

## THE MINERALS OF THE WHITE RAVEN MINE, WARD, COLORADO

ERNEST E. WAHLSTROM, *University of Colorado, Boulder, Colorado*

The White Raven Mine is located in California Gulch, which is about a mile south of the old mining town of Ward, Boulder County, Colorado. The White Raven Mine has been a heavy producer of silver in past years, especially in 1913 and the immediately following years. It is estimated that \$800,000 in lead and silver have been produced since 1913.

The ore bodies of this mine are especially interesting because they are of an unusual type in the Ward District, which was known in the early days for its gold production. This paper contains a study of the individual minerals, their occurrence, and origin.

A brief summary of the geology of the White Raven Mine and the surrounding area follows.<sup>1</sup> The country rocks of the area are igneous and metamorphic. The nearest unmetamorphosed sediments lie along the east flank of the Front Range of the Colorado Rockies, and are about ten miles to the east of the area under discussion. Pre-Cambrian schists, gneisses, granites, and quartz diorites constitute about two thirds of the exposed rocks. Tertiary (?) rocks, including small batholiths, stocks, and dikes of acid to intermediate intrusives occupy most of the rest of the area. There are a few small basic intrusions.

The White Raven Mine is located on a fissure vein in massive gray pre-Cambrian granite, which contains a few inclusions of schist. Intruded into the granite, roughly parallel to, and in places cut by the vein, is a dike of monzonite porphyry which is probably genetically related to the vein. The White Raven vein strikes approximately west and dips steeply to the north.

An investigation of the vein and its minerals by the present writer has resulted in the observations and conclusions described in the following parts of this paper.

The lead-silver ore was formed in a fissure which resulted from the reopening and brecciation of an older vein of gold-bearing quartz-pyrite-chalcopyrite ore. Brecciated fragments of this ore are found in many places in the vein and are covered in most cases

<sup>1</sup> Adapted from a summary by P. G. Worcester, *The Geology of the Ward Region, Boulder County, Colorado: Bull. 21, Colo. Geol. Survey, 1920.*

by a coating of galena and siderite. These relations prove that the lead-silver vein is of a later date than the quartz-pyrite-chalcopyrite mineralization.

The following minerals have been found in important amounts in the ore shoots of the lead-silver vein: horn quartz, manganiferous siderite, barite, galena, and native silver. Other minerals occurring in minor amounts are pyrite, sphalerite, and calcite. The lower levels of the mine, at present inaccessible, have been reported to contain tennantite in addition to the minerals mentioned. In many places in the mine the minerals occur as layered coatings in

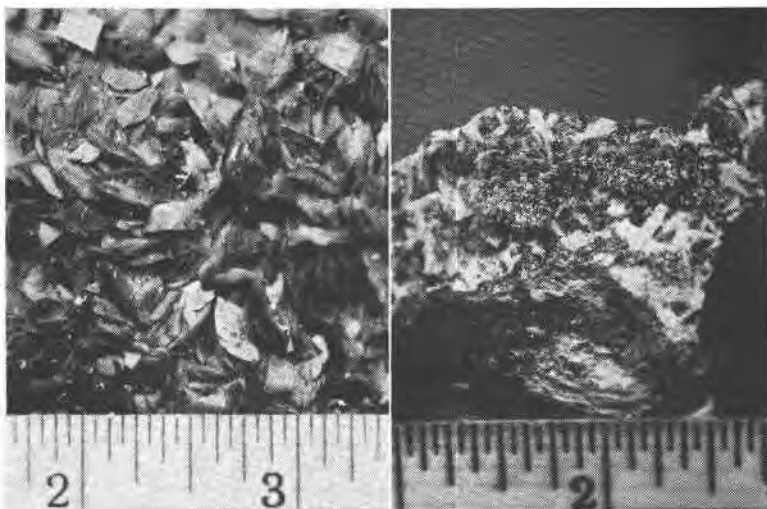


FIG. 1. Manganiferous siderite, White Raven Mine, Ward, Colo. The small white crystals are barite.

FIG. 2. Mat of wire silver on barite crystals, White Raven Mine, Ward, Colo.

openings or "vugs," many of which are a foot or more across. These openings have permitted the free growth of crystals of siderite, galena, and barite.

The minerals appear to have formed in the following order: horn quartz, massive galena with small amounts of pyrite and sphalerite, manganiferous siderite, crystallized galena, manganiferous siderite, and finally, native wire silver. It is seen that the solutions from which the minerals were deposited varied and that the galena and siderite were deposited at two distinctly different periods. Further

evidence pointing toward a variation in the chemical character of the solutions is the fact that some specimens from the vein show casts of barite. It appears that the barite was dissolved because of a change in composition of the solutions. In addition, some of the galena crystals show distinct etch patterns.

The most conspicuous vein mineral is the manganeseiferous siderite. Because it varies somewhat in general appearance from place to place within the vein, the writer made chemical analyses of three different specimens, and crystallographic measurements on two of the three analyzed specimens in an effort better to understand the variations. The analyses follow:

	No. 1	No. 2	No. 3
FeO	40.37%	38.11%	42.69%
MnO	18.62	22.85	16.95
CaO	1.17	0.55	0.05
MgO	1.26	0.02	0.10
ZnO	0.42	0.80	0.50
CO <sub>2</sub>	38.95	38.40	37.63
Insol.	—	—	2.94
	100.79%	100.73%	100.86%

No. 1. East drift, main level, White Raven Mine, Ward, Colo.

No. 2. Stope, intersection of crosscut and drift, main level, White Raven Mine, Ward, Colo.

No. 3. Black Jack Tunnel, drift on White Raven vein, Ward, Colo.

Using the above analyses, and correcting for the insoluble residue in No. 3, the carbonates are found to have the following molecular percentages:

	No. 1	No. 2.	No. 3
FeCO <sub>3</sub>	65.10%	61.45%	70.92%
MnCO <sub>3</sub>	30.17	37.02	28.29
CaCO <sub>3</sub>	2.08	0.98	0.09
MgCO <sub>3</sub>	2.63	0.04	0.21
ZnCO <sub>3</sub>	0.64	1.23	0.79

An inspection of the above analyses shows that there is considerable variation in the composition of the carbonates from place to place within the vein. The high percentage of manganese carbonate is noteworthy. All three of the samples analyzed approach manganosiderite in composition.

The color on the fresh surface of the siderite is a light grayish-brown. This color varies from slightly lighter to slightly darker

shades from place to place within the vein. The siderite is in many cases coated with a film of dark manganese and iron oxides, formed by the oxidation of the manganese and iron in the carbonates.

Measurements of the acute angle between the rhombohedral cleavage faces, using a Fuess reflecting goniometer, gave the following results: carbonate No. 1, 73.1 degrees, average of 12 readings; carbonate No. 2, 73.0 degrees, average of 12 readings. Because of the fact that the surfaces of the siderite crystals are curved, it was found necessary to use very small cleavage pieces for the measurements, and as a result, the individual readings varied somewhat. Carbonate No. 3 was too dull and earthy to measure.

The characteristic occurrence of the manganiferous siderite is as

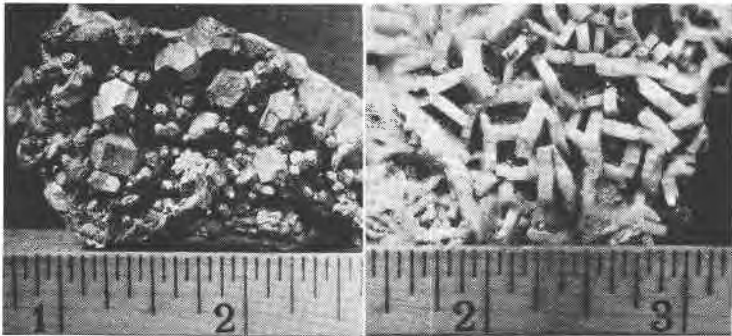


FIG. 3. Galena crystals from the White Raven Mine, Ward, Colo. The crystals show a combination of a cube and an octahedron.

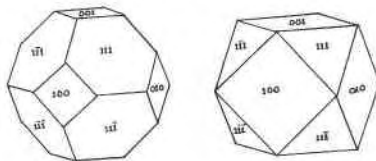
FIG. 4. Barite crystals from White Raven Mine. The coating seen on some of the crystals is siderite.

a lining in "vugs," where it forms well developed crystals with the other vein minerals. The crystals vary considerably in size. The smallest crystals are microscopic, and the largest crystals are as much as three quarters of an inch wide. The crystals appear as flat rhombohedrons, and upon close inspection are seen to have curved surfaces similar to those frequently found on dolomite crystals.

The barite occurs as simple, tabular crystals partly or completely embedded in the siderite, indicating that it started to form in the veins before the precipitation of the first generation of siderite was complete. However, in many specimens that were examined, the second generation of siderite has completely covered the barite, so

that its presence may be observed only by examining a cross-section of the vein. The largest crystals of barite are about three quarters of an inch long and half an inch wide. The crystals are zoned and have a transparent core surrounded by a thin layer of white barite. Many of the barite crystals are encrusted with small crystals of galena and siderite.

The galena is found in crystals showing a combination of cube (100) and octahedron (111). Many of the galena crystals are distorted and have tabular or elongated shapes because of rapid growth in a direction parallel to an octahedron face. This type of crystal is shown in figure 7. The surfaces of the galena crystals have a dull appearance, and a few crystals show well developed etch patterns formed, possibly, by the action of solutions of the same origin as those from which the galena and other vein minerals were deposited. The largest galena crystals are about three quarters of an inch in diameter.



FIGS. 5 and 6. Drawings of galena crystals showing combination of cube (100) and octahedron (111), White Raven Mine, Ward, Colo.

The last primary mineral to be formed in the vein was native wire silver. It is present only in certain restricted zones within the mine, and is usually found as a coating on the other vein minerals in "pipes," which are subcircular enlargements in the vein extending down the dip. Several samples taken from the mine show a heavy mat-like covering of fine, interlacing wires of silver. The individual wires are about as thick as a hair and have a maximum length of half an inch.

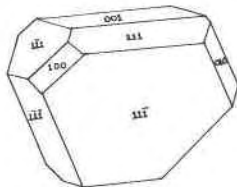


FIG. 7. Drawing of distorted crystal of galena, White Raven Mine, Ward, Colo.

Secondary minerals formed by the action of downward moving surface waters are calcite, which occurs in small, colorless crystals and in granular masses, and hydrous iron and manganese oxides.

The solutions from which the minerals were precipitated probably were intimately associated with the intrusion of the dike rocks in the Ward Region. Because the minerals occur in many cases as linings in large "vugs," it is believed that conditions of medium to low pressure prevailed during the precipitation. It is difficult to imagine the existence of the "vugs" under a high pressure, particularly when it is considered that the material in which the "vugs" exist is a loosely consolidated breccia, which in many places is cemented only by the manganiferous siderite. The fact that certain portions of the vein are hundreds of feet away from the nearest late igneous intrusion and the fact that the wall rocks of the vein are in many places fresh indicate that the temperature of the mineral bearing solutions was probably medium to low.

The changes in the solutions so as to cause precipitation of the minerals were probably complex. It seems reasonable to think that slowly cooling, ascending magmatic waters percolated through a brecciated zone in the granite and first deposited a layer of colloidal quartz which solidified to form the horn quartz. This layer of quartz was fractured by movement along the fissure. The cooling solution then became saturated with metallic sulphides, and galena, pyrite, and sphalerite were precipitated. Further cooling resulted in the formation of the manganiferous siderite and barite. After the deposition of the barite the solutions changed, possibly due to the renewal of igneous activity near the source of the solutions, and the solutions became saturated with sulphides and carbonate for the second time.

As the solutions continued to percolate through the fissure, they began to etch and corrode the previously precipitated minerals. Some of the barite crystals were dissolved completely, leaving casts; and some of the galena crystals were etched, producing dendritic patterns.

The origin of wire silver is more hypothetical. It seems that the research of Kohlschutter and Eydmann<sup>2</sup> has resulted in a satisfactory explanation of the formation of wire silver. They have

<sup>2</sup> V. Kohlschutter and E. Eydmann, *Liebig's Annalen der Chemie*, vol. 390, pp. 340-364, 1912.

proved experimentally that wire silver may be formed by either the oxidation or reduction of argentite under conditions of moderate temperature, and they believe that the wire silver of Freiberg and other European localities was formed in this way. It seems probable that the wire silver of the White Raven Mine was also formed in like manner. Argentite might be expected to be a logical accompaniment of the other sulphides found in the vein; hence, although argentite was not found by the writer, it may be present as minute disseminations in the argentiferous galena.

In conclusion, the writer wishes to express his appreciation to Dr. R. D. Crawford of the University of Colorado for his friendly advice in matters pertaining to the above work, and for his critical reading of the manuscript.