Seismic Evidence for Hotspot-Induced Buoyant Flow Beneath the Reykjanes Ridge

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Volcanic hotspots and mid-ocean ridge spreading centers are the surface expressions of upwelling in Earth’s mantle convection system, and their interaction provides unique information on upwelling dynamics. I investigated the influence of the Iceland hotspot on the adjacent mid-Atlantic spreading center (the Reykjanes Ridge, RR) using seismic surface waves from mid-Atlantic ridge earthquakes recorded at the Global Seismic Network station BORG and stations of the ICEMELT and HOTSPOT PASSCAL deployments (left). The surface waves from these events travel along and adjacent to the RR, and the travel times of these waves are sensitive to the average crust and upper-mantle velocity along each path. These delay times were inverted for age-dependent models of radial anisotropy (right). The models show a distinct pattern of shear anisotropy ($\Delta V_S$), with negative values ($V_{SV} > V_{SH}$) above about 100 km depth, and positive values between about 100-200 km depth. This pattern of anisotropy is unlike that in comparable oceanic models, which display $\Delta V_S > 0$ throughout the upper 200 km of the mantle. This anisotropy suggests that the hotspot induces buoyancy-driven upwelling in the mantle beneath the ridge. In this model, the melt-zone upwelling is driven by buoyancy associated with retained melt, melt residuum, and/or locally hot mantle. Such models produce a tight circulation within the melting zone, and as the mantle material moves out of the spreading center, a near-vertical fabric associated with the downgoing limb of the circulation is retained in the off-axis lithosphere to a depth of ~60-100 km. This result suggests that buoyancy-driven upwelling is an important component of ridge dynamics, especially in environments where passive sea-floor spreading is too slow to accommodate melt production. It also implies that the anisotropic structure of oceanic lithosphere may not be as simple as inferred through studies from the fast-spreading Pacific ridges, and that this structure holds important clues to ridge and plume dynamics.