Water, melt, and shear initiation in the Josephine Peridotite, SW Oregon

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Shear localization in the upper mantle is necessary for plate tectonics. Various mechanisms for shear localization have been proposed, including the presence of melt, addition of water, grain size reduction, and development of a strong LPO. The Josephine Peridotite of southwestern Oregon contains shear zones that provide an excellent opportunity to examine the initiation of shear localization. These shear zones are relatively small-scale (1-60 m width) and low-strain compared to many shear zones in peridotite massifs, which typically have extreme grain size reduction indicating extensive deformation.

To evaluate the mechanisms leading to shear localization, we performed major, trace, and volatile element analyses on a suite of harzburgite samples from transects across three shear zones. Water concentrations in orthopyroxene were determined using secondary ion mass spectrometry and range from 180 to 334 ppm H_2O. These concentrations correlate with both aluminum and ytterbium concentrations in orthopyroxene, consistent with a melt source for the hydration that contained ~3-4 wt% H_2O. We estimate that water was incorporated into orthopyroxene at temperatures >690˚C, based on the relationship between aluminum and water, a pressure estimate for shear zone formation of 0.3-1.0 GPa, and the solubility surface for water in enstatite.

Lithological and geochemical variations across the three shear zones indicate a complex history of melting, melt addition, and melt-rock interaction during shear localization. The distribution of aluminum and heavy rare earth elements across the shear zones suggest that melt flow was focused in the centers of the shear zones during deformation. The presence of melt and of water (added by the melt) provide mechanisms for a local viscosity reduction leading to initial shear localization. As deformation progressed, the development of a shear-aligned LPO and grain size reduction also contributed to the localization of deformation.