

## RE-EXAMINATION OF COLUSITE

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Colusite was named by Mr. Reno H. Sales, Chief Geologist of the Anaconda Copper Mining Company, a number of years before the mineral was studied in detail by Landon and Mogilnor (1933), and by Zachariassen (1933).<sup>\*</sup> Somewhat earlier Schneiderhöhn and Ramdohr (1931) had referred the mineral to the tetrahedrite group, but without evidence. We have re-examined the mineral in this laboratory using well-authenticated material labelled *colusite*, which was collected a number of years ago by geologists associated with the Anaconda Company. A re-examination of the paragenesis of colusite has been undertaken by Nelson (p. 369, this journal) of the Montana School of Mines, in cooperation with the Anaconda Copper Mining Company staff. Our manuscript was submitted to Mr. Nelson whose independent check of our results is contained in his paper.

Crystals have been measured; an analysis of material has been made on a sample first examined in polished section; and finally an *x*-ray study of the same material, together with a density determination, was made. We find that colusite is, as Schneiderhöhn and Ramdohr have already hinted, a member of the tetrahedrite group, and that the unusual formula assigned to the material examined by Zachariassen is not applicable to our analysis. The material described by Landon and Mogilnor has the physical properties and apparently the general appearance of our colusite. However, the analysis given by them departs from ours, and the unit cell edge measured by Zachariassen is exactly half of our value. On the other hand, the partial analyses made in the laboratory of the Anaconda Company (by professional chemists), and quoted by Landon and Mogilnor, are essentially in agreement with our analysis, and consequently in complete disagreement with the analyses of Gross. Further, partial analyses, repeated by the Anaconda Company chemists (in Nelson's paper, this journal) verify our new analysis, and indicate that the material analyzed by Gross (in Landon and Mogilnor) was not representative of the composition of colusite. Therefore, on the basis of composition and physical properties, our material appears to be what was originally referred to as colusite, and some doubt must be cast on the samples examined by Landon and Mogilnor and by Zachariassen. This latter material may be a new mineral, but its properties are only in

<sup>\*</sup> The mineral was known to be tin-containing as early as 1917, in Professor Graton's laboratory at Harvard. Crystals were measured by Professor Palache and found to be tetrahedral. The investigation was, however, never completed.

part those of colusite, in the sense of Sales, Schneiderhöhn and Ramdohr, Nelson, and ourselves.

The following is a description of what we believe to be colusite.

*Crystallography*: Isometric—hextetrahedral

Forms:  $d(011)$ ,  $e(012)$ ,  $o(111)$ ,  $n(112)$ .

Figure 1 shows the average development of a crystal; all of the examined crystals show the tetrahedral development clearly, and leave no question concerning the crystal class. The habit of colusite is unique in that the tetrahexahedron  $e(012)$  is found in combination with the tetrahedron; careful study of Goldschmidt's Atlas revealed no tetrahedral mineral with this unusual combination. Other forms still uncon-

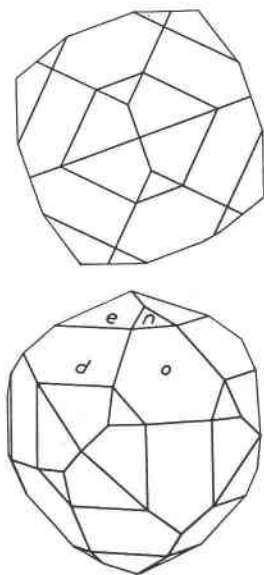


FIG. 1. Plan and elevation of typical crystal of colusite.

firmed because of their uncertain measurements are  $(001)$ ,  $(\bar{1}\bar{1}1)$ , and  $(1\bar{1}\bar{2})$ . The crystallographic work was done by C. W. Wolfe.

*Structure cell*:  $a_0 = 10.60 \pm 0.01 \text{ \AA}$ . The value here given was determined approximately, at first, on long exposures of crystals, using copper radiation and a rotating crystal, and later with more precision using the Weissenberg goniometer. The odd-order layer lines are weak and appear only after five hours (at about 40 KV and 10 MA; camera radius 28.65 mm.). A tennantite crystal examined in the same way showed a similar,

but not so pronounced, weakness of the odd-order layer lines. (The cell edge given by Zachariassen is  $5.304 \pm 0.001 \text{ \AA}$ .)

*Physical properties:* Cleavage none. Brittle. H = 3-4. G. = 4.50, 4.434 calculated. Metallic luster. Color bronze. Streak black. Opaque. Isotropic in polished section.

The following etch reactions on a polished section by Esper S. Larsen, 3d, on the sample analyzed, establish the close relationship between our material and the other members of the tetrahedrite group.

Color—Coppery cream

Hardness—C+ or D-, Talmadge scale.

HNO<sub>3</sub>—Stains differentially in brown, bringing out a zoned structure. Often negative within the ordinary time limit because of the slow start of the reaction.

HCl—neg.

KCN—brings out scratches. No discoloration.

FeCl<sub>3</sub>—neg.

KOH—neg.

Aqua Regia—negative for 1 minute.

These etch reactions differ in some respects from those of Landon and Mogilnor, and are, therefore, another indication that the material of the two investigations was probably not identical.

The specific gravity given by Landon and Mogilnor is 4.2. Our density value, 4.50, was determined (using a micro-balance yielding values in general well within one per cent accuracy) on the same crystals as were used for the crystallographic and *x*-ray work.

*Chemistry:* The sample for analysis was chosen from the specimen containing the crystals measured. No important amounts of any other sulphide mineral were noted in the hand specimen, and the associated quartz was easily eliminated by separation in heavy solutions. The purity of the analyzed sample was determined by examination of part of the prepared material in polished section. A grain count (by Esper S. Larsen, 3d) gave: colusite 94 per cent, chalcopyrite and pyrite  $\frac{3}{4}$  per cent, a white undetermined mineral  $5\frac{1}{4}$  per cent. In the following table the analysis is given:

TABLE 1. ANALYSIS OF COLUSITE

	1	2	3	4
Cu	47.99	.7549 = $24 \times .0315$	24.52	47.67
Fe	1.09	.0195	0.63	1.05
Sn	6.71	.0565	1.84	6.45
V	2.28	.0448	1.46	2.20
Te	1.26	.0099	0.32	1.21
Sb	0.19	.0016	0.05	0.19
As	9.54	.1287	4.14	9.18
S	30.65	.9560 = $32 \times .0299$	31.06	32.05
	99.71			100.00
G	4.50			(calc.) 4.434

1. Colusite, Butte. Specimen number 92255. Analysis by F. A. Gonyer, on 0.8 gms.
2. Molecular proportions.
3. Number of atoms in the unit cell of  $M_0 = 3248.5$  = molecular weight of the unit cell derived from *x*-ray data and density.
4. Calculated composition for the formula  $8Cu_3(As, Sn, V, Fe, Te)_4S_4$  with As:Sn:V:Fe:Te as given in the analysis.

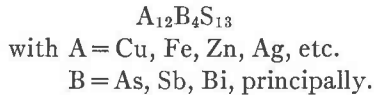
In Table 2 are given the previously published analyses of colusite, together with our analysis. Striking differences are shown, particularly in the presence of vanadium in our analysis, and the large amount of iron and considerable percentage of molybdenum in the analysis by Gross. The early Anaconda Company analysis (columns 1 and 2 of Table 2) and the newer partial analysis by the Company chemists (in Nelson, p. 369 of this journal) are essentially in agreement with our analysis.

TABLE 2. COLLECTED ANALYSES OF COLUSITE

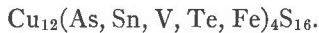
	1	2	3	4
Cu	48.0	46.9	35.82	47.99
Fe	?	3.6	18.37	1.09
Zn	0.0	0.9	0.90	
Sn	6.9	5.8	6.64	6.71
Mo			8.80	
V				2.28
Te	3.0	0.4	2.97	1.26
Sb	2.6	0.64	0.58	0.19
As	6.8	8.4	2.50	9.54
S	27.5	29.2	24.20	30.65
	94.8	95.84	100.78	99.71
G			4.2	4.50

1. Leonard mine. In Landon and Mogilnor. Bi 0.0, Anaconda Copper Mining Co., Geological Dept.
2. Mountain View mine. Anaconda Copper Mining Co., anal.
3. Tramway mine. S. T. Gross, anal., in Landon and Mogilnor. Av. of 2 analyses.
4. F. A. Gonyer, anal. Harvard no. 92255. Analysis sample 0.8 gms.

On the basis of the chemistry of the tetrahedrite group as established by Kretschmer (1910) and by Wherry and Foshag (1921), and from structural studies by Machatschki (1928) and by Pauling and Newman (1934), the generally accepted formula may be expressed as follows:



Our formula for colusite (for half the cell contents) is



The colusite composition corresponds to the tetrahedrite requirement in an important respect, namely, that the ratio of Cu: As+Sn+V+Te+Fe = 3:1. In addition, the unit cell content in both instances is approximately the same. The excess of sulphur atoms in colusite over that ascribed to the tetrahedrite minerals is not a serious discrepancy since the structural studies indicate the probability that vacant positions could readily accommodate extra sulphur atoms.

The close similarities between the sphalerite and tetrahedrite groups in their crystallographic, structural and chemical properties have been repeatedly noted. It is not surprising, therefore, that colusite has been placed previously in the sphalerite group. But no members of the sphalerite group have the large unit cell found by us for colusite, nor any considerable amount of arsenic (and similar kinds of atoms) in their composition.

Germanite has been placed tentatively by de Jong (1930) in the sphalerite group. Its composition can, however, be expressed as



and this mineral may also well be a member of the tetrahedrite group.

#### REFERENCES

- DE JONG, *Zeits. Krist.*, **73**, 176 (1930).  
 KRETSCHMER, *Zeits. Krist.*, **48**, 484 (1910).  
 LONDON AND MOGILNOR, *Am. Mineral.*, **18**, 528 (1933).  
 MACHATSCHKI, *Zeits. Krist.*, **68**, 204 (1928).  
 NELSON, This journal, p. 369 (1939).  
 PAULING AND NEWMAN, *Zeits. Krist.*, **88**, 54 (1934).  
 SCHNEIDERHÖHN AND RAMDOHR, *Lehrbuch der Erzmikroskopie*, **2**, 433 (1931).  
 WHERRY AND FOSHAG, *J. Washington Ac. Sc.*, **11**, 1 (1921).  
 ZACHARIASEN, *Am. Mineral.*, **18**, 534 (1933).