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Fluid inclusions and microstructures in experimentally deformed quartz single crystals

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The “H_2O-weakening” effect that reduces the strength of quartz dramatically (e.g. Griggs & Blacic 1965) is still not understood. For example, Kronenberg & Tullis (1984) conclude that the weakening effect is pressure dependent while Paterson (1989) infers a glide and recovery control of water. Obviously, the spatial distribution and transport of H_2O are important factors (Kronenberg et al. 1986, FitzGerald et al. 1991).

We have carried out experiments on milky quartz in a Griggs deformation apparatus. Cylinders (6.5 mm in diameter, 12-13 mm in length) from a milky zone of a natural quartz single crystal have been cored in orientations (1) normal to one of the prism planes and (2) 45˚ to <a> and 45˚ to <c> (O^+orientation).

At 1 GPa confining pressure, 900˚C and $10^{-6}s^{-1}$, the flow strength is 150 MPa for samples with orientation (1). Further experiments are needed to establish the flow strength for orientation (2).

FTIR measurements on double-polished thick sections (200-500 μm) in the undeformed quartz material yield an average H_2O content of approximately 100 H/10^6Si. The water is heterogeneously distributed in the sample. Direct measurements on fluid inclusions yield a H_2O content of more than 25 000 H/10^6Si. Thus, the H_2O in the undeformed material is predominantly present in fluid inclusions of size from tens to hundred microns.

Micro-thermometric measurements at low temperature indicate the presence of different salts in the fluid inclusions. The ice melting temperature, between -6.9 and -7.4˚C, indicate an average salinity of 10.5 wt% NaCl.

After deformation the distribution of H_2O is more homogeneous throughout the sample. The majority of the big inclusions have disappeared and very small inclusions of several microns to sub-micron size have formed. FTIR measurements in zones of undulatory extinction and shear bands show an average H_2O content of approximately 3000 H/10^6Si. Moreover, the larger fluid inclusions are characterized by a higher salinity (12 wt%) due to H_2O loss into the healed cracks.

First observations of deformed samples show abundant deformation lamellae. With higher deformation the lamellae form conjugated zones of high dislocation density and undulatory extinction. Micro cracks are frequently connected to fluid inclusions. Recrystallized grains are rare in deformed samples because of the low strain acquired. In semi-brittle experiments at lower temperature and faster strain rates considerable recrystallization features are visible and clearly connected to initial brittle deformation features.

We conclude that fluid inclusion rupture and fast crack healing at high temperatures are necessary for the redistribution of H_2O and a prerequisite of ductile deformation.

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