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Direct Shear of Olivine Single Crystals under Hydrous Conditions

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The rate of plastic deformation of upper mantle materials controls many important geophysical processes, including convection in the Earth's upper mantle and the associated movements of Earth's tectonic plates. The strength of nominally anhydrous silicate minerals in Earth's mantle is strongly influenced by the addition of hydrogen as a point defect, a phenomenon referred to as hydrolytic weakening. A large literature documents hydrolytic weakening of olivine, the major mantle phase, during high-temperature ($\geq$ 1200°C) deformation experiments of fine-grained olivine aggregates. However, interpretation of recent diffusion experiments on iron-free olivine crystals has called the significance of deformation experiments on fine-grained olivine aggregates into question, citing the possible large contribution of "grain boundary water" to deformation. One direct means of measuring hydrolytic weakening in olivine is by performing deformation experiments on single crystals, which avoids the complications of "grain boundary water". In order to quantify hydrolytic weakening in olivine, we are carrying out a series of deformation experiments on olivine single crystals over a range of pressures and hydrogen contents typical of the Earth's upper mantle. The experiments are being prepared under both anhydrous and hydrous conditions, using a direct shear deformation geometry, and will be carried out in both a gas-medium and a solid-medium apparatus. The direct shear geometry allows for the isolation of both the slip plane and slip direction and, thus, the strength of the four dominant dislocation slip systems in olivine. Data from these experiments will be used to derive flow laws that describe strain rate as a function of stress, temperature, and hydrogen content for each of the four dominant dislocation slip systems. These flow laws will have important implications for understanding lattice-preferred orientation development and the resultant seismic and viscous anisotropy in olivine-rich rocks.