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Mantle Components and Mantle Reservoirs: Bridging the Disconnect

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Several geochemical components have been identified in the convecting mantle based on isotopic data for Mid-Ocean Ridge Basalts (MORB) and ocean island basalts (OIB). However, because geochemical data contains little or no depth information, the simple recognition of a geochemically identified "component" does not by itself implicate a specific "reservoir" whose location is known or inferred from independent geophysical data (the upper mantle source of MORB being the lone exception). The original classification of mantle components into 4 or 5 distinct mantle end-members (Zindler and Hart, 1986) held out some hope of making a connection between small numbers of components and reservoirs, but this taxonomy appears now to be overly simplified. Increasing characterization of these mantle components using newly-applied radioactive and stable isotope systems (Eiler et al., 1996; Lassiter and Hauri, 1998) suggests the widespread presence of recycled slabs in many (but not all) mantle plumes, however the presence of these slabs does not result in a uniquely identified mantle component and rare gas isotope systematics do not appear to conform strictly to this identification. In addition, the possible products of core-mantle interaction are suggested in at least one hotspot (Hawaii; Brandon et al., 1999). While the current zoology of mantle plume compositional end-members (based on the DMM-HIMU-EM1-EM2 tetrahedron, Hart et al. 1992) may be reflecting specific processes, it now appears likely that the chemistry of each hotspot is the result of a unique history of surficial alteration, subduction zone processing, core-mantle interaction, aging and mixing of diverse melts during upwelling, rather than being a specific mixture of a limited number of homogeneous components.

At first blush, these developments would seem to greatly complicate the effort to link specific geochemical components with large-scale mantle reservoirs identified from global seismic data. However, one common denominator among many hotspots is the presence of recycled ancient mafic crust (Hauri and Hart, 1997). The physical properties of recycled mafic crust should be sufficiently different from mantle peridotite to predict its accumulation and storage time from fluid dynamical models, and to identify regional concentrations of recycled slabs from seismic studies. The same may also be true of the products of core-mantle interaction, but the geochemical identification of core material in hotspots is more controversial at the present time.

Recent models invoking a hot, chemically dense reservoir below 1500km depth (Kellogg et al., 1999) are consistent with geochemistry and global seismic tomography, and seem to be required based on an apparent 6-8TW deficit in radiogenic mantle heat production. However, the heat production of recycled mafic crust has not previously been included in a global heat budget. If the recycled crustal reservoir has MORB-like K, Th and U concentrations, then it would need to make up 5-10% of the mantle (by mass) to balance the heat flow budget. This is exactly the amount required to balance the depletion of the Re/Os ratio in the upper mantle (Hauri and Hart, 1997). Although the mantle helium isotope systematics might be explained by such a dense layer in the lower mantle (e.g. van Keken and Ballentine, 1999), it need not be hot. Indeed, a mild depletion of K, Th, U, Rb and LREE in this layer would be consistent with the isotopic composition of Sr, Nd and Pb in those hotspots characterized by high ^{3}He/^{4}He ratios (Hauri et al., 1994).

The resolution of plume-scale and planetary-scale fluid dynamic and seismic studies is improving. At the same time, mantle geochemistry is capable of placing increasingly specific constraints on the composition of regions of the mantle. Opportunities for bridging these disciplines should not be missed, but such opportunities are presently limited by several factors. Among them are the paucity of data on the rheological and seismic properties of high-pressure mineral phases, the lack of global seismic coverage in the oceans (where most of the hotspot geochemical effort is focussed), and the expense of dense ocean-bottom teleseismic studies which might identify (or at least clarify) the depth of origin of mantle plumes.

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