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Shear Wave Splitting, Continental Roots, and Patterns of Mantle Flow

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In this study we investigate patterns of mantle flow, strain, and anisotropy that are induced by the translation of relatively rigid continental roots through the mantle. A particular goal is to quantitatively estimate the component of observed shear wave splitting that can be explained by mantle flow-induced asthenospheric anisotropy and to determine the amount and geometry of anisotropy that is required in the overlying root and lithosphere. We examine the relationship of root morphology to shear wave splitting for regions beneath North America, Australia, southern Africa, and Europe. The shear wave splitting observations are derived from our own analysis of data from the Missouri-Massachusetts broadband seismometer deployment (MOMA), as well as the work of numerous other authors.

We calculate 3D mantle flow using finite-difference models in which a continental root translates through the mantle, generating a combination of root-induced return flow and plate-driven flow. We use the resulting velocity flow fields to determine the distribution of strain, which allows us to estimate the development of lattice-preferred orientation (LPO) in a peridotite mantle. In our models, fast directions tend to wrap around root margins, but we obtain more complex fast direction patterns for regions where rapid changes in root morphology exist. Assuming that the maximum depth of anisotropy does not change laterally beneath the root (i.e. the transition from a dislocation creep to diffusion creep regime occurs at a fixed depth), splitting times are smallest for regions directly above the root.

We have applied this method to calculate asthenospheric flow, strain, and anisotropy around the North American root and have found that predicted fast directions match observed variations in most regions. However, a few regions within the continental root require a component of lithospheric anisotropy to explain the observed fast directions, and the asthenospheric model tends to underestimate splitting times for stations located above the root. In a number of other areas, comparison of observed shear wave splitting parameters with constraints on root morphology obtained from 3D velocity models indicates that asthenospheric flow may make significant contributions to observed splitting. In Australia, observed shear wave splitting parameters (*Van der Hilst et al.*) suggest asthenospheric mantle flow around the eastern margin of the continental root. Shear wave splitting measurements that sample the mantle beneath the Kaapvaal craton in southern Africa (*Vinnik et al.*) are roughly parallel to absolute plate motion and suggest flow-induced anisotropy in the asthenosphere. In contrast, fast directions observed in Europe are not obviously consistent with simple asthenospheric flow around the southeastern margin of the root beneath the Baltic Shield, suggesting that either lithospheric anisotropy dominates observed splitting in this region, or that the root margin is significantly more arcuate than in current images (c.f. *Zielhuis and Nolet*).

We plan to perform a quantitative analysis for each region. Using available constraints on regional root geometry, we will calculate mantle flow patterns and predict shear wave splitting in the mantle for paths that correspond to splitting observations. Comparisons of predicted and observed splitting parameters will help to elucidate the partitioning of anisotropy and strain between the lithosphere, asthenosphere, and deeper upper mantle, and perhaps ultimately provide constraints on the degree of coupling between deep continental roots and the surrounding mantle.