Dynamics and internal structure of a mantle plume conduit

Recent studies on Hawaiian lavas, including those made possible by the 3000m drill core into Mauna Kea Volcano (Hawaiian Scientific Drilling Project, HSDP) have provided a rich detail of the plume compositional heterogeneity, which is seen on several length and time scales, ranging from differences in melt inclusion compositions of single olivine crystals to broad differences between the two parallel volcanic chains (the so called Kea and Loa trends).

However, the interpretation of such observations in terms of plume internal structure is far from straightforward and several models have been proposed. The pioneering work by Hauri et al., (1996) suggested a concentrically zoned plume structure induced by entrainment of surrounding mantle, while more recent models interpret the shorter-term compositional fluctuation of the HSDP lavas as reflecting predominantly vertical fluctuations of the rapidly rising plume (Blichert-Toft et al., 2003) or predominantly horizontal variations associated to vertical filaments in the plume conduit (Abouchami et al., 2005).

Clearly, a better understanding of how the geochemical observations reflect the actual compositional structure of the plume requires an understanding of plume dynamics. Deep mantle plumes are often thought of as thermal structures, the key parameter being their excess temperature with respect to the surrounding mantle, while the associated velocity field is frequently neglected. However, in order to understand the internal structure of a plume conduit it is necessary to change perspective and focus on velocities and strain rates. Like the hands of an invisible sculptor, velocity gradients constantly modify the shape of heterogeneities rising in the plume conduit.

Our high resolution numerical simulations show how initial heterogeneities in the basal thermal boundary layer evolve as they are drawn into into the plume conduit and transported upward in the Earth's mantle, and subsequently how they are deformed when the plume approaches a fast (9 cm/yr) moving oceanic lithosphere. Our two main objectives are: First, to investigate the relation between initial length-scales of heterogeneities across D'' and the length- and time-scale of geochemical variations induced in the plume conduit. Second, to investigate the relation between heterogeneous structures in the mantle plume and the spatio-temporal geochemical variability registered by the volcanos drifting over an heterogeneous plume.

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