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Radial Miscible Viscous Fingering within Mantle Plumes

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The Icelandic mantle plume, a major convective upwelling, has had a significant influence on the geological and oceanographic evolution of the North Atlantic Ocean throughout Cenozoic times. Significant shear wave velocity anomalies, observed in full-waveform tomography at 100-200 km depth, show the Icelandic plume has a complex, irregular planform. These anomalies suggest about five horizontal fingers extend radially beneath continental margins, the bestimaged fingers lying beneath the British Isles and beneath western Norway. It is proposed these radial miscible fingers develop due to the Saffman-Taylor instability, a fluid dynamical phenomenon which occurs when a less viscous fluid is injected into a more viscous fluid. Mobility ratio (i.e. the ratio of fluid viscosities), Péclet number (i.e. the ratio of advective and diffusive transport rates) and thickness of the horizontal layer together control the presence of fingering. Preliminary estimates for the Icelandic plume suggest that the mobility ratio is at least 20-50, the Péclet number is O(10 4), and the asthenospheric channel thickness is 100 $\pm$ 20 km. This analysis has also been applied to plumes of varying vigour (e.g. Hawaii, Cape Verde, Yellowstone). Appropriately scaled laboratory experiments play a key role in developing a quantitative understanding of the spatial and temporal evolution of plume planforms. Preliminary results show that the absence of fingering is principally a consequence of smaller buoyancy fluxes. Further work will constrain how the presence or absence of radial miscible fingering is controlled by changes in mobility ratio and Péclet number. Our hypothesis supports the notion that dynamic topography can be affected by fast, irregular horizontal flow within thin, but rapidly evolving, asthenospheric fingers.