Heterogeneity of calcium isotopes in Earth's mantle

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The Earth's mantle has been inferred to have a homogeneous Ca isotope composition based on limited measurements of igneous rocks [1-2]. In order to better understand the behavior of Ca isotopes during magmatic processes, and to provide a robust compositional estimate for Bulk Earth, we have analyzed a representative suite of mantle-derived rocks (n > 50), including mantle xenoliths, oceanic island basalts (OIB), komatiites and carbonatites.

Calcium isotope compositions were analyzed by MC-ICP-MS following methods outlined in [3], and are reported as $\delta^{44}Ca = (^{44}Ca/^{40}Ca)_{sample}/(^{44}Ca/^{40}Ca)_{SRM\ 915a}$. Geostandard analyses agree well with previous measurements using TIMS and double-spike techniques [4-5]. Cogenetic samples from the Canary Islands have similar $\delta^{44}Ca$ despite exhibiting substantial chemical variability, indicating limited isotopic fractionation during fractional crystallization of mafic magmas. However, significant isotopic variations exist amongst different rock types and tectonic settings, with, in general, $\delta^{44}Ca$ decreasing from ultramafic to mafic rocks.

The $\delta^{44}Ca$ values for mantle xenolith samples vary from 0.81 to 1.25 ± 0.10 ‰ (2sd), indicating that Ca is isotopically heterogeneous in Earth's mantle. We infer that this is due to different degrees of partial melting, combined with recycling of ancient crust materials into the mantle and metasomatic alteration [4]. The OIB samples have a smaller $\delta^{44}Ca$ range, ~0.2‰ lighter than the mantle xenoliths. This offset likely stems from Ca isotopic fractionation during partial melting, and implies that the $\delta^{44}Ca$ values of primitive basaltic melts does not represent the composition of the mantle source. The $\delta^{44}Ca$ of komatiites cluster between the average value of basalts and mantle xenoliths, however, samples from the 3.3 Ga Weltevreden Formation (South Africa), which have experienced sea-floor metasomatism, are significantly enriched in heavy isotopes (av. 1.36 ± 0.10‰; n=4). These new results indicate that Ca isotopes are potentially powerful tracers of partial melting and differentiation.

[1] Amini *et al* (2009) *GCA* 73 [2] Simon & Depaolo (2009) *EPSL* **289** [3] Valdes *et al EPSL* (submitted) [4] Huang *et al* (2011) *GCA* **75**. [5] Amini *et al* (2009) *GGR* **33**