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Imaging Water in Deformed Quartzites: Examples from Caledonian and Himalayan Shear Zones

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Infrared IR measurements of OH absorption bands due to water in deformed quartz grains have been collected from major shear zones of the Caledonian and Himalayan orogens. Mean intragranular water contents were determined from the magnitude of the broad OH absorption at 3400 cm^{-1} as a function of structural position, averaging over multiple grains, using an IR microscope coupled to a conventional FTIR spectrometer with apertures of 50-100 μm. Images of water content were generated by scanning areas of up to 4 mm^2 of individual specimens with a 10 μm synchrotron-generated IR beam and contouring OH absorptions. Water contents vary with structural level relative to the central cores of shear zones and they vary at the grain scale corresponding to deformation and recrystallization microstructures.

Gradients in quartz water content expressed over structural distances of 10 to 400 m from the centers of the Moine Thrust (Stack of Glencoul, NW Scotland), the Main Central Thrust (Sutlej valley of NW India), and the South Tibetan Detachment System (Rongbuk valley north of Mount Everest) indicate that these shear zones functioned as fluid conduits. However, the gradients differ substantially: in some cases, enhanced fluid fluxes appear to have increased quartz water contents, while in others, they served to decrease water contents. Water contents of Moine thrust quartzites appear to have been reduced during shear at greenschist facies by processes of regime II BLG/SGR dislocation creep. Intragranular water contents of the protolith 70 m below the central fault core are large (4078 $\pm$ 247 ppm, H/10^6 Si) while mylonites within 5 mm of the Moine hanging wall rocks have water contents of only 1570 ($\pm$ 229) ppm. Water contents between these extremes vary systematically with structural level and correlate inversely with the extent of dynamic recrystallization (20 to 100%). Quartz intragranular water contents of Himalayan thrust and low-angle detachment zones sheared at upper amphibolite conditions by regime III GBM creep show varying trends with structural level. Water contents increase toward the Lhotse detachment of the Rongbuk valley, reaching 11,350 ($\pm$ 1095) ppm, whereas they decrease toward the Main Central Thrust exposed in the western part of the Sutlej valley to values as low as 170 ($\pm$ 25) ppm.

Maps of intragranular water content correspond to populations of fluid inclusions, which depend on the history of deformation and dynamic recrystallization. Increases in water content require the introduction of secondary fluid inclusions, generally by brittle microcracking followed by crack healing and processes of inclusion redistribution documented in milky quartz experiments. Decreases in water content result from dynamic recrystallization, as mobile grain boundaries sweep through wet porphyroclasts, leaving behind dry recrystallized grains.

Intragranular water contents throughout greenschist mylonites of the Moine thrust are comparable to those of quartz weakened by water in laboratory experiments. However, water contents of upper amphibolite mylonites of the Main Central Thrust are far below those required for water weakening at experimental strain rates and offer challenges to our understanding of quartz rheology.