ART. XXXVIII.—*The Eozoonal Rock of Manhattan Island;*
by L. P. GRATACAP.

A BED of serpentine rock bordering the western margin of New York Island between 55th street and 60th street, and now for the most part built over, some years ago awakened a momentary interest from its display of strips of ophio-calcite which resembled the eozoonal beds of Canada, and led to some surmises as to their organic character. This area of serpentine rock, forming a band enclosed on the west and east by mica schists or a highly micaceous gneiss and limited southward by a broad outcropping of granite, is gradually disappearing from view and may at any time become an affair of local record. At present its best exposure is on the north side of 59th street between 10th and 11th avenues, and it can be traced to near 56th street, by isolated knobs appearing above the level of the sidewalk and in back yards. It was recently uncovered to some extent when the cisterns for the immense gas-holders of Equitable Gaslight Company were being constructed, and some examinations then made both of the rock in place and of microscopic sections, may prove of interest in view of the general attention given to the discussion of the origin of serpentine, a discussion which seems to widen; and to which the later contributions by Dr. Becker* would seem to give a new impetus.

This outcropping of serpentine is intimately associated with and intermingles with an acicular fibrous partially altered hornblende or actinolite, the hydrous anthophyllite of Dana. From this area were derived the numerous bowlders of this rock which are found to the south as far as the northern margins of Long Island. Dr. L. D. Gale, as quoted by Mather,† describes this anthophyllite locality in the following words: "This rock extends from 59th street following the strike, which is N. 30° E.; varies from this to due north and south as far as 63d street, where it dips down and disappears below the river.

* Cretaceous Metamorphic Rocks of California, by G. F. Becker, this Journal, xxxi, p. 348.

† Geological Survey of New York, Pt. 4, p. 581.

The rock varies considerably in character in different places where it has been uncovered, and occupies a series of conical hills some five or six in number, distributed in a northerly and southerly direction. In some places, as at 60th street, it is talcose in structure, and may be split into thin slabs; in others it is dark gray, almost black, composed of straight fibers arranged in a columnar form, meeting and crossing each other frequently at right angles." He further says, "it is remarkable that the granite lying on the west and the gneiss on the east of the rock in question, come in complete contact with it without intermixing. So remarkable is the line of separation on the side next to the gneiss, where there is the best opportunity to examine the two, that within the space of three inches, each rock possesses all of its own peculiarities, with none of those of its neighbor." In speaking of the serpentine, he says, "in the same vicinity are found masses of serpentine and limestone intermixed exhibiting a porphyritic appearance, the serpentine appearing green and the limestone white;" this refers to the eozoonal-like portions which would seem, so far as their microscopic appearance goes, to easily warrant their reference to a close relationship with the Canadian rock containing that debateable organism.

Cozzens, in his Geological History of Manhattan or New York Island (1843), p. 12, refers to this locality, saying, "between 54th and 62d streets, the shore and 10th avenue, there are four or more small knolls of black serpentine, with scales of silvery or golden talc, accompanied by a vein of anthophyllite about twelve feet wide. This vein is in a vertical position. At the north end of the serpentine proper, this anthophyllite shows itself in two places, *in place*; one, on the rising ground, and near the sienite, the other at high-water mark on the shore. Actinolite is found imbedded in the anthophyllite. The serpentine locality commences where the granite ends. At the south end there is a vein of carbonate of lime. This carbonate of lime has many small specks of serpentine diffused through it, and forms a kind of 'verd antique,' which, when polished, makes handsome specimens."

These early observers speak of the association of the serpentine with hydrous anthophyllite, and this association points significantly to the origin of the serpentine itself. This bed of serpentine is in all probability an altered amphibole or hornblende schist and the "porphyritic," "verde antique," eozoonal portions, the products of such, are alterations produced under conditions of strain and pressure, accompanied by aqueous infiltrations. I have not seen the vein of anthophyllite alluded to above, but on visiting the locality on 59th street, where a ledge rises up in a mound-like prominence, I found

anthophyllite in masses, apparently recently blasted and removed from their beds of place, with which was seen actinolite largely serpentinized. An examination of the hill showed a vertical face where Eozoon structure (ophio-calcite) was seen at a number of points. It appeared in seam-like bands, expanding in some places and contracting at others, forming an irregular scattered prolongation of parts, varying in grain from fine to coarse, the former accompanying an apparent flexure or contortion of the original stratum. On the south side of 59th street, where the excavations were being made, mentioned above, an exposure of the serpentine bed was accessible where the ophio-calcite was seen, frequently presenting a seam-like appearance, contracting to narrow bands and again developed in broader sections, while sometimes it sporadically occupied nests or spots enclosed in the surrounding rock. Away from these parts the serpentine was fibrous or micaceous.

Should any one feel disposed to refer these eozoonal-like portions (fig. 7) to an organic origin, the extended irregular

vein-like parallel strips, which they present, would form a seemingly strong objection to such a reference. Coralline bodies occur in reefs or reef-like lines, but this mosaic of serpentine and calcite has nothing coralline about it in any sense, and when placed, as it only can be placed, on the assumption of its zoological affinities, with the protozoa or metazoa, it repels all analogies with any thing in those classes of animal life, by its linear extent, the actual length of these broken strings of ophio-calcite, being in the exposed sections, from 10 to 20 feet.*

The films of this "verde antique" are not horizontal, but

* It is true that Professor Hyatt (*Science*, vol. vi, p. 386) speaks of spongioid bodies *Archæocyathus*, *Ethmophyllum*, etc., as probably the reef-builders of the primordial seas, so that linear extent merely might not preclude the possibility of the eozoonal rock being referred to an organic origin. But when in connection with their length these eozoonal veins have only a moderate width of a few inches their reference to the reef-like masses of sponges seems incredible.

rise and fall as if they had undergone plication, but so strongly do they suggest the quartz or granite veins found in the folded gneiss layers of the island, that their origin may be connected with this very plication, the incipient change in the original hornblende schist having been induced at the moment of folding, the alteration involving the change of the hornblende to serpentine, with the exclusion of lime, which through the action of percolating waters finally filled the interstitial spaces as calcite.

An examination of the thin microscope slides, made of sections of this ophio-calcite, proved very satisfactorily the change of the hornblende into serpentine, threw some light upon the process of change, and lent some support to the view of the segregated character of the calcite.

Groups of hornblende crystals were constantly encountered surrounded by the serpentine (figs. 5, 6), while in these, phases

of alteration were detected and separated. The change of the hornblende to serpentine seemed to be frequently preceded by a breaking up of the hornblende into fibers, giving the blade a striated appearance, while the serpentine granules develop along these. In some cases the hornblende blade is replaced in patches by serpentine, against which the remaining fibrous substance, partially changed, but not deprived of its acicular appearance, abuts with a crenulated margin. A second method of change seems to consist in a sort of exfoliation, the hornblende stripping up, the alteration entering from all sides with no apparent physical change, to the condition of asbestos. In this second process the hornblende presents an eroded appearance and frequently shows minute cavities, the whole aspect being not dissimilar to that of a melting fragment or

pellicle of ice. In one instance a section displayed a pavement of hornblende enclosing a strip of serpentine with a plentiful sprinkling of magnetite, and in another example, an interesting illustration of the change of the hornblende to serpentine, was observed where a long fiber of the actinolite (?) was altered to serpentine at nearly equal lengths throughout its extent. The alteration started from minute transverse breaks and progressed on either side for a short distance into the substance of the crystal. The unchanged portions of the amphibole separating these serpentinized joints, gave the fragment the appearance of an equisetum (fig. 2). This was repeated less strikingly in the same section over its entire surface. Again aggregates of viridite or chlorite were seen scattered over the serpentine in one slide (fig. 4), a possible phase in the change of the hornblende to serpentine or a secondary product of its alteration.

The formation of the calcite in an interrupted manner seemed clearly shown in many instances, as where two irregularly interlocked areas of this mineral were seen with the cleavage lines of one section abruptly terminating at the margin of the other (fig. 1). This would lead to the inference that the deposition of the two parts was not simultaneous and lend support to the view of the intermittent secretion of the calcite from aqueous solutions, in the interstices of the serpentinized hornblende. Lacunæ of calcite appear irregularly through the serpentine, the ragged and spiculate edges of the serpentine yielding inwards, while in some instances a semi-dark line marking a change of thickness, separated an interior core of calcite from the border contiguous with the serpentine, an indication of intermittent secretion.

The examination of these sections leaves little room for doubt that a bed of hornblende rock has undergone a conversion more or less complete into serpentine, and that along lines of strain incident to its folding, where thermal conditions of an intense character were developed, accompanied, or perhaps succeeded by the introduction of water, the change has been perfected most rapidly and has been assisted by the elimination of lime carbonate as calcite, and probably in some cases the double carbonate of lime and magnesia as dolomite.