Filaments in a laterally heterogeneous plume tail

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Unraveling mantle plume's structure and dynamics using petrological and geochemical observations of surface lavas is certainly a challenging task. For some hotspots (e.g., Hawaii) the question is not only to understand the origin of geochemical variability within each volcano, but to combine observations for different volcanoes and at different times to reconstruct the puzzle of the internal plume structure.

Numerical models of plume dynamics can be useful to constrain the temperature and velocity fields within the plume conduit. Moreover, the advection of passive tracers forward in time allows us to understand how deep mantle heterogeneities are deformed within rising mantle plumes. Our results show that plume tails are laterally heterogeneous, with a highly irregular zonation. Across the plume tail radial variations of the vertical velocity induce a shear stress that readily stretches heterogeneities into long and distinct filaments. Such filaments will be successively sampled by different volcanoes as the oceanic plate moves over the plume tail. Ideally, the isotopic fingerprint of a distinct filament could be detected in several volcanoes of different ages. Our results strongly indicate that filaments represent a fluid dynamically consistent framework to interpret space and time geochemical variability of hotspot lavas.

An explanation of the longevity and composition of hotspot volcanism in terms of the dynamics of mantle plume formation

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A physical link has been proposed between hotspots, regions with particularly persistent, localized, and high rates of volcanism, and underlying low viscosity deep mantle plumes constructed of large spherical heads and long-lived narrow trailing conduits. This plume model has provided a way to interpret observable phenomena including the volcanological, petrological and geochemical evolution of large igneous provinces, ocean island volcanoes, the relative motion of plates, continental breakup, global heat flow and the Earth's magnetic field within the broader framework of the thermal history of our planet. An essential test of the mantle plume hypothesis is to understand the longevity and composition of hotspot volcanism in terms of the mechanics governing the formation of mantle plumes at ther core-mantle boundary. Using a combination of laboratory experiments, numerical simulations and scaling analyses we show that: 1) The high temperatures (and low viscosities) inferred for mantle plumes are likely a result of strong cooling of the mantle by large-scale stirring driven by plate tectonics; 2) The head-tail structure of such plumes is a necessary but insufficient condition for their longevity; 3) The longevity, spatial position and composition of mantle plumes are a consequence of interactions between plate tectonics, core cooling and a dense, low viscosity layer within D”, which is plausibly composed of a mixture of silicate partial melt and outer core material. Under certain conditions, analysis of entrainment from this dense layer leads to a prediction that the variation in $^3He/^4He$ (or any tracer of the silicate component of the lower mantle plume source) will be proportional to plume buoyancy flux, which is broadly consistent with observations.