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Effect of confining pressure on the strength of wet quartzite revisited

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The ability of water to enhance plastic deformation of a quartz aggregate has been experimentally demonstrated during the sixties (e.g. Griggs and Blacic 1965), however the processes involved are still questioned. Notably the processes combining the effect of water and pressure during the deformation are still not completely understood. Pressure strongly influences the strength of fine-grained (3.6 - 4.9 µm) wet quartz aggregates (Kronenberg and Tullis 1984), where diffusion creep operates (Fukuda et al. 2018) but its effect on coarser-grained material expected to deform only by dislocation creep is not well constrained. To re-assess the effect of pressure on quartz crystal plastic deformation, natural wet quartzite samples from the Tana quarry in northern Norway (grain size ≈ 150 µm) have been deformed using a Griggs-type apparatus at varying confining pressures (from 0.6 to 2.0 GPa). All the samples with 0.1 wt. % H_2O added were shortened coaxially up to 30% strain at constant strain rate (≈10^{-6} s^{-1}) and temperature (900°C).

All mechanical records show that quartzite flow stresses decrease systematically with increasing pressure. These results allow to determine the strength of quartzite as a function of water fugacity, such as introduced in the flow law by Kohlstedt et al. (1995) to account for both pressure and water effects. In our case, the fugacity coefficient is m≈1 when using a stress exponent of n=2.

Microstructure and image analyses of samples reveal that the bulk strain results mainly from crystal plastic deformation of original grains whereas the recrystallization processes are limited volumetrically (less than 5%) and restricted to the boundaries of original grains. Deformation is not strongly partitioned into recrystallized domains compared to flattened original grains. Optical and SEM-cathodoluminescence images revealed the presence of cracks in conjunction with recrystallization (even for high-pressure samples) and associated chemical/fluid interaction, but the cracks do not contribute significantly to the bulk strain of the samples.

In order to determine the amount of water used for the deformation and the redistribution of H_2O during deformation, the H_2O content of the quartzite has been calculated from FTIR (Fourier Transform InfraRed spectroscopy) measurements for both, grain interiors and grain boundaries. The H_2O concentrations decrease inside grains with the onset of deformation with respect to the

starting material. H_2O is primarily stored in the grain boundary region. There is no systematic correlation with pressure. Thus, pressure dependence of H_2O weakening is not restricted to fine-grained materials at high pressure and temperature. Deformation redistributes water from the grain interiors to their grain boundaries.

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