

COLUSITE—ITS OCCURRENCE, PARAGENESIS AND GENETIC SIGNIFICANCE

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INTRODUCTION

Considerable interest has been evinced, not only locally, but also in research laboratories outside of Butte, in the mineral "colusite," a sulfosalt of copper and tin. The present investigation is an outgrowth of apparent discrepancies observed to exist between published data and laboratory results obtained at Montana School of Mines.

Mr. Reno H. Sales, Chief Geologist of the Anaconda Copper Mining Company, first named the mineral, taking the name "colusite" from a claim, the Colusa, near which it was first found (2). Since its discovery on the 1200-foot level of the Leonard mine, colusite has been recognized on various levels of the West Colusa, Tramway, and Mountain View mines at Butte. In these mines it is valued only for its copper content, recovery of the tin being impractical under present metallurgical practice.

A preliminary study of the new mineral was made in 1922 by Mr. George G. Griswold, consulting metallurgist of Butte. In 1933 Landon and Mogilnor published a short general survey of colusite, including its formula, properties, and paragenetic relationship. Other than this material and a supplementary article concerning x -ray examination of the mineral (6), no descriptive literature concerning colusite exists.

Realizing that lack of laboratory x -ray equipment precluded a comprehensive study of the crystal structure and system, such work was left to others, our work being centered on:

1. Obtaining *pure* colusite for accurate determination of its chemical composition and specific gravity.
2. Observing its occurrence and associations, both underground and in polished sections, using iridescent-filming solutions as a tool in the latter work.
3. Incorporating these observations into an interpretation of the genetic significance of colusite.

UNDERGROUND OCCURRENCE

Sales (4) has mapped the Butte ore deposits in a zonal pattern consisting of: (1) a central copper zone, (2) an intermediate zinc zone, and (3) a peripheral manganese zone. It is not difficult to fit colusite in the broad geologic pattern outlined above. It has been observed in sizable amounts only in the central copper zone. It must be explained that minute inclu-

sions of the mineral have been observed, microscopically, in ores from the Mountain Con and other mines bordering the central zone. Such inclusions are to be expected, as all the sulfide minerals commonly overlap from zone to zone. Colusite has been noted only in veins belonging to the Anaconda or east-west system, thus suggesting an age for the mineral that is coincidental with the earliest mineralization in the district.

Colusite is found almost entirely within the "horse tail" area, that "frayed out" structure that becomes evident on the eastward extension of the east-west system. This section of the vein system lies entirely within an area of intensely altered quartz-monzonite.

Sales has stated that "primary chalcocite and enargite occur only in association with the intensely altered granite [quartz monzonite] of the district" (4). Significantly, it is noted that colusite almost always occurs with either or both of these two minerals. Glassy quartz and pyrite, minerals generally regarded as having a high temperature of formation, were noted in abundance near exposures of colusite.

Colusite has not been noted above the 1200-foot level. Furthermore, downward extension of the tin-bearing sulfide is probable, colusite occurring throughout the zone from the 2800-foot to the 3000-foot level at the Tramway mine. The vein is not developed below that point in the colusite area.

In summation it may be said of the occurrence of colusite as determined by field studies: It is a primary mineral, occurring with minerals deposited under conditions of relatively high temperature; it probably resulted from primary ore deposition and it probably never reached the present outcrop. The available tonnage of the mineral is small in relation to that of other copper minerals.

EXPERIMENTAL PROCEDURE

Through the cooperation of the Anaconda Copper Mining Company's geological staff, about 200 pounds of colusite-bearing ore was collected from stopes between the 2800-foot and 2900-foot levels of the Tramway mine, and from a vein in a 2800-foot-level drift at the West Colusa mine.

It soon became evident that segregation of pure colusite from associated impurities, the major one being enargite, would be impossible by ordinary hand picking, so efforts to purify the mineral were limited to:

1. Picking out idiomorphic crystals under a microscope.
2. Selectively floating colusite in flotation tests.

The picking operations resulted in two grams of colusite crystals being segregated. The specific gravity of this material was determined.

The flotation tests yielded two colusite concentrates. These were subsequently briquetted and examined under the microscope, grain counts being made. Knowing the percentages of impurities present and their respective compositions and specific gravities, it was a simple matter to calculate exact element-percentages for colusite and to determine an accurate specific gravity.

Flotation procedure for these tests can be summarized as follows: The ore, containing approximately 40% colusite, was comminuted to the flotation range, deslimed, and then subjected to a very gentle roast, drying on a hot plate to slightly inhibit all sulfides; actual flotation was accomplished using small quantities of pine oil and potassium xanthate, lime and potassium cyanide being added to inhibit pyrite, chalcocite and bornite.

It was found that colusite floated somewhat more readily than enargite, but not sufficiently faster to permit of rigorous separation of these two minerals. A grain count of the concentrate from Test No. 1 gave the following percentages: colusite, 86.1%; enargite, 12.2%; bornite, 0.6%; covellite, 1.1%. Concentrate No. 2 gave the following percentages: colusite, 88.4%; enargite, 9.9%; bornite, 0.3%; chalcocite, 1.4%.

MINERALOGY

Composition: The two concentrates were analyzed by chemists of the Anaconda Copper Mining Company, the composition of colusite being calculated on the basis of the known impurities as determined by the grain counts listed in the preceding paragraph.

Calculation sequence: (1) weight percentages of the mineral impurities were computed from the observed volumes, using specific gravities as given by Dana and Schneiderhöhn for the known minerals and using a specific gravity of 4.6 for colusite (see under specific gravity); (2) the impurity, SiO_2 , was subtracted from the chemist's analysis and the weight percentages adjusted to the total amount of sulfides present; (3) amounts of copper, sulfur, iron, and arsenic sufficient to make up the known impurities were subtracted from the chemist's analysis; (4) remaining element percentages were attributed to colusite and were recast to a one hundred per cent basis.

The chemist's analyses of the concentrates and the calculated element percentages for colusite (Tramway Mine) are as follows:

	Colusite No. 1		Colusite No. 2	
	Analysis	Calculated	Analysis	Calculated
Sn	5.30%	6.18%	5.00%	5.68%
SiO ₂	0.80		0.40	
S	26.50	25.83	28.55	28.41
As	8.90	7.77	8.80	7.92
Cu	49.22	49.47	48.67	48.28
Ag			1.32 oz.	
Au			0.01 oz.	
Sb	0.43	0.50	0.51	0.58
Zn	None		None	
Fe	1.36	1.51	0.98	1.07
Unanalyzed balance	7.49	8.74	7.09	8.06
Total	100.00	100.00	100.00	100.00

It will be noted that the analyses are only partial, approximately 8.0% being unaccounted for. Analyses by other investigators indicate that vanadium and tellurium account for the bulk of this remainder.

Samples from three mines, the Leonard, Tramway, and West Colusa, representing the major part of all developed colusite, check consistently in content of important elements (2) (3), with the exception of the analysis by Gross (2). Accordingly, this analysis should be dropped.

Although there is general agreement between the various analyses, there is not absolute agreement. This is perhaps due to the fact that enargite constitutes a substantial impurity in what has been regarded as pure colusite. On the other hand, in view of the zonal structure of colusite, which is described below, it is unreasonable to expect absolute uniformity as between samples secured from different mines or in different samples from the same place. Actually it seems as if the elements unquestionably present in colusite include four; namely, copper, tin, arsenic, and sulfur. Minor quantities of vanadium, antimony and iron are present, probably in solid solution.

Preliminary attempts at the pyrosynthesis of colusite from copper, tin, arsenic and sulfur have resulted in the production of small quantities of colusite as determined by the similarity of their physical properties to those of colusite, i.e., color, hardness, isotropy, and by their identical reaction to the same filming bath used for colusite. Filming brought out a rudimentary banded structure.

Specific Gravity: The specific gravity of this concentrate, recalculated on the basis of known impurities, is 4.58 when a water-pycnometer

method is used. This may be compared with a specific gravity of 4.45 obtained with a water-pycnometer on the colusite crystals previously mentioned. It would then seem that the specific gravity lies within the range of 4.4 to 4.6.

Substitution of acetone and amyl alcohol for water as the liquid medium in pycnometer measurements resulted in complete elimination of buoyant air bubbles. Specific gravity results, however, were discordant, the values obtained ranging from 4.6 to 4.9. Such discordance appeared due to high coefficients of expansion and volatilities of these liquids. Likelihood of a specific gravity lower than 4.6 appears improbable.

Other Properties: Other properties observed in hundreds of examinations of colusite are: color, steel-gray bronze (megascopic) and creamy tan (in polished section); hardness, 3+ in Mohs' scale, being harder than enargite and so brittle as to be easily pulverized; cleavage, none; fracture, uneven to hackly (see Fig. 1); lustre, metallic, with a reflectivity of the order of magnitude of that of galena or chalcopyrite; streak, sooty-black like enargite. These check consistently with those found by Ber- man.

Colusite commonly occurs in complex aggregates of isometric crystals some of which are perhaps twins.

Structure: With the standard filming solutions described heretofore (1), colusite and enargite remain unaffected, though structure and paragenetic relationships of the other minerals are brought out. Therefore, a more potent filming solution was prepared as follows:

To 10 c.c. of a 50% (by weight) solution of chromium trioxide in water is added 10 c.c. of concentrated hydrochloric acid; this solution is stirred and allowed to cool to room temperature (18–20°C.).

Exposure of the polished section of colusite to this filming solution for 20 seconds develops in colusite an amazing banded structure, as may be seen from Figs. 3 and 4. The colors of the bands range from various shades of first-order tans and browns in 15 seconds, to beautiful first-order blues and hiatus yellows in 30 seconds. Marked contrasts of first-order browns and blues may be obtained by immersion of 20 seconds. Duplication of this color range, using longer periods of immersion, may be obtained by decreasing the strength of the chromium trioxide solution, e.g., 10 c.c. 30% CrO_3 +6.4 c.c. HCl gives tan bands in one minute to various shades of blue and yellow in 3 minutes.

The banded structure is explainable only by postulating that the crystals grew in such a way that different layers had a somewhat different composition and that these layers of solid-solution oscillated about an average composition. This average composition is all that can be determined by chemical analysis.

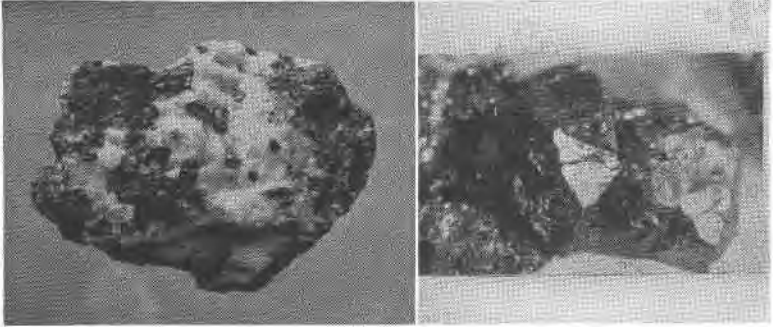


FIG. 1. Colusite with quartz. Note the hackly fracture, ($\frac{1}{2}\times$).

FIG. 2. Broken crystal aggregate of colusite showing crystal faces, ($4\times$).

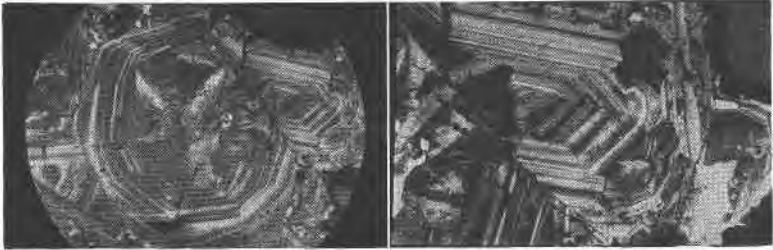


FIG. 3. Polished section showing zoning in colusite. Filmed two minutes in saturated solution of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in HNO_3 . Colors: first-order blues to second-order yellows, ($50\times$).

FIG. 4. An enlargement of the above specimen showing the geometric arrangement and varied width of the bands, ($100\times$).

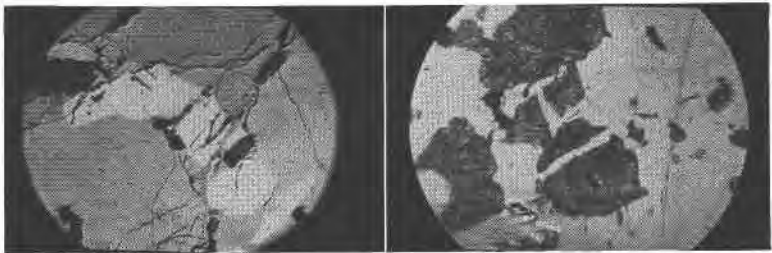


FIG. 5. Colusite (gray) veined by enargite (white) which is, in turn, veined by bornite (gray, slightly darker than colusite). Unfilmed, crossed nicols, oil immersion, ($50\times$).

FIG. 6. Colusite areas observed in U.S.G.S. enargite specimen from Butte (Ref. No. 106). Note the enargite veins cutting across the banded structure of the colusite. Filmed 15 seconds in 10 cc. 50% CrO_3 +10 cc. HCl . Colusite banded in tans and blues, ($102\times$).

It must be strongly emphasized that these bands, as brought out by the filming solution, do not indicate a progressive change in chemical composition from center to edge, but rather pulsating changes in composition as the crystals grew. These growth rings vary in width as may be seen in Fig. 3 and, furthermore, their cycles of deposition must have been interrupted by frequent and extensive shattering and cementation, some banded segments being faulted and broken with new bands enclosing the whole. The colusite crystal represented in Fig. 3 has a center distorted and otherwise complicated by such diastrophism, yet the outer bands have a geometric simplicity that indicates lack of diastrophism.

If this banding represents differences in composition, it should be possible to homogenize them by heating the specimen to some temperature below the melting point. Attempts at such a homogenization were made using various oil baths at temperatures up to 400°C., and for times as long as four hours. Appreciable differences in the banded structure did not occur, some higher temperature being necessary to effect the change. Therefore, it seems likely that the mineral could withstand relatively high vein temperatures subsequent to formation and still retain its complex structure. It is significant that similar banding in tetrahedrite did become partially homogenized when subjected to a similar treatment, the filmed color becoming uniform with the bands remaining as a ghost pattern.

PARAGENESIS

Colusite was deposited with the older generation of sulfides and sulfosalts closely following the quartz-pyrite stage of deposition. With few exceptions it occurs in close association with enargite. When the polished surface is unfiled it is impossible to decide which is earlier. However, iridescent filming brings out the fact that colusite is antecedent to enargite. Enargite veins frequently cut squarely across the banded colusite as may be seen in Fig. 6. Such evidence is most conclusive when the continuity of the same colusite band can be established on both sides of the enargite vein, as it is there. In other instances, colusite crystals have been stoped along some less resistant bands, and are now enveloped by enargite.

Bornite, chalcocite and chalcopyrite are definitely later than colusite, always filling cracks or fissures in the latter mineral. These veins occasionally contain inclusions of pyrite, which probably are the remnants of an earlier pyrite filling which had been replaced, as suggested by Landon, or else the stoped remnants of an early pyrite which had been carried in by fluid movement during the vein-forming stage.

Both enargite and colusite are veined by tetrahedrite-tennantite, this

veining antedating that of the bornite-chalcocite as is shown by the cutting of the tetrahedrite veins by more recent veining.

In respect to the minerals observed together in the present investigation the sequence of deposition of sulfides was as follows:

- (1) Pyrite
- (2) Colusite
- (3) Enargite
- (4) Tennantite-Tetrahedrite
- (5) Chalcocite and Bornite

Colusite is not an exclusive Butte mineral. The author observed its occurrence with enargite in U.S.G.S. specimen: Nat. Museum No. 81,127, from Red Mountain, Colorado. Further observation will doubtless disclose other occurrences.

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