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Solution-precipitation creep and microcracking in water-weakened quartzite

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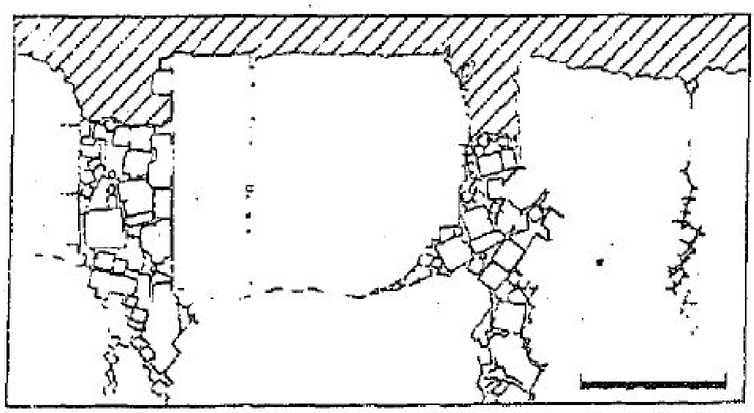
The present paper reports an experimental investigation into the water-weakening of quartzite. The results indicate that the action of water is to enhance solution-precipitation creep (SPC) and microcracking (MC), rather than dislocation creep. This casts doubt on the widespread belief that water-weakening is an intracrystalline effect. Furthermore, it appears that by SPC and MC microstructures are produced that look very much like microstructures that are commonly ascribed to dislocation creep (e.g. blocky undulatory extinction, deformation bands, subgrains, recrystallized grains). Consequently one should be cautious to use such microstructures as indicators for dislocation creep.

Deformation experiments were performed on Dongelberg quartzilte (very low porosity, ±150 μm grain size) using a Griggs solid medium deformation apparatus. Samples (12 mm in length, 6 mm in diameter) were deformed in compression at a temperature of 1073 K, a confining pressure of 1.2 GPa and strain rates of 10^{-5}, 10^{-6} and 10^{-7} s^{-1}. Samples were placed in gold jackets with 0.4 wt-% of added water. After deformation, individual grains of samples deformed at 10^{-5} and 10^{-6} showed abundant, mostly subbasal deformation lamellae, indicating crystal plastic deformation. In contrast, samples deformed at 10^{-7} s^{-1} (and to a leser extent at 10^{-6} s^{-1} as well) show aggregates of new fine (sub)euhedral quartz grains (5-50 μm) in axially aligned grain boundary and transgranular microcracks (see figure). These aggregates show abundant voids, channel structures and fluid inclusions. Crack walls show syntaxial overgrowth structures, with micas pinning the grain boundary and fluid inclusion trails separating distinct growth cells. Grain boundaries perpendicular to the shortening direction show evidence for dissolution. The microstructures are interpreted to result from SPC and MC. Unfortunately the reliability of the mechanical data obtained is very poor, but the results indicate that the stress exponent for power law creep in the range $\varepsilon<10^{-6}$ s^{-1}

is very low (n<1.3). This agrees well with mechanical data reported in the literature and is consistent with existing models of SPC.

The microstructures seen in samples deformed at 10^{-7} s^{-1}, and interpreted to result from SPC and MC are easily mistaken for microstructures that are commonly attributed to deformation by dislocation creep, i.e. non-perfect syntaxial overgrowths look like subgrains, the (sub-)euhedral quartz grains in the axially aligned aggregates resemble grains resulting from (solid state) recrystallization, and slightly rotated blocks separated by (later healed) microcracks resemble deformation bands and (blocky) undulose extinction. This suggests that microstructures that are widely believed to indicate deformation by dislocation creep, such as fine recrystallized grains, deformation bands, undulose extinction, subgrains and/or core and mantle structures may possibly result by SPC and MC as well. Microstructures observed in several natural quartz mylonites will be briefly discussed in view of this suggestion.



Schematic representation of experimentally produced aggregates of new (sub)-euhedral quartz grains and syntaxial overgrowths in transgranular and grain boundary microcracks. Shortening direction is vertical. The gold of the jackets (between the piston and the sample) is squeezed into the microcracks. Scale bar is 50 µm.