The use of thallium isotopes to trace ferromanganese sediments in the mantle sources of ocean island basalts

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Ocean island basalts (OIB) are generally thought to be the surface expression of mantle plumes. One model infers that OIBs originate from a deep mantle source, which was previously contaminated with ocean crust that entered the mantle via subduction zones.

Thallium is one of the heaviest elements in the periodic table (isotopes ^{203}Tl and ^{205}Tl) and has a large ionic radius, which makes it incompatible in mantle minerals and leads to its enrichment in melts and the continental crust, as well as a strong affinity for subduction-related fluids. Moreover, Tl is strongly enriched in both sediments and altered basalts compared with the mantle such that even small additions to the mantle should contribute significantly to the overall Tl isotope composition of the mixture. The advent of the technique of multi-collector inductively coupled plasma mass spectrometry (MC-ICPMS) recently allowed the first high-precision isotope composition measurements of Tl. Although Tl is a very heavy element, large isotopic fractionations of up to 20 $\varepsilon^{205}Tl$-units (where $\varepsilon^{205}Tl = 10^4 \times (^{205}Tl/^{203}Tl_{sample} - ^{205}Tl/^{203}Tl_{NIST\ 997}) / ^{205}Tl/^{203}Tl_{NIST\ 997}$) between seawater and seafloor ferromanganese sediment deposits were observed. Hence, Tl isotope ratios may be an excellent monitor of Fe-Mn sediment additions to OIB source regions. We have therefore measured the Tl abundances and isotope compositions of 11 Hawaiian picrites in order to determine if the Hawaii mantle source contains Fe-Mn sediments.

The Tl isotope compositions of the Hawaiian picrites vary from $\varepsilon^{205}Tl = -3.1$ to $+3.8$, whereby the most positive values are about 6 ε-units "heavier" compared to the depleted mantle as represented by MORB which displays $\varepsilon^{205}Tl \approx -2$. Additionally, the Tl isotope data display a negative correlation with Cs/Tl ratios. Thallium and Cs exhibit very similar incompatibilities in igneous processes and are therefore not expected to fractionate during partial melting or magma differentiation processes. As a consequence, it appears likely that a component with positive $\varepsilon^{205}Tl$ and low Cs/Tl contributed to the Hawaiian lavas. In addition to high Tl contents and positive $\varepsilon^{205}Tl$-values, Fe-Mn sediments are known to display low Cs/Tl ratios. The correlation between $\varepsilon^{205}Tl$ and Cs/Tl is therefore most readily explained by the addition of Fe-Mn sediments into the Hawaiian mantle source region. Assuming that ancient Fe-Mn sediments are similar in Tl concentration and isotope composition to their modern analogues quantitative modelling shows that less than 25 ppm of Fe-Mn sediments by weight need to be added to a primitive mantle source in order to explain the observed variations.