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The Origin of Shear Wave Splitting Beneath Iceland

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The origin of shear wave splitting (SWS) in the mantle beneath Iceland is examined using numerical models that simulate three-dimensional mantle flow and the development of seismic anisotropy due to lattice-preferred orientation (LPO). Using the simulated anisotropy structure, we compute synthetic SKS waveforms, invert them for fast polarization directions and split times, and then compare the predictions with the results from three observational studies of Iceland. Models that simulate a mantle plume interacting with the Mid-Atlantic Ridge in which the shallow-most mantle has a high viscosity due to the extraction of water with partial melting, or in which C-type olivine LPO fabric is present due to high water content in the plume, produce the largest chi-squared misfits to the SWS observations and are thus rejected. Models of a low-viscosity mantle plume with A-type olivine fabric everywhere, or with the added effects of E-type fabric in the plume below the solidus produce lower misfits. The lowest misfits are produced by models that include a rapid (∼50 km/Myr) northward regional flow (NRF) in the mid-upper mantle, either with or without a plume. NRF was previously indicated by a receiver function study and a regional tomography study, and is shown here to be a major cause of the azimuthal anisotropy beneath Iceland. The smallest misfits for the models with both a plume and NRF are produced when LPO forms above a depth of 300-400 km, which, by implication, also marks the depth range in which dislocation creep dominates over diffusion creep. This depth of transition between dislocation and diffusion creep is greater than expected beneath normal oceanic seafloor, and is attributed to the unusually rapid strain-rates associated with an Iceland plume and the NRF.