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Behaviour of wet quartzite: deformation experiments revisited

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Since quartz is among the most abundant minerals in continental crust and one of the first to show plasticity with increasing pressure and temperature, understanding its mechanical behavior is crucial for estimates on crustal strength and modeling of geodynamic processes. Since discovery of significantly lower mechanical strength of quartz as a consequence of H_2O presence in the crystal (Griggs & Blacic, 1965), remarkable amount of work has been done in order to improve knowledge about processes and mechanisms responsible for so called H_2O weakening effect. As the weakening effect depends on molecular H_2O, it is a disequilibrium weakening process that is difficult to incorporate into existing flaw laws.

In order to estimate mechanical behavior of quartz in presence of H_2O, we performed deformation experiments in solid-medium Griggs-type apparatus in coaxial setting under controlled laboratory conditions using very pure natural quartzite from Tana quarry in northern Norway. Behavior of as-is and 0.1 wt% H_2O added samples was studied in 1) eight shortening experiments at 900 °C, 1 GPa and constant strain rate of 10^{-6} s^{-1} reaching 5% and 30% strain, 2) six strain rate stepping experiments covering 10^{-5}, 10^{-6} and 10^{-7} s^{-1}, 3) two temperature stepping experiments covering 750, 850 and 950 °C and 4) one hot-pressing experiment maintaining the starting experimental conditions for 14 hours.

There is a negligible strength difference between the as-is and H_2O added samples. Both H_2O added and as-is strain rate steeping experiments had shown surprisingly low stress exponent, with the highest value of 2.26. Temperature stepping experiments gave activation energy values of 177 kJ/mol and 198 kJ/mol. In all studied samples, strain increases towards the sample centers exhibiting grain size decrease from initial 250 – 300 μm. Three principal deformation mechanisms contributing to the bulk strain were identified: 1) crystal plasticity of original grains manifested by flattening, undulatory extinction, and development of subgrains, 2) cracking of original grains demonstrated by fluid inclusion trails and minor grain offset and 3) dynamic recrystallization via subgrain rotation recrystallization indicated by misorientation analysis from EBSD data. FTIR spectroscopy was applied to evaluate H_2O speciation, quantity and distribution. Regardless of added H_2O, most of deformed original grains showed relative H_2O concentration between 0 and 400 $H/10^6Si$, implying significant decrease of H_2O content from original 600 to 2000 $H/10^6Si$ measured in undeformed grains. Average H_2O concentration in grain boundaries showed 750

$H/10^6Si$ for as-is samples and 1300 $H/10^6Si$ for H_2O added. Plasticity is most visible in CL-images, as well as higher degree of grain fragmentation and crack density in samples with added H_2O. Ubiquitous presence of fluid along the grain boundaries, demonstrated by FTIR results, may have facilitated sliding along grain boundaries which, in turn, could explain the low stress exponent derived from strain rate stepping experiments.

REFERENCES:

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