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Hf and Nd isotope systematics of early Archean komatiites from surface sampling and ICDP drilling in the Barberton Greenstone Belt, South Africa

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Abstract

To constrain the origin of komatiites from the Barberton Greenstone Belt, South Africa, we measured ^{147}Sm-^{143}Nd and ^{176}Lu-^{176}Hf compositions for 18 komatiites from core obtained during the International Continental Drilling Program in the Komati Formation of the Barberton Belt, as well as 33 komatiites from surface outcrops of the Komati, Hooggenoeg, and Weltevreden Formations, these latter for purposes of comparison between core and surface samples. Magmatic clinopyroxene from surface samples near the drill site was also analyzed. For the Lu-Hf isotope system, the Komati Formation core and surface samples including the clinopyroxene define a linear array whose slope corresponds to an age of 3426 ± 16 Ma (MSWD = 118; $\varepsilon_{Hf(T)}$ = +2.2), which is slightly younger than the accepted age of the rocks (3.48 Ga). The Sm-Nd isotope data for the same set of samples likewise fall along a linear array also yielding a younger age of 3339 ± 12 Ma (MSWD = 42; $\varepsilon_{Nd(T)}$ = +2.8). The high MSWD for both isotope systems indicate substantial scatter at variance with normal magmatic processes, likely implying element mobility disturbing even these relatively robust isotopic systems shortly after eruption of the lavas. The average initial ε_{Nd} and ε_{Hf} of the core samples at 3.48 Ga are +0.45 and +1.4, respectively, in overall accordance with the positive errorchron intercepts and a depleted mantle source at 3.5 Ga. In contrast, the clinopyroxene and their host rocks have strongly positive $\varepsilon_{Hf(T)}$ of about +5 and negative $\varepsilon_{Nd(T)}$ of about –2. Given the overall scatter of the whole-rock data, the most robust constraint on the composition of the komatiite source comes from the clinopyroxene. Their positive $\varepsilon_{Hf(T)}$ is in line with, though somewhat higher than other results from komatiites from the Komati Formation, but their negative $\varepsilon_{Nd(T)}$ is unexpected in that it indicates a source with long-term low Sm/Nd, which is at odds with its long-term high Lu/Hf. This signature is also found in the trace element compositions of some of the komatiites, such as moderately enriched LREE, negative Hf anomalies, and low Hf/Sm ratios. The origin of these features is uncertain but one possibility is that the discordance between the Hf and Nd isotope systems reflects the presence of deep-sea sediments in the source of some of the Barberton komatiites. The possible presence of a surface component in an ancient deep mantle source has wide-ranging implications for mantle-crust interaction and dynamics in the early Earth and for constraining a minimum age for the onset of plate tectonics.

Keywords: Komatiites, clinopyroxene, deep-sea sediment, chert, Barberton Greenstone Belt, Lu-Hf isotopes, Sm-Nd isotopes, International Continental Drilling Program, Invited Centennial article