

MAGNESIUM ISOTOPE SYSTEMATICS OF SNC METEORITES: EVIDENCE FOR CRYSTAL FRACTIONATION OR SURFACE PROCESS? T. Magna¹, Y. Hu², F.-Z. Teng², and K. Mezger³, ¹Czech Geological Survey, Prague, Czech Republic (tomas.magna@geology.cz), ²University of Washington, Seattle, USA, ³Institut für Geologie and Center for Space and Habitability, Universität Bern, Switzerland.

Introduction: Mass-dependent Mg isotope systematics have been reported for a range of Solar System materials, including Earth's mantle, Moon, chondrites and achondrites [1], with the aim to establish a link between Mg isotope compositions and distinct planetary bodies or planetesimals. This could help understand the behavior of moderately refractory elements in the earliest epoch of the Solar System evolution and consolidation, with some implications for the distribution of then-live ²⁶Al.

Available data show a significant Mg isotope homogeneity of Solar System materials. This is manifest in $\delta^{26}\text{Mg}$ value for the Earth's mantle of -0.25 ± 0.04 (2sd), derived from pristine mantle peridotites [2,3], as well as for chondrites [2,3], Moon [4] and achondrites [5], all of which converge to a uniform $\delta^{26}\text{Mg}$ value, identical with that of the Earth. Magnesium isotope analyses of Martian meteorites are sparse and, to some extent, contradictory, but available data appear to be consistent with the range observed for other planetary bodies (see review by [1]). Because low-temperature Mg isotope fractionation can be significant [6,7] and considering a large range in chemistry of Martian surface materials (clays, sulfates, Cl-bearing minerals; [8]), any significant departure of $\delta^{26}\text{Mg}$ from a range defined by mantle-derived melts would provide indirect evidence for large-scale recycling of isotopically distinct surface lithologies by major tectonic processes [9]. However, such an observation would need to be reconciled with the lack of isotope fractionation of other major isotope systems found for Mars [e.g., 10].

Methods: Magnesium isotope compositions were obtained for a suite of 31 Martian meteorites, involving shergottites, nakhlites, chassignites, cumulate orthopyroxenite ALH 84001 and crustal breccia NWA 7034. Shergottites comprised all important types recognized to date, i.e. basaltic, lherzolitic, olivine-phyric, olivine-orthopyroxene-phyric, and diabasic. Cation-exchange chemistry was used to obtain pure Mg fractions [11] and a *Nu Plasma* multiple-collector ICPMS, housed at the University of Arkansas, was employed to collect Mg isotope data. A subset of samples was analyzed using a *Nu Plasma II* MC-ICPMS, housed at the University of Washington. The data is reported in per mil units ($\delta^{26}\text{Mg}$) relative to DSM-3 reference material [12]. The $\delta^{26}\text{Mg}$ values of international reference ma-

terials (Kilbourne Hole olivine, Hawaiian seawater, Murchison chondrite) replicated well and are in agreement with literature data.

Results: Despite a stark lithological contrast for the entire Martian suite (clinopyroxene cumulates, olivine cumulates, plagioclase-rich rocks, orthopyroxene cumulate), the $\delta^{26}\text{Mg}$ variability is minor (from -0.32 to -0.11%) with most samples ranging between -0.28 and -0.14% . This range is similar to that observed for typical mantle-derived reservoirs on Earth [2,3], attesting to the first-order homogeneity of $\delta^{26}\text{Mg}$ for major terrestrial planets of the inner Solar System. There is a general trend of increasing $\delta^{26}\text{Mg}$ values with decreasing MgO contents for the whole suite. Basaltic shergottites tend to have a heavy Mg isotope signature with the shergottite Los Angeles having the highest $\delta^{26}\text{Mg}$ of the entire suite (-0.11%). Similarly, nakhlites (clinopyroxene cumulates) display a ²⁶Mg-enriched signature (-0.19 to -0.11%) compared with shergottites and chassignites. Crustal breccia NWA 7034 has $\delta^{26}\text{Mg} = -0.17\%$, which is intermediate between basaltic shergottites and most other olivine-bearing samples, the latter group having a generally light Mg isotope composition.

Discussion:

Magnesium isotope composition of Bulk Silicate Mars. From previous reports [13,14] it was not possible to derive a robust $\delta^{26}\text{Mg}$ value for Bulk Silicate Mars because those studies have used chemically evolved samples (basaltic shergottites). For this study, we used pristine lherzolitic shergottites that more closely reflect the composition of the Martian mantle [15]. The results for these samples, combined with near-primary melts from Martian mantle (such as Yamato-980459) and olivine-bearing specimens (e.g., EETA 79001A, RBT 04262, LAR 06319, Tissint), yield a mean $\delta^{26}\text{Mg} = -0.27 \pm 0.04\%$ (2sd) for the silicate Mars. This value is robust and insensitive to small-degree variation in chemistry and modal mineralogy.

The Mg isotope homogeneity between chondrites and the mantles of terrestrial planetary bodies (Earth, Mars, Moon, Vesta) indicates that there may be only a barely resolvable $\delta^{26}\text{Mg}$ difference between primordial materials and later silicate condensates from the Solar

nebula. It also implies that condensation of Mg from the Solar nebula was essentially complete and without any attendant mass-dependent Mg isotope fractionation while some variation in ^{26}Mg may be accounted for via radioactive decay of ^{26}Al during the earliest epoch of the Solar System history [16].

Magnesium isotope composition of Martian surface. The Mg isotope variability of terrestrial crustal magmatic and sedimentary materials shows a significant $\delta^{26}\text{Mg}$ spread of $\sim 4\text{‰}$ (-2 to $+2\text{‰}$) with predominantly light Mg isotope compositions in carbonates and prevalently heavy Mg isotope values in silicate sediments/soils. Weathering at low-temperature to hydrothermal conditions gives rise to a range of $\delta^{26}\text{Mg}$ values [1]. Carbonates are rare on Mars but Mg-sulfates are widespread [8] and are the key phase of cement in soils and dust. Unfortunately, the critical lack of experimental data for Mg isotope fractionation in sulfate–solution systems relevant for Martian conditions, does not allow to derive a more precise estimate of $\delta^{26}\text{Mg}$ for Martian crust. At present, NWA 7034 remains the best candidate for estimating the Mg isotope composition of Martian crust.

Magnesium isotopes in nakhlites. Nakhlites show generally heavy Mg isotope compositions. On Earth, clinopyroxene has higher $\delta^{26}\text{Mg}$ values than olivine and orthopyroxene. High modal proportion of clinopyroxene in nakhlites makes it a principle high- $\delta^{26}\text{Mg}$ carrier compared with most other Martian meteorites. However, it should also be stressed that the mantle source of nakhlites experienced early segregation of garnet [17]. Garnet preferentially incorporates light Mg isotopes [18] and could, in part, imprint high $\delta^{26}\text{Mg}$ values on the residual melts. Alternatively, incorporation of surface materials with elevated $\delta^{26}\text{Mg}$ values into nakhlite melts via recycling could provide a means to depart from a strictly defined range of Mg isotope compositions for Martian mantle-derived melts.

Conclusions: The new Mg isotope data for a suite of Martian meteorites show a limited variation in $\delta^{26}\text{Mg}_{\text{DSM-3}}$ values (-0.32 to -0.11‰), irrespective of a large range in lithology and distinct petrogenetic histories of SNC meteorite groups. None of the primitive Martian samples shows Mg isotope differences from the estimated bulk Martian mantle value at $-0.27 \pm 0.04\text{‰}$ (2sd). The Mg isotope value of Bulk Silicate Mars also implies large-scale Mg isotope homogeneity in the Solar nebula and essentially complete condensation of Mg from the Solar nebula at the time of live

^{26}Al . At present, it is unclear whether or not magmatic differentiation of Mars imparted measurable effects on Mg isotopes so that all $\delta^{26}\text{Mg}$ variations observed could unequivocally be attributed to magmatic differentiation during the genesis of SNC meteorites. A distinctive Mg isotope signature could possibly be detected in crustal breccia NWA 7034 and black glass fraction of the Tissint shergottite although the exact origin of a slight shift towards higher $\delta^{26}\text{Mg}$ at the Martian surface remains unclear.

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