CRYSTAL STRUCTURE OF COMMON ZOISITE

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Zoisite, $Ca_2Al_3(OH)(SiO_4)_3$, is said by Groth[1] and others to exist in two modifications, orthorhombic and monoclinic. The monoclinic variety, clinozoisite, usually contains some Fe^{+++} in place of Al^{+++} and is then called epidote.

Gossner and Mussgnug[2] have made x-ray analyses of zoisite and epidote from the Austrian Tyrol and report zoisite as orthorhombic, $a:b:c = 16.21:5.63:10.08$.

Two dimorphous series are considered to exist.[3]

$$\begin{tikzcd}
\alpha\text{-zoisite} \arrow[r, leftrightarrow] \arrow[d, leftrightarrow] & \beta\text{-zoisite} \arrow[d, leftrightarrow] & \text{orthorhombic} \\
\text{clinozoisite} \arrow[r, leftrightarrow] & \text{epidote} & \text{monoclinic}
\end{tikzcd}$$

Winchell states that

> "more than 5% Fe^{+++} in zoisite seems to favor crystallization in the monoclinic system as epidote. Iron free zoisite has the optic plane parallel to 010 (the cleavage), and normal to 100, while ferriferous zoisite (β-zoisite) has the optic plane parallel to 001 (normal to the cleavage), and normal to 100. Iron free zoisite has (+) $2V = 30°$, β-zoisite (+) $2V = 60°$. Between the limits 2V passes through zero. $a:b:c = 0.620:1:0.343$."[4]

Zoisite occurs in schists, in igneous rocks as an alteration product of plagioclase feldspars, in impure contact metamorphosed limestones and in quartz veins in altered basic igneous rocks. Winchell states that zoisite is less common than clinozoisite, and iron-bearing zoisite still less common. Some others list zoisite as more common.

Zoisite is said to be clear and transparent only when fresh. Good

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[1] Groth, P., *Chemische Kristallographie*, p. 283. W. Englemann, *Leipzig*, **1908.**

[2] Gossner, B., and Mussgnug, F., *Centralblatt für Mineralogie and Geologie*, **1930,** A. p. 369.

[3] Winchell, N. H., and Winchell, A. N., *Elements of Optical Mineralogy*, Part **II,** p. 353. John Wiley and Sons, *New York*, **1927.**

[4] Winchell's notation differs from that of Gossner and this paper by interchange of *a* and *b*, and *b* and *c*.

crystals appear to be rare, and these usually translucent. Most occurrences of the mineral are in massive form.

It is probable that Winchell's data are for fresh zoisite, instead of the common zoisite of rocks. Because there appeared to be a difference, the following work was begun.

The crystals used in this work were from Praegratten, Austria, and therefore represent a fair comparison with Gossner's work. The crystal of zoisite used was about 1×1×2 mm. and appeared to be orthorhombic. The crystal was translucent and striated both parallel and at angles with prism edges. On completion of the *x*-ray analysis it was broken up and examined with the petrographic microscope. Fragments showed various degrees of birefringence, no apparent cleavage, and in general were in an unsatisfactory state for microscopic analysis, as is often the case.

Assuming the crystal to be orthorhombic, oscillation measurements were made on three normal axes believed to be crystallographic axes, using both layer line and principal spectrum data. The results obtained are listed in Table 1.

TABLE 1

Axes (orthorhombic)	Axial length A.U.
a	16.30
b	5.60
c	10.21

These results agree with Gossner's, probably within experimental error.

A Laue photograph made with the beam parallel to the orthorhombic *c*-axis showed planes of symmetry parallel to *a*- and *b*-axes, and apparently agreed with the orthorhombic assignment.

Figure 1 shows a Laue photograph with the beam parallel to the orthorhombic *b*-axis. One can assume two planes of symmetry in the reproduction of this photograph as well, in which case one arrives at the same conclusion as Gossner.

Figure 2 shows a Laue diagram of epidote, with the beam parallel to the monoclinic *b*-axis. It is most interesting to note that the symmetry of Figure 1 of zoisite can be exactly duplicated both in the projection and reproduced photograph by a twinning of 2 on 100. Furthermore, epidote is reported as twinning on this face.

Oscillation measurements were made, assuming that the above twinning might have taken place.

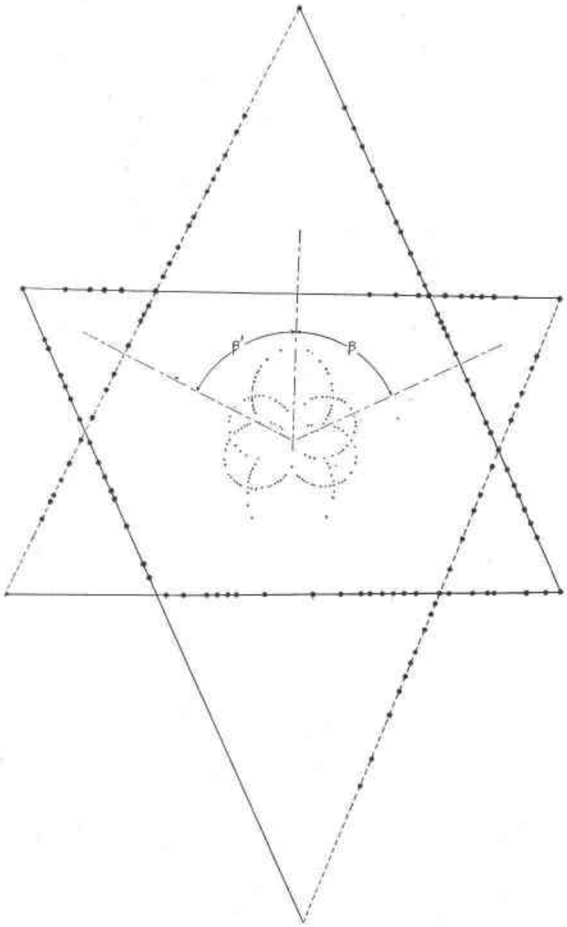

FIG. 1. Gnomonic projection of Zoisite. X-rays parallel to *b*-axis.

TABLE 2

Axes (monoclinic)	Axial Length A.U. Common Zoisite	Axial Length A.U. Gossner-Epidote
a	8.92	8.96
b	5.60	5.63
c	10.21	10.20

Figure 3 is a comparison of powder diffraction photographs of epidote and zoisite. It will be noted that line for line the two agree, except for a very slight difference in spacing.

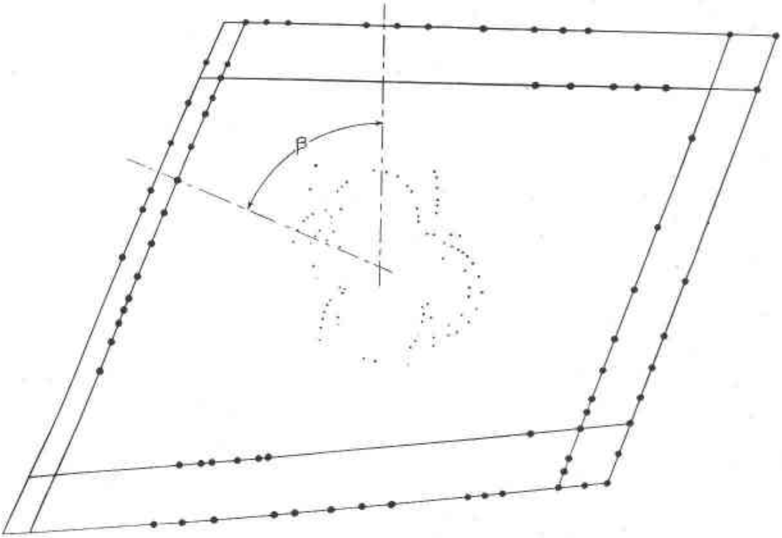

FIG. 2. Gnomonic projection of epidote. X-rays parallel to *b*-axis.

The results of Table 2 compared with Gossner's values for epidote, coupled with Figure 3 and the fact that β and β′ of Figure 1 correspond to β for epidote, leave no doubt that the crystal examined is not orthorhombic but is made up of submicroscopic multiple twins, or is a mosaic crystal giving an orthorhombic appearance. The relation of pseudo-orthorhombic and

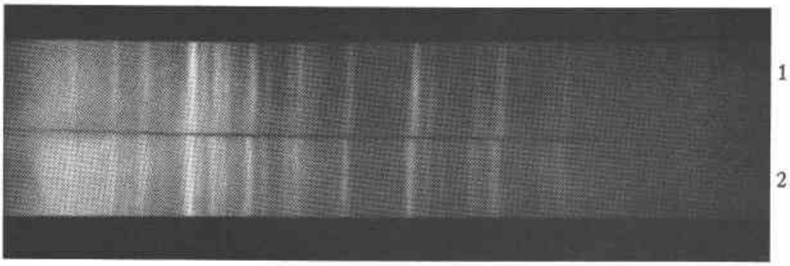

FIG. 3. 1., Zoisite; 2., Epidote.

monoclinic axes is the same except that the monoclinic *a* is inclined to the orthorhombic *a*-axis.

Since the monoclinic cell is the smaller of the two, and since the measurements are a good check on Gossner's epidote measurements, it is proper to assign this zoisite to the monoclinic system, name it clinozoisite, and apply the data of Table 2 to the unit cell.

The number of molecules per unit cell was calculated. Two mols. of zoisite were found to make up the monoclinic unit cell, corresponding with Gossner's results of two for epidote.

The Laue photograph with *x*-rays parallel to *c* can be interpreted as having two planes of symmetry, or a plane in *a* and *c*, with *b* or *c* a two-fold axis. The only monoclinic space group having this symmetry is the group C_2^h (monoclinic prismatic class) which has a plane of symmetry in *a* and *c*, with *b* a two-fold axis.

The authors are not in a position to state whether Gossner's orthorhombic zoisite was correct or not, and do not seriously question the possibility of transparent zoisite being orthorhombic, but in view of the close agreement of measurements, and the locality of collection it would appear that Gossner's zoisite was the same as that here analyzed, and that he had mistaken the symmetry introduced by twinning for true symmetry.

By interchange of *a* and *b*, and *b* and *c*, to compare with Winchell's notation, and using the orthorhombic measurements the authors arrive at $a:b:c=0.626:1:0.343$, an interesting comparison with the previously given values. The question arises, "Is fresh transparent zoisite an unstrained multiple twinning of clinozoisite, and the translucent variety merely the result of slight shattering due to a change in conditions?" That is, may not fresh zoisite have all the necessary symmetry for an orthorhombic assignment, yet be more correctly placed as monoclinic, as the translucent zoisite of this paper has been?

It appears to the authors that an investigation of fresh transparent zoisite would be worth while. However, no fresh zoisite is available, and no one seems able to supply it. Likewise other dimorphous series might well be examined more critically with a view to determine whether some pseudo-symmetry might exist.

The fact remains that the translucent variety of zoisite is clinozoisite. It is very possible that the material crystallizes in the orthorhombic form and that the peculiarities mentioned are due to a recrystallization. Probably, when sufficient iron is present, the stable form crystallizing is monoclinic since epidote shows no signs of recrystallization.

CONCLUSIONS

1. Common translucent zoisite is made up of a mosaic consisting of submicroscopic multiple twins of clinozoisite.
2. Clinozoisite, part of the isomorphous epidote series, has $a:b:c=8.92:5.60:10.21$ and belongs to the space group $C_2{}^h$, the unit cell containing two molecules.
3. With (1) in mind fresh transparent zoisite might well be examined by x-rays.