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Influence of H2O Rich Fluid Inclusions on Quartz Deformation

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The effect of H_2O on the strength of quartz is well known and has been discussed many times in the literature (e.g. Griggs & Blacic 1965, Kronenberg 1994). In this project we study the H_2O interactions between natural dry quartz and H_2O rich fluid inclusions during deformation in the solid medium Griggs apparatus.

High pressure and temperature experiments were carried out using a quartz single crystal containing a large number of H_2O-rich fluid inclusions. Adjacent to the fluid inclusions the crystal is essentially dry (< 100 H/10^6Si, as determined by FTIR). Two sample orientations where used: (1) $\perp\{m\}$ orientation: normal to one of the prism planes, (2) O^+ orientation: 45° to <a> and 45° to [c]. Confining pressures were 700 MPa, 1000 MPa and 1500 MPa, with a constant displacement rate of $\sim 10^{-6}$ s^{-1} and a constant temperature of 900°C. Additionally, experiments where carried out at lower temperatures (800°C, 700°C) and faster strain rate ($\sim 10^{-5}$ s^{-1}). During increasing pressure and temperature we remained close to the fluid inclusion isochore and exceeded the $\alpha - \beta$ transition as late as possible.

The strengths of the majority of the samples are between 150 and 250 MPa (the weakest is 84 MPa, the strongest 414 MPa). Low strength can be explained by dynamic recrystallization and deformation by dislocation creep, higher strength correlates with a lower H_2O content and absence of dislocation creep.

In the undeformed material, the H_2O rich fluid inclusions contain different chlorides like antarticite ($CaCl_2 \cdot 6H_2O$) and hydrohalite ($NaCl \cdot 2H_2O$), as measured with micro thermometry. They show a large range in size from 50 μm to 700 μm and their spatial distribution is extremely heterogeneous. After deformation the inclusions are more homogeneously distributed throughout the sample and dramatically reduced in size ($< 0.1\mu$m). Regions with a high density of very small fluid inclusions are the regions with the highest concentration of deformation and yield an H_2O content up to 3000 H/10^6Si. There is also a difference in fluid homogenization for the two different orientations. In crystals with orientation $\perp\{m\}$, the fluid distribution is more homogeneous and to a finer scale than in crystals of O^+ orientation. After deformation the salinity of the fluid inclusions is increased, from $\sim$10.6 wt.% equivalent NaCl up to $\sim$12 wt.% equivalent NaCl.

FTIR spectra (point measurements, $100*100$ μm) also show a change in H_2O content. Before deformation, the absorption spectra show no evidence for H_2O in the quartz, H_2O is only detected in the fluid inclusions (broad absorption band indicating molecular water). After deformation, the absorption spectra display a discrete peak, indicating OH^- bonding in the quartz lattice.

The release of H_2O from fluid inclusions is an important process for crystal plastic deformation. Fluid inclusion rupture, micro cracking and the fast crack healing at these temperatures promote the distribution of H_2O through the quartz and influences the strength of the material.

Reference:

Griggs, D.T. & Blacic, J.D., 1965: Quartz: Anomalous weakness of synthetic crystals. Science 174, 293-295.

Kronenberg A.K., (1994): Hydrogen specifications and chemical weakening of quartz, *Rev. Mineral. Ser.* 29 (1994), pp. 123–176.