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Os, Hf, Nd and Sr Isotope Analyses from the Pitcairn Hotspot: Constraints on the Composition of EM1

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Introduction

Identification of recycled lithospheric material in ocean island basalts (OIBs) using radiogenic isotope systems is an important means to constrain the chemical geodynamics of the Earth's mantle. The isotope topology of the mantle is conventionally explained by mixing between depleted and enriched components (DM, HIMU, EM1 and EM2) (Zindler and Hart, 1986). While involvement of oceanic crust in the HIMU component and recycling of terrigenous material in EM2 is well established, the nature of the EM1 component is a matter of debate. Two hypotheses have been invoked to explain the nonradiogenic Nd-, Pb- and intermediate Sr-isotopic composition of EM1: recycling of subcontinental lithospheric mantle and recycling of oceanic crust with pelagic sediment. Here, we attempt to distinguish between these two components in the lavas from Pitcairn hotspot by utilizing Os, Nd and Hf isotopes. Os isotopes are ideally suited to demonstrate the presence of ancient subcontinental lithospheric mantle as the latter is the only reservoir possessing subchondritic $^{187}Os/^{188}Os$ ratios (<0.120). On the other hand, decoupling between Nd and Hf isotopes, which usually define a tight mantle array (Vervoort et al., 1999), indicates an ancient pelagic sediment component in the source of OIBs (Blichert-Toft et al., 1999). Pitcairn lavas are the most extreme example of EM1 in Nd, Sr and Pb isotope space (Woodhead and Devey, 1993). Woodhead et al. (1993) found high $\delta^{18}O$-values in glasses from the Pitcairn seamounts and suggested that they resulted from crustal recycling. These results could not be substantiated by Eiler et al. (1995), who analysed oxygen isotopes in olivines from island lavas.

Results

We examined tholeiites, hawaiites and potassic trachybasalts from the shield-building Tedside (0.95 to 0.76Ma) and post-erosional Pulawana volcanics (0.67 to 0.45Ma) from Pitcairn Island and basaltic glasses from Pitcairn seamounts. Os isotopic ratios range between $^{187}Os/^{188}Os$=0.129 to 0.254 with Os concentrations, [Os], between 2 and 303pg/g. Radiogenic $^{187}Os/^{188}Os$ ratios (>0.15) occur only in low [Os] samples (<20pg/g) and could reflect contamination during magma emplacement at shallow depths. The Nd, Hf and Sr isotopic values range between ε_{Hf} = -5.3 to +2.19, ε_{Nd} = -5.99 to +1.01 and $^{87}Sr/^{86}Sr$ = 0.7036 to 0.7053 and show linear correlations. Pb isotopic values on the seamount samples were reported to range between $^{206}Pb/^{204}Pb$ = 17.46 and 18.04 (Woodhead and Devey, 1993). In Os-Nd space (Figure 1), the high [Os] samples of Tedside volcano and Pitcairn seamount appear to form two distinct arrays with opposite slopes. Different enriched end-members in the island and seamount lavas also emerge in other isotope systems: in Nd-Sr and Hf-Sr isotope correlations, most of the Pitcairn Island data are offset toward lower ε_{Hf} and ε_{Nd} values by one to two units relative to the seamount. In an ε_{Hf} versus ε_{Nd} diagram Pitcairn Island and seamount define similar, but not identical trends with slopes that are shallower than the mantle array, with slopes of 1.0 and 1.3 (R^2 = 0.97 and 0.99).

Conclusions

(1) We have not found subchondritic Os isotopic ratios and therefore, there is, at present, no indication of recycled ancient lithospheric mantle at Pitcairn. (2) Radiogenic Os isotopes could stem from contamination processes in low [Os] samples. High [Os] samples show different slopes in correlation with other isotopes for the island and seamount. The radiogenic Os isotopic ratios could be produced by several processes, including recycling of crustal material or preferential melting of radiogenic mantle domains. (3) The linear data arrays in Nd-Sr, Hf-Sr and Nd-Hf isotope plots show mixing between a depleted and an enriched end-member with small but significant differences between the subaerial and submarine samples. Pitcairn Island has a plume end-member that is less radiogenic in Sr, more radiogenic in Os, Nd and Hf than Pitcairn seamount. (4) The shallow slope in the ε_{Hf} - ε_{Nd} correlation indicates an end-member that has fractionated Lu/Hf from Sm/Nd, most likely an ancient recycled pelagic sediment component. (5) Recycling of oceanic crust and a sedimentary component with low Lu/Hf and Sm/Nd, variable Re/Os and high Rb/Sr-ratios could explain the present-day composition of the Pitcairn hotspot. Mixing calculations indicate that the natural variations in these ratios in such a recycled component could produce the distinct isotope arrays observed in Pitcairn island and seamount.

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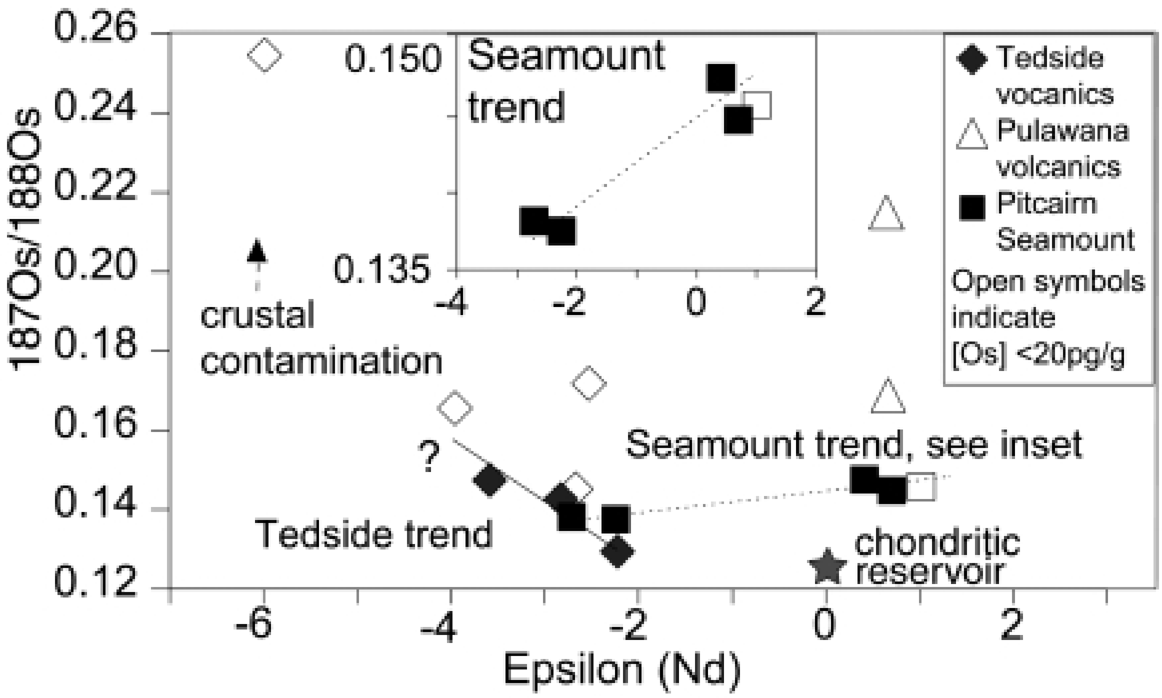

Figure 1: Os-Nd correlation for Pitcairn Island and seamount

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