

FIG. 2. Modification of the Norelco rotating flat sample holder to properly position the planchet. We have discarded the original indexing ring which obstructed the beam at low angles. This present arrangement permits studies at very low values of 2θ .

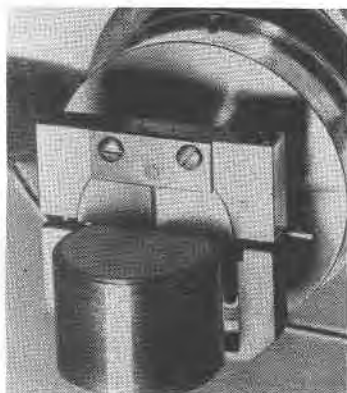


FIG. 3. Packet planchet held by a special clip on the Norelco glass slide holder. The clip slides off readily and even when left on does not interfere with the use of glass slides.

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ORIENTED OVERGROWTHS OF TENNANTITE AND COLUSITE ON ENARGITE

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A specimen from the Cerro de Pasco mine, Cerro de Pasco, Peru, now in the writer's collection, consists of a radiating aggregate of prismatic enargite crystals up to 20 mm. long. The enargite crystals are covered

with a druse of minute tetrahedra which seemed to have a preferred orientation on the enargite. These tetrahedra were found to be a member of the tetrahedrite-tennantite series with $a_0 = 10.22 \text{ \AA}$. Several of the enargite crystals were selected for measurement on the two-circle reflecting goniometer: the orientation was determined as $\{111\} [111]$ tennantite // $\{001\} [001]$ enargite.

As shown in Fig. 1, the tennantite tetrahedra on (001) of enargite are further oriented with an apex pointing towards $(00\bar{1})$ of enargite and with their opposite edges parallel to $[010]$, $[210]$ or $[2\bar{1}0]$ of the enargite. The larger tetrahedra growing on $\{101\}$ of enargite maintain this same orientation. The structural control of the tetrahedra incrusting the enargite

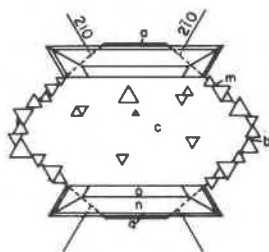


FIG. 1. Basal projection of enargite showing $c\{001\}$, $b\{010\}$, $a\{100\}$, $m\{110\}$ and $k\{101\}$ with oriented tennantite tetrahedra showing $o\{111\}$, $n\{112\}$ and $a\{001\}$. Cerro de Pasco mine, Cerro de Pasco, Peru.

prism zone appears not to be so rigid, as a number are in random orientation; however, reflections from tetrahedra with an apex pointed towards (001) of enargite were searched for but not observed. This is taken as indirect confirmation of the polar character of both the c axis of enargite and the $[111]$ directions of tetrahedrite-tennantite. While $\{010\}$ and $\{110\}$ of enargite are thickly incrustated, $\{100\}$ is not; the few tetrahedra observed on this form are developed along striations parallel to $[001]$ of enargite.

In the structural study of enargite by Pauling and Weinbaum (1934) it is pointed out that this structure can be derived from that of wurtzite by the appropriate substitution of copper, arsenic and sulfur atoms for the zinc and sulfur atoms of the wurtzite. Similarly, Pauling and Neuman (1934) consider that the structure of tetrahedrite-tennantite can be arrived at through the replacement of the zinc and sulfur atoms in eight unit cells of sphalerite by copper, arsenic and/or antimony, and sulfur atoms, with some sites vacant. Further, the structure of sphalerite in the $[111]$ direction and wurtzite in the $[0001]$ direction differ only in the sequence of stacking of similar layers of sulfur-zinc tetrahedra.

Mitchell and Corey (1954) describe artificial oriented overgrowths of sphalerite tetrahedra on wurtzite prisms. The orientation of the sphalerite on wurtzite is identical to that described above for tennantite on enargite. As the [0001] direction of wurtzite is analogous to the [001] direction of enargite, the observed orientation of tennantite on enargite is not unexpected.

A fine group of enargite crystals from the Leonard mine, Butte, Montana in the collection of Edward McDole of Butte, contains a number of enargite prisms which are capped by complex silver-white crystals which were thought to be colusite. Other specimens of these overgrowths were supplied to the writer by Richard W. Thomssen and Sidney A. Williams of Tucson, and Albert L. McGuinness of Eugene, Oregon. All of these specimens were collected in the past few years.

Several of these groups were measured on the optical goniometer, and the identity of the enargite and the isometric, hextetrahedral character of the colusite established. The largest colusite crystals seen reached a maximum dimension of about 6 mm. An x-ray powder pattern of these capping crystals gives spacings essentially in agreement with the published pattern of colusite in Murdoch (1953). The unit cell edge of this recent material is 10.64 Å, with values around 10.61 Å previously reported. Additionally, the carbon-arc spectrogram of this material shows strong lines of copper and arsenic, and weaker lines of antimony, tin, iron and vanadium. This particular set of elements seems to characterize the reported analyses of colusite, and helps to distinguish it from the similar minerals germanite, reni rite and gallite.

All of the colusite crystals examined, with one exception, show large {111}, and smaller {012}, {112} and {011}. As noted by Wolfe in Berman and Gonyer (1939), colusite is the only mineral in the hextetrahedral class which shows the combination of {111} and {012}. All colusite crystals seen were twinned by rotation about [111], but with the two or more colusite individual's [111] axes parallel rather than coincident, allowing the alternate morphological explanation of reflection across {112} with {112} as the composition plane. Characteristically, the twinned individuals are also displaced slightly along [111] from one another, so that their (111) faces are not continuous. The enargite prisms, deeply striated parallel to [001], show development of {010}, {100}, {110}, {120}, {130} and {150} in the prism zone, and are terminated by smooth (001). (Figs. 2 and 3). One of the colusite twins lacked {111}. (Fig. 4). These colusite twins are oriented on enargite in the same manner as the above described tennantite crystals from Cerro de Pasco, Peru. This can be construed as additional evidence of a structural similarity between colusite and tetrahedrite-tennantite.

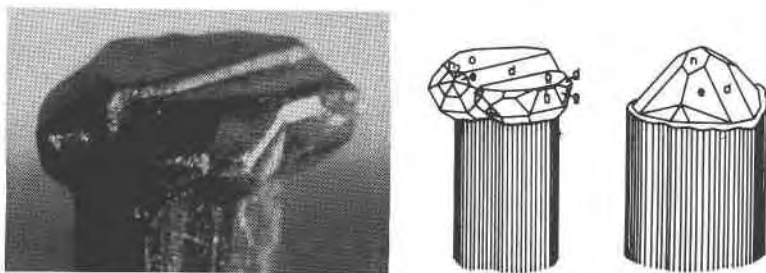


FIG. 2 (left). Group of three twinned colusite crystals oriented on an enargite prism. Leonard mine, Butte, Montana. Photograph by John W. Anthony.

FIG. 3 (center). Colusite twin oriented on enargite. Forms on the colusite twin are $o\{111\}$, $e\{012\}$, $n\{112\}$ and $d\{011\}$.

FIG. 4 (right). Colusite crystal oriented on enargite. This crystal lacks $o\{111\}$; other forms as in Fig. 3.

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A METHOD FOR THE DIRECT DETERMINATION OF LATTICE PARAMETERS

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Although the calculation of lattice parameters by Cohen's method of least squares (1) has proved a highly successful means of attaining accuracy and precision from x -ray powder data, it incorporates an analyti-