc, however, were mere fragments, imbedded in the limestone, and incapa-

AM. JOUR. SCI.—SECOND SERIES, VOL. XLVI, No. 137.—SEPT., 1868.

ble of showing the general form. I may explain, in reference to this, that long practice in the examination of these limestones has enabled me to detect the smallest fragments of *Eozoon* when present, and that in this way I had ascertained the existence of this fossil in one of the limestones of Madoc before the discovery of the fine specimen now under consideration.

I am disposed to regard the present specimen as a young individual, broken from its attachment and imbedded in a sandy calcareous mud. Its discovery affords the hope that the comparatively unaltered sediments in which it has been preserved, and which also contain the worm-burrows described by me in the 'Quarterly Journal of the Geological Society' for November,* will hereafter still more largely illustrate the Laurentian fauna.

II. SPECIMENS FROM LONG LAKE AND WENTWORTH.

Specimens from Long Lake, in the collection of the Geological Survey of Canada, exhibit white crystalline limestone with light green compact or septariiform† serpentine, and much resemble some of the serpentine-limestones of Grenville. Under the microscope the calcareous matter presents a delicate areolated appearance, without lamination; but it is not an example of acervuline *Eozoon* but rather of fragments of such a structure, confusedly aggregated together, and having the interstices and cell-cavities filled with serpentine. I have not found in any of these fragments a canal-system similar to that of *Eozoon Canadense*, though there are casts of large stolons, and, under a high power, the calcareous matter shows in many places the peculiar granular or cellular appearance which is one of the characters of the supplemental skeleton of that species. In a few places a tubulated cell-wall is preserved, with structure similar to that of *Eozoon Canadense*.

Specimens of Laurentian limestone from Wentworth, in the collection of the Geological Survey, exhibit many rounded siliceous bodies, some of which are apparently grains of sand, or small pebbles; but others, especially when freed from the calcareous matter by a dilute acid, appear as rounded bodies, with rough surfaces, either separate or aggregated in lines or groups, and having minute vermicular processes projecting from their surfaces (Pl. III, fig. 3). At first sight these suggest the idea of spicules; but I think it on the whole more

* Vol. xxii, p. 608.

† I use the term 'septariiform' to denote the *curdled* appearance so often presented by the Laurentian serpentine.

likely that they are casts of cavities and tubes belonging to some calcareous Foraminiferal organism which has disappeared.

Similar bodies, found in the limestone of Bavaria, have been described by Gumbel, who interprets them in the same way.* They may also be compared with the siliceous bodies mentioned in a former paper as occurring in the loganite filling the chambers of specimens of *Eozoon* from Burgess.

III. SPECIMENS FROM MADOC.

I have already referred to fragments of *Eozoon* occurring in the limestone at Madoc, one of which, found several years ago, I did not then venture to describe as a fossil. It projected from the surface of the limestone, being composed of a yellowish dolomite, and looking like a fragment of a thick shell. When sliced, it presents interiorly a crystalline dolomite, limited and separated from the enclosing rock by a thin wall having a granular or porous structure, and excavated into rounded recesses in the manner of *Eozoon*. It lies obliquely to the bedding, and evidently represents a hollowed flattened calcareous wall filled by infiltration. The limestone which afforded this form was near the beds holding the worm-burrows described in the Society's Journal for Nov. 1866.

[A thin section of this body, carefully examined microscopically, presents numerous and very characteristic examples of the canal-system of *Eozoon*, exhibiting both the large widely branching systems of canals and the smaller and more penicillate tufts (Pl. III, figs. 4, 5) shown in the most perfect of the serpentine specimens—but with this difference, that the canals, being filled with a material either identical with or very similar to that of the substance in which they are excavated, are so transparent as only to be brought into view by careful management of the light.—w. B. C.]

IV. OBJECTIONS TO THE ORGANIC NATURE OF EOZOON.

The discovery of the specimen from Tudor, above described, may appear to render unnecessary any reference to the elaborate attempt made by Profs. King and Rowney to explain the structures of *Eozoon* by a comparison with the forms of fibrous and dendritic minerals,† more especially as Dr. Carpenter has already shown their inaccuracy in many important points. I think, however, that it may serve a useful purpose shortly to point out the more essential respects in which this comparison fails with regard to the Canadian specimens—with the view of relieving the discussion from matters irrelevant to it, and of

* Proceedings of Royal Academy of Munich, 1866; Q. J. G. S., vol. xxii, pt. i. p. 185 *et seq.*; also Can. Naturalist, vol. iii, p. 81.

† Quart. Journ. Geol. Soc., vol. xxii, pt. ii, p. 23.

fixing more exactly the limits of crystalline and organic forms in the serpentine-limestones and similar rocks.

The fundamental error of Messrs. King and Rowney arises from defective observation—in failing to distinguish, in the Canadian limestones themselves, between organic and crystalline forms. This is naturally followed by the identification of all these forms, whether mineral or organic, with a variety of purely crystalline arrangements occurring in other rocks, leading to their attaching the term ‘Eozoönal’ to any rock which shows any of the characters, whether mineral or organic, thus arbitrarily attached to the Canadian *Eozoon*. This is obviously a process by which the structure of any fossil might be proved to be a mere *lusus naturæ*.

A notable illustration of this is afforded by their regarding the veins of fibrous serpentine, or chrysotile, which occur in the Canadian specimens, as identical with the tubulated cell-wall of *Eozoon*,—although they admit that these veins traverse all the structures indifferently, and do not conform to the walls of the chambers. But any microscopist who possesses specimens of *Eozoon* containing these chrysotile veins may readily satisfy himself that, under a high power, they resolve themselves into *prismatic crystals in immediate contact with each other*; whereas, under a similar power, the true cell-wall is seen to consist of *slender, undulating, rounded threads of serpentine, penetrating a matrix of carbonate of lime*. Under polarized light, more especially, the difference is conspicuously apparent. It is true that, in many specimens and parts of specimens, the cell-wall of *Eozoon* is badly preserved and fails to show its structure; but in no instance does it present the appearance of chrysotile, or of any other fibrous mineral, when examined with care under sufficiently high powers. In my original examination of Sir William Logan’s specimens from Grenville and the Calumet, I did not detect the finely tubulated cell-wall which is very imperfectly preserved in those specimens; but the veins of fibrous serpentine were well known to me; and when Dr. Carpenter discovered the tubulation of the cell-wall in the specimens from Petite Nation, I compared this structure with that of these veins, and satisfied myself of its distinctness before acceding to his conclusions on this point.

It would also appear that the radiating and sheaf-like bundles of crystals of tremolite, or similar prismatic minerals, which occur in the Canadian serpentines, and also abound in those of Connemara, have been confounded with the tubulation of *Eozoon*; but these crystals have no definite relation to the forms of that fossil, and often occur where these are en-

tirely absent; and in any case they are distinguished by their straight prismatic shape and their angular divergence from each other. Much use has also been made of the amorphous masses of opaque serpentinous matter which appear in some parts of the structure of *Eozoon*. These I regard as, in most cases, simply results of alteration or defective preservation, though they might also arise from the presence of foreign matters in the chambers, or from an incrustation of mineral matter before the final filling up of the cells. Generally their forms are purely inorganic; but in some cases they retain indications of the structures of *Eozoon*.

With reference to the canal-system of *Eozoon*, no value can be attached to loose comparisons of a structure so definite with the forms of dendritic silver and the filaments of moss-agates; still less can any resemblance be established between the canal-system and vermicular crystals of mica. These occur abundantly in some serpentines from the Calumet, and might readily be mistaken for organic forms; but their rhombic or hexagonal outline when seen in cross section, their transverse cleavage planes, and their want of any definite arrangement or relation to any general organic form, are sufficient to undeceive any practised observer. I have not seen specimens of the metaxite from Reichenstein referred to by Messrs. King and Rowney; but it is evident, from the description and figure given of it, that, whether organic or otherwise, it is not similar to the canals of *Eozoon Canadense*. But all these and similar comparisons are evidently worthless when it is considered that they have to account for definite, ramifying, cylindrical forms, penetrating a skeleton or matrix of limestone, which has itself a definite arrangement and structure, and, further, when we find that these forms are represented by substances so diverse as serpentine, pyroxene, limestone, and carbonaceous matter. This is intelligible on the supposition of tubes filled with foreign matters, but not on that of dendritic crystallization.

If all specimens of *Eozoon* were of the acervuline character, the comparisons of the chamber-casts with concretionary granules might have some plausibility. But it is to be observed that the laminated arrangement is the typical one; and the study of the larger specimens, cut under the direction of Sir W. E. Logan, shows that these laminated forms must have grown on certain strata-planes before the deposition of the overlying beds, and that the beds are, in part, composed of the broken fragments of similar laminated structures. Further, much of the apparently acervuline *Eozoon* rock is composed of such broken fragments, the interstices between which should not be confounded with the chambers; while the fact

that the serpentine fills such interstices as well as the chambers shows that its arrangement is not concretionary.* Again, these chambers are filled, in different specimens, with serpentine, pyroxene, loganite, calcareous spar, chondrodite, or even with arenaceous limestone. It is also to be observed that the examination of a number of limestones, other than Canadian, by Messrs. King and Rowney, has obliged them to admit that the laminated forms in combination with the canal-system are 'essentially Canadian,' and that the only instances of structures clearly resembling the Canadian specimens are afforded by limestones Laurentian in age, and in some of which (as, for instance, in those of Bavaria and Scandinavia) Carpenter and Gümbel have actually found the structure of *Eozoon*. The other serpentine-limestones examined (for example, that of Skye) are admitted to fail in essential points of structure; and the only serpentine believed to be of eruptive origin examined by them is confessedly destitute of all semblance of *Eozoon*. Similar results have been attained by the more careful researches of Prof. Gümbel, whose paper is well deserving of study by all who have any doubts on this subject.

In the above remarks I have not referred to the disputed case of the Connemara limestones; but I may state that I have not been able to satisfy myself of the occurrence of the structures of *Eozoon* in such specimens as I have had the opportunity to examine.† It is perhaps necessary to add that there exists in Canada abundance of Laurentian limestone which shows no indication of the structures of *Eozoon*. In some cases it is evident that such structures have not been present. In other cases they have been obliterated by processes of crystallization. As in the case of other fossils, it is only in certain beds, and in certain parts of those beds, that well-characterized specimens can be found. I may also repeat here that in the original examination of *Eozoon*, in the spring of 1864, I was furnished by Sir W. E. Logan with specimens of all these limestones, and also with serpentine-limestones of Silurian age, and that, while all possible care was taken to compare with the specimens of *Eozoon*, it was not thought necessary to publish notices of the crystalline and concretionary forms observed, many of which are very curious, and might afford materials for other papers of the nature of that criticised in the above remarks.

* I do not include here the 'septariiform' structure referred to above, which is common in the Canadian serpentine and has no connection with the forms of the chambers.

† Such Irish specimens of serpentine limestone as I have seen, appear much more highly crystalline than the beds in Canada which contain *Eozoon*.

[The examination of a large number of sections of a specimen of *Eozoon*, recently placed in my hands by Sir William Logan, in which the canal-system is extraordinarily well preserved, enables me to supply a most unexpected confirmation of Dr. Dawson's statements in regard to the occurrence of dendritic and other forms of this system, which cannot be accounted for by the intrusion of any foreign mineral; for many parts of the calcareous lamellæ in these sections, which, when viewed by ordinary transmitted light, appear quite homogeneous and structureless, are found, when the light is reduced by Collin's 'graduating diaphragm,' to exhibit a most beautiful development of various forms of canal-system (often resembling those of Dr. Dawson's Madoc specimen, represented in Pl. III, figs. 4, 5), which cross the cleavage planes of the shell-substance in every direction. Now these parts, when subjected to decalcification, show no trace of canal-system; so that it is obvious, both from their optical and from their chemical reactions, that the substance filling the canals must have been *carbonate of lime*, which has thus completely solidified the shell layer, having been deposited in the canals previously excavated in its interior, just as crystalline carbonate of lime fills up the reticular spaces of the skeleton of Echinodermata fossilized in a calcareous matrix. This fact affords conclusive evidence of *organic structure*, since no conceivable process of crystallization could give origin to dendritic extensions of carbonate of lime disposed on exactly the same crystalline system with the calcite which includes it, the two substances being mineralogically homogeneous, and only structurally distinguishable by the effect of their junction-surfaces on the course of faint rays of light transmitted through them.—W. B. C.]

EXPLANATION OF THE PLATES.

Plate II.

Specimen of *Eozoon Canadense*, imbedded in a dark-colored homogeneous limestone occurring in the Lower Laurentian series in Tudor, Ontario; two-thirds of the natural size.

Plate III.

- Fig. 1. Section of one of the calcareous layers of the Tudor specimen (Plate II), showing canal-system imperfectly infiltrated with black (carbonaceous?) matter; magnified 120 diameters.
2. Section of the shelly layer of a specimen of *Eozoon* from Grenville, showing a minute form of canal-system partly injected with black matter, and partly with serpentine; magnified 120 diameters.
3. Siliceous bodies (internal casts?) from a specimen of *Eozoon* from Wentworth; magnified 50 diameters.
- 4, 5. Sections of a fragment of *Eozoon* from the Madoc limestone, showing various forms of canal-system filled with carbonate of lime; magnified 120 diameters.

Roberts & Renbald. Little Montreal.

EZOON CANADENSE.

Roberts & Reinhold, both Magnified.

EZOON CANADENSE.