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Evolution of whole-mantle plumes: Consequences for hotspot volcanism

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Hotspot volcanism commonly displays bilateral asymmetry of geochemical signatures and temporal variability of volcanic flux. For example, the bilateral expression of volcanism as the "Loa-Kea" double chain is mostly restricted to the young end of the Hawaiian ridge, coinciding with a recent surge of volcanism. Whether these recent changes in hotspot expression are related to lower-mantle or upper-mantle processes remains poorly understood. Using geodynamic models, we here link the ascent of plumes (from the deep mantle to the base of the lithosphere) to surface characteristics of hotspot volcanism. We find that plumes commonly entrain intrinsically dense mafic heterogeneity as they rise from the tops or sides of thermochemical piles (i.e. seismically imaged as "LLSVP") in the deep mantle. This entrainment leads to bilateral plume asymmetry that is stable over 100s of Myrs in the lower mantle, but not consistently transferred into the upper mantle. Instead, any bilateral asymmetry that intermittently occurs in the upper mantle is related to the interaction of the rising plume with the transition zone, and not directly to any structure rising out of the deep mantle. Similarly, plume-flux pulsations on timescales of 10s of Myrs can occur as a whole-mantle plume passes through the transition zone. Such a pulse may account for the general increase of Hawaiian volcanic flux over the last 30-40 Ma. Our geodynamic models show that any intermittent setbacks in volcanic flux have likely been caused by increase(s) in Pacific Plate at ∼20 Ma. Integrated trans-disciplinary studies of plume ascent and volcanism are required to better link surface observations at major hotspots to the structure and dynamics of the lowermost mantle.