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**TITLE:** Quantifying the effect of pyroxene on peridotite deformation in a natural shear zone

**AUTHORS (FIRST NAME, LAST NAME):** Lars N Hansen<sup>1</sup>, Jessica M Warren<sup>1</sup>

**INSTITUTIONS (ALL):** 1. Stanford University, Stanford, CA, United States.

**ABSTRACT BODY:** The rheological behavior of peridotites is key to understanding convective processes in the upper mantle, the long-term strength of the lithosphere, and the dynamics of tectonic plate boundaries. Much work has been dedicated to elucidating the rheological behavior of olivine aggregates, which are often assumed to behave the same as pyroxene-bearing peridotites. Some field studies, however, demonstrate that the addition of pyroxene can significantly affect deformation behavior. Unfortunately, laboratory studies disagree on the strength of pyroxene at lithospheric conditions by many orders of magnitude. Thus, it remains unclear whether pyroxene primarily affects peridotite deformation through its increased (or decreased) strength relative to olivine or through its effect on olivine microstructure.

We provide constraints on the viscosity of pyroxene relative to olivine through examination of paired harzburgites and dunites from a natural shear zone exposed in the Josephine Peridotite. Shear zone P deforms centimeter- to meter-scale alternating layers of harzburgites and dunites. Microstructures in paired harzburgite and dunite samples from a transect across the shear zone were analyzed by electron-backscatter diffraction to obtain mean grain size, mean subgrain size, and crystallographic fabric for olivine. Olivine grain sizes are about a factor of 1.5 larger in dunites than in harzburgites, whereas olivine subgrain sizes are about a factor of 1.2 smaller in dunites than in harzburgites. We estimate the average stress in olivine grains for each sample using a laboratory-derived subgrain-size piezometer. Average stresses in olivine are inversely correlated with pyroxene volume fraction and directly correlated with mean olivine grain size. The evolution of crystallographic fabric shape and orientation with increasing shear strain is comparable in both harzburgites and dunites, indicating the operation of similar deformation mechanisms in olivine.

The ratio of pyroxene viscosity to olivine viscosity for each harzburgite/dunite pair is estimated using olivine stresses determined from the subgrain-size piezometer. The observed variation in average olivine stress is best explained with either (i) the Reuss bound (homogeneous stress among phases) assuming paired samples are deforming at different rates or (ii) with the Voigt bound (homogeneous strain rate among phases) assuming paired samples are deforming at the same rate. In both cases, we determine the ratio of pyroxene viscosity to olivine viscosity to range between approximately 1 and 10. At the conditions of Shear Zone P, pyroxene is stronger than olivine, indicating that pyroxene flow laws yielding viscosities higher than those predicted for olivine are more applicable to upper-mantle conditions. However, the calculated viscosities of pyroxene and olivine are much closer in magnitude than predicted by any published flow laws. In addition, our data are best explained by an olivine flow law that is non-Newtonian with a small grain-size sensitivity. We suggest that the increase in bulk strength with larger pyroxene fractions is offset by correspondingly smaller olivine grain sizes.

**KEYWORDS:** 3902 MINERAL PHYSICS Creep and deformation, 8033 STRUCTURAL GEOLOGY Rheology: mantle, 8012 STRUCTURAL GEOLOGY High strain deformation zones, 8162 TECTONOPHYSICS Rheology: mantle.

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**Contact Details**

**CONTACT (NAME ONLY):** Lars Hansen

**CONTACT (E-MAIL ONLY):** lars.norman.hansen@gmail.com

**TITLE OF TEAM:**

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