

ART. XIV.—*Pinite in Eastern Massachusetts: its Origin and Geological Relations*; by W. O. CROSBY.

ONE of the most interesting constituents of the conglomerate so extensively developed in the vicinity of Boston is a soft, greenish and somewhat unctuous, amorphous mineral, which many observers have mistaken for serpentine, but which is shown by its ready fusibility not to be magnesian; while analysis proves that it is essentially a hydrous alkaline silicate of aluminum. In fact, it presents in its chemical, as well as its physical, characters a close agreement with the species pinite. (See analyses below). The hardness is ordinarily near, or a little above, 3; the purer varieties, however, usually refuse to scratch calcite. The specific gravity, so far as determined, is between 2.7 and 2.75. Luster none, or waxy and feebly shining. The predominant color is a whitish-green; but the variation is from nearly white through whitish, grayish and dirty

greens to a dull grass or olive green. The deeper color seems usually to belong to the purer varieties.

At some points, the paste or cement of the conglomerate appears to include much pinite; yet in its purest state this substance occurs mainly in the form of pebbles. In either case, however, it is always clearly an imported constituent of the rock. Although not properly a principal ingredient of the conglomerate, the pinite detritus is scarcely ever entirely wanting; while in several limited localities the rock is mainly composed of it; forming a distinct pinite conglomerate. The following are the principal localities in the Boston basin where the conglomerate is notably rich in pinite: the north shore of Squantum; Milton, on and near Central Avenue; several points in Newton, especially in the vicinity of Newton Corner and Newton Upper Falls; and along the line of the Sudbury River Aqueduct in South Natick.

The pinite pebbles, probably on account of their inferior hardness, being permanently plastic, as it were, are usually very much flattened in parallel planes; giving rise, where they are sufficiently abundant, to a decidedly schistose structure in the rock, or more properly an imperfect cleavage. This cleavage structure in the pinite conglomerate is very clearly the result of pressure, and shows a nearly constant dip and strike in all parts of the district; being entirely independent of the stratification, and agreeing perfectly in all these respects with the cleavage of the slate rocks. Where the pinite pebbles are scattering, they are sometimes found as contorted layers enveloping pebbles of harder materials.

The distinctly stratified rocks of the Boston basin include two principal varieties—the conglomerate, or “Roxbury pudding stone,” and the slate. The volume of each of these varies from four hundred or five hundred to perhaps one thousand feet; and the former constitutes the lower half and the latter the upper half of one continuous and conformable series. The upper or argillaceous member of the formation includes the Paradoxides slate in Braintree; and this determines the Primordial age of the entire series. The slate, and more especially the sandstone which marks the passage from the slate to the conglomerate, is sometimes greenish and evidently composed in part of the débris of pinite. The sediments in the basin of the River Parker, some thirty miles northeast of Boston, are also probably of Primordial age; and the conglomerate portions are largely, sometimes almost entirely, composed of pinite. Traces of this mineral have been frequently observed in the conglomerate of uncertain age skirting the southern base of the Blue Hills, and extending thence southwesterly to Rhode Island.

The pinite is also found in other fragmental formations of this region. Underlying the Primordial beds of the Boston and River Parker basins, and having its best development in the towns of Marblehead, Saugus, Melrose, Malden, Medford, Dedham, and Hyde Park, is an extensive and somewhat peculiar conglomerate rock known locally as the "breccia" or "petrosilex breccia," being principally, usually almost wholly, composed of fragments of petrosilex cemented by a paste of the same rock more finely comminuted. The breccia is often of a greenish color, and in not a few localities includes in both fragments and cement large amounts of what appears to be more or less perfect pinite, i. e., material of a light green or greenish-white color, which yields readily to the knife, affords water in the closed tube, and is somewhat unctuous, resembling serpentine in many of its physical characters, and yet easily fusible before the blowpipe. Dr. T. Sterry Hunt has called my attention to the existence of pinite in the breccia in Saugus; and my own observations have convinced me that its occurrence in this way is a general fact. The best points for observing this variety of breccia are the following: East Saugus, south of the railroad; Newton, about one mile south by west from Newton Center; West Dedham; many points in Hyde Park and the adjacent part of Dorchester (Mattapan); and Milton, between the Neponset River and Pine Tree Brook.

The basins mentioned as holding the Primordial strata and the underlying breccia have been excavated from the ancient Huronian formation, which, in Eastern Massachusetts, consists mainly of the following lithological members: granite, binary and hornblendic; petrosilex, stratified and unstratified; stratified and unstratified diorite; and quartzite. In these old crystalline rocks we have the sources of all the materials observed in the conglomerate and breccia, not excepting the pinite. In this connection, the most interesting Huronian terrane is the petrosilex. For the sake of convenience, I here include under the name petrosilex both the acidic division of the compact feldspar rocks, or petrosilex proper, and the basic division, or true felsite. The physical distinctions between the true petrosilex and felsite, in Eastern Massachusetts, are not conspicuous. They both include exotic and indigenous varieties; and both present the same general range in textures, including, besides the ordinary compact and porphyritic forms, many different kinds of banded structure. Elvanite or quartz porphyry is a common rock; but this belongs, of course, entirely to the acidic group. As a result of numerous chemical analyses, I find that the petrosilex predominates, and is usually of red, brown or purplish tints; while the characteristic colors of the felsite are greenish, whitish and sometimes black.

Although associated with both the petrosilex and felsite, the pinite is found most frequently with the latter. Wherever occurring in the conglomerate and breccia, as already observed, this material is always clearly an imported constituent; but with the Huronian formation it never presents this aspect, all the facts pointing to the conclusion that it is indigenous here. In other words, and more explicitly, the pinite, as far as the evidence allows us to judge, exists in the Huronian series only in association with the petrosiliceous group, and here only as a product of the superficial decomposition or alteration of these rocks. Indications of this may be observed in many places. In the first place, we have abundant evidence in the fragmental rocks themselves that the pinite which they contain has been derived from, and owes its genesis to the alteration of, the Huronian petrosilex (using this term in its comprehensive sense, as explained above); for there exists, both in the pebbles of the puddingstone and the fragments of the breccia, every possible gradation between unaltered petrosilex and the purest pinite; and it seems highly probable that much of the petrosiliceous débris of these rocks is still suffering some change in the direction of a conversion to pinite.

Turning now to the parent formation, we find the evidence even more conclusive. For instance, the greenish elvanite which covers a large area in Needham, usually presents a slaty appearance, yields to the knife, and affords water abundantly. Substantially the same statement may be repeated concerning the green petrosilex in West Dedham, and the greenish "toadstone" and some other varieties of petrosilex in Newbury. In all these cases the rock is green, at least superficially. In Marblehead, Lynn, and other districts, I have observed the brown, gray, black, and other colors of the petrosilex changing to green near the joints. In many instances, probably, the change is to kaolinite rather than pinite, but not always.

Another argument showing the derivation of the pinite in the fragmental rocks from the petrosilex is found in the fact that, with few exceptions, those portions of the conglomerate (and the same is true of the breccia), marked by a predominance of pinite débris occur in close proximity to ledges of petrosilex; and in the exceptional cases the underlying rocks are probably petro-siliceous. This association is very significant; but the strongest evidence on all these points yet remains to be adduced.

The locality affording at once the clearest proof that the pinite is indigenous in the petrosilex, that it makes its appearance in this association as a decomposition product, and that pinite so originating is essentially identical with, and the source of, that in the more recent, detrital formations of Eastern Mas-

sachusetts, is in Milton, on Central Avenue, about one-fourth mile south of the Neponset River. The petrosilex is exposed here only on the northwest side of the avenue, forming the southwest end of a section which is composed mainly of a typical example of pinite conglomerate. The small pinite pebbles are embedded in a brownish, slaty paste, and have suffered an extraordinary degree of compression, developing a well-marked foliation or cleavage in the rock. The contact between the petrosilex and conglomerate is straight and well-defined. It strikes east-west, and dips to the north  $75^\circ$ , being exactly parallel with the schistosity or cleavage of the last named rock; while this imperfect cleavage agrees perfectly in dip and strike with that observed elsewhere among the slates and conglomerates of the Boston basin. The contact just noticed almost certainly marks a fault, and both it and the cleavage are at right angles to the strike of the beds. The stratification, however, is much obscured by the cleavage, though it can still be made out by careful observation.

The color of the unaltered petrosilex in this case is dark purple, and the pea-green pinite occurs in it in the form of irregular and ill-defined masses which seem to have their major axes normal to the surface of the ledge. Closer observation shows that they follow the jointing of the petrosilex; each joint being bordered on either side by pinite which exhibits a *gradual* passage into normal petrosilex at a distance of a few inches. The rather limited exposure is best in the vertical direction; and tracing one of the pinite-bordered joints downward, it seems plain that the zone of this material is broadest and best-marked near the surface, becoming narrower below, and almost entirely fading out at a depth of a few feet. The best examples of the pinite are found along those joints which have become the seats of slender veins of quartz. The disposition of the pinite in the petrosilex evidently leaves us no option but to believe that here at least it is a decomposition-product; and that percolating atmospheric water, for which the joints have afforded channels, has been the chief agent in its formation.

The indications are very strong that, geologically speaking, the conglomerate has not been long removed from this part of the petrosilex; hence this is probably, in all essential respects, an ancient surface; and I take it that we have here an example of pre-Primordial decomposition. The composition of a characteristic specimen of the pinite, taken from its original position in this ledge, is shown by the following analysis (I), made by Miss E. M. Walton:—

	I.	II.
SiO <sub>2</sub>	57·924	59·520
Al <sub>2</sub> O <sub>3</sub>	23·739	21·628
FeO	2·826	5·840
K <sub>2</sub> O	4·560	6·900
Na <sub>2</sub> O	5·283	·804
H <sub>2</sub> O	3·142	3·490
MnO	1·443	not det.
Cr and Mg	traces	not det.
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	98·917	98·182

The pinite in this petrosilex is unquestionably the source of that with which the overlying slaty and schistose conglomerate is so replete. For, first, the pinite in the conglomerate diminishes rapidly as we recede from the outcrops of petrosilex; and, secondly, the mineral, in the two geological positions, is essentially identical physically and chemically. The pinite pebbles are mostly quite small and well flattened; and hence considerable samples are not easily secured. The portion submitted to analysis was obtained from perhaps a dozen pebbles from different parts of the ledge, great care being taken to prevent admixture with the slaty paste. This was analyzed by Mrs. Alice B. Crosby, and the result is given in analysis II above.\*

The formation of pinite by the alteration, and particularly by the hydration, of feldspathic rocks and minerals, which has been denied by some authorities, must apparently be conceded in some cases. Of course where derived from a rock holding free quartz in an impalpable state, such as petrosilex, the pinite, though appearing quite pure, may, as the above analyses show, afford an abnormally high percentage of silica. A typical example of purple banded petrosilex from the Milton area, though not from the pinite ledge, afforded 66·3 per cent of silica. This is, strictly speaking, essentially a true felsite. Other ledges in the vicinity of Central Avenue contain an abundance of pinite, but the exposures are not favorable for displaying its relations to the felsite.

In summarizing the geological history of the pinite (or pinite schist, since, considering its origin, it is rather more properly a rock than a mineral), we may say that, to furnish the pinite detritus of the various fragmental rocks in Eastern Massachusetts, an extensive formation has been required. No vestiges of such a formation, distinct from the Huronian petrosilex, now exist in this region; and with the petrosilex we have the pinite only as a product of superficial decomposition. The facts seem to warrant, or at least to forcibly suggest, the con-

\* Both of these analyses were made in the Woman's Laboratory of the Massachusetts Institute of Technology.

clusion that, in pre-Primordial times, the petro-siliceous rocks, to a considerable depth, were changed by the action of atmospheric agents, not to kaolin, as generally at the present time, but to or toward pinite; and that subsequently this decomposition-product was, for the most part, swept away by the sea in which were deposited the breccia and the Primordial conglomerate.

Another very clear example of the derivation of pinite from feldspar has been observed on the rocky peninsula of Marblehead Neck. On the northwest shore of the Neck, visible only at low tide, is a hard, whitish, compact, feldspathic sandstone or slate, the age of which is unknown. It rests unconformably upon the banded petrosilex forming the shore at this point; and the layer of pebbles at its base shows very clearly that the sandstone is chiefly composed of the débris of the petrosilex. This origin explains the highly feldspathic nature of the sandstone. Scattered through the sandstone are clear, almost transparent, rhombic crystals of orthoclase, 3 to 6<sup>mm</sup> long, which are very clearly indigenous in their present positions. Occasionally they are sufficiently numerous to give a porphyritic aspect to the rock. Erratics of this sandstone are scattered all over the Neck; and in some of these which are very thoroughly weathered, the orthoclase crystals are changed to a soft, unctuous, waxy, green mineral,—in other words, to pinite. Where the weathering has been less thorough, the characters of the pinite are less strongly marked.