Geophysical Research Abstracts
Vol. 18, EGU2016-7933, 2016
EGU General Assembly 2016

Direct Shear of Olivine Single Crystals

Jacob Tielke (1,2), Mark Zimmerman (2), and David Kohlstedt (2)
(1) University of Liverpool, United Kingdom, (2) University of Minnesota, United States (tielk003@umn.edu)

Knowledge of the strength of individual dislocation slip systems in olivine is fundamental to understanding the flow behavior and the development of lattice-preferred orientation in olivine-rich rocks. The most direct measurements of the strengths of individual slip systems are from triaxial compression experiments on olivine single crystals. However, such experiments only allow for determination of flow laws for two of the four dominate slip systems in olivine. In order to measure the strengths of the (001)[100] and (100)[001] slip systems independently, we performed deformation experiments on single crystals of San Carlos olivine in a direct shear geometry. Experiments were carried out at temperatures of 1000° to 1300°C, a confining pressure of 300 MPa, shear stresses of 60 to 334 MPa, and resultant shear strain rates of 7.4 x 10^{-6} to 6.7 x 10^{-4} s^{-1}. At high-temperature (≥1200°C) and low-stress (≤200 MPa) conditions, the strain rate of crystals oriented for direct shear on either the (001)[100] or the (100)[001] slip system follows a power law relationship with stress, whereas at lower temperatures and higher stresses, strain rate depends exponentially on stress. The flow laws derived from the mechanical data in this study are consistent with a transition from the operation of a climb-controlled dislocation mechanism during power-law creep to the operation of a glide-controlled dislocation mechanism during exponential creep. In the climb-controlled regime, crystals oriented for shear on the (001)[100] slip system are weaker than crystals orientated for shear on the (100)[001] slip system. In contrast, in the glide-controlled regime the opposite is observed. Extrapolation of flow laws determined for crystals sheared in orientations favorable for slip on these two slip systems to upper mantle conditions reveals that the (001)[100] slip system is weaker at temperatures and stresses that are typical of the asthenospheric mantle, whereas the (100)[001] slip system is weaker at conditions typical of the lithospheric mantle. These observations demonstrate that the relative strength of the dislocation slip systems in olivine and, thus, the development of lattice-preferred orientation and anisotropic viscosity in olivine-rich rocks are strongly dependent upon temperature and stress.