# *A note on the crystallography of epidote.*

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[Communicated and read by Dr. M. H. Hey, November 10, 1949.]

IN any monoclinic crystal, the zone-axis [$uvw$] is perpendicular to the plane ($hkl$) if $u/(hc^2-lac\cos\beta) = v/(kc^2a^2\sin^2\beta) = w/(la^2-hac\cos\beta)$. In particular, the normal to the face (100) is quasi-parallel to the zone-axis [$r0\bar{1}$] if $c/(a\cos\beta)$ approximates to a rational number $r$.

Epidote has $a:b:c = 1{\cdot}5807:1:1{\cdot}8057, \beta\ 115^\circ\ 24'$, and is often twinned on $a$(100). G. Friedel[1] describes and explains these twins in terms of a pseudo-normal zone-axis [301], with an obliquity of 3° and a twin-index 3. But the choice of a pseudo-normal zone-axis is necessarily arbitrary, since it is always possible to find a rational zone-axis making an angle with any given face-normal less than any assigned angle $\delta$: though the indices of such an axis may involve large numbers. Friedel prefers 'simple' indices, but does not give a strict definition of this term.

Now the zone-axis [803] makes an angle of only $1\frac{1}{2}'$ with the normal to (100), and the (100)-twins of epidote can therefore be described in terms of a pseudo-normal zone-axis [803] with an obliquity of $1\frac{1}{2}'$ and a twin-index 4, and we think this description is preferable.

For consider, in an arbitrary monoclinic crystal a face ($hkl$) cutting the crystallographic axes and the zone-axis [803] in the points $H$, $K$, $L$, and $P$ respectively. Producing $PO$ to $P'$ and making $OP' = OP$, construct the plane ($h'k'l'$) through the points $P'$, $K$, and $L$. Then $h' = -4h-3l$, $k' = 4k$, and $l' = 4l$. If now the zone-axis [803] is perpendicular to (100), the faces ($hkl$) and ($h'k'l'$) are related to one another as mirror-images in the plane (100). Hence in epidote pairs of faces reciprocally related by the transformation $\bar{4}0\bar{3}/040/004$, as, for example, (011) and ($\bar{3}44$), will display this special orientation so exactly that goniometrical measurement will disclose no disagreement.

A scrutiny of O. Matthes's[2] angle-table shows that there are many such pairs of forms (see table I) among the 119 'gesicherten typischen Formen des Epidots' listed by him. Remembering that twins on (100) are very common with epidote, one sees that there is room for doubt in

[1] G. Friedel, Bull. Soc. Industrie Minérale, 1904, ser. 4, vols. 3–4, p. 399.

[2] O. Matthes, Neues Jahrb. Min., Abt. A, 1928, Beilage-Band 56, p. 418. [M.A. 4–88.]

assigning indices to many faces. For instance, the faces ($\overline{11}$.0.4) and ($\bar{7}$04) might well be (201) and (101) respectively, of a twinned portion of the crystal. We conclude that a number of the 119 forms listed by Matthes need verification by methods other than gonimetrical measurement, for example, etching, or epitaxy of suitable chemical compounds.

TABLE I. Pairs of faces symmetrical about (100) and liable to confusion in twinned crystals.

(The numbers in column 1 are those of the crystal-forms in O. Matthes's angle-table.)

| No. | $\phi$. | $\rho$. | Symbol. |
|---|---|---|---|
| 1 | 64° 36′ | 90° | (001) |
| 44 | 115° 20′ | 90° | ($\bar{3}$04) |
| 15 | 64° 36′ | 31° 30′ | (011) |
| 103 | 115° 25′ | 31° 30′ | ($\bar{3}$44) |
| 17 | 18° 25′ | 90° | (201) |
| 67 | 161° 35′ | 90° | ($\overline{11}$.0.4) |
| 18 | 22° 52′ | 90° | (302) |
| 63 | 157° 7′ | 90° | ($\bar{9}$04) |
| 20 | 25° 56′ | 90° | (504) |
| 62 | 154° 2′ | 90° | ($\bar{2}$01) |
| 21 | 29° 54′ | 90° | (101) |
| 60 | 150° 5′ | 90° | ($\bar{7}$04) |
| 23 | 35° 5′ | 90° | (304) |
| 56 | 144° 53′ | 90° | ($\bar{3}$02) |
| 26 | 42° 5′ | 90° | (102) |
| 51 | 137° 53′ | 90° | ($\bar{5}$04) |
| 30 | 51° 39′ | 90° | (104) |
| 47 | 128° 18′ | 90° | ($\bar{1}$01) |
| 33 | 80° 59′ | 90° | ($\bar{1}$04) |
| 35 | 98° 57′ | 90° | ($\bar{1}$02) |
| 75 | 29° 54′ | 48° 0′ | (111) |
| 107 | 150° 5′ | 48° 0′ | ($\bar{7}$44) |
| 81 | 128° 18′ | 35° 12′ | ($\bar{1}$11) |
| 99 | 51° 39′ | 35° 13′* | (144) |
| 98 | 42° 5′ | 39° 33′ | (122) |
| 104 | 137° 53′ | 39° 33′ | ($\bar{5}$44) |

* Matthes made here an error in his calculations and gives 35° 2′.

In the course of the goniometrical investigation of a very beautiful epidote crystal (47 × 7 × 2 mm., figs. 1 and 2) from Sulzbachthal, Salzburg, we found the forms (100), (001), ($\bar{1}$04), ($\bar{1}$02), ($\bar{3}$04), ($\bar{1}$01), ($\bar{7}$04), ($\bar{1}$03), ($\bar{2}$01), ($\bar{3}$01), (210), (110), (010), (012), (011), (144), (111), ($\bar{3}$44), ($\bar{1}$11), and ($\bar{7}$44), all with values of $\phi$ and $\rho$ in excellent agreement with the values cited by Matthes. But we also observed two faces at $\phi$ 16° 45′, $\rho$ 90° and $\phi$ 115° 22′, $\rho$ 50° 48′ (zone adjusted, [010]), which do not appear in Matthes's table; the faces ($\bar{3}01$) and (012), however, have positions $\phi$ 163° 14′, $\rho$ 90° and $\phi$ 64° 36′, $\rho$ 50° 48′ respectively, and are therefore the mirror-images of our observed faces in (100). Further, we observed the rare face ($\bar{3}04$) with a considerable expanse.

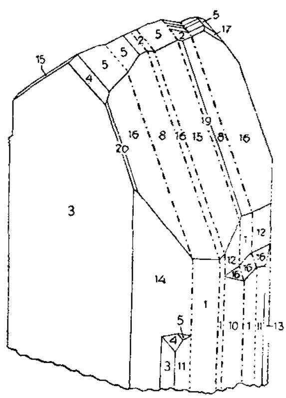

FIG. 1

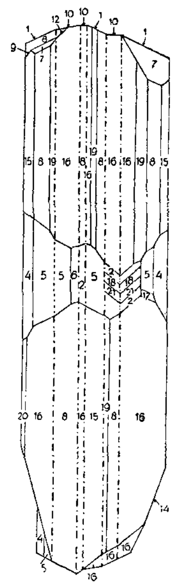

FIG. 2

FIG. 1. Epidote crystal from Sulzbachthal, Salzburg.

FIG. 2. Orthographic projection of the same on the plane (010).

The lines —·—·—· represent re-entrant or salient twin-edges, while ——————— are twin-boundaries on a plane face (nos. 5, 5; 1, 1; 2, 2). The faces are numbered as follows: 1 (001), 2 (010), 3 (100), 4 (210), 5 (110), 6 (120), 7 (012), 8 (011), 9 (101), 10 ($\bar{1}02$), 11 ($\bar{3}04$), 12 ($\bar{1}01$), 13 ($\bar{2}01$), 14 ($\bar{3}01$), 15 (111), 16 ($\bar{1}11$), 17 ($\bar{2}21$), 18 ($\bar{1}71$), 19 ($\bar{2}33$), 20 ($\bar{2}11$), 21 ($\bar{2}$.13.2).

These observations are readily explained if we assume that our crystal, though apparently simple, is really twinned, and that the above two forms are ($\bar{3}01$) and (012) of a twinned part of the crystal; also, the supposed ($\bar{3}04$) may be really (001) of a twinned part. Working on these lines, and exploring diligently for re-entrant edges and other hints (striations, &c.), we were able to explain our crystal by supposing it to consist of a twin-group of at least six parts. Several of the faces mentioned above then get simpler indices: ($\bar{1}04$) $\rightarrow$ ($\bar{1}02$), ($\bar{7}04$) $\rightarrow$ (101), (144) $\rightarrow$ ($\bar{1}11$), ($\bar{3}44$) $\rightarrow$ (011), ($\bar{7}44$) $\rightarrow$ (111).

A close inspection yielded a harvest of very small facets belonging to the forms (120), ($\bar{2}21$), ($\bar{1}71$), ($\bar{2}33$), ($\bar{2}11$), and ($\bar{2}.13.2$). The last-named is not in Matthes's table, but the face gave a good reflection with $\phi$ 128° 20′, $\rho$ 6° 14′ (calculated from the above elements, $\phi$ 128° 18′, $\rho$ 6° 12′); it has, however, been previously recorded, on two crystals from Sulzbachthal studied by H. Bücking.[1]

[1] H. Bücking, Zeits. Kryst. Min., 1878, vol. 2, pp. 339 and 409.