IRON ISOTOPIC FRACTIONATION DURING METAL/SILICATE SEGREGATION IN ENSTATITE CHONDRITE AND AUBRITE PARENT BODIES. Kun Wang, Frédéric Moynier, and Randal C. Paniello, Department of Earth and Planetary, Washington University in St. Louis, One Brookings Drive, St. Louis, MO 63130 (wangkun@wustl.edu).

Introduction: Primitive meteorites enstatite chondrites have received significant attention due to their remarkable similarities to the Earth when it comes to various isotope systems, notably oxygen isotopes [1], and an enstatite chondrite Earth model has been suggested [2]. However, silicon isotope fractionation between the bulk silicate Earth and enstatite chondrites have brought some reservations about this model [3, 4].

Besides oxygen and silicon, iron is another main element of the Earth. Previous studies have shown differences between enstatite chondrites and terrestrial igneous rocks in Fe isotope compositions [5,6]. However, the Fe isotope composition of the bulk Earth is still unknown and it is unclear whether this difference is caused by distinct reservoirs or isotopic fractionations during planetary differentiation processes (and more importantly, which process). Enstatite chondrites can be divided into two subgroups (EH and EL), and are genetically associated with aubrites; they represent at least five different parent bodies [7]. Here, we focus on the entire enstatite meteorite group (including genetically related rocks) to systematically investigate the nature of the Fe isotopic fractionation on the enstatite parent bodies.

Sample and Method: We have studied 22 samples, representative of the five (EH, EL, aubrite-main group, aubrite-Shallowater, and Happy Canyon impact melt) enstatite meteorite parent bodies. Six samples are from the aubrite main group and one from Shallowater.

Fifteen enstatite chondrites include EL3 (2), EL6 (8), EH3 (2), EH4 (2), and Happy Canyon impact melt. In addition to the whole-rock samples, some aubrites and enstatite chondrites were subjected to phase separation (magnetic and non-magnetic separated with a hand magnet). Some non-magnetic portions were also further treated with sequential dissolution to isolate the silicate and sulfide phases, following the same method as in [8].

Iron was purified and the Fe isotopic ratios were measured on a Thermo Scientific Neptune (or a Thermo Scientific Neptune Plus) MC-ICP-MS at the University of Chicago and Washington University in St. Louis, following the same procedure as in [9]. Isotope ratios are expressed as parts per 1,000 deviations: $\delta^{56}Fe=[(^{56}Fe/^{54}Fe)_{sample}/(^{56}Fe/^{54}Fe)_{IRMM-014}-1]\times1000$.

Results: *Whole-rock samples.* Isotope compositions of bulk aubrites and enstatite chondrites are plotted in Figure 1. On average, the different groups of meteorites give the following values: aubrite main group ($\delta^{56}Fe=-0.15\pm0.03$; 95% confidence intervals); Shallowater aubrite ($\delta^{56}Fe=0.05\pm0.04‰$); EH3-4 ($\delta^{56}Fe=0.00\pm0.03$); EL3 ($\delta^{56}Fe=0.02\pm0.04$); EL6 ($\delta^{56}Fe=-0.01\pm0.04$); Happy Canyon impact melt ($\delta^{56}Fe=0.14\pm0.04$). Except for the aubrite and Happy Canyon impact melt, all other enstatite meteorites in average are the same with carbonaceous chondrites ($\delta^{56}Fe=0.02\pm0.04$ [10]) and are different from terrestrial and lunar basalts that $\delta^{56}Fe\sim0.1$-$0.2‰$ [5, 6, 11]. In addition, all EH of different metamorphic grades and
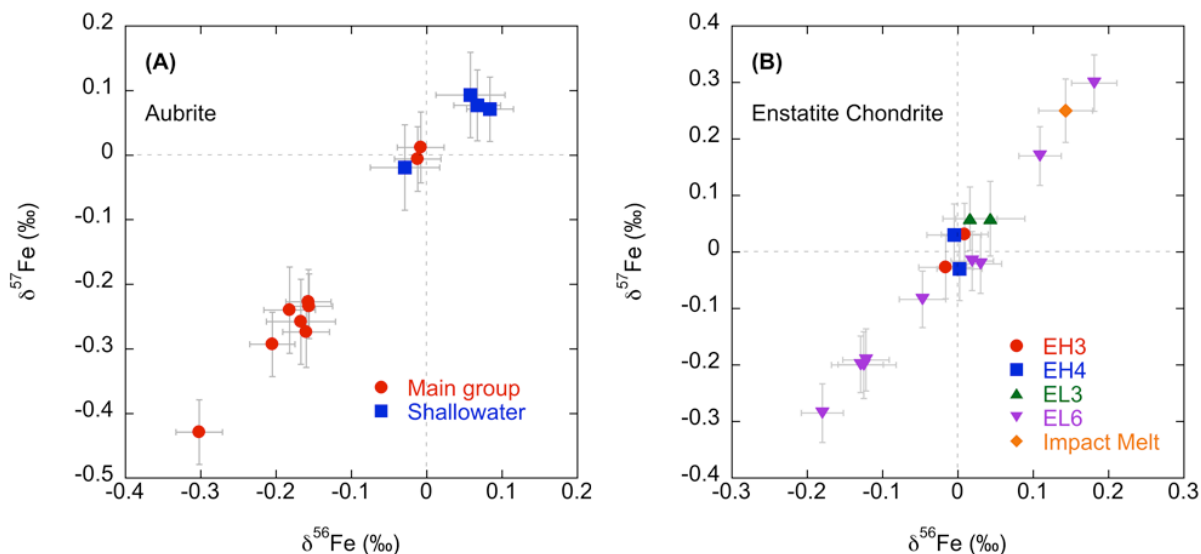
Figure 1. Iron isotope compositions of aubrites (A) and enstatite chondrites (B) in this study.

EL3 have the same Fe isotopic composition within error, however, EL6 ($-0.18‰<\delta^{56}Fe<0.18‰$) and aubrites ($-0.30‰<\delta^{56}Fe<0.08‰$) have a large range of isotopic variations.

Separated mineral phases. As shown in Figure 2, in general, the magnetic phases (mostly Fe from metal) were systematically enriched in heavy isotopes when compared to the non-magnetic phases (mostly Fe from sulfide): $\Delta^{56}Fe_{metal/sulfide} = \delta^{56}Fe_{metal} - \delta^{56}Fe_{sulfide} = 0.21$. Some non-magnetic phases were further divided into silicate and sulfide portions via stepwise dissolutions. As predicted from a mass balance, sulfide portions should have the same isotopic composition as the whole non-magnetic phases. However, due to imperfect separation between phases, the compositions of separated "sulfide" portion vary in a large range.
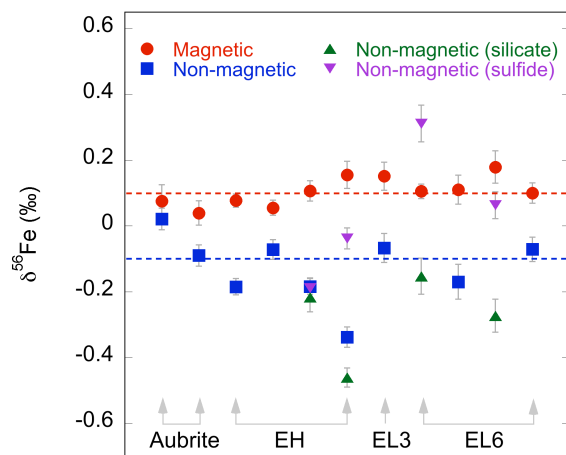

Figure 2. Iron isotopic fractionation between magnetic (metal) and non-magnetic (silicate and sulfide) phases in aubrites, and enstatite chondrites.

Discussion: Previous studies have observed that carbonaceous and enstatite chondrites have $\delta^{56}Fe$ ~0.0 [6, 10]. Here, we confirm that the EH, EL3 and carbonaceous chondrite have the same iron isotope compositions. However, EL6 and aubrites are fractionated in iron isotope compared to carbonaceous and other enstatite chondrites. The EL6 enstatite chondrites are highly thermal metamorphosed and are clearly depleted in Fe ([Fe]=21.3-21.9 wt.%) when compared to EL3 ([Fe]=26.2-26.6 wt.%) and EH ([Fe]=26.7-31.3 wt.%) [12]. The EL6 samples have been isotopically fractionated during intense thermal metamorphism, while partially melted aubrites have been fractionated during melting and differentiation on their parent bodies.

Experimental results [13,14] and theoretical calculation [15] suggest that the metal is enriched in the heavy isotopes of Fe compared to the silicate and sulfide phases during segregation. The mineral phase separation presented here shows a difference in $\delta^{56}Fe$ of 0.21 ‰ between metal and sulfide phases, and >0.21

‰ between metals and silicates, which is in the same range as *ab initio* calculations for 600K to 1200K [15], an equilibrium temperature range for enstatite chondrites and aubrites [16,17]. Because of a possible non-perfect separation of different phases in our experiments, these fractionation values represent minimum values. As shown in Figure 3, we evaluated the possible end-member compositions of metals (kamacite), sulfides (troilite) and silicates (enstatite). These evaluations are larger than what we have measured in the separated phases and theoretical calculation [15]. A possible origin of this difference is that we only considered three phases in our model (troilite, kamacite, and enstatite). Enstatite meteorites contain many additional Fe-bearing phases that would contribute to the Fe isotopic budgets of the different samples.
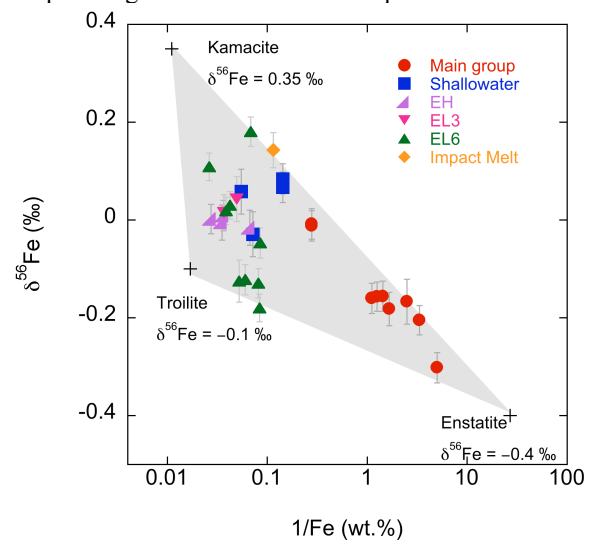
Figure 3. $\delta^{56}Fe$ vs. 1/[Fe] for aubrites and enstatite chondrites. The grey area shows the mixing model of kamacite, troilite and enstatite.

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