Geophysical Research Abstracts
Vol. 21, EGU2019-11157, 2019
EGU General Assembly 2019

Mechanisms of Strain Localization during Dynamic Recrystallization of Olivine

Pamela Speciale (1), Whitney Behr (2), and Greg Hirth (3)

(1) The University of Texas at Austin, Jackson School of Geosciences, Dripping Springs, United States (pamela.speciale@utexas.edu), (2) ETH Zurich, Department of Earth Sciences, Zurich, Switzerland, (3) Brown University, Earth, Environmental and Planetary Sciences, Providence, United States

The development of very fine grain size in both crustal and mantle shear zones suggests that grain size reduction leads to strain localization in the Earth's lithosphere. However, whether grain size reduction is effective in maintaining localization is debated. Processes commonly proposed include a) geometric softening, b) a switch to grain size-sensitive creep, and c) grain boundary migration recrystallization. One or more of these mechanisms may contribute to the strain weakening observed in olivine during experiments (and inferred in nature), and each should exhibit unique mechanical and microstructural signatures.

To simulate deformation after the accumulation of high strain, and near-complete dynamic recrystallization, we conducted 15 deformation experiments on experimentally synthesized mylonites and ultramylonites. We used a Griggs rig with a molten salt cell, on dry San Carlos olivine in general shear at 1050-1100°C, 1 GPa confining pressure, 200-600 MPa equivalent stress, 6.5E-4 – 5.5E-5 /sec equivalent strain rate, and shear strains up to 4. One set of samples was fabricated to mimic natural mylonites, with porphyroclasts (150-250 μm) embedded in a matrix with grain size similar to that predicted by the olivine piezometer for the imposed stress magnitude. For another set of samples, we synthesized fine-grained ultramylonites (without embedded porphyroclasts). On each set of samples, we ran both constant strain rate and constant stress experiments to explore their behavior under different boundary conditions. The constant stress experiments were conducted using a DC motor, which enabled the variable motor speeds required to maintain differential stress at the desired magnitude.

In mylonitic samples deformed at both constant strain rate and constant stress, matrix grains wrap around the porphyroclasts, which developed tails extending 200-500 μm sub-parallel to the shear direction. Ultramylonitic samples deformed at constant strain rate exhibit a relatively uniform grain size. In contrast, ultramylonitic samples deformed at constant stress (at their peak stress) to low strain magnitude ($<2\gamma$) show some grains much larger than matrix grains, oriented 45° to the shear direction, with aspect ratios up to 1:18, and subgrain walls sub-perpendicular to the shear direction. These grains are much larger than the starting grain size, as well as the grain size of statically annealed samples held at the same temperature for even longer periods of time. In similar, but higher strain runs ($>2\gamma$), these highly elongate grains are much more abundant, are sub-parallel to the shear direction, and often dominate zones of localized strain bounded by more equant grains. In both mylonitic and ultramylonitic samples, under constant strain rate conditions, we observed a $\sim$50% viscosity reduction from the peak stress to the final stress. In contrast, the accelerating strain rate under constant stress conditions resulted in almost an order of magnitude viscosity reduction in both types of samples.