Detection of Upper Mantle Flow Associated with the African Superplume*

Mark D. Behn (WHOI), Clinton P. Conrad (Univ. Michigan), and Paul G. Silver (DTM/CIW)

A continental-scale, low seismic velocity anomaly in the mid to lower mantle beneath Africa is a robust feature of global tomographic models. Assuming the low velocities are associated with warm, less dense material, the African seismic anomaly has been ascribed to a long-lived thermal upwelling from the lower mantle. Such a large-scale upwelling is predicted to affect the regional horizontal flow field in the upper mantle. To test this model we compared seismic anisotropy inferred from shear wave splitting measurements with instantaneous flow calculations that incorporate mantle density structure determined from seismic tomography.

We calculated splitting parameters at 13 ocean island GSN and Geoscope stations surrounding Africa. Splitting measurements from island stations are ideal for interpreting anisotropy induced by asthenospheric flow because they lack a thick overlying lithosphere that may also contribute to the observed anisotropy. We tested for a possible lithospheric contribution by comparing the splitting measurements with the fossil spreading directions. We found that although the fossil lithospheric fabric closely matches the observed fast polarization directions at stations < 500 km from a ridge axis, they are a poor fit to the data at stations located farther off-axis. Thus, we conclude that far from a ridge axis the observed anisotropy is dominated by asthenospheric flow. To test for an active component of mantle upwelling, we considered several models with varying assumptions about the velocity at the base of the mantle by plate motions at the Earth’s surface, or 3) driven by a combination of plate-motion and mantle density heterogeneity inferred from either seismic tomography or the history of subduction. We found that the best-fitting flow field is one generated by plate motions and density heterogeneity associated with large-scale upwelling originating in the lower-mantle beneath southern Africa and is manifest as a radial pattern of flow at the base of the asthenosphere (Fig. 1). This model provides a significantly better fit to the observed anisotropy than a model in which mantle flow is driven through a passive response to subduction.

*Results published in EPSL, v. 224, pp. 259–274, 2004

---

Fig. 1. A. Comparison of splitting observations to anisotropy predicted from global mantle flow. Black symbols indicate the orientation of the fast polarization direction from shear-wave splitting measurements at GSN and Geoscope stations. Red bars show horizontal projection of maximum shear calculated at the center of the asthenosphere for plate+density-driven mantle flow. Flow is calculated using the S20RTS tomography model [Ritsema et al., 1999] and the NUVEL-1A plate motions [DeMets et al., 1994]. B. Predicted flow field illustrating upwelling from lower mantle beneath southern Africa.