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A hidden mantle reservoir in the continental lithosphere? Evidence from Hf-Sr-Nd-Pb isotopes in megacrysts and kimberlites

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Hidden mantle reservoirs with distinct isotopic compositions have been proposed to explain several apparent differences between the isotopic composition of the mantle inferred from oceanic basalts and estimates of the bulk silicate earth (BSE) composition based on meteorites (e.g., $^{142}Nd/^{144}Nd$, coupled $^{143}Nd/^{144}Nd$-$^{176}Hf/^{177}Hf$ and noble gas isotope variations). In particular, the displacement of the εNd-εHf array for oceanic basalts away from the BSE composition toward toward slightly more radiogenic eHf values has prompted speculation that a complementary reservoir exists that has relatively unradiogenic Hf for a given Nd isotope composition [e.g., 1]. Ancient subducted crust has been proposed to constitute such a hidden reservoir, segregated at a deep mantle boundary layer (e.g., the transition zone or core-mantle boundary region) and tapped by kimberlite magmatism [e.g., 2, 3]. However, evidence presented here suggests that a hidden reservoir with unradiogenic Hf may rather exist within the continental lithosphere itself.

New Hf-Sr-Nd-Pb isotope data for clinopyroxene kimberlite megacrysts show isotopic variations that correlate systematically with crystallization temperature. These megacrysts come from Cretaceous southern African Group 1 kimberlites, with 6-8 megacrysts analysed per suite, selected to span a range of compositions (Cr-poor to Cr-rich) and crystallization temperatures based on Ca# (i.e., Ca/(Ca+Mg)). In each suite studied, the samples with the highest crystallization temperatures have the lowest $^{87}Sr/^{86}Sr_i$ (0.7027-0.7032), highest εNd(t) (3.5-6.5) and highest $^{206}Pb/^{204}Pb_i$ ratios (19.6-20.7), similar to 'HIMU' or 'FOZO' ocean island basalts, and have εNd-εHf values that fall only slightly below the global oceanic basalt array. As crystallization temperatures decrease, the $^{87}Sr/^{86}Sr$ values of the megacrysts increase and εNd, εHf and $^{206}Pb/^{204}Pb$ values all decrease. The samples that crystallized at the lowest temperatures typically fall furthest (up to 8.5 εHf units) below the Nd-Hf oceanic basalt array. This pattern is most easily explained by assimilation of a lithospheric component that has anomalously low εHf compared to εNd, combined with high $^{87}Sr/^{86}Sr$ and low εNd and $^{206}Pb/^{204}Pb$ values. The above isotopic variations are also correlated with increases in Hf concentration and decreases in $(Lu/Hf)_N$ ratios. The Sr-Nd-Hf isotope variations observed in the megacryst data from this study are virtually identical to those previously described for kimberlite megacrysts [e.g. 2,4], but these earlier studies lacked the crucial major element information on crystallization temperature. Variations in the Hf-Sr-Nd-Pb isotope compositions of southern African (and some Canadian) Group 1 kimberlites are broadly similar to those seen in the megacrysts and may be explainable through mixing of similar source components [e.g., 2, 3, 5, 6].

Although many metasomatised peridotite xenoliths from ancient continental lithosphere have Sr, Nd and Pb isotopic characteristics in common with the lithospheric component inferred from the megacrysts, these xenoliths tend to have low Hf concentrations and radiogenic eHf values (falling well above the Nd-Hf oceanic basalt array) that rules out cratonic peridotite as a plausible candidate for the low-eHf source component in kimberlite megacrysts. Rather, if this unradiogenic Hf component is present in the lithosphere, it does not appear to be well-represented in mantle xenolith suites. Recent isotopic measurements of cpx from southern African MARID xenoliths [7] suggest that this material could represent an appropriate source for the low-eHf component, although other metasomatic xenolith types (e.g., the phlogopite-ilmenite-clinopyroxene or PIC suite; [8]) might also have appropriate isotopic compositions. Identifying this component will require better Hf-Sr-Nd-Pb isotopic characterisation of a range of metasomatic xenolith types.

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