144. *Morphological Studies of Enargite.*

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(Comm. by S. KÔZU, M.I.A., Dec. 12, 1935.)

K. Takané of our institute in his account¹⁾ has discussed the proposition that As in enargite (Cu_3AsS_4) must be taken as an isomorphous member of Cu when the crystal belongs to the holohedral class as has been believed by mineralogist until the present time. Immediately after his publication, L. Pauling and S. Weinbaum²⁾ published the results of studies of the crystal structure of enargite, and in their paper the crystal is treated as if it belongs to the hemimorphic class without giving any special description from the mineralogical point. The chief reason for adopting this space group appears to be that the equivalent points referring to As can be explained more satisfactorily than by taking any other space group.

In order to determine this question morphologically, we examined the crystal habit of enargite from the Kinkwaseki mine for some thousand crystals which were kindly presented by Mr. Rikichi Shimada, the chief manager of the mine and we were able to obtain proof by which we know that the crystal must be grouped in the hemimorphic class.

Crystal habit.—The crystals used for the present investigation show a prismatic habit elongated towards $[001]$, its terminal crystal faces at one end being usually absent because of the crystals being attached to the host mass. Their dimensions vary from 5 to 10 mm. in length and from 2 to 5 mm. in width. The well developed faces belonging to the $[001]$ -zone are (100) , (110) and (120) , sometimes associated with (230) . The base (001) is also well developed and it is often cut by the smaller or larger face of (101) . Of these faces, the prismatic ones are markedly striated by numerous heavy lines parallel to $[001]$ and these striations are made of the oscillatory combination of (100) , (110) and (120) . The base is also striated with the finer lines running parallel to rectangular directions, $[100]$ and $[010]$, or parallel to either of these two. (101) is usually smooth and shines by reflected rays.

Combination of crystals.—It is generally said that enargite crystals twin with the twinning plane (320) , we can not observe this type of twinning in the crystals from Kinkwaseki, though a similar combination is rarely found as will be seen later. However, other different kinds of the combination of crystal individuals can be observed. For instance, three crystal individuals in a combination are given in Fig. 1 and their stereographic projections are as is seen in Fig. 2, the inter-

1) Proc. 9 (1933), 524.

2) Z. X., B. 88, H. 1 (1934), 48-53.

facial angles and zonal relations being determined by a two-circle goniometer. In order to see the relative positions of the two crystals I and II, two great circles passing through $(\bar{1}20)$ and $(\bar{1}\bar{1}0)$ for I and II were drawn respectively. Two other great circles, passing through the middle points between the two projections of $(\bar{1}20)$ for I and II and between those of $(\bar{1}\bar{1}0)$ for I and II and at the same time

Fig. 1.

Three crystal individuals of enargite in a combination, whose relation is shown in Fig. 2.

Fig. 2.

The stereographic projection of Fig. 1, showing the relation of the combination of three crystals I, II and III.

perpendicular to the former two great circles respectively, were drawn. The latter two great circles intersect in a straight line which can be taken as the axis of rotation by which a crystal coincides one after the other with an angle which is obtainable stereographically. In this case, the angle is 16° and the rotation axis is normal to $(0\bar{3}2)$. The same relation of crystal II to crystal III is given as $4^\circ \sim 5^\circ$ for the angle rotating along an axis which is normal to $(\bar{5}52)$. In other cases, the rotation-axes $[\bar{1}22]$, $[112]$, $[\bar{2}65]$ and $ca [001]$ and the corresponding rotation angles 29° , $56^\circ.5$, 67° and 126° were obtained. The last case is very similar to that of the twin with $(3\bar{2}0)$ as the twinning plane, in which the axis of rotation is $[001]$ and the angles is 120° . If we observe carefully a crystal which can be taken as a single crystal in general appearance, it is often seen that the crystal is a combination of two or three individuals. These can be judged from different images of reflected rays from the base. Further, there is practically no crystal which shows the reflections from the prismatic faces at a definite place in the field of the telescope attached to a goniometer when we rotate the crystal along the zone-axis $[001]$, indicating that these faces are slightly inclined against the zone axis. The polished surface of the crystal appearing as a single crystal shows different orientations at different parts of the crystal when we examine the surface under the reflection-microscope using polarized light (Fig. 3). From the observations stated above, we can see that enargite crystals are markedly characterized by complicated combinations of different crystal individuals.

Hemimorphic form :—As already stated, it is an important task to determine definitely the crystallographic class to which enargite belongs. Among a considerable number of enargite crystals, those which possess two terminal end-faces are rare, but we were able to see that these two end-faces are so different as to indicate that the

Fig. 3.

Mozaic intergrowth
of enargite, diagram-
atically drawn.

Fig. 4.

Hemimorphic forms of
enargite, diagrammatically
drawn.

Fig. 5.

existence of the plane of symmetry perpendicular to $[001]$ is impossible. For instance, a crystal of this type was drawn diagrammatically as is seen in Figs. 4 and 5. The hollow at the upper base is surrounded by the prismatic faces and its bottom is parallel to (001) , while the hollow at the lower base is pyramidal, its vertex being directed towards the inner part of the crystal and its base hexagonally sided. The triangular faces are striated by heavy lines made of the oscillatory combination of narrow faces such as (001) , (011) , (012) , (013) , (035) , (059) , (101) , (102) , (103) , (1010) , (407) , (112) , (114) , (115) , (124) , (126) etc..