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Measurement of activation volume and determination of preferred slip systems for creep of dry olivine at upper mantle pressure

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Olivine is the most abundant and probably weakest phase in the upper mantle, and thus its rheological properties have a critical role in controlling convective flow in this region. A persistent obstacle to understanding the behavior of olivine in the mantle has been the difficulty of determining activation volume (V*), the influence of hydrostatic pressure on high-temperature creep. The bulk of previous studies examining V* were conducted at low pressure (<300 MPa) and over small pressure ranges in gas-medium deformation machines, limiting precision and raising questions about application to relevant geological conditions. For this study, we conducted numerous deformation experiments on dry polycrystalline olivine in the D-DIA apparatus to pressures 1.5 to 9 GPa at 1373 K. Stress and strain were measured in-situ with synchrotron x rays. Refinement of diffraction technique has allowed stress resolution of $\pm$0.02 GPa. For the pressure range in this study, we have measured an average activation volume of about 15 cm3/mol for dry polycrystalline San Carlos olivine. This is a substantial pressure effect, representing a pressure-induced viscosity increase of nearly 7 orders of magnitude from the base of the lithosphere to the bottom of the upper mantle. The diffraction technique used for stress measurement in these experiments also illuminates the relative strength of differently oriented grains in our polycrystalline sample, providing new experimental evidence for preferred dislocation slip systems in olivine at high pressure.