ON THE STRUCTURE, AFFINITIES, AND GEOLOGICAL POSITION OF EOZOON CANADENSE.

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(*With Two Illustrations.*)

Among the communications made to the British Association at its recent meeting at Bath, there was certainly none of higher scientific interest than the announcement by Sir William Logan, the director of the Canadian Geological Survey, of the discovery of large masses of a fossil organism referable to the Foraminiferal type, near the base of the Laurentian series of rocks in North America. The geological position of this fossil, indicating the vast remoteness in time of its existence as a living organism, is scarcely more remarkable than its zoological relations; for, at what (so far as we at present know) was the dawn of animal life upon our globe, it affords evidence of a most extraordinary development of that Rhizopod type of animal life which now presents itself only in forms of comparative insignificance,—a development which enabled it to separate carbonate of lime from the ocean-waters, in quantity sufficient to produce masses rivalling in bulk and solidity those of the Stony Corals of later epochs, and thus to furnish (as there seems good reason to believe) the materials of those calcareous strata, of whose occurrence in the Laurentian series it had previously been impossible to give a satisfactory account.

Having been requested by Sir William Logan to verify the conclusions regarding the nature of this fossil which had been arrived at by Dr. Dawson of Montreal, and having been kindly supplied by him with ample materials for the further elucidation of its structure, I propose in the present paper to direct attention to the points of most striking interest, Geological as well as Zoological, which this discovery brings into view. And since the bare statement that the *Eozoon* occurs near the base of the Laurentian series of rocks, will not convey, save to such as have followed the most recent progress of geological research, any definite idea of the extraordinary interest that attaches to the marvellous glimpse which its presence there affords into the ancient life of our globe, I shall in the first instance take back my readers to that stage in the history of the science, which preceded the establishment of the "Silurian system" by Sir Roderick Murchison.

Geological Position of Eozoon.—Under the general designation "Primary Rocks" was formerly ranked an immense series of formations, some evidently stratified, others presumed to be non-stratified, chiefly originating in the disintegration of the granite on which they rested, and consisting of gneiss, mica-schist, clay-slate, quartz, alum-shale, grauwacke, with occasional limestone beds. The older of these rocks were not supposed to contain any fossil remains; and from the indications they presented of changes in their condition subsequent to their original deposition, they were distinguished as *metamorphic*. In the newer strata, on the other hand, the presence of fossils had been recognized; but no such comparison had been made between these and the fossils of the Old Red Sandstone and Carboniferous Limestone (which were the oldest strata that had then been systematically studied), as threw any light on their mutual relations.

It was a little more than thirty years ago that Sir Roderick (then Mr.) Murchison was enabled, by the careful study of the order of superposition of the newer of these rocks in South Wales and along the Welsh border, to establish the existence of a regular series of strata, graduating downwards continuously from the lower beds of the Old Red Sandstone, and characterized by a distinct and peculiar assemblage of organic remains; and this series he designated the *Silurian system*, the region which had first revealed its existence being that once inhabited by the ancient Silures. The base of this series (which was marked out into Upper and Lower Silurian, both by a want of geological conformity and by differences in the fauna of the two divisions) was supposed to be formed by the hard beds of fissile sandstone largely developed near the town of Llandeilo in Carmarthenshire, and known as the "Llandeilo flags." These rest unconformably upon what was then designated the "Clay-slate" system; and it seems to have been at first assumed by the investigator of the Silurian system, that organic life had no existence on the globe previously to the epoch thus marked out.

But whilst Sir Roderick Murchison was thus working out in South Wales the later portion of the series of "primary rocks," Professor Sedgwick was applying himself with equal zeal and energy to the study of the older, as displayed in Cumberland and North Wales; and he succeeded in proving that whilst a regular order of superposition, broken however by many disturbances, may be traced through that massive series of slaty rocks of which a large proportion of the mountain ranges of Cumberland and North Wales are composed, the newer of these rocks present fossil remains in sufficient numbers to show that it was incorrect to assume the absence of life in those ancient seas. Thus a thick stratum of fissile sandstone underlying the "Tremadoc slates," which, again, lie beneath the Llandeilo flags, contains such a vast abundance of shells of the still existing genus *Lingula*, that this stratum is known by the designation "Lingula-flags." For the whole series of stratified rocks underlying the original Silurian system of Sir R. Murchison, the names of *Cambrian* or *Cumbrian*, indicative of its special development in North Wales and Cumberland, were proposed by Professor Sedgwick; but geologists for some time hesitated in admitting it as a distinctly characterized group. The fossil types which it contained did not seem to differ so much from those of the Lower Silurian strata, as to justify the separation of the Cambrian from the Silurian fauna; and it was argued by Sir Roderick Murchison that there was more reason for carrying downwards the base of his Silurian system, so as to make it include the Lingula flags and the slates which intervene between it and the Llandeilo flags, than for admitting the existence of any pre-Silurian life. Even as late as 1851 we find so impartial and highly-qualified a judge as Sir Charles Lyell thus expressing himself on this point (*Manual of Elementary Geology*, 3rd ed., p. 361):—"Below the Silurian strata in North Wales, and in the region of the Cumberland Lakes, there are some slaty rocks devoid of organic remains, or in which a few obscure traces only of fossils have been detected, for which the names of Cambrian and Cumbrian have been proposed. Whether these will ever be entitled, by the specific distinctness of their fossils, to rank as independent groups, we have not yet sufficient data to determine."

The required data had been already furnished, however, by the labours of M. Barrande in Bohemia; in which country the older stratified rocks are developed even more remarkably than in Britain. Although scarcely more than twenty species of fossils had been previously obtained from this locality, M. Barrande had already acquired in 1850 no fewer than 1100 species; namely, 250 crustaceans (chiefly trilobites), 250 cephalopods, 160 gasteropods and pteropods, 130 acephalous mollusks, 210 brachiopods, and 110 corals and other fossils. This vast assemblage he found to comprise not merely the equivalents of the Upper and Lower Silurian fauna, but also a fauna clearly distinguishable from the latter, and designated by him "primordial," under the belief that it afforded evidence of the first appearance of life on this planet, and that consequently no fossiliferous strata of older date would or could ever be discovered;—an anticipation as vain as that which the founder of the Silurian system had entertained respecting the strata which he originally adopted as its base.

The peculiarity of the so-called "primordial fauna" specially consisted in the distinctness of its Trilobites from those of the Lower Silurian strata; not only the species, but even many of the genera, discovered by M. Barrande having been previously unknown. And the occurrence of these generic types in strata very remote geographically, has served to identify them geologically; so that no doubt any longer remains that the Upper Cambrian rocks of North Wales, the alum-schists of Sweden, and the Potsdam sandstone of the United States (formerly ranking as the lowest member of the North American Silurians) with an underlying series of slaty rocks extending from New York to Newfoundland, belong to the same epoch as the Bohemian strata supposed by M. Barrande to present the earliest forms of organic life.

But below the Tremadoc slates and Lingula flags which constitute the *Upper* Cambrian, there is a vast series of sandstones and slates, known as "Harlech grits" and "Llanberis slates" (sometimes designated the "Longmynd" group, from being the components of the hills of that name in Shropshire), which constitute the *Lower* Cambrian series. The organic remains hitherto discovered in these are extremely scanty as regards number of *types;* consisting only of five species of Annelids and one obscure Crustacean form in the Harlech grits, and two species of the Zoophyte *Oldhamia* in the Irish equivalent of the Llanberis slates. But the number of *individual* Annelids whose remains are preserved is enormous; they are stated to occur in countless myriads through a mile in thickness in the Longmynd.

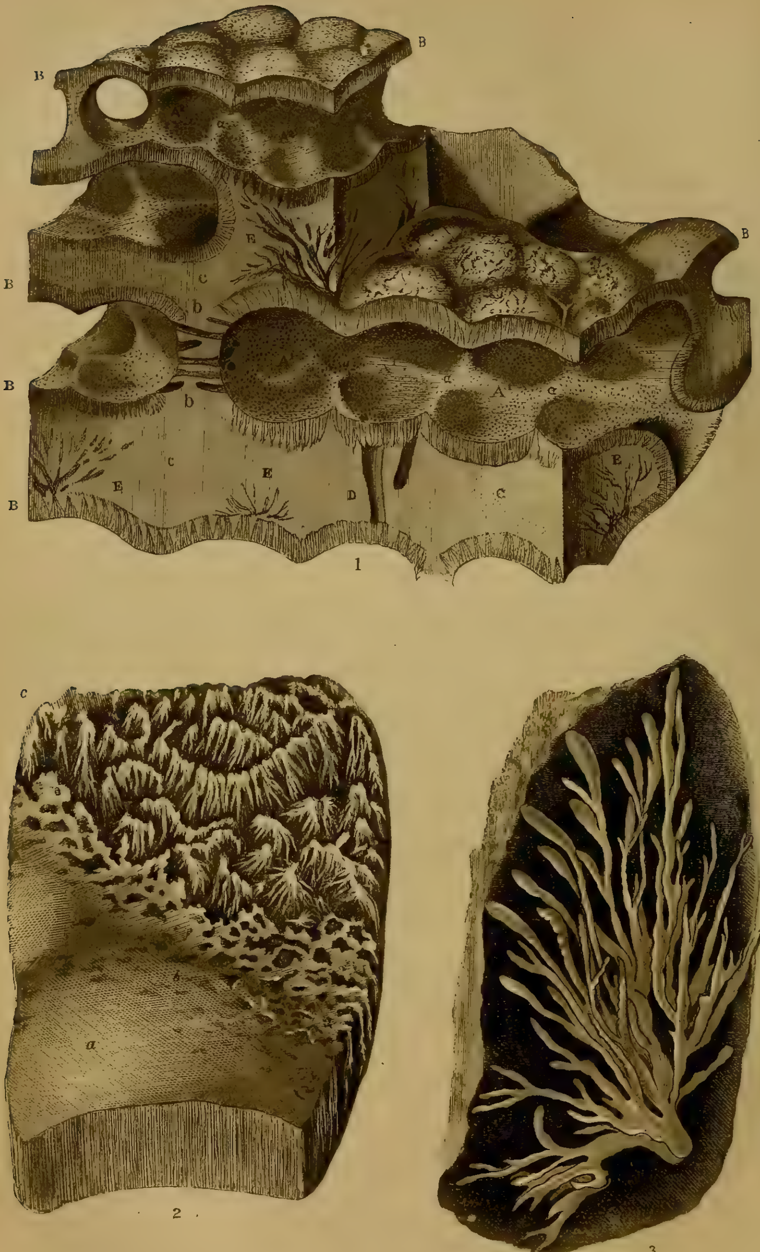
Of the immense lapse of time that must have been occupied in the deposit of the Cambrian strata, both the nature of their materials, which must have been derived from the disintegration of rocks of exceeding hardness, and their vast thickness afford ample evidence. The Tremadoc slates are estimated at 2000 feet, and the Lingula flags at 6000, making 8000 feet for the *Upper Cambrian.* Again, the Harlech grits present a thickness of from 6000 to 7000 feet, and the Llanberis slates about 3000, thus giving 10,000 feet as the thickness of the *Lower Cambrian.** The labours of our Canadian geologists have brought to light a series of strata in the neighbourhood of Lake Huron, and thence designated *Huronian,* which are believed to be the equivalents of our Lower Cambrian, and which attain a thickness of not less than 18,000 feet. These consist chiefly of quartz-rock, with great masses of greenish chloritic slate, which sometimes include pebbles of crystalline rocks belonging to the still older Laurentian formation to be presently described. No organic remains have yet been discovered in this series, but beds of Limestone occur in it, one of them 300 feet in thickness; and as the

* The above figures are those given by Sir C. Lyell. By Professor Phillips the Longmynd strata are spoken of as "supposed to be 20,000 feet thick or more."

belief has been gradually gaining ground among geologists, that all limestones have been originally formed by the agency of Coral-polypes, Echinoderms, Mollusks, etc., which fix carbonate of lime from sea-water, just as plants fix carbon from the atmosphere, the mere fact of the occurrence of a limestone bed in strata otherwise non-fossiliferous, raises a presumption that organic life had not been wanting, even at that very early period. And it is to this epoch, represented in our own country by the Lower Cambrian strata, that one of our ablest and most experienced geologists, Professor Phillips, has recently assigned the origin of life on the earth.* He points out that in passing downwards through the Lower Palæozoic strata, the forms of life grow fewer and fewer, until in the lowest Cambrian rocks they vanish entirely, though these strata are of a kind such as might be expected to yield them. And the deficiency is not confined to the British types of the series; it is equally noticeable in their equivalents in North America, in Norway, and in Bohemia—countries well searched for this very purpose. "The absence is general; it seems due to a general cause. Is it not probable that during these very early periods the ocean and its sediments were nearly devoid of plants and animals, and in the earliest time of all, which is represented by sediments, quite deprived of such?" The following table is given by him as showing the marked reduction in number of types as we descend to the lowest beds of the Lower Silurian, and thence to the Upper Cambrian; this last reduction involving the entire loss of the representatives of a large proportion of the higher groups of mollusca. To complete the table we add a line, in which are noted all the types yet discovered in the Lower Cambrian.

		Amorphozoa	Foraminifera	Zoophyta	Echinodermata	Annelida	Crustacea	Polyzoa	Brachiopoda	Monomyaria	Dimyaria	Gasteropoda	Heteropoda	Pteropoda	Cephalopoda
Upper Silurian	Ludlow	...	1	10	17	18	39	1	30	17	41	27	4	4	30
	Wenlock	3	...	66	34	6	36	25	79	12	15	18	3	3	22
Middle Silurian	Llandovery	2	...	26	6	3	16	5	69	5	13	26	6	3	13
Lower Silurian	Caradoc	3	...	23	20	8	82	27	67	7	31	25	7	7	26
	Llandeilo	...	...	4	...	7	34	22	18	1	2	3	2	6	4
Upper Cambrian	Lingula	...	...	2?	...	2	11	1	3	...	...	...	...	...	...
Lower Cambrian	Longmynd	...	...	2	...	5	1	...	...	...	...	...	...	...	...

* *Life on the Earth; its Origin and Succession.* Cambridge, 1860.



Structure of Eozoön.

If Professor Phillips had introduced into this table the far richer fauna of the Upper Cambrian strata in Bohemia, the comparative poverty of organic life in that epoch would have seemed less striking; but, on the other hand, the diminution in the number of types as we pass from the Upper to the Lower Cambrian, would have been still more obvious. "No doubt," he remarks, "it is open to any one to compare this approach to a Hypozoic zero with the reductions of life to a minimum above the Palæozoic, and above the Mesozoic deposits; and to *suppose* that below the Palæozoics *were* other earlier strata, and earlier systems of life, though they are now all lost in the general metamorphism which has produced the gneiss and mica schist. No one is likely to believe this, however, who attends seriously to the facts regarding the successive appearance of the classes, orders, families, genera, and species, as we search the records of geological time." More philosophical in its appreciation of what Mr. Darwin calls "the imperfection of the geological record," and more true as the event has proved, was the remark of Sir C. Lyell upon the "primordial" assumption of M. Barrande—"I have been opposed from the first to a nomenclature the adoption of which would seem to imply the acceptance of such a theory; for I always felt sure, on contemplating the past history of geology, that we had not yet pushed our inquiries into the past so far as to lead us to despair of extending our discoveries at some future day, when vast portions of the globe hitherto unexplored should have been thoroughly surveyed."

This sagacious anticipation has been marvellously verified by the discoveries which the excellent geologists of our Canadian survey, under the able direction of Sir William Logan, have recently made in the region of which the exploration was committed to them: for they have shown that the rocks which compose the Laurentian mountains in Canada, and the Adirondacks in New York, spreading over an area of about 200,000 square miles, belong to a system distinct from and antecedent to the Cambrian, just as the Cambrian form a system distinct from and antecedent to the Silurian.* These *Laurentian* strata consist chiefly of quartzose, aluminous, and argillaceous rocks, like the sedimentary deposits of less ancient times; but for the most part in a condition of *metamorphism* which has given them a crystalline character. By a break in the continuity of the strata they are marked out into two distinct groups, the Upper or Labrador series resting unconformably on the Lower; and the united thickness of these groups in Canada is certainly not less than 30,000 feet, and probably

* See the *Quarterly Journal of the Geological Society*, February, 1865, pp. 45—50.

much exceeds that vast amount.—The Lower part of the Laurentian series is represented in Scotland by the "fundamental gneiss" of Sir Roderick Murchison, which forms the whole of the island of Lewis, and on which, in various parts of the western highlands, the Lower Cambrian and various metamorphic rocks rest unconformably. The Upper, or Labrador group, seems to be represented by the Labradorite and Hypersthene rocks of Skye; which, though formerly supposed to be unstratified, correspond so closely with those of the Labrador series in Canada and New York as to leave no doubt that they belong, like the latter, to a regularly stratified system.—The "primitive gneiss" formation, again, which attains at least an equal thickness in Norway, has been shown to correspond with the Laurentian series of Canada; and the "primitive slate" formation which rests upon it is no less remarkably similar at once to the Huronian of Canada and to the Lower Cambrian of our own island.—The labours of Sir Roderick Murchison in Central Europe have shown that the ancient gneissic series of Bavaria and Bohemia, which underlies the "primordial zone" of Barrande, with a vast thickness of intervening clay-slate, corresponding to the Lower Cambrian, is the equivalent in position of the Laurentians of Canada and Scotland; and that, like them, it is divisible into an older and a newer series, the two together attaining the colossal thickness of 90,000 feet.

The following Table represents the general results of the inquiries whose history has been thus briefly sketched; showing the present state of our probable knowledge of the two vast series of stratified rocks, the Cambrian and the Laurentian, which underlie the Lower Silurian:—

GREAT BRITAIN.	NORTH AMERICA.	SCANDINAVIA.	CENTRAL EUROPE.
Upper Cambrian.	Potsdam Sandstone.	Alum-schists.	Primordial zone.
Lower Cambrian.	Huronian.	Primitive Slates.	Primitive Slates.
Hypersthene rock of Skye.	Upper Laurentian	Primitive Gneiss.	Primitive Gneiss.
Fundamental Gneiss.	Lower Laurentian		

"The united thickness of these three great series" (the Huronian and the Upper and Lower Laurentian), says Sir William Logan, "may possibly far surpass that of all the succeeding rocks, from the base of the Palæozoic series to the present time. *We are thus carried back to a period so far remote, that the appearance of the so-called Primordial Fauna may be considered a comparatively modern event.*"

Clear evidence had been found in the constitution of the Laurentian and Huronian rocks, that the same chemical and mechanical processes which have ever since been at work in disintegrating and reconstructing the earth's crust, were then in operation; the great question remaining for determination was, whether *vital* activity had any place in those ancient seas, or whether they were altogether untenanted by living beings.

This question might be presumptively answered in the affirmative by two important sets of facts. In both the Upper and the Lower Laurentian series there are several zones of Limestone, each of sufficient volume to constitute an independent formation. The aggregate thickness of these is said by Dr. Bigsby to be not less than 5000 feet thick. Similar limestones occur in Scotland, and also in Norway and Finland, where they form beds of 1000 feet or more in thickness. Since these limestones are in a highly crystalline condition, the apparent absence of fossils in them could not be considered as in any way negativing the probability that they had been originally formed by the agency of animal life, and subsequently altered by metamorphic action—such being now universally admitted to have been the history of many newer limestones in which there is a like absence of any distinguishable organic remains. So, again, the occurrence of carbon—which, in the form of graphite, both constitutes distinct beds, and is disseminated through the calcareous or siliceous strata of the Laurentian series, as well in Norway as in Canada—might be taken as an evidence of the existence of vegetation during that epoch, since no one disputes the organic origin of this mineral in more recent rocks. Further, Sir William Logan had observed that certain of the Laurentian marbles, on being struck, gave forth the same overpowering smell of carburetted hydrogen, as is well known to be given off from many beds of carboniferous limestone, whose organic origin is most distinct. And Mr. Sterry Hunt, the accomplished mineralogist of the Canadian survey, had argued for the existence of organic matters on the earth's surface during the Laurentian period, from the presence of great beds of iron-ore, and from the occurrence of metallic sulphurets.

But however strong might be these presumptions, considered either separately or collectively, they could not be regarded as in themselves by any means sufficient to establish so important a conclusion, as the dating-back the commencement of organic life from the Lower Cambrian epoch, to the immeasurably more remote period during which the Lower Laurentian strata were in process of formation. The needed proof has been supplied, however, by the discovery of the very remarkable fossil which it is my special object to describe; the *Eozoon Canadense* thus taking rank as by far the earliest form of animal life yet known, its development having been antecedent to the deposition of the greater part of the Laurentian series, nearly the whole thickness of which, with the Huronian in addition—amounting, as we have seen, in Canada to nearly 50,000 feet, and in Central Europe to 90,000—had been superimposed upon the lowest beds in which it occurs, before the epoch of the Lingula flags, which once, in the opinion of many geological authorities, marked the first appearance of life on our planet.

The history of this discovery is in itself not a little curious. Certain bodies presenting forms apparently organic were brought by Mr. J. McCulloch to Sir Wm. Logan, in 1858, from the Grand Calumet limestone on the river Ottawa; and these were found to be composed of alternating parallel or somewhat concentric layers of crystallized pyroxene and carbonate of lime. This alternation called to mind other specimens exhibiting a similar structure, which had some years previously been obtained, by Dr. Wilson, of Perth, from the Burgess limestone, but which had been regarded merely as minerals; their forms were the same as those of the Grand Calumet specimens, but their composition was different, the alternating layers being formed of Loganite (dark green silicate of magnesia) and Dolomite (magnesian limestone). Thus in both cases the alternation, though formed by different minerals, always consisted of *siliceous* and *calcareous* layers; and hence Sir William Logan, thinking it strange that identical forms should be derived from minerals of such different composition, was led to look upon them as fossils. As such they were exhibited by him at the meeting of the American Association for the Advancement of Science in 1859; and they were shown to some of his geological friends on this side of the Atlantic in 1862. One of the specimens had been sliced and submitted to microscopic examination; but unfortunately it was one of those composed of Loganite and Dolomite, in which minute structure rarely occurs; and in the absence of any evidence from this source, few except Professor Ramsay seemed disposed to believe in their organic nature.

The true character of these bodies thus remained in suspense until a little more than twelve months ago, when Sir Wm. Logan observed indications of similar forms in blocks of the Laurentian limestone from the Grenville bed, which is the highest of the three zones of limestone occurring in the Lower Laurentian series, and which attains, in some places, a thickness of 1500 feet. These blocks had been brought to the Museum to be sawn into marble; and on being cut through, they were found to be composed of serpentine alternating with calc-spar. Thin slices of them having been prepared, distinct evidence of organic structure was observed in the very first specimen submitted to microscopic examination. The prosecution of the inquiry was confided to that experienced observer, Dr. Dawson, the accomplished Principal of M'Gill College, Montreal; and under the guidance of the figures and descriptions which I had given of the minute structure of various types of Foraminifera, in the series of Memoirs which had found a place in the *Philosophical Transactions*, and in my general *Introduction to the Study of the Foraminifera*, published by the Ray Society, he was led to the conclusion that this organism, notwithstanding its comparatively gigantic dimensions, belongs to the group of Foraminifera; being especially related to *Polytrema* in its zoophytic mode of growth, to *Carpenteria* in the imperfect separation of the cavity of its shell into distinct chambers, and to *Calcarina* in its canal-system. By Dr. Dawson and by Dr. Sterry Hunt it was further shown that the *calcareous* layers represent the original *shell*, which in the best preserved Grenville specimens has undergone very little change, but which in the Grand Calumet specimens has become crystalline, whilst in the Burgess specimens it has been completely metamorphosed by magnesian infiltration. On the other hand, they showed that the *siliceous* layers represent the original *sarcode-body* of the animal, which has been replaced by the infiltration of various silicates, as serpentine, pyroxene, and loganite—just as the sarcode-bodies of Foraminifera of various subsequent deposits, from the Silurian to the present time, have been replaced by the infiltration of glauconite and other siliceous minerals; enabling us to obtain, by the dissolution of their calcareous shells in dilute acids, most perfect *models* of the soft parts, exhibiting the forms and connections which they possessed in life, with far more truth and completeness than they could be determined by any other method of study.*

* The existence of such "internal casts" of the shells of *Foraminifera*—the models of the bodies which occupied them during life—in the Greensands of various Geological epochs, was first made known by Prof. Ehrenberg. Not long afterwards it was shown by Prof. Bailey, that the Foraminiferal shells of our existing seas are sometimes infiltrated in like manner; and many beautiful examples of this modelling process have been obtained by Messrs. Parker and Rupert Jones, to whose kindness I owe the "internal cast" of a recent *Polystomella*, of which I have given a figure in my description of that genus (*op. cit.*), and which was well designated by my friend Prof. Blanchard as a *bijou zoologique*. I certainly would not exchange it for a diamond of the same size, since it demonstrated the correctness of my account of the very complex arrangement which I had worked-out, before obtaining it, in the canal-system of the shell of that remarkable genus.

Such models were shown by the specimens recently brought over by Sir William Logan to be obtainable by submitting portions of *Eozoon* to the action of acid, so as to remove the calcareous shell; the siliceous infiltration having not merely filled the chambers, so as to give us the precise forms of the sarcodic segments which occupied them, but having also penetrated into the "canal system," which extends itself from these into the most solid and massive portions of the shell; and, as I shall presently show in addition, having actually taken the place of those wonderfully minute threads of sarcode which traversed the porous walls of the chambers, so as to stereotype (so to speak) their exquisitely beautiful brush-like arrangement, which is thus exhibited, in by far the oldest known fossil, with a perfection that could not be imitated by any means we possess of preparing and displaying the existing animals of the same type.

External Configuration and Internal Structure of Eozoon.—Owing to the indefinite mode of growth of this gigantic Foraminifer, and the manner in which its fossilized masses are connected with the matrix in which they are imbedded, it is impossible to say with certainty either what was its characteristic *shape*, or what were the limits to the *size* of its individual growths. There is no doubt, however, that these often spread over the area of a square foot, or even more, and attained a thickness of several inches; thus forming blocks which bear a general resemblance to those of the massive Stony Corals, such as *Meandrina*. The aggregation of such blocks, whose continuous extension at their margins would bring them into contact, so that those which originally began from distinct centres would become grafted, as it were, together, seems to have formed Foraminiferal reefs, similar in their general characters to coral reefs; save that while the coral reefs of subsequent epochs, like those of the present time, usually had shells, echinoderms, etc., associated with them (as we know from their remains), in these most ancient reefs the only organic remains yet found are those of the animals which built them. In some of these reefs, from the description given by Sir William Logan, the older portions appear to have undergone fossilization before the newer were built-up on the base which they furnished. Thus, in the Grenville limestone, the lower stratum is composed of large and small masses of white crystalline Pyroxene, some of them twenty yards in length by four or five wide; these appear to be confusedly placed one above another, with many ragged interstices, and many smooth-worn, rounded, large and small pits. In these masses of pyroxene, compact as they appear, are a multitude of small spaces filled with carbonate of lime; and these show the characteristic structure of the fossil. The spaces between them, moreover, are filled with a mixture of serpentine and carbonate of lime. The whole thickness formed by the aggregation of these masses is not less than two hundred feet; and over their surface is spread a sheet of dark-green serpentine, varying from one-sixteenth of an inch to six inches in thickness. This forms the base of a set of newer growths, composed of alternating plates of carbonate of lime and serpentine; the upper surface of which, again, appears to have been worn and broken up by currents and eddies, so as to modify whatever may have been the original surface given by the natural growth of the animal. The difference that presents itself between the deeper and the more superficial parts of the reef, in the fossilizing mineral which has filled up the cavities in the shell that were occupied during life by the sarcodic body of the animal, seems to mark a considerable difference in the conditions under which this substitution took place; while the fragmentary character of the older pyroxenic portion, and the wear of its surface into cavities and deep recesses, indicate a long period of suspension, during which disintegrating changes were going on, before that renewed growth took place which is represented by the superposed masses wherein the pyroxene is replaced by serpentine.

A vertical section of a well-preserved mass of *Eozoon* exhibits in its basal portion a more or less regular alternation of calcareous and siliceous lamellæ; the former being distinguished by their whiteness, the latter by their light-green hue. This alternation, however, frequently gives place in the more superficial parts to a mutual interpenetration of these minerals; the green spots of the serpentine being scattered over the surface of the section, instead of being collected in continuous bands, so as to give it a granular instead of a striated aspect. This difference depends on a departure from what may be considered the typical plan of growth, which often occurs (as in other Foraminifera) in the later stages; the minute chambers being no longer arranged in continuous tiers, but being piled together irregularly, or in an *acervuline* manner. The contrast between the two modes of growth is well shown by the siliceous model of the animal body which occupied the chambers, represented in the Coloured Plate; the lower portion being that which shows in vertical section a regular series of lamellæ of serpentine, the spaces between which were occupied by lamellæ of calcareous shell; while in the upper is seen the acervuline arrangement of the segments which gives rise to the scattered disposition of the serpentine granules, the calcareous shell having occupied the irregular spaces between these.

The minute structure of *Eozoon* may be determined by the microscopic examination either of thin transparent sections, or of portions which have been subjected to the action of dilute acid, so as to remove the calcareous shell, leaving only the *internal casts,* or *models,* in silex, of the chambers and other cavities originally occupied by the substance of the animal. Each of these modes of examination, as I have elsewhere shown,* has its peculiar advantages; and the combination of both, here permitted by the peculiar manner in which the *Eozoon* has been fossilized, enables us to attain a completeness of knowledge of its structure, such as is afforded by no other fossil with which I am acquainted. For in well-preserved specimens, the shelly substance often retains its characters so distinctly, that the details of its structure can be even more satisfactorily made out, than can those of most of the comparatively modern *Nummulites.* This arises from the fact, that whilst the latter, when imbedded (as they usually are) in a matrix of the same material, have been subjected to *calcareous* infiltration, which has filled-up alike their minute tubules and their larger canals, and has thus rendered the shell-substance nearly homogeneous, these tubules and canals have been filled up in *Eozoon* by a *siliceous* infiltration, which does not coalesce with the substance of the shell, so that the boundaries of the tubules and canals can be distinctly defined. But what renders the condition of *Eozoon* so peculiarly favourable for the investigation of its organic structure, is the marvellous completeness with which the minutest extensions of the sarcode-body of the animal are represented in decalcified specimens by their siliceous models; even the most delicate pseudopodial threads, consisting of the softest and most transitory form of living substance, which were put forth through pores in the shell-wall of less than $\frac{1}{10,000}$th of an inch in diameter, being thus, as it were, perpetuated to all time; and the varieties of their course being exhibited, by what appear under the microscope as most perfect models, in asbestiform fibre, having this advantage over the most skilfully executed works of human hands, that they are not *imitations,* but *the very threads themselves* turned into stone by Nature's cunning. For there can, I think, be no doubt that the siliceous mineral found its way into the cavities of the shell, not by mere *mechanical infiltration* occasioned by pressure from without, but by a process of *chemical substitution* which took place, particle by particle, between the sarcode-body of the animal and certain constituents of the ocean-waters, *before* the destruction of the former by ordinary decomposition.

* Memoir on *Polystomella,* in the *Philosophical Transactions* for 1860, pp. 538, 540; and *Introduction to the Study of the Foraminifera,* pp. 9, 10.

Interpreting the copious information which we derive from these two sources, by the knowledge we already possess of the life-history of existing Foraminifera, we find ourselves able to *reconstruct* our *Eozoon* with at least as much certainty as the comparative anatomist can restore an Iguanodon or a Plesiosaurus. And as the greater part of the details on which this reconstruction rests have been already recorded in the form and order in which they have actually presented themselves to Dr. Dawson and myself,* I prefer that the present description, and its accompanying figures, should place the creature before my readers as it existed in life, whilst building up in the ancient sea-beds those massive reefs which formed the materials of the Laurentian limestones.

The calcareous skeleton or shell of *Eozoon* might be likened to a building made up of successive tiers of chambers (Uncoloured Plate, Fig. 1); the chambers A^1, A^1, A^1, and A^2, A^2, of each tier, however, communicating very freely with each other, so that the segments of the sarcodic layer which occupied them were intimately connected, as is shown by the continuity of their siliceous models (Coloured Plate). In most existing Foraminifera, the successive chambers communicate only by narrow orifices, so that the segments of the body which occupies them are mutually connected by slender bands or *stolons*: but in *Carpenteria* we have an example of a communication nearly as free as that which exists between the chambers of the same tier in *Eozoon;* and I have occasionally met with chambers as completely isolated from the rest as are those of Foraminifera generally, the communication being established by several narrow passages (Uncoloured Plate, Fig. 1, *b, b*), exactly corresponding to those which I have described in *Cycloclypeus*. Moreover, I not unfrequently find, projecting from the surfaces of the principal layers, little groups of comparatively small segments, which have budded-forth from the larger ones, and which might almost be taken for internal casts of *Globigerinæ* or other small separate Foraminifera.

The proper walls of the chambers are everywhere formed of a pellucid, vitreous shell-substance, minutely perforated with tubuli, so as exactly to correspond with those of *Nummulites, Operculinæ*, etc. These tubuli, as in the existing representatives of the Nummuline series, usually run parallel to each other, passing directly from the inner to the outer surface of the chamber-wall (Uncoloured Plate, Fig. 1, B, B), without coalescence or ramification; and the siliceous casts of the cavities of these tubules often remain *in situ* after the removal

* See the *Quarterly Journal of the Geological Society*, February, 1865, pp. 51—66.

of the calcareous shell, standing side by side, like the filaments that form the "pile" of velvet, their lower ends resting on the subjacent segment, whilst their upper form a uniform surface so close in texture as to be with difficulty resolvable into the points of its constituent aciculi (Uncoloured Plate, Fig. 2, *a*). This residuary layer (when not thrown off, as it often is, by the disengagement of gas in the process of decalcification) is at once distinguished by its whiteness; as is shown at the upper part of the Coloured Plate on the *surface* of the segments, and at the lower in the *section* of the lamellæ. If a small portion of it be detached with the point of a needle, it is easily shown to be composed of the most delicate asbestiform fibres, each of them representing the original pseudopodium of sarcode which passed through the tubule. But, as I have shown to be often the case in *Operculina*,* the tubuli may depart from their normal parallelism, separating from each other in some parts, and becoming more closely crowded in others; so that instead of the uniform punctation which the *internal* surface of the chamber-wall exhibits, we may find great diversities in the disposition of their *external* orifices, these being often congregated in bands and clusters, with intervals of non-tubular shell-substance between them. A yet greater variety in their course presents itself in *Eozoon*. For the intervals of non-tubular shell-substance left in some parts of the chamber-wall by the crowding together of the tubules in others, are marked in the decalcified layer of asbestiform fibres by fissures in the "pile" (Fig. 2, *b*), such as would be made in the surface of a piece of velvet by doubling it back so as to separate the free ends of the filaments; whilst the convergence of the intervening fibres often unites them into minute flattened leaf-like tufts. A more marked degree of the same convergence, bringing the greater number of the pseudopodia proceeding from each segment into one bundle (Fig. 2, *c*), is not unfrequently seen in parts in which there has been a great development of the "intermediate skeleton" presently to be described; and a portion of the asbestiform layer in which this arrangement is well exhibited, constitutes, under the Binocular Microscope, one of the most beautiful objects with which I am acquainted, every individual thread glistening brightly under appropriate illumination, and holding its own proper place, while an infinite variety of detail is shown in the arrangement of the brush-like bundles, of which no two are precisely similar. Another variety in the disposition of the tubuli is one to which I have seen no parallel in other Foraminifera. Retaining their separate parallelism, they some-

* Memoir on *Operculina* in the *Philosophical Transactions* for 1859, p. 24, and Plate IV., figs. 2, 4; also, *Introduction to the Study of the Foraminifera*, p. 256.

times pass off very obliquely, or even tangentially, so as to run for considerable distances in the chamber-walls; and their asbestiform casts thus form elongated bundles lying on the surfaces of the segmented layers of serpentine.

Between the proper walls of the successive tiers of chambers, there usually intervene layers of very variable thickness (Uncoloured Plate, Fig. 1, C, C), composed of homogeneous shell-substance; these represent the "intermediate" or "supplemental" skeleton, which I have described in several of the larger Foraminifera, and which attains a peculiar development in *Calcarina*.* This is an exogenous deposit on the surface of the proper wall of the chamber, which seems to be formed by the sarcodic layer that originates in the coalescence of the pseudopodia after they have issued from its tubuli, and which is traversed by a more or less minutely distributed "canal-system," occupied during life by prolongations of that sarcodic layer. This canal-system is often brought into view in thin transparent sections of the shell (Uncoloured Plate, Fig. 1, E, E); but as the plane of section will seldom coincide with any considerable part of the course of the passages, a much better idea of their distribution is gained from the study of decalcified specimens, which present us with siliceous models of the sarcodic extensions that occupied those passages in the living animal. These extensions certainly originate in some cases in the sarcodic segments occupying the cavities of the chambers; in other instances I find them to proceed from the stems formed by the convergence of the brush-like tufts of pseudopodia; but more commonly they seem to have sprung (as I have shown to be probably the case in the recent *Calcarina*) from the sarcodic layer, which is formed by the coalescence of the pseudopodia on the outer surface of the proper wall of the chamber, this layer being represented in the decalcified specimens by a thin plate of serpentine that is often found resting on the extremities of the asbestiform bundles. They differ very remarkably in size and form: being sometimes slender cylindrical rods, which come off from the subjacent layer at regular intervals, and pass straight onwards into the shell-substance without either sub-division or junction; sometimes presenting themselves as broad flattened plates, which gradually thin out to a sharp edge; but being commonly more or less arborescent, and often presenting either beautiful denditric ramifications (lower part of Coloured Plate, andUncoloured Plate, Fig. 3) or a sheaf-like divergence of their component filaments. All these representatives of the sarcodic prolongations that occupied the canal-system are distinguished

* Memoir on *Calcarina*, in the *Philosophical Transactions*, 1860, p. 553; and *Introduction to the Study of the Foraminifera*, p. 220.

in decalcified specimens—like the acicular layers occupying the place of the proper walls of the chambers,—by their pure whiteness, which contrasts strongly with the green of the serpentine that has filled the cavities of the chambers; and though this might seem to indicate a difference in the infiltrating material, no such difference really exists. I am informed by Sir William Logan that Mr. Sterry Hunt has determined the chemical identity of the two substances; and hence it is obvious that the whiteness of the internal casts of the tubes and canals is due (like that of pounded glass) to the reflection of light occasioned by the fine division of their component particles; each rod, plate, stem, or branch, being composed of minute asbestiform filaments, which represent, it would seem, so many original threads of sarcode that partially coalesced to form a bundle. Besides these definite shapes, however, we meet in many decalcified specimens with large white amorphous masses of like composition, occupying spaces which must have been originally surrounded by the shell-substance of the intermediate skeleton. The nature of these was for some time a puzzle to me; but I fortunately succeeded in gaining a clue to their character by the decalcification of very thin sections which had traversed them; and I find that they consist in some instances of parallel lamellæ disposed like the leaves of a book, and in others of solid bunches of rounded filaments reminding one of a sailor's "swab;" thus being in each case but a mere aggregation of the elementary forms of sarcodic prolongation already described.

In those portions of the organism in which the chambers, instead of being regularly arranged in floors, are piled together in an "acervuline" manner, there is little trace either of "intermediate skeleton," or of "canal-system"; but the characteristic structure of their proper walls is still unmistakably exhibited, not only in transparent sections, but also in decalcified specimens, wherever the asbestiform layer has not been detached by the disengagement of gas from the surface of the segment on which it should rest.

The mode in which, in the regularly stratified portions of the organism, each successive layer originated from the one that preceded it, does not seem to have been always the same. There is certainly no regular system of apertures for the passage of *stolons*, giving origin to new segments, such as are found in all ordinary many-chambered Foraminifera, whether their type of growth be rectilineal, spiral, or cyclical; and although, when one layer is separated from another by nothing else than the proper walls of the chambers, the coalescence of the pseudopodia emerging from the upper surface of the last formed layer would suffice to lay the foundation of a new layer of sarcodic segments, it is obvious that where this surface has been overgrown by a thick exogenous deposit of non-tubular shell-substance, some more special provision must exist for the origination of a new tier of chambers above this. Such a provision seems to have been occasionally made by the extension of riband-like prolongations of sarcode, through large passages left in the intermediate skeleton, proceeding from the chambers beneath, and opening on its upper surface; for I have not only occasionally met with such flattened passages in transparent sections of the shell (Uncoloured Plate, Fig. 1, D), but have still more frequently found the void spaces in decalcified specimens, left by the removal of the thickest layers of the intermediate skeleton, to be traversed by the internal casts of such passages, which seem to represent the sarcodic stolons of the living animal body.*

The origination of new layers, however, seems more frequently to have taken place in a much larger extension of the sarcode-body of the pre-formed layer; which either folded back its margin over the surface already consolidated (in a manner somewhat like that in which the mantle of a *Cypræa* doubles back to deposit the final surface-layer of its shell), or sent upwards wall-like plates, sometimes of very limited extent, but not unfrequently of considerable horizontal length, which, after traversing the substance of the shell, spread themselves out over its free surface. For it is frequently to be observed in decalcified specimens, that two bands of serpentine (or other infiltrating mineral), which represent two layers of the original sarcode-body of the animal, approximate each other in some part of their course, and come into complete continuity (as on the left-hand side of the Coloured Plate), so that the upper layer would here seem to have originated in a folding-over of the lower. And even where these bands are most widely separated, we find that they are commonly held together by vertical dykes of the same material, which traverse the intervening calcareous layers like trap-dykes passing through a bed of sandstone. That such have not been formed by mineral infiltration into accidental fissures in the shell, but represent extensions of the sarcode-body of the living animal, is indicated not merely by their distinct continuity with the horizontal layers, but also by the fact that portions of the canal-system may frequently be traced into connexion with them.

The only information which seems to me yet wanting to bring up our knowledge of the life-history of this organism to the highest level of that (still far from complete, especially as

* See the white bands passing from the middle of the lowest layer in the Coloured Plate to the layer next above it.

regards the generative process,) which we possess in respect to the best-known existing representatives of the Foraminiferal group, is that which concerns the early stage of its development. At present we know *Eozoon* only in its massive forms; and we have no clue, save that furnished by analogy, to the mode in which these are built up. In the *Rotaline* series, which is characterized by the *coarse* perforation of the shell, we find the original spire of *Planorbulina* overgrown by chambers piled upon it in an irregular acervuline manner; in *Tinoporus*, whose young state closely resembles the early form of Planorbulina, the chambers, successively superposed on the original spire and its marginal extension, are piled in layers of greater regularity; while in *Polytrema* similar rotaline chambers bud forth one from another, in such a manner as to give to the organism the aspect of a minute branching Coral, for which it was long mistaken. Now, in virtue of the *fine* tubulation of the proper walls of its chambers, *Eozoon* belongs to the *Nummuline* series, of which I have shown this structure to be the special characteristic; and this series presents a remarkable parallelism, as regards variations in mode of growth, to the Rotaline. For we may pass from the typical *Operculina* or *Nummulina*, through *Heterostegina* and *Cycloclypeus*, to *Orbitoides*, in which, as in *Tinoporus*, the chambers multiply both by horizontal and by vertical gemmation; and between this and *Eozoon* the difference is not greater as regards plan of growth than between *Tinoporus* and *Polytrema*.*

Notwithstanding the striking contrast which is presented between the massive growths of *Eozoon* and those microscopic *Rotaliæ*, *Miliolæ*, etc., which are the examples of the Foraminiferal type most familiar to collectors on our own shores, there is no more essential difference in plan of structure, than that which exists between the most insignificant flowering plant and the gigantic Wellingtonia or the wide-spreading Banyan. In the one case, as in the other, the difference consists, not so much in the size of the individual parts, as in the extent to which these parts are multiplied by the production of new buds in continuity with the pre-existing fabric. A contrast scarcely less remarkable exists among the Foraminifera of the existing epoch. Thus the shells of the minute *Globigerinæ*, which cover to an unknown thickness the sea-bottom of all that portion of the Atlantic Ocean which is traversed by the Gulf stream (the "ooze," of which specimens are brought up by the sounding apparatus, containing not less than 95 per cent. of them), consist of not more than eight or ten chambers, showing that the *continuous* increase of the individual body by

* See the descriptions of the Structure of these Generic types in my *Introduction to the Study of the Foraminifera.*

the gemmation of new segments ceased at that point; and that if new segments be still budded-off, they detach themselves, so as to lay the foundation of new *Globigerinæ*. On the other hand, in the large discoidal *Cycloclypeus* of the coast of Borneo, which attains a diameter of 2¼ inches, the number of segments formed by continuous gemmation must be many thousand.

It is a fact of no little interest, that we have another example of the comparatively gigantic development of the Foraminiferal type in what would have been formerly accounted the earliest fossiliferous rocks. Some years since, Mr. Salter, then the Palæontologist to the Geological Survey of Great Britain, showed me some fossil remains which he had received from the Silurians of Canada, and asked my opinion respecting them. My reply, after a not very detailed examination of them, was to this effect :—"If it were not for their gigantic size, I should say that they were internal casts of an Orbitolite." Having subsequently received additional specimens of these fossils, and having carefully compared them with my description of the genus *Orbitolites* in the *Philosophical Transactions* for 1855, Mr. Salter felt himself justified in identifying them with that type; and published an account of them (under the designation *Receptaculites*) with excellent illustrative figures, in the *First Decade of Canadian Organic Remains*. Now the largest recent *Orbitolite* I have seen is about the size and thickness of a shilling; whilst the Canadian *Receptaculites* attains a diameter of twelve inches and a thickness of a third of an inch; and if this had increased by vertical as well as by horizontal gemmation, piling up its chambers in successive tiers like the recent *Tinoporus* or the fossil *Orbitoides*, it would have formed a mass equalling *Eozoon* in its ordinary dimensions.

Remains of *Eozoon* are not by any means confined to Canada. The serpentine marble of Tyree, which forms part of the Laurentian system on the West of Scotland, and a similar rock in Skye, when subjected to minute examination, are found to present a structure clearly identical with that of the Canadian *Eozoon*. And the like structure has been discovered by Mr. Sanford in the serpentine marble of Connemara, well known to ornamental builders under the name of "Irish green." I have examined several pieces of this rock by placing them in dilute acid, and have not the smallest hesitation in identifying the residuum with the *acervuline* portion of the corresponding residuum of the Canadian *Eozoon*, shown in the upper part of the Uncoloured Plate: I have not, however, met with anything corresponding to the lamellated structure shown in the lower part of that plate. Moreover, I find, in place of a continuous asbestiform layer covering the segments, long straight bundles of asbestiform filaments radiating from them. What is the import of these—whether they represent a part of the original structure of the animal, or are (as I am disposed to suspect) a product of subsequent metamorphism—is a point which must be reserved for further investigation. The age of the Connemara rock, too, can scarcely be regarded as conclusively settled. Sir Roderick Murchison, by whom its relations were carefully studied some years ago, seemed not indisposed, when it was first found to contain *Eozoon*, to believe that it might belong to the Laurentian series; but he has since withdrawn that admission, and has expressed the opinion that the Connemara marble is of Silurian age.* If this be the case, it proves that *Eozoon* was not confined to the Laurentian period, but that it had a vast range in time, as well as in geographical distribution; in this respect corresponding to many later forms of Foraminifera, which have been shown by Messrs. Parker and Rupert Jones to range from the Triassic to the present epoch.

It is much to be desired that a careful examination should be made of all Serpentine marbles that contain a Calcareous admixture. Such admixture may be at once detected by their effervescence when touched with dilute acid; and if, on the removal of the lime by continuous maceration in acid, the siliceous residuum should exhibit forms bearing any decided resemblance to either portion of the Uncoloured Plate, the participation of *Eozoon* in their original production may be confidently inferred. It is specially to be desired that search should be made for it in any limestone beds occurring in the Laurentian rocks of Scandinavia, and in those of Bohemia and Bavaria.

It is not only, however, in those rocks which exhibit well-preserved representations of the original animal, that we may trace the agency of *Eozoon* in extracting from the ocean-waters the materials now forming the solid crust of the globe. There can be no reasonable doubt that—as has occurred in many subsequent epochs, and may be shown to be in progress at the present time—there was a continual disintegration, by the mechanical force of the ocean-waters, of those structures which had been built-up by living agency; and that the particles resulting from the progressive wearing-down of the Foraminiferal reefs would be deposited as sediments elsewhere, and, when subjected to subsequent metamorphic action (as by the infiltration of heated water) would be converted into highly crystalline limestones. Sir William Logan has shown me thin sections of solid masses, which presented unmistakable

* See the *Geological Magazine* for April, 1865.

evidence, when microscopically examined, of having been made up of an aggregation of fragments of the proper walls of the chambers of *Eozoon;* these fragments presenting the most beautifully preserved examples I have yet seen in transparent section, of the characteristic Nummuline tubulation. And as these sections presented no indication of such remains of a canal-system as would have marked the presence of fragments of the intermediate skeleton, I am disposed to think that the breaking-up of the surface of the original *Eozoon* must have taken place before the proper walls of its highest tiers of chambers had been strengthened by exogenous deposit. Further, in sections of Laurentian limestones, which did not exhibit to the naked eye any evidence of organic structure, Dr. Dawson was able, by microscopic examination, to recognize minute fragments, of whose derivation from *Eozoon* there could be no reasonable doubt.

Hence, it would appear that these gigantic Rhizopods performed, in the seas of the Laurentian epoch, the same part in the production of limestone rocks which was subsequently taken by Coral polypes, Echinoderms, and Mollusks, as well as by minuter forms of Foraminifera. And it is a fact not without an important significance, that this, the lowest type of animal life known to the Physiologist, should have thus culminated in the very earliest period in the history of the life of our globe with which the Palæontologist is at present acquainted. If, as I consider, that we are quite justified in doing, we refer the animal of *Eozoon* to the type whose characteristic features we are able to study in our existing *Rotaliæ* and *Miliolæ,* we may say of it, as I have elsewhere stated of the Foraminifera generally,* that its substance "does not present any such differentiation as is necessary to constitute what is commonly understood as 'organization,' even of the lowest degree and simplest kind; so that the physiologist has here a case in which those vital operations which he is accustomed to see carried on by an elaborate apparatus, are performed without any special instruments whatever—a little particle of apparently homogeneous jelly changing itself into a greater variety of forms than the fabled Proteus, laying hold of its food without members, swallowing it without a mouth, digesting it without a stomach, appropriating its nutritious material without absorbent vessels or a circulating system, moving its parts without muscles, feeling (if it has any power to do so) without nerves, propagating itself without a genital apparatus, and forming a shelly covering that possesses a symmetry and complexity not surpassed by those of any testaceous animals." It is not possible to conceive any living being of greater simplicity

* *Introduction to the Study of the Foraminifera,* Preface, p. vii.

than a Rhizopod of the Foraminiferal type; its homogeneous jelly-like substance not being even invested by the semblance of a membrane, so that its pseudopodial extensions, when they meet each other, coalesce like the glutinous threads separately proceeding from the spinnerets of a Spider. But it *is* possible to conceive of a system of rocks preceding the Laurentian, as the Laurentian preceded the Cambrian, and the Cambrian preceded the Silurian; and it would be a most rash assumption to maintain that the first appearance of *Eozoon* above the Laurentian horizon really marked the dawn of animal life on our planet. As Dr. Dawson has justly remarked, "though the abundance and wide distribution of *Eozoon*, and the important part it seems to have acted in the accumulation of limestone, indicate that it was one of the most prevalent forms of animal existence in the seas of the Laurentian period, they do not imply the non-existence of other beings. On the contrary, independently of the indications afforded by the limestones themselves, it is evident that in order to the existence and growth of these large rhizopods, the water must have swarmed with more minute animal and vegetable organisms on which they could subsist."

It would be difficult, I think, to find a more "pregnant instance" of the value of Microscopical investigation than that which is afforded by the discovery of which I have now given an account; a discovery which I am strongly disposed to regard as only the first of many similar results, which will follow its intelligent application to the study of the internal structure of other fossils, hitherto known only by their external forms. The organic structure and precise zoological affinities of a body which was at first supposed to be a product of purely physical operations, have been shown to be determinable with certainty from the examination of a particle which a pin's head would cover; and we are thus enabled to predicate the nature of the living action by which it was produced, at a Geological epoch whose remoteness in *time* carries us even beyond the range of the imagination, with no less certainty than the Astronomer can now, by the aid of spectrum-analysis, determine the chemical and physical constitution of bodies whose remoteness in *space* alike transcends our power to conceive.

EXPLANATION OF PLATES.

The *Coloured Plate* represents the various appearances exhibited by a specimen of *Eozoon Canadense,* which has been macerated in dilute acid, so as to dissolve away the calcareous shell which originally contained the body of the animal, now replaced by its model in green serpentine. In the lower part of the plate the segments are seen to be united into continuous horizontal lamellæ, which are connected with each other at intervals by vertical bands; in the upper part, the segments preserve their distinctness to a much greater degree, and are piled one upon another without any regular plan. The exposed surface of the segments, both in the lamellated and in the acervuline portions, is seen to be whitened by the asbestiform layer, also shown as a narrow edging in the sectional view of the lamellated portion. This layer consists of the needle-like siliceous filaments which take the place of the pseudopodia originally, occupying the minute parallel tubuli of the proper walls of the chambers, and which remain *in situ* after the removal of the calcareous shell that was traversed by them. Between the two lower lamellæ of serpentine, in the broad space originally occupied by a thick layer of the "intermediate skeleton," is seen on the right the siliceous model of a small group of stolon-processes, which passed directly from the sarcode body occupying the chambers of the lower tier to that of the tier next above, whilst on the left is shown the internal cast of a part of the canal system, forming a model in serpentine of the arborescent clusters of sarcodic prolongations which occupied it.

Tinted Plate.—Structure of Eozoon.—Fig. 1. Portion of the calcareous shell (restored), the contents of the chambers having been removed. A^1, A^1, A^1, chambers of a lower tier, communicating with each other freely at *a*, *a*, and separated from an adjacent chamber at *b*, *b*, by an intervening septum traversed by passages. A^2, A^2, chambers of an upper tier. B, B, B, B, proper walls of the chambers, traversed, as in the *nummuline* type, by fine tubules. These tubules are seen, in the upper wall of the chambers, A^2, A^2, to pass with uniform parallelism, from the inner to the outer surface, where they open at regular distances from each other; but in the upper wall of the chambers, A^1, A^1, A^1, the tubules are seen to converge in their passage outward, so as to open on the surface in irregular bands and clusters. C, C, C, intermediate skeleton, composed of homogenous shell substance, traversed at D by a stoloniferous passage connecting the chambers of two tiers, and at E, E, E by the canal system.

Fig. 2. Highly magnified portion of the asbestiform layer, left after the decalcification of the shell-wall, showing varieties in the arrangement of the siliceous internal casts of the tubules, which represent the pseudopodia that occupied them in life. At *a* is shown the uniform surface given by the ends of the closely-packed parallel *aciculi*, which are seen standing side by side in the sectional view beneath. At *b*, the uniformity of surface is interrupted by the partial convergence of the aciculi, leaving vacant spaces between. And at *c* is shown the more

complete convergence of the siliceous threads into brush-like bundles.

Fig. 3. Internal cast of a portion of the canal system, in a decalcified specimen, showing the arborescent distribution of the sarcodic prolongations which occupied it during life.

TEN YEARS IN SWEDEN.*

THERE is a manifest tendency towards an increase of communication and connection between England and Sweden. Its vast stores of the richest and purest varieties of iron ore, and the ample supplies of serviceable timber abounding in its extensive forests, attract the notice of the speculative capitalist, who sees in them important sources of wealth hitherto imperfectly developed, and offering splendid prospects of profit to enterprises carried out on a sufficient scale, and with adequate skill. The naturalist and the sportsman find their attention turned to Sweden from the interesting character and variety of its wild animals; while the manners of the people, their Protestant faith, and free political system, tend to render their country an agreeable residence for English families during the milder portions of the year.

It is easy to understand why, notwithstanding the merits of the people, Sweden has been somewhat slow in making the most of her resources. Though a large country—nearly three times the size of England and Wales—only a small part is fairly adapted to agriculture, and much of the wealth in minerals and timber can only become accessible through the construction of railways, the improvement of river navigation, and other proceedings of a costly kind. Out of 3868 Swedish square miles, which Agardth estimates as the total area, lakes occupy one-eighth, or 498 Swedish square miles, fells and barren plains take up 1500, forests 1623, leaving only 247 for meadow and arable land. By degrees the cultivated portion will, no doubt, be considerably increased, but the climate opposes serious obstacles, and it is from her mines and her forests that Sweden must expect to obtain the means of purchasing food and comforts for her growing population.

A really good book upon this interesting and important country has been much wanted, and such a work could only be written by a shrewd observer, who had domesticated himself amongst the people, and become familiar, through a lengthened residence, with their language, customs, habits, and resources. Such a work the "Old Bushman" has produced, and we feel no hesitation in saying that, for some years to come, his *Ten Years in Sweden* will be an acknowledged authority, to which merchants, capitalists, naturalists,

* *Ten Years in Sweden;* being a Description of the Landscape, Climate, Domestic Life, Forests, Mines, Agriculture, Field Sports, and Fauna of Scandinavia. By "An Old Bushman," author of "Bush Wanderings in Australia," "A Spring and Summer in Lapland," etc. Groombridge.