Sir J. W. Dawson F.R.S. &c
with the authors'
respectful compliments

[October, 1894.]

THE

SCIENTIFIC TRANSACTIONS

OF THE

ROYAL DUBLIN SOCIETY.

VOLUME V. (SERIES II.)

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EOZOONAL STRUCTURE OF THE EJECTED BLOCKS OF MONTE SOMMA.

By PROF. H. J. JOHNSTON-LAVIS, M.D., M.R.C.S., B-ès-Sc., F.G.S., &c., and
J. W. GREGORY, D.Sc., F.G.S.

Plates XXX. to XXXIV.

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[COMMUNICATED BY PROFESSOR GRENVILLE A. J. COLE, F.G.S.]

[Read April 18, 1894.]

Part I.—Introduction.

The belief in the organic origin of the structure known as *Eozoon canadense* was based on four points—(1) The interlamination of successive, irregular, lobulated layers of a calcareous and a magnesian mineral (usually calcite and serpentine).* (2) The occurrence in the limestone bands of certain fibrous and radiating minerals identified as the casts of organic canals. (3) The connection of the serpentine layers by pillar-like rods, stretching across the calcareous layers, much as the stolen passages connect the different body-chambers of a foraminifera. (4) The fact that the serpentine and calcite layers are often separated by a thin layer composed of numerous short columns or fibres presenting an appearance such as would be assumed by the injection of the "proper wall" or "nummuline layer" of a foraminifera.

But with more detailed study many features have been observed wholly inconsistent with the foraminiferal or even the organic origin of each of these four structures; and it is probably no exaggeration to say that as large a majority of geologists now pronounces against the organic origin of Eozoon as once did in its favour. Even the late Dr. W. B. Carpenter finally † admitted that each of these four structures could be paralleled in the mineral kingdom, though he claimed that their association was proof of an organic origin.

The main credit for this change of front is unquestionably due to two Irish geologists, Profs. King and Rowney, of Queen's College, Galway. At a time

* The asserted claims of the occurrence of Eozoon preserved in carbonate of lime alone, which are based on the Tudor specimen, need not be here considered, since its recent redescription by one of us: J. W. Gregory, "The Tudor Specimen of Eozoon," Quart. Journ. Geol. Soc., vol. xlvii., 1891, pp. 348–355, pl. facing p. 354.

† Whitney and Wadsworth, "The Azoic System," Bull. Mus. Comp. Zool. Cambridge Man., vol. xi., 1884. p. 535; and J. W. Gregory, "Eozoon Canadense: the Pseudo Dawn of Life," Science Gossip, vol. xxiii., 1887, pp. 103, 104, footnote.

when Eozoonism was triumphant they first raised serious protest against *its truth*, and in a long series of masterly memoirs published in the Quarterly Journal of the Geological Society, the Transactions of the Royal Irish Academy, and elsewhere, they demonstrated that Eozoon was not organic in its origin. Their destructive criticism seems to us to have been complete and unanswerable, but their attempt to explain its method of formation was not so successful. Their theory may be thus summarized, using their terminology :—Eozoon is due to the methylotic alteration of a laminated hermithrene; that is to say, the alteration including replacement of material of a crystalline limestone containing layers of pyroxene or peridote. Merrill * has urged a very similar view, attributing Eozoon to the alteration of a pyroxene limestone, though by metasomatic instead of methylotic processes. Gratacap † has also described a similar Eozoonal rock, the serpentine of which he regards as formed from hornblende. Profs. Sollas and Cole ‡ have removed the difficulty of regarding the serpentine as formed from either pyroxenes or amphiboles by the suggestion that the parent rock may have been formed by the deposition of alternate layers of grains of limestone and olivine around the shores of a reef-bound volcanic island. Neither of these theories explain many fundamental points in the structure of Eozoon; they may account for the lamination of the two minerals, but not for the remarkable regularity of the layers combined with one peculiar variation: they give no help in explaining the lenticular or spheroidal shape of the Eozoonal masses, or of the gradual decrease in thickness from the strong and persistent layers at the periphery of the specimens to the attenuated and scattered flecks of the "acervuline" layer. Nor did any of them account for the fact that the typical Eozoonal nodules occur enclosed in a rock of which a white pyroxene is the leading constituent.

The mere interlamination of two minerals is such a common occurrence among rocks which are unquestionably inorganic, that but little value would be attached to this point alone, and it is only the mode of formation of this which the above theories explain. Early in 1890, Mr. L. Fletcher showed to one of us a specimen, belonging to the mineralogical collection of the British Museum, which presented a most striking resemblance to the typical Eozoon. This was shown to several palæontologists, all of whom unhesitatingly identified it as Eozoon, one of them declaring that the specimen was of especial interest, as showing the "osculiform" structure described by Sir J. W. Dawson.§

* George P. Merrill, "On the Ophiolite of Thurman, Warren Co., N. Y., Amer.," Journ. Science, ser. 3, vol. xxxvii., 1889, pp. 189–191.

† Gratacap, "The Eozoonal Rock of Manhattan Island," Amer. Journ. Science, ser 3, vol. xxxiii., 1887, pp. 374–378.

‡ "The Origin of Certain Marbles: a Suggestion," Proc. Roy. Dub. Soc., vol. vii., 1891, p. 126.

§ "Note on New Facts relating to *Eozoon canadense*," Geol. Mag., new ser., dec. 3, vol. 5, p. 50, pl. iv., fig. 2.

The specimen, however, is really an ejected block from Monte Somma. It belongs to the Hamilton Collection, and there seemed no reason to question the authenticity of its locality. Whatever doubts one might have felt on this point were removed by the examination of a microscopic section, which showed in it the minerals and structure of these well-known rocks. Nevertheless, considering the important nature of the question, it was advisable to secure other specimens, respecting which no possible doubt could be entertained. Inquiries were made of the first author of this Paper, when it was found that he had been likewise impressed by the identity of the rock-structure from the two localities, he had long been collecting materials for a memoir, and had already made a partial microscopic study of these rocks from Somma. It was then decided that a joint communication should be arranged, as the first writer possessed a very extensive series of specimens, exhibiting the true Eozoonal structure, besides many curious variations from and modifications of it, the principal of which are here described. We must thank Mr. L. Fletcher, F.R.S., for kind permission to describe the block in the Hamilton Collection, and Dr. H. Woodward, F.R.S., for free access to the splendid series of the classical Eozoon specimens in the Carpenter Collection. This, owing to the generosity of the Rev. J. Estlin Carpenter, is now preserved in the British Museum (Nat. Hist.).

Part II.—Classification of the Ejected Blocks of Monte Somma, and conditions under which they originated.

The cretaceous and jurassic rocks that, together with unimportant but more recent geological deposits, constitute the subvolcanic platform of Vesuvius, have been exposed to the metamorphosing action of the molten magma that bathed the sides of the volcanic canal as it rose to supply the outpourings and ejections of that volcano. This limestone was, and doubtless still is, traversed by the main volcanic stock and neck ; it is, moreover, also penetrated and threaded through by subsidiary dykes, such as we see in the denuded roots of ancient volcanoes. During the great explosive eruptions which more especially characterized Phases VI. and VII., the crater-apex was shown by one of us to have extended down for 800 metres* below sea level, and no doubt some hundreds of metres through the subvolcanic platform; for the amount of materials derived from such sources is very considerable. It was likewise shown that, as the crater-apex extended downwards, it traversed post-pliocene fossiliferous sand- and mud-stones, calcareous conglomerates, pleistocene clays and sands, and possibly even the eocene *macigno*,

* H. J. Johnston-Lavis, "The Geology of Monte Somma and Vesuvius," Quart. Journ. Geol. Soc., vol. xl., 1884, pp. 35–112, Pl. ii. ; also other papers by the same author.

until it reached the upper limestones, which are but altered or slightly metamorphosed. When the fourth great explosive eruption of Phase VI. occurred the crater-apex had penetrated further into metamorphosed limestones, which have undergone the extreme modifications that only occur at very considerable depths. All this is proved by the deposits of these eruptions, which contain the included fragments of such rocks; these are at present arranged in an order inverse to that of their original deposition; the more recent of these explosive products are mixed with the most metamorphosed limestones. The fossiliferous tertiary rocks are almost always unaltered, or are at most but slightly altered, and in the pumice beds lumps of plastic clays, containing delicate fossils, adhere to the fragments of pumice, amongst which they fell.

Overlying the sedimentary rocks of secondary and tertiary age which form the subvolcanic platform, there was also a certain amount of volcanic *debris*, probably derived from neighbouring vents anterior to Somma-Vesuvius. Amongst these rocks, including various tuffs, trachytes, basalts, and other allied products, occur fragments of older cooled plugs and dykes; these rocks are of a coarsely crystalline structure, and bear the same relations to the extratelluric rocks of Somma-Vesuvius, as granites, gabbros, &c., do to their subærial equivalents. During a later stage, and after some of the great eruptions that excavated the crater, this was finally filled by a mixture of ejected limestones and other volcanic materials; it is in these that subsequent metamorphism has produced the most remarkable changes. The silicates of the igneous rock have acted upon the enclosed limestone, whilst this in its turn has changed the composition of the former, hence the remaining material tends more towards a basic, or ultrabasic composition, as is indicated by the minerals that have crystallized. In the calcareo-volcanic breccias the metamorphism is often shown in a most striking manner. We may in some cases, in which the limestone fragments have been but slightly changed, get the Eozoon-like structure; in another case we find the limestone has been completely fused, and subsequently cooled as milky vesicular tears of calcite lining the cavity it once filled. Sometimes this fusion is so complete that the limestone occurs partly filling its old space like an ingot at the bottom of a crucible. It has cooled in this position with a crowd of wollastonite crystals projecting from its surface; they were formed there at the expense of the limestone, and floated while it was fused. At other times metamorphism has been so active that the angular cavity no longer contains a trace of limestone, but is lined by mica, olivine, pyroxene, wollastonite, or spinel. It appears strange in a breccia of this kind that different calcareous fragments have been frequently changed in very different manners: this fact is easily explicable by the great variation in composition of the limestone beds from which they were derived, as may be seen by an examination of the neighbouring sedimentary rocks. In these the magnesia varies more than the silica or iron.* Part of this effect may also be due to the minerals in the igneous rock in contact with the limestone fragments.

Besides these there are numerous leucitic tuffs and lavas of the earlier eruptions of Somma-Vesuvius, which have been metamorphosed, and subsequently ejected.

So far advanced has the metamorphic process extended that a series may be collected, beginning with a leucitic basanite on the one hand, and extending to a bituminous limestone on the other; the line of demarcation between the truly igneous and the metamorphic rock cannot be seen.

Specimens can be shown in which not a trace of calcite is left, which look exactly like ultra-basic, deep-seated igneous rocks, and which nevertheless can be shown to have been originally limestone of only cretaceous, or at the most of jurassic age. These facts have been introduced here to show the intense igneo-chemical changes of which the Eozoon of Somma-Vesuvius is but one of the early stages.

Accidental Ejecta.		Post-tertiary.	Trachytes, basalts, tuffs, &c., parts of pre-existing volcanic rocks covering the sedimentary volcanic platform.
Accidental Ejecta.	Sedimentary origin.	Post-tertiary.	Calcareous conglomerates and volcanic sands united by calcareous cement.
Accidental Ejecta.	Sedimentary origin.	Tertiary.	Fossiliferous mudstones, sandstones, clays, &c.
Accidental Ejecta.	Sedimentary origin.	Jurassic and Cretaceous.	Unaltered bituminous limestones, with fossils.
Accidental Ejecta.	Sedimentary origin.	Jurassic and Cretaceous.	Limestones in which the original bituminous matter has been graphitized and saccharoidal structure developed.
Accidental Ejecta.	Sedimentary origin.	Jurassic and Cretaceous.	Limestones, containing along their ancient bedding-planes, where these are more or less impure, periclase, peridote, pyroxene, nepheline, garnet, wollastonite, &c.
Accidental Ejecta.	Sedimentary origin.	Jurassic and Cretaceous.	Altered limestones, with geodes containing peridote, pyroxene, anorthite, leucite, meionite, wollastonite, nepheline, sodalite, facellite, &c., with Eozoonal-like structures developed around such cavities.
Accidental Ejecta.	Sedimentary origin.	Jurassic and Cretaceous.	Ultra-basic and basic rocks associated with wollastonite, peridote, magnetite, garnet, nepheline, anorthite, black and other micas, idocrase, &c.
Supplementary Ejecta.	Igneous origin.	Somma.	Coarse-grained, deep-seated (equivalents of the surface outflows and ejections of pumice, scoria, and lapilli).
Supplementary Ejecta.	Igneous origin.	Somma.	Lavas, scorias, tuffs, breccias, &c., parts of the old volcano of Somma.
Supplementary Ejecta.	Igneous origin.	Somma.	Igneo-calcareous, breccias, more or less re-metamorphosed crater and chimney plugs of loose material.
Essential Ejecta.	Igneous origin.	Somma.	Pumice.
Essential Ejecta.	Igneous origin.	Vesuvius.	Scoriaceous pumice.
Essential Ejecta.	Igneous origin.	Vesuvius.	Lava, scoria, lapilli, dust, &c.

* H. J. Johnston-Lavis, "The Ejected Blocks of Monte Somma. Part I. Stratified Limestones." Trans. Edinb. Geol. Soc., vol. vi., 1893, pp. 314–351, 3 pl., 1 fig.

The Eozoon structure has, therefore, been produced in those limestones which have, under great pressure, in the presence of different gases, and in the neighbourhood of a comparatively basic magma, undergone whole or partial fusion. Sometimes we observe a limestone nodule enclosed in a silicious rock, or a minute dyke or detached fragment surrounded by a pasty limestone that has been partly fused. So much liquification has occurred in the limestone that large bubbles have been able to form within the crystals; the replacement of the carbonic radicle of its compounds by a silicic or aluminic or other radicle, has been preceded, moreover, by the separation, first, of minute gas-cavities, and subsequently of fluid cavities.

The actual method by which this peculiar laminated structure has resulted from the contact and inter-reaction of a silicate rock, and a more or less impure limestone is not at all certain; but it is sufficient for our purpose if we can show that the structure is due to metamorphism. The following hypothesis might, perhaps, explain the process:—As the silicic fluid or vapour penetrated the limestone it collected and carried with it the magnesia until sufficient had been obtained to form with some lime a forsterite, monticellite, or if iron or fluorine be present, even an olivine or humite. These separated out as a band which would be parallel, in a fairly homogeneous limestone, to the free surface of absorption. Then, silicic fluid or vapour would have to penetrate a certain distance farther before the process can be repeated, and another band be formed. The regularity and the penetrative power of the silicic substances will diminish *pari passu* with the distance at which they must work, due to the increasing thickness of limestone, and the inevitable slight want of homogeneity. Thus we see the silicate bands get thinner and thinner, and more irregular, until finally the so-called acervuline layer is reached. The stolon-like columns are probably the main passages along which the fluid or gases penetrated, for we find them enveloped by groups of minute gas-cavities, as is also the silicate layer in some specimens (figs. 1, 5, Pl. XXXII.)

We may tabulate the necessary conditions for the occurrence of Eozoonal structure as follows:—

(1.) Injection of an igneous magma through limestone. This will be favoured by the limestone being hot and pasty, with breaking-up of the igneous magma into fragments or blobs scattered through the limestone.

(2.) Ejection of volcanic rocks with broken-up limestone, their refalling back into the volcanic neck and re-metamorphism.

(3.) Metamorphism of old agglomerates of mixed igneous and calcareous rocks.

The effects produced may be—

(*a*) When the limestone fragments are surrounded by volcanic material the metamorphism will extend inwards, as in specimen 133 (Pl. xxxiv.).

(*b*) When a detached bleb, fragment, apophysis, or dyke of igneous rock is enclosed in limestone, the lamination will extend from the latter outwards into the limestone. In consequence of mutual modification the igneous rock crystallizes, or re-crystallizes, as leucite, meionite, anorthite, pyroxene, garnet, idocrase, &c., these separately or together, line the geodes and fissures in the metamorphosed limestones of Somma (Pl. xxxiii.).

The whole process seems to be the removal of the silica, possibly a little alumina, iron, &c., from the igneous rock by the limestone; this may itself contain some magnesian, silicious, or ferruginous material. The magma is therefore rendered more basic, both by the loss of silica, and the introduction of lime, and possibly magnesia. In the injected rock we find every gradation from the normal igneous magma to an association of minerals, representing gradually increasing quantities of lime, magnesia, and sometimes iron. These are combined with other elements to form the numerous minerals met with in the ejected blocks. The lime in great part is no doubt derived from the limestone, as also is possibly a portion of the magnesia. The magnesia and iron are increased relatively on account of the loss of silica. Where the fragments of paste are small, and have become detached and enveloped in the limestone, this process reaches its extreme limit with the formation of meionite with augite; but where the last branch of the system was still connected with the main intrusion, then the only change is that the magma is itself rendered somewhat more basic.

In the limestones and their derivatives quartz is practically unknown. A few minute crystals may be found, but they are the rarest of Vesuvian minerals; they generally line cavities and fissures in the old dolerites and trachytes that belong to the subvesuvian platform, and have been ejected with other minerals.

Part III.—Locality and Mode of Occurrence of the Specimens.

Forming a great mantle to Monte Somma are deposits of pumice, which are the *essential* ejecta of a series of explosive eruptions that excavated the great crater of the Atrio del Cavallo. It is especially amidst the pumices of Phase VI., period 4, and to a less extent among those of Phase VII., period 1 (the Plinian eruption),* that the blocks of altered limestone are met with,

* H. J. Johnston-Lavis, "The Geology of Monte Somma and Vesuvius," Quart. Journ. Geol. Soc., vol. xl., 1884, pp. 35–119, pl. ii.

associated with all the other kinds of blocks already mentioned. They are scattered throughout the pumice beds of each eruption, chiefly in the upper division. They occur as irregular angular, or subangular masses, ranging to more than a cubic metre, though more commonly less than a quarter of that size. Not infrequently patches of pumice adhere to their surface, or are retained in some depression of it. The Eozoonal structure is exceedingly common, and easily strikes the observer's eye; it has also been an enigma to one of us well acquainted with this structure at Vesuvius for upwards of fourteen years, that no one else had noticed the identity between this and the original *Eozoon canadense.* This is the more surprising, as Mierisch in part refers to this zonal structure.

A typical specimen of these blocks exhibits, next to a crystalline geode or mass of volcanic rock, a broad pale greenish band corresponding to the outermost layer of the Eozoon; like this it is fibrous, normal to its surfaces (*a. a.* fig. 1, Pl. XXX.; *a. a.* fig. 5, Pl. XXXI.; and *a. a.* fig. 2, Pl. XXXII.). Sometimes it is banded parallel to its faces, owing to variation in its mineralogical composition; a very similar change is seen also in Eozoon.

It varies in thickness from one millimetre to one centimetre. This band or geode-wall can be made out in some cases to be composed of mica-plates, which are so elongated as to constitute a complicated and tangled mass, having a fibrous appearance. Associated with it is usually a varying amount of pleonaste-spinel, peridote,* and possibly pyroxene, besides other indefinitely fine dusty material. Haüyne is not an exceptional constituent, and in fact any of these may predominate to such an extent as to practically exclude the others. They are all minerals that easily pass into serpentine, or some allied margarophyllite silicate. Usually immediately implanted on the geode side of the wall is a layer of dark-green pyroxene, or of large crystals of peridote. The former may reach a centimetre or more in length. Upon this base all the other geode-minerals are placed.

Beneath this true geode-wall we find band upon band of a darker coloured material; these bands, which we will call, for brevity, the silicate laminæ, alternate with laminæ of calcite. The former are insoluble in dilute acid, and are composed usually of white peridote, pleonaste-spinel, humite, and haüyne, and enclose sometimes grains of pyrrhotite. Not infrequently those bands nearest the geode-wall partake of its nature, so that if mica or haüyne is the dominant mineral in the wall, the first two or three layers will consist of the same (*b. b. b.* fig. 6, Pl. XXXII., spec. 148); but as we recede through the limestone, peridote and spinel usually exclude the others. These bands are thickest near the geode-wall, as also are the intervening calcite bands (*b. b.* fig. 1, Pl. XXX.); but farther off they become

* Peridote is used here to denote indifferently a number of the chrysolitic group with varying proportions of magnesia, lime, and iron—usually a more or less ferriferous montecellite, or forsterite.

more regular and thinner; finally, they are less regular and more interrupted, until they assume the appearance of the acervuline part of *Eozoon canadense.* The details above mentioned agree completely with the supposed fossil organism, except for serpentinization.

Not uncommonly the continuity of the laminæ is broken by a patch which marks a want of homogeneity in the original limestone, such as would be produced by an enclosure of some kind, or a fossil, replaced by pure carbonate of lime, and, therefore, not able to supply the necessary magnesia. Such an example is seen in fig. 3, Pl. XXXII.

Frequently fibrous pillars extend across the calcite band from one silicate lamina to another, just as in the stolon passages of Eozoon. We have not been able to determine the mineral composition of these transverse columns; but they seem to differ from the components of the silicate lamina just as does the infilling material of these supposed passages in Eozoon. Under high powers they are seen to be birefrangent fibres, surrounded by a sheath of some material full of minute gas-cavities; they vary greatly in thickness. Three of different dimensions are well seen in *e. e.*, *g. g.*, and *h. h.*, fig. 1, Pl. XXXII., spec. 148). Their outer layer is continuous, with a well-defined stratum of calcite, which clothes the silicate lamina, but which is sharply defined from the ordinary calcite, as shown by its totally different extinction.* This calcite layer corresponds with the proper wall of the so-called Eozoon. The stolon-like columns are sometimes situated at the junction of two or three calcite crystals, and may then be only the dirty inter-crystalline substance seen in section (figs. 1 and 3, Pl. XXX.; figs. 4 and 6, Pl. XXXI.; fig. 3, Pl. XXXII.). In other cases, however, one or more of these columns traverse a single individual crystal of calcite, the twinning and cleavage-planes being continuous across these, showing that in that case they are cylindrical columns and not partitions seen edgewise (fig. 1, Pl. XXXII., spec. 148). The calcite bands are sometimes composed of numerous small grains in a single lamina; at others the single crystal extends from one silicate band to the other, and for a considerable distance laterally. Sometimes the calcite is full of minute cavities, so as to look like some forms of quartz; at others it is vesicular (Pl. XXXII., fig. 5). In cases of more advanced metamorphism it may be more or less charged with peridote, wollastonite (fig. 4, Pl. XXXII.), or other minerals, which sometimes entirely replace it.

These, then, are the general characteristics of the structure, in illustration of which we give the following examples, which exhibit the principal details and deviations commonly met with:—

Pl. XXXII., spec. 148, fig. 1.—When examined under the microscope the calcites are seen to contain round cavities either within or between the crystals. These

* See Pl. XXXII., fig. 1, *i. i.*

vesicles are very frequent in all the coarse saccharoidal limestones, as well as in the drop-shaped fused crystals of calcite which line cavities in the silicated limestones. In this specimen a single crystal of calcite usually forms the whole width of one of the bands, and extends for some distance along it; the bands vary from mm. ·3 to ·5 in width. Twinning and cleavage are both well exhibited. A number of very minute club-shaped cavities occur in a band along the margin of the calcite laminæ (*i. i.*); they may be single or multiple, and in the latter case are often radial in arrangement. Their minute size renders it impossible to determine whether they contain gas or liquid. The band which contains these often extinguishes at a different angle to the rest of the lamina, as if the inclusions had caused a different crystallographic orientation. This layer is the equivalent of the "proper wall," or nummuline layer of Eozoon. The cavities in some parts of this, and in other specimens, have a remarkably geometrical arrangement. Small nodules of pyrrhotite occur in the specimen. The silicate layers are rusty and opaque near the junction with the calcite.

Thin fibrous columns of a faint greenish-yellow tinge cross the calcite from one silicate lamina to the next; they are surrounded by a sheath crowded with minute cavities similar to those on the horizontal borders of the calcite (*e. e.*, *g.g.*, and *h.h.*). The columns transmit a little light when the calcite is extinguished between crossed nicols; they are wholly independent of either the cleavage or twinning planes, as is shown in the figure. These columns are frequently branched; they represent the "stolon passages" of Eozoon.

In this specimen the peridote bands are granular. The rod-like crystals in the calcites may be wollastonite or meionite.

In another interesting specimen the contents of the geode consist mainly of sanidine and mica, with a little augite. The wall of the geode is composed of a thick band of what is probably a clear biotite; this mostly shows aggregate polarization; where the crystals are elongated the extinction is straight. On the walls are traces of a light-coloured pyroxene. Near the layer the peridote occurs in association with numerous microliths of spinel, and forms fine-grained and irregularly laminated masses, with a transverse feathery structure. Layers of dirty calcite occur between them. About 1 cm. from the geode-wall the lamination is more distinct, but numerous well-defined grains of peridote are scattered through the calcite. Further away the mass is a contorted aggregate of calcite, peridote, and large violet spinel, with traces of other minerals.

Pl. XXXII., fig. 2.—The geode contains large crystals of felspar, leucite, amphibole, a little pyroxene, and a colourless, highly refracting mineral which is peridote or humite. The geode-wall is composed of a fibrous, yellowish mineral, which is probably mica, but which we cannot determine with certainty. It is very dirty on the surface turned away from the geode. The peridote laminæ are composed of coarse grains, with numerous microliths of spinel. The bands of calcite are broader than in the specimens previously described, and enclose grains of peridote. There are numerous interlaminar stolon-like columns, most of which, however, occur along the junctions of two crystals.

Pl. XXXIII.—The specimen consists of the final tongue of a dyke of dark lava,* surrounded by from 1 to 2 cm. of an ultrabasic mass very similar in many respects to the geode mass of Eozoon. Enveloping this again with great uniformity is a geode-wall followed by thick silicate and calcite laminæ, forming a band 3·00 mm. in thickness; at a centimetre distance this is replaced by exceedingly fine (·2 to ·15 mm. in width), continuous laminæ, which are of such regularity as to resemble the growth rings of very fine-grained wood. Beyond this is a very coarse saccharoidal marble.

Microscopically the dyke material (fig. 1, Pl. XXXI.) proves to be chiefly composed of crystals of very light pyroxene with a darker crust, in some cases again covered by another lighter one. Large numbers of grains and microliths of a dark olive-green pyroxene make up the main mass of the rock. Besides these are a few grains of peridote and magnetite. The whole is enveloped in a base of what appears to be nepheline, so that practically the rock is a nephelinite. The next zone is separated from the true igneous rock by a thin imperfect crust, which is fibrous normally to its surface; it is composed of small highly refracting grains, probably peridote, enclosing crystals of an almost white pyroxene, with a few grains of greenish-blue haüyne and patches of calcite (*a. a.* Pl. XXXIII.); these increase in number towards the next outer zone, which corresponds to the true geode-wall of the other specimens. This wall is rather irregular in thickness; it is frequently banded and fibrous, as in the original Eozoon (*b. b.* Pl. XXXIII.). It is principally composed of a mineral, which is probably peridote, and includes numerous crystals of haüyne. On its outer margin are minute black spinels. The Eozoonal bands that follow next are wide, and as in Eozoon often disconnected (*c. c. c.* Pl. XXXIII.). They are composed of granular peridote, and the two or three external ones contain many grains of haüyne. After two or more of these bands there follows a series of two dozen very fine silicate laminæ, which are arranged with remarkable regularity (*d. d. d.* Pl. XXXIII., and fig. 3, Pl. XXXII.). These are composed of rounded grains of peridote, and possibly a few of haüyne. Still further on they pass into an irregular mass like the "acervuline layer" of Eozoon (*e.* Pl. XXXIII.), in which violet spinels are so abundant as to give the limestone a lavender tint; and further out, coarse white saccharoidal limestone is found. Stolon-like pillars occur in the laminar portion, separating one calcite grain from another.

* Not seen in figure.

Pl. XXXII., fig. 4.—The geode-wall is probably formed of a fine-grained mica, containing one or two groups of dirty prismatic crystals, with very acute terminal pyramids. The calcite bands are broad, and composed of crystals which are fairly pure, but are smaller than usual. At one spot some good lath-shaped crystals of wollastonite are enclosed, as shown in the figure. The bands of peridote are broad, and made up of numerous crystals of very various sizes, associated with much violet spinel. The first one or two bands nearest to the geode-wall are composed of the same minerals as it is. Included in the specimen are also patches of pyrrhotite.

Pl. XXXII., fig. 5.—The geode-wall is composed of a very fine-grained mass, which appears dirty, owing to the abundance of included microliths. Its fibrous structure gives it a resemblance to some compound spherulites. Superposed on it near the geode is a very light-coloured pyroxene enclosing blue grains of haüyne. Leucite occurs above the pyroxene; the haüyne is always enveloped by pyroxene, and surrounded by a cavity as if it had been formed at the expense of its matrix. The calcite occurs in broad bands. The crystals on the centre of the broader laminæ are clear, and exhibit fine twinning planes. Those on the sides near the silicate bands are crowded by trains and patches of minute and probably liquid cavities, and exhibit hardly any trace of twinning planes.

The clear nuclear calcites, as well as those containing the microscopic cavities, are frequently vesicular. The whole mass seems to have been fused into a viscous paste, and the gas or liquid represents part of the carbon dioxide liberated in the formation of the lime-magnesia-peridote in the immediate neighbourhood of which they occur. The superabundance of vesicles formed by gas or liquid is a very common structure in many of the calcite of Monte Somma.

The silicate bands are broad, especially near the crust, and composed of fine grains of peridote covered on each side by one row of larger clear crystals of the same mineral. The fine grains appear dirty, owing to the abundance of minute microliths of spinel.

Pl. XXXII., fig. 6, spec. 148.—A section from another part of same block as fig. 1 is of interest, as it illustrates the mutual modifications effected by the dyke and its limestone sheath. The geode is represented by an aggregate of olive-coloured and white pyroxene crystals, with some calcite and plagioclase, traces of meionite, and a matrix consisting probably very largely of nepheline. The silicate bands are very regular as seen in the figure; probably composed of granular mica, and bounded by rusty surfaces and grains of pyrrhotite; the calcite bands are crowded with clear crystalline rods, arranged transversely or normal to the surfaces of the lamina.

Pl. XXXIV., spec. 133.—The specimen is a remarkable one, as it has probably been formed by the alteration of a number of lumps of limestone enveloped in some old volcanic dust, or lapilli. The silicate laminæ are made up of what is apparently a groundwork of very fine peridote crusted over on both sides by minute dark-green octahedra of spinel. The interlaminar layers are sometimes of calcite, but frequently most of this is replaced by a very light pea-green, uniaxial mica. The nuclei of each globe are pure calcite, with a little peridote, augite, mica, spinel, or idocrase. The interior is sometimes hollow, with some of these crystals lining the cavity. Between each metamorphic globe the interspace is filled in with a quantity of minute dark-green spinels and peridote; in some places there are straggling masses of very black iron ore arranged as in some serpentinous and ultrabasic rocks.

Pl. xxxi., fig. 2.—This is a unique specimen. The surface of the block at one end has a dirty vitreous crust, enclosing peridote, pyroxene, &c. Beneath this, extending down through the block, were the usual laminæ of silicates and calcite, showing striking regularity as regards the distance apart and breadth of each band. The point, however, in which this specimen differs from the others is, that the laminated part is divided into narrow bands, running at right angles. The breadth of these calcite divisions is several times that of the calcareous laminæ between the silicate ones, which they, of course, join at right angles. These bands of laminated and plain calcareous rock slightly curved or serpentine in direction, so as to look like strips of transversely-marked ribbon, as seen on the rock surface. We can only explain them in supposing metamorphism to have extended parallel to a stratified rock in which some strata were dolomitic, and therefore suitable to the formation of Eozoonal structure, and others were pure carbonate of lime, which has simply become saccharoidal. The curvature might be explained by pasty folding, for all the calcite is filled by numerous and large versicular cavities.

The silicate bands are composed of good sized peridote grains, with dusty matter, probably spinel, a little haüyne, and, in some spots, wollastonite; in other places the calcite has been replaced by a clear mica, in large patches, which entirely envelope the periodote grains.

This specimen has a strikingly organic look about it; but yet it is difficult to compare it to any known group of organisms.

PART IV.—THE DIAGNOSIS OF EOZOON AND ITS APPLICABILITY TO THE MONTE SOMMA SPECIMENS.

After this description of the Monte Somma specimens, it remains but to consider in how far this structure agrees with that of the typical Canadian *Eozoon*; in our comparison of the two it may be added that we used only the most authentic material which has received the *imprimatur* of either Dr. Carpenter or Sir J. W. Dawson, and generally of both. The simplest method will be to take the latter's latest diagnosis, and to see in how far the specimens must be included within it. The generic diagnosis is as follows:—"Foraminiferal skeletons, with irregular and often confluent cells, arranged in concentric and horizontal laminæ, or sometimes piled in an acervuline manner. Septal orifices irregularly disposed. Proper wall finely tabulated. Intermediate skeleton with branching canals."*

If we substitute for the words "foraminiferal skeletons," some descriptive definition of these, such as "skeletons of which the separate chambers are united by foramina," and do not press the significance of the terms cells, canals, and chambers, we find the diagnosis applicable to the Monte Somma blocks. If we like to call the small silicate nodules "cells," or "chambers," and the branching fibres and tubes in the calcite "canals," then the diagnosis agrees. The "proper cell-wall" is well represented by the special calcite layer clothing the silicate bands, and crowded with great numbers of minute pores. But, even were this absent, Dr. Carpenter had already acknowledged "the proper cell-wall to be an inorganic alteration product."† In every other respect the agreement is absolute. The specimens may be truly defined as masses of which the separate chambers are united by small or large points of contact (foramina). They are arranged in concentric and horizontal laminæ (figs. 1, 2, 3, Pl. XXX.; figs. 2, 3, *j.j.* 4, 6, Pl. XXXI.; 2, 3, 4, 6, Pl. XXXII.; Pl. XXXIII., and Pl. XXXIV.), and are sometimes piled in an acervuline manner (*c.* fig. 1, *m.* fig. 2, Pl. XXX.). The septal orifices are irregularly disposed, and the intermediate skeleton has branching "canals."

The more detailed specific diagnosis agrees as closely, "in rounded masses or thick encrusting sheets, frequently of large dimensions." [The normal form is in that of rounded masses, but it occurs encrusting dykes which burst into the blocks; the size of the specimens also agrees well.] "Typical structure stroma-

* "The Dawn of Life." London, 1875. Appendix, p. 235. † See *ante*, footnote, p. 259.

toporoid, or with concentric calcareous walls, frequently uniting with each other, and separating flat chambers, more or less mammillated, and spreading into horizontal lobes, and small chamberlets; chambers often confluent and crossed by irregular calcareous pillars connecting the opposite walls, upper part often composed of acervuline chambers of rounded forms." [The variations are all well shown in our specimens; one small nodule collected by one of us is remarkably stromatoporoid in aspect, consisting of a small rounded mass with the concentric layers persistently regular from the periphery to the central cavity. This is well shown in one of the smaller specimens from Monte Somma: a specimen from Côte St. Pierre kindly lent to us by Prof. Rupert Jones, agrees very strikingly with specimen (fig. 2, Pl. XXX.) from Monte Somma of about the same size. The proportion of acervuline to the more coarsely laminated area is approximately the same.] "Proper wall tubulated very finely" [probably due to the fluid or gas cavities having undergone alteration; otherwise well defined, as in our specimens (fig. 1, spec. 148, and fig. 5, Pl. XXXII.)]. "Intermediate skeleton largely developed, especially at the lower part, and traversed by large canals, often with smaller canals in their interstices. Lower laminæ and chambers often 3 mm. in thickness. Upper laminæ and chambers 1 mm. or less" [fig. 1, Pl. XXX., shows specimens with canals which agree precisely with some of those ink-marked as typical by Dr. W. B. Carpenter in a specimen in which the layers range from 2·0 to 0·33 mm.] "Age Laurentian, or, perhaps, Huronian." [We cannot prove *absolutely* that our specimens are not palæozoic, on account of their metamorphism; but the graduated series from the undoubtedly Upper Mesozoic limestones which occur abundantly with them would prevent any practical geologist who studies their mode of occurrence and associations from urging such a possibility.]

The agreement in all essential points between these ejected blocks and the typical Canadian Eozoons seems to prove the identity of origin of the two; the one point of the absence of the *proper wall* in some of our specimens is not sufficient to separate them, as it has been generally admitted that this structure consists really of only a layer of chrysolite, formed from the superficial layer of the serpentine; it could not be expected, therefore, in a rock which has not been extensively altered and decomposed. We may, therefore, claim to have proved that *Eozoon canadense* has been formed at a period geologically recent, as a product of contact-alteration, combined with the absorption of a magma of basic silicates. We must therefore proceed to inquire whether there is any evidence as to whether the Canadian specimens have been formed in like manner. Unfortunately the only *Eozoon* which either of us has been able to examine *in situ* was not typical. Prof. J. F. Blake, however, when on a visit to Canada in 1884, examined the Côte St. Pierre sections, with a result unfavourable to the organic theory of the structure, which he said was concretionary. At our request he has kindly written the following notes:—

"I came away with the clear conviction that we need no longer trouble about its organic nature. The arrangement of it in the mass was incompatible with such an idea. The supposed fossil is found in a great outstanding knot of white rock, in which there are more or less spherical patches bounded with a series of thin bands getting wider towards the surface. These patches are isolated, and so, as we may say, stand back to back. I brought away some specimens showing this, the best of which now lie before me. The dark boundary is very characteristic; they all have it.

"On examining these under the microscope, the intervening substance appears to be malacolite, the dark band is certainly serpentine, and so are the dark lines within for some way; but they gradually change to olivine. I think, at all events, its polarization tints are more brilliant, and it lacks the cleavage of the malacolite.* The lighter bands are calcite; but these appear to be formed later than the olivine, as the calcite is pushed aside by it. These bands are by no means continuous, but die out where the olivine and serpentine are most abundant, like distorted lenticles.† The outermost coat, being always of serpentine, could not represent the flesh of an animal, which must have been inside only, if it were to be preserved in such a mass. Thus the Eozoonal-like appearance is the boundary between two different mineral masses, the calcite-olivine within, and the matrix of malacolite without. In only one patch of the calcite have I seen any branching tubes, and if these be organic, which I can find no proof about one way or the other, they might be the last relics of some animal which had supplied the calcite by its decomposition, but the bands have no relation whatever to such a supposed animal.

"The border of the calcite is often well marked, but its shape is caused by the olivine crystals, and often there are small olivine crystals in the centre of the calcite, as well as blebs of calcites in the centre of the olivine (serpentine). The same mass of rock which shows these well-marked concretions also shows more feebly distinguished masses, till the masses of mineral become almost mixed. My conclusion was, and is, that Eozoon properly so called is concretionary. But when we ask what caused the concretions, and remember that concretions very commonly originate in the remains of some organism. I am not sure that these also may not have originated by the aggregation of the remains of some calcareous organism, of which we may see the relics in the occasional canals, as

* Our specimens, as described, often showed more mica, hauyne, &c., in the geode-wall and the neighbouring silicate laminæ, which, in the Canadian specimens, seem to have more easily become serpentinized.

† See fig. 2, Pl. XXX.; fig. 2, Pl. XXXI.; fig. 3, Pl. XXXII.; Pl. XXXIII.

you may find sponge-spicules in a flint, though the flint itself in no way owes its form to a sponge, but indicates the structure of a sponge.

"I exhibited these specimens, and stated my interpretation of them on the labels, at the soirée of the International Geological Congress in 1888. Professor T. R. Jones communicated my ideas to Sir J. W. Dawson, who replied to them, without affecting them in my mind, in the 'Geological Magazine.' Similar conclusions had been arrived at by Julien.

"J. F. BLAKE."

Most of the specimens sent to London are too small to show that the best Eozoons occur as such concretionary masses; there are, however, several such which are familiar to all visitors to the extensive Eozoonal collections made by Sir J. W. Dawson for the Peter Redpath Museum in Montreal. Dr. Carpenter's Collection also contains several blocks and slabs which show this arrangement. There is the same central massive nucleus surrounded by a laminated zone; there is the same gradual passage from the coarse outer layer to the irregular acervuline layer within; but the most important point which these specimens demonstrate is that concentric Eozoonal masses are included in a coarse-grained rock, which is composed of white pyroxene, and which, therefore, may safely be regarded as igneous in origin. The fact that the acervuline layer occurs in the interior of the Eozoonal spheroid is in itself an argument against its organic origin. When it occurs as the uppermost band of a horizontal sheet, as it of course appears to be in a section across one segment of the spheroid, the explanations and figures of Sir J. W. Dawson are quite plausible.* But we cannot apply this to a spheroid, as the gradual exhaustion of the supply of carbonate of lime would cause the acervuline layer to be formed on the exterior. It may be urged in reply that in these cases the skeleton was formed encrusting a central mass of limestone, and that the acervuline layer represented the younger and thinner layers. This would, however, be a complete change of front, and would turn what has previously been regarded as the oldest part of the colony into the youngest; any further proof of the elasticity of explanation of the Eozoonal skeleton would not increase public confidence in the organic theory. There are, moreover, two points which clearly demonstrate that any such change is useless; for if Eozoon arose as an encrustation, the line of junction should be quite sharp, as it is on the periphery; but around the central nucleus there is a very gradual passage from the massive limestone to the banded zone; again, if it grew round a boulder, this must have rested on something, and on the under side the thin delicate layers could not have withstood the weight above; the growth must at least have been much quicker on the upper surface. The boulder must never have been at rest, for

* See "Dawn of Life," pl. v., pp. 66 and 67.

we presume that even in Laurentian days rolling stones would have been as little likely to have gathered Eozoon as later stones to gather other living coverings.

Nor is the theory that the animal lived and built its skeleton in a previously formed hollow likely to meet with general acceptance; for it is not easy to see how a marine organism could have lived in such closely sealed cavities.

Either the accretionary or concretionary mode of origin would exclude any organic agency. The gradual passage from the nucleus to the acervuline layer renders the former improbable. The suggestion that Eozoon is concretionary cannot be so readily dismissed, for the term is often so loosely applied that before we consider how far it is correct to apply it to Eozoon, it will be advisable to define the sense in which we use it.

It seems most in harmony with current usage to accept the term concretionary in a very general sense, and to include the following types :—

(1.) *Accretions* due to the deposition of matter from solution around a central nucleus, *e.g.* oolitic grains; or on a surface, as in amygdaloids.

(2.) *Concretionary nodules* found by the mechanical accumulation of material around a central nucleus, *e.g.* clay-galls. The deposition of calcareous material in the cracks and interstices may strengthen the nodule, as in septaria.

(3.) *Chemical segregations* due to the solution of one constituent of a rock and its re-deposition in a local segregation, such as flints. The replacing material may penetrate from without.

(4.) *Igneous segregation* formed by local segregations of one of the constituents of a molten rock, *e.g.* of the ferro-magnesian minerals in granite.

The *Eozoon* masses will not fall under either of these categories, for though some of the Monte Somma blocks have been fused and re-solidified, those are not the ones that show the zonal structure.

It is only if it should be found that the silicates *Eozoon* have been deposited from solution that a concretionary origin could be assigned to the structure. Though the work of Professor E. S. Dana on the stalactites of Hawaii have shown that the minerals in question may sometimes be thus formed; the method is probably quite exceptional, and the conditions under which these silicates occur in *Eozoon* are quite different to those met with in the Hawaiian lavas.

We are thus thrown back on some other mode of origin, and the fact that the surrounding rock is doubtless of igneous origin at once suggests that the *Eozoonal* structure in its typical localities is also a zonal banding due to contact-alteration, combined with absorption of the ferromagnesian silicious magma. This theory explains the fact of the lamination as well as its irregularity, the thickness of the silicate bands on the periphery, and their gradual reduction as they become further from the surrounding rock, and the presence in the larger specimens of a massive limestone nucleus. The injection of minute quantities of the same magma into the cleavage cracks of the calcite has also been favourable to the subsequent formation of branching filamentous minerals identified as the canal system. It may, however, be objected that if this be the true explanation, why is the structure comparatively rare, whereas inclusions of rock fragments in lavas are not uncommon. To this there is the obvious reply that several conditions are essential to the formation of the structure. The most important of these is that there must be a certain chemical affinity between the inclusion and the igneous rock. If the inclusion be acid and the magma basic, or *vice versa*, and the former be not liquefied, and the latter be only viscid, then the inclusion will undergo metasomatic rather than methylotic alteration without the development of a zonal structure. But a block of limestone included in a molten rock rich in isomorphous, magnesian, or ferruginous minerals will be in a most favourable condition for the absorption of the surrounding magma, and for a zonal development of silicates. Under such conditions the structure is likely to arise, and the fact that it has been described from Skye, Connemara, Bavaria, Bohemia, Sweden, Trinidad, &c., shows that it is not so very restricted either in space or time.

The development of the structure is of course not limited only to included fragments, but where a dyke rich in ferromagnesian constituents has penetrated a limestone, a zonal development of silicates is likely to occur along the contact; especially will this be so if the limestone is dolomitic. The Côte St. Pierre spheroids are, however, probably cases of blocks included in either a volcanic or plutonic mass. We are glad to be able to quote the support of Professor A. C. Lawson for this view, for he has previously suggested from purely stratigraphical considerations that the Eozoonal limestones may have been originally inclusions in intrusive igneous rocks. We contend that this view is fully maintained by both the microscopic and macroscopic structures of Eozoon when these are interpreted in the light of the evidence afforded by the study of the development of identically the same structures in the ejected blocks of Monte Somma.

EXPLANATION OF PLATE XXX.

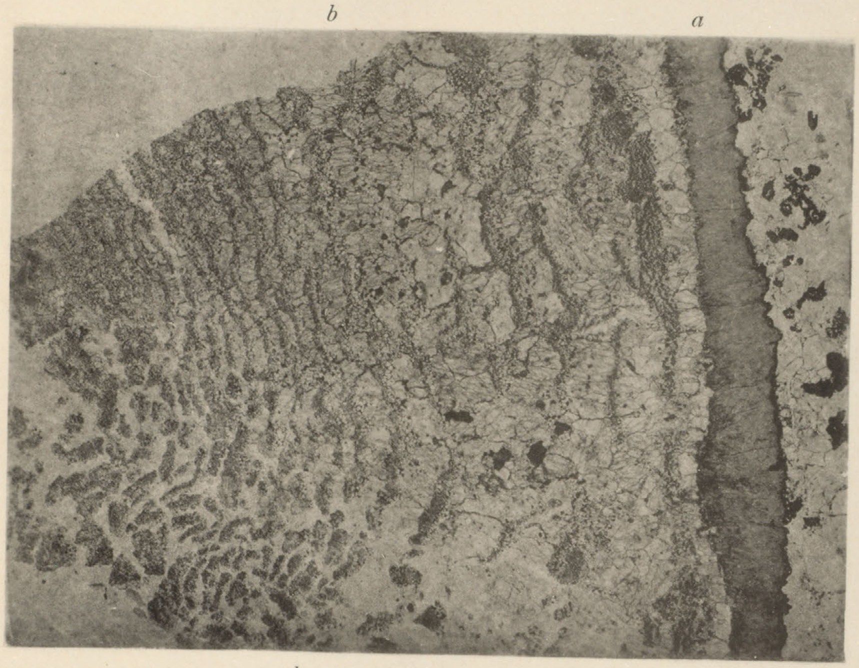
Figure

1. Magnif. nearly 4 diameters. Good characteristic type of Eozoonal structure. Geode materials, *d. d.*, brown and green pyroxene, leucite, sanidine, melanite, and possibly meionite. Geode-wall, *a. a.*, silicate and calcareous layers, with pseudo stolon columns across calcite bands. Acervuline part at *c*. The lower part of section has been etched with weak acid; the insoluble portions are seen to have become deranged in the balsam.

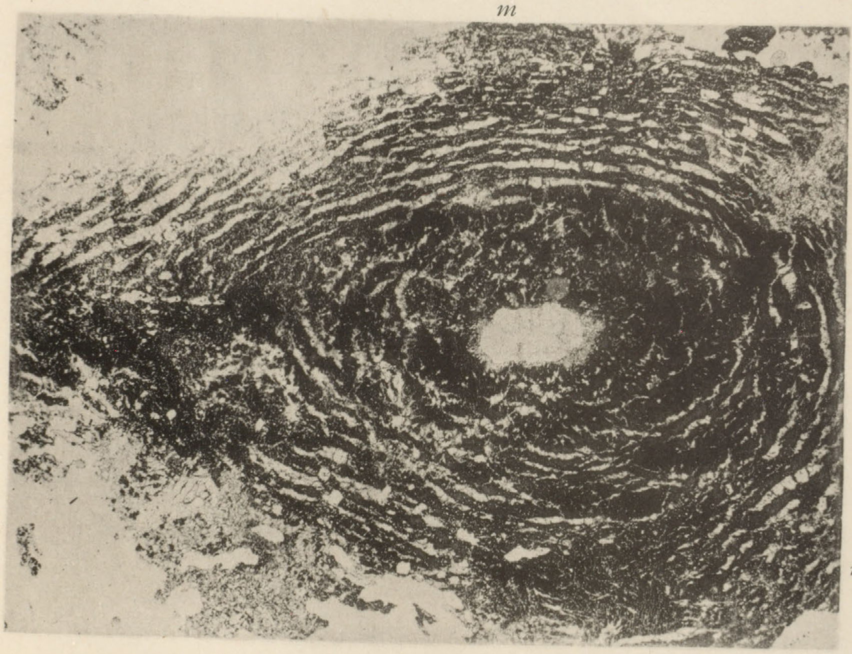
2. Magnif. nearly 4 diameters. The silicate laminæ, *a. a. a.*, are composed of clear glistening grains of peridote and mauve-coloured spinels. The calcite bands are composed of clear crystals, traversed by very meandering joints, the walls of which are crowded by clouds of minute gas or fluid cavities.

3. Magnif. 14½ diameters. The silicate laminæ, *a. a. a.*, are composed of clear glistening grains of peridote and mauve-coloured spinels. The calcite bands, *b. b. b.*, are constituted of clear crystals, traversed by very meandering joints, the walls of which are crowded by clouds of minute gas or fluid cavities. The silicate laminæ are frequently traversed by columns of calcite, as at top of fig. *d. d.*

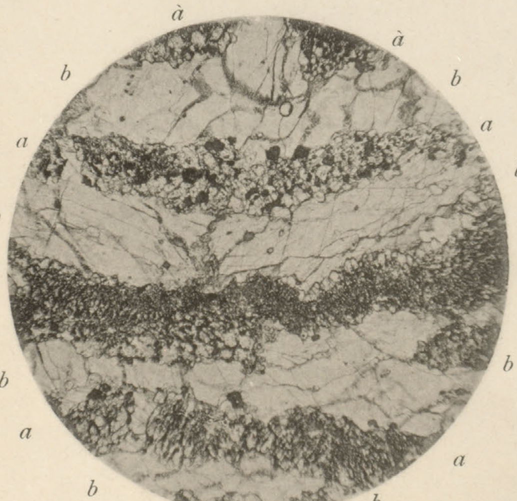
(FIG. 1.) × 4.



(FIG. 2.) × 4.



(FIG. 3.) × 14½.



Johnston-Lavis, photo.

University Press, Oxford.

PLATE XXXI.

EOZOONAL STRUCTURE OF THE EJECTED BLOCKS OF MONTE SOMMA.

EXPLANATION OF PLATE XXXI.

Figure

1. Magnif. 14½ diameters. Dyke rock, around which specimen seen in fig. 3, Pl. xxxii., and Pl. xxxiii., was formed. Large white augites, of first consolidation, with dark-green peripheries, of second consolidation, (*a. a.*, fig. 1, Pl. xxxi.), as also crystal grains of the same mineral of dark-green colour. Large crystals of biotite, *b.*, and haüyne, near *c.*

2. Magnif. 14½ diameters. Laminar eozoonal structure extending down from surface of metamorphism in band separated by vertical instead of horizontal stripes of calcite, probably due to metamorphism extending parallel to old stratification.

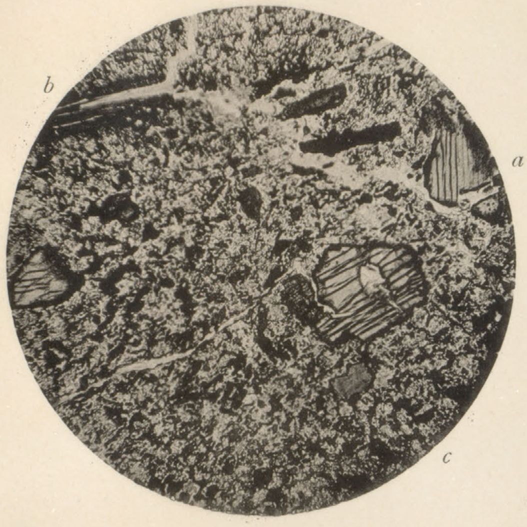
3. Magnif. 24 diameters. Silicate layers, probably composed of peridote and minute dusty spinel, with very marked fibrous structure, normal to their surfaces. Very pure calcite intervening.

4. Magnif. 24 diameters. Part of fig. 2, Pl. xxx. Silicate bands, *j. j. j.*, fibrous, as in last, showing an acervuline arrangement at lower part of figure *b. b.* The regular calcite bands show transverse stolon-like columns, and at places a layer corresponding to the *proper cell-wall* of eozoon.

5. Magnif. 14½ diameters. Top of figure shows part of geode cavity. Geode wall of fibrous mica (?) *a. a.*, with crust of dark augite on geode side. Next below clear calcite band, and at the bottom a bit of silicate band composed of grains of greenish-brown spinel and clear peridote.

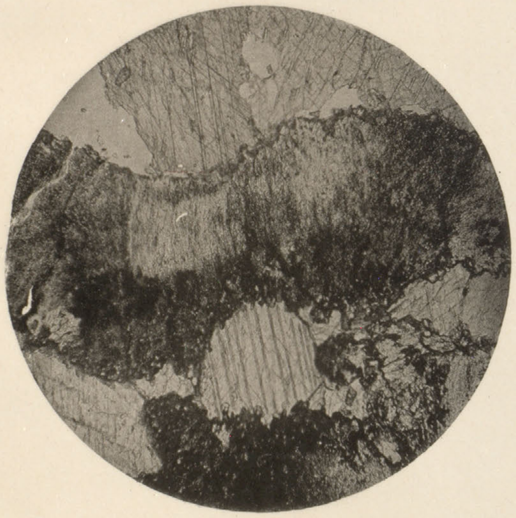
6. Magnif. 24 diameters. Same specimen as last, showing silicate bands in more detail, with stolon-like columns, and the calcite enclosing peridote grains.

(Fig. 1.) × $14\frac{1}{2}$.

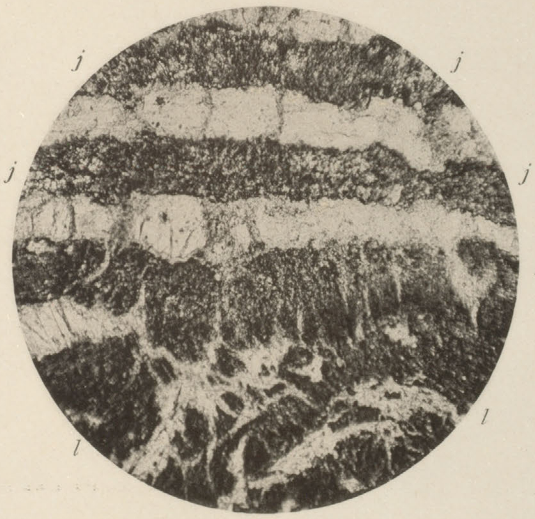


(Fig. 2.) × $14\frac{1}{2}$.

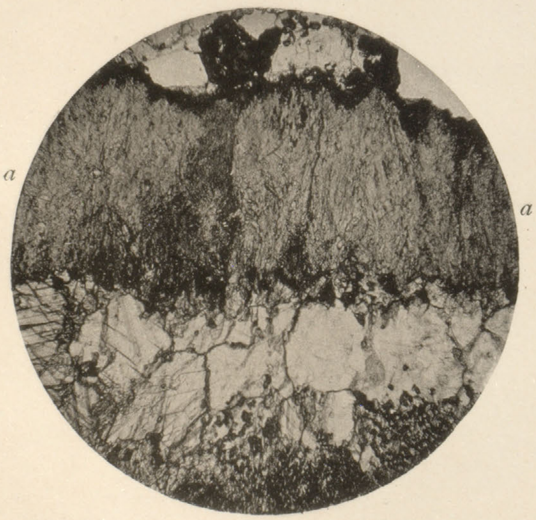
(Fig. 3.) × 24.



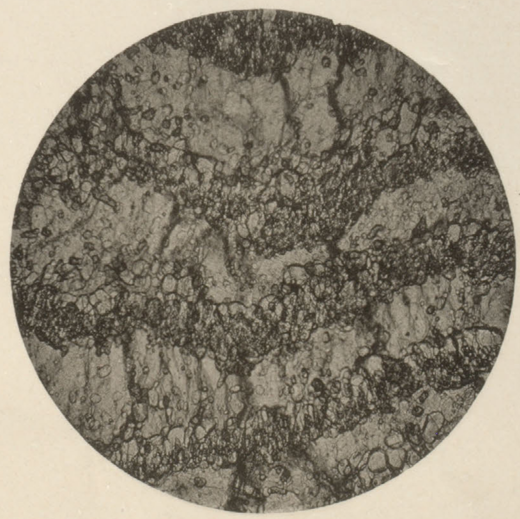
(Fig. 4.) × 24.



(Fig. 5.) × $14\frac{1}{2}$.



(Fig. 6.) × 24.



Johnston-Lavis, photo. *University Press, Oxford.*

PLATE XXXII.

EOZOONAL STRUCTURE OF THE EJECTED BLOCKS OF MONTE SOMMA.

EXPLANATION OF PLATE XXXII.

Figure

1. (Specimen 148). Magnif. 45 diameters. Between two silicate bands, *g. g.*, part of a calcite band composed of one optically continuous crystal, as seen by the cleavage planes. Crossing it are three columns, or stolon-like passages. That marked *e. e.* is long and slender, *g. g.* is broader, and *h. h.* still more so. In the latter the structure is fairly seen, but is lost in the other two in the photograph and engraving. At *f.* is seen another of those stolon-like passages, communicating with a round cavity, and extending a short distance beyond. The cavity is hollow, spherical, and its walls clothed by minute projecting fibres, or spines.

2. Magnif. 14½ diameters. Top part of figure is composed of geode minerals—felspar, leucite, amphibole, pyroxene, and peridote, or humite (?). Beneath this comes the geode-wall of yellow fibrous mica, with green crust of pyroxene on the geode side, and dirty, dusty matter on the opposite surface. Below this comes one calcite layer and one silicate layer of peridote, and a few grey spinels.

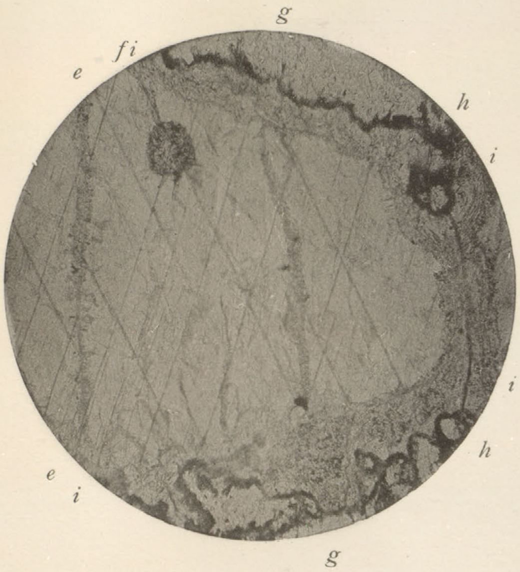
3. Magnif. 14½ diameters. Very regular laminar structure, interrupted at one spot by what may have been a pure calcite filling of some fossil.

4. Magnif. 14½ diameters. Two silicate bands, with intervening calcite laminæ enclosing space, and wollastonite crystals.

5. (Specimen 83.) Magnif. 24 diameters. Part of a curved silicate band, enclosing calcite, with broad crust of calcite (?), with a different optical orientation, corroded with vast numbers of minute pores, and numerous larger vesicles. The former have lost much of their detail in engraving, and the latter are shown as faint clear circles in the plate.

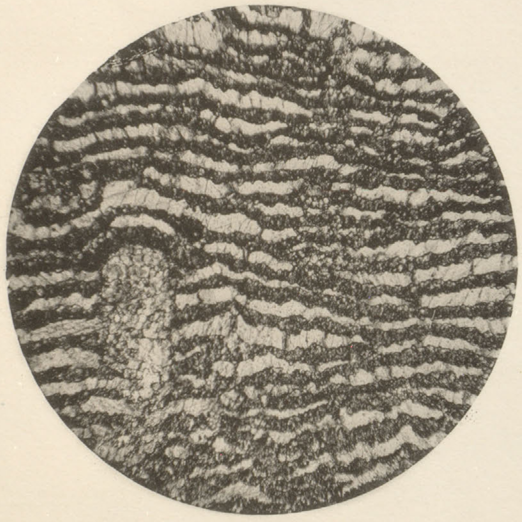
6. (Specimen 148.) Magnif. 24 diameters. Regular banded structure near the geode-wall. The silicate bands partake of its nature in being micaceous. The calcites are clear, but crowded by glass-clear rods, normal to the direction of the bands which might give, in an altered rock, the appearance of innumerable stolon passages. (Compare with fig. 1, cut farther from the dyke-wall.

(Fig. 1.) × 45.



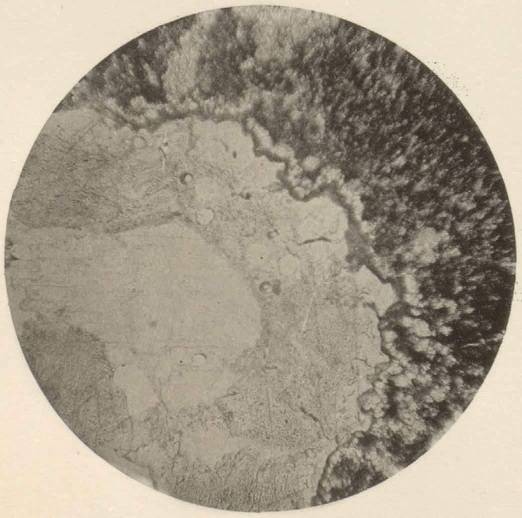
(Fig. 2.) × 14½.

(Fig. 3.) × 14½.



(Fig. 4.) × 14½.

(Fig. 5.) × 24.



(Fig. 6.) × 24.

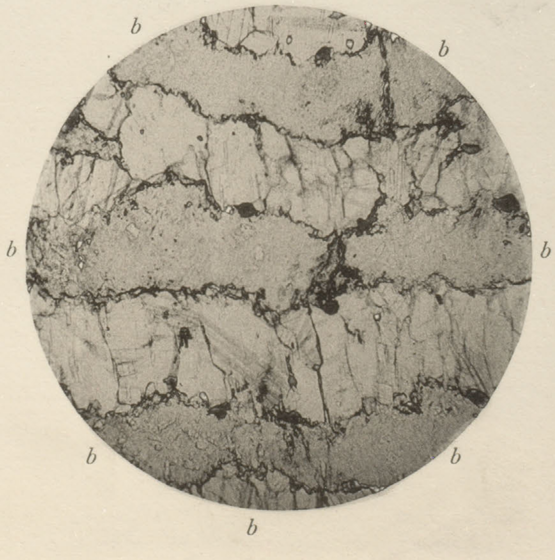


PLATE XXXIII.

EOZOONAL STRUCTURE OF THE EJECTED BLOCKS OF MONTE SOMMA.

EXPLANATION OF PLATE XXXIII.

Magnif. 5 diameters. The central portion formed the envelope to the dyke that penetrated the limestone, but not in the plane of the section *a. a.* This central portion is composed of peridote (?), white pyroxene, haüyne, and calcite. Next comes a zone, *b. b. b. b.*, of haüyne and spinel. Then follows coarse eozoonal bands, *c. c. c. c.*, of granular peridote and haüyne. Finally appear the very regular bands, seen in more detail in fig. 3, Pl. xxxii.

× 5.

Johnston-Lavis, *photo.*

University Press, Oxford.

PLATE XXXIV.

EOZOONAL STRUCTURE OF THE EJECTED BLOCKS OF MONTE SOMMA.

EXPLANATION OF PLATE XXXIV.

Specimen 133. Magnif. 4¼ diameters. A curious association of stromatoporoid nodules, exhibiting eozoonal banding.

× $4\frac{1}{4}$

Johnston-Lavis, photo.

University Press, Oxford.

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