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## On some Canadian Rocks containing Scapolite, with a Few Notes on some Rocks associated with the Apatite Deposits.

By Frank D. Adams, of the Canadian Geological Survey, and Andrew C. Lawson, Ph. D., of the Canadian Geological Survey.

At the meeting of the British Association for the Advancement of Science, held in Montreal in the summer of 1884, a short paper entitled "On the Occurrence of the Norwegian 'Apatitbringer' in Canada, with a Few Notes on the Microscopic Characters of some Laurentian Amphibolites," was read before the Geological Section by Mr. Frank D. Adams. Only a short extract of some dozen lines was prepared for the Transactions, as it was proposed to continue the investigation of these rocks and especially to study their geological relations in the field. A thorough geological examination of the district from which these rocks were obtained has not, however, been found to be practicable, and in the following paper it is proposed to give a more detailed description of them, together with the results of the examination of a few others collected since that time.

The peculiar scapolite rock, referred to above as the "Apatitbringer," was first mentioned by Brögger and Reusch in a paper entitled "Vorkommen des Apatit in Norwegen."[1] In this paper, the authors state that at Oedegarden in Bamle (Southern Norway), where the largest apatite deposits of that country are found,—some idea of the extent of these deposits may be obtained from the fact that in 1882, at Oedegarden alone, 15,000 tons of apatite were mined, between 700 and 800 men being employed—the mineral occurs in, or in the immediate vicinity of, a rock described by them as "Geflecter Gabbro." This rock, however, differed from gabbro, as that word is generally understood, as it was stated to be composed essentially of amphibole and labradorite, and it has been shown to be a peculiar form assumed by the normal gabbro of the country on approaching the apatite veins. Referring to this work, Kjerulf, in his "Geologie des südlichen und mittleren Norwegen," after mentioning one variety of gabbro as an "Erzbringer," says:—"Der bunte oder Hornblende Gabbro......wegen seiner Rolle als 'Apatitbringer' gekannt zu sein verdient." It was also described as Hornblende Gabbro in a paper by H. Möhl.[2] Michel Lévy,[3] who subsequently examined the work, showed that, as conjectured by Lang,[4] the white mineral was really not plagioclase, but a mineral of the scapolite family, which he referred to the species wernerite. Sjögren,[5] who has more recently

[1] Zeit. d. deutsch. geol., Gesellsch, 1875, Heft III.

[2] Die Eruptivgesteine Norwegens, mikroskopisch untersucht und beschrieben. Nyt magazin for Naturwidenskaberne. Bd. XXIII.

[3] Sur une roche à sphene, amphibole et wernerite granulitique de Bamle (Norwège). Bull. Soc. Min. France. No. 3. 1878.

Sur le gisement de l'amphibolite à wernerite granulitique d'Oedegaard pres Bamle (Norwège). Bull. Soc. Min. France. No. 5. 1878.

[4] E'in Beitag zur Kenutniss norwegischer Gabbros, Z D. G. G. 1879. XXXI. 484.

[5] Om de norska apatitforekomsterna, etc. Geol. Fören i, Stock. Förh. 1883. 447.

carefully examined the rock, refers the mineral to the species dipyr, calling the rock a dipyr diorite.

It is believed by those who have studied the rock and its relations in the field, to be derived from the alteration of the true gabbro adjoining it, the pyroxene of the gabbro being altered to hornblende and the plagioclase of the gabbro to scapolite. The change would be essentially one of diagenesis. Intermediate varieties are found containing diallage "rests" in the hornblende and plagioclase mixed with scapolite.[1] In this connection, an observation made by Fouqué and Michel Lévy[2] is especially interesting, namely, that when the rock is fused and allowed to cool, the magma recrystallizes as a mixture of labradorite and augite.

The occurrence of scapolite in certain of the crystalline schists, especially augite gneiss and amphibolite, has been mentioned by Törnebohm[3], Dathe[4], Becke[5], Wulf,[6] Mügge,[7] Svedmark,[8] and others. The last-named author, in addition to a number of scapolite-bearing gneisses and amphibolites, describes an amphibolite from Orebro which contains scapolite to the exclusion of plagioclase, and which also holds a little diallage and mica. In composition, therefore, it would be closely allied to the Oedegarden rock.

Lacroix and Baret[1] have also recently described a pyroxene wernerite rock which occurs associated with gneiss

[1] See Sjögren, loc. cit., and Rosenbusch, Mass. Gest. I., 165.

[2] Sur la transformation par voie ignée, etc. Bull. Soc. Min. France. 1879. 105.

[3] Ett par Skapolitförande Bergarter. Geol. Fören. i. Stöck. Förh. 1882. VI. 192.

[4] Jahr. preuss. geol. Landesanstalt. 1884. LXXVI.

[5] Die Gneissformation des niederösterr. Waldviertels. T. M. P. M. 1882. 369.

[6] Beitrag zur Petrographic des Hererolandes in Südwest-Africa, T. M. P. M. 1887. 213.

[7] Ueber einige Gesteine des Massai-Landes. N. J. Beil. Band. IV. Heft III.

[8] Om nagra Svenska Skapolitförande bergarter. Geol. Fören. i. Stock. Förh. VII. 1884. 293.

and amphibolite at Point-du-Jour, near St. Nazaire, in France. In this rock the pyroxene is associated with, and sometimes completely replaced by, a very pleochroic amphibole, and in some specimens the wernerite is associated with oligoclase, the rock thus passing into a wernerite oligoclase amphibolite.

A most interesting paper in this connection and one which will be referred to again, was published by Dr. A. P. Coleman in the Transactions of the Royal Society of Canada for 1887.[2]

As Canada is the only country, except Norway, in which apatite is extensively mined, and as in most respects the character and mode of occurrence of the mineral in both countries are very similar, a corresponding relation to dipyrdiorite might be looked for. In Canada, however, as pointed out by Dr. Harrington in his excellent "Report on the Minerals of some of the Apatite-bearing Veins of Ottawa County, Que.[1]," this relation does not exist, the important deposits of apatite occurring associated with a granular pyroxene rock, which is always regarded by prospectors as indicative of the presence of apatite, and occupies, in that way, to a certain extent, the position of the "Apatitbringer" in Norway. "These[2] pyroxene rocks, which have been called by Hunt pyroxenites, vary considerably in their characters. Sometimes they consist almost exclusively of pyroxene, though more commonly quartz and orthoclase are present. Mica, too, is of frequent occurrence, while minute garnets may occasionally be seen. The frequent presence of disseminated grains of apatite is also an important fact. When pyroxene is the principal mineral, the rock commonly shows little or no trace of

[1] Lacroix et Baret.—Sur la pyroxénite à wernérite du Point-du-Jour près Saint-Nazaire. Bull. Soc. Min. France, July, 1887.

Lacroix, A.—Note sur une roche à wernérite granulitique des environs de Saint-Nazaire. C. R. CIV. 1011.

[2] Microscopic Petrography of the Drift of Central Ontario.

[1] Reports of Progress of the Geological Survey of Canada, 1877-8.

[2] Ibid.

bedding, but is often a good deal jointed. Its aspect, when the pyroxene is of a dark colour, is often that of a massive eruptive rock." It is very intimately associated with the apatite, in some places apparently passing imperceptibly into it.

In order to ascertain whether these pyroxenites contained any scapolite, two specimens—one from lots 35 and 36, range V. of Portland West, and the other from the well-known McLaurin Mine in Templeton—were sliced and examined microscopically. They are both rather coarse-grained, that from Portland being of a light greyish colour and holding a little disseminated apatite, sphene and pyrite, while the Templeton rock is light green in colour, and in certain places contains a good deal of biotite. Neither of them contained any scapolite, nor could any be found in the wall rock of the Emerald Mine in the township of Buckingham.

Mr. Coste, Mining Engineer to the Geological Survey of Canada, who has had occasion to visit a number of the apatite mines, considers that the apatite occurs in the form of more or less irregular veins, the above mentioned pyroxene rocks occupying the position of vein stones. He also believes that these veins of apatite and pyroxenite are found almost invariably in connection with a certain eruptive rock, which varies much in texture but is generally rather coarse-grained, and which is composed largely of orthoclase generally having a bluish or lilac tint. Two specimens of this rock, collected by Mr. Coste,—one from the "Star Hill Mine," range VIII., Portland West, in the Province of Quebec, and the other from the "Blessington Mine," lots 29 and 30, range I., Inchinbrooke, in the Province of Ontario,—were also sliced and examined. The two rocks resemble one another in appearance, that from the "Blessington Mine," however, being somewhat darker in colour.

Under the microscope, the "Star Hill" rock is seen to be composed essentially of orthoclase and biotite, with very small amounts of magnetite and pyrite. The orthoclase is almost always clear and fresh; the biotite is also very fresh, although in places it is slightly decomposed to chlorite. The magnetite is probably titaniferous, as occasionally it is altered to leucoxene. Another hand specimen of the same rock was found to contain, in addition to the minerals mentioned above, a little quartz and a little plagioclase, and the orthoclase contained the peculiar intergrowths characteristic of perthite. This specimen had a very obscure foliation, and the quartz and orthoclase showed evidence of having been submitted to pressure. It also contained a few forms of some mineral which had been entirely decomposed, but which may have been pyroxene.

The rock from the "Blessington Mine" is composed essentially of orthoclase, biotite, pyroxene and magnetite, with a little plagioclase, hornblende, pyrite, calcite and apatite. The orthoclase contains a multitude of minute, black, rod-like inclusions and fine dust. The pyroxene occurs in large amount, and is more plentiful than the biotite. It is pale green in colour, with scarcely noticeable pleochroism and large angle of extinction. It is generally without good crystalline form, but occasionally occurs in rude crystals. It is also occasionally twinned. The hornblende occurs in very small amount—intergrown with the pyroxene and biotite. The calcite is present in small amount, and results from the decomposition of the pyroxene and feldspar. The magnetite may be titaniferous. The apatite is uniaxial and negative, and occurs in irregular shaped grains, with high index of retraction and faint bluish colour, generally associated with the pyroxene.

The rock from the "Star Hill Mine" is therefore a *mica syenite*, and that from the "Blessington Mine" an *augite mica syenite.* It will be a matter of interest to ascertain whether these rocks occupy a similar relation to the apatite at the other mines. A monograph of the apatite district of the Province of Quebec, which is now being prepared by Mr. Ingall of the Geological Survey, willl decide this and many other important points.

Among a series of specimens from the vicinity of the town of Arnprior, on the River Ottawa, which were some time ago, sent to Mr. Hoffmann of this Survey for examination, there was, however, one small specimen which exactly resembled the Oedegarden rock, and which, when sliced and examined with the microscope, proved to be identical with it. Unfortunately, we were unable to obtain any further specimens or to ascertain the locality from which it came more precisely than that, as above mentioned, it was from near the town of Arnprior. The large collection of rocks in the museum of the Geological Survey of Canada was then carefully examined, and sections were prepared of all those which at all resembled this rock in appearance. An examination of these sections resulted in the discovery of three other specimens, from widely separated localities, rich in scapolite, but unlike the Arnprior rock, containing also a considerable proportion of plagioclase.

The first of these specimens was collected by the late Mr. Vennor at Mazinaw Lake, in the township of Abinger, in the county of Addington; the second was obtained by Mr. Coste at the Robertsville or Mississippi Iron Mine, on lot 3, range VIII. of the township of Palmerstone, in the county of Frontenac, and the third was collected by Dr. Bell from lot 28, range I. of McDougall, in the Parry Sound district. All three rocks are of Laurentian age, and come from that great stretch of Laurentian country lying north of Lake Ontario and south of of Lake Nipissing and the River Ottawa. The eastern half of this area was examined by Mr. Vennor, and found by him to be rich in amphibolites, dioritic schists and diorites; a very common, coarse-grained variety of the latter being called by him "blotched diorite," and it is associated with these dioritic rocks, whose occurrence at Mazinaw Lake is mentioned by Mr. Vennor, that the Arnprior and Mazinaw Lake rocks apparently occur. The rock from the Robertsville Mine is found associated with crystalline limestone and granite. In some places it forms the wall rock of the magnetite, between 50,000 and 60,000 tons of which have been mined. The mode of occurrence of the McDougall rock is described by Dr. Bell in the following extracts from his report on the country north of Lake Huron and east of Lake Superior.[1]

"Eastward of the village of Parry Sound, along the road of the same name, dark, hornblendic gneiss or schist prevails for a distance of about a mile and a half. A band of crystalline limestone, and one of mottled white and black diorite, *occur in association with these rocks where this road* crosses lot 28, concession I., township of McDougall." "The rock which is here immediately associated with the limestone is a remarkable looking diorite, consisting of a white ground, thickly mottled with patches of dark-green or blackish hornblende, having their longer diameters arranged parallel to the general bedding. This appears to be the rock which Mr. Vennor has described in the Hastings, Lanark and Renfrew region, under the name of 'blotched diorite." The rock from near Arnprior is rather coarse-grained, and with the naked eye is seen to consist of white of bluish-white scapolite, with a rather larger amount of what looks like a dark greenish hornblende. In appearance, the scapolite closely resembles that occurring in the Norwegian rock, which has been aptly compared by Brögger to wet snow. The rock appears to have an indistinet foliation, but the specimen sent was too small to show its structure distinctly. *When thin sections are examined with the* microscope, the rock is seen to be fresh and almost entirely free from decomposition products. The structure is for the most part granular, none of the minerals being idiomorphic.[2] The principal constituents are found to be pyroxene, hornblende and scapolite; and the accessory ones epidote, enstatite, pyrrhotite and rutile.

The pyroxene is very light in colour and faintly pleochroic. $\mathfrak{A}$=yellowish; $\mathfrak{B}$=greenish; $\mathfrak{C}$=light green. The absorption is $\mathfrak{C} > \mathfrak{B} > \mathfrak{A}$. Basal sections show well-marked prismatic cleavages intersecting at an angle of about 90°;

[1] Reports of Progress of Geological Survey of Canada, 1876-77, pp. 199 and 204.

[2] Rosenbusch.—Mikroskopische Physiographie der massigen Gersteine. Band II. i. Abtheilung,—1886.

while in sections parallel to the clinopinnacoid, the extinction is seen to be about 39° or 40° against C. Most of the pyroxene has a peculiar, fibrous or mottled appearance, due to what is apparently its partial alteration into a light green pleochroic hornblende. This hornblende is darker in colour and generally has a shred-like character at its contact with the pyroxene, the two minerals, however, often having a sharp line of contact, which in this case is usually a cleavage trace. The various patches, streaks or shreds of hornblende scattered through an individual of pyroxene generally have a common orientation, presenting elongated forms in prismatic sections of the pyroxene, but on basal sections generally appearing as irregular spots, the hornblende strings being inlaid parallel to the C axis of the pyroxene, and sometimes also elongated parallel to $\infty$ P $\infty$, both minerals having the B axis in common.

In addition to the hornblende associated with the pyroxene, the rock contains other hornblende which shows no evidence of derivation from pyroxene. This is of a deep green colour, has the usual perfect cleavages, and occurs scattered through the rock in irregular shaped masses, which however occasionally have well defined prismatic contours. The pleochroism is strongly marked 𝕮=dark bluish-green; 𝕭=dark green; 𝕬=light yellowish or brownish-green.

The scapolite is abundant, and occurs in large, colourless grains. In basal sections a very distinct uniaxial figure was repeatedly obtained, and by means of the quarter-undulation plate its negative character was clearly established. The quadratic cleavage parallel to $\infty$ P $\infty$ is distinct. The polarization colours are either brilliant or are of a pale bluish-gray tint like those of the feldspars. The brilliantly polarizing scapolite occurs side by side with that which shows the soft gray tints, so that the difference does not seem to be due to a varying thickness of the section. In two instances, traces of polysynthetic lamellæ were observed, in which the extinction, though much less distinct than in plagioclase, resembled it otherwise very strongly. The appearance was very suggestive of the derivation of the scapolite from plagioclase, and if this be the case the twinning structure of the latter is retained after the mineral has apparently been entirely changed to scapolite. Probably, however, in these cases the change may not be complete, and although the mineral has the characters of scapolite, there may be sufficient plagioclase remaining in twinning position to cause the alternate oblique extinction observed. There are in the scapolite, inclusions of a dusty, opaque character, besides fluid inclusions and microlites. The dust and fluid exclusions are disposed either in planes or irregularly; in the latter case, the section may be really parallel to the planes in which the inclusions lie. The microlites lie for the most part in cleavage lines, and have their long axes either perpendicular or oblique to certain planes (sometimes cracks) which cross the cleavages. In some instances, numerous opaque, thick plates and stout rods were observed lying parallel to the cleavage lines. When seen on edge, these plates and rods had rectangular outlines, although rounded patches of the same opaque material could sometimes be seen. Occasionally the scapolite is somewhat cloudy, owing to the presence of a kaolin-like decomposition product, but generally it is quite fresh and clear. The epidote occurs in small, nearly colourless grains of irregular shape. Scattered through both the hornblende and the pyroxene, and occasionally to be observed in larger grains situated between those of the other constituents, there are irregularly rounded or oval grains of a mineral which is referred to the rhombic pyroxenes. It is biaxial, possesses a rather high index of retraction, and polarizes in brilliant though somewhat subdued tints. It has one well-marked cleavage, to which the extinction is parallel, and has a fine, fibrous structure, also parallel to the cleavage, which seems to be due to decomposition. The mineral is not quite colourless, but has a faint purplish or amythestine tint, and occasionally seems to be slightly pleochroic. Pyrrhotite occurs very sparingly, and is distinguished by its opacity and its bronze colour in reflected light. In one instance it was seen to be included in the scapolite, which was stained yellowish-green in the vicinity of the grain. Other grains occur bedded in the hornblende. Rutile occurs in occasional grains, rather large in size and irregular in shape, but has not been observed in its usual prismatic habit. It has a high index of retraction and a faint brownish or reddish colour, and resembles titanite very much both in ordinary light and between crossed Nichols. In convergent light, however, it gives a distinct uniaxial interference figure, and there are traces of a quadratic cleavage. It polarizes in dull, leaden-gray tints. In two instances these grains of rutile were seen to be made up of lamellæ, as if polysynthetically twinned. There was, however, no alternation of extinction corresponding to the alternate lamellæ. In a certain position between crossed Nichols, the section was broken up into these lamellæ, which were alternately light and dark. On revolving the stage through 90°, the same appearance is produced, *i.e.*, the same lamellæ are light and dark as before, and there is no position in which the light lamellæ become dark and the dark lamellæ light. In one of these two instances, the polyxenthetic lamellæ appeared to cross each other, the angle between the two sets being, as nearly as could be measured, 53°. The rutile is associated with the scapolite, and in the last-mentioned case, where the grain has a diameter of 1·4 mm., it is entirely surrounded by scapolite. In this case the glass cover having been removed, the section was treated with hydrochloric acid, the mineral, however, was quite unacted upon. Following Sjögren, the rock may be termed a *Scapolite Diorite.*

The rock from Mazinaw Lake [Museum Number 2930] is rather coarse-grained and distinctly foliated. The principal constituents are hornblende, biotite, scapolite, plagioclase and, in smaller amount, quartz. The accessory minerals are epidote, ziosite and titanite. Pyroxene does not occur in any of the slides. In nearly all the sections the rock is seen to be made up of two parts: (1) a fine-grained, granulitic "groundmass" composed chiefly of feldspar with some quartz, biotite and hornblende; and (2) a coarser grained portion imbedded in this "groundmass," but not having any definite crystalline boundaries. The minerals composing this coarser grained portion are scapolite, plagioclase, biotite, hornblende, and occasionally quartz. A gradation between the "groundmass" and the coarser constituents can generally be observed, and in some few instances there appears to be evidence that the former was derived from the latter, particularly from the plagioclase, by crushing, the structure being cataclastic. In this connection, the absence of pyroxene is noteworthy. The scapolite is generally coarsely crystalline, and present in large amount. Only occasionally is it sparing in quantity or finely crystalline. Very commonly it occurs in large plates of uniform orientation, in which more or less elongated individuals of hornblende or biotite lie irregularly imbedded, the structure being quite analogous in appearance to the ophitic structure seen in diabases. In one case, a large plate of scapolite was observed to inclose an irregular grain of plagioclase, the latter being somewhat decomposed. The scapolite usually occurs side by side with plagioclase or with plagioclase and quartz, all being in very irregular shaped grains, evidently allotriomorphic. The line of contact between the plagioclase and scapolite is quite sharp, and generally there is but little evidence of the derivation of the latter from the former. Associated with the scapolite, there is often a fine-grained aggregate of gray decomposition products, which shows aggregate polarization in brilliant but subdued colours, and which probably consists of muscovite, calcite, etc.

Hornblende and biotite are well represented in all the sections, the former being rather more abundant than the latter. The hornblende is of a deep green colour, strongly pleochroic, and contains numerous inclusions. The biotite is of the usual brown colour, and some grains contain inclusions, in the shape of films running in between the cleavage lamellæ, of a mineral which between crossed Nichols resembles scapolite, but which are so minute that their character cannot be determined with certainty. The plagioclase is usually quite fresh and clear. In the "groundmass," the feldspars are only twinned occasionally and can be distinguished from the quartz only by means of the interference figure in convergent polarized light.

The most striking of the accessory minerals, and at the same time the only constantly idiomorphic constituent of the rock, is the epidote. It occurs in elongated prisms of rhombic cross-section, which vary much in width, in some cases forming slender needles, but elsewhere being of stout columnar habit. The crystals are colourless, but between crossed Nichols, polarize in the usual brilliant manner. The extinction is parallel to the side of the prism that is to the axis, and in cross-sections is oblique to both of the crystallographic lines. The plane of the optic axes may readily be determined to be perpendicular to B. The index of retraction is high, the prisms standing out in marked relief, and irregular transverse partings can occasionally be observed. In one section a large plate of zoisite was observed. It was oblong in shape, showed a perfect cleavage parallel to its length ($\infty P \breve{\infty}$), and a distinct cross parting. The plane of the optic axes was found to be at right angles to the C axis. The mineral is colourless, and shows dull gray to deep blue polarization colours. Titanite is rare, and occurs in small, rudely wedge-shaped grains. The rock may be called a *Plagioclase Scapolite Amphibolite.*

The rock from McDougall [Museum Number, 2996,] is coarse-grained, and possesses a rather indistinct foliation. Under the microscope, it is seen to be a granular aggregate of plagioclase, scapolite and green hornblende, with a sparing amount of pyroxene and quartz and a little accessory epidote and pyrite. The plagioclase is for the most part fresh, though occasionally a little cloudy, and by means of Lévy and Pumpelly's method was found to belong to the anorthite-labradorite end of the plagioclase series. The plagioclase and hornblende are present in about equal proportions. The scapolite is less abundant, and occurs in large, irregular-shaped plates, usually somewhat cloudy from the presence of decomposition products. The pyroxene is present in rather sparing amount, and is not seen in every slide. It is pale green in colour and without noticeable pleochroism, and is intimately associated wtth the hornblende, being in many cases apparently in process of alteration into that mineral, as in the case of the Arnprior rock. It may, perhaps, best be termed a *Plagioclase Scapolite Diorite.*

The rock from the Robertsville Mine is rather coarse-grained, and in external appearance bears a strong resemblance to that from McDougall, but possesses a more distinct foliation. Under the microscope it is seen to be composed of scapolite, plagioclase and hornblende, with accessory biotite and epidote. The scapolite is present in large amount, and is generally very free from decomposition products. It usually occurs in rather large plates, which polarize in brilliant colours. The cleavage with extinction parallel to it is well seen, and in sections parallel to the base the mineral is found to be uniaxial and negative. The plagioclase, which is also present in large amount, polarizes in much more subdued tones. Polysyntheti twinning is seen in many, but not in all cases. It is often rendered cloudy by the presence of decomposition products, which resemble kaolin in appearance, and as a general rule is not so fresh as the scapolite which occurs side by side with it. The hornblende, which is light green in colour, is without good crystalline form, but is not fibrous in character. It is strongly pleochroic, in yellowish and bluish-green tints. The biotite occurs in very small amount, intimately associated with the hornblende and partly altered to chlorite. Scattered through the plagioclase, and less frequently also in the scapolite, are many small, stout prisms and irregular grains of a colourless mineral, with high index of retraction, and which polarizes in brilliant colours. Occasionally these are pleochroic, with the yellowish tint characteristic of epidote, and have been referred to that species. The rock, which under the microscope resembles one of the crystalline schists, may be termed a *Plagioclase Scapolite Amphibolite.*

Although these scapolite rocks have been ascertained to exist at only four localities, they probably occur abundantly in various parts of the district from which these were obtained, and it is very interesting to note that in his study of the Petrography of the Drift of Central Ontario,—his materials being collected principally about Cobourg, situated about the middle of the southern limit of this same district,—Dr. Coleman found several specimens of "scapolite-diorite schist," which, judging from his description, must be identical in character with the rocks described in this paper.

Although the derivation of at least a part of the hornblende of these rocks from pyroxene is well nigh certain, the derivation of the scapolite from plagioclase, which, as before stated, has been pretty clearly proved in the case of the Norwegian rock, is not so evident in these similar rocks from Canada. There is certainly nothing in the sections fatal to this supposition, and several facts mentioned in this description of the slides seem to give some support to it. A much more exhaustive study of the rocks in their relations to the pyroxenic and dioritic rocks of the district would, however, be required to decide the question, and such an investigation would probably throw additional light on the curious paramorphism which the constituents of some rocks undergo, apparently under changed conditions of pressure. Fouqué's experiment, referred to above, on the minerals resulting from prism of the Norwegian rock, is of especial interest in this connection, as tending to show that hornblende and scapolite are not stable forms at high temperatures, at least under the ordinary pressure. The whole question is one of much interest, and one which, of late, has attracted a good deal of attention.[1]

As mentioned above, the rocks from McDougall and Palmerstone occur associated with crystalline limestones

[1] See Williams on The Gabbros and Associated Hornblende Rocks occurring in the neighbourhood of Baltimore, Md., p. 49. Bull. U. S. Geological Survey, No. 28.

of the Laurentian System. There are, however, many amphibolites and dioritic rocks occurring in the same district intimately associated with these limestones, but which contain no scapolite whatever. There is, for example, a great thickness of amphibolites, interstratified with crystalline limestone, exposed on the north shore of the Ottawa, just below the town of Arnprior, which we examined some years ago when on a visit to that locality for the purpose of endeavouring to discover the Scapolite-Diorite in place. They are all rather fine-grained and weather dark gray and black, and have a more or less distinct foliation. They were followed for a distance of about five miles below Arnprior, being gradually replaced by quartz feldspar rocks. Like all the other amphibolites and dioritic rocks of the district which do not hold scapolite, when examined with the naked eye the feldspar is seen to be wanting in that peculiar bluish-white tint characteristic of the scapolite, and which the Norwegian geologists compared to wet snow. Three specimens, collected respectively a quarter of a mile, two and a quarter, and three and a half miles below Arnprior, were sliced and examined. The last of these is traversed by little pegmatite veins, and under the microscope is found to be composed of hornblende, biotite and plagioclase, with accessories of epidote and sphene. The hornblende is green in colour, strongly pleochroic and without any tendency to a fibrous structure. It occurs in irregular shaped fragments, which occasionally have an imperfect idiomorphic development, and which mark the lines of foliation. The biotite, which is present in much smaller amount than the hornblende, is brown, with the usual strong dichroism and parallel extinction. The plagioclase is generally twinned, the lamellæ being narrow and the twinning generally faint. All untwinned grains which could be found cut in a direction at right angles to an optic axis, showed the revolving bar of a biaxial crystal. They polarize in rather dull tints, and extinguish simultaneously over the whole surface, showing little or no evidence of having been submitted to pressure.

The pyrite, epidote and sphene occur in small amount in little irregular shaped grains.

The other two specimens contain no biotite, but hold a certain amount of quartz, recognized by the absence of cleavage and decomposition products and by its uniaxial and positive character. The quartz grains are sometimes broken, but do not show much evidence of pressure either. The specimen collected about a quarter of a mile below Arnprior contains a considerable amount of quartz, while that from two and a quarter miles below, holds less quartz, and contains, in addition to the pyrite, a little magnetite or ilmenite.

To sum up, therefore, it may be said :—

(1) That the Scapolite Diorite, which in Norway occurs so intimately associated with the apatite deposits, does not occupy the same relation to the Canadian deposits.

(2) That its place in Canada is taken by certain pyroxenic rocks which have not, as yet, been thoroughly studied.

(3) That Scapolite Diorite and transition rocks between it and gabbro, identical with the Norwegian rocks, do occur in our Laurentian System, associated with amphibolites and crystalline limestones.

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## EOZOON CANADENSE.

By Sir J. WILLIAM DAWSON, F.R.S., etc.

[Extracts from a memoir by Sir William Dawson in the Publications of the Peter Redpath Museum, Sept., 1888.]

### I. STATE OF PRESERVATION.

We may first ask, under this head, what are the structures supposed to be preserved. On the supposition that Eozoon was a marine organism, its test or hard part, which grew on the sea bottom, consisted of a series of calcareous laminæ, not perfectly parallel, but bending towards each other at intervals, and uniting so as to form flattened chambers, deeper toward the base and becoming shallower in the upper part, while at the top they sometimes become broken up into rounded cells or chamberlets, constituting an

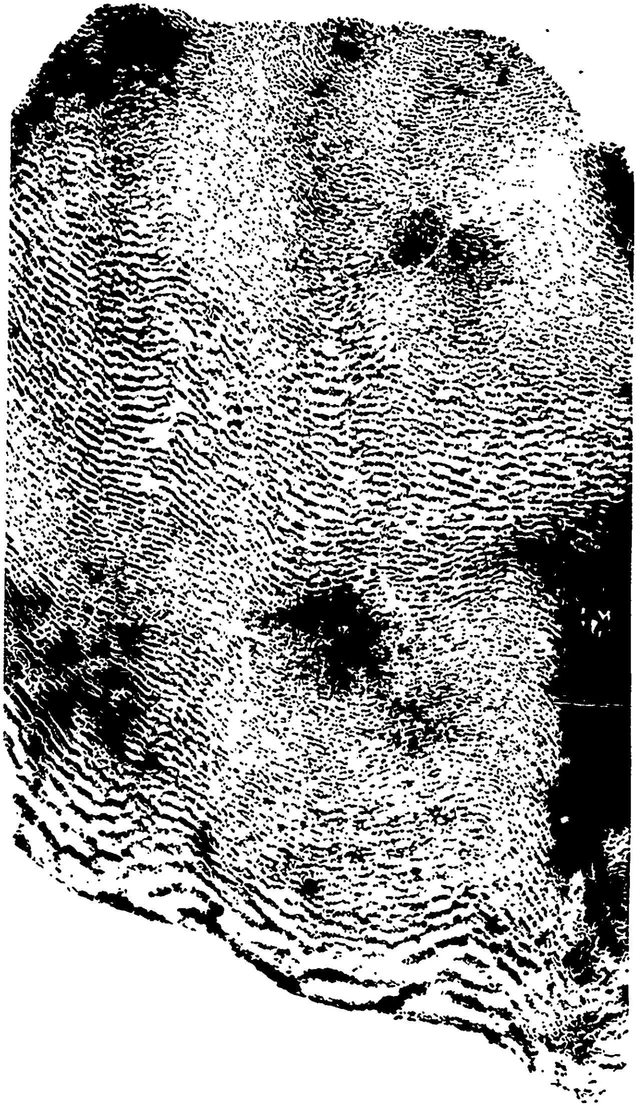

Fig. 2. Nature-printed specimen of Eozoon.

"acervuline" mass. The chambers, which, on the supposition above stated, were originally filled with the sarcodic matter of the animal, were after death and the burial of the skeleton in some calcareous sediment, occupied with mineral substances introduced by infiltration, and more especially with serpentine and pyroxene, which were at the same time being deposited in layers and concretions in the surrounding material. When well preserved, the calcareous laminæ are seen to be traversed with innumerable canals, terminating in very fine tubuli. These canals are occupied by serpentine, pyroxene or dolomite, or by limestone, according to the state of preservation. (See Figs. 2, 3, 4).

The masses of Eozoon sometimes consist of as many as one hundred and fifty laminæ superimposed. Originally flat or rounded, they assumed in growth club-shaped or turbinate forms, and sometimes by coalescence formed wide sheets or irregular masses, in which case they are often observed to be traversed in their thickness by conical or cylindrical tnbes or oscula. The outer surface and the walls of these tubes were strengthened by bending and coalescence of the laminæ. The mode of growth would be similar to that of more modern organisms of the genera *Loftusia, Carpenteria* and *Polytrema*, and to that of some kinds of *Stromatoporæ*. Finally, these calcaceous tests were liable to be broken up and scattered in fragments over the sea bottom, constituting the material of beds of organic limestone, like the coral sand that surrounds modern reefs and islands.

Assuming Eozoon to be a fossil animal of the characters above described, its mode of preservation in the ordinary serpentinous specimens is more simple than that of many fossils of later date. The calcareous walls have remained substantially unchanged, except that they have become somewhat crystalline in structure, and in many cases have assumed the crystalline cleavage of calcite; but this change is quite common in Palæozoic shells and crinoids. The chambers have been filled and the canals and tubuli traversing the calcareous test have been

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FIG. 3. Coral System of Eozoon injected with serpentine (magnified).
FIG. 4. Very fine canals and tubuli filled with Dolomite (magnified).
(From Micro-photographs.)

injected with a hydrous silicate. This is a filling up by no means infrequent in later fossils, and as Dr. Carpenter has shewn, it is going on in the modern seas in the case of foraminifera and other porous tests and shells injected with glauconite. Numerous instances of this kind exist in Palæozoic limestones. Several of these are described in my paper on fossils mineralized by silicates (*Jour. Geol. Society*, Feb. 1879, *et infra*), and I have recently met with another interesting example in a limestone from the Lower Carboniferous of Maxville, Ohio, collected by Prof. E. B. Andrews. and presented to me by Dr. T. Sterry Hunt, in which many crinoids and corals are beautifully injected with a greenish hydrous silicate resembling glauconite.

Mineralization of this kind is in reality greatly less complex than that in which, as in many fossil corals and fossil woods, the calcarerous or woody matter has been entirely removed and replaced by silica, oxyde of iron or pyrite. In many cases also in Palæozoic fossils the cavities have been filled with successive coats of different minerals giving very complex appearances. I have in my collection a specimen of Stigmaria in which every vessel has been coated in the interior with successive linings of red and white calcite, and subsequently filled with calcite and pyrite, and in a Sternbergia from the coal formation the phragmata are silicified and encrusted with crystalline silica and pyrite, while the interstices are filled in with sulphate of barium. Such complex and eccentric examples of fossilization are much more intricate than anything that occurs in the ordinary examples of Eozoon.

Geologists should also be reminded that porous fossils, once infiltrated with siliceous minerals, are practically indestructible. Nothing short of absolute fusion can wholly deface their structures, and these remain in many cases in the utmost perfection when the external forms have been wholly lost or inseparably united with the matrix.

There is therefore nothing anomalous in the preservation of Eozoon, except its occurrence in rocks highly crystalline and of unusually great age; and but for these circumstances it is probable that no doubt would have been entertained on the subject. The question of the crystalline structure of rocks containing fossils deserves, however, some further consideration.

That in limestones a crystalline condition is compatible with the preservation of fossils, and more especially with the preservation of their microscopic characters, is very well known. Many Palæozoic limestones are of a highly crystalline character, and yet retain abundant evidence of their organic origin. For example, the Chazy and Trenton limestones of the vicinity of Montreal have a perfectly crystalline fracture, and present to the naked eye no trace of any form but cleavage planes of calcite, yet, when sliced and studied with the microscope, they are seen to consist of organic fragments having their most minute structures preserved, but so completely enveloped and identified with the crystalline calcite which fills their pores and interstices that they cleave with it. It is to be observed also that in these limestones, instances occur in which organic fragments are inscribed in hexagonal crystals and might be mistaken for mere crystals containing impurities, did not these latter show on examination the original structures. Mesozoic and even Tertiary limestones have sometimes assumed the same conditions. That the Laurentian limestones holding Eozoon have undergone no change incompatible with the preservation of fossils, is proved by the fact that they still retain their original lamination, and present layers, often quite thin, of dolomite and calcite, and of the latter with various mixtures of serpentine, graphite, &c. Now there is no reason why the structures of any fossil should not survive when the lamination of the limestone remains.

Another example quite in point is that of some large calcified trees of the coal period. When broken, these trunks show large coarse cleavable crystals like those of stalagmite, but when sliced it is often found that the structure has been perfectly preserved in the midst of the crystallization.

That the laminæ of Eozoon themselves are in some cases replaced by dolomite, or partially by flocculent serpentine, is no argument against their organic nature. Stromatoporæ, shells and corals are often found to have their calcareous material wholly or in part replaced by other minerals, as dolomite, carbonate of iron, pyrite and silica. The replacement by the latter mineral more especially gives us many of our most beautifully preserved Palæozoic fossils. At Pauquette's Rapid on the Ottawa, among the numerous fossils found in a silicified state imbedded in the limestone, are many Stromatoporæ, and in these the layers are not merely filled but actually replaced with silica, which, while it retains the form of the laminæ is itself arranged in curious concretionary grains which might at first sight be mistaken for a part of the structure.

In the Silurian dolomite of Guelph in Ontario, specimens of Cœnostroma, replaced by perfectly crystalline dolomite, not only show their lamination, but in some cases even their fine canals. In the gray dolomite of Niagara, similar appearances are observed. In some places it is filled with masses of Stromatopora dispersed through the dolomite just as Eozoon is in the Laurentian limestone. These fossils are silicified and vary in diameter from a foot to an inch. The greater part are spheroidal in form, but some are cylindrical or club-shaped, while others spread into flat sheets or are of various irregular shapes. In many specimens, the structure is beautifully preserved; but in others it has partially disappeared, and the substance of the fossil is replaced by coarsely crystalline calcite or dolomite, or presents cavities lined with crystals of these minerals. There is reason to believe that many cavities in the limestone, now empty and coated with these crystals, were once occupied by Stromatoporæ, or by the species of sponge found in this limestone. In every respect, except in the absence of hydrous silicates, the mode of occurrence of these fossils resembles that of Eozoon at Côte St. Pierre.

In some such cases of replacement it is probable that the original material of the fossil was arragonite, and for this reason more easily removed or replaced. Every Palæontologist is familiar with the fact that arragonite or prismatic shell has been removed in cases where lamellar shell has remained, and the latter has sometimes disappeared when compact calcite shells, like those of Balanus, for example, have escaped. In the case of Eozoon, however, as in that of foraminifera in general, the calcite seems to have been of the less perishable kind, and this may be connected with the integrity of the calcareous wall in the better preserved specimens.*

By what appears to a palæontologist a strange perversion of reasoning, some of the opponents of the organic nature of Eozoon take the badly preserved specimens as typical, and suppose that these represent an original mineral condition, which in the better preserved specimens has only assumed its greatest perfection.

As I have often urged, this kind of argument would invalidate all reasoning from the structures of fossils. In all large masses of fossil coral or wood, we find portions in

* I have elsewhere remarked that the calcareous wall of Eozoon retains a *finely granular* texture, similar to that seen in shells, etc., in altered Palæozoic limestones.

all stages of disintegration. Sometimes the centre is a mere structureless mass, when the surface is perfectly preserved; Sometimes it is the surface that is disorganised. In other cases portions are well preserved, and others disintegrated in the most capricious manner. I have specimens of fossil coniferous wood in which portions are disintegrated along the medullary rays, giving the appearance of widely separated wedges, and others in which concentric bands are alternately preserved and destroyed, others in which irregular spaces have been eaten out and filled with structureless matter, and others in which crystalline or concretionary structures have been developed in spots, giving the most grotesque and inexplicable appearances. Yet in all these cases we have the general form of a trunk and portions of it in which the structures are preserved. In one example of silicified wood I have found regularly formed prisms of quartz deposited in rows along the woody fibres as if these had formed original parts of the structure. In fossil woods it is also very common to find the tissues compressed, folded and contorted in spots, so as to give the most unnatural possible appearances. Now in all such cases it is surely reasonable to take the well-preserved portion as the means of interpreting the rest, though I have known cases where, for want of attention to this, portions of woody tissue have been described as cellular, in consequence of their being disintegrated by the crystallization of quartz.

It is also to be observed that there is a gradation in the probability of the preservation of structures. A very finely tubulated structure, like that which is supposed to have constituted the proper wall of Eozoon, is rarely perfectly preserved. In modern foraminifera infiltrated with glauconite, we usually see their finer structures preserved only in spots, or a part of the length of the tubes only filled. The larger cells are often infiltrated when the tubuli are empty. A coarse canal system is more likely to be perfectly infiltrated. Further, in Tertiary Nummulites the fine tubes are often filled with calcite, while the glauconite has penetrated the coarser portions only. This is very well seen in the beautiful specimens from Kempfen in Bavaria. All this applies to Eozoon. The most difficult part to find is its proper wall. The coarser canals are often present without the finer. The coarser parts of the canals are sometimes filled with serpentine, when the finer branches are filled with calcite or dolomite. The cells and laminæ are sometimes quite manifest when the finer structures are absent. All this is in perfect harmony with the analogy of other fossils.

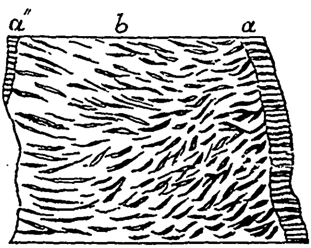


Fig. 5. Slice of single lamina of Eozoon, magnified. (*a*) Tubulated wall; (*b*) Canal system; both injected with Serpentine.

Eozoon also agrees with other fossils in the independence of its form with reference to the mineral matter with which the cavities may be filled. This peculiarity commended itself to the sagacity of Sir William Logan, and induced him to argue for the organic nature of Eozoon before its minute structures were known, and since these were investigated the argument has been much strengthened. The minerals serpentine, pyroxene and loganite are found filling the chambers, and the two former with dolomite and calcite occupy the canals, which often present calcareous fillings in the finer ramifications, when the main stems are occupied with serpentine. These facts are readily explained if we assume cavities and tubes of definite form to be filled with minerals according to circumstances; but they are not explicable on the supposition of a merely inorganic origin. They correspond perfectly with facts observed in the infiltration and replacement of all classes of fossils, which often occur in such a way that similar spaces are occupied in one part of the fossil with one mineral, in others with another.

In connection with this, the imperfections in the preservation of Eozoon are also parallel with those observed

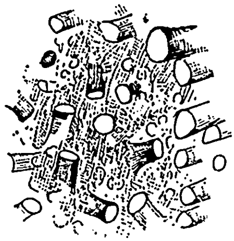

*Fig. 6. Cross section of canals, injected with serpentine, highly magnified.*

in different organic substances. As an example, I have already mentioned that in some of the specimens a white flocculent serpentine encroaches upon the calcareous walls or in part replaces them. This would indicate the partial removal of the calcite prior to or at the same time with the filling. In some cases also the calcite wall is wholly or in part replaced with dolomite. Such changes are not infrequent in Palæozoic fossils in which the substance of a calcareous part has often been wholly removed and replaced by another mineral or has been partially eroded and so in part replaced.

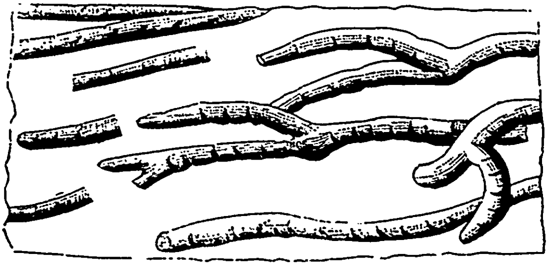

Fig. 7. Longitudinal section of canals, highly magnified.

There are other peculiarities deserving special notice:—

1. In some specimens the serpentine filling the chambers presents a laminated appearance, as if deposited in successive layers. There even occur serpentine-lined cavities and canals with calcareous filling. This may depend on the deposition of serpentine in coatings on the sides of those cavities, leaving perhaps a central portion to be filled with calcite, or may in some cases be the result of the filling of the cavities with successive laminæ of serpentine from below upward. In either case we have frequent examples of these varieties of filling in ordinary fossils.

2. There are examples of Eozoon in which no serpentine or other mineral filling appears, and in which the whole mass is calcareous, though presenting canals filled with serpentine or dolomite. In these cases the explanation is that the mass of Eozoon has not had its cavities filled, but has been compressed by pressure into a solid mass. Such a state of preservation is often observed in other fossils, more especially in fossil wood, in which the cell-walls often become under pressure wholly coalescent.

3. The condition of the proper wall also illustrates the manner of preservation. The tubes which compose it are so extremely fine that they are rarely injected with silicates. Sometimes they are merely occupied with calcite, and in this case the wall constitutes an apparently structureless band, or merely presents a band of slightly different appearance from the remainder. Sometimes the tubuli appear as fine continuations of the canals; or as a more or less perfect fringe of fine lines, and in decalcified specimens, this part is often represented merely by a tabular space between the ends of the canals and the serpentine filling. In the best specimens and in very thin slices under a high power, these tubuli appear as hollow threads with expanded terminations, but this is rarely to be seen. All these conditions may be equally well observed in Nummulites injected with glauconite.

4. The larger masses of Eozoon have often suffered considerable contortion and even faulting, and this seems to have occurred in some instances previous to complete fossilization. This is a condition often observed in fossils of all

ages, and every palæontologist is familiar with the fact that in all the older formations even the hardest calcareous fossils have been affected with accidents of this nature.

There are even a few examples in the collections which would seem to indicate that portions had been broken off, perhaps by the action of the waves, previous to fossilization. It is not unlikely that some of the specimens have been loose and subject to the action of the waves and currents before being imbedded.

5. An interesting feature in connection with the specimens of Eozoon from St. Pierre, noticed in previous papers, is the occurrence of layers filled with little globose casts of chamberlets, single or attached in groups, and often exactly resembling the casts of Globigerinæ in greensand. On weathered surfaces they were often especially striking when examined with the lens. In some cases, the chamberlets seem to have been merely lined with serpentine, so that they weather into hollow shells. The walls of these chamberlets have had the same tubulated structure as Eozoon ;

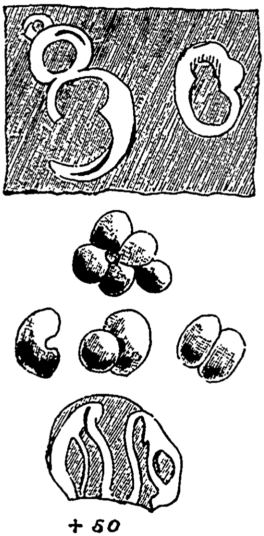

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Fig. 8. Sections and casts of detached chamberlets, magnified.

so that they are in their essential characters minute acervuline specimens of that species, and similar to those I described in my paper of 1867 as occurring in the limestones of Long Lake and Wentworth, and also in the Loganite filling the chambers of specimens of Eozoon from Burgess. Some of them are connected with each other by necks or processes, in the manner of the groups of chamberlets described by Gümbel as occurring in a limestone from Finland, examined by him. That they are organic I cannot doubt, and also that they have been distributed by currents over the surface of the layers along with fragments of Eozoon. Whether

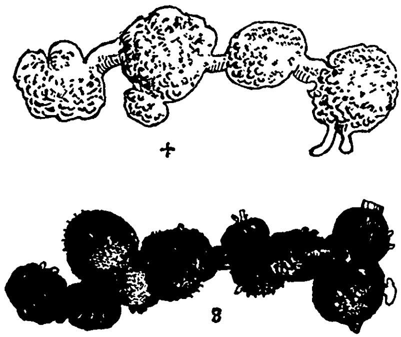

Fig. 9. Groups of chamberlets, Canada and Finland, magnified.

they are connected with that fossil or are specifically distinct, may admit of more doubt. They may be merely minute portions detached from the acervuline surface of Eozoon, and possibly of the nature of reproductive buds. On the other hand they may be distinct organisms growing in the manner of Globigerina. As this is at present uncertain, and as it is convenient to have some name for them, I have proposed to term them Archæosphærinæ, understanding by that name minute Foraminiferal organisms, having the form and mode of aggregation of Globigerina, but with the proper wall of Eozoon.

A specimen in the colleetions from Cote St. Pierre deserves notice (Fig. 11 *infra*) as illustrating the nature of Archæosphærinæ. It is a small or young specimen, of a flattened oval form, 2½ inches in its greatest diameter and of no great thickness. It is a perfect cast in serpentine, and completely weathered out of the matrix, except a small portion of the upper surface, which was covered with limestone which I have carefully removed with a dilute acid. The serpentinous casts of the chambers are in the lower part regularly laminated; but they are remarkable for their finely mammilated appearance, arising from their division into innumerable connected chamberlets resembling those of Archæosphærinæ. In the upper part the structure becomes acervuline, and the chamberlets rise into irregular prominences, which in the recent state must have been extremely friable, and, if broken up and scattered over the surfaces of the beds, would not be distinguishable from the ordinary Archæosphærinæ. This specimen thus gives further probability to the view that the Archæosphærinæ may be for the most part detached chamberlets of Eozoon, perhaps dispersed in a living state and capable of acting as germs. Other specimens weathered out and showing granular forms have been collected by Mr. E. H. Hamilton and are now in the Museum.

6. Specimens of Eozoon have been traversed by veins of chrysotile and calcite which cross all their structures indifferently, and often seriously affect their preservation. But similar accidents have affected fossils of every age, and especially those of the older and more altered rocks. The

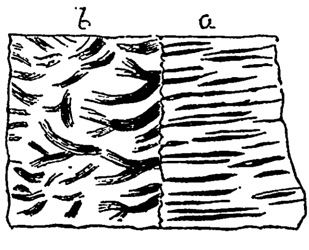


Fig. 10. Chrysotile vein crossing Eozoon, magnified. (*a*) Vein of fibrous Serpentine or Chrysotile; (*b*) Tubulation of Eozoon.

manner in which these veins cross the forms of Eozoon in truth present an additional proof that these are original enclosures in the limestone, and not products of any subsequent change.

7. In connection with this I would refer to a fact which I have often previously mentioned, namely, that the Laurentian limestones, when destitute of the laminated forms characteristic of Eozoon, are nevertheless often filled with small patches showing the minute structures. These I regard as fragments of Eozoon broken up and scattered by the currents. In this case, the remainder of these bands of limestone must be composed of fragments of other organisms which not being porous have not been so preserved by infiltration as to be distinguishable. In the original investigation of Eozoon, however, a great number of slices of these fragmental limestones were prepared by Mr. Weston the lapidary of the Geological Survey, and carefully examined, and though they showed no distinct structure except that of Eozoon, I felt convinced, and expressed this conviction in my original description, that these fragments presented such traces of structure as one is familiar with in metamorphosed organic limestones of more modern date.* At Côte St. Pierre there are several layers of limestone and dolomite studded with this fragmental Eozoon, and in specimens from Brazil, from Warren County, New York, and from Chelmsford in Massachusetts, and St. John, New Brunswick, the traces of Eozoon which I have observed consist of these fragments.

8. In slicing one of my specimens from Côte St. Pierre, I have recently observed a very interesting peculiarity of structure, which deserves mention. It is an abnormal thickening of the calcareous wall in patches extending across the thickness of four or five lamellæ, the latter becoming slightly bent in approaching the thickened portion. This thickened portion is traversed by regularly placed parallel canals of large size, filled with dolomite, while the intervening calcite presents a very fine dendritic tubulation. The longitudinal axes of the canals lie nearly in the plane of the ad-

* Especially the finely granular structure above referred to.

jacent laminæ. This structure reminds an observer of the *Cœnostroma* type of *Stromatopora*, and may be either an abnormal growth of Eozoon, consequent on some injury, or a parasitic mass of some stromatoporoid organism finally overgrown by the Eozoon. The structure of the dolomite shows that it first incrusted the interior of the canals, and subsequently filled them—an appearance which I have also observed in some of the larger canals filled with serpentine, and which is very instructive as to their true nature.

The above statements have reference to state of preservation, and are intended to remove misconceptions on that subject, but the mere fact of so many coincidences both in state of preservation and defects and imperfections between Eozoon and ordinary fossils, furnishes in itself, independently of other evidence, no small proof of its organic origin.

## II. NEW FACTS AND SPECIAL POINTS.

Under this heading, I shall summarize some of the previous statements, and add some special facts bearing on the character of the specimens and their interpretation.*

### (1.) *Form of Eozoön Canadense.*

Hitherto this has been regarded as altogether indefinite, and it is true that the specimens are often in great confluent masses or sheets, the latter sometimes distorted by the lateral pressure which the limestone has experienced. The specimen from Tudor, however, figured by Sir W. E. Logan in the *Quarterly Journal* of the Geological Society, 1867, p. 253, and that described by me in the "Proceedings of the American Association" in 1876, and figured in my work, "Life's Dawn on Earth," gave the idea of a turbinate form more or less broad. More recently additional specimens weathered out of the limestone of Côte St. Pierre have been

* Nos. 1 to 11 were read at the Meeting of the British Association, Sept. 5, 1387, and printed in part in *Geological Magazine*, February, 1888.

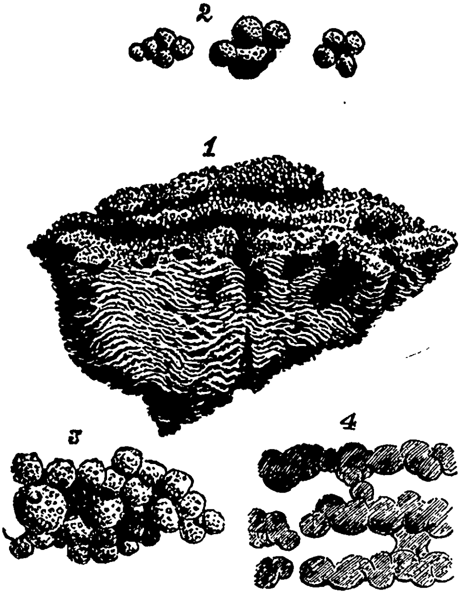


Fig. 11. *Eozoon Canadense.* (1) Small specimen disengaged by weathering. (2) Acervuline cells of upper part—magnified. (3) Tuberculated surface of lamina—mag. (4) Laminæ of Serpentine in section, representing casts of the sarcode—mag.

obtained by Mr. E. H. Hamilton, who collected for me at that place; and these, on comparison with several less perfect specimens in our collections, have established the fact that the normal shape of young and isolated specimens of *Eozoön Canadense* is a broadly-turbinate, funnel-shaped, or top-shaped form, sometimes with a depression on the upper surface giving it the appearance of the ordinary cup-shaped Mediterranean sponges. (Fig. 11.) These specimens also show that there is no theca or outer coat either above or below, and that the laminæ pass outwards without change to the margin of the form, where, however, they tend to coalesce by subdividing and bending together. The laminæ are thickest at the base of the inverted cone, and become thinner and closer on ascending, and at the top they become confounded in a general vesicular or acervuline layer. I feel now convinced that broken fragments of this upper surface scattered over the sea-bottom formed those layers of *Archæosphærinæ* which at one time I regarded as distinct organisms.

It is to be observed, however, that other forms of Eozoön occur. More especially there are rounded or dome-shaped masses, that seem to have grown on ridges or protuberances, now usually represented by nuclei of pyroxene.

### (2.) *Osculiform tubes.*

In the large number of specimens of Eozoön which have been cut or sliced in various directions, and are now in our museum at Montreal, it has become apparent that there are more or less cylindrical depressions or tubes, sometimes filled with serpentine and sometimes with inorganic calcite, crossing the laminæ at right angles. These seem to occur chiefly in the large and confluent masses, and are without any regular or definite arrangement. In some of the narrower openings of this kind the laminæ can be observed to subdivide and become confluent on the sides of these tubes, in the same manner as at the external surface. This circumstance induces me to believe that these are not accidental, but original parts of the structure, and intended to admit water into the lower parts of the masses. (See Frontispiece.) A central canal of a similar kind is well shown in the accompanying illustration.

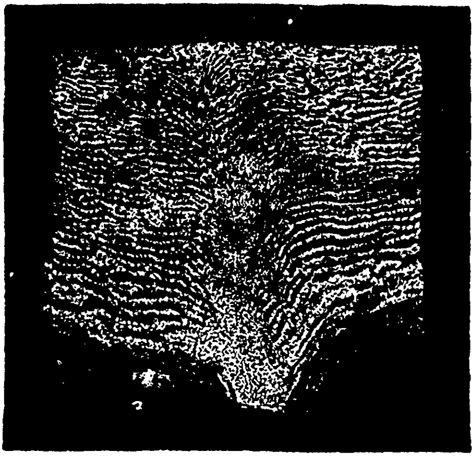

Fig. 12. Section of the base of a specimen of *Eozoon*. This specimen shows an osculiform, cylindrical perforation, cut in such a manner as to show its *reticulated wall* and the descent of the laminæ toward it. Two-thirds of natural size. From a photograph. Coll. Carpenter, also in Redpath Museum.

[This illustration (from Prof. Prestwich's "Geology," vol. ii., p. 21) has been courteously lent by the Clarendon Press, Oxford.]

## (3.) *Beds of Fragmental Eozoön.*

If Eozoön was an organism growing on the sea-bottom, it would be inevitable that it would be likely to be broken up, and in this condition to constitute a calcareous sand or gravel. I have already in previous pages noticed Laurentian limestones containing such fragments, from the Grenville band at Côte St. Pierre, from the Adirondack Mountains in New York State, from Chelmsford, Massachusetts, and from St. John, New Brunswick, as well as from Brazil and the Swiss Alps. Indeed, the Laurentian limestones of most parts of the world hold fragmental Eozoön. In the Peter Redpath Museum are some large slabs of Laurentian limestone sawn under the direction of Sir W. E. Logan, and showing irregular layers and detached masses of Eozoön with layers or bands of limestone and of ophiolite. These are evidently layers successively deposited, though somewhat distorted by subsequent movements. On selecting specimens from the white and more purely calcareous layers, I was pleased to find that they abound in fragments of laminæ of Eozoön, having the canals filled either with dolomite or with colourless serpentine. Other portions of the limestone show the peculiar granulated structure characteristic of the calcareous laminæ of Eozoön, but without any appearance of canals, which may in this case be occupied with calcite, not distinguishable from the substance of the laminæ. There are also indications in these beds of limestones of the presence of Eozoön not infiltrated with serpentine, but having its laminæ either compressed together, or with the spaces between them filled with calcite. There are other fragments which, from their minute structure, I believe to be organic, but which are apparently different from Eozoön.

### (4.) *Veins of Chrysotile.*

I have in previous pages noticed the fact that the veins of fibrous chrysotile which abound in serpentinous limestones of the Laurentian are of secondary aqueous origin, as they fill cracks or fissures not merely crossing the beds of the limestone, but passing through the masses of Eozoön and the serpentinous concretions which occur in the beds. They must, therefore, have been formed by aqueous action long after the deposition, and in some cases after the folding and crumpling of the beds. In this respect they differ entirely from the laminæ of Eozoön, which have been subject to the same compression and folding with the beds themselves.

The chrysotile veins have, of course, no connection with the structures of Eozoön, though they have often been mistaken for its more finely tubulated portion. With respect to this latter, I believe that some wrong impressions have been created by defining it too rigorously as a "proper wall." In so far as I can ascertain, it consisted of finely divided tubes similar to those of the canal system, and composed of its finer subdivisions placed close together, so as to become approximately parallel. (See Fig. 4 above.)

### (5.) *Nodules of Serpentine.*

Reference has been made in previous papers to the nodules and grains of serpentine found in the Eozoön limestone, but destitute of any structure. These nodules, as exhibited in the large slabs already referred to, have however often patches of Eozoön attached to or imbedded in them, and they appear to indicate a superabundance of this siliceous material accumulating by concretionary action around or attached to any foreign body, just as occurs with the flints in chalk. The layers and grains of serpentine parallel to the bedding appear to be of similar origin.

### (6.) *State of Preservation.*

Recent observations more and more indicate the importance and frequency of dolomite as a filling of the canals, and also the fact that the serpentine deposited in and around the specimens of Eozoon is of various qualities. Dr. Sterry Hunt has shown that the purely aqueous serpentine found in the Laurentian limestones is of different composition from that occurring with igneous rocks, or as a product of the hydration of olivine. There are, however, different varieties even of this aqueous serpentine, ranging in colour from deep green to white; and one of the lighter varieties has the property of weathering to a rusty colour, owing to the oxidation of its iron. These different varieties of serpentine will, it is hoped, soon be analysed, so as to ascertain their precise composition. The mineral pyroxene, of the white or colourless variety, is a frequent associate of Eozoon, occurring often in the lower layers and filling some of the canals. Sometimes the calcareous laminæ themselves are partially replaced by a flocculent serpentine, or by pyroxenic grains imbedded in calcite.

### (7.) *Other Laurentian Organisms.*

In a collection recently acquired by the Peter Redpath Museum, from the Laurentian of the Ottawa district, are some remarkable cylindrical or elongated conical bodies, from one to two inches in diameter, which seem to have occurred in connection with beds or nodules of apatite. They are composed of an outer thick cylinder of granular, dark-coloured pyroxene, with a core or nucleus of white felspar; and they show no structure, except that the outer cylinder is sometimes marked with radiating rusty bands, indicating the decay of radiating plates of pyrite. They may possibly have been organisms of the nature of *Archæocyathus*; but such reference must be merely conjectural.

### (8.) *Cryptozoum.*

The discovery by Prof. Hall, in the Potsdam formation of New York, and by Prof. Winchell in that of Minnesota, of the large laminated forms which have been described under the above name, has some interest in connection with Eozoon. I have found fragments of these bodies in conglomerates of the Quebec group, associated with Middle Cambrian fossils; and, whatever their zoological relations, it is evident that they occur in the Cambrian rocks under the same conditions as Eozoon in the Laurentian. I find also in the Laurentian limestones certain laminated forms usually referred to Eozoon, but which have thin continuous laminæ, with spongy porous matter intervening, in the manner of *Cyptozoum* or of *Loftusia.* Whether these are merely Eozoon in a peculiar state of preservation or a distinct structure, I cannot at present determine.

### (9.) *Continuity and Character of containing Deposits.*

At a time when so many extravagant statements are made, more especially by some German petrologists, respecting the older crystalline rocks, it may be proper to state that all my recent investigations of the part of system which I have called Middle Laurentian, especially in the district east of the Ottawa, vindicate the results of the late Sir William Logan as to the continuity of the great limestones, their regular interstratification with the gneisses, quartzose gneisses, quartzites, and micaceous schists, and their association with bedded deposits of magnetite and graphite, and also the regularity and distinctly stratified character of all these rocks. Farther, I regard the Upper Laurentian, independently of the great masses of Labradorite rock, which may be intrusive, as an important aqueous formation, characterised by peculiar rocks, more especially the anorthite gneisses. I am also of opinion that some of the crystalline rocks of the country west of Lake Superior are stratigraphically, and to a great extent lithologically, equivalent to the Upper Laurentian of St. Jerome and other places in the Province of Quebec, differing chiefly in the greater or less abundance of intrusive igneous rocks.

### (10.) *Imitative Forms.*

The extraordinary mistakes made by some lithologists in studying imperfect examples of Eozoon and rocks supposed to resemble it, and which have gained a large amount of currency, have rendered necessary the collection and study of a variety of laminated rocks, and considerable collections of these have been made for the Peter Redpath Museum. They include banded varieties of dolerite and diorite, of gneiss, of apatite and of tourmaline with quartz, laminated limestone with serpentine, graphic granites, and a variety of other laminated and banded materials, which only require comparison with the genuine specimens to show their distinctness, but many of which have nevertheless been collected as specimens of Eozoon. I do not propose to enter into any detailed description of these here, but may hope, with the aid of Dr. Harrington, to notice them in forthcoming Memoirs of Peter Redpath Museum.

It is easy for inexperienced observers to mistake laminated concretions and laminated rocks either for *Stromatopora* or for *Eozoon*, and such misapprehensions are not of infrequent occurrence. As to concretions, it is only necessary to say that these, when they show concentric layers, are deficient altogether in the primary requirements of laminæ and interspaces; and under the microscope their structures are either merely fragmental, as in ordinary argillaceous and calcareous concretions, or they have radiating crystalline fibres like oolitic grains. Laminated rocks, on the other hand, present alternate layers of different mineral substances, but are destitute of minute structures, and are either parallel to the bedding or to the planes of dykes and igneous masses. In the Montreal mountain there are beautiful examples of a banded dolerite in alternate layers of black pyroxene and white felspar. These occur at the junction of the dolerite with the Silurian limestone through which it has been erupted. Laminated gneissose beds also abound in the Laurentian. Still more remarkable examples are afforded by altered rocks having thin calcite bands, whether arising from deposition or from vein-segregation. One of these now before me is a specimen from the collection of Dr. Newberry, and obtained at Gouverneur, St. Lawrence County, New York. It presents thick bands of a peculiar granitoid rock containing highly crystalline felspar and mica with grains of serpentine; these bands are almost a quarter of an inch in thickness, and are separated by interrupted parallel bands of calcite much thinner than the others. The whole resembles a magnified specimen of *Eozoon*, except in the absence of the connecting chamber-walls and of the characteristic structures. A similar rock has been obtained by Mr. Vennor on the Gatineau; but it is less coarse in texture though equally crystalline, and appears to contain hornblende and pyroxene. These are both Laurentian, and I consider it not impossible that they may have been organic; but they lack the evidence of minute structure, and differ in important details from *Eozoon*. Another specimen from the Horseshoe Mountain in the Western States (I regret that I have mislaid the name of the gentleman to whom I am indebted for this specimen) is a limestone with perfectly regular and uniform layers of minute rhombohedral crystals of dolomite. The layers vary in distance regularly in the thickness of the specimen from two millimetres to one, and must have resulted from the alternate deposition in a very regular manner of dolomite and limestone. These are but a few of the examples of imitative structures which might readily be confounded with *Eozoon*, or which, if resulting from organic growth, have lost all decisive evidence of the fact.

Perhaps still more puzzling imitative forms are those referred to by Hahn, which occur in some felspars, and which I have found in great beauty in certain crystals of orthoclase from Vermont. They are ramifying tubes resembling the canal-system of *Eozoon*, and are evidently a peculiar form of gas-cavities or inclusions. Similar appearances are, however, often presented by the more minute and microscopic varieties of graphic granite, in which the little plates might readily be mistaken, in certain sections, for organic tubulation.

In the present state of knowledge, it is perhaps more excusable to mistake such things for organic structures than to deny the existence of true organic structures because they resemble such forms. Those who have examined moss-agates are familiar with the fact that while some show merely crystals of peroxide of iron or oxide of manganese, others present the forms of *Vaucheriæ* or *Confervæ*. So if one were to place side by side some fibres of asbestos, spicules of *Tethea*, and coniferous wood, preserved, like some from Colorado, as separate white siliceous fibres, they might appear alike; but, even if thoroughly mixed together, the microscope should be able easily to distinguish them. I have specimens of fossil wood, collected by Hartt in Brazil, which have been mineralized by limonite in such a manner that no one, without microscopic examination, could believe them to be other than fibrous brown hæmatite. Such difficulties the micro-geologist must expect to find, and by patient observation to overcome.

### (11.) *Alternation of Mineral Layers.*

It has been suggested by Mr. Julien* and others that Eozoönal structure may be due to the alternation of mineral layers formed in the passage-beds between concretions and other mineral masses, and their enclosing matrix. The objections to this view are:

1. Laminated passage-rocks and laminated concretionary forms have only simple laminæ, whereas *Eozoon* has connected or reticulating laminæ.

2. Laminated passage-rocks have no structure other than crystalline. *Eozoon* has beautiful tubulation in its calcareous walls, besides large tubes or oscula.

3. Sometimes (not usually) pyroxene is the siliceous part of *Eozoon;* or, as we hold, the mineralizing agent. More usually it is serpentine, sometimes loganite, or dolomite, or mere earthy limestone. It is not possible that all these minerals should assume the same forms.

4. Pyroxene and serpentine both occur in nodules and bands in the Laurentian limestones, and in most cases without any traces of *Eozoon*, while *Eozoon* occurs in the limestone remote from such nodules and bands, where no passage of any kind can occur, and presents distinct forms.

5. There are only two localities known to me, one in a quarry near Côte St. Pierre, and one at Burgess, where a bed with badly preserved *Eozoon* occurs in a manner which would even suggest such an idea. Pyroxene is present in the one case, and loganite in the other.

6. I have often thought of this suggested explanation, and have compared *Eozoon* with all sorts of banded and passage-rocks taken from the Laurentian and other formations, but have seen no reason to adopt such a view for *Eozoon*. I have accumulated in the Peter Redpath Museum at Montreal as above stated, a very large number of laminated and passage-rocks and concretions for purposes of comparison.

7. How on such an hypothesis can we explain the beds of limestone composed of or filled with fragments of *Eozoon?*

* Proceed. Amer. Assoc. vol. xxxiii. 1884, pp. 415, 416.

# "Ringed Trees."

By W. L. Goodwin, Queen's University, Kingston.

It is usually the case that a tree from which a complete ring of bark has been removed, dies within a year. Botanists teach that the continuity of the cambium layer at any part is essential to the life of all parts above. When the bark is removed, the cambium layer is torn asunder, and the part adhering to the tree as a slimy layer soon dries and decays. The tree may survive during the rest of the summer, but puts forth no leaves the next spring. In fact, I believe "ringed" trees *usually* survive the operation for some months, but on this point I should like to hear the testimony of those who have had experience of destroying trees in this way. It is a pretty well established fact that the circulation of the nutritive juices of a tree takes place mostly through the cambium, but that there are other channels for the sap is proved by the existence of the tree after it has been ringed. However, these subsidiary channels are evidently not sufficient to sustain life in the tree for more than a very limited period. As far as I know, only one exception to this rule has been recorded. A tree in the Botanical Gardens of Paris survived the operation for several years. I have to bring before the readers of the *Record of Science* another case which first came under my observation five years ago (the summer of 1883). It is a common pine tree, which had been ringed several years before I saw it—just how many, I could not ascertain. The tree stands at the edge of the pine woods of Studley, Halifax, Nova Scotia, and is one of two rising from a common trunk which bifurcates immediately above the surface of the soil. The trees are about twenty-two feet high, and begin to branch freely at about six feet from the ground. The ring is about four feet from the fork and is eight inches broad. The exposed wood is dead, and no signs of life appear within half an inch of the surface. Within that the wood seems to be living. That the tree has grown considerably since it was ringed is shown by the following measurements, made this summer:—

| | | |
|---|---|---|
| Circumference below ring | ................ | 19½ inches. |
| " above " | ................ | 26 " |

The diameter of the tree has thus become two inches greater above than it is below the ring. The condition of the bark and cambium layer below the wound shows that the surface of the tree has died for a considerable distance (over six inches.) Above the wound, the bark and cambium are living and seem to have pushed down over the scar about half an inch. The same process had been evidently begun below the ring before the death of the cambium layer.

From measurements made five years ago, I should judge that the tree must have been ringed at least ten years before that date, so that this tree has survived its injury probably fifteen years. Unfortunately the notes of the first measurement are not at hand for comparison. At that date the ringed tree seemed almost as thrifty as its companion, but the foliage showed some signs of imperfect nutrition. At present, the tree is in much poorer condition, many of the branches being dead and the foliage scanty on those that are living.

The problem is: How has the tree been nourished since it was ringed? Is it a case like that often occurring in surgical cases and depending on the anastomosis of arteries? Is it possible that the subsidiary channels of communication between the earth and the branches enlarged to meet the emergency for a time, but not sufficiently to allow the tree to live out its life.

Studley, Halifax, Sept. 1, 1888.

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[It is well known that the general nutrition of a tree is dependent upon the movement of fluids upward from the soil through the sap wood, in which the process of lignification has been developed in only a slight degree; while the formation of the new structure proceeds from tissues nourished by fluids contained in the living bark, and having a general downward direction of movement. In cases of girdling, the conductive sap wood becomes exposed to the atmosphere and dessication proceeds radially inward, while there is a simultaneous lignification of the same tissues radially outward. Both causes operate to destroy the conductive power, and, under ordinary circumstances, it therefore only becomes a question of time how long the tree will live. Generally a tree will put forth its leaves the second year, but die before the season is over.

Under very favorable conditions of growth, the girdle may be bridged over in season to save the tree. One case of this kind was brought under the notice of the present writer a few years ago, in which a willow tree had been girdled by mice for a distance of over a foot. Yet during the growth of the spring immediately following, new structure was pushed out from above in such a way as to form a bridge, which later united to the trnnk, and also several roots which struck the soil and established independent connection between it and the upper part of the tree. Similar reparation is known to have occurred in other cases, but it is usually found that the favorable conditions are great vitality and the presence of an excess of moisture.

The case cited above is an interesting and peculiar one. It is not susceptible of explanation upon the theory of anastormosing vessels. It may possibly be accounted for upon the ground that the outer layers of wood in becoming hard, dry and filled with air, thereby established a protective layer which prevented, or at least retarded, further change in that direction; while the necessarily reduced vital condition of the tree may have greatly retarded the ordinary lignifaction of the cells to such an extent as to render the continued passage of fluids, and thus a very slow rate of growth in the tree as a whole, possible. In such case, the final death of the tree could only be a question of time. and from the facts stated, it would appear that at the time of the last observation its end must have been near.—Ed.]

# On the Eozoic and Palæozoic Rocks of the Atlantic Coast of Canada in Comparison with those of Western Europe and the Interior of America.*

By Sir J. W. Dawson, LL.D., F.R.S., F.G.S.

(*Abstract.*)

The author referred to the fact that since 1845 he had contributed to the Proceedings of the Geological Society a number of papers on the geology of the eastern maritime provinces of Canada, and it seemed useful now to sum up the geology of the older formations, and make such corrections and comparisons as seemed warranted by the new facts obtained by himself and by other observers of whom mention is made in the paper.

With reference to the Laurentian, he maintained its claim to be regarded as a regularly stratified system, probably divisible into two or three series, and characterized in its middle or upper portion by the accumulation of organic limestone, carbonaceous beds, and iron ores on a vast scale. He also mentioned the almost universal prevalence in the northern hemisphere of the great plications of the crust which terminated this period, and which necessarily separate it from all succeeding deposits. He next detailed its special development on the coast of the Atlantic, and the similarity of this with that found in Great Britain and elsewhere in the west of Europe.

The Huronian he defined as a literal series of deposits skirting the shores of the old Laurentian uplifts, and referred to some rocks which may be regarded as more oceanic equivalents. Its characters in Newfoundland, Cape Breton, and New Brunswick were referred to, and compared with the Pebidian, &c., in England. The questions as to an Upper Member of the Huronian or an intermediate series, the Basal Cambrian of Matthew in New Brunswick, were discussed.

* Proc. Geolog. Soc., London.

The very complete series of Cambrian rocks now recognized on the coast-region of Canada was noticed, in connection with its equivalency in details to the Cambrian of Britain and Scandinavia, and the peculiar geographical conditions implied in the absence of the Lower Cambrian over a large area of interior America.

In the Ordovician age a marginal and submarginal area existed on the east coast of America. The former is represented largely by bedded igneous rocks, the latter by the remarkable series named by Logan the Quebec Group, which was noticed in detail in connection with its equivalents further west, and also in Europe.

The Silurian, Devonian, and Carboniferous were then treated of, and detailed evidence shown as to their conformity to the types of Western Europe rather than to those of America.

In conclusion, it was pointed out that though the great systems of formations can be recognized throughout the Northern Hemisphere, their divisions must differ in the maritime and inland regions, and that hard and fast lines should not be drawn at the confines of systems, nor widely different formations of the same age reduced to an arbitrary uniformity of classification not sanctioned by nature. It was also inferred that the evidence pointed to a permanent continuance of the Atlantic basin, though with great changes of its boundaries, and to a remarkable parallelism of the formations deposited on its eastern and western sides.

## The St. Lawrence Basin and the Great Lakes.*

J. W. Spencer.

(*Abstract.*)

### Establishment and Dismemberment of Lake Warren.

This is the first chapter in the history of the great lakes and is subsequent to the deposit of the upper boulder clay, and therefore the lakes are all very new in point of geological line. By the movements of warping of the earth's crust, as shown in the beaches—after the deposit of the later boulder clay—the lake region was reduced to sea level and there were no Canadian highlands northward of the great lakes. Upon the subsequent elevations of the continent beaches were made around the rising islands. Thus between Lakes Erie, Huron and Ontario a true beach is found at 1,690 feet above the sea, around a small island rising thirty feet higher. With the rising of the land, barriers were brought up about this lake region, producing lake (or perhaps gulf of) Warren—a name given to the sheet of water covering the basin of all the great lakes. A succession of beaches of this lake have been partially worked out in Canada, Michigan, Ohio, Pennsylvania and New York, covering many hundreds—almost thousands—of miles. Everywhere the differential uplift has increased from almost zero about the western end of the Erie basin to three, five, and, in the higher beaches, from five to nine feet per mile. With the successive elevations of the land, this lake became dismembered, as described in the succeeding papers—and the present lakes had their birth. The idea that these beaches in Ohio and Michigan were held in by glacial dams to the northward, is disproved by the occurrence of open water and beaches to the north, which belong to the same series, and by the fact that outlets existed where glacial dams are required.

The Erie basin is very shallow, and, upon the dismemberment of Lake Warren, was drained by the newly

* Proc. of Am. Ass. Adv. of Sc.

constructed Niagara River, except, perhaps, a small lakelet southeast of Long Point. Subsequently, the northeastward warping (very much less in quantity than out farther northward at the Trent outlet) eventually lifted up the rocky ledge and formed Erie into a lake in recent times; thus Erie is the youngest of all the lakes. The beaches about Cleveland are not those of separated Lake Erie, but belong to the older and original Lake Warren.

## Discovery of the Ancient Course of the St. Lawrence River.

Previous investigations by the author showed that there was a former river draining the Erie basin and flowing into the extreme western end of Lake Ontario, and thence to the east of Oswego, but no further traceable, as the lake bottom rose to the northeast. Upon the southern side there was a series of escarpments (some now submerged) with vertical cliffs facing the old channel. By recent studies of the elevated beaches it is demonstrated that the disappearance of this valley is due to subsequent warpings of the earth's crust, and that the valley of the St. Lawrence was one with that of Lake Ontario. Recent discoveries of a deep channel upon the northern side of Lake Ontario (a few miles east of Toronto) and of the absence of rocks to a great depth in the drift below the surface of Lake Huron, between Lake Ontario and the Georgian Bay, and in front of the Niagara escarpment between these lakes; of the channel in Georgian Bay, at the foot of the escarpment, and of the channel across Lake Huron, also at the foot of a high submerged escarpment across that lake, show that the ancient St. Lawrence, during a period of high continental elevation, rose in Lake Michigan, flowed across Lake Huron and down Georgian Bay, and as drift filled the channel to Lake Ontario, thence by the present water to the sea—receiving on its way the ancient drainage of the Erie basin and other valleys.

The paper awakened a warm discussion, in which Professors Cook, Newberry, Wright, Winchell, McGee and

Hitchcock took part. The author's conclusions were upon observed facts in the field, some of which ran against some extreme forms of the glacial theory.

### Discovery of the Outlet of the Huron—Michigan—Superior Lake and Lake Ontario by the Trent Valley.

With the continental rise described in the last paper—owing to the land rising more rapidly to the northeast—Lake Warren became dismembered, and Huron, Michigan and Superior formed one lake; the Erie basin really was lifted out of the bed of Lake Warren and became drained, and Ontario remained at a low level. The outlet of this lake was southeast of Georgian Bay, by way of the Trent valley, into Lake Ontario (at about sixty miles west of the present outlet of this lake). The waters of this upper lake were twenty-six feet deep over this outlet into the Trent valley, and long continued to flow through a channel from one to two miles wide. It has cut across a drift ridge to a depth of 500 feet, as the whole area has been rising. With the continued continental uplift to the northeast (which has raised the old beach at the outlet about 300 feet above the present surface of Lake Huron) the waters were backed southward and overflowed into the Michigan basin and into the Erie, thus making the Erie outlet of the upper lakes to be of recent date. This is proven by the fact that the Georgian beach which marked the old surface of the upper great lake descends to the present water level at the southern end of Lake Huron, and is beneath the surface of the water upon its southwestern side, as the uplift, which has been measured, was to the northeast.

The two questions involved are "origin of the valleys" and "cause of their being closed into water basins." The basins of Lakes Ontario and Huron are taken for consideration. The previous paper upon the course of the ancient St. Lawrence shows that the Huron and Ontario basins are sections of the former great St. Lawrence valley, which was bounded, especially upon the southern side, by high and precipitous escarpments, some of which are submerged. But upon their northern sides there are also lesser vertical escarpments, now submerged, with walls facing the old valley. The valley was excavated when the continent was at a high altitude, for the eastern portion stood at least 1,200 feet higher than at present, as shown by the channels in the lower St. Lawrence, in Hudson's straits, and in the New York and Chesapeake bays. The valley was obstructed in part by drift, and in part by a north and northeastward differential elevation of the earth's surface, due to internal movements. The measurable amount of warping defied investigation until recently, but now it is measured by the amount of uplift of beaches and sea cliffs. Only one other explanation of the origin of the basins has been given—the "Erosion by Glaciers." (a) Because the latter occur in glaciated regions. (b) That the glaciers are considered (by some) to erode. (c) The supposed necessity, as the terrestrial warping was not known.

In reply: Living glaciers abrade, but do not erode, hard rocks, and both modern and extinct glaciers are known to have flowed over even loose moraines and gravels. Again, even if glaciers were capable of great plowing action, they did not affect the lake valleys, as the glaciation of the surface rocks shows the movement to have been at angles (from 15° to 90°) to the direction of the side of the vertical escarpments against which the movement occurred. Also the vertical faces of the escarpments are not smoothed off, as are the faces of the Alpine valleys, down which the glaciers have passed. Lastly, the warping of the earth's surface in the lake region, since the beach episode, after the deposit of the drift proper, is sufficient to account for all rocky barriers which may obstruct the basins.

## THE STUDY OF MINERALOGY.

By T. STERRY HUNT, LL.D., F.R.S.

(*Abstract.*[1])

§ 1. Our knowledge of the inorganic kingdom, as seen in this earth, may be comprehended under geography, geology and mineralogy; the latter in its wider sense including all non-organised forms of matter, with their whole dynamical[2] (physical) and chemical history. In didactic language, however, minerology is limited to the study of native species, and includes a knowledge aliko of their external characters and their chemical relations. The so-called natural-history method in mineralogy, disregarding these latter, is based exclusively on specific gravity, hardness, optical characters, texture and structure, including crystallization; while the chemical method regards the results of chemical analysis alone, and mixed methods consider these in connection with crystallization, and even endeavour to take into account other physical characters. The defects of all the methods hitherto devised are obvious, and no system of classification can be complete which does not assign a value and a place to all characters whatsoever. There exists in the nature of things such an interdependence of these, that

[1] Read before the British Association for the Advancement of Science, Bath, 1888.

[2] We use the words dynamics and dynamical in the sense in which they are employed by Thomson and Tait in their treatise on *Natural Philosophy*, wherein all those manifestations of force which are neither chemical nor vital (biotic), including, besides ordinary motion, the phenomena of sound, temperature, radiant energy, electricity and magnetism, are embraced under the general title of Dynamics, corresponding to what in popular language is designated Physics. Other eminent students of our time have sanctioned this use of the term dynamics, in which they were to a certain extent anticipated by Berzelius, who in 1842 included electricity, magnetism, light and heat—all of which he regarded as affections of matter, and compared their phenomena with those of sound—under the common term of Dynamides. (See Hunt, *Mineral Physiology and Physiography*, p. 13.)

a true natural system can exclude none. To the establishment of such a system, a clearer view of the nature and relations of physical and chemical phenomena than that generally received will materially aid us.

§ 2. Matter is susceptible of changes of volume of two kinds. (1) Those produced from without, by variations of temperature and of pressure, which changes are constant and regular. Effecting no essential alteration in species, they may be called *extrinsic* or, as the result of external dynamic agencies, *mechanical* changes. (2) Those which have been described as due to "internal disturbances," which effect specific alterations in character. These constitute *chemical* or what may be called *intrinsic* changes, and differ from the last in that, instead of being constant and regular, they are periodic and subordinated to definite and unforeseen relations of volume. Intrinsic changes of volume in matter connote chemical as distinguished from dynamical processes. In chemical union we have intrinsic contraction or condensation (variously designated as interpenetration, compenetration, identification, integration, unification); and in chemical decomposition, intrinsic expansion or division. These changes may be either homogeneous, involving one species of matter, or heterogeneous, involving two or more species. The first includes so-called polymerization and depolymerization, which may be described as homogeneous intrinsic union and homogeneous intrinsic division; constituting what we have called collectively *chemical metamorphosis.* Those intrinsic changes which involve two or more species we have included under the title of *chemical metagenesis;* the process being one of heterogeneous intrinsic union or of heterogeneous intrinsic division. In the former, intrinsic contraction involves volumes of unlike species, and in the latter, intrinsic expansion resolves a species into two or more unlike species. The relations to volume of all such changes are most simple and evident in the case of gases and vapours; but the same laws of intrinsic contraction and expansion by volumes apply alike to gases and to the liquid and solid species formed by their condensation. In all of these chemical changes temperature and pressure play an important part, and, beyond certain limits the intrinsic or dynamic changes thereby produced, themselves provoke chemical changes. These in their turn are accompanied by thermic changes, the study of which is the object of thermo-chemistry.

§ 3. All chemically stable forms of matter may theoretically, by sufficient elevation of temperature, assume, even under the greatest pressure, a gaseous condition; the more or less dense polymeric vapours thus produced being subject to intrinsic expansion or depolymerization on diminution of pressure. By reduction of temperature these pass, as may be seen under favourable conditions, through successive polymerizations, or processes of intrinsic contraction, into liquid (or solid) species; the passage from the vapour to the liquid being apparently continuous. The ideal gas is wholly obedient to the dynamic influence of pressure, according to Boyle's law, to which the ideal solid is wholly indifferent. These ideal forms are, however, constant only within certain limited ranges of temperature and pressure, beyond which even the so-called permanent gases become liquid or solid by intrinsic changes.

The regularity of the extrinsic variations in volume for gases and vapours, within certain known limits, enables us for such bodies to determine their specific gravity, for which purpose atmospheric air at 0° and 760 mm. is taken as unity. If for this we substitute hydrogen gas represented as $H_2$=2·0), the lightest body known, at the same temperature and pressure, the specific weight of an equal volume of any given vapour or gas, calculated for this standard temperature and pressure, is its equivalent weight, or in the language of the popular hypothesis, the molecular weight of the species. Extending the same method from normal gases and vapours to polymeric vapours, and thence to liquids and solids, and remembering that none of these forms are stable beyond certain ranges of temperature and pressure, we proceed to determine the specific gravity of all such bodies in terms of the same gaseous unit; the number thus obtained being for each body its equivalent weight. We thus find, as has long been suspected, that the equivalent (or so-called molecular) weights of liquid and solid species are exceedingly elevated. That of water, a litre of which at 100° (its temperature of formation under a pressure of 760 mm.) weighs 958·78 grams, corresponds to 1192 volumes of water vapour at standard temperature and pressure ($H_2O$=17·96) condensed into a single volume; or to 1192 × 17·96=21,408, approximately 21,400. Representing by $p$ the empirical equivalent weight, which is really the specific gravity on the hydrogen basis ($H_2$=2·0), and by $d$ the specific gravity taking water =21,400 as unity, we obtain by the formula $p \div d = v$, the reciprocal of the coefficient of the condensation which takes place in the passage of a normal gaseous species, by intrinsic contraction or polymerization, into the liquid or solid species, the specific gravity of which we have determined by comparison with water.

§ 4. The reciprocal number thus got is, as we shall show, one of great significance. In determining the specific weight of any given liquid or solid species, the fact of prime importance is not simply its specific gravity as compared with water, but the relation of the value thus determined to the equivalent weight, or, in other words, to its specific gravity on the hydrogen basis. It is not $d$, nor yet $p$, but the relation $p : d$, as expressed by $v$. In the case of volatile species the true value of $p$ may be known, but for the comparison of fixed solids, as oxyds, carbonates, and silicates, we deduce from the received formulas an arbitrary value for $p$ by dividing the value calculated therefrom by twice the number of oxygen portions. Thus for MgO, $p=40 \div 2$; for $SiO_2$, $p=60 \div 4$; for $Al_2O_3$, $p=102 \div 6$; for $SiMg_2O_4$, $p=140 \div 8$; for $CCaO_3$, $p=100 \div 6$. For metalline minerals, including metals, and their compounds, with S, Se, Te, As, Sb, Bi, the value assumed for $p$ is that got by dividing the empirical equivalent weight by the sum of the valencies.

While the specific gravity of liquid and solid species is represented by $d$, the hardness, infusibility and insolubility or resistance to chemical change are, for related species, *directly as the condensation, or inversely as the value of v.* This may be seen in comparing colourless ordinary phosphorus, $v$=17·2, with the metalloidal form, $v$=13·2; the isomeric silicates, meionite, $v$=6·5, and zoisite, $v$=5·3; or calcite, $v$=6·2, with dolomite, chalybite and diallogite, $v$=5·2, and with magsenite and smithsonite, $v$=4·7; for aragonite, $v$=5·55. These examples will serve to show the relations between sensible characters and chemical constitution, the interdependence of which must be taken into account in a natural system of mineralogical classification. The differences in hardness and in solubility of the different species just named are familiar to chemists. The behaviour of native silicates with fluorhydric acid, lately studied by J. B. Mackintosh, illustrates in a striking manner the relations between condensation and solubility.

§ 5. The successive forms imposed upon matter gives us the order in which such a system of mineralogy should be built up. First, the form which we may call the *chemical form* of the species, either elemental or compound, due to the unknown stochiogenic process, or to subsequent chemical metagenesis. Second, what may be called the *mineralogical form*, which involves the greater or less intrinsic contraction (polymeric condensation) of the normal chemical species—often gaseous or volatile, but frequently unknown to us—and the assumption by it of a liquid or solid state, having greater or less specific gravity, hardness, fixity and insolubility, and being metallic or non-metallic, colloidal or crystalline. Third, the *crystalline form*, being the geometric shape assumed by the crystalline individual, which connotes a certain structure, apparent in the cleavage, the varying hardness, and the thermic, optical and electrical relations, of the crystal, but is, notwithstanding its value in determinative mineralogy, the least essential or most accidental form of the mineral species. The significance involved in the note of metallicity is very apparent when we consider the metallic and non-metallic conditions of selenium and of phosphorus, the similar dual conditions of the sulphide of mercury and antimony, the non-metallic and sparry characters of the native sulphids of zinc, cadmium and arsenic, and the singular metallic character assumed by the complex tungstates or Tungstometalloids, known as tungsten bronzes. These, with the not less remarkably complex soluble tungstates or Tungstosalinoids, and the native tungstic species, make the Tungstates one of the most instructive orders known.

§ 7. The author has elsewhere proposed to divide the mineral kingdom into four classes, including (1) Metalline, (2) Oxydized, (3) Haloid, (4) Pyricaustate (combustible or fire-making) species. Each of these classes is again divided into orders, tribes, genera and species. In the first class a single order includes two sub-orders and nine tribes, named (1) Metalloideæ; (2) Galenoideæ, including three sub-tribes corresponding to sulphur, selenium, and tellurium compounds; (3) Bournonoideæ; (4) Pyritoideæ; (5) Smaltoideæ; (6) Arsenopyritideæ; (7) Spatometalloideæ; (8) Sphaleroideæ; (9) Proustoideæ; each tribe including one or more genera. Again, in the second class are grouped under different orders, Oxyds, Silicates, Carbonates, Borates, Sulphates, Phosphates, Tungstates, &c. Three sub-orders of silicates include protoxyd, protoperoxyd and peroxyd silicates; among peroxyd bases being reckoned aluminic, ferric, manganic, chromic, bismuthic, and also, for special reasons, zirconic oxyd. Recognising in each sub-order various types designated Hydrospathoid, Spathoid, Adamantoid or gem-like, Phylloid or micaceous, and Porodic or colloidal; the tribes may be named Pectolitoid, Willemoid, Amphiboloid, Talcoid, Ophitoid, Zeolitoid, Feldspathoid, Granatoid (garnet-like), Micoid, Pinitoid, Perzeolitoid, Eulyioid, Topazoid, Pyrophilloid and Argilloid. Soluble saline species in any order are referred to a salinoid type, as Borosalinoid, Tungstosalinoid. The extension of this system to the Haloid and Pyricaustate classes is easy, and has been elsewhere explained.

The work of arranging in genera and species, with a Latin binomial nomenclature, and the determination for each species of the value of *v*, is now nearly complete for the first two classes; and the whole will probably soon appear, with a proper introduction, as a Systematic Mineralogy, to be followed by a Descriptive Mineralogy. The general principles here set forth are discussed at length in the author's "Miner Physiology and Physiography" (Boston, 1886), pp. 279-401, where, in a chapter entitled "A Natural System in Mineralogy," will be found an examination of the constitution and relations of the known natural silicates arranged in tribes, and tabulated, with the calculated values of *v*, and a new quantivalent chemical notation. See farther, a paper on "The Classification and Nomenclature of Metalline Minerals,"[1] discussing Class I, in the "Proceedings of the American Philosophical Society" for May 4, 1886, and in the *Chemical News*, August 10 and 27; also the author's "New Basis for Chemistry," 2nd edition (Boston, 1888), where, in chapters vii. and xiv., many points in the proposed mineralogical classification are elucidated.

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## Mineralogical Evolution.[2]

By T. Sterry Hunt, LL.D., F.R.S.

(*Abstract.*[3])

In a paper read by the author in 1887, before the Geological Section of the British Association for the advancement of Science, on The Elements of Primary Geology, it was said that the "transformation of the primitive igneous material of the earth's crust through the action of air and water, aided by internal heat, presents a mineralogical evolution not less regular, constant, and definite in its results than the evolution apparent in the organic kingdoms." The details of this complex evolutionary process,

[1] An abstract of this paper, printed in the programme of the Royal Society of Canada, without revision or correction by the author, will be found in the *Chemical News* for June 29, 1888.

[2] Read before the British Association for the Advancement of Science, Bath, 1888.

[3] *Transactions*, p. 704; also *Geological Magazine*, November, 1887.

as explained by what the writer has named the crenitic hypothesis, have been elsewhere set forth at length, on more than one occasion, and involve the whole chemical history of the various mineral species which enter into the constitution of rock-masses, but especially their relations to subterranean changes under the influence of heated water, and to atmospheric action. As we have pointed out, the transformation of basalt into the hydrous porodic body known as palagonite, and the subsequent partial conversion of this into a crystalline zeolite, as described by Bunsen, furnishes a significant illustration of the process under consideration.

The stability of silicated species under atmospheric influences is very variable, some being readily decomposed, and others very permanent; the indifference or chemical resistance, moreover, increasing with the hardness or mechanical resistance. These two qualities vary for species of analogous constitution directly as their condensation; while for species of similar condensation and hardness, the chemical indifference increases as alumina takes the place of the ordinary protoxyd-bases, lime, magnesia, ferrous oxyd and alkalies—a fact readily explained by the comparative insolubility of alumina and aluminous silicates in atmospheric waters. The less partial action of dilute fluorhydric acid on the various silicates shows more clearly than the atmospheric process, the relation of condensation to chemical indifference. This relation may be made evident by a few examples. The condensation being inversely as the so-called atomic volume, we find that when calculated by a simple formula (elsewhere given by the author) for all silicates and oxyds, this value, represented by $v$ $(=p \div d)$ for the various feldspars and scapolites, for nephelite, iolite, and petalite, equals 6·8–6.2; for the muscovitic or non-magnesian micas, 5.9–5·6; for garnet, epidote, zoisite, and the various tourmalines, 5·4–5·3; for staurolite and spodumene, 4·9; and for andalusite, topaz, fibrolite, and cyanite, 5·0–4·5, approximately. Comparing with these the common protoxyd-silicates, we find for wollastonite and willemite, $v=6 \cdot 6$; for amphibole, 5·9; for pyroxene and enstatite, 5·5; for chrysolite, 5·4–5·3; and for phenakite, 4·6. In the sub-aerial decay of crystalline rocks, while feldspars and scapolites among aluminiferous silicates are kaolinised, the micas, notwithstanding their laminated structure, are much less readily changed; and garnet, epidote, tourmaline, andalusite, and topaz are found unaltered with the quartz, corundum, spinel, cassiterite, and magnetite left behind by the decay of the feldspathic rocks—a process in which even amphibole, pyroxene, and chrysolite share. "The greater stability of those [silicates] which belong to the more condensed types is shown in their superior resistance to decay, and is thus of geological significance."

While the above are examples of the varying resistance to the atmospheric influences of carbon dioxyd and water combined, other changes less well known take place in silicates by the subterranean action of watery solutions, where a greater insolubility determines the formation of certain softer hydrated magnesian and aluminous species by epigenesis from harder and more condensed species. The production of these epigenic products, as was said in 1885, is due to their "chemical stability under the circumstances," and it was added, "The constancy in composition and the wide distribution of pinite show that it is a compound readily formed and of great stability." Such being its character, it might be expected to occur as a frequent product of the aqueous changes of other and less stable silicates. It is met with in veinstones in the shape of crystals of nephelite, iolite, scapolite, feldspars, and spodumene, from each of which it is supposed to have been formed by epigenesis. Its frequent occurrence as an epigenic product is one of the many examples to be met with in the mineral kingdom of "the law of the survival of the fittest." It is, however, difficult to assign such an origin to beds of this (described as dysyntribite and parophite), which are probably the results of original deposition or of diagenesis.

Mr. E. A. Ridsdale, who during the present year (1888) has done good service by publishing a suggestive essay called "Notes on Inorganic Evolution," speaks of the production and conservation of more stable species, as above described, as a gradual "selection of inert forms," and further, as "a survival of the most inert." But as inertness consists in stability, and in fitness to resist alike the chemical and the mechanical agencies which destroy other species, it is evident that this phraseology is but another statement of the formula of "the survival of the fittest."

The great principle of the change of the mineral matters which existed in former conditions of our planet, into other forms more stable under the altered conditions of later ages, is but an extenston to the mineral kingdom of the laws already recognised in astronomical and biological development. As was written in 1884, "That a great law presided over the development of the crystalline rocks was from the first my conviction, but until the confusion which a belief in the miracles of metamorphism, metasomatism, and vulcanism had introduced into geology had been dispelled, the discovery of such a law was impossible." To this we may add that "the great successive groups of stratiform crystalline rocks mark necessary stages in the mineralogical evolution of the planet;" and that the principles which we have elsewhere laid down will help us "to recognise the existence and the necessity of an orderly lithological development in time." The reader who desires to follow the questions here raised will find them discussed in the author's "Mineral Physiology and Physiography," (Boston, 1886,) at much length, in chapters v., vi., vii. and viii., and further noticed in the Appendix, p. 688, where will be found references to previous pages here cited.

## Autumn Field Day.

For the first time in its history, the Natural History Society this year instituted a new departure in its annual excursions, by providing an Autumn Field Day. The Society, however, is under great obligations to Mr. Gibb for causing it to adopt such a popular course, since it was his earnest and most cordial invitation to accept the hospitality of his country residence, that brought about such a result.

The Field Day was held on the 29th of September. The excursionists, to the number of one hundred twenty, proceeding to Abbotsford *via* the Canada Pacific, and there found a most hospitable welcome and an abundant provision for all their wants. Immediately upon arrival the various announcements for the day were made, after which the party had abundant opportunity to inspect the large and valuable orchards in the immediate vicinity, where, thanks to the energy of Mr. Gibb, a centre of fruit culture is gradually being built up, which is destined to produce an important influence upon the fruit industry of this Province. Mr. Gibb himself has a large number of important varieties of Russian apples, and also a valuable collection of ornamental and forest trees, the adaptability of which, to this climate, he is endeavoring to determine.

After a bountiful lunch, the excursionists distributed in various directions under the leadership of Sir Wm. Dawson, Prof. Penhallow, Mr. Holden, Mr. Gibb and others. The largest party proceeded to the summit of Yamaska Mountain, whence a most extended view of the surrounding country was obtained, and where Sir Wm. Dawson delivered an address upon the peculiar geological features of the vicinity.

The collections made were chiefly geological, although a number of interesting botanical specimens were brought in, amongst others various species of Lycopodium, Agaricus, Aster; a number of ferns and Geranium Robertianum. On re-assembling at the house, addresses on the Natural History of the locality, were made by Sir Wm. Dawson and Prof. Penhallow, and a vote of thanks tendered Mr. Gibb by Prof. Bovey.

The day was fine, notwithstanding a snow-storm on the summit of Mount Yamaska, and the party returned to the city with the feeling that it had been a day of much pleasure and great profit.