

NEW OCCURRENCES OF MINERALS AT IRON MOUNTAIN, MISSOURI*

VICTOR T. ALLEN, *Institute of Technology,*
St. Louis University, St. Louis, Mo.,

AND

JOSEPH J. FAHEY, *U. S. Geological Survey, Washington, D.C.*

ABSTRACT

Salite, actinolite, dolomite, and fluorite at Iron Mountain, Missouri, are reported for the first time. Salite, $\text{Ca}(\text{Mg,Fe})(\text{SiO}_3)_2$, an intermediate pyroxene of the diopside-hedenbergite series, occurs as grayish-green columns up to 10 inches long in a skarn formed by the action of iron-bearing solutions on andesitic lava of pre-Cambrian age. It has the following chemical composition and optical properties: SiO_2 , 52.76; Al_2O_3 , 1.12; TiO_2 , 0.16; Fe_2O_3 , 1.73; FeO , 8.92; MnO , 0.47; CaO , 20.48; MgO , 13.43; Na_2O , 0.35; K_2O , 0.05; H_2O , 0.45; $\gamma=1.718$; $\beta=1.700$; $\alpha=1.691$; $2V=60^\circ$; positive; $r>v$; $Z\wedge c=45^\circ$; density=3.350. Locally salite was changed to actinolite, which has been called amphibole or tremolite; but optical properties of numerous grains fall within the range of actinolite with $\gamma=1.645$; $\alpha=1.625$; $Z\wedge c=15^\circ$. The iron garnet, andradite ($N=1.88$), replaces actinolite; and euhedral, zoned dodecahedrons contain relict fibers of actinolite. Calcite, quartz, and hematite replace early minerals. Purple fluorite occurs in quartz, but it is not in contact with hematite so its age relation to hematite is uncertain. A pink carbonate the color of rhodochrosite occurs in veins cutting the andesitic lava, but it contains only 1.45 percent MnO and has the optical properties of dolomite with $\omega=1.685$. Thus, doubt is raised concerning the rhodochrosite and manganocalcite from this deposit that were reported in 1895.

INTRODUCTION

Extensive enlargement of the Hayes Cut in a specular hematite deposit at Iron Mountain, St. Francois County, Missouri, exposed additional outcrops of ore and the pre-Cambrian andesitic lava that forms the country rock. On August 1, 1950, the senior author collected four minerals there that had not been previously described in the Iron Mountain assemblage. These are salite, an intermediate pyroxene of the diopside-hedenbergite series; actinolite that had previously been called amphibole or tremolite; purple fluorite; and pink dolomite that has the color of rhodochrosite. On January 22, 1951, the senior author revisited both the Hayes Cut and the Big Cut with Joseph W. Fusso; and they found salite only in a restricted contact zone 1 to 10 inches wide in the new workings a few feet southeast of the old part of the Hayes Cut.

* Publication authorized by the Director, U. S. Geological Survey.

PREVIOUS WORK

Hematite has been mined at Iron Mountain almost continuously from 1845 to the present. During this interval the total production of iron ore from the deposit has been reported to exceed 4,500,000 tons (Lake, 1932).

The geology of the deposit has been studied by Schmidt (1873), Nason (1892), Winslow, Haworth, and Nason (1894), Crane (1912), Spurr (1927), Singewald and Milton (1929), and Lake (1932).

Nason (1892, p. 51) considered the veins in porphyry as veins of infiltration, formed by replacement and precipitation when the waters are sufficiently saturated.

Crane (1912, p. 113) listed hematite, martite (slightly magnetic), quartz, amphibole (tremolite), and apatite as the vein minerals. He regarded the ore in part as a fissure filling but more largely as a replacement of porphyry.

Spurr (1927, p. 363) cited the deposit as an example of intrusive vein dikes of specular iron in porphyry.

Singewald and Milton (1929, p. 330) emphasized the fact that the ore bodies at Iron Mountain show replacement characteristics. They reported the mineral assemblage directly associated with the introduced hematite as quartz, apatite, garnet, tremolite, and calcite and regarded it as indicative of high-temperature mineralization.

Lake (1932, p. 56) stated that the primary ore consists principally of hematite with as much as 12 per cent of magnetite and small amounts of apatite and tremolite. Later minerals present in the ore are calcite, garnet, and quartz, which replace mainly the apatite and tremolite. He ascribed the ore to solution and stoping of the andesite porphyry by ore-bearing solutions.

OCCURRENCE AND PROPERTIES OF SALITE

Salite, a grayish-green pyroxene of the diopside-hedenbergite series, occurs as columns up to 10 inches long in a skarn formed by the action of iron-bearing solutions on andesitic lava of pre-Cambrian age now exposed in the Hayes Cut at Iron Mountain. Most of the material is contaminated with grains and stains of hematite and is unsatisfactory for chemical analysis. However, by careful hand-picking under a binocular microscope and rejecting fragments containing hematite impurities and by purifying with an electromagnet, a sample was prepared with less than one per cent hematite. This was analyzed by Joseph J. Fahey; the results are listed in Table 1. Joseph M. Axelrod of the U. S. Geological Survey made an *x*-ray diffraction pattern of this sample and reported it to be a monoclinic pyroxene with only a trace of hematite.

TABLE 1

	1	2	3
SiO ₂	52.76	50.19	
Al ₂ O ₃	1.12	2.73	
TiO ₂	0.16	0.20	
Fe ₂ O ₃	1.73	2.98	
FeO	8.92	7.54	
MnO	0.47	0.40	
CaO	20.48	23.58	
MgO	13.43	12.38	
Na ₂ O	0.35	0.45	
K ₂ O	0.05	0.00	
H ₂ O	0.45	0.02	
	99.92	100.47	
γ	1.718	1.7185	1.720
β	1.700	1.6980	1.697
α	1.691	1.6915	1.692
2V	60°	59°	56°
Z \wedge c	45°	45°	41°

No. 1. Salite from a skarn at the Hayes Cut at Iron Mountain, St. Francois County, Mo. Collected by V. T. Allen. J. J. Fahey, *analyst*.

No. 2. Salite from a skarn at the Clifton magnetite mine, St. Lawrence County, N. Y. Collected by B. F. Leonard. Norman Davidson, *analyst*. Optical properties by H. H. Hess. *Am. Mineral.*, **34**, 663 (1949).

No. 3. Optical data on salite from Iron Mountain, Mo., determined by H. H. Hess, using the same method as he did on No. 2. Data on salite from a similar but not the identical specimen No. 1. According to Hess it contains small inclusions or alterations.

Optically the salite from Iron Mountain, Missouri is positive, has indices of refraction $\gamma = 1.718$, $\beta = 1.700$; $\alpha = 1.691$, $2V = 60^\circ$; $Z \wedge c = 45^\circ$; dispersion faint, $r > v$; pleochroism faint, none observable in thin section, X = Y = pale bluish green; Z = yellowish green. Density is 3.350. The optical properties, chemical composition, and occurrence of the salite at Iron Mountain are compared in Table 1 with those of salite from the Clifton magnetite mine, in St. Lawrence County, N. Y. Salite is a relatively rare mineral in the United States, but Hess (1949) has compiled four analyses of salite and three of ferrosalite from the anorthosite and magnetite regions of New York. Schmitt (1939) has reported salite from Hanover, New Mexico.

OCCURRENCE AND PROPERTIES OF ACTINOLITE

The fibrous gray amphibole at Iron Mountain has been called amphibole and tremolite, but the optical properties of numerous grains fall within the range of actinolite with $\gamma = 1.645$, $\alpha = 1.625$, $Z \wedge c = 15^\circ$. At-

tempts were made to prepare some of it for chemical analysis by hand-picking and by using the electromagnet and heavy solutions, but hematite stains permeate all the material collected so that an accurate quantitative determination of the iron present as actinolite is impossible. Joseph M. Axelrod made *x*-ray diffraction patterns of the prepared samples and reported that they were the patterns of an amphibole containing several per cent of hematite as an impurity. Joseph J. Fahey determined the MnO on a typical sample of the actinolite from Iron Mountain to be 0.24 per cent. The possibility of the actinolite at Iron Mountain containing appreciable amounts of manganese and being related to winchite is thus removed. Also, the similarity to the amphibole at Thorny Mountain, Missouri, which gave a manganese bead test, is less striking than has been suggested (Grawe, 1943).

OCCURRENCE OF FLUORITE AND DOLOMITE

Purple fluorite with $N = 1.43$ occurs in quartz as granular masses 1 cm. or more long and about 0.5 cm. wide. It is not in contact with hematite, so its age relation to hematite is uncertain.

Pink dolomite fills veins up to $\frac{1}{2}$ inch wide that cut the andesite porphyry. It has the color of rhodochrosite but has the optical properties of dolomite with $\omega = 1.685$. Joseph J. Fahey determined the manganese content of this pink carbonate as 1.45 per cent MnO. Wheeler (1895) reported rhodochrosite and manganocalcite filling seams in specular hematite at Iron Mountain. He named W. B. Potter as the collector, but did not give the evidence on which the determination was made. The pink dolomite with 1.45 per cent MnO shows that color is unreliable as a diagnostic property of rhodochrosite. The validity of this reported occurrence of rhodochrosite and manganocalcite is questionable.

ORIGIN AND SEQUENCE OF MINERALS

Salite, $\text{Ca}(\text{Mg,Fe})(\text{SiO}_3)_2$, was formed by hot iron-bearing solutions that arose along fissures and attacked the andesitic lava at Iron Mountain. Salite occurs in contact with the andesite porphyry, and stout columns up to 10 inches long project from the wall rock into the ore.

As the temperature of the iron-bearing solutions decreased salite was locally changed to actinolite, $\text{Ca}(\text{Mg,Fe})_5(\text{OH})_2(\text{Si}_4\text{O}_{11})_2$. Specimens are present in which the columnar structure of salite grades into the fibrous habit of actinolite. Small relict areas of salite that have the extinction angle and indices of refraction of salite persist locally in the actinolite, but in most of the commercial ore the change to actinolite is complete. Apparently, one area southeast of the old part of the Hayes Cut escaped the effect of this later alteration, for there large columns of salite remain unaltered. At many places at Iron Mountain the composition of the lava

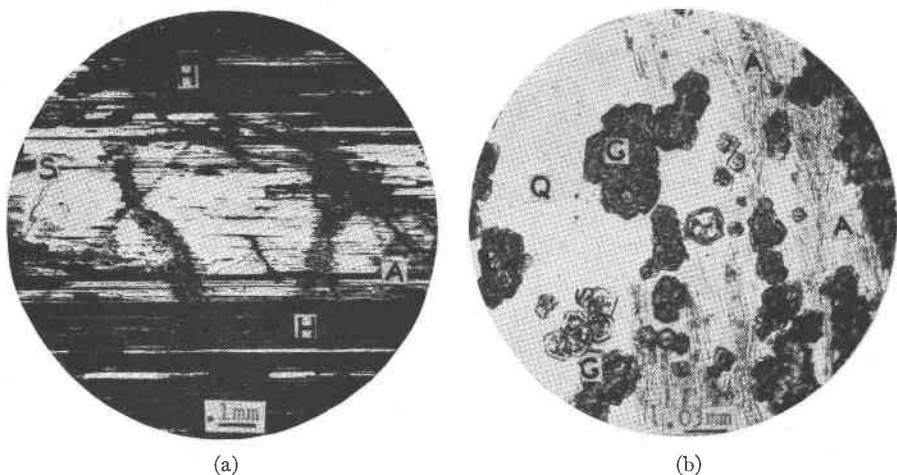


FIG. 1*a*. Salite (*S*) is altered to actinolite (*A*). Hematite (*H*, black) replaces actinolite and salite along cracks and cleavage. In other thin sections remnants of salite remain in some of the actinolite.

FIG. 1*b*. Zoned garnets (*G*) replace actinolite needles (*A*) and contain relict needles of actinolite. White (*Q*) is quartz.

series and the conditions of crystallization favored the formation of epidote, $\text{HCa}_2(\text{Al,Fe})_3\text{Si}_3\text{O}_{13}$, without any trace of salite or actinolite. In the Big Cut at Iron Mountain, epidote is the characteristic mineral associated with the ore.

The iron garnet andradite, $(\text{Ca}_3\text{Fe}_2)(\text{SiO}_4)_3$, is present as euhedral, zoned dodecahedrons that cut across the actinolite and contain fibrous inclusions of actinolite (Fig. 1*b*). The zoned andradite is birefringent and has an index of refraction of 1.88. The determination of the temperature at which birefringent garnets become isotropic by heating has been used to indicate the temperature below which the garnet crystallized. Merwin (1915) found that contact garnets from Alaska lost their birefringence when they were heated to about 800°C . Stose and Glass (1938) determined 860°C . as the temperature at which zoned birefringent andradite from Pennsylvania became isotropic. Ingerson and Barksdale (1943) observed that in an iridescent garnet from Nevada the birefringence did not decrease until the temperature reached 1060°C . and continued practically to the melting point. If the garnet at Iron Mountain actually crystallized after the hematite as Lake (1932, p. 58) suggested, the loss of birefringence of the garnet at Iron Mountain could be used to fix the temperature above which the associated specular hematite was formed. But, the opinion of Singewald and Milton (1929) that garnet at Iron Mountain tends to be earlier than hematite, and is replaced by it is supported by several specimens studied during this investigation in

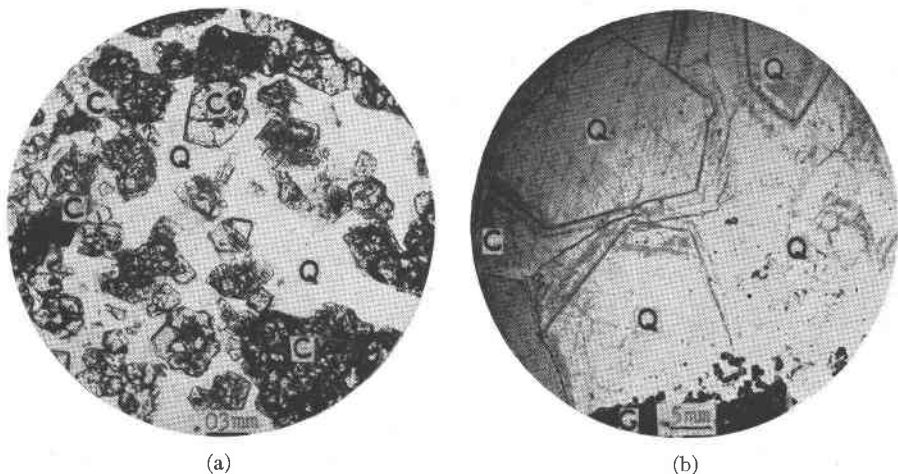


FIG. 2a. Garnet is replaced by calcite (C). White (Q) is quartz.
 FIG. 2b. Prismatic quartz (Q), calcite (C), garnet (G).

which garnet is cut by and replaced by hematite. In the light of the work of several investigators on the loss of birefringence of garnets, a temperature below 800° C. is suggested for the formation of specular hematite at the Iron Mountain deposit.

Calcite replaces garnet (Fig. 2a) and the centers of garnet crystals are occupied by calcite that entered through channels cutting the rim. The replacement of early minerals by calcite at Iron Mountain produces unusual effects in thin section. In some of the calcite replacing early minerals the color is brown, almost the brown of siderite, but the indices of refraction are within the range of those for calcite.

Quartz occurs as prismatic crystals in the ore (Fig. 2b). It also fills cracks or veins cutting hematite, garnet, and the early minerals (Fig. 3b). The period of quartz deposition was probably long and overlapped the formation of hematite. Terminated crystals of hematite that suggest growth in an open cavity are in contact with quartz (Fig. 3a), but veins of quartz also cut hematite and garnet in the same specimen (Fig. 3b). Some of the quartz replacing other minerals has a peculiar tan to brown color. Other quartz contains myriads of needles of actinolite that are oriented parallel to the adjacent actinolite (Fig. 1b) and portray convincing evidence of replacement. Likewise hematite penetrates and replaces salite along cracks and cleavage (Fig. 1a) and permeates and replaces the actinolite so thoroughly that even the smallest needle is contaminated with it. The color of the cleavage surfaces of some actinolite has been changed to reddish brown by hematite that has impregnated it. Chlorite is associated with the hematite in thin section and probably accom-

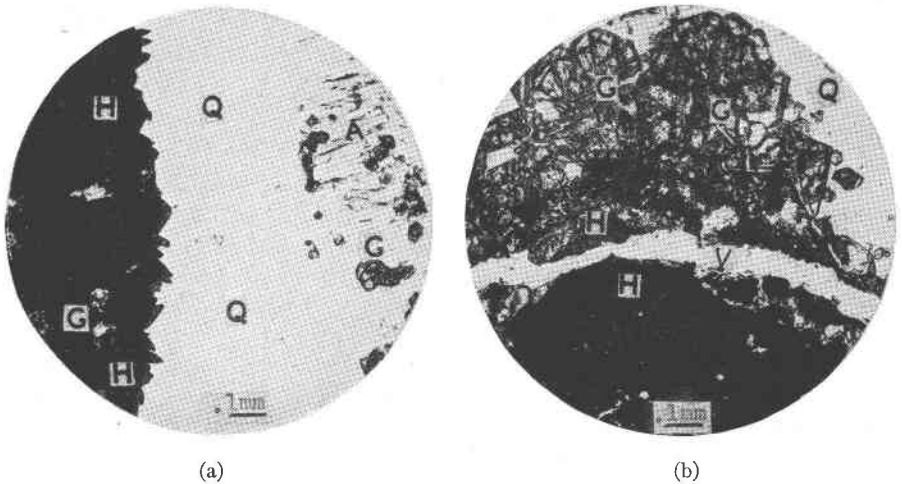


FIG. 3a. Terminated crystals of hematite (*H*, black) suggest growth in a cavity. Later quartz (*Q*) filled the cavity. Actinolite (*A*) and garnet (*G*) are cut by quartz (*Q*).

FIG. 3b. Quartz vein (*V*) cuts hematite (*H*) and garnet (*G*).

panied its introduction. Apatite reported by other observers at Iron Mountain is absent from the thin sections and specimens studied during this investigation. Fluorite occupies the center of massive quartz in a vein an inch wide and appears to be the last mineral to form. The sequence of minerals extending in each direction perpendicular to the center of the vein includes fluorite, quartz, calcite of white and brownish color, garnet, hematite, and actinolite.

TABLE 2. SEQUENCE OF MINERALS AT IRON MOUNTAIN, MISSOURI

Salite, $\text{Ca}(\text{Mg},\text{Fe})(\text{SiO}_3)_2$	---				
Actinolite, $\text{Ca}_2(\text{Mg},\text{Fe})_5(\text{OH})_2(\text{Si}_4\text{O}_{11})_2$		---			
Andradite, $(\text{Ca}_3,\text{Fe}_2)(\text{SiO}_4)_3$			---		
Hematite, Fe_2O_3				---	
Calcite, CaCO_3				---	
Quartz, SiO_2				-----	
Fluorite, CaF_2					---

CONCLUSIONS

Salite was the first mineral to be formed from the andesite porphyry by the iron-bearing solutions at Iron Mountain, Missouri. In most of the commercial ore the salite is absent and its place is taken by actinolite or epidote. Andradite, calcite, quartz and specular hematite replace the early minerals and the andesite porphyry. The mineral sequence sug-

gests that magnesia was removed first from the ore-bearing solutions and was fixed as salite and actinolite crystallized. After the deposition of andradite at some places and epidote at others, the temperature was favorable and sufficient carbon dioxide was present in the system to utilize most of the calcium to form calcite. This liberated iron to form hematite and silica to form quartz and concentrated fluorine and calcium to form fluorite.

ACKNOWLEDGMENTS

The writers are grateful to Mr. Joseph W. Fusso for his help and for the specimens that he contributed to this investigation. The *x*-ray determinations by Joseph M. Axelrod and his estimates of the amount of hematite in the samples of actinolite and pyroxene prepared for chemical analyses are gratefully acknowledged. Appreciation is expressed to the resident staff members of the Ozark Ore Company for courtesies extended during several visits to their property, and to Professor H. H. Hess for checking the birefringence and indices of refraction of a specimen of salite from Iron Mountain.

REFERENCES

- CRANE, G. W. (1912), The iron ores of Missouri: *Missouri Bur. Geol. and Mines*, **10**, 2nd ser., 1-434.
- GRAWE, OLIVER R. (1943), Manganese deposits of Missouri: *Mo. Geol. Survey and Water Resources*, 62nd Biennial Report, App. VI, 20.
- HESS, H. H. (1949), Chemical composition and optical properties of common clinopyroxenes: *Am. Mineral.*, **34**, 621-666.
- INGERSON, E., AND BARKSDALE, J. D. (1943), Iridescent garnet from the Adelaide mining district, Nevada: *Am. Mineral.*, **28**, 303-313.
- LAKE, M. C. (1932), The iron-ore deposits of Iron Mountain, Missouri: *Int. Geol. Congress*, 16th session. Guidebook **2**, 56-67.
- MERWIN, H. E. (1915), Geology and ore deposits of Copper Mountain and Kassan Peninsula, Alaska: *U.S.G.S., Prof. Paper* **87**, 108.
- NASON, F. L. (1892), A report on the iron ores of Missouri: *Missouri Geol. Survey*, **2**, 1-366.
- SCHMIDT, ADOLF (1873), The iron ores of Missouri: *Missouri Geol. Survey*, 45-214.
- SCHMITT, HARRISON (1939), The Pewabic Mine: *Bull. Geol. Soc. Am.*, **50**, 791.
- SINGEWALD, J. T., JR., AND MILTON, CHARLES (1929), Origin of iron ores of Iron Mountain and Pilot Knob: *Am. Inst. Min. Met. Eng. Trans.*, 1929 Year Book, 330-340.
- SPURR, J. E. (1927), Iron ores of Iron Mountain and Pilot Knob: *Eng. and Min. Jour.*, **123**, No. 9, 363-366.
- STOSE, GEORGE W., AND GLASS, JEWELL J. (1938), Garnet crystals in cavities in metamorphosed Triassic conglomerate in York County, Pennsylvania: *Am. Mineral.*, **23**, 430-435.
- WHEELER, H. A. (1895), Recent additions to the mineralogy of Missouri: *Trans. St. Louis Acad. Sci.*, **7**, 128.
- WINSLOW, ARTHUR, HAWORTH, ERASMUS, AND NASON, F. L. (1894), A report on the Iron Mountain sheet: *Missouri Geol. Survey*, **9**, No. 3, 1-85.