Mantle heterogeneities in early Earth

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The heterogeneous nature of the terrestrial mantle in terms of its chemical composition and physical properties has long been known; however, the origin of these heterogeneities and their residence time in the mantle are not fully understood. Some of the heterogeneities may have been inherited from the time of accretion or crystallization of a primordial magma ocean, while others may be due to recycling of crustal materials back into the mantle. Yet others may have resulted from changes in the thermal regime of the planet affecting the melting process through time, and some may simply represent sampling bias as only a tiny fraction of the mantle is accessible for study, and even that fraction is usually not directly representative of the mantle as a whole. In order to address these issues, we have used combined $^{143}Nd/^{144}Nd$ and $^{176}Hf/^{177}Hf$ systematics of komatiite/basalt systems from around the globe ranging in age from 3.55 to 0.089 Ga to establish the composition and evolution of mantle sources through Earth history, in particular its earliest eras. Although the majority of the data (Kostomuksha, Abitibi, Belingwe, Birimian, Ottawa Islands, and Gorgona) plot on the terrestrial evolution curve in time-integrated $^{147}Sm/^{144}Nd$–$^{176}Lu/^{177}Hf$ and $\varepsilon^{143}Nd(T)$–$\varepsilon^{176}Hf(T)$ space and show a broad increase from values close to chondritic in the oldest komatiite systems to $\varepsilon^{143}Nd(T) \approx +10$ and $\varepsilon^{176}Hf(T) \approx +18$ in the youngest Gorgona komatiites, there are notable exceptions. First, all the studied early Archean rocks (*i.e.*, Schapenburg, Komati, and Weltevreden) plot well above the curve due to elevated time-integrated Lu/Hf at a given Sm/Nd, reflected in correspondingly high $\varepsilon^{176}Hf(T)$ at a given $\varepsilon^{143}Nd(T)$. This feature most likely attests to the derivation of these komatiites from remelted crystallization products of a primordial magma ocean in deep mantle plumes. Second, komatiites from the 2.4 Ga Vetreny Belt also plot above the terrestrial evolution curve; however, in this case, the Hf-Nd isotope incongruence is ascribed to the presence of deep-sea pelagic sediments in the Vetreny mantle source. Third, the 2.0 Ga Onega Plateau lavas uniquely plot below the terrestrial evolution curve. These lavas represent close analogues to modern OIB and hence may also have sampled ancient heterogeneities in the mantle. If confirmed, this observation would indicate very sluggish mixing of the terrestrial mantle on the scale of at least 2.5 Ga. Finally, conspicuous decrease in the time-integrated $^{147}Sm/^{144}Nd$ and $^{176}Lu/^{177}Hf$ of komatiite sources over time possibly indicates back-mixing into the deep mantle of a relict early enriched reservoir.