No. 4.—*A Microscopical Study of the Iron Ore, or Peridotite, of Iron Mine Hill, Cumberland, Rhode Island. By* M. E. Wadsworth.

The attention of the writer was first particularly called to this formation by some specimens presented to him by Mr. H. B. Metcalf in the spring of 1880. These did not appear to the writer to be any common ore of iron, but rather fragments of a basic eruptive rock containing much iron. Sections were accordingly made which revealed its true character.

The formation was described by Dr. Charles T. Jackson in his report on the Geological Survey of Rhode Island in 1840. He states that Iron Mine Hill "is a mountain mass of porphyritic magnetic iron ore, 462 feet in length, 132 feet in width, and 104 feet in height above the adjoining meadow. From these measurements, which were made over only the visible portion of this enormous mass of iron ore, it will appear that there are 6,342,336 cubic feet of the ore above natural drainage. . . . Its specific gravity is from 3.82 to 3.88. . . . This ore is remarkable both on account of its geological situation and its mineralogical and chemical composition. It appears to have been protruded through the granite and gneiss at the same epoch with the elevation of numerous serpentine veins which occur in this vicinity. This will appear the more probable origin of this mass, when we consider its chemical composition in comparison with that of the iron ore, which we know to have been thrown up with the serpentine, occurring on the estate of Mr. Whipple, and the fact that the ore at Iron Mine Hill is accompanied by serpentine mixed with its mass in every part, gives still greater reason for this belief." (*l. c.*, pp. 52, 53.)

He gives as the result of his chemical analysis of the "Porphyritic Iron Ore from Iron Mine Hill, Cumberland," the following (*l. c.*, p. 53):—

SiO_2	23.00
Al_2O_3	13.10
Fe_2O_3	27.60
FeO	12.40
MnO	2.00
MgO	4.00
TiO_2	15.30
H_2O and loss	2.60
Total,	100.00

In 1869 the Rhode Island Society for the Encouragement of Domestic Industry published a report relating to the coal and iron in Rhode Island, from which we glean the following. The iron ore is regarded as practically inexhaustible, the mass at Iron Mine Hill visible above drainage being estimated at two millions of tons.

"It is also conceded, as regards quality, that the Cumberland ore is free from sulphur and phosphorus, the most common and worst impurities, and that it contains manganese, the most prized of all the elements found in connection with iron. For these reasons the Cumberland ore is sought by manufacturers at a distance, to mix with softer ores and improve their quality, and is now exported from this State for that purpose."

It seems that this Iron Mine Hill ore was employed in 1703, mixed with the hematite of Cranston, R. I., for the casting of cannon. The work was done at Cumberland, and, in part at least, "the cannon used in the celebrated Louisburg expedition, in 1745," were cast from these ores. The manufacture was abandoned in 1763, owing to an explosion of the furnace, by which the proprietor was killed.

During the administration of John Adams the same ores were also used for the manufacture of cannon. It seems that the Cumberland (Iron Mine Hill) ore was employed in the manufacture of charcoal iron at Easton, Chelmsford, and Walpole, Mass., as late as 1834. "The Cumberland ore, mixed with equal quantities of Cranston hematite or bog ore, produced, for a long period, a charcoal iron unsurpassed in this country. . . . The Cumberland ore contains an uncertain percentage of titanium, which, while it improves its quality, helps make it refractory. The ore is porphyritic, the magnetic oxide being associated with earthy minerals, principally feldspar and serpentine." It would seem that in 1869, and before, the ore was largely shipped to Pennsylvania to mix with other ores.

A letter of Professor R. H. Thurston, published in this report, states: "The Cumberland iron ore is of the kind known to mineralogists as 'ilmenite'; among metallurgists as 'titaniferous magnetic ore,' and iron manufacturers, on account of its peculiar value for producing steel, would term it a 'steel ore.' . . . The Cumberland ore is conveniently located and of inexhaustible extent; it is perfectly free from noxious elements, though somewhat refractory; it will furnish a very strong iron or a most excellent steel; it can be smelted within the State at a profit; it can be made directly into steel at a much greater profit; steel made from it will bring the highest prices in the market."

Professor Thurston states that the mean of various analyses made of this ore is about as follows: —

SiO_2	22.87
Al_2O_3	10.64
Fe^2O^3 } FeO }	44.88
MnO	2.05
CaO	0.65
MgO	5.67
TiO	9.99
Zn	0.20
H_2O and loss	3.05
Total	100.00

The ore on one side of the hill, where it has been most extensively quarried, shows a dark, somewhat resinous groundmass, holding large striated crystals of feldspar. The resinous lustre and greenish-yellow color, as observed under the lens, are caused by the presence of olivine. The olivine becomes more strongly marked on the slightly weathered surfaces seen on the faces of the quarry. Under a lens of high power, the olivine shows clearly on the fresh fractures. The olivine in weathering decomposes to a yellowish and reddish-brown ferruginous powder, leaving the other constituent of the rock, the magnetite, well marked. The magnetite decomposes more slowly, and forms an incoherent mass after the decay of the olivine. The rock gelatinizes with hydrochloric acid, and yields a titanium reaction. A fragment allowed to stand a day or two in weak hydrochloric acid yielded gelatinous silica copiously.

A section made with special reference to the feldspar crystals shows large porphyritic crystals of the latter enclosed in a mass of magnetite and olivine.

The magnetite forms irregular, more or less connected masses, making a sort of sponge-like structure. Its rounded and irregular cavities are filled with olivine, which also occupies the interspaces between the magnetite masses. The olivine is in rounded forms, which sometimes show one or more crystal planes. It is cut through by numerous fissures, that usually show a ferruginous staining along their sides. The olivine also holds grains of the magnetite. Except the fissuring and ferruginous staining, the olivine is comparatively clear, and shows little signs of alteration.

The plagioclase feldspar shows well-marked lines of cleavage and fracture, and is somewhat kaolinized along these lines. It contains a few irregular flakes of biotite together with grains of olivine and magnetite.

The order of crystallization appears to have been, first the magnetite, then the olivine, and lastly the feldspar.

This rock is similar to the celebrated iron ore of Taberg, Sweden, as described by A. Sjören in the Geologiska Föreningens Forhandlingar (1876, III. 42–62; see also Neues Jahrbuch für Mineralogie, 1876, 434, 435). The Taberg rock has been worked as an iron ore for over three hundred years. This Swedish ore is called by Sjören "magnetite-olivinite."

The feldspar is confined to the peridotite found on one side of the hill, where the peridotite passes into a compact greenish-black rock, showing patches of serpentine and grains of magnetite. From this fact it seems necessary to regard the feldspar as abnormal and local in the rock, which in general is composed of olivine and magnetite or their alteration products.

The structure remains about the same in the non-feldspathic portions as it is in those before mentioned as holding feldspar. But the olivine is entirely changed to a greenish serpentine which shows beautiful fibrous polarization. The serpentine retains the form of the olivine grains, their inclusions, and the network of fissures before mentioned. In some of the sections considerable carbonate was seen, presumably dolomite. In one section part of the olivine grains, especially towards their interior, remained unchanged, but on their edges they were altered to serpentine. Another change was observed here: the formation of secondary crystals of irregular outline that belong probably to actinolite. Some are elongated and narrow; others are short and broad, traversed by cleavage planes. They evidently belong to the monoclinic system.

The origin of this rock could not be told from its field relations, as its contact with any other rock could not be found. Since the only method in which its origin can be absolutely shown cannot be used without expensive excavation, it only remains to give the probabilities so far as ascertainable from the mass itself. Such microscopic characters and mineral association have been, so far as we know, only found in eruptive rocks when the origin of such rocks has been studied with sufficient care to determine it. Hence we must conclude it is most probable that this mass is eruptive also, until found to be otherwise.

It closely resembles in structure and composition some of the meteorites, except that its iron is oxidized and not in a native state, — a resemblance which for others of the peridotites has long been pointed out.

It is rocks of this character, as has been suggested by others, that give us the most probable clew to the interior composition and structure of the earth.

The rock in the field shows, to our mind, no signs of structural planes that should be referred to sedimentation. On one side the rock is massive and jointed, and on the other it is jointed in fine parallel planes. This portion of the rock is more highly metamorphosed than the other, and, as is usual in highly altered eruptive rocks, joints parallel to certain lines of pressure occur. The writer has seen this structure in many rocks that were indisputably eruptive, forming well-marked dikes in other rocks.

A rod away from the main mass of the iron ore, near one end, some serpentine appears that cannot be directly connected with the other peridotite. Microscopically its characters and structure are the same as the main rock, and there is no reason to regard it as distinct. The rock nearest to the peridotite is a mica schist some hundred feet away. It shows no characters that would indicate the transition of the ore into it.

The locality was visited by the writer in October last, in company with Professor A. S. Packard, Jr., of Brown University, and Mr. T. S. Battey, of the Friends' School, Providence, R. I. To the latter gentleman I am especially indebted for a copy of the paper of the Rhode Island Society before mentioned, and for other favors.

This examination may serve as an illustration of the aid that microscopical lithology may be to the practical side of life, since now, for the first time since this rock has been worked, can the ironmaster who wishes to use it approach understandingly the metallurgical problems it presents; whether he desires to employ the rock as a whole, or to concentrate the magnetite first.

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