Structural Imperfections in Alpine Quartz Crystals

(PLATE VII)

By C. Friedlaender

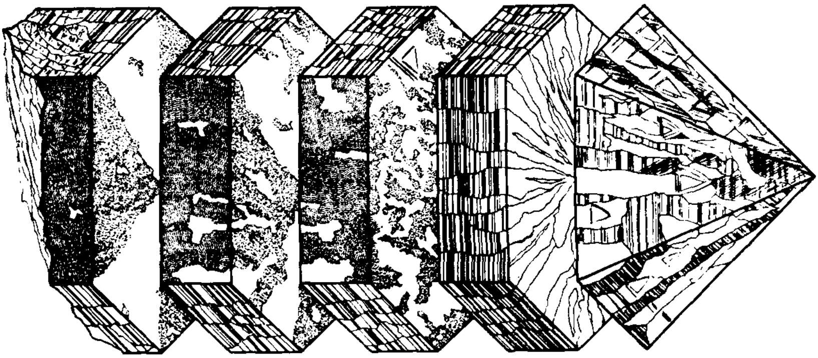
ABSTRACT

A description is given of structural imperfections such as twinning, lineage sutures and optical streaks, in Alpine quartz crystals.

AT the suggestion of Professor Niggli, the " usability " of Alpine quartz crystals for piezoelectric communication equipment was systematically investigated. It was ascertained that carefully selected parts of Alpine quartz crystals gave quite satisfactory results (Friedlaender, 1944, 1951 ; Friedlaender and Locher, 1945 ; Hedinger, 1948). The inadequate total quantity of available high-grade Alpine quartz crystals sets rather narrow limits to their use. Furthermore, a precision orientation may be rendered deceptive by characteristic structural imperfections. Whereas the technical importance of Alpine quartz is slight, at least in normal times, some of the observations made may be of general interest.

Twinning.—Dauphiné twinning was found to some extent in all Alpine quartz crystals examined. With respect to the extent of twinning and to the course of the twin boundaries within the crystal, different types can be distinguished ranging from almost complete absence of Dauphiné twinning to intricate twinning throughout the whole crystal. Generally speaking, the twin boundaries grow more intricate toward the apex of the crystal, that is to say with decreasing temperature, while the bottom of the crystals frequently show a far simpler pattern of intergrowth of the parts of a Dauphiné twin. There is obviously a fundamental difference between Dauphiné and Brazil twinning. R–L twins appear, in fact, not to be developed with the same facility as Dauphiné twins where both parts involved are of the same hand. From morphological evidence only, Brazil twinning is recognizable in Alpine quartz crystals in very rare instances. It is fairly frequent, however, in small peripheral regions of evidently late formation relative to the host crystal, as satellite crystals in the sense of Gaudefroy (1933).

Lineage Sutures.—According to a commonly held belief, Alpine quartz crystals could not be used at all for piezoelectric applications on account of their intricate twinning. This belief very likely was founded on an erroneous interpretation of the sutures : they are frequently taken as an indication of twinning. The sutures, seam-like lines running roughly parallel the c-axis, cut the horizontal striation on prism faces which is due to alternation of prism- and steep rhombohedral planes so as to cause a marked discontinuity. While there are true twinning seams, it must be emphasized that these sutures are quite distinct from twinning. On the other hand, the sutures are an indication of lineage structure such as occurs frequently and in many minerals (see Buerger, 1934). A line drawing (Text-fig. 1) schematically shows the internal lineage and twin structure of an Alpine quartz crystal ; the sutures are seen to be independent of the twin boundaries.



TEXT-FIG. 1.—Schematic diagram of an Alpine quartz crystal of hexagonal habit. The crystal is dissected by four cuts normal to the c-axis into five parts. The rhombohedral faces show natural etching, sutures, and horizontal striation.

Z-slab 1 : on polished Z-plane, lamellar lineage boundaries (represented with some exaggeration). Sutures on prism faces intersected by horizontal striation.

Z-slab 2 : etched Z-plane shows intricate boundaries of Dauphiné twinning and small region with Brazil twinning. Prism facing front finely gound and etched so as to show course of twin boundaries.

Z-slab 3 : Z-plane and one prism face etched.

id. on Z-cut of basal portion of the crystal. Twin boundaries are seen to be far simpler in basal part of crystal than in upper part.

Throughout, lineage sutures independent of twinning.

Optical Streaks.—Viewed in parallel light, a slab of a certain thickness and with two polished parallel faces (as represented in the Z-slab 1 of Text-fig. 1) will reveal optical streaks, similar to those observed when dissolving sugar in water. These streaks (Plate VII, fig. 1), however, are not due to dissolution of any foreign material ; they are accounted for solely by a slight difference in orientation of adjoining lamellae. If the optical axes of adjoining lamellae in a quartz crystal differ from each other, there will be a certain difference in refraction, $n_\gamma - n_{\gamma 1}$. For a difference in orientation of 3°, $n_{\gamma 1}$ would be $1\cdot5534 \times \cos 3° = 1\cdot5508$; $n_\gamma - n_{\gamma 1} = 0\cdot0026$. For a difference of 4° between adjoining lamellae, $n_{\gamma 1}$ would be $1\cdot5492$ and $n_\gamma - n_{\gamma 1}$

0·0042. Differences of refraction of that importance must be quite perceptible.

In a thick slab, there will be a considerable amount of superposition. This may explain the observation that the streaks seem to lie nearer to each other than would be inferred from observation in any plane normal to the viewing direction and that on tilting the slab slightly the streaks appear to move. In polarized light, polished Z-slabs reveal contrasting patches of strong interference colours. This is due to the optical activity and to the lineage structure.

Some observations of optical streaks in polished quartz slabs have been described by various authors (Kundt, 1883 ; Laemmlein, 1937 ; Töpler, 1864, 1866, 1867 ; Weil, 1931), but no explanation had been attempted. The observation of streaks in polished slabs presents a very sensitive means of detecting structural imperfections.

The lineage structure is clearly recognized when plates cut parallel to the c-axis, as X-cuts and Y-cuts, are viewed in polarized light. As a rule such a plate prepared from an Alpine crystal will not extinguish uniformly. One may observe differences in the orientation of the c-axis of adjoining lineages up to 3°. Laue diagrams within single lineages appear normal apart from showing a rotation of about 3° around the c-axis ; the superposition of lineages results in doubling of X-ray spots.

On observation with low power magnification, the borders and termination of the lineages become discernible as irregularly tilted, wedge-like seams of birefringence (Plate VII, fig. 2). A very conspicuous deviation of the lineages may be reminiscent of accessory heteroaxial twinning (Plate VII, fig. 3).

REFERENCES

BUERGER, M. J., 1934. The lineage structure of crystals. *Zeit. Krist.*, lxxxix, 195–220.

FRIEDLAENDER, C., 1944. Untersuchungen an alpinen Quarzen. *Verhandl. Schweiz. Naturf. Ges.*, cxxiv, p. 119.

—— 1951. Untersuchungen über die Eignung alpiner Quarze für piezoelektrische Zwecke. *Geol. Schweiz., Geotechn. Ser.*, xxix, Berne.

—— and LOCHER, F., 1945. Vorlaüfige Untersuchungsergebnisse über die Eignung alpiner Quarze für piezoelektrische Zwecke. *Vierteljahrsschr. Naturf. Ges. Zürich*, xc, 126–135.

GAUDEFROY, C., 1933. Sur les groupements de cristaux de quartz à axes parallèles. *Bull. Soc. Franç. Min.*, lvi, 5–63.

HEDINGER, R., 1948. *Untersuchungen über das piezoelektrische Verhalten alpinen Bergkristalle.* Promotionsarbeit E.T.H., Zürich ; Schmidberger and Müller, Kilchberg (Zürich).

KUNDT, A., 1883. Benutzung der Schlierenmethode zur Untersuchung von Verwachsungen im Quarz. *Ann. Physik und Chemie, N.F.*, xx, 688–690.

LAEMMLEIN, G. G., 1937. Observations on the twisted quartz. *Bull. Acad. Sci. URSS. Cl. Mat. Sci.*, 937–964.

TÖPLER, A., 1864. *Beobachtungen nach einer neuen optischen Methode.* Max Cohen and Co., Bonn.

https://doi.org/10.1017/S0016756800067625

Töpler, A., 1866. Ueber die Methode der Schlierenbeobachtung als mikroskopisches Hilfsmittel, etc., *Pogg. Ann.*, cxxvii, 556–580.

—— 1867. Optische Studien nach der Methode der Schlierenbeobachtung. *Pogg. Ann.*, cxxxi, 33–5.

Weil, R., 1931. Quelques observations concernant la structure du quartz. *C.R.1re Réunion Inst. Optique*, p. 11.

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EXPLANATION OF PLATE VII

Figure 1.—Optical streaks. Polished Z-slab, about 2 cm. thick, of R-quartz, Furka. Length of crystal 25·7 cm., diameter 8 cm. Viewed in parallel light, 1 : 1.

Figure 2.—Lineage structure. Borders and termination of lamellae. X-cut plate, 1 mm. thick, Z running N.–S. L-quartz, Göscheneralp. Seams of birefringence, reveal tilting and divergence in orientation of adjoining lamellae. Polarized light. 18 : 1.

Figure 3.—Lineage structure. Borders of lamellae. X-cut plate, 1 mm. thick, Z running N.–S., L-quartz, Göscheneralp. Seams of birefringence reveal divergence of orientation suggesting analogy to hetero-axial twin. Polarized light. 18 : 1.

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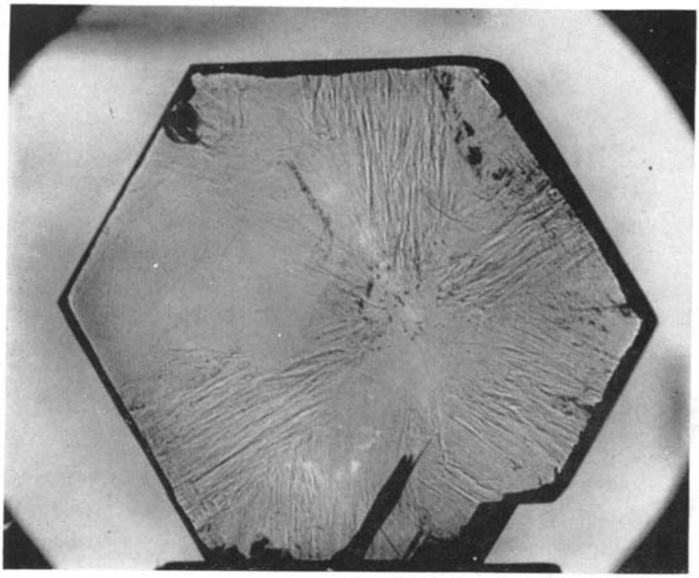

FIG. 1.

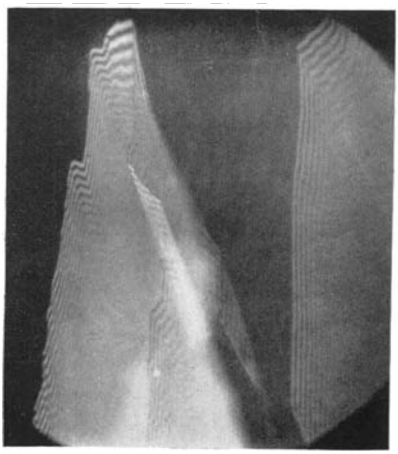

FIG. 2.

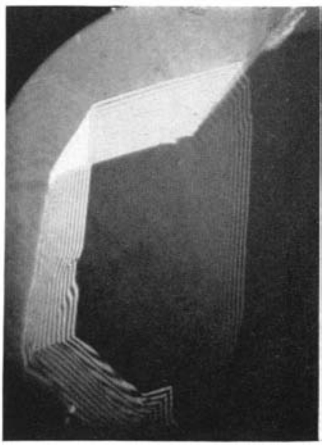

FIG. 3.

STRUCTURAL IMPERFECTIONS IN ALPINE QUARTZ.

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