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Microstructures and Crystallographic Misorientation in Experimentally Deformed Natural Quartz Single Crystals

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Samples of natural milky quartz were deformed in a Griggs deformation apparatus at different confining pressures (700 MPa, 1000 MPa, 1500 MPa), with constant displacement rates of $1 * 10^{-6}s^{-1}$, axial strains of 3 - 19%, and at a temperature of 900˚C. The single crystal starting material contains a large number of H_2O-rich fluid inclusions. Directly adjacent to the fluid inclusions the crystal is essentially dry (50-150H/10^6Si, determined by FTIR). The samples were cored from a narrow zone of constant "milkyness" (i.e. same density of fluid inclusions) in a large single crystal in two different orientations (1) normal to one of the prism planes ($\perp${m} orientation) and (2) 45˚ to <a> and to <c> (O^+ orientation).During attaining of the experimental P and T conditions, numerous fluid inclusions decrepitate by cracking. Rapid crack healing produces regions of very small fluid inclusions ("wet" quartz domains). Only these regions are subsequently deformed by dislocation glide, dry quartz domains without cracking and decrepitation of fluid inclusions remain undeformed. Sample strain is not sufficient to cause recrystallization, so that deformation is restricted to dislocation glide. In experiments at lower temperatures (800, 700˚C) or at lower strain rate ($10^{-5}s^{-1}$) there is abundant cracking and semi-brittle deformation, indicating that 900˚C, ($10^{-6}s^{-1}$) represents the lower temperature end of crystal plastic deformation in these single crystals.
Peak strengths (at 900˚C) range between 150 and 250 MPa for most samples of both orientations. There is a trend of decreasing strength with increasing confining pressure, as described by Kronenberg and Tullis (1984) for quartzites, but the large variation in strength due to inhomogeneous sample strain precludes a definite analysis of the strength/pressure dependence in our single crystals.

In the deformed samples, we can distinguish a number of microstructures and inferred different slip systems. In both orientations, deformation lamellae with a high optical relief appear in the usual sub-basal orientation; often they are associated with "fluid inclusions trails", cracks or en echelon arrays.

In $\perp${m} orientation, conjugate misorientation bands sub-parallel to the prism planes can be observed. The barreled shape of the samples can be explained by prism <a> glide. Unfortunately, since prism <a> glide does not affect the c-axis orientation it cannot be recognized on a c-axis orientation image. Nevertheless, changes in the c-axis orientation are observed locally, indicating either the activity of an additional slip system or a different deformation process (not specified yet).

In O^+ orientation, we observe the formation of internally kinked shear bands. They are up to 100 μm wide and oriented at $\alpha \sim 90^\circ$ w/r to the host c-axis, slightly oblique to the sense of shear. The width of the kinked domains is ∼20-40 μm and the average misorientation (β) is $\sim 5^\circ$. The dispersion of c-axis orientation with synthetic rotation of the c-axis is evidence of basal <a> glide.

References:
Kronenberg, A.K. & Tullis, J. (1984): Flow strength of quartz aggregates: grain size and pressure effects due to hydrolytic
weakening. JGR Vol. 89, 4281-4281.