**THE CHONDRITIC IRON ISOTOPIC COMPOSITION OF THE EARTH.** P.R. Craddock[1], Jessica M. Warren[2] and N. Dauphas[1], [1]Origins Laboratory, Department of the Geophysical Sciences and Enrico Fermi Institure, The University of Chicago, 5734 S Ellis Ave, Chicago, IL 60637, USA (craddock@alum.mit.edu) , [2]Geological and Environmental Sciences, Stanford University, 450 Serra Mall, CA 94305, USA

**Introduction:** The bulk iron isotopic composition of the Earth is debated [1-6], yet has key implications for our understanding of the conditions of core formation and mantle differentiation. The contention arises from the competing hypotheses put forth to account for the approximately +0.1 ‰ enrichment in the $^{56}Fe/^{54}Fe$ ratio of terrestrial mid-ocean ridge basalts (MORBs) relative to that of primitive meteorites (chondrites; Fig. 1) [3,7,8]. It has been proposed that during core formation, Fe metal-silicate equilibration at pressures > 100 GPa enriched the bulk silicate portion of the Earth in the heavy isotopes of Fe [6]. A second interpretation is that kinetic isotope fractionation associated with partial vaporization of light Fe during the Moon-forming giant impact also enriched the silicate Earth in the heavy isotopes of Fe [1]. In both of these models, MORBs directly inherit and record a non-chondritic isotopic composition of the silicate Earth (*i.e.*, $\delta^{56}Fe_{BSE}$ = +0.1 ‰, where $\delta^{56}Fe$ = $[(^{56}Fe/^{54}Fe)_{sample}/\ (^{56}Fe/^{54}Fe)_{IRMM-014} − 1] × 10^3$). Alternatively, the enriched $\delta^{56}Fe$ composition of terrestrial basalts has been interpreted as reflecting isotopic fractionation during partial melting of the silicate mantle [2,3,9-11]. According to this model, the Fe isotopic composition of the bulk silicate Earth is close to chondritic (*i.e.*, $\delta^{56}Fe_{BSE}$ ~0 ‰).

To evaluate these opposing hypotheses and estimate the Fe isotopic composition of the bulk silicate Earth, we have measured the Fe isotopic composition of suites of well-characterized abyssal peridotites and peridotite mylonites from ultra-slow oceanic spreading centers (Southwest Indian, Gakkel and Molloy Ridges). These samples provide a direct glimpse into the upper oceanic mantle composition, as they are the direct complements to the modern derivatives of partial melting – MORBs. We show here that abyssal peridotites have an iron isotopic composition nearly identical to that of chondrites, but lighter than MORBs by ~0.1 ‰. Our data indicate that iron isotopic fractionation in terrestrial igneous rocks did not result from core-mantle differentiation in early Earth nor by partial iron vaporization during the Moon-forming giant impact. Instead, our results support mounting evidence for iron isotopic fractionation during partial mantle melting. These characteristics indicate that iron isotopes can be used as indicators of planetary magmatism.
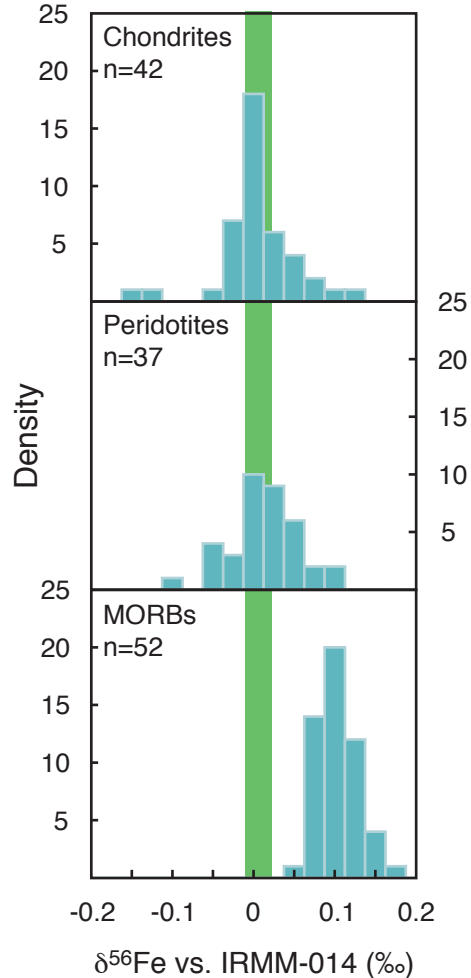


*Fig. 1. Frequency distributions of $\delta^{56}Fe$ compositions among chondrites [7,11,14], terrestrial mantle abyssal peridotites/peridotite mylonites [this study], and terrestrial mid-ocean ridge basalts (MORBs) [1,7,8]. Our abyssal peridotite data suggest that the sub-oceanic mantle and the bulk silicate Earth as a whole has an Fe isotopic composition near-identical to primitive/undifferentiated planetary bodies. The heavy Fe isotopic composition of MORBs relative to their peridotite residues supports evidence for Fe isotopic fractionation during terrestrial mantle melting.*

**Samples and Methods:** *Abyssal Peridotites*: A total of 29 undeformed abyssal peridotites from three spreading centers were studied. Thirteen samples are from the ultraslow spreading (< 20 mm/yr full rate) 9°-

16° E Oblique Segment of the Southwest Indian Ridge. Fifteen samples are from the Gakkel ridge in the high Arctic Ocean. Sampling was focused in the western half of the Gakkel ridge, with peridotites recovered primarily between 3° and 29° E, where seafloor spreading is amagmatic and associated with little or no volcanism. A single peridotite from the Tonga trench between 20 and 21° S was also studied. This sample is associated with the edge of the Tonga Plate, which is over-riding the Pacific Plate. *Peridotite Mylonites*: A total of six abyssal peridotite mylonites were also studied for their iron isotopic compositions. The term mylonite refers to rocks that have undergone intense ductile deformation. Four of the peridotite mylonites in this study are from the Southwest Indian Ridge, collected from the 9° E Shaka and 33°-35° E Prince Edward fracture zones. In addition, two peridotite mylonites are from the Molloy ridge in the Arctic Ocean at 79° N, 3° E between the Knipovich Ridge and the Lena Trough.

The samples chosen span the range of abyssal peridotite chemical and radiogenic isotopic compositions, from typical depleted abyssal peridotites to melt-veined peridotites. The samples have a variety of alteration histories, ranging from completely fresh (< 1 vol. % serpentine), to highly serpentinized, to seafloor weathered. The mylonite peridotites are extremely fresh, with seafloor weathering limited to 1 mm rims on the exterior of samples.

Iron isotopic analyses were performed on a Thermo Scientific Neptune Plus MC–ICPMS at the University of Chicago following the procedures developed in our laboratory [12,13].

**Results:** The $\delta^{56}$Fe values of all whole-rock abyssal peridotites and peridotite mylonites fall within a limited range from -0.094 to +0.108 ‰ (Fig. 1). The peridotites with the heaviest Fe isotopic compositions (+0.052 to +0.108 ‰) are visibly and geochemically the most altered, otherwise the Fe isotopic composition of other whole-rock samples cluster about 0.00 ‰. The mean of the least altered peridotite samples ($\delta^{56}$Fe = +0.005 ± 0.015 ‰, 95% c.i., n = 29) is indistinguishable from that of carbonaceous, ordinary and enstatite chondrites ($\delta^{56}$Fe = +0.005 ± 0.007 ‰, 95% c.i., n = 42). In contrast, the average Fe isotopic composition of abyssal peridotites is significantly lighter than that of their MORB complements (mean $\delta^{56}$Fe = +0.110 ± 0.003 ‰, 95% c.i., n = 52).

**Discussion:** Our abyssal peridotite data provide compelling evidence that the upper oceanic mantle and bulk silicate earth has a near-chondritic Fe isotopic composition (*i.e.*, $\delta^{56}$Fe$_{BSE}$ ~ 0 ‰). Abyssal peridotites and peridotite mylonites sampled at spreading centers from different oceanic basins have indistinguishable Fe

isotopic compositions, suggesting that the mantle is globally homogeneous with respect to Fe isotopes.

The heavy Fe isotopic composition of MORBs relative to chondrites [7,11,14] and to basalts from Mars and Vesta [1,2] has been interpreted as reflecting planetary scale differences owing to isotopic fractionation during core formation [6] or vaporization during the Moon-forming impact [1]. Our abyssal peridotite Fe isotopic data argue directly against these interpretations because the upper oceanic mantle has an unfractionated Fe isotopic composition that is identical to chondrites. Instead, the chondritic Fe isotopic composition of abyssal mantle peridotites and the contrasting, heavy isotopic composition of MORBs support mounting evidence for fractionation of Fe isotopes during partial mantle melting on Earth. Such fractionation during mantle melting on Earth and the angrite parent-body, but not on other planetary bodies Mars and Vesta, may record differences in the intrinsic planetary oxidation states [9,10,13].

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