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Primordial magnesium isotope heterogeneity preserved in the martian mantle

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The accretion and differentiation history of Mars, including the potential preservation of primordial mantle isotopic heterogeneity, can be investigated by the study of Martian meteorites. Among them, the most predominant group are the SNC meteorites that includes shergottites, nakhlites, and chassignites, representing mantle-derived, near-surface extrusive lavas. Crust formation appears to have occurred as early as 6.4 Myr [1], offering the possibility that short-lived chronometers can probe the primordial mantle differentiation of Mars. With its short half-life of 0.73 Myr, the ^{26}Al-^{26}Mg decay system is well suited to probe the timing of planetary differentiation [e.g., 2] because of the contrasting geochemical behaviour of aluminium and magnesium during magmatic differentiation, where the incompatible aluminium is enriched in the melt relative to magnesium. As such, high precision magnesium isotope measurements of Martian meteorites have the potential to detect small variations in the abundance of ^{26}Mg due to the decay of ^{26}Al related to the early differentiation events on Mars. In this study, we report high precision stable (d$^{25/24}$Mg) and mass-independent (mu$^{26/24}$Mg*) Mg isotopic compositions of 28 Martian meteorites to better evaluate the timing of silicate differentiation of Mars. We observe large mu$^{26/24}$Mg* variations between the Martian meteorites ranging from -13.3 ± 2.8 to 9.3 ± 2.2 ppm with the majority of samples recording deficits relative to bulk silicate Earth. The variations do not co-vary with their mass-dependent Mg isotopic values. We infer these deficits to reveal residual primordial heterogeneity in the Martian mantle that is related to silicate differentiation occurring within the first million year after solar system formation. The preservation of these signatures on Mars may be explained by either rapid solidification of a global magma ocean or localised partial melting of the mantle. Alternatively, the Mg isotope signatures may represent an inherited feature of the building blocks of Mars invoking a collisional growth scenario driven by early differentiated planetesimals. In any case, the preservation of primordial Mg isotopic heterogeneity requires the presence of a heterogeneous modern Martian mantle.

[1] Zhu et al. (2022) Science Advances 8

[2] Schiller et al. (2011) The Astrophysical Journal Letters, 740:L22