Investigating the Moon's early differentiation using calcium isotopes

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Recent studies have shown that Ca isotopes fractionate during magmatic processes, suggesting that they are a geochemical tracer with considerable potential [1, 2, 3, 4]. The refractory, lithophile nature of Ca means that its isotopes are ideal for tracing the establishment and evolution of lunar magma ocean (LMO) reservoirs. Because crystals growing in a differentiating magma system record changes in the isotope composition of the liquid from which they crystallize, we aim to investigate the role of crystallization and cumulate settling on mass-dependent fractionation of Ca isotopes.

Inter-mineral Ca isotope variability has been predicted [1] and measured for co-existing minerals within terrestrial mantle xenoliths [2, 3]. Evidence for inter-mineral Ca isotopic fractionation has also been indirectly measured for bulk lunar basalts (olivine types are enriched in the heavier isotopes of Ca compared to ilmenite types, indicating that olivine can be enriched in heavier Ca isotopes during lunar magmatic processes) [4]. Pronounced and systematic Ca isotopic variation (up to 3.25‰) with CaO content has also been shown in the rocks of the Guelb el Azib ultramafic-mafic-anorthosite complex, which represents the products of a full crystallization sequence [5]. The olivine-rich layer of the complex is the most enriched in heavy Ca isotopes, and is several permil heavier than the anorthosite layer produced later on from the same magma.

Given the extensive new evidence for inter-mineral Ca isotopic fractionation during magma differentiation, we measured the Ca isotopic composition of a suite of lunar rocks including ferroan anorthosites, Mg-suite rocks, and coarse-grained basaltic gabbros to test for signatures of early differentiation as a result of LMO solidification. As in the Guelb el Azib rocks, we see an enrichment in the light isotopes of Ca with increasing CaO content of the rock. This corresponds to an increase in the rock's proportion of plagioclase and clinopyroxene and a decrease in olivine and orthopyroxene, corroborating what has been observed terrestrially. [1] Feng et al. (2014). *GCA* 143: 132-142. [2] Huang et al. (2010). *EPSL* 292: 337-344. [3] Kang et al. (2016). *GCA* 174: 335-344. [4] Valdes et al. (2014). *EPSL* 394: 135-145. [5] Valdes et al. *(in prep)*.