Lattice-like inclusions in Calcite from North Burgess, Ontario.

(*With Plates VIII–X.*)

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THE pale celestite-blue calcite which occurs on the eastern half of Lot 13, Range V, of North Burgess township, Lanark county, Ontario, contains very remarkable lattice-like inclusions of a hydrous magnesium silicate.

The calcite forms crystalline masses belonging to the Grenville series, which has a very extensive areal development in certain parts of Ontario. The texture varies from medium to very coarse, in which the individual cleavage-rhombs of calcite measure one inch or more in diameter. Repeated twinning on *e* $(01\bar{1}2)$ or (101) is almost invariably exhibited, and is especially pronounced in the more coarsely crystallized varieties. Both the twinning and the crystalline character are results of the very intense metamorphism to which this Archaean limestone has been subjected.

The inclusions described below were first observed in a coarsely crystallized specimen in the McGill University collection; subsequently the Geological Survey kindly presented several larger specimens, which rendered possible a more detailed examination and analysis of the material.

In these specimens, owing to the secondary twinning, each cleavage face of the calcite is traversed by three sets of twin-lamellae or striae, which are somewhat evenly spaced from one to two millimetres apart; a large rhombohedron-face is thereby subdivided by fine striae into a number of small rhombs, which are themselves intersected by the more prominent twin-lamellae following the direction of their longer diagonals.

On examination, it was observed that the calcite is penetrated by extremely fine, white needles. Owing to the colour and cloudiness of the crystals, the presence of these needles is not very noticeable by casual inspection of the specimens, but with a lens they can be clearly seen for some depth within the calcite, and their regular orientation is at once evident. The needles follow three directions, which are related to the calcite crystal in such a way that they correspond to the edges of the rhombohedron *e* (01$\bar{1}$2), and they thus lie in three planes, which would truncate the terminal edges of the cleavage rhombohedron. Moreover, the needles invariably emerge from the cleavage-faces at points of intersection of the fine lines formed by the repeated twinning already referred to. These features are illustrated diagrammatically in Plate X, fig. 1, which represents a cleavage rhombohedron of the calcite viewed normally to one of its faces.

By treatment with cold dilute hydrochloric or nitric acid, the calcite is readily dissolved, but the needles, being practically insoluble, remain as a scaffolding or lattice having the angles and form of the negative obtuse rhombohedron *e* (01$\bar{1}$2). If care is taken to avoid excessive effervescence, as well as movement of the specimen, during solution, it is possible to obtain an unbroken and continuous lattice from cleavage-pieces an inch or more in diameter. The lattices are sufficiently strong to permit of their being moved about in the solution, and the smaller ones may even be transferred with safety from one vessel to another, provided they are kept completely immersed; but they immediately collapse when an attempt is made to remove them from the solution or water. It is unfortunately not possible to obtain a very satisfactory photograph of these beautifully delicate structures when they are at all large; the needles being so close together that those in successive planes interfere and overlap to give the network a false appearance of solidity. Some examples of smaller ones, however, are shown in Plates VIII and IX. For these photographs, which illustrate very clearly the characteristic features and general appearance of the structures, the writer is indebted to Mr. S. Werner, of the Metallurgical Department.

The orientation of the lattice within the cleavage rhombohedron of calcite is shown diagrammatically in Plate X, fig. 2; this figure also illustrates the way in which the needles emerge at points lying along lines parallel to each of the rhombohedron-edges, and also parallel to the longer diagonal of each face, as well as the fact that the planes in which the needles lie would truncate the terminal edges of the cleavage rhombohedron, and coincide with the planes of the obtuse negative rhombohedron *e* (01$\bar{1}$2). To avoid complication, the secondary twinning is omitted in this figure.

The fact that the needles build up a lattice which has the form of the rhombohedron *e* (01$\bar{1}$2), and also that the skeletal planes of the structure are invariably coincident with the planes of the twin-lamellae within the calcite, indicate at once a close connexion between the development of the twinning and of the enclosed needles. Evidently the secondary twinning preceded the formation of the needles, although not necessarily by any long time interval; indeed, the two may well have had an essentially contemporaneous origin. The twinning is not only repeated, but it has taken place on three mutually inclined planes, whose intersections correspond with the directions of the edges of the rhombohedron *e* (01$\bar{1}$2). This secondary twinning has been imposed upon the crystalline limestone as a result of the extreme pressure to which it was subjected during its metamorphism. Under these conditions, capillary pressure channels, if formed at all, would be expected to develop at the intersections of the inclined twin-planes; every line of intersection of the thin lamellae, in reversed position, might well constitute a line of extreme disturbance and weakness in the calcite, and it is along these lines that the needles have developed.

Thus the occurrence is not to be regarded as a regular intergrowth in the proper sense of the term, since the needles have been deposited along capillary channels[1] whose positions within the calcite were pre-determined by the secondary twinning: the resulting lattice does not owe its form to any crystallographic similarity between its material and that of the calcite, but is in reality pseudomorphous.

The needles are extremely thin; an idea of their dimensions, and also of their relative and rather uniform spacing within the lattice, may best be gained from Plate VIII, in which the specimens are shown magnified 4½ diameters. The needles are pure white, with a dull lustre, though both these features may be due to the etching of the surface by the dilute acid. Two surfaces, opposite to one another, frequently have a feeble vitreous lustre, as though the needles were platy; some examined in cross section were found to be four-sided or polygonal. They are quite soft, non-flexible, and brittle. The specific gravity is in the neighbourhood of 2·5; the material floats on a liquid of specific gravity 2·6, and sinks when this is lowered to 2·45, but owing to the minute

[1] These were studied by Sir David Brewster in 1844, and described in greater detail by G. Rose, Über die im Kalkspath vorkommenden hohlen Canäle. Abhandl. Akad. Berlin, for 1868, 1869, 57–79.

size of the needles a more exact determination was not possible. Heated before the blowpipe, the needles are fusible.

The needles do not exhibit very definite optical characters. Immersed in oil and examined under the microscope, they appear drusy and do not transmit much light; they have straight extinction, weak or medium birefringence, and compensation takes place when the quartz-wedge is inserted normal to their length. In thin sections of the calcite itself, the needles are scarcely noticeable. Fine, but indistinct, lines may be seen traversing the calcite crystals, but except that they follow different directions, they can hardly be distinguished from the usual cleavage-traces and twin-lamellae.

In order to obtain material for analysis, a quantity of the calcite was dissolved in dilute hydrochloric acid, and the residue washed. From this a preliminary separation of the white needles from the insoluble minerals present was made by repeatedly agitating the mixture in a beaker full of water and filtering off the needles which, largely owing to their habit and small size, remained in suspension after the other minerals had sunk to the bottom. This material was dried at 100° C., after which the needles were separated as cleanly as possible from admixed minerals (for the most part minute flakes of graphite) by picking the latter out under the microscope.

Two separately-prepared samples gave the results shown in columns I and II below. The quantity of material used was in each case very small (0·0821 and 0·2987 grams respectively). The 10·78 per cent. H_2O given in analysis II represents the loss in weight on ignition. The FeO shown in the analyses is the total iron calculated as ferrous oxide.

	I.	II.	Calculated for $5\ MgO \cdot 6\ SiO_2 \cdot 4\ H_2O$.
SiO_2 ...	57·23 ...	56·37 ...	56·96
MgO ...	30·35 ...	30·43 ...	31·65
FeO ...	1·66 ...	2·47 ...	—
CaO ...	0·37 ...	none ...	—
H_2O ...	Not detd. ...	10·87 ...	11·39

The material is not entirely unacted on by hydrochloric acid. A small quantity was digested with concentrated acid for some time, and the residue, after washing and drying at 100° C., was found to contain SiO_2 63·93, MgO 26·16, FeO 1·21, H_2O 8·08 per cent. It is thus possible that the analyses given in columns I and II above may not express the true composition of the needles, which were no doubt affected in some slight degree by the cold dilute acid in which the calcite enclosing them was dissolved. However, the material used in each analysis was the product of a separate preparation, and from the close correspondence in the results obtained it may be concluded that the essential composition is approximately as given.

The needles are thus a hydrous magnesium silicate, and in composition they may be nearly related to certain varieties of serpentine or talc. The figures actually obtained in the analyses agree most nearly with the formula $5\,MgO \,.\, 6\,SiO_2 \,.\, 4\,H_2O$, which is that usually assigned to spadaite; the last column gives the theoretical composition for this compound.

The minerals left undissolved when the calcite is treated with cold dilute acid include pyroxene and quartz, both of which usually have the form of small, colourless, transparent grains, sometimes almost perfectly spherical, and at other times exhibiting bright faces with rounded edges. Titanite of a clove-brown colour is less common; it also is usually lenticular, but occasionally occurs as well-developed crystals. Graphite is fairly plentiful, as thin hexagonal plates, whose edges in many cases are modified by narrow facets which yield bright reflections; measurement showed that in most cases these belong to the rhombohedron $(10\bar{1}1)$, but other forms are probably also present. Pyrite is not common, and the majority of the crystals observed have the normal habit and are rich in forms. More interesting are some extremely thin capillary crystals of this mineral, a few only of which were found when picking out the material for analysis; one has a length of 2 mm., but for the most part they are much shorter than this. These crystals are bright, with perfect faces and sharp edges; they are elongated in the direction of an octahedron edge, and are doubly terminated. The forms present were identified by partial measurement of two or three of the crystals. The principal form in the 'prism' zone is the octahedron, and the edges between its four faces are replaced by very narrow facets belonging to the cube, rhombic-dodecahedron, and trapezohedron *n* (211). These are all well defined on the crystals measured, and readings by maximum illumination indicated, in addition, the presence on some of the crystals of faces belonging to the forms *m* (311), *p* (221), *q* (331), and *r* (332). The elongation of pyrite crystals in the direction of an octahedron edge, instead of along a cubic axis, is apparently unusual.

The crystals of these included minerals are all small, seldom more than 1 or 2 mm. in diameter. They were all formed prior to the needles of hydrous magnesium silicate. The minute flakes of graphite are frequently seen to be caught up and held in the lattice, but not penetrated by the needles; and the same is no doubt true of the other minerals also, but owing to their weight they break away from the fragile structure when the calcite supporting them is removed by solution.

With regard to the source of the solutions which have supplied the magnesium silicate of which the needles are composed, several alternative hypotheses might be advanced. The blue calcite itself contains little or no magnesium; an analysis gave CaO 56·12, MgO 0·41, and CO_2 43·53 per cent., the last constituent being estimated from the loss in weight on ignition. It is quite possible, however, that the original limestone may have contained some magnesium, and that this was set free, and rendered available in the form of a solution of magnesium silicate, during the metamorphism of the limestone, when it acquired its crystalline character and the secondary twinning was imposed upon it. The possibility of such a source receives support if, as has been suggested, the needles were formed contemporaneously with, or immediately after, the development of the twin-lamellae.

On the other hand, the alteration of magnesian silicates contained in the crystalline limestone might have provided the necessary solutions. It may be recalled that serpentine is found in the Grenville limestone in many parts of Ontario as well as in Quebec and elsewhere, disseminated through the rock in the form of rounded grains, and usually in small amount only. Adams and Barlow[1] have shown that there is every reason to believe that this serpentine has been derived from the alteration of the grains of pyroxene which are so abundant in some of these limestones. In other cases, the serpentine has clearly resulted from the alteration of chondrodite, and of olivine or forsterite. In all these occurrences, the serpentine retains the form of the parent mineral, and there has been little or no transportation of material, such as has evidently taken place in the case of the needles under consideration. As stated above, pyroxene, in small rounded crystals, is distributed rather plentifully through the blue crystalline limestone of North Burgess township; so far as observed, however, this pyroxene is quite clear and fresh, with no accompanying serpentine, and there is no evidence to suggest that it has been in any way responsible for the magnesium silicate of the lattice-like structures.

[1] F. D. Adams and A. E. Barlow, Geology of the Haliburton and Bancroft areas, Province of Ontario. Geological Survey of Canada, Memoir No. 6, 1910, p. 213.

The cause of the celestite-blue colour of the calcite was not ascertained; it may, in part at least, be due to the great number of minute inclusions.

Explanation of Plates VIII–X.

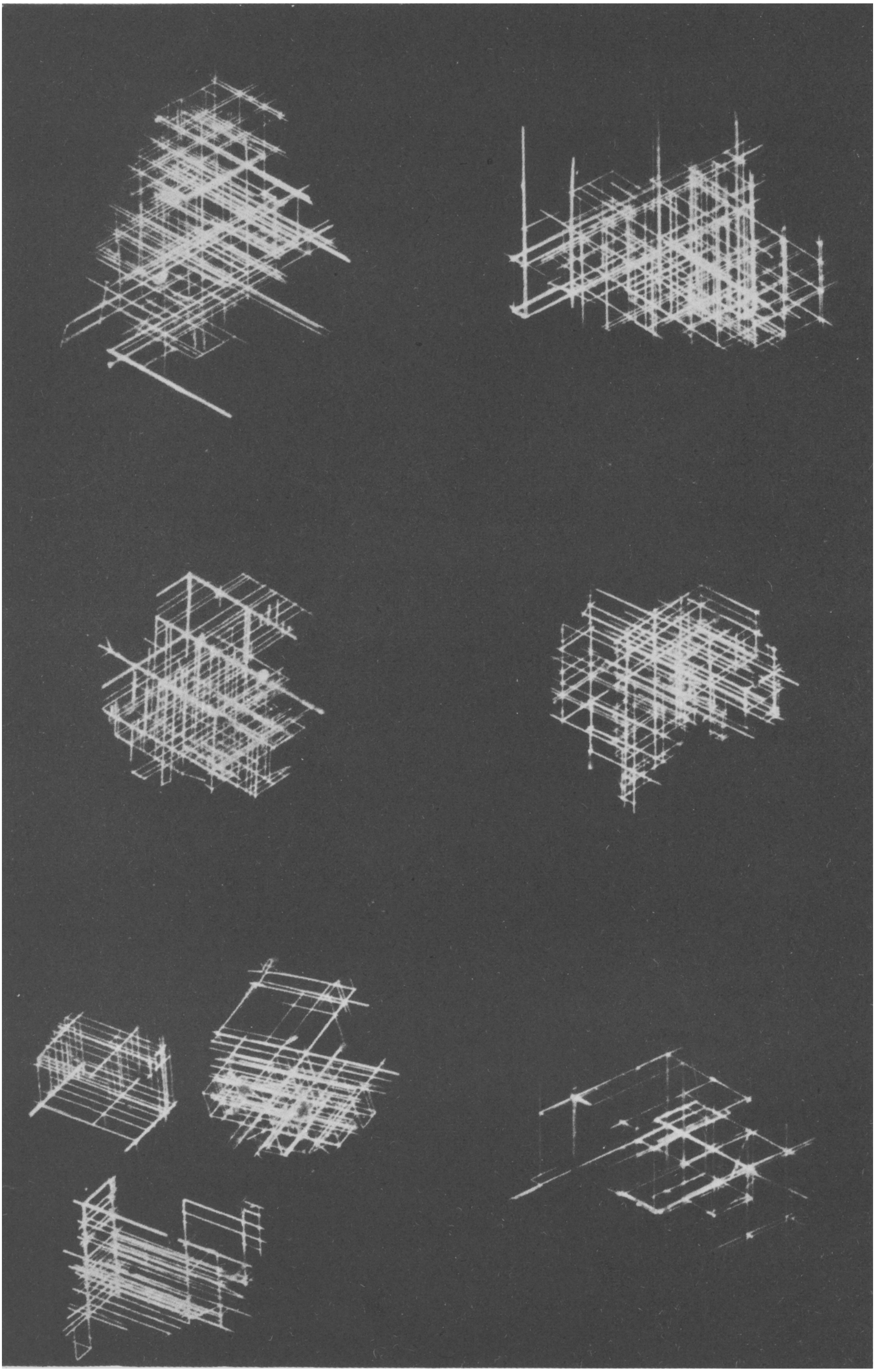
Plate VIII.—Photographs of delicate lattice-like structures, consisting of hydrous magnesium silicate, isolated by dissolving the enclosing calcite in acid. (×4½.)

Plate IX.—The same. (×10.)

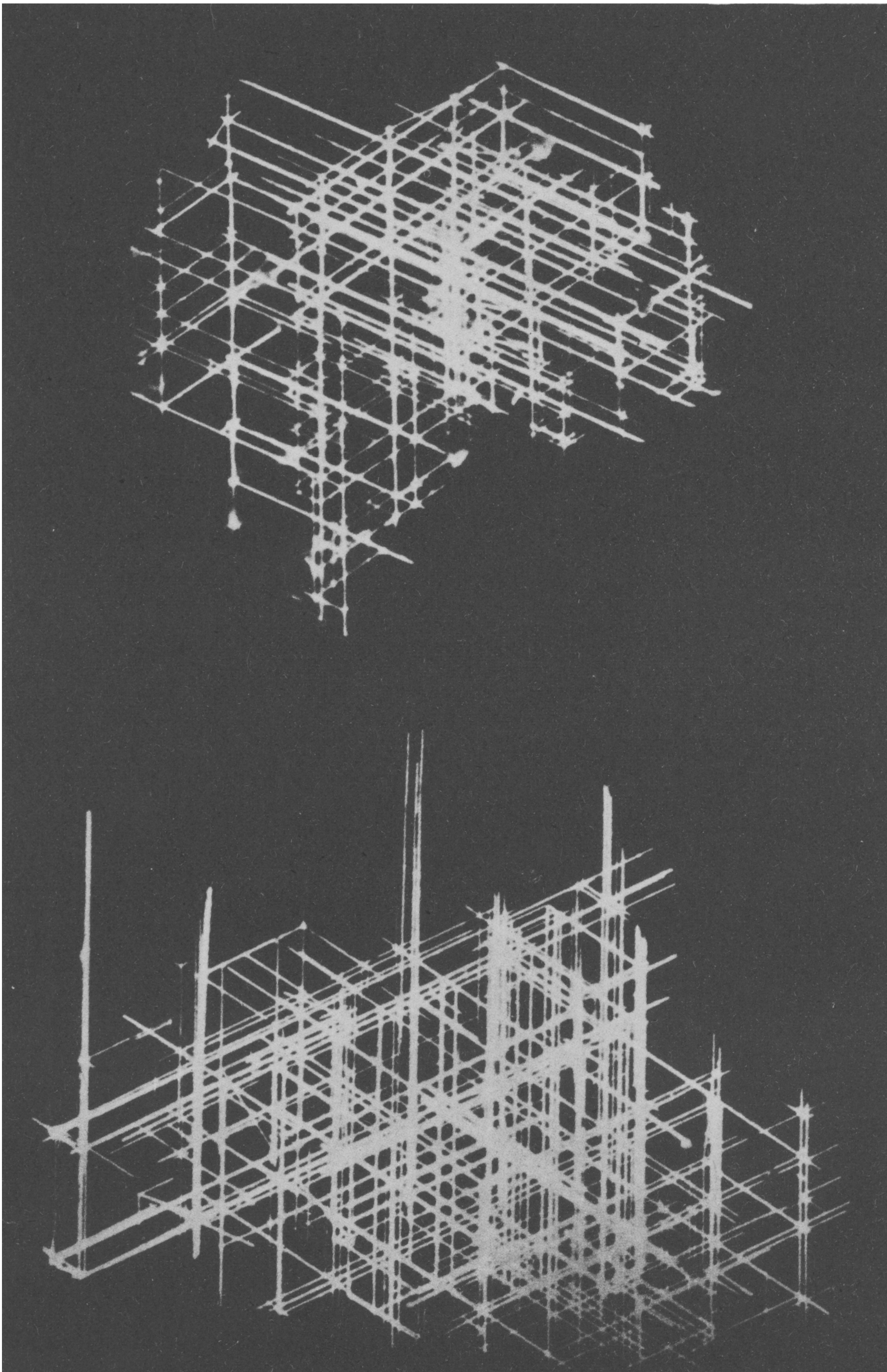
Plate X.—Diagrammatic representation of the same.

Fig. 1.—Cleavage rhombohedron of calcite, viewed normally to one face, showing striae due to lamellar twinning parallel to the three faces of the obtuse negative rhombohedron *e*. The enclosed needles emerge from the faces at the points of intersection of these twin-striae.

Fig. 2.—Cleavage rhombohedron of calcite showing orientation of the enclosed lattice. The needles are in there directions parallel to the edges of the obtuse negative rhombohedron *e*. (See p. 253.)



R. P. D. GRAHAM: LATTICE-LIKE INCLUSIONS IN CALCITE. ($\times 4\frac{1}{4}$.)



R. P. D. Graham: Lattice-like Inclusions in Calcite. (× 10.)

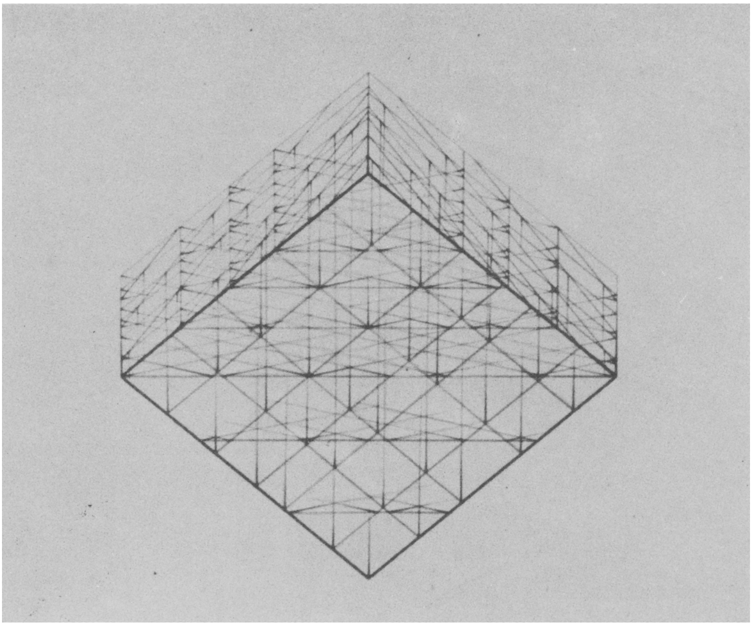


Fig. 1.

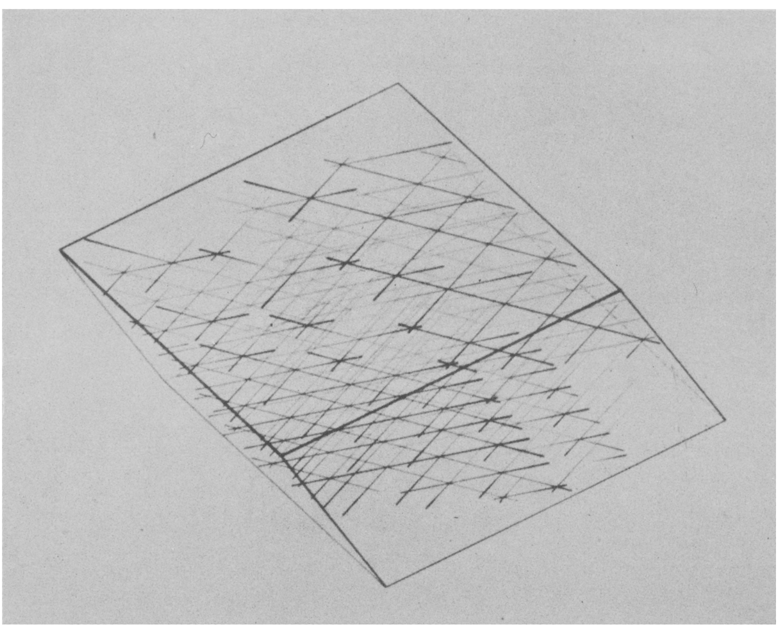


Fig. 2.

R. P. D. Graham: Lattice-like Inclusions in Calcite.