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Widely-spaced Double Hotspot Chains due to Forked Plumes sample Lower Mantle Geochemical Structure

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Age-progressive volcanic "hotspot" chains result from the passage of a tectonic plate over a deep-rooted thermochemical plume, thereby sampling the otherwise-inaccessible lowermost mantle. A common feature of oceanic hotspot tracks is the occurrence of two parallel volcanic chains. For example, the Hawaiian Loa and Kea chains are separated by a gap of 50 km, and likely sample the same ~100-km wide mantle melting zone. Several other tracks (including Tristan-Gough, Shona, the Wake seamounts, Tuvalu and Cook-Australs) are made up of a double chain with a 200-400 km spacing, but the origin of such widely-spaced double hotspots remains unknown.

Here, we explore 3D Cartesian geodynamic models of thermochemical plume ascent through the upper mantle. We investigate the effects of the lateral distribution of intrinsically-dense eclogitic material across the plume stem on upwelling style. For small eclogite contents, the plume rises as a "classical" columnar upwelling. For a wide range of intermediate eclogite contents in in the plume, the plume spreads laterally in the depth range of 300~410 km, where the excess density of eclogite is greater than above and below, as also predicted by [1]. This "Deep Eclogitic Pool" then splits up into two lobes that feed two separate shallow plumelets, particularly for significantly higher eclogite contents in the center than the periphery of the underlying plume stem. These two plumelets sustain two separate melting zones at the base of the lithosphere, which are elongated in the direction of plate motion due to interaction with small-scale convection. Such a "forked plume" morphology can account for hotspot chains with two widely-spaced (200~350 km) tracks and with long-lived (>5 Myr) coeval activity along each track. Some cases can even account for intermittent tripe-chain hotspot volcanism. Forked plumes may provide an ideal opportunity to study geochemical zonation of the lower-mantle plume stem, because each of the two plumelets robustly samples a distinct sector of the underlying deep plume stem, preserving chemical heterogeneity from the lowermost mantle.

We compare our model predictions to geochemical asymmetry evident along the Wake, Tuvalu and Cook-Austral double-chain segments, which together make up the extensive (>100 Ma) Rurutu-Arago hotspot track. The preservation of a long-lived NE-SW geochemical asymmetry along the Rurutu-Arago double chain indicates a deep origin, likely originating from the southern margin of the Pacific large low shear-velocity province. Our findings highlight the potential of the ocean-

island basalt geochemical record to map lower-mantle structure over space and time, thus complementing seismic-tomography snapshots.

[1] Ballmer et al., 2013 (doi:10.1016/j.epsl.2013.06.022)