

ANHYDRITE AND GYPSUM IN THE LYON MOUNTAIN MAGNETITE DEPOSIT OF THE NORTHEASTERN ADIRONDACKS

PAUL W. ZIMMER*

ABSTRACT

The occurrence of the minerals anhydrite and gypsum at the Chateaugay Mine at Lyon Mountain, New York is described. The anhydrite is believed to be hypogene and is compared with other previously described hypogene anhydrite deposits. The intergrowth of anhydrite and the magnetite in the absence of all sulfides suggests that the temperature range for anhydrite is greater than formerly believed. Gypsum is secondary in nature and derived from the anhydrite at this locality.

INTRODUCTION

Location

The Chateaugay Mine of the Republic Steel Corporation is located in the town of Lyon Mountain, Clinton County, New York. This is in the northwestern part of the Lyon Mountain Quadrangle at the north base of the mountain of the same name, one of the northernmost mountains of the Adirondack group.

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GEOLOGY OF THE CHATEAUGAY MINE

The geology of the Chateaugay Mine area has been described by Miller.¹ The mine is located in the Lyon Mountain Granite at a place where the "gabbro phase" contaminates the granite. The area is considered by Gallagher² to be underlain in part at least by assimilated Grenville sediments. Magnetite occurs in two parallel zones designated as the footwall vein and hanging-wall vein. The magnetite has replaced pyroxene, albite, and microperthite, and in thin section commonly shows cata-

* Geologist, Chateaugay District, Republic Steel Corporation, Lyon Mountain, N. Y.

¹ Miller, W. J., Geology of the Lyon Mountain Quadrangle, N. Y.: *N. Y. State Mus., Bull.* 271 (1926).

² Gallagher, David, Origin of the magnetite deposits at Lyon Mountain, N. Y.: *N. Y. State Mus., Bull.* 311 (1937).

clastic texture. These zones of magnetite parallel the strike, dip, and plunge of the mineral lineation as shown particularly by the pyroxene, through all the major and minor folds in the mine block. Throughout the mine and vicinity small amphibolite zones, locally called "Gray Bands," are distributed irregularly. About 500 feet from the footwall vein into the footwall, and a similar distance from the hanging-wall vein into the hanging wall, two thick amphibolite zones have been located. These "Gray Bands" and possibly the amphibolite zones may be remnants of the old Grenville sediments partly assimilated.

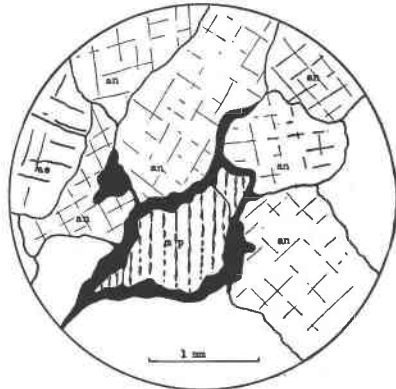


FIG. 1. Drawing of thin section from the 1813 level in the hanging-wall ore zone, showing magnetite (black) rim around micropertthite (mp) with tongues into the anhydrite (an) as well as along the crystal boundaries. Aegirinaugite (ae).



FIG. 2. Drawing of thin section from the 2113 level in the footwall ore zone, showing magnetite (black) in the crushed anhydrite (can) zone as well as a tongue into the anhydrite (an) crystal. Aegirinaugite (ae)

ANDHYDRITE

On the 1813 level (El. 350', about 1600' below shaft collar) a raise penetrated a large body of magnetite intergrown with anhydrite, and aegirinaugite. This was in the hanging-wall vein; a similar body has been found in the footwall vein on the 2113 level (El. 50'). Anhydrite has also been found within 300 feet of the surface, both as a vein cross-cutting the magnetite body, and as a mutual intergrowth with the magnetite.

The association of the anhydrite and magnetite as seen in Fig. 1 in which magnetite appears to be replacing anhydrite along the crystal boundaries as well as in several tongues into the anhydrite crystals, suggests that anhydrite in this section was earlier than magnetite. In Fig. 2. early anhydrite is highly crushed and magnetite was introduced within

this crush zone with a tongue into the solid anhydrite crystal. The drawing in Fig. 3 shows a vein of anhydrite cross cutting the magnetite ore zone, definitely showing the late nature of this anhydrite.

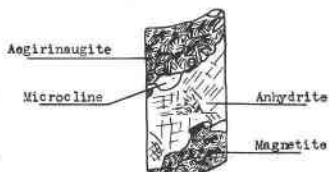


FIG. 3. Drawing of diamond drill core showing anhydrite vein cutting across the magnetite ore zone 297' from surface.
($\frac{1}{2}$ natural size)

From the results of the work by Newhouse³ in which he states that ". . . the mutual-boundary relation can have no particular significance in interpretation of mineral relations," seemingly unwarranted importance is placed on the interpretation of the mutual boundary between anhydrite and magnetite, a relationship that is commonly seen. With the definite proof that part of the anhydrite is earlier than, and part is later than, the magnetite, I feel that the mutual boundary is here strongly indicative of simultaneous deposition.

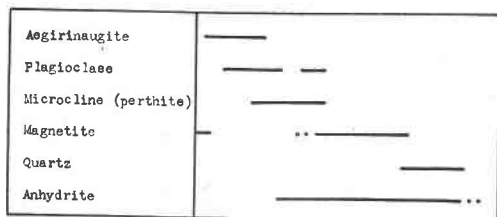


FIG. 4. Diagram showing the age relations of the principal minerals in the ore zone at Lyon Mountain, N. Y.

The diagram in Fig. 4 shows age relations of the anhydrite as seen in the thin sections. This occurrence of anhydrite in the magnetite zone at Lyon Mountain, which Gallagher⁴ considers the result of pneumatolytic metasomatism, suggests a high upper limit to the temperature range for the formation of anhydrite.

Optically this anhydrite shows normal characteristics ($\alpha=1.570$, $\beta=1.575$, $\gamma=1.615$, $2V=45^\circ \pm$). The cleavage at right angles and the

³ Newhouse (1928), The microscopic criteria of replacement. Chapt. VIII p. 160, Laboratory Investigation of the Ores., McGraw-Hill, N. Y.; Fairbanks editor.

⁴ Gallagher, David (1937), *op. cit.*, p. 79.

twinning show up in both the thin section and the powder. X-ray powder diffraction pattern shows a marked degree of similarity with a sample of anhydrite from Hillsboro, New Brunswick. Similarly, the calculated d spacings have been compared with the d spacings of anhydrite as recorded in the American Society for X-ray and Electron Diffraction card index. In both cases there were six extra lines on the Lyon Mountain anhydrite that suggests either impurities or a slightly different form. Checking the card index against these lines for minerals that were known to be in the area did not show any similarity. This suggests a deviation in form from the previously measured anhydrite.

This mode of occurrence is in contrast with that of previously described hypogene anhydrite. Butler⁵ in a paper in 1919 records and describes localities known at that time. The nature of occurrence of anhydrite in seven more localities are described below in order to bring this list up to date.

Anhydrite has been described in the Ajo Mining District in Arizona by Gilluly⁶ at such depths below the supergene zone, and associated with such minerals as pyrite, chalcopyrite, and barite, as to suggest its hypogene origin.

Langford and Hancox⁷ describe hypogene anhydrite at the McIntyre Mine in Ontario, Canada, where it is found at depths of 2000 to 4000 feet and associated with the ore minerals galena, sphalerite, chalcopyrite, and pyrite. Brown⁸ describes anhydrite in the zinc mines at Balmat, N. Y., with sphalerite, galena, chalcopyrite, pyrrhotite, and pyrite in metamorphosed Grenville sediments.

Osborn⁹ has described another deposit of anhydrite in the Grenville metamorphic sediments from the Calumet Mine, Calumet Island, Quebec, Canada. There the anhydrite is replacing the deformed limestone. Osborn also describes two other occurrences of anhydrite, one, the Boncamp map area, within the Grenville, and the other within the alkaline gabbro of Mount Royal. This latter was described as being pyrogenetic by Bancroft and Howard.¹⁰

In all of these localities anhydrite is associated with sulfide minerals.

⁵ Butler, B. S., Primary hypogene sulfate minerals in ore deposits: *Econ. Geol.*, **14**, 581-609 (1919).

⁶ Gilluly, J., The Ajo Mining District, Arizona: *U.S.G.S. Prof. Paper* 209 (1946).

⁷ Langford, G. B., and Hancox, E. G., Hypogene anhydrite from McIntyre Mine. Porcupine District, Ontario: *Econ. Geol.*, **31**, 600-609 (1936).

⁸ Brown, J. S., Structure and primary mineralization of the zinc mine at Balmat, N. Y.: *Econ. Geol.*, **31**, 233-258 (1936).

⁹ Osborn, F. F., Anhydrite and gypsum at Calumet Mine, Calumet Island, Quebec: *Contrib. Can. Min.*, U. of Toronto Studies, No. 46 (1941).

¹⁰ Bancroft, J. A., and Howard, W. V., The essexites of Mount Royal, Montreal, P. Q.: *Trans. Roy. Soc. Can.*, **17**, sec. 4, 13-43 (1923).

In contrast to this, at Lyon Mountain essentially no sulfides have been found. The occurrence of anhydrite at Britannia Beach, B. C., in a vein system separate from the sulfide mineralization as described by James¹¹ is of interest here. Although he believes the anhydrite to be primary but younger than the copper mineralization, it is important to record this deposition of sulfates without sulfides.

The relative insolubility of anhydrite at high temperatures¹² led Lindgren¹³ and Butler¹⁴ to conclude that calcium sulfate was not in the ascending solutions as such at high temperatures, but that the sulfur trioxide was in the ascending solutions, and when it came in contact with the calcium in descending solutions, the anhydrite was deposited at relatively high temperatures as hypogene deposits. Butler¹⁵ later describes two possible methods for the formation of sulfates from igneous emanations: (1) In the presence of free oxygen and sulfur or sulfur dioxide, as they cool sulfur trioxide would form and at suitable temperatures the sulfates would form. At the time of Butler's paper all the deposits of anhydrite were associated with sulfides and this method would necessitate the supposition that sulfides and sulfates were deposited in the presence of free oxygen, which is not likely. (2) If emanations contain no free oxygen the oxides of metals formed at high temperatures may be reduced at lower temperatures to form oxides of sulfur. The dissociation of sulfur trioxide at 450° C. is cited by Butler as the limiting temperature for the formation of sulfates and suggests that because the boiling temperature of H₂SO₄ is much lower probably they would form at much lower temperatures. Sulfates probably will not form above 200° C.

Above 450° C. sulfur trioxide is in equilibrium with sulfur dioxide and oxygen in amounts shown by the curves in Butler's paper. As he points out the amount of sulfur trioxide would be small and become less the higher the temperature. If conditions were such that the small amount of sulfur trioxide would react with calcium present to form anhydrite, which is very insoluble at these high temperatures, the sulfur trioxide would be removed from the system. The equilibrium of the system would thus be lost and the formation of sulfur trioxide would be favored to regain this lost equilibrium. It seems that the temperature above which sulfur trioxide is all decomposed (1000° C.) is the maximum temperature for the formation of anhydrite. This is well above the temperature of hypogene mineralization.

¹¹ James, H. T., Britannia Beach map area, B. C.: *Geol. Surv. Can., Mem.* 158 (1929).

¹² Posnjak, E., The system CaSO₄-H₂O: *Am. Jour. Sci.* (V) 35A, 247-272 (1938).

¹³ Lindgren, W. T., Anhydrite as a gangue mineral: *Econ. Geol.*, 5, 422-527 (1912).

¹⁴ Butler, B. S., Geology and ore deposits of San Francisco and adjacent districts, Utah: *U.S.G.S., Prof. Paper* 80 (1913).

¹⁵ Butler, B. S. (1919), *op. cit.*, p. 609.

Butler¹⁶ has described how the wall-rock alteration in the Cactus Mine might supply the necessary calcium for the formation of anhydrite. At Ajo the calcium for the anhydrite possibly was derived from the wall-rock alterations also, as Gilluly¹⁷ describes albitization at this locality with the removal of the calcium from the rock. At both of these localities the wall rock is monzonite which generally contains an adequate supply of calcium.

At Lyon Mountain the low percentage of calcium in the wall rocks, which are granites and syenites, is noteworthy because such a low amount of calcium would not make this a very likely source rock for the calcium necessary for the formation of anhydrite. Buddington's¹⁸ average of five Alexander type granites in the Adirondacks gives 0.86% CaO. Recent analyses of syenites at Lyon Mountain give 2.01% CaO.¹⁹ These may be contrasted with the average that Daly²⁰ gives of 12 monzonites, 6.5% CaO.

Early carbonates in the McIntyre Mine are described by Langford and Hancox²¹ as the source for the calcium there. Carbonates do not occur in the ore at Lyon Mountain except as much later veins.

The presence of anhydrite in the Grenville sediments at Balmat, Calumet, and also at the Bonnecamp map area suggests that these sediments were the source for the calcium, and as pointed out by Brown²² might be the source for the sulfates. The small amount of "Gray Band" which has been considered to be assimilated Grenville sediments has from 9 to 12% CaO, and possibly may be the source of the calcium at Lyon Mountain.

GYP SUM

Selenite is not uncommon in the shaft between the 1513 level (El. 600') and the 2113 level (El. 50') and generally is found intergrown with aegirinaugite, magnetite, microcline, sphene, and quartz in cavities similar to those described by Gallagher²³ as miarolitic gas cavities. At the time of Gallagher's work the mine had not been developed below the 1513 level.

¹⁶ Butler, B. S. (1913), *op. cit.*, p. 124.

¹⁷ Gilluly, J. (1946), *op. cit.*

¹⁸ Buddington, A. F., *Adirondack Igneous Rocks and their Metamorphism: G.S.A., Mem. 7, 148 (1933).*

¹⁹ Average of eight samples of syenite. Analyst Waltz, chief chemist, Republic Steel Corporation, Canton, Ohio.

²⁰ Daly, R.A., *Igneous Rocks and the Depths of the Earth, McGraw-Hill, N. Y., 9-13 (1933).*

²¹ Langford, G. B., and Hancox, E. G., *op. cit.*, p. 604.

²² Brown, J. S., Natural gas, salt, and gypsum in pre-Cambrian rocks at Edwards, N. Y.: *Bull. Am. Ass. Petro. Geol.*, **16**, 727-735 (1932).

²³ Gallagher, David, (1937), *op. cit.*, p. 17.

A large cavity which contained a single swallowtail selenite twin 32 inches long was found a few hundred feet from the shaft toward the hanging-wall ore zone on the 1813 level (El. 350'). One end of the crystal was intergrown with microcline, quartz, aegirinaugite, and magnetite crystals of the cavity lining. Gallagher²⁴ has suggested that these cavities in the syenite are of primary origin. If this were true, the selenite should be considered primary. However, one wall of the cavity is a diabase dike covered with calcite and small albite crystals. Obviously, the opening could not have existed at the time of the dike invasion without being filled with the diabasic magma, so that the idea that the cavities are secondary as suggested by Whitlock²⁵ is strongly supported. There have been five of these cavities with similar dike relationships found to date.

Commonly these cavities are found full of water confined under considerable pressure. Prider's²⁶ suggestion that the formation of gypsum crystals in cavities is due to a decrease in pressure accompanied by evaporation, may account for selenite crystals at the Chateaugay Mine.

In the lower levels of the mine the horizontal joints are frequently found coated with gypsum and/or calcite. In the upper levels the surface waters have washed the joints clean of all secondary minerals. Although Whitlock examined the locality in 1905 before the present mine was opened and at a time when there was no development below the 800 level, he does describe a type of calcite crystal which is characteristic of deposition from corrosive waters frequently associated with gypsum.²⁷ This deposition with secondary calcite further suggests the secondary nature of the gypsum.

The anhydrite was probably the source of the gypsum for the anhydrite in several sections shows this alteration in progress along the cleavage of the anhydrite.

CONCLUSIONS

At Lyon Mountain all of the anhydrite found has been in the magnetite zones. The continuous deposition of the anhydrite previous to, simultaneous with, and continuing beyond the deposition of the magnetite suggests that the anhydrite is a mineral of the hypothermal temperature range at this locality. The "Gray Band," which is considered to be assimilated Grenville sediments, is the only known source for the calcium which is needed to form the anhydrite.

The gypsum is secondary in nature and derived from the anhydrite.

²⁴ Gallagher, David, (1937), *op. cit.*, p. 19-21.

²⁵ Whitlock, H. P., Minerals from Lyon Mountain, Clinton County: *N. Y. State Mus., Bull.* 107, 55-96 (1907).

²⁶ Prider, R. T., An unusual occurrence of gypsum at Kalgoorlie, Western Australia: *Am. Mineral.*, 25, 591-605 (1940).

²⁷ Whitlock, H. P. (1907), *op. cit.*, p. 63.