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He-3 and other isotopes in the lower mantle: the HSDP perspective

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The Hawaii Scientific Drilling Project recovered 2.85 km of core from the Mauna Kea volcano. The lavas show systematic stratigraphic variation of isotopic ratios. These variations can be mapped into radial variations in the mantle plume magma source. Interpretations must incorporate models for the relationships between the plume thermal structure, upwelling velocity structure, and melting processes. Models of Ribe and Christensen (1999) and Hauri et al. (1994) are used.

Due to the ca. 80 km thickness of the lithosphere under Hawaii, only the hottest, central portion of the plume melts, and hence the lava sequence records only the structure of the plume core region. At the average depth of melting (120km), the melting region is roughly circular and 100km wide, whereas the thermal anomaly that represents the plume is about 400km wide. At deep levels, before the plume starts to spread beneath the lithosphere, the thermal anomaly may be 250-300 km wide.

Isotopic data on He, Sr, Nd, Pb, Hf, and Os (among other elements) have been collected and are mostly published (Eisele et al., 2003; Blichert-Toft et al., 2003; Kurz et al., 2004; Bryce et al., 2004). Within the plume melting region there are strong gradients in ^3He and ^{208}Pb , weaker gradients in Hf and Nd isotopes, and very weak gradients in Os, Sr, and ^{206}Pb isotopes. The He-3 anomaly has a width of only about 25km, 10% of the thermal radius of the plume, which suggests that Hawaiian He-3 is coming from the base of the mantle (the core or a dense layer mantling the core), and that most of the lower mantle has $R/\text{Ra} \approx 6-8$. Hawaiian Sr, Nd, Os, Hf isotopes show only weak stratification in the lower mantle.

The tentative conclusion is that most of the lower mantle under Hawaii is not enriched in $^3\text{He}/^4\text{He}$; but instead is similar to the upper mantle. Only the base of the lower mantle is enriched in $^3\text{He}/^4\text{He}$. The distinct isotopic signatures of the other elements are more broadly representative of the lower mantle.

References

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Isotopic signature in OIB mantle sources: The metasomatic alternative

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Metasomatized lherzolites from the deep portions of recycled oceanic lithosphere, rather than subducted oceanic crust, may be the principal component of OIB sources [1]. However, the exact chemical and physical nature of this metasomatic process and how this process produces chemical variations in recycled lherzolite that reflect the different OIB isotopic "signatures" is unclear. Chemical variations observed in the Cantal basalt (France), interpreted as the result of a lithospheric metasomatic mechanism, provide important new constraints on the nature of this metasomatic process.

The Cantal basalts, similar to OIB in composition, show unusual variations in Nb/Th, Nb/U, La/Nb and Ce/Pb ratios from the first to the last emitted basalt. We postulate that these trace element variations result from an evolution of metasomatic vein composition present in a vein-plus enclosing lithospheric mantle source [2].

These different basalt compositions allowed us to constrain the trace element variation generated by the evolution of a metasomatic agent within the lithosphere. Reconstruction of different part of the lithosphere indicates significant heterogeneities in Th/Pb, U/Pb and Sm/Nd resulting from the metasomatic process. If this type of metasomatized lithosphere was subducted and isolated during a long period of time (1-2 Ga), the chemical variations would create Nd and Pb isotopic variations in this heterogeneous lithosphere similar to isotopic range observed in some oceanic islands. Moreover, these isotopic variations would be correlated with trace element ratio variations commonly interpreted as the product of mixing between different end-member mantle components (HIMU and EM). This suggest that isotopic and trace element variations observed in basalts from individual oceanic islands may more likely be the result of melting metasomatized subducted oceanic lithosphere rather than from a mixture of chemically distinct mantle sources that formed and evolved independently from one another. A change in the interpretation of OIB source material, as proposed here, implicates a re-evaluation of the nature of the process which controls the chemical evolution of Earth's mantle.

References

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