Planetary scale Ca-isotope heterogeneity and the formation history of the Earth-Moon system

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The Moon is thought to be the result of a collision between a Mars-sized object, Theia, and the Earth [1]. In this model, the Moon is dominantly composed of impactor material. The isotopic similarity in many elements between the Earth and the Moon requires that isotopic re-equilibration occurred after the impact through a vapour plume [2] or, alternatively, Theia was nearly isotopically identical to Earth [3]. Distinguishing between these scenarios require investigating the isotope composition of highly refractory elements, as these have long isotopic equilibration timescales.

As one of the most refractory elements, Ca is ideally suited for this task. Moreover, it was recently shown that the abundance of ^{43}Ca, ^{46}Ca and ^{48}Ca is variable and correlated amongst inner solar system primitive and differentiated parent asteroids [4]. Using improved techniques, we have analyzed the mass-independent ^{43}Ca/^{44}Ca and ^{48}Ca/^{44}Ca compositions of several lunar and Martian meteorites by HR-MC-ICPMS. Our preliminary data suggest the existence of Ca-isotope heterogeneity between the Earth, Moon and Mars. The ^{43}Ca/^{44}Ca and ^{48}Ca/^{44}Ca compositions of Martian meteorites are depleted by –1.1±0.9 and –21.2±5.6 ppm relative to Earth's mantle. In contrast, lunar meteorites are enriched ^{43}Ca/^{44}Ca by +1.5±1.0 ppm but have a terrestrial ^{48}Ca/^{44}Ca composition (+0.4±3.9 ppm). The observed isotopic variability cannot be explained by neutron capture during exposure. This suggests that, although their isotopic make-up is similar, the Earth, Mars and Theia sampled isotopically distinct precursor material, arguing against the proposal of a uniform inner solar system Ca isotope reservoir [3]. Moreover, preliminary Ca-isotope data for two enstatite chondrites are not consistent with this material being the precursor of Theia. Thus, the observed planetary and asteroidal Ca-isotope heterogeneity cannot be solely attributed to admixing of ^{48}Ca-rich outer system material to a depleted inner solar system composition.

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