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Synthesis and deformation of a Ti doped quartz aggregate

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A primary advantage of studying mylonites for thermobarometric reconstructions of tectonic events is that it enables direct comparison of P-T estimates with the mechanics of quartz deformation. Quartz is a common phase in crustal mylonites and is a particularly sensitive recorder of metamorphic and rheologic conditions in shear zones, owing to its responsiveness to dynamic recrystallization, involvement in metamorphic reaction, and propensity for dissolution and precipitation. The signature of its trace element chemistry, particularly Ti, can reflect involvement from each of these processes. The concentration of Ti in mylonites is typically heterogeneous at the thin section scale, providing a rich record of the different factors that influence the incorporation of Ti in quartz.

Observations of quartz in deformed mylonite and undeformed protolith from an extensional shear zone in the North American Cordillera (Shuswap Complex, Canada) show that an originally uniform Ti distribution was modified during deformation to form zoned crystals in which the core preserves a higher Ti concentration than the rim. The zoned Ti concentration likely records a continuum of deformation conditions during extension-related exhumation, and this presents a challenge in resolving the effect of deformation on the equilibrium solubility of Ti in quartz in natural settings. By conducting deformation experiments on synthetic quartz aggregates with known Ti concentration at a constant, elevated temperature and pressure under high strain conditions, we investigate the influence of progressive dynamic recrystallization on Ti solubility in quartz.

This study applies a novel doping technique that enables the synthesis of a large population of quartz crystals with a precisely controlled Ti concentration and distribution. This produces a sample that most closely replicates the protolith of extensional shear zones that typically develop under retrograde conditions. This strategy can be used to generate the equilibrium concentration predicted by previous solubility calibrations for selected P-T conditions. Experiments were performed using a shear assembly to deform quartz samples to high shear strain in dislocation creep at constant temperature, pressure, and strain rate for 24, 48, and 72 h with and without the addition of 0.1 wt% H_2O. Experiments were also run under hydrostatic conditions for equivalent lengths of time for comparison with deformed samples. Experimental specimens were prepared as a two layer sample with a doped half and an undoped half to study Ti mobility during deformation. Experimental samples are analyzed with EMPA and SIMS to determine the Ti concentration of quartz in the sample, SEM-CL to observe the distribution of Ti in quartz grains, and SEM-EBSD to evaluate crystallographic fabrics and grain size. Results suggest that the duration of dynamic recrystallization influences the final Ti concentration, implying the importance of kinetics and diffusion even at the elevated temperatures of the experiments. Water content affects Ti concentration, potentially owing to the importance of point defect concentration on the solubility of Ti in quartz. Furthermore, recrystallized grain size shows a dependence on Ti concentration, as samples doped at supersaturated levels recrystallize with finer grain sizes relative to undoped samples. This suggests that exceeding the equilibrium solubility of Ti in quartz may pin grain boundary migration. The ultimate expression of Ti supersaturation in quartz is strain-induced rutilation and the progressive rotation and boudinage of exsolved rutile needles.