^{190}Pt-^{186}Os isotopic systematics of the upper mantle and some plumes

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An important factor in determining the physical and chemical evolution of the Earth is the scale of convection in the mantle. If convection is restricted to separate cells within the upper and lower mantle, then little material transport likely occurs across the 670 km discontinuity. If whole mantle convection occurs, which is predicted on the basis of various geophysical observations, then some plumes are likely to have been generated at the core-mantle boundary in the D″ layer. Highly fluid metal from the outer core is likely transported into the lowermost kilometers of the D″ layer by capillary flow (Jeanloz, 1990). Low seismic velocities in the D″ layer have been interpreted in terms of chemical interactions between the mantle and core (Jeanloz and Garnero, 1997). Therefore, if plumes are generated from the D″ layer, compositional evidence for core-mantle interaction may be present in lavas derived from such plumes.

Walker *et al.* (1995) proposed that some radiogenic ^{187}Os present in some ocean island basalts could result from addition of outer core material into the D″ layer source of some plumes. This is because during solidification of the inner core, partitioning of Re and Os between solid and liquid metal may result in enrichment of Re/Os in the outer molten core relative to chondrites. Because of the predicted suprachondritic Re/Os ratio and high abundance of Os (*c.* 1 ppm) in the outer core, only small additions of outer core liquid ($\leqslant 1\%$) are required to produce the observed $^{187}Os/^{188}Os$ ratios of ~0.130 to 0.140 in OIB. For instance, if the inner core formed early, Walker *et al.* (1995) calculated that the outer core would have a $^{187}Os/^{188}Os$ of ~0.137, assuming Re and Os partitioning during core crystallization similar to that in asteroidal cores.

Because radiogenic $^{187}Os/^{188}Os$ in OIB can be interpreted to result from core-mantle interaction or crustal recycling in their source regions, additional evidence is needed to determine whether core-mantle interaction can be identified. Walker *et al.* (1995) suggested that inner core crystallization may also enrich the Pt/Os ratio of the outer core relative to chondrites. ^{190}Pt decays to ^{186}Os via the α transition ($\lambda = 1.542 \times 10^{-12} a^{-1}$). Consequently, the long-term Pt/Os ratio of a geological reservoir can be monitored via examination of the $^{186}Os/^{188}Os$ ratio of that reservoir. Because of the high Pt/Os ratio that may be present in the outer core resulting from inner core crystallization and using the same inferences for the Re-Os abundances by Walker *et al.* (1995), the outer core would have an approximately 0.01% more radiogenic $^{186}Os/^{188}Os$ than a chondritic mantle allowing for 4 to 4.5 Ga of *in situ* growth of ^{186}Os. Given these constraints, to detect variations in $^{186}Os/^{188}Os$ for plume-derived lavas that might be radiogenic relative to depleted upper mantle, precisions of better than $\pm 0.005\%$ must be obtained on $^{186}Os/^{188}Os$ measurements.

As a first step in examining whether $^{186}Os/^{188}Os$ ratios vary between the upper oceanic mantle and plumes, we have determined high-precision $^{186}Os/^{188}Os$ and $^{187}Os/^{188}Os$ ratios for 10 Os-Ir alloys and 3 chromitites from peridotite massifs and ophiolites worldwide, 2 abyssal peridotites from ODP Leg 153 (Site 920). These materials should provide an upper mantle $^{186}Os/^{188}Os$. Also, 5 picrites from Hawaii were analysed. Hawaiian picrites were chosen because Hawaiian magmas are derived from one of the longest-lived hotspots on Earth. This characteristic points toward an unusually high thermal anomaly beneath the Hawaiian islands, and potentially this is the most favourable present-day case for upwelling of material from the deep mantle.

Results and discussion

The Os-Ir alloys, chromitites, and abyssal peridotites, have $^{187}Os/^{188}Os$ ratios ranging from 0.119861 to 0.127343, though most samples are at the more radiogenic end-member, consistent with derivation from the recent upper mantle. Averages for triplicate analyses of each of the Os-Ir alloy and chromitite samples for $^{186}Os/^{188}Os$ range only from 0.119304 to 0.1198365. Uncertainties (2σ) for each sample are in the 25 to 35 ppm range, hence, there is no significant variation within this suite. The average $^{186}Os/^{188}Os$ for all 10 samples is 0.1198340 ± 12 (n = 30). This average is identical, within uncertainty, to the $^{186}Os/^{188}Os$ ratio of 0.1198310 ± 60 measured for the carbonaceous chondrite Allende (Walker *et al.*, 1997). The two abyssal peridotites give $^{186}Os/^{188}Os$ ratios of 0.1198347 ± 50 and 0.1198345 ± 57. These $^{186}Os/^{188}Os$ values are indistinguishable from those of the Os-Ir alloys and chromitites, and are also within uncertainty of the $^{186}Os/^{188}Os$ ratio for Allende. The similarity between Allende and these upper mantle samples indicates limited fractionation (<30%) of the long-term Pt/Os ratio for the upper mantle.

In contrast to these upper oceanic mantle materials, results for picrites from Hawaii have $^{186}Os/^{188}Os$ = 0.119841–0.119852. In addition, a Noril'sk ore with a chondritic Pt/Os ratio and γ_{Os} = +8.5, has a $^{186}Os/^{188}Os = 0.1198491 \pm 53$ (Walker *et al.*, 1997). These $^{186}Os/^{188}Os$ ratios are significantly more radiogenic than the presumed upper oceanic mantle samples, consistent with long term Pt/Os enrichment in the sources of the Os contained in these materials. What is more striking is that there is a linear relation between $^{186}Os/^{188}Os$ and $^{187}Os/^{188}Os$ for the Hawaiian and Noril=sk samples. Such a correlation was predicted by Walker *et al.* (1995) to result from core-mantle interaction. Linear systems are very unlikely to occur as a result of crustal recycling into the sources of these plumes. Further, >>80% of ocean crust is required to generate the observed 0.008 to 0.018% of excess ^{186}Os in the Hawaii and Noril=sk samples (Brandon *et al.*, 1998). Therefore, we believe the Os isotopic data for these rocks are best explained by additions of small amounts of outer core (0.3 to 1.0 weight %) to plumes originating deep in the lower mantle.

References

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