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Contributions to Shear Wave Splitting from Mantle Flow Around the North American Continental Root

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Seismic anisotropy in continental regions has generally been attributed to deformation in the lithosphere and crust, flow in the asthenosphere, or a combination of both. In this study we evaluate the potential contribution to observed anisotropy generated by asthenospheric flow around the margins of the North American continental root. We have determined shear wave splitting parameters for teleseismic core phases (SKS, SKKS, etc.) recorded by the Missouri to Massachusetts Broadband Seismometer Deployment (MOMA), an IRIS/PASSCAL experiment that extended from western Massachusetts to eastern Missouri. At stations located above the thick (200-300 km) high-velocity root imaged beneath interior North America, fast directions are roughly parallel to absolute plate motion. However, fast directions measured at stations in the northeastern U.S. near the root margin are more variable. In addition, shear wave splitting measurements from other stations to the south and southeast of the root boundary indicate fast directions that appear to wrap around the lateral margin of the root (c.f. Barroul et al. [1997]). Our goal is to evaluate the amount of observed splitting that may be explained by flow around and beneath the continental root, and the amount that must be attributed to anisotropy and deformation within the root and overlying lithosphere.

We have calculated 3D mantle flow fields using finite-difference models in which a continental root translates through the mantle with North American plate motion and generates a combination of root-induced local return flow and plate-driven flow. From the model strain fields, we have estimated the lattice-preferred orientation (LPO) for a peridotite mantle and predicted seismic anisotropy and shear wave splitting for paths that correspond to splitting observations. For a simple root geometry which is spherical in map view, we find that predicted fast directions follow root contours on or near the root margin, but that fast directions beneath the root interior are parallel to absolute plate motion. For a root morphology which includes an indentation beneath the northeastern U. S. imaged by van der Lee and Nolet [1997], we find that the indentation channels flow and produces rapid variations in predicted fast directions that mimic patterns in shear-wave splitting observed at the eastern MOMA stations. At stations located outside of the root, predicted splitting times are on the order of observed splitting times. In these regions, asthenospheric anisotropy is sufficient to explain the overall pattern of observed splitting, although a few strong variations in splitting parameters over small spatial scales may require additional anisotropy in the lithosphere. For stations located in the root interior, asthenospheric anisotropy predicts splitting times that are significantly smaller than observed values, indicating that substantial lithospheric anisotropy is probably required.