OBSERVATIONS ON QUARTZ DEFORMATION IN THE BRECCIAS OF WEST CLEARWATER LAKE, CANADA, AND THE RIES BASIN, GERMANY

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Planar elements in shocked quartz grains from Clearwater Lake and the Ries basin are parallel to {0001}, {10$\bar{1}$3}, {10$\bar{1}$1}, {10$\bar{1}$2}, {10$\bar{1}$0}, and to other planes of the quartz lattice; they show a characteristic frequency distribution. Quartz grains containing planar elements also have reduced refractive indices, reduced birefringence, and reduced density; the measurements extend over nearly the whole range between normal quartz and fused quartz glass.

Two principal types of planar elements can be distinguished. *Decorated planar elements* consist of planar arrangements of very small inclusions or cavities. *Non-decorated planar elements* are not resolvable with the microscope. Preferential, cleavage-like separation occurs parallel to planes of non-decorated elements. Refractive indices and density of quartz with non-decorated elements are lower than those of quartz with decorated planes. The latter are apparently produced by lower shock wave pressures than the former.

Planar elements in quartz are assumed to have been formed by plastic deformation and by non-conservative movements of dislocation lines under high shock pressures.

QUARTZ FROM CLEARWATER LAKE, QUEBEC

In a breccia from Hole No. 4 (depth 179 ft.), drilled in 1963 by the Dominion Observatory within the circle of islands of West Clearwater Lake, Quebec (Dence, 1965), small fragments of granitic rock were found containing quartz which had been strongly affected by shock waves. The quartz appears as a white, silky, and friable mass similar to fine-grained sericite. Under the microscope, it can be seen that the individual grains contain several closely-spaced sets of planes, visible as some kind of optical heterogeneity which forms a plane, the orientation of which can be determined by universal stage methods. Similar planar features have been described from quartz in many impact craters under a variety of different terms (Bunch and Cohen, 1963; Bunch and Cohen, 1964; Dence, 1964; Dence, 1965; Engelhardt and Stöffler, 1965; Carter, 1965; Engelhardt *et al.*, 1967b; Robertson *et al.*, *this vol.*, p. 433). These planar features are here called planar elements (Fig. 1).

Orientations of planar elements and of the optic axes of quartz were measured in 30 grains of a thin section and in 32 grains of a powder mount. For every grain, stereographic projections were drawn containing the positions of the optic axis and the poles of all measurable planar elements. An example of such a plot is shown in Figure 2. There are, in this particular grain, six different sets of planar elements. The "blind circle" encloses the area not accessible to the universal stage. The stereographic projection can then be rotated into a position with the optic axis in the center (Fig. 3). In this projection, the measured planar elements can be identified with crystallographic directions. The dots and the crosses in Figure 3 indicate the ideal poles to crystallographic planes and the poles to sets of planar elements, respectively. A planar element was assumed to coincide with a crystallographic plane if the angle between measured and ideal poles was less than 6 degrees. This allowance corresponds to the accuracy of the universal stage measurements.

It is remarkable that, in most grains, sets of all planes equivalent by symmetry were often not completely developed. For example, in the grain described in Figure 3, the planes (1$\bar{3}$21) and ($\bar{3}$211) are symmetrically equivalent to the observed (21$\bar{3}$1). The plane ($\bar{3}$211) falls within

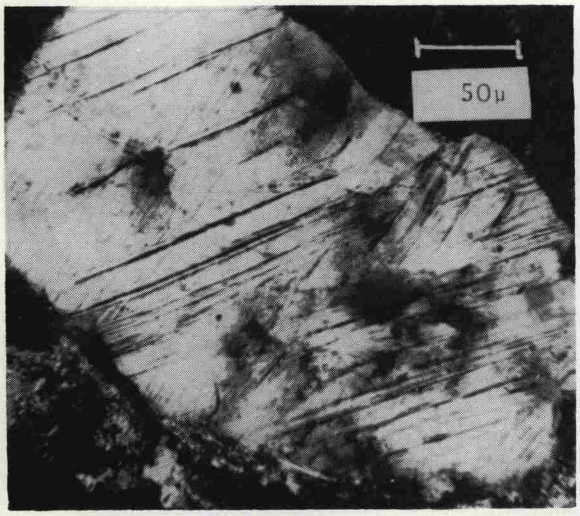

Fig. 1. Quartz grain with planar elements. Granite, hole No. 4 (1963), depth 179 ft, West Clearwater Lake, Quebec.

the "blind circle"; but ($1\bar{3}21$) could have been observed and was not found as a planar element.

There were, on the average, five different sets of measurable planar elements in each grain. Out of a total of 319 measured planar elements, 278, or 87 percent, could be identified with definite crystallographic planes (growth planes) of quartz, by means of the stereographic projections. The results of our measurements are summarized in Table 1.

In order to compare planar elements of different orientation, three methods for calculating frequencies (F_{I}, F_{II} and F_{III}) were used.[1]

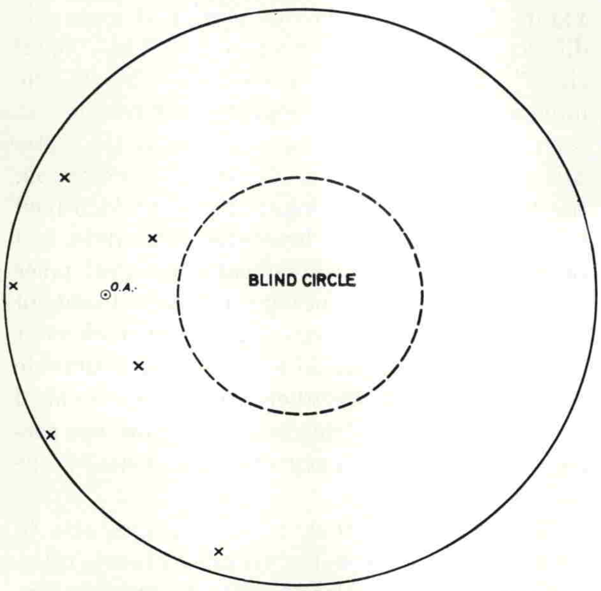

Fig. 2. Quartz grain (No. 31a), from a thin section of granite, hole No. 4 (1963), depth 179 ft, West Clearwater Lake, Quebec. The diagram is a stereographic projection of the poles of six sets of planar elements and of the optic axis.

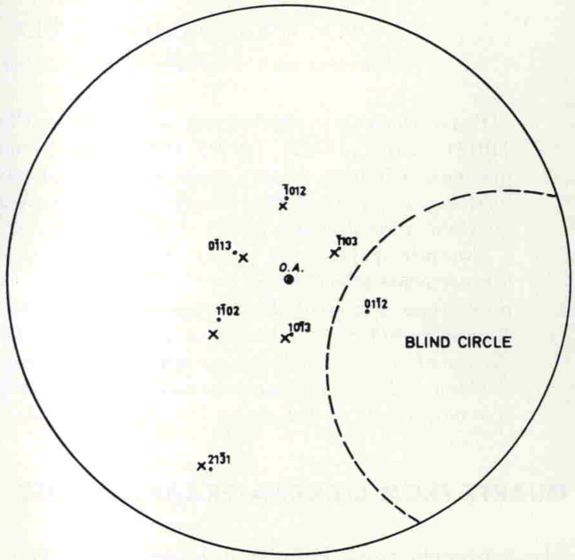

Fig. 3. Stereographic projection of the same quartz grain as shown in Figure 2, with the optic axis rotated into the center. Points indicate ideal positions of crystallographic planes. Crosses indicate measured positions of the poles to sets of planar elements.

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[1] *Editor's note.* The statistical treatment of the petrofabric data outlined here is more complicated than that performed by some other investigators. The authors here include corrections for two factors: (1) the possible nonobservation of planar sets due to inherent spatial limitations on the use of universal stage; (2) the fact that only one set of planes may develop parallel to {0001} in quartz, whereas six symmetrically equivalent planar sets can develop parallel to other forms.

Other investigators have used a simpler treatment, in which frequency diagrams are constructed directly from the number of *observed* planar sets (see Carter, *this vol.*, p. 453; French, *this vol.*, p. 383; Robertson *et al.*, *this vol.*, p. 433). Aside from possible debates on the relative merits of each method, it should be noted that frequency distributions constructed by the two different methods will not be entirely comparable; for instance, relative peak heights will differ. However, the grouping of planar sets into orientations closely related to a small number of specific crystal directions appears to be a unique property of quartz from such rocks, and will be apparent regardless of how the petrofabric data are treated.