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NOTES ON ORE MINERALS FROM THE SUGAR LOAF DISTRICT, LAKE COUNTY, COLORADO[1]

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ABSTRACT

This paper reports on a study of ore specimens from the Sugar Loaf district, Lake County, Colorado. The lead-zinc-silver ore occurs in veins in rocks of pre-Cambrian age. The minerals and their paragenesis as interpreted from polished surfaces are:

1. Pyrite (minor amount).
2. Sphalerite with chalcopyrite inclusions, and galena.
3. Light-colored sphalerite, pyrite and quartz.
4. Galena, chalcopyrite, argentite, tetrahedrite.
   (Some overlapping of 3 and 4)

It is suggested that some later sphalerite of a honey-yellow color associated with quartz was deposited at lower temperatures than the earlier, dark sphalerite. The silver minerals in the specimens are regarded as hypogene. No reliable evidence of secondary sulphide enrichment was found. A comparison is made with ore deposits of the Leadville district.

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Introduction

This paper presents the results of a microscopic study of ore minerals from the Sugar Loaf district, Lake County, Colorado. The specimens, about 100 in number, were supplied in two sets, one collected for the U. S. Geological Survey by C. H. Behre, Jr.; the other collected for the E. J. Longyear Company, of Minneapolis, Minnesota, by G. M. Schwartz. The writer is indebted to the above-named gentlemen for the loan of these specimens and for suggestions and criticisms.

Location and Geology

The Sugar Loaf district lies at the east foot of the Sawatch Range, west of and across Arkansas River from Leadville, and between the valleys of Lake Creek on the north and Colorado Gulch on the south. Its altitude above sea level is about 10,500 feet. Practically nothing has been published on the geology of this district, and the brief account given here was kindly supplied by Dr. G. M. Schwartz from his reconnaissance notes.

The area consists almost entirely of pre-Cambrian granite correlated by Behre[3] with the Silver Plume granite (Algonkian) of the Georgetown quadrangle, Colorado. Masses of quartz-biotite schist cut by the granite are also present, notably on the east slope of Sugar Loaf Hill, near the Black Iron shaft. The granite is cut by relatively small dikes of porphyry essentially like the White porphyry of the Leadville district and presumably of early Tertiary age. At places the granite is fresh, but over much of the Sugar Loaf district and to the north in the St. Kevin district it is cut by extensive shear zones along which it has been silicified, sericitized, and impregnated with ore minerals. Near the ore shoots it has been so completely altered that its original nature has been obscured. The productive veins have in general a northerly strike.

[3]Personal communication.

The Ores

A complete record of production in this area is not available to the writer, but partial production figures, together with the size of the dumps, the extent of the workings, and the character of the ore, indicate an output, mainly of silver, worth several million dollars. This production doubtless came mainly from oxidized ores and perhaps from enriched sulphide ores also, but no material representing such ores was available to the writer. At the time the ores were collected most of the underground workings were inaccessible, and the specimens were taken largely from dumps; furthermore, ore specimens only were collected, so that the remarks that follow apply to specimens only, not to veins, and may have only limited significance in the broader problems of the district.

The ores are pitted and vuggy, with numerous well-formed crystals of sphalerite, pyrite, quartz, and galena in the vugs. The specimens contain the following minerals in order of abundance: sphalerite, pyrite and quartz, galena, chalcopyrite, tetrahedrite, and argentite. Although the ore specimens show a predominance of sphalerite it is possible that, considering a vein as a whole, pyrite, at least in places, would be more abundant. One group of veins at the southwest side of the district consists almost entirely of quartz and pyrite.[4] Quartz is usually the only gangue mineral present, a characteristic feature of many Colorado ore deposits.

Sphalerite.—The greater and earlier portion of the sphalerite is medium to dark brown in color, though honey-yellow sphalerite of later age was noted in minor amount. The dark brown sphalerite and early galena are closely related. Rounded and irregular grains of galena are sparsely and irregularly scattered in sphalerite, and the larger areas of galena contain patches of sphalerite into which veinlets of galena penetrate (Fig. 1). The two minerals commonly show mutual embayments and were noted cutting each

[4]Schwartz, G. M., Personal communication.

other in veinlets in the same specimen. In some cases they are intimately mixed in such a way as to resemble pseudo-eutectic textures[5] with sphalerite showing convex boundaries toward galena. This relationship has been cited[6] as a criterion, that may be generally applicable, indicating the later age of the sphalerite; but veinlets of galena cutting into sphalerite across such boundaries offer more conclusive evidence to the contrary. Similar observations were made by Tuck,[7] who concludes that "in view of this, it seems that solution boundaries can be used only with the greatest of caution in determining paragenesis and as criteria of replacement." Crystallographic directions do not appear to play any part in the mutual relations of sphalerite and galena in the specimens studied.

In a few specimens veinlets of dark sphalerite cut pyrite, but pyrite veinlets in sphalerite are more common. Sphalerite contains some pitted grains of early pyrite, most of which are irregular, although a few are conspicuously well-formed cubes. Ragged patches of sphalerite are enclosed in pyrite areas, and grains several mm. in diameter are surrounded by rims or crusts of pyrite, or a mixture of pyrite and quartz.

In most of the specimens examined the dark sphalerite contains swarms of minute chalcopyrite specks or blebs more or less uniformly distributed and having in places a faint suggestion of orientation. They bear no apparent relation to fissures, veinlets, or grain boundaries. This occurrence of chalcopyrite in sphalerite has been observed by many investigators and has been interpreted by some as due to replacement, by others as due to unmixing of a solid solution. These interpretations have recently been reviewed

[5]Lindgren, Waldemar, Pseudo-eutectic textures: Econ. Geol., vol. 25, p. 9, fig. 11, 1930.

[6]Bastin, E. S., and others, Criteria of age relations of minerals: Econ. Geol., vol. 26, pp. 589, 600-602, 1931.

[7]Tuck, Ralph, A lead-zinc deposit at Geneva Lake, Ontario: Econ. Geol., vol. 26, p. 308, 1931.

by Schwartz.[8] In the Sugar Loaf occurrence no criteria were found to establish either view. A few elongated, straight, narrow rods of chalcopyrite appear to occupy cleavages in sphalerite. In addition to this occurrence in sphalerite, chalcopyrite is also found as thin stringers in and as patches surrounding grains of sphalerite.

A few small veinlets of tetrahedrite, containing galena and chalcopyrite, were found cutting sphalerite (Fig. 5), and sphalerite patches were noted enclosed in tetrahedrite areas.

Sphalerite and quartz appear to have overlapping relations, although quartz clearly outlasts sphalerite. In several specimens veinlets of sphalerite cut quartz, and quartz euhedra are surrounded by sphalerite. In the same specimens and in many additional ones veinlets of quartz cut sphalerite, and well-formed crystals of quartz attached to some of these veinlets project out into sphalerite, as though replacing it. Sphalerite is commonly embayed by quartz and occurs as ragged patches in it.

The foregoing remarks refer only to sphalerite not definitely recognized as light sphalerite. Both shapeless and well-formed crystals of quartz are surrounded by light-colored sphalerite and larger areas of quartz are embayed by it. In several specimens the light-colored sphalerite was noted in the central portion of veins, closely associated with quartz. Chalcopyrite specks in light-colored sphalerite are the exception rather than the rule as in the case of the dark-colored blende. It was noted above that well-formed crystals in vugs are numerous. Many of these crystals are of sphalerite, about half of which are recognizably light-colored. The age relations of the light-colored sphalerite are not clearly defined, but it is apparently later than the dark-colored sphalerite, and overlapping with (though outlasted by) quartz.

[8]Schwartz, G. M., Textures due to the unmixing of solid solutions: Econ. Geol., vol. 26, pp. 757-758, 1931.

Pyrite.—Pyrite relations have been described in part above. It occurs in two stages, the first generally as residual grains, the second usually in veinlets cutting other minerals. It is pitted throughout, and the later pyrite is closely associated with quartz, the two minerals frequently forming veinlets and deep embayments in sphalerite and galena. Quartz is usually in excess, with pyrite occurring in its as well-formed crystals, irregular grains, alternating bands, and veinlets. Pyrite and quartz may be seen in the same specimen cutting each other in veinlets, and each incloses well-formed crystals of the other.

Although veinlets of pyrite cut galena and grains and patches of galena are surrounded or crusted by pyrite, it is more common for galena to surround pyrite grains and to cut pyrite in veinlets. Galena also may form a matrix inclosing groups of angular pyrite fragments which evidently represent a fracturing of pyrite before deposition of galena.

Galena.—Galena relations have been described in part under sphalerite and pyrite. In a few specimens the cleavage notches, which usually appear on polished surfaces of this mineral, show considerable curvature and distortion, and included grains of sphalerite and pyrite are fractured, as though the ore had been sheared. On many surfaces galena surrounds well-formed quartz crystals, and it is found as vug fillings, molding itself against quartz prisms in the central portion of veinlets (Fig. 3). Early galena is cut by quartz veinlets and later galena veinlets cut quartz. Veinlets of quartz and quartz-pyrite in sphalerite contain scattered patches of galena. Further description of galena occurs below.

Chalcopyrite.—Chalcopyrite is only sparingly present. In addition to the occurrences already described, it is found lining vugs in sphalerite and quartz, some areas molding themselves against quartz prisms which point in toward vugs. It was noted cutting quartz in veinlets, and occurs as veinlets introduced along boundaries between quartz and sphalerite, galena and sphalerite, and galena and pyrite.

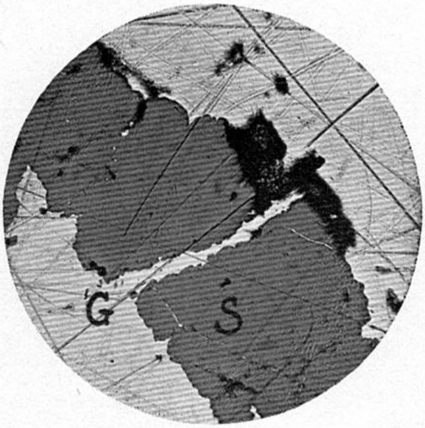

Fig. 1

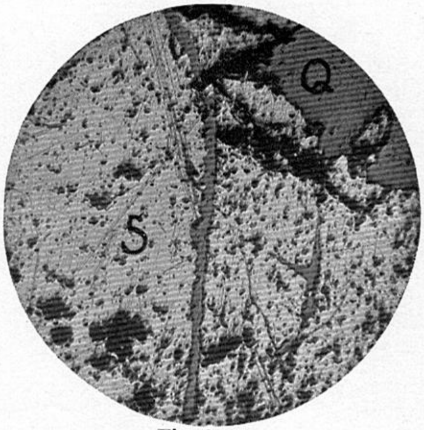

Fig. 2

Fig. 3

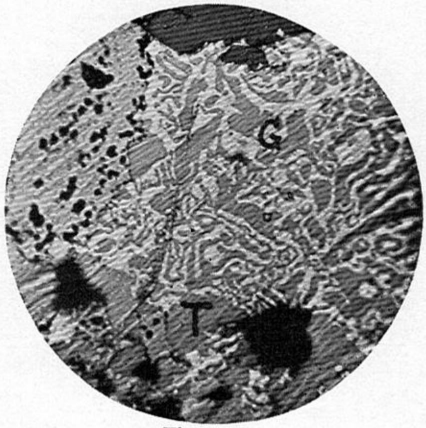

Fig. 4

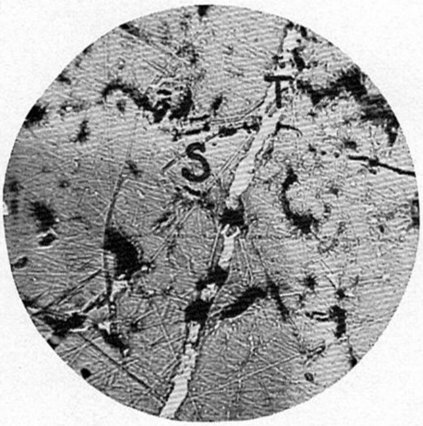

Fig. 5

Fig. 6

Fig. 1. Elongate patch of sphalerite (S) in galena (G), with galena veinlets cutting sphalerite. X-100

Fig. 2. Quartz veinlet (Q) in sphalerite (S). X-30

Fig. 3. Galena (G) molding itself against quartz (Q) euhedra along vug in quartz vein. X-30

Fig. 4. Intimately intergrown area of galena (G) and tetrahedrite (T). X-300

Fig. 5. Tetrahedrite (T) veinlet in sphalerite (S). The veinlet contains some chalcopyrite and galena which do not show because of lack of contrast. X-85

Fig. 6. Rods and dots of argentite (white) in etched galena (black). X-75

Pyrite grains, a few well-formed, are inclosed in chalcopyrite and small grains of chalcopyrite are inclosed in pyrite.

Chalcopyrite is closely associated with galena. Some rounded patches, part galena, part chalcopyrite, occur in sphalerite. They also occur together as vug linings and, together with tetrahedrite, as small veinlets in sphalerite. A galena veinlet in sphalerite, connected to an area of more or less intergrown galena, chalcopyrite, and tetrahedrite, was found to give way to chalcopyrite, and to continue on as a veinlet of that mineral.

Tetrahedrite.—Tetrahedrite occurs in small amounts in a few of the specimens examined. Its principal occurrence is in close association with galena with which it forms intergrowths (Fig. 4) without apparent relation to crystallographic directions or fractures. These intergrowths contain a few rounded and smoothly-curving patches of chalcopyrite, and occur as shapeless areas in dark sphalerite. The relation of these intergrown areas to sphalerite is obscured by the pitted, vuggy nature of the surfaces on which they occur. However, the veinlets of tetrahedrite with galena and chalcopyrite cutting sphalerite, previously referred to, indicate that tetrahedrite is later than sphalerite.

It is likely that some silver occurs with the tetrahedrite. Polished surfaces of ore from the Gunnison mine, which has been cited as producing the richest silver ore in the district, show considerable tetrahedrite as a minor constituent.

Argentite.—Argentite appears on etched galena surfaces (Fig. 6) as sparsely and irregularly distributed rods and dots, occasionally showing a faint suggestion of orientation, but no discernible relation to fissure or veinlets.

Gangue minerals.—The chief gangue mineral is quartz, which has already been described. A small amount of carbonate is also present. The only carbonate which occurs in sufficient quantity to be accurately identified is a pink rhombohedral mineral which quantitative analysis shows to contain approximately 67 per cent of $MnCO_3$ to 33 per cent of $CaCo_3$. This material came from the dump of the Fanchon shaft. The carbonate surrounds isolated areas of galena which it cuts in veinlets, and occurs as well-formed crystals in vugs.

Paragenesis

The first mineral to crystallize was pyrite, in small amount. This was followed by dark brown sphalerite, chalcopyrite (as inclusions in sphalerite), and galena, these being closely associated and probably in part contemporaneous, though galena appears to outlast the sphalerite.

If sphalerite and galena are in part contemporaneous, as seems highly probable, then the restriction of small chalcopyrite inclusions to sphalerite may be due to a selective process of replacement, or to the unmixing of a solid solution. As already stated, there is no conclusive proof for either view. The essential restriction of chalcopyrite specks to the dark sphalerite suggests that they were introduced with or shortly after it.

The next minerals to be introduced were pyrite and quartz in close association, as veinlets, embayments, and crusts. Some light-colored sphalerite is closely associated here with quartz. It is possible that the earlier, ferruginous sphalerite was deposited at higher temperatures and that limited quantities continued to be deposited as the solutions cooled, although leaner in iron and therefore of a lighter color. This relationship has been noted by Smyth.[9]

Galena occurs in part overlapping with, though apparently outlasting, pyrite and quartz, and is associated with minor amounts of chalcopyrite, tetrahedrite, and argentite.

Especial interest is attached to the paragenesis of silver minerals, particularly as to whether they are of supergene or hypogene origin. As previously mentioned, silver possibly occurs as argentiferous tetrahedrite closely associated and intergrown with galena (Figs. 4 and 5), and was seen

[9]Smyth, C. H., Jr., Genesis of the zinc ores of the Edwards District, St. Lawrence County, N. Y.: New York State Mus. Bull. No. 201, pp. 26-28, 1917.

in the form of argentite inclusions in galena (Fig. 6). The writer is unable to find any evidence in the surfaces studied or in the literature to explain the relations of tetrahedrite and argentite to galena on the basis of unmixing. However, in view of their close intergrowth association with galena, a mineral rarely if ever formed in noteworthy quantity by secondary enrichment, and their lack of definite relationship to veinlets, cleavage directions, and grain boundaries, they are regarded as hypogene. The rich silver ore mined in the early operations, as at the Gunnison mine, together with field evidence, indicate that there was an oxidized zone. If there was a secondary sulphide zone, no evidence of it was seen in the specimens studied.

The relations of the minerals in the Sugar Loaf District are much the same as the relations of the same minerals at Leadville, but with certain differences. Early pyrite, sparingly present in the ores studied, is the most abundant sulphide mineral at Leadville. The early, ferruginous sphalerite is abundant at both places, but is generally darker or more ferruginous at Leadville where it is the marmatite variety. In both districts it is mainly earlier than the galena. Shoots of rich silver ore are small and scattered and commonly contain considerable bismuth at Leadville. While no accurate information as to the distribution of the silver ore at Sugar Loaf is available to the writer, it appears to be more uniformly distributed, and not to be accompanied by bismuth minerals. The two stages of galena deposition are found at both places. The late pyrite-quartz stage is doubtless present at Leadville, but quite insignificant, whereas it is conspicuous in the specimens from the Sugar Loaf district.

The deposits of the Sugar Loaf district are similar to the deposits of the marginal parts of the Leadville district. As no barite was noted comparison with the more outlying deposits like those of the Continental Chief mine are not readily suggested, but the presence of carbonates suggests a resemblance to ores in the vicinity of the Hellena mine in Iowa Gulch.

Conclusions

1. The successive stages of mineral deposition as interpreted from polished surfaces is summarized as follows:
   A. Pyrite (minor amount).
   B. Sphalerite with chalcopyrite inclusions, and galena.
   C. Light-colored sphalerite, pyrite and quartz
   (Some overlapping of C and D)
   D. Galena, chalcopyrite, argentite, tetrahedrite
2. Some later sphalerite of a honey-yellow color associated with quartz is suggested to have been deposited at lower temperatures than the earlier, dark sphalerite.
3. The silver minerals in the specimens studied are regarded as hypogene. No reliable evidence of supergene minerals was found.
4. The deposit is comparable in certain respects to deposits in the marginal parts of the Leadville district, as at the Hellena mine, in Iowa Gulch.