THE EFFECT OF WATER ON THE EXPERIMENTAL DEFORMATION OF NATURAL QUARTZITE; EVIDENCE FOR DIFFUSIONAL CREEP

S W J den Brok, (Institute of Earth Sciences, State University of Utrecht, The Netherlands.)

It is widely accepted in the literature that experimentally observed water weakening phenomena in quartz are due to the influence of a Hydrogen-Related Crystal Defect (HRCD) on intra-crystalline plasticity. However, the weakening effects observed in experiments on natural crystals deformed in the presence of water cannot be unambiguously related to intra-crystalline processes, since samples invariably show extensive cracking and recrystallization in addition to dislocation microstructures. In addition, recent evidence (Gerretsen 1987) indicates that HRCD's cannot significantly diffuse into single crystals on laboratory time scales, thus casting doubt on the whole concept of intra-crystalline hydrolytic weakening in single crystals.

In very fine-grained polycrystalline quartz, however, where HRCD diffusion may be significant, some authors claim that experimentally observed water weakening is indeed related to intra-crystalline effects. This is inferred from the association with grain flattening and strong crystallographic fabrics, though low stress exponents (1.4) sometimes suggest a diffusional creep mechanism.

To determine if diffusional creep might explain some of the water weakening effects seen in polycrystals, we have conducted a detailed experimental/microstructural study. Quartzite specimens (6 mm diameter, grain size ≈100 μm) were weld-sealed in Au-capsules with 3 μm water added and deformed in a Griggs rig (with NaCl confining medium) at 1073 K, 1.2 GPa confining pressure and at various strain rates. Samples deformed at 10^{-5} s^{-1} show undulatory extinction, deformation bands and deformation lamellae. In samples deformed at 10^{-7} s^{-1}, no evidence was found for deformation lamellae, and very little undulatory extinction was observed. However, the samples contained numerous inter-granular axial cracks filled with finely crystalline (≤10 μm) quartz. SEM analysis shows that the infills consist of newly grown, mostly euhedral quartz crystals, separated by an inter-connected network of micron scale tubes and channels. The total volume of this newly grown material accounts closely for the imposed strain. No meltphase was detected. We suggest that stress corrosion cracking and pressure solution are responsible for water weakening during deformation at 10^{-7} s^{-1}. This is supported by calculations based on a diffusion controlled pressure solution model.

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