LXVI.—*New Observations on* Eozoon canadense.

By William B. Carpenter, M.D., LL.D., F.R.S.

[Plate XIX.]

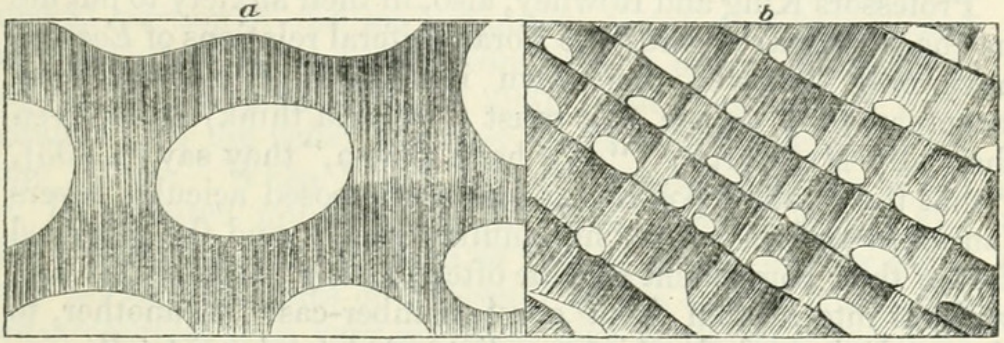
It may be thought that Mr. Carter would have best consulted, not only the interests of science, but his own reputation, by abstaining from any further attempts to disprove the Foraminiferal nature of *Eozoon*, until he had either acquainted himself with the careful descriptions and "fac-simile" representations of its structure given by Dr. Dawson, Prof. T. Rupert Jones, and myself*, or had satisfied himself, by an examination of the specimens which I expressed my readiness to show him, of the fallaciousness of my interpretation. But I make no complaint of his having chosen the opposite course, since his adoption of it has led me to a careful re-examination of the whole subject, with the result of not only removing a difficulty I had myself felt, and of thus strengthening my own conviction, but of enabling me (as I anticipate) to carry that conviction to the mind of every competent judge, who has not so completely made up his mind to a foregone conclusion as to be unable to appreciate the force of the new evidence I have now to produce.

I shall first dispose of the objection which Mr. Carter adduces as *fatal* to the Foraminiferal doctrine, viz. that the supposed nummuline tubuli frequently lie *parallel* to the chamber-walls, instead of *perpendicular* to them—a character which, says Mr. Carter, "is *utterly* incompatible with Foraminiferal structure." This *dictum*, when translated from *Carterese* (p. 278) into English, merely means that it is incompatible with *Mr. Carter's notions* of Foraminiferal structure; to which, as I have already had occasion to show, Nature refuses to bind herself. I fully admit the fact as he states it, and now find a perfectly simple explanation of it in the structure of those very *Nummulites* which Mr. Carter knows so well. In the lower or "lamellar" portion of the Canadian *Eozoon*, the nummuline tubulation (where preserved) always presents—so far as my experience extends—its normal perpendicularity to the surface of the chambers; as shown in Pl. XIX. figs. 1, 2. The arrangement referred to by Mr. Carter presents itself only in that upper or "acervuline" portion, in which, as in many recent Foraminifera, the chamber-

* The "constructed" figure which I introduced for mere convenience of reference, was built-up (as every one of my "constructed" figures has been) from parts which were separately described and figured ten years ago from the actual specimens, for the sake of showing the *relations* between them,—a method used by every Palæontologist.

lets are irregularly piled one on the other (see p. 281, fig. 1); and the *parallelism* of the tubuli to the walls of the chamberlets they adjoin, simply arises from the fact that they are passing-by these, *in that perpendicular course from the chamberlets in which they originate, towards the external surface*, which Mr. Carter himself recognizes as *perfectly normal*. This is shown in the subjoined figure (*a*) traced from a transparent section in my possession—the *precise counterpart to it* (*b*) being shown in those Nummulites which have the "alar

Fig. 1.



a

Parallel tubulation in acervuline portion of *Eozoon canadense*, showing the course of the tubuli between the irregularly-piled chamberlets.

b

Parallel tubulation of *Nummulites lævigata*, showing the course of the tubuli between the alar prolongations of successive whorls. After D'Archiac and Haime.

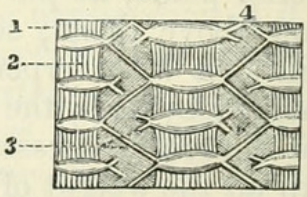
prolongations" of successive whorls prolonged over those which preceded them, so as to be piled one upon another, often dividing themselves into irregular chamberlets. For when these are laid open by vertical section, it continually happens that the tubuli coming off *vertically* from the chambers of an inferior plane, lie *parallel* to the sides of the chambers of the plane above them; so that, if the chambers and tubuli were infiltrated with serpentine, and the calcareous skeleton were removed by acid, the appearance presented would be exactly that figured by Messrs. King and Rowney, which Mr. Carter, with all the weight of his authority, pronounces to be "*utterly* incompatible with Foraminiferal structure."—That I have not evolved this parallelism out of my own consciousness, will be manifest to any one who may take the trouble to refer to the admirable plates of Nummuline structure given by MM. D'Archiac and Haime in their 'Animaux Fossiles du Groupe Nummulitique de l'Inde.' For it is distinctly seen in *every one* of their thin vertical sections of those species in which the "alar prolongations" are conspicuous—as *N. intermedia*,

pl. iii. fig. 4, *e*, *N. garansensis*, pl. iii. fig. 7, *g*, *N. lævigata*, pl. iv. fig. 1, *d*, and *N. obtusa*, pl. vi. fig. 13, *c*,—the figure given above being copied from a portion of the third of those just cited, that I may not be charged with having "constructed" it.

Thus, so far from Mr. Carter's case of *utter incompatibility* proving fatal to the Foraminiferal doctrine of *Eozoon*, a "comparison of the actual specimens" (his own test) gives to that doctrine the additional support of *a very striking conformity*. Speaking for once in *Carterese*, I might say that Mr. Carter has "found a mare's nest."

Professors King and Rowney, also, in their anxiety to put me in the wrong as regards the Foraminiferal relations of *Eozoon*, have only betrayed their own ignorance of Foraminiferal structure, to a degree that must (I should think) shock even their ally Mr. Carter. "We have shown," they say (p. 393), "that the relative position of two superposed acicular layers (an *upper* and an *under* 'nummuline wall'), and the admitted fact of their component aciculæ often passing continuously and without interruption from one 'chamber-cast' to another, to the exclusion of the 'intermediate skeleton,' are *totally incompatible* with the idea of the said 'nummuline layers' having resulted from pseudopodial tubulation." Now, putting aside the *first* part of this statement, which betrays the confusion existing in the minds of its writers between the *true* "nummuline layer," as described by me from transparent sections, and the "acicular layers" of decalcified specimens, which may or may not represent it (see p. 461),—what must be said by Mr. Carter of the *second*? For *he*, of course, knows perfectly well that in the superposed whorls of *Nummulites*, as described by me in 1849, and in the superposed layers of *Orbitoides*, as described by himself in 1861, the pseudopodial tubulation *normally* passes on "continuously and without interruption from one chamber to another, to the exclusion of the 'intermediate skeleton.'" This is represented alike in my original figures of the "Nummuline tubulation" (Quart. Journ. of Geol. Society, 1850), in every one of D'Archiac and Haime's vertical sections of Nummulites, and in Mr. Carter's own sections of *Orbitoides*, of which one is here reproduced.

Fig. 2.



Vertical Section of columns of *Orbitoides dispansa*; 1, column of chambers; 2, vertical tubuli of the test; 3, 4, tubes of intercommunication between the chambers.—After Carter.

It was doubtless the apparent force of the argument whose fallacy I have thus demonstrated, which led Prof. Max Schultze, after reading the paper of Professors King and Rowney, to write to Mr. Barker that it had "made a very great impression" on him, and that "with respect to the 'proper wall' of Carpenter" he was "entirely of their opinion." I have no reason to believe that Prof. Max Schultze ever did see the "proper nummuline wall," such as I shall presently describe and figure it; Professors King and Rowney *certainly have not*, if they can identify it with a film of chrysotile or asbestiform serpentine, forming "an integral portion of the grains and plates of serpentine," and can assert that in its typical condition it occurs in cracks or fissures of the serpentine (p. 393); and they misled Prof. Schultze into the belief that they and I were speaking of the same things. When I sent him the preparations he asked for, I expressed my regret at not being able to supply him with a characteristic specimen of this structure, having given away all the duplicates of it I could spare; and, as it is rarely well-preserved, it is very probable that he did not find it by his own examination of the larger specimens he afterwards received from me and from other sources. At any rate, there is no mention of the "nummuline wall" in his communication to the Wiesbaden Association—his acceptance of *Eozoon* as a Foraminifer entirely resting on the "canal-system," which he had minutely studied*, and as to which *there is no evidence whatever that he had changed his opinion*, as asserted by Professors King and Rowney. Had he lived to see what I shall presently describe, I cannot doubt that he, in common with the numerous Microscopists to whom I have recently shown it, would have accepted the "nummuline wall" without the slightest hesitation.

Before, however, I proceed to describe it, I find myself obliged to notice the following statement made by Professors King and Rowney in the second note to p. 393 of their last paper:—

* Mr. Carter questions the existence of a canal-system in *Polytrema*, referred to by Prof. Schultze, because his own "mounted specimens" do not show it. When he has extended his knowledge of Foraminifera by the careful study of my "Introduction" and of the types minutely described in it, he will find that the development of the "canal-system" is correlated to that of the "intermediate skeleton," and that varietal or even individual differences may occur in this particular. I had never myself seen it in *Planorbulina* (for example), until M. Munier-Chalmas showed it to me, a few weeks since, in a specimen in the Sorbonne Museum. This specimen had grown so closely attached to a Coral, as to have shaped itself on the inequalities of the Coral-surface; and yet its lower or attached side was *as perfectly tubulated* as its upper or free side—a fact which I commend to the consideration of Professors King and Rowney.

"The so-called 'nummuline wall' in Dr. Carpenter's constructed representation, fig. 2, ought not to be represented in the way it is—bounded by two *continuous* lines—as it is an *integral* portion of the grains and plates of serpentine (the so-called 'chamber-casts'), and not a *chemically* differentiated part like the true calcareous wall of certain Foraminifers." I have represented nothing that my specimens do not distinctly show; and the only excuse for such an imputation can be, that those who made it have never seen the *true* "nummuline wall," such as I figured it ten years ago, before a question had been raised as to the organic nature of *Eozoon* (Quart. Journ. Geol. Soc. vol. xxi. plate viii. figs. 3, 4), and such as I now again figure it from a still better specimen in Plate XIX. figs. 1, 2. Professors King and Rowney, merely because they have not met with what I have represented, take upon themselves to deny its existence.

My *true* "nummuline wall" is the representative of that which, in recent Foraminifera, immediately surrounds the chambers (Pl. XIX. fig. 1, *a a*). It is *not* a layer of chrysotile aciculæ; but is a *calcareous* lamella, perforated by minute tubuli, which usually lie straight and parallel, but are often more or less curved. These tubuli, like the chambers and canal-system, are usually filled with serpentine, which has passed into them from the chambers in which they originate; and thus it happens that the original tubulation is generally obscured, being only represented microscopically by the difference in refractive index between the calcareous shelly layer and the serpentine which has filled its tubes,—just as in a specimen of fresh bone or dentine mounted in Canada balsam the tubuli are only represented by the different refractive indices of the matrix and the balsam. But in the specimen of *Eozoon* figured in Pl. XIX. figs. 1, 2, many of the tubuli remain empty; and *they can be distinguished as tubuli under any magnifying-power that the thickness of the covering-glass allows to be used.* Further, they have the somewhat sinuous course of the tubuli of organic structures; and they present, at what was probably a plane of interrupted growth, the sharper flexures which Prof. Owen first pointed out in the tubuli of dentine, and which I described and figured twenty-seven years ago in the hard dentine-like substance of the end of the Crab's claw*.

That the matrix in which these tubules are channelled out is *calcareous*, is shown in this section by the extension into it of the planes of crystalline cleavage (fig. 1, *c c*) of the "cal-

* Report of the British Association for 1847, pl. xx. fig. 81.

careous layer, representing the intermediate skeleton," with which it is continuous. And it is shown also by the effect of dilute acid on any true "nummuline layer" of which the tubules have been filled with serpentine; for it is only *after the removal of the calcareous matrix* that the internal casts of its tubules, remaining as separate aciculæ, present the least resemblance to the chrysotile fibres to which Professors King and Rowney persist in likening them, notwithstanding my repeated assertions that the two things are altogether different. I can show a precisely similar arrangement of vertical aciculæ on the surface of a chamber-cast of a recent *Amphistegina*, and *know* them to be the internal casts of the tubuli of its Nummuline wall. But Professors King and Rowney's argument would make out *these* also to be mere products of mineralization, because they resemble chrysotile-fibres. I am perfectly acquainted with the mineral pseudomorphs to which they refer, and freely admit their resemblance to certain forms of the "acicular layer" left after the decalcification of the "nummuline layer;" but I cannot believe that any microscopist who is familiar either with dentinal or any other form of tubulation, can entertain the slightest doubt that if figs. 2, 3 be correct, the unaltered structure they represent is *organic*. If it be one that any kind of mineralization can produce, I do not see why we are to call Bones and Teeth any thing else than inorganic concretions. The only alternative hypothesis is, that not only Mr. George West and I, but all the Microscopists who have verified our representation, are suffering under "tubulation on the brain;" and this the Galway Professors and Mr. Carter are quite welcome to assert, if they think proper, *when they shall have examined the specimen itself*, which is open to their inspection at any time. At present they are in the position of the opponents of Galileo, who would not look through the telescope which showed the Satellites of Jupiter.

I now pass on to a *second* probative fact of at least equal cogency,—the relation exhibited in the same specimen between the "canal-system" and the tubuli of the "nummuline layer."

In my original description of *Calcarina* (Phil. Trans. 1860)—the type to which, as regards the general distribution of its canal-system and its relation to the intermediate skeleton, *Eozoon* has the closest resemblance—I gave the following account of that relation (p. 554):—"The proper walls of the chambers are uniformly perforated, like those of the chambers of *Rotaliæ*, by foramina of considerable size (averaging above 1 3000th of an inch in diameter); with these the canals of the

supplemental [or intermediate] skeleton do not seem to be directly continuous, for they are of about double the diameter and lie further apart from one another; but immediately round the proper walls of the chambers there seem to be irregular lacunar spaces, into which the foramina open externally, and from which the passages of the canal-system originate." Now, in my "Supplemental Notes on the Structure and Affinities of *Eozoon canadense*" (Proceed. Geol. Soc., Jan. 10, 1866, p. 222), I stated that precisely the same relation is shown to exist in decalcified specimens of *Eozoon*, by the implantation of the dendritic models of the chamber-casts in plates formed by the coalescence of the aciculæ that occupied the tubules of the "proper wall." Having now been fortunate enough to meet with a *transparent section* which exhibits this relation most unmistakably (Plate XIX. fig. 1, *b b*), I fearlessly ask the verdict of any Biologist familiar with microscopic structure, whether any more exact realization *could* be presented of the structure I had described in *Calcarina*,—allowance being of course made for the different scale of the tubulation of the "proper wall," which is here *fine* "nummuline" not *coarse* "rotaline."

There is another feature in the canal-system of this specimen, which, by leading me to a more careful examination of its ordinary distribution, has brought into view what seems to me a new point of difference between the typical canal-system and mineral dendritic ramifications. It will be observed that the principal trunks are here *in the middle* of the calcareous layer, the ramifications extending from them towards each of its surfaces. This, of course, cannot be so clearly brought out in any plane section, as it can be in such decalcified specimens as are represented in figs. 3, 4; in which a set of canals are seen to originate from the ceiling of the chamber *beneath* them, and to converge like the roots of a tree into a stem, from which diverging branches are given off towards the floor of the chamber above. Now, in all dendritic ramifications I have seen (I do not presume to speak with confidence of things I have not seen), the branches go off from a main trunk which originates at once from the source of the infiltration, instead of being formed by the coalescence of roots *. I do not lay any stress on the difference; but this peculiar distribution of the canal-system is not without its significance, in regard to the

* As I was accustomed to see dendrites *made* at a Pottery in Bristol forty years ago, I am not quite so ignorant in regard to them as Professors King and Rowney seem to suppose that I must be, from the fact that I am a Biologist and not a Mineralogist. The process was simply this:—The cylindrical "biscuit" beer-cup (sold for a penny) having been dipped

mode in which it ministered to the deposition of the intermediate skeleton.

The *third* of the additional probative facts I have now to adduce is *the existence of a canal-system in the calcareous lamellæ, anteriorly to the intrusion of any foreign mineral*; as is distinctly proved by the fact stated in my previous "Remarks" (p. 283), that the minuter part of the canalicular system is often not infiltrated with any foreign mineral at all. As I hold this fact to be of cardinal importance, and as I cannot see that it has been met, either by Professors King and Rowney, or by Mr. Carter, in their replies to my previous Remarks, I now present an exact representation (Pl. XIX. fig. 5) of the aspect of such a portion of the canalicular system—showing by its semi-opacity in one part the extent to which the serpentinous infiltration has proceeded, and by its transparence in the rest that the canalization is not the result of any foreign infiltration whatever. These canals (as formerly stated, p. 283) are filled with calcite having the same crystalline axis as that of the matrix—just as is the reticular structure of fossilized skeletons of *Crinoids*, spines of *Cidaris*, &c. It would be just as logical to refuse to that reticulation the character of an organic structure, because it possesses (even in the recent state) a crystalline arrangement, as to say that this canalicular system is not an evidence of the organic origin of the calcareous lamellæ in which it presents itself. "Is it possible," said one of our most distinguished Naturalists to me a few days since, "that it is seriously maintained that these canaliculi do *not* pre-exist?" As I know them to be contained in the section which I long since forwarded to Prof. Rowney, the only conceivable reason for the non-recognition of them, alike by the two Galway Professors and by Mr. Carter, is that they have not used the reduced light, which, through the extreme transparence of the minuter canaliculi, is necessary to bring them into clear view.

I have thus shown:—(1) that the "utter incompatibility" asserted by my opponents to exist between the arrangement of the supposed "nummuline tubulation" of *Eozoon* and true *Nummuline* structure, so far from having any real existence, really furnishes an additional point of conformity; and (2) that three most striking and complete points of conformity exist be-

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in its viscid "glaze," and held in an inclined position, a brush dipped in a viscid pigment was brought into contact with it at the proper point; and the pigment ran down into the glaze, first forming a stem, and then spreading out in an arborescent ramification. The success of the operation depends on a very nice adjustment between the viscidities of the two liquids.

tween the structure of the best-preserved specimens of *Eozoon*, and that of the *Nummulites* whose tubulation I described in 1849, and of the *Calcarina* whose tubulation and canal-system I described in 1860. And I leave it to the judgment of those who know the differences between Organic structure and any conceivable results of Physical or Chemical action, whether the appearances represented in Plate XIX., to the minute accuracy of which representation I pledge myself, are compatible with the doctrine that the Canadian Ophite is nothing more than a product of mineralization.

That I have not troubled myself to reply to the reiterated arguments in favour of that doctrine, which have been advanced by Professors King and Rowney on the strength of the occurrence of undoubted results of mineralization in the Canadian Ophite, and of still more marked evidences of the same action in other Ophites, has been simply because these arguments appeared to me, as I thought they must also appear to others, entirely destitute of logical force. Every scientific Palæontologist I have ever been acquainted with has taken the *best* preserved specimens, not the *worst*, as the basis of his reconstructions ; and if he should meet with distinct evidence of characteristic organic structure in even a very small fragment of a doubtful form, he would consider the organic origin of that form to be thereby substantiated, whatever might be the evidence of purely mineral arrangement which the greater part of his specimen may present,—since he would regard that arrangement as a probable result of *subsequent* mineralization, by which the original organic structure has been more or less obscured. If this is *not* to be our rule of interpretation, a large part of the Palæontological work of our time must be be thrown aside as worthless. If, for example, Professors King and Rowney were to begin their study of *Nummulites* by the examination of their most mineralized forms, they would deem themselves justified (according to their canons of interpretation) in denying the existence of the tubulation and canalization which I described (in 1849) in the *N. lævigata* preserved almost unaltered in the London Clay of Bracklesham Bay.

My own notions of *Eozoic* structure have been formed on the examination of the Canadian specimens selected by the experienced discrimination of Sir William Logan, as those in which there was *least* appearance of metamorphism ; and having found in these what I regarded as unmistakable evidence of an organic structure conformable to the Foraminiferal type, I cannot regard it as any disproof of that conformity,

either to show that the true Eozoic structure has been frequently altered by mineral metamorphism, or to adduce the occurrence of Ophites more or less resembling the *Eozoon* of the Canadian Laurentians at various subsequent Geological epochs. The existence of any number or variety of *purely mineral* Ophites would not disprove the organic origin of the Canadian *Eozoon*—unless it could be shown that some wonderful process of mineralization is competent to construct not only its multiplied alternating lamellæ of Calcite and Serpentine, the dendritic extensions of the latter into the former, and the "acicular layer" of decalcified specimens, but (1) the *pre-existing canalization* of the calcareous lamellæ, (2) the *unfilled nummuline tubulation* of the proper wall of the chambers, and (3) the peculiar *calcarine* relation of the canalization and tubulation, here described and figured from specimens in the highest state of preservation, showing the *least* evidence of any mineral change.

On the other hand, Professors King and Rowney began their studies of Eozoic structure upon the Galway Ophite—a rock which Sir Roderick Murchison described to me at the time as having been so much "tumbled about," that he was not at all sure of its geological position, and which exhibits such obvious evidences of mineralization, with such an entire absence of any vestige of organic structure, that I should never for a moment have thought of crediting it with an organic origin, but for the general resemblance of its Serpentine-grains to those of the "acervuline" portion of the Canadian Eozoon. They pronounced with the most positive certainty upon the Mineral origin of the Canadian *Eozoon*, before they had subjected transparent sections of it to any of that careful comparison with similar sections of recent *Foraminifera*, which had been the basis of Dr. Dawson's original determination, and of my own subsequent confirmation, of its organic structure. And while Prof. Rowney never laid claim to any knowledge of Micro-Palæontology, the accuracy of Prof. King's information in this department of inquiry may be estimated by the fact, that when (about the same time) he made his first acquaintance with the *Orbulina universa* brought up in the 'Porcupine' soundings off the West of Ireland, he forthwith described them as not improbably affording the explanation of the granular concretionary structure of Oolites.—That I did not shrink (as is imputed to me in Profs. King and Rowney's last communication) from meeting them in their own selected field, will appear from the following statement.

When, about five years since, the Galway Professors presented their Memoir on *Eozoon* to the Royal Irish Academy,

the Secretary of that body wrote to me, stating that its Members were desirous of forming their own judgment on the subject, and requesting that I would transmit specimens for their examination. I immediately replied, forwarding the two best duplicates I had to spare, with a request that after they had served their immediate purpose they might be presented to the Museum of Trinity College, Dublin; and I further offered to *go over* to Dublin and *personally exhibit my own selected series of specimens* (which I declined to part with out of my hands) if I could obtain a short leave of absence from my official duties. Not receiving any acknowledgment, either of my specimens or of my proposal, I wrote a second time to the Secretary, and again waited in vain for a reply. I then wrote to the President of the Academy, stating the purport of my previous communications to its Secretary; but as he, too, deemed me unworthy of the honour of an answer, I thought it unadvisable to take any further action in so thankless a matter.

As the readers of these 'Annals' have never had placed before them the *general* evidence in favour of the organic origin of *Eozoon*, adduced by Sir William Logan and Dr. Dawson when they first brought their discovery before the Geological Society nearly ten years ago, I venture to ask their consideration of the following brief summary of the *facts* of this remarkable case, and of the *inferences* which they seem to me to justify.

1. There occurs in the Lower Laurentians of Canada a stratum of "Serpentine Limestone" or "Ophite," extending over several hundred square miles, and impressing the able Geological Surveyors of Canada with its resemblance to a Coral Reef.

2. Most Geologists now accept it as a probability, that the formation of Limestones generally is due, either directly or secondarily, to Animal growth; and the evidence of this doctrine is continually accumulating. The antecedent probability that such was the case with the Laurentian limestone, is increased by the circumstance that beds of Graphite (which every Mineralogist now recognizes as of Vegetable origin) occur in the same formation—that many specimens of the Limestone give forth when struck the overpowering smell of carburetted hydrogen, which is well known to be given off from many beds of Carboniferous Limestone whose organic origin is most distinct—and that so strong a musky odour was emitted from the specimen of which I sent slices to Prof. Rowney and Prof. Schultze, when it was being cut in Mr.

Cuttell's workshop, as to be almost unbearable.—These facts are not advanced as *probative*, but simply as affording *confirmatory probabilities*.

3. The arrangement of the two components of the Canadian Ophite is most remarkable, and extremely significant of some process of *progressive construction*. In the ordinary type there is *a regular alternation of lamellæ of Serpentine and Calcite*, sometimes to the number of *fifty* of each—the thickness of the Calcareous lamellæ being greater below, and progressively diminishing above, whilst that of the Serpentinous presents a singular uniformity throughout. When minutely examined, the Calcareous lamellæ present appearances strongly suggestive to the Micro-Palæontologist of an organic origin, their crystalline cleavage being common to them with almost every calcareous fossil. On the other hand, the Serpentinous lamellæ are seen to be formed by the coalescence of spheroidal segments having a general uniformity of size (see fig. 1, p. 281); while in the upper part of every complete typical specimen, the arrangement of these segments in continuous lamellæ gives place to an irregular piling of them together, the intervening calcareous walls being very thin.

4. Fixing our attention in the first instance on the Calcareous portion of this Ophite (fig. 2, p. 282), we recognize in it a general conformity to the Foraminiferal type,—the lamellated portion showing large "chambers" formed by the coalescence of "chamberlets;" whilst in the "acervuline" portion the chamberlets are isolated, still communicating with each other, however, by apertures through the calcareous septa resembling those of ordinary Foraminifera*.—This transition from a regular plan of growth to the "acervuline" mode is very common in Foraminifera, as must be known to every one who has studied my "Introduction." On the other hand, I have lately come into possession, through the kindness of M. Munier-Chalmas of the Sorbonne Museum, of a new fossil type of Foraminiferal structure belonging to the Orbiculine group, in which a partial coalescence (or subdivision) of chamberlets, like that of the lamellar portion of *Eozoon*, is very distinctly marked, so as to establish precisely the link of connexion which was wanting between the chambers of *Peneroplis* and the completely-divided chamberlets of *Orbiculina*. Thus, then, in the general arrangement of the Calcareous component of the Canadian Ophite, there is a marked conformity to the

* Mr. Carter denies the existence of these passages, simply because he did not find them in the one transparent specimen he examined. He can verify the representation of it given in fig. 2, *b b* (p. 282), whenever it may please him to come and examine my specimens.

Foraminiferal type. And this conformity is equally shown when (as happens in certain localities) the Calcite is replaced by Dolomite. I have frequently met with veins or dykes of the latter mineral running through the ordinary calcareous lamellæ; and there is obviously nothing wonderful in such conversion of the Calcite into Dolomite, either locally or generally, when Magnesia in solution was largely present. But the co-existence of *the same structural arrangement* with *a different mineral composition*, strongly indicates (as Sir William Logan pointed out) the origin of that structure to lie in something else than a mineralizing process.

5. Turning now to the arrangement of the Serpentinous lamellæ, and seeking for a *rationale* of their presence, we find it in the fact first pointed out by Prof. Ehrenberg, then confirmed by Prof. Bailey (who first showed it to be true of existing types), and verified by Prof. Rupert Jones, Mr. W. K. Parker, and myself, that the cavities of *Foraminifera* become occupied, without any process that can be likened to "infiltration" (since it takes place on the ordinary sea-bottom), by Glaucite or other silicates; so that when their calcareous shells are dissolved away by dilute acid, perfect internal casts of their chambers are left. That this is the origin of the *greensands* which occur in various Geological formations, from the Silurian upwards, is the well-known doctrine of Prof. Ehrenberg, which is based on the striking conformity between the forms of the particles of these sands and the chambers of known Foraminifera. And by that fundamental rule of Geological interpretation, which requires us to explain every thing that we *can* so explain by reference to changes now going on, I hold myself fully justified in contending that the same process—*whatever may be its nature*—which is filling the cavities of existing Foraminifera with siliceous compounds, and which can be traced backwards as far as the Silurian epoch, may fairly be accepted as the *rationale* of the presence of the regular lamellæ and acervuline segments of Serpentine in the Canadian Ophite, its calcareous interstructure having a close conformity to the Foraminiferal type. And here, again, the probability is strengthened by the fact that *the same structure* shows itself, alike in recent and fossil Foraminifera, *with different minerals*. My own recent specimens show it with at least two silicates, a green and an ochreous; and so, as Sir William Logan tells us, the chambers of *Eozoon* may be occupied with pyroxene or loganite, instead of with serpentine—the alternation of *calcareous* with *siliceous* lamellæ, however, being always preserved.

6. The presence of Serpentine, however, is not limited to

the lamellæ; for it penetrates the Calcareous layers, exactly in the same manner that the Silicates which occupy the chamber-cavities of existing Foraminifera penetrate the walls of those cavities, extending into the canal-system of their "intermediate skeleton," and even filling the minute tubuli of their "proper walls,"—so as, when the calcareous skeleton has been dissolved away, to afford the most perfect models, not only of the sarcodic segments which occupied the chambers, but also of their extensions into the canal-system, and even of their minute pseudopodial threads. Now to all this I can show *the most precise parallel* in the Canadian *Eozoon*—even to those departures from the ordinary parallelism of the tubules, which I described in certain varieties of *Operculina* (Phil. Trans. 1859, p. 24). And I am fully justified, therefore, by the accepted rules of Palæontological interpretation, in asserting that whatever exercise of "Nature's cunning" does this work on our present sea-bottom, was adequate to do it in the Laurentian period. The explanation which I suggested, that it is due to a process of chemical "substitution" (the progressive decomposition of the sarcode-body producing a precipitation of silicates from sea-water, which replace the sarcode, particle by particle), however "unscientific" in the eyes of Professors King and Rowney, has approved itself to Chemical and Palæontological authorities of considerably higher standing than the Galway Professors, as the only one by which the silicification of fossil wood, and the silicification of the animal substance of recent Corals (described by Dr. Duncan as even now going on), can be accounted for. On the other hand, Professors King and Rowney, to whom I sent, about three years ago, an exquisite little internal cast (in glauconite?) of *Polystomella*, from Captain Spratt's dredgings in the Ægean, with a request that they would give me their opinion of the process by which it was produced, replied that they considered it to be composed of *mud*; and though I have recently invited them to reconsider this opinion, they have not in any way qualified it. Now let these casts, for the sake of argument, be supposed to have been formed by the infiltration of mud, then a like infiltration would equally account for the production of the deposit in the chambers, canal-system, and nummuline tubules of *Eozoon*, which is *precisely paralleled* by that of many fossil and existing Foraminifera in regard to its mineral condition—as my specimens show.

My contention is, therefore, that the hypothesis of *the Foraminiferal origin of Eozoon canadense* entirely accords with the features alike of the *general* and of the *minute* structure of

the *best-preserved* specimens of this body, and that it is the *only* hypothesis which fits all the facts of the case; whilst the hypothesis of *subsequent* metamorphic change, which has every probability to recommend it, fully accounts for all the appearances on which the Anti-Eozoonists rely as evidence of its Mineral origin, which, in the face of the new evidence I have now adduced, is to my own mind utterly "unthinkable." I do not attempt, however, by dint of hammering-in, to impose my own (doubtless) prejudiced conclusion upon the minds of others, but have endeavoured to place before them the *facts* of the case in such a form as may help them to form their own judgment in regard to them.

Until these facts shall have been disproved by the examination of the specimens which I am ready to submit to any or all of my opponents, I must claim to withdraw from a controversy which cannot be carried further to any advantage without a "comparison of actual specimens." For whilst I admit to the full every evidence of Mineralization adduced by Professors King and Rowney, neither they nor Mr. Carter admit the evidence of Organic structure which they have *not* seen, but which I have expressed my willingness to place before them, with the parallelisms presented by recent Foraminifera.

I am endeavouring to engage my Canadian associates in the preparation of a joint Monograph on *Eozoon canadense*, to be offered to the Palæontographical Society—with a request that before determining either to accept or to decline it, the Council will appoint a Committee of "experts," qualified by their knowledge of Micro-Palæontology and Micro-Mineralogy to judge whether what we hold to be Organic structure can be possibly regarded as the product of any kind of Physical or Chemical action.

EXPLANATION OF PLATE XIX.

Fig. 1. Vertical Section of a portion of one of the calcareous lamellæ of *Eozoon canadense*, showing the tubular "nummuline layer" *a a*, the "intermediate skeleton" *c c*, and the relations of the origins of the canals, *b b*, to the tubuli of the nummuline layer, the flexures of which are seen along the line *a' a'*: 100 diameters.

Fig. 2. Vertical Section of a portion of the "nummuline layer" *a a*, under a higher magnifying-power, showing its distinct tubulation, with sharp flexures along the line *a' a'*: 250 diameters.

Figs. 3, 4. Internal Casts of Canal-system, showing what appears to be its typical mode of distribution: 35 and 15 diameters.

Fig. 5. Transparent Section of a portion of the Canal-system, showing an only partial filling of the canals: 100 diameters.