Displaced helium in mantle plumes

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The distribution of primordial He and Ne in the mantle is the subject of lively debate. Here we assume that these primordial gases enter the source regions of some mantle plumes from an external reservoir such as the D'' layer at the base of the mantle [1]. Support for (though not proof of) this is derived from geochemical mapping of He and Ne at hotspot locations ascribed to plumes. On Iceland and the adjacent MAR, high $^3He/^4He$ is centered on the hotspot. At Amsterdam-St. Paul on the SEIR, high $^3He/^4He$ is also centered on the hotspot, but also appears on the normal ridge segment N of the Amsterdam fracture zone. On the Hawaiian and the Galapagos hotspots, the high-$^3He/^4He$ signal is asymmetrically distributed toward the "edge" of the plume on Loihi and Fernandina, respectively. In all three cases, the He signal is offset from the plume center in the "upstream" direction of asthenospheric flow driven by local plate motions. We propose that this asthenospheric flow tilts the plume. Primordial He, initially located in the plume center, is strongly partitioned into a small amount of carbonatite liquid [2], which forms in the plume at depths of 400 km or more, migrates vertically through the tilted plume, and displaces the helium maximum from the plume core toward its margin.

We model this process for the Hawaiian plume to explain the $^3He/^4He$ maximum located in Loihi melts, which sample the front edge of this plume rather than its center. Relative ascent velocities of this (low-ρ, low-μ) carbonatite liquid are on the order of tens of centimeters/year. The model predicts significant displacements of the He signal derived from plume cores and decoupling of He from Sr, Nd, Pb isotope signatures in tilted plumes, if helium is similarly incompatible in the mantle as carbon. This is consistent with the similar $^3He/C$ ratios found in OIB as in MORB and experimental data [3]. The high rates of migration are consistent with permeabilities inferred from [4, 5].

[1] Tolstikhin & Hofmann (2005) Phys. *Earth Planet. Int.* **148**, 109-130. [2] Dasgupta & Hirschmann (2006) *Nature* **440,** 659-662. [3] Heber *et al*. (2007) *GCA* **71,** 1041-1061. [4] Minarik & Watson (1995) *Earth Planet. Sci. Lett.* **143,** 423-437. [5] Wark *et al*. (2003) *J. Geophys. Res*. **108,** 10.1029/ 2001JB001575.

Sub-micron scale Ti variations in zircons of known provenance

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The Ti-in-zircon geothermometer has been applied to zircons from rocks of both known (e.g., [1]) and unknown (e.g., [2]) provenance. Hofmann *et al*. [3] have recently shown that Ti concentrations ([Ti]) in Hadean zircons from the Jack Hills, Australia, are positively correlated with other trace elements and cathodoluminescent (CL) banding at the sub-micron scale; these correlations suggest that Ti partitioning in zircon is dependent upon non-equilibrium effects in addition to temperature and/or that the incorporation of co-varying trace elements (e.g., Y, P, Ce) affects Ti partitioning. Here we consider whether younger zircons of known provenance show similarly correlated trace-element distributions.

Zircons from volcanic and plutonic rocks (i.e., Toba and Bishop Tuffs, Quottoon quartz diorite and Sierra Nevada batholith) and metamorphic zircons from an Adirondack migmatite were analyzed down to length scales of ca. 300 nm using a CAMECA NanoSIMS 50L ion microprobe with an O- primary beam. All data were calibrated by comparison to primary and secondary standards previously characterized by other laboratories. The external precision of our measurements on 2-µm raster images is typically < 10%.

Most volcanic and plutonic zircons we analyzed display positively correlated [Ti], [P], [Ce], and [Y] conformable to oscillatory µm- to sub-µm CL zonations. In these cases, high trace-element concentrations correspond to CL-dark regions, and [Ti] varies by a factor of ~2-3 between adjacent oscillatory CL bands. These variations resemble those observed in Jack Hills zircons [3]. One Toba zircon exhibits a different zoning pattern in which [Y], [P], and [Ce] are positively correlated with one another and *negatively* correlated with [Ti] (all concordant with CL bands); average trace-element concentrations in this zircon are a factor of 3-5 times higher than those we have observed in other samples. We are synthesizing zircons from granitic melt compositions in order to deconvolve Ti temperature-dependent equilibrium partitioning from potential kinetic effects and/or Ti partitioning as a function of [Y], [P], or [Ce].

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