ON THE MECHANISM OF DEFORMATION AND ORIENTATION OF QUARTZ IN TECTONITES

1961

SovietRxiv

Abstract

Full Text

CRYSTALLOGRAPHY

M. P. Volarovich and N. E. Galdin

ON THE MECHANISM OF DEFORMATION AND ORIENTATION OF QUARTZ IN TECTONITES

(Presented by Academician A. V. Shubnikov, 1 VI 1961)

The mechanism by which a uniform orientation of the optical axes of quartz arises in tectonites is explained by means of hypotheses of crushing and translation (1). These hypotheses are not based on any definite mechanism of plastic deformation of quartz crystals that has been established and proved experimentally. At the same time, two possible mechanisms of plastic deformation of quartz crystals have been described: the formation of Dauphiné twins (2, 3) and bending relative to the crystallographic axis of the 2nd order (4).

We have carried out petrographic and X-ray studies of quartz from thin veins occurring in porphyroids. The formation of so-called R-tectonites of quartz took place under conditions of compression and rotation in a definite plane (the tectonic plane ac), as well as flattening and elongation along the b axis (5). The b axis coincides with the lineation of the porphyroids enclosing the quartz veins and is inclined to the horizon at a small angle, of the order of 10–15°. As a result of the joint deformation of the quartz and the porphyroids, the large quartz grains in the veins underwent intense crushing and acquired a very characteristic ribbon texture. The axes of the ribbons are oriented strictly parallel to the lineation of the surrounding porphyroids, while the ribbons themselves, especially in the contact zone with the porphyroid, show signs of plastic flow (Fig. 1A). Statistical measurement of the orientation of the optical axes of quartz in the ribbons showed that the optical axes are oriented strictly uniformly in the ac girdle and give a concentration near the emergence of the a axis (Fig. 1B). Thus, in the quartz ribbons the optical axes are oriented strictly transverse to their elongation.

To determine the complete crystallographic orientation of quartz in the ribbons, an X-ray diffraction study was carried out. For X-ray photography, individual, most characteristic and typical areas were selected under the microscope in plates 0.1 mm thick. Figure 2 presents two X-ray diffraction patterns corresponding to two typical areas: A—a fine-ribbon structure; the optical axes of the ribbons showed oscillations in the ac plane, and the texture diagram reflects the orientation of several ribbons; B—a single dark ribbon, uniformly extinguishing along its entire length, of the type of ribbon 2 in Fig. 1A.

Fig. 1

Figure 1: Fig. 1

In the X-ray diffraction patterns one can see three doubled rings corresponding to reflections from the faces m $(10\bar{1}0)$, r $(10\bar{1}1)$, and n $(11\bar{2}0)$. The interplanar spacings are respectively 4.25, 3.34, and 2.45 Å (from the center to the periphery). Both X-ray diffraction patterns show well-expressed textures, somewhat different from one another. A common feature of both X-ray diffraction patterns is the presence of a clearly expressed maximum of reflections from the faces m (inner ring) in the direction of the b axis (shown by arrows). These maxima are emphasized still more by paired reflections from the faces n (shown by triangles), located symmetrically on both sides of the b axis. Thus, these X-ray diffraction patterns make it possible to establish that, in the overwhelming mass of cry-

of the quartz crystallites one of the prism faces is oriented perpendicular to the b axis, i.e., perpendicular to the axis of the lenses and the lineation axis.

On both X-ray photographs one can also note two other paired maxima of reflections from the faces m, arranged at an angle of 60° to one another. In the X-ray photograph in Fig. 2B these maxima are expressed more clearly. This is quite understandable if one takes into account that in the latter case we are dealing with a single quartz lens, uniformly extinguishing along its entire length, whereas in the first case—with several thin lenses whose optical axes fluctuate in the region of emergence of the a axis. The asymmetric manifestation of the maxima in the X-ray photograph in Fig. 2B is explained by the assumed deviation of the direction of the X-ray beams from the direction of the optical axis of the lens.

Fig. 1. **A**—zone of contact between porphyroid 1 and quartz vein 2; protruding plagioclase grain 3 at the contact with quartz is crushed; 4—dark quartz lens, showing a sharp decrease in thickness at the boundary with grain 3. 30×, crossed nicols. **B**—diagram of the orientation of the optical axes of quartz in the *ac* plane; contours 0—1—3—5—7—9%; 128 measurements

X-ray beams from the direction of the optical axis of the lens. In the present case this is not of fundamental significance, since it does not prevent clarification of the type of X-ray texture of the quartz.

Reflections from the faces r (marked by crosses) show a tendency toward the formation of three paired symmetrical concentrations, arranged analogously to the corresponding concentrations of reflections from the faces m, but they are less clearly expressed. The hexagonal symmetry of the reflections from r in the X-ray photograph in Fig. 2A is emphasized by bands of asterism. In both X-ray photographs the splitting into lines is very clearly manifested. This phenomenon, as is known, may serve as an indication of polygonization or the formation of a block structure. Thus, the hexagonal symmetry of the texture diagrams of quartz is established, corresponding to the symmetry of Dauphiné twins.

Fig. 2. Texture diagrams of quartz ribbons in the *bc* plane; copper radiation without a filter; diaphragm distance—specimen 40 mm, exposure 10 h.

Figure 2: Fig. 2. Texture diagrams of quartz ribbons in the *bc* plane; copper radiation without a filter; diaphragm distance—specimen 40 mm, exposure 10 h.

In explaining the mechanism of deformation and orientation of quartz in tectonites, it is necessary to take into account the following circumstance: quartz grains undergo intergranular and intragranular plastic deformation; a homogeneous crystallographic orientation of the grains can arise only in the case of the joint and concordant manifestation of these two types of plastic deformation. Although the X-ray photographs have the symmetry of Dauphiné twins, they nevertheless cannot serve as proof of their presence, since here we are dealing not with quartz single crystals, but with aggregates of the finest crystallites that have undergone relative rotation. Bailey, Bell, and Peng (4), who discovered the ability of quartz to undergo plastic bending about one of the second-order axes (the translation plane is not was found), noted that in a number of cases rotation also occurs about two second-order axes or about the mechanical axis. If this mechanism is taken as the basis, then in the final stages of deformation the axis of intracrystalline rotation of the crystallites should coincide with the tectonic rotation axis *b*. Optical observations indicate a very widespread occurrence of rotation of the optical axes in quartz grains in thin sections cut parallel to the *ac* plane. This rotation is effected by crushing of quartz into thin prisms parallel to the optical axis and the subsequent rotation of individual prisms through an angle of 5—10° in the *ac* plane. The splitting of quartz into prisms parallel to the optical axis is explained by the concentration of dislocations in this direction during bending about one of the second-order axes. This phenomenon can also be explained by twinning according to the Dauphiné law ([2], [3]). Such a structure of quartz is characteristic of the middle stages of deformation; in the late stages, a dense series of ruptures and intense rotation about the *b* axis are superimposed on it.

Fig. 2. Texture diagrams of quartz ribbons in the *bc* plane; copper radiation without a filter; diaphragm distance—specimen 40 mm, exposure 10 h.

Thus, the emergence of quartz orientation in tectonites can readily be explained if the following deformation mechanism is taken as the basis: in the course of deformation, the smallest quartz crystallites tend to occupy such a position that the axis of their internal rotation (the mechanical axis) coincides with the rotation axis of the tectonites (the *b* axis).

Institute of Physics of the Earth
Academy of Sciences of the USSR

Received
29 V 1961

REFERENCES

1. Kh. V. Ferbern, *Structural Petrology of Deformed Rocks*, IL, 1949.
2. A. V. Shubnikov, *Priroda*, No. 2 (1933).
3. A. V. Shubnikov, E. V. Tsinterlin, *Proceedings of the Lomonosov Institute, Academy of Sciences of the USSR*, issue 3 (1933).
4. S. W. Bailey, R. A. Bell, C. J. Peng, *Bull. Geol. Soc. Am.*, **69**, No. 11 (1958).
5. H. E. Galdin, *Izv. AN SSSR, ser. geol.*, No. 4 (1957).

Note: Figure translations are in progress. See original paper for figures.