Ca isotope systematics of the Moon

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The Moon is believed to have a differentiated mantle that formed as a result of equilibrium and fractional crystallisation of a Lunar Magma Ocean (LMO). Whilst the anorthositic crust is thought to be a direct product of LMO crystallisation through flotation of plagioclase cumulates, the mare basalts represent partial melts of the variably differentiated mantle [e.g., 1]. Crystallisation of the LMO is predicted to induce significant mass-dependent Ca isotope fractionation between these cumulate reservoirs [2]. As such, the Ca isotope composition of lunar basalts is uniquely suited to interrogate LMO crystallisation models. However, precious few Ca isotope data are available for lunar samples.

Multi-collector-ICP-MS is the instrument of choice for high-precision isotope measurements. In the case of Ca, however, measurements are severely hindered by the presence of the high-intensity $^{40}Ar^{+}$ beam, meaning that typically only the minor isotopes of Ca can be measured. We resolve this problem by using Proteus, a collision-cell MC-ICP-MS developed in collaboration with Thermo-Fisher Scientific. Introduction of He and H_2 gas into the collision cell means that Ar^{+} is reduced to baseline levels, allowing direct high-precision measurements of ^{40}Ca. Using this setup, we measured radiogenic ^{40}Ca anomalies, expressed as $\varepsilon^{40/44}Ca$, and mass-dependent Ca variations ($\delta^{44/40}Ca$) of lunar mare basalts reported relative to NIST SRM 915a. Typical precisions (2*s*) are better than 0.5 ε for $\varepsilon^{40/44}Ca$ and better than 0.05 ‰ for $\delta^{44/40}Ca$.

Lunar low-Ti and high-Ti basalts have $\varepsilon^{40/44}Ca$ identical to terrestrial basalts, consistent with the similar K/Ca of the lunar samples and Earth's mantle. A single KREEP-rich sample (15386) has a positive radiogenic ^{40}Ca anomaly of ~0.5 ε relative to the other basalts. Mass-dependent Ca isotope compositions, measured with a ^{42}Ca-^{43}Ca double spike, of the lunar samples are similar to previously reported lunar data [3, 4] and estimates of Earth's mantle.

[1] Snyder *et al.* (1992) *GCA* **56** 3809-3823. [2] Huang *et al.* (2019) *EPSL* **510** 153-160. [3] Valdes *et al.* (2014) *EPSL* **394** 135-145. [4] Simon *et al.* (2017) *EPSL* **472** 277-288.