portance to the origin of subbasal lamellae. McLaren and others (1967) have shown, by transmission electron microscopy, that Brazil twins parallel to {0001} (some containing or terminated by dislocations) were produced at high shearing stress in experiments on single crystals at 500° and 700°C (basal slip regime). These authors showed that the twins could be produced mechanically by a translation of about 1/2 *a* and that only the hand of the crystal within the twinned region is changed. More recently, Tullis (1970) has shown that Dauphiné twins in quartz can be produced mechanically with ease. In this instance, the polarity of the *a*-axes is reversed so that negative forms become positive and vice versa, and this process gives rise to preferred orientations of $\perp$ *r* $\{10\bar{1}1\}$ parallel to σ_1.

Recent work on bromellite (BeO; Newkirk and Smith, 1965) has also shown the presence of extensive inversion twins parallel to the basal plane. As pointed out by Bentle and Miller (1967) such a twin boundary becomes impregnable to dislocations with Burgers vectors normal to the boundary because beryllium atoms at the edge of the half-planes are forced against those of the twin causing mutual repulsion. They also showed that the inversion twins and cores of high densities of point defects, probably impurities, interferred with basal slip in the crystals. In a similar manner, complex interactions of basal and prismatic dislocations in quartz with basal twins and impurity concentrations could account for the non-rational subbasal lamellae.

In order to test the notion that the basal twins in quartz and BeO may affect lamellae orientations, we conducted a series of experiments on beryl (class 6/m, 2/m, 2/m) whose basal plane is a symmetry plane. The experiments were carried out in compression at 15 kb confining pressure, a strain rate of $7.8 \cdot 10^{-5}$/sec, and temperatures of 300°, 600°, 900°, and 1200°C (the melting temperature of beryl is about 1420°C). Faults parallel to {0001} were produced at 300°C. In the experiments at 600° and 900°C both basal faults and basal deformation lamellae were abundant. In the final experiment at 1200°C, only basal lamellae were observed. Subbasal lamellae were not produced in any of the experiments, in accord with our prediction.

We suggest, therefore, on the basis of the circumstantial evidence presented above, that the lack of a symmetry plane parallel to the base is likely to be involved in the origin of subbasal lamellae. We note that Borg and Heard (1970) have also observed subbasal deformation lamellae in their compression experiments on plagioclase at 10 kb confining pressure, 800°C, and a strain rate of 10^{-5}/sec. Lacking the critical evidence, which must come from painstaking transmission electron microscopy of both experimentally and naturally deformed materials, we do not wish to propose a specific model for the origin of subbasal lamellae. However, any detailed future model must account for the observations discussed above as well as the profound pressure, temperature, and strain-rate dependences of quartz lamellae orientations.

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REFERENCES

Bentle, G. G., and Miller, K. T., 1967, Dislocation, slip and fracture in the BeO single crystals: Jour. Appl. Physics, v. 38, p. 4248-4257.

Borg, I. Y., and Heard, H. C., 1970, Experimental deformation of plagioclases, *in* Paulitsch, P., ed., Experimental and Natural Rock Deformation (Bruno Sander birthday volume): Berlin-Heidelberg-New York, Springer-Verlag, p. 375-403.

Carter, N. L., ms, 1963, Experimental deformation and recrystallization of quartz: Ph.D. thesis, Univ. Calif. Los Angeles, Los Angeles, Calif., 213 p.

——— 1965, Basal quartz deformation lamellae—a criterion for recognition of impactites: Am. Jour. Sci., v. 263, p. 786-806.

——— 1968, Dynamic deformation of quartz, *in* French, B. M., and Short, N. M., eds., Shock Metamorphism of Natural Materials: Baltimore, Maryland, Mono Book Corp., p. 452-474.

Carter, N. L., Christie, J. M., and Griggs, D. T., 1961, Experimentally produced deformation lamellae and other structures in quartz sand: Am. Geophys. Union Trans., v. 42, p. 229.

——— 1964, Experimental deformation and recrystallization of quartz: Jour. Geology, v. 72, p. 687-733.

Carter, N. L., and Friedman, Michael, 1965, Dynamic analysis of deformed quartz and calcite from the Dry Creek Ridge Anticline, Montana: Am. Jour. Sci., v. 263, p. 747-785.

Carter, N. L., and Raleigh, C. B., 1969, Principal stress directions from plastic flow in crystals: Geol. Soc. America Bull., v. 80, p. 1231-1264.

Christie, J. M., and Green, H. W., 1964, Several new slip mechanisms in quartz [abs.]: Am. Geophys. Union Trans., v. 45, p. 103.

Christie, J. M., Griggs, D. T., and Carter, N. L., 1964, Experimental evidence of basal slip in quartz: Jour. Geology, v. 72, p. 734-756.

Christie, J. M., Tullis, J. A., and Blacic, J. D., 1968, The non-rational nature of deformation lamellae in quartz [abs.]: Am. Geophys. Union Trans., v. 49, p. 314.

Clark, S. P., Jr., and Ringwood, A. E., 1964, Density distribution and constitution of the mantle: Rev. Geophysics, v. 2, p. 35.

Coe, R. S., and Peterson, M. S., 1969, The α-β inversion in quartz: A coherent phase transition under non-hydrostatic stress: Jour. Geophys. Research, v. 74, p. 4921-4948.

Cottrell, A. H., 1964, The mechanical properties of matter: New York, John Wiley and Sons., 430 p.

Frondel, Clifford, 1962, Dana's The System of Mineralogy, V. III: Silica minerals: New York, John Wiley & Sons, 334 p.

Griggs, D. T., 1967, Hydrolytic weakening of quartz and other silicates: Geophys. Jour. Royal Astronomical Soc., v. 14, p. 19-31.

Griggs, D. T., and Blacic, J. D., 1964, The strength of quartz in the ductile regime [abs.]: Am. Geophys. Union Trans., v. 45, p. 102-103.

——— 1965, Quartz: anomalous weakness of synthetic crystals: Science, v. 147, p. 292-295.

Heard, H. C., ms., 1962, The effect of large changes in strain rate in the experimental deformation of rocks: Ph.D. dissert., Univ. California, Los Angeles, Los Angeles, Calif., 202 p.

Heard, H. C., and Carter, N. L., 1968, Experimentally induced "natural" intragranular flow in quartz and quartzite: Am. Jour. Sci., v. 266, p. 1-42.

McLaren, A. C., and Retchford, J. A., 1969, Transmission electron microscope study of the dislocations in plastically deformed synthetic quartz: Physics Status Solidi, v. 33, p. 657-668.

McLaren, A. C., Retchford, J. A., Griggs, D. T., and Christie, J. M., 1967, Transmission electron microscope study of Brazil twin and dislocations experimentally produced in natural quartz: Physics Status Solidi, v. 19, p. 631-644.