**MAGNESIUM ISOTOPES IN THE EARTH, MOON, MARS, AND PALLASITE PARENT BODY: HIGH PRECISION ANALYSIS OF OLIVINE BY LASER-ABLATION MULTI-COLLECTOR ICPMS.**

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**Introduction:** Magnesium isotopes potentially offer new insights into a diverse range of processes including evaporation and condensation in the solar nebula, melting and metasomatism in planetary interiors, and hydrothermal alteration [1,2,3,4]. Volatility-related Mg isotopic variations of up to 10 per mil/amu relative to a terrestrial standard have been found in early nebular phases interpreted as evaporation residues [1], and relatively large variations (up to 3 per mil/amu) in the terrestrial mantle have been reported recently [4].

In order to investigate possible differences in the nebular history of material contributing to the terrestrial planets, and to search for evidence of a high-temperature origin of the Moon, we have measured the magnesium isotopic composition of primitive olivines from the Earth, Moon, Mars, and pallasite parent body using laser-ablation multi-collector ICPMS.

**Methods:** Data were obtained with a Neptune MC-ICPMS operated in medium resolution mode ($10^{11}$ ohm resistor), and an excimer UV laser (193 nm, 5 Hz, 47-62 micron spot diameter, 80 mJ/pulse). $^{26}$Mg was measured at an off-center peak position to avoid interference from $^{12}$C-$^{14}$N. An on-peak baseline was used to correct for instrumental background. Replicate analyses of olivines from a mantle xenolith (Mt. Shadwell, SE Australia) demonstrate an external precision of $\pm$0.2 per mil/amu (2$\sigma$ stdev, n = 10) on $^{25}$Mg/$^{24}$Mg and $^{26}$Mg/$^{24}$Mg relative to the San Carlos reference olivine, using the standard-unknown bracketing method.

**Results:** Primitive terrestrial olivines (Fo88-91) from a variety of settings have Mg isotopic compositions which span about ~0.5 per mil/amu (Fig. 1). This includes picritic lavas from Hawaiian volcanoes (Mauna Loa, Kilauea, and Ko'olau), a picrite from the Vanuatu volcanic arc [5], a suite of modally metasomatised peridotite xenoliths from SE Australia [6], and Early Archean ($\geq$3.8 Ga) peridotites from SW Greenland [7,8].

Initial results on olivines from Apollo 12 picritic mare basalts showed a systematic variation to heavier Mg isotopic compositions in more Fe-rich olivines (Fig. 2). Subsequently, we were able to show that this reflects a composition-dependent matrix effect rather than a natural variation by analysis of synthetically crystallized olivines ranging in composition from Fo50-90 (Fig. 3). The matrix effect appears to be related to isotopic fractionation during the ablation process, as solutions with a similar range in Mg/Fe show no variation in measured isotopic composition. After correction, the Apollo 12 olivines were found to have Mg isotopic compositions identical (within uncertainty) to the San Carlos terrestrial reference olivine (Fig. 1).

Similarly, the Mg isotopic compositions of olivines from the SNC meteorites Chassigny (Fo-corrected) and the Brenham pallasite are also within uncertainty of the San Carlos terrestrial reference (Fig. 1).

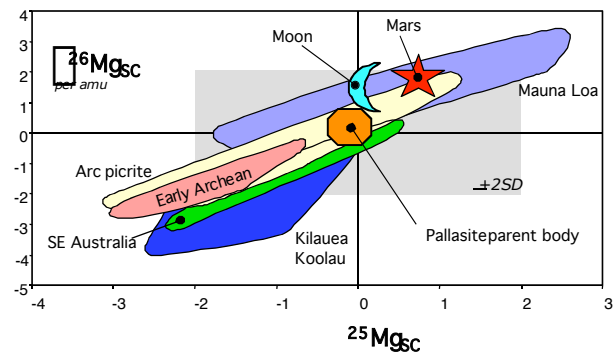


**Figure 1.** Mg isotopic composition of primitive olivines from the Earth, Moon, Mars, and the Brenham pallasite relative to the San Carlos (SC) terrestrial reference olivine. All data have been corrected for laser-induced variations in isotopic composition related to Fo-content. The grey rectangle shows $\pm$2SD analytical uncertainty.

**Conclusions:** Magnesium isotopic compositions of olivine can be measured by laser-ablation multi-collector ICPMS with about an order of magnitude better precision than previous methods, including SIMS and TIMS. Under the conditions used for this study, a laser-induced matrix effect was found in which systematically heavier isotopic compositions are measured in more Fe-rich olivines. Fortunately, this effect is a regular function of Fo-content of the olivine (Fig. 2), which allows corrections to be made.

We have found a much more restricted range of Mg isotopic compositions in rocks from the terrestrial mantle than has been reported by other recent laser ablation MC-ICPMS studies [4], although additional work is required to ensure similar sample suites are studied. There appears to be no temporal variation in the Mg isotopic composition of the Earth's mantle since at least 3.8 Ga, and only limited variations in the compositions of diverse mantle sources (e.g. OIB vs volcanic arcs). In contrast to [4], we find no measurable difference in the Mg isotopic composition of the Earth's mantle and the pallasite parent body. After correction for the composition-dependent matrix effect, the Mg isotopic composition of olivines from the Moon and Mars are also identical to that of the Earth's mantle.

Earth, Moon, Mars, and the differentiated asteroids appear to have formed from a nebular reservoir that was homogeneous with respect to Mg isotopes. This implies either a minor role for evaporation-condensation processes in the inner solar system prior to accretion, or a limited variation in the proportion of refractory CAI-like material contributing to the terrestrial planets. This may be contrary to predictions of the X-wind model in which mixing of material with diverse thermal histories occurs at planetary distances in the solar nebula [9]. No evidence for a high-temperature origin of the Moon was found by this study.

**References:** [1] Richter F.M. (2002) GCA 66, 521. [2] Galy A. et al. (2000) Science 290, 1751. [3] Young E.D. et al. (2002) GCA 66, 683. [4] Pearson N.J. et al. (2002) Goldschmidt conf. abstracts, A584. [5] Eggins, S. M. (1993) CMP 114, 79. [6] Yaxley G.M. et al. (1991) EPSL 107, 305. [7] Friend C.R.L. et al. (2002) CMP 143, 71. [8] Bennett V.C. et al. (2002) GCA 66, 2615. [9] Shu F.H. (2001) Astrophys. J. 548, 1029.

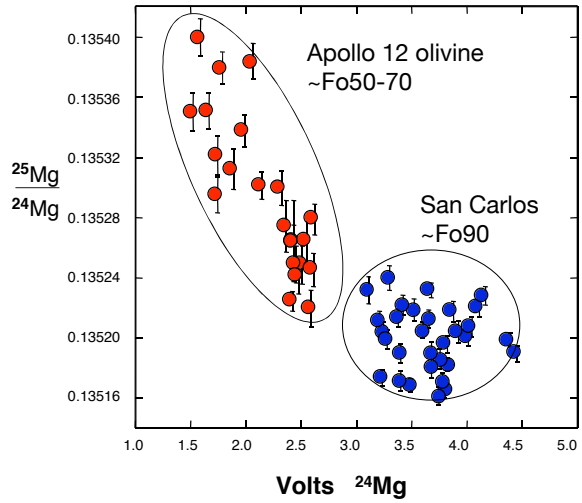


**Figure 2.** Measured Mg isotopic composition vs. signal intensity for San Carlos and Apollo 12 olivine. The apparent trend to heavier Mg isotopic compositions in the Apollo 12 picritic basalts reflects a composition-dependent matrix effect on the laser ablation analyses and is not a primary signature of heavy Mg in the Moon.

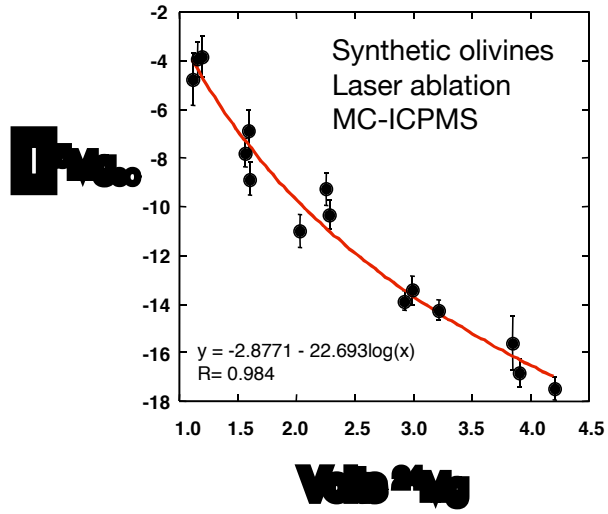


**Figure 3.** Measured Mg isotopic composition of synthetic olivines relative to the San Carlos (SC) reference. The trend to heavier isotopic compositions in more Fe-rich olivines reflects a matrix effect on the laser ablation analyses.