The origin and survival of mantle heterogeneities in early Earth unveiled by komatiites

JANNE BLICHERT-TOFT[1] AND IGOR S. PUCHTEL[2]

[1]ENS de Lyon, 69007 Lyon, France (jblicher@ens-lyon.fr)
[2]University of Maryland, College Park, MD 20742, USA

While the heterogeneous nature of the terrestrial mantle has long been established, its origins along with the mixing times of the mantle are not well constrained. Some of the chemical heterogeneities may have been primordial, reflecting accretion and/or magma ocean crystallization processes. Others may have resulted from processes associated with the dynamic regime of the planet, such as crustal recycling and secular cooling. In order to shed clearer light on the origin and evolution of terrestrial mantle heterogeneities, we modeled our new and previously published $^{143}Nd/^{144}Nd$ and $^{176}Hf/^{177}Hf$ data on komatiite–basalt systems worldwide ranging in age from 3.55 to 0.089 Ga. The data for late Archean and younger komatiite–basalt systems (2.82 Ga Kostomuksha, 2.72 Ga Pyke Hill and Boston Creek, 2.69 Ga Belingwe, 2.42 Ga Vetreny, 2.10 Ga Birimian, 1.90 Ga Ottawa Islands, and 0.089 Ga Gorgona) fall on the terrestrial evolution curve in time-integrated $^{147}Sm/^{144}Nd$–$^{176}Lu/^{177}Hf$ space. However, all so-far studied early Archean komatiite–basalt systems (3.55 Ga Schapenburg, 3.48 Ga Komati, 3.33 Ga Commondale, and 3.26 Ga Weltevreden) plot well above the evolution curve owing to elevated time-integrated Lu/Hf at a given Sm/Nd, as also reflected in high $\varepsilon^{176}Hf(T)$ relative to the corresponding $\varepsilon^{143}Nd(T)$. This feature most likely is due to derivation of these komatiite systems from the differentiation products of a primordial magma ocean. Another example of decoupled behavior is displayed by the 1.97 Ga Onega Plateau lavas that plot well below the terrestrial evolution curve. These lavas represent close analogues to modern OIB and may also have sampled ancient heterogeneities in the mantle, thus suggesting very sluggish mixing of the terrestrial mantle on a timescale of at least 2.5 Ga. The observed decrease in the time-integrated Sm/Nd and Lu/Hf of komatiite sources over Earth history [1] likely indicates gradual back-mixing, on a billion-year timescale, into the deep mantle of a putative early enriched reservoir formed during primordial differentiation of the planet and recently identified in Eoachean rocks. Additionally, [2] found evidence for the presence of pelagic sediments in the deep mantle source of 3.48 Ga Barberton komatiites, placing minimum constraints on the timing of onset of plate tectonics.

[1] Blichert-Toft and Puchtel (2010) EPSL 297, 598-606.
[2] Blichert-Toft et al. (2015) Am. Min. 100, 2396-2411.