

**THE MAGNESIUM ISOTOPIC COMPOSITION OF THE EARTH AND CHONDRITES.** F.-Z. Teng<sup>1</sup>, S., Ke<sup>1,2</sup>, B. Marty<sup>3</sup>, N. Dauphas<sup>4</sup>, S. Huang<sup>5</sup> and A. Pourmand<sup>6</sup>, <sup>1</sup>Isotope Laboratory, Department of Geosciences and Arkansas Center for Space and Planetary Sciences, University of Arkansas, Fayetteville (fteng@uark.edu), <sup>2</sup>State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, <sup>3</sup>Centre de Recherches Pétrographiques et Géo-chimiques, CNRS, <sup>4</sup>Origins Laboratory, Department of the Geophysical Sciences and Enrico Fermi Institute, The University of Chicago, <sup>5</sup>Department of Earth and Planetary Sciences, Harvard University and <sup>6</sup>Department of Marine Geology and Geophysics, University of Miami.

**Introduction:** Studies of Mg isotopic composition of the Earth not only are important for understanding its geochemistry but also can shed light on the accretion history of the Earth [1-3]. However, to date, the Mg isotopic composition of the Earth is still poorly constrained and debated. There is uncertainty in the magnitude of Mg isotope fractionation at mantle temperatures [1, 4-7] and whether the Earth has a chondritic Mg isotopic composition or not [3, 5-8]. The uncertainties mainly result from the limited database for terrestrial samples and meteorites, as well as possible analytical artifacts in high-precision Mg isotopic analysis by multi-collector inductively coupled plasma mass spectrometer (MC-ICPMS).

Knowledge of the mantle is derived largely from studies of peridotites, the only direct samples of the lithospheric mantle [9, 10], and oceanic basalts, the products of decompression melting of the mantle [11]. Absence of isotope fractionation during partial melting and basalt differentiation is required to use oceanic basalts to derive information on the isotopic compositions of their mantle sources. Teng et al. [8] investigated basalts from Kilauea Iki lava lake and found no measurable Mg isotope fractionation during basalt differentiation, suggesting that oceanic basalts can be used to study the Mg isotopic composition of the mantle.

**Samples:** To eliminate potential bias in high-precision Mg isotopic data produced in different laboratories, to constrain further the Mg isotopic composition of the mantle and chondrites, and to investigate Mg isotope fractionation during planetary formation and magmatic processes, we have analyzed Mg isotopes for a globally dispersed, chemically diverse set of fresh samples, including 47 mid-ocean ridge basalts (MORBs) covering major ridge segments of the world, 63 ocean island basalts (OIBs) from Hawaii and French Polynesian Islands, 63 olivine grains extracted from OIBs, 29 peridotite xenoliths from Australia, China, France, Tanzania and USA. We also analyzed 38 chondrites from all major groups (CI, CM, CO, CV, L, LL, H, EH and EL). All samples are fresh and well-characterized.

**Analytical Methods:** Separation of Mg was achieved by cation exchange chromatography with Bio-Rad 200-400 mesh AG50W-X8 pre-cleaned resin in 1 N HNO<sub>3</sub> media by following a similar procedure as that described by Teng et al. [8]. Magnesium isotopic compositions were analyzed by the sample-standard bracketing method using a *Nu Plasma* MC-ICPMS at the Isotope Laboratory of the University of Arkansas. The precision on <sup>26</sup>Mg/<sup>24</sup>Mg and <sup>25</sup>Mg/<sup>24</sup>Mg ratios was better with a “wet” plasma than with a “dry” plasma. Loss in sensitivity was largely obviated by a substantial gain in stability.

Precision and accuracy were assessed by full procedural replicate analyses of synthetic solutions, seawater, rocks, minerals and pure Mg standards. The in-run precision on the <sup>26</sup>Mg/<sup>24</sup>Mg ratio for a single measurement of one block of 40 ratios is less than ± 0.02 ‰ (2SD). The internal precision on the measured <sup>26</sup>Mg/<sup>24</sup>Mg ratio, based on ≥ 4 repeat runs of same sample solution during a single analytical session, is better than ± 0.1 ‰ (2SD). The external precision, as shown by replicate analyses of a synthetic solution, mineral and rock standards, is ~ ± 0.07 ‰ for δ<sup>26</sup>Mg. Multiple analyses of IL-Mg-1, a synthetic multi-element standard solution with concentration ratios of Mg:Fe:Al:Ca:Na:K:Ti = 1:1:1:1:1:1:0.1, yielded δ<sup>26</sup>Mg values of -0.07 to +0.05, with an average value of -0.01 ± 0.07 (2SD, n=13). This is in agreement with the expected true value of 0 and shows that our data are accurate within a precision of ± 0.07 ‰ for δ<sup>26</sup>Mg.

**Results:** Global oceanic basalts and peridotite xenoliths have similar Mg isotopic composition (Fig. 1), with δ<sup>25</sup>Mg = -0.13 ± 0.05 and δ<sup>26</sup>Mg = -0.26 ± 0.07 in 110 global oceanic basalts and with δ<sup>25</sup>Mg = -0.13 ± 0.03 and δ<sup>26</sup>Mg = -0.25 ± 0.04 in 29 global peridotite xenoliths. Olivine grains from Hawaiian lavas have δ<sup>25</sup>Mg = -0.13 ± 0.08 and δ<sup>26</sup>Mg = -0.26 ± 0.14, identical to global oceanic basalts and peridotites. This, together with identical Mg isotopic compositions in oceanic basalts and peridotites, suggests that Mg isotope fractionation during partial melting of peridotite mantle and magmatic differentiation of basaltic magma is insignificant.

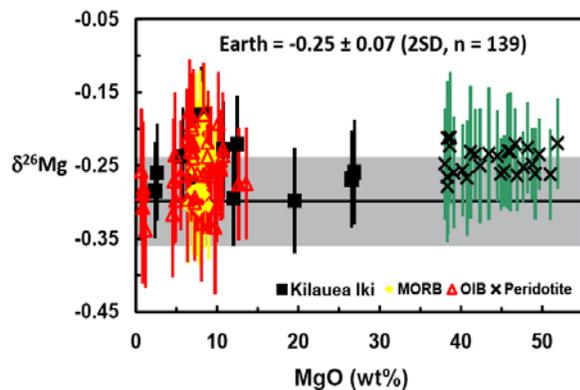


Fig. 1. Magnesium isotopic composition of the Earth based on studies of global oceanic basalts and peridotites as well as all types of chondrites (Grey bar).

Thirty eight chondrites have indistinguishable Mg isotopic composition, with  $\delta^{25}\text{Mg} = -0.16 \pm 0.03$  and  $\delta^{26}\text{Mg} = -0.30 \pm 0.06$  (Fig. 2). The constant Mg isotopic composition in all major types of chondrites suggests that the primary and secondary processes that affected the chemical and oxygen isotopic compositions of chondrites did not significantly fractionate Mg isotopes.

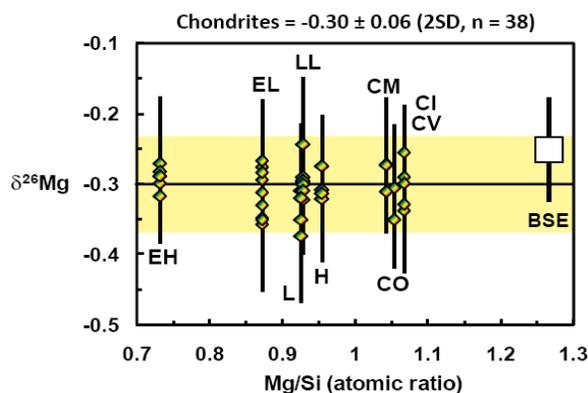


Fig. 2. Magnesium isotopic composition (this study) and Mg/Si ratios [12] of chondrites.

**Conclusion:** Collectively, the Mg isotopic composition of Earth's mantle, based on oceanic basalts and peridotites, is estimated to be  $-0.25 \pm 0.07$  for  $\delta^{26}\text{Mg}$  and  $-0.13 \pm 0.04$  for  $\delta^{25}\text{Mg}$  (2SD, n=139). The Earth, as represented by the mantle, has Mg isotopic composition similar to chondrites ( $\delta^{26}\text{Mg} = -0.25$  vs.  $-0.30$ ;  $\delta^{25}\text{Mg} = -0.13$  vs.  $-0.16$ ) when the long term external precision of  $\pm 0.07$  for  $\delta^{26}\text{Mg}$  and  $\pm 0.06$  for  $\delta^{25}\text{Mg}$  is considered.

Our results are different from Wiechert and Halliday [3], who concluded that the  $\delta^{26}\text{Mg}$  of the Earth was on average  $\sim 0.3\%$  higher than that of chondrites hence the Earth had a non-chondritic Mg isotopic

composition. The difference may reflect analytical artifact associated with high-precision Mg isotopic analysis by MC-ICPMS. Our results are consistent with other recent high-precision Mg isotopic studies [5-6, 8], which suggested that the Earth and chondrites actually have identical Mg isotopic composition at a precision of  $\pm 0.1\%$  for  $^{26}\text{Mg}/^{24}\text{Mg}$  ratio. However, these studies [5-6, 8] relied on a limited and uncertain data set of chondrite measurements (Fig. 3). The 38 chondrite measurements presented here clearly show that there is no heterogeneity in Mg isotopic composition from one chondrite group to another.

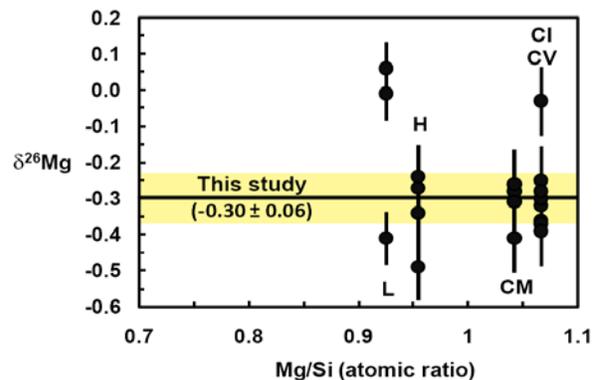


Fig. 3. Comparison of  $\delta^{26}\text{Mg}$  of chondrites between this study and literature data [1,3,5,7,8,13].

The chondritic composition of the Earth implies that Mg isotopes have been well mixed and have not been affected by planetary accretion processes. Similar processes should not fractionate isotopes of lithophile elements with similar volatility to Mg either.

**References:** [1] Young E.D. and Galy A. (2004) in *Geochemistry of Non-Traditional Stable Isotopes*, MSA, Washington D. C. 197-230. [2] Norman M.D., et al., (2006). *GRL* 33, L15202. [3] Wiechert U. and Halliday A.N. (2007) *EPSL*, 256, 360-371. [4] Pearson N.J., et al. (2006) *Chemical Geology*, 226, 115-133. [5] Yang W., et al. (2009) *EPSL*, 288, 475-482. [6] Handler M.R., et al. (2009) *EPSL*, 282, 306-313. [7] Young E.D., et al. (2009) *EPSL*, 288, 524-533. [8] Teng F.-Z. et al. (2007) *EPSL*, 261, 84-92. [9] Jagoutz E., et al. (1979) *Proc. 10th Lunar Planet. Sci. Conf.*, 2031-2050. [10] McDonough W.F. and Sun S. S. (1995), *Chemical Geology*, 120, 223-253. [11] Hofmann A.W. (2003) in *The Mantle and Core*, Elsevier-Pergamon: Oxford, 61-101. [12] Wasson J.T. and Kallemeyn G.W. (1988) *Philos. Trans. R. Soc. London, Ser. A*, 1988, 325, 535-544. [13] Baker J. A. et al. (2005) *Nature*, 436, 1127-1131.