EGU23-15457, updated on 25 Apr 2024
https://doi.org/10.5194/egusphere-egu23-15457
EGU General Assembly 2023

Backstresses in polycrystalline olivine and implications for transient deformation of the mantle

Diede Hein, Lars Hansen, and Amanda Dillman
University of Minnesota, College of Science and Engineering, Earth and environmental sciences, Minneapolis, United States of America (hein0477@umn.edu)

Transient creep controls the behavior of Earth's mantle at human timescales. Transient creep occurs during postseismic creep, glacial isostatic adjustment, and tidal deformation of planetary interiors experiencing large tidal stresses, such as Jupiter's moon Io or various identified exoplanets. Unfortunately, laboratory data of transient creep of olivine, the most abundant mineral in Earth's upper mantle, remain limited, and at present we lack the microphysical understanding of transient creep required to extrapolate experimental data to geological grain sizes and time scales. Several mechanisms for transient creep have been proposed, both intergranular mechanisms such as plastic anisotropy and elastically or diffusionally-assisted grain boundary sliding, and intragranular mechanisms including long-range dislocation interactions and various other dislocation damping mechanisms. Each mechanism produces distinct rheological behavior, presenting a hurdle for modeling geodynamic processes occurring on timescales of hours to years.

To distinguish among the various proposed microphysical mechanisms for transient creep, we performed compressional load-reduction experiments on cylindrical, isostatically hot-pressed aggregates of San Carlos olivine in a gas-medium Paterson apparatus at confining pressures of 300 MPa and temperatures of 1200°C. Samples were subjected to a constant differential stress of 200 MPa, which resulted in a steady-state strain rate of ~10^{-5} s^{-1}. After steady state was achieved, the samples were subjected to a near-instantaneous load reduction of 10–70% of the original load.

For load reductions exceeding ~50%, the samples exhibited a period of transient anelastic relaxation with zero or negative strain rate before continuing to strain at a positive strain rate lower than the previous steady state. The duration of relaxation increased with the magnitude of the load reduction. Multiple load reductions from the same steady-state strain rate were performed during a single experiment to test for reproducibility.

We interpret our results to indicate that, at these conditions, the backstress stored in polycrystalline olivine is approximately half of the differential stress applied to the material. The magnitude of backstress is compatible with long-range dislocation interactions on the [100](010) and [100](001) or [001](100) slip systems previously observed for single crystals of olivine. If transient creep is controlled by such dislocation interactions then it may be inappropriate to apply

the traditional Burgers rheology based exclusively on intergranular dissipation processes or power-law flow laws calibrated for steady-state creep to model transient creep and transient viscosity evolution in the upper mantle.