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# The nature of the lithosphere-asthenosphere boundary from laboratory investigations of olivine anisotropy

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The nature of the lithosphere-asthenosphere boundary (LAB) determines the mechanical coupling between rigid plates and the underlying convecting mantle. Seismological studies reveal distinct reflectors (G discontinuity) in the uppermost oceanic mantle that are sometimes interpreted as the LAB. The discontinuity in seismic velocity is suggested to arise from abrupt changes in composition, including the melt fraction. Interestingly, these reflectors roughly correlate with the location of discontinuities in radial seismic anisotropy, but do not correlate with the location of discontinuities in azimuthal anisotropy.

To investigate the correlation between these datasets, we draw on recent laboratory measurements of crystallographic texture development in olivine-rich rocks. The textural evolution of dry olivine aggregates has been well described in recent experiments, while micromechanical models are available for incorporating these observations into larger-scale models of upper-mantle flow. Unfortunately, the systematics of textural evolution in melt-bearing olivine aggregates have not been similarly described. Here we present a new experimental data set detailing the evolution of anisotropy during deformation of partially molten peridotite. Torsion experiments were conducted on samples composed of San Carlos olivine and basaltic melt at a temperature of 1473 K and a confining pressure of 300 MPa. Seismically fast axes of olivine tend to lie at a high angle to the flow direction in a manner similar to previous experiments. The anisotropy in these samples is weak compared to that in dry, melt-free olivine deformed to similar strains. The anisotropy also exhibits relatively little change in strength and orientation with progressive deformation. Detailed microstructural analyses allow us to distinguish between competing models for the grain-scale deformation processes, favoring one in which crystallographically controlled grain shapes govern grain rotations.

We incorporate results for dry and melt-bearing olivine into a 1-D, time-dependent flow model to predict the anisotropic structure of the Pacific upper mantle. Flow occurring outside of the melting region below the ridge axis is assumed to generate a texture similar to that observed in our dry olivine experiments. This flow generates a discontinuity in azimuthal anisotropy in agreement with seismological observations. The predicted discontinuity also coincides with the base of a high viscosity region and, therefore, acts as a proxy for the rheological LAB. Flow occurring within the melting region beneath the ridge axis is assumed to generate a texture similar to that observed in our melt-bearing experiments. This subset of the model yields a discontinuity in radial anisotropy at shallow depths that is also in agreement with seismological observations. The depth of this discontinuity in radial anisotropy is set by the maximum depth at which melting occurs beneath the ridge axis.

We conclude that, following a rheological definition of the lithosphere, the LAB is best defined by a discontinuity in azimuthal anisotropy that is coincident with a thermal boundary layer. The discontinuity in radial anisotropy appears related to melting near the ridge axis, which is consistent with the nature of the associated sharp reflectors. We suggest that these reflectors and the discontinuity in radial anisotropy do not represent the LAB but instead represent intralithospheric structure that does not significantly modify the rheological behavior of the lithosphere.