SIGNIFICANCE OF IRON ISOTOPE MINERAL FRACTIONATION IN PALLASITES AND IRON METEORITES. F. Poitrasson[1,2] , S. Levasseur[2] and N. Teutsch[2,3]. [1]Laboratoire de Géochimie, CNRS, 38, rue des 36 Ponts, 31400 Toulouse, France (Franck.Poitrasson@cict.fr). [2]Department of Earth Sciences, ETH-Zentrum, Sonneggstrasse 5, 8092 Zürich, Switzerland. [3]EAWAG, Überlandstrasse 133, 8600 Dübendorf, Switzerland.

Introduction: Earlier studies of the Fe isotope composition of meteorites, lunar and terrestrial rocks revealed that although significant variations may occur at the grain scale [1-3], these isotope signatures are much less variable at the bulk meteorite and planetary scale [4,5]. Among the Fe isotope variations observed at the mineral scale, Zhu et al. [6] presented two pallasite data showing a metal fraction with consistently heavier iron than that of the coexisting olivine. Given the potential implication this finding might have on our understanding of planetary mantle-core differentiation, we extended this database to other pallasites, iron meteorites and bulk chondrites.

Methods: Iron meteorites and pallasite minerals were sawn using diamond dentist tools and extracted with aluminium devices. For the bulk chondrites, a minimum of one gram of rock was powdered and homogenized for each sample to ensure whole-rock representativity. An aliquot of these samples was dissolved and iron was purified using anionic exchange chromatography [7]. The Fe isotope composition was determined by MC-ICP-MS (Nu Plasma) using the sample-standard bracketing technique with the international IRMM-14 Fe isotopic standard [8]. Special care was taken to ensure that matrix effects were not present. Repeated analyses of an in house hematite standard over one year indicate that the $^{57}Fe/^{54}Fe$ ratio can be measured with a reproducibility better than 0.09‰ (2SD) provided that each sample is analyzed several times across different analytical sessions. Although less precisely measured, $^{57}Fe/^{56}Fe$ ratios are in good agreement with $^{57}Fe/^{54}Fe$ values. Analyses of the hematite standard using high resolution MC-ICP-MS (Nu 1700 in Zürich and ThermoFinnigan Neptune in Toulouse) are indistinguishable within uncertainty to our repeated measurements made at low resolution.

Results: Both bulk chondrites and iron meteorites $\delta^{57}Fe/^{54}Fe$ values show a restricted scatter. On average, however, 7 chondrites, with $\delta^{57}Fe/^{54}Fe$ values between –0.1‰ to 0‰ relative to IRMM-14, tend to be slightly lighter than iron meteorites, wich have $\delta^{57}Fe/^{54}Fe$ values ranging from 0.04‰ to 0.2‰. At the mineral scale, taenite from two iron meteorites appears to show $\delta^{57}Fe/^{54}Fe$ values heavier by 0.15‰ (Cranbourne) to 0.3‰ (Toluca) than their kamacite counterpart. On three pallasites, we measured a heavier iron isotope composition for the metal fractions compared to olivines like Zhu et al. [6], but the range of $\delta^{57}Fe/^{54}Fe$ differences is larger than originally found by these authors since it goes from 0.32‰ for Esquel down to the value of 0.07‰ for Marjalathi. Troilite from two pallasite appears to be even heavier than the metal fraction whereas a schreibersite from Springwater display a $\delta^{57}Fe/^{54}Fe$ lighter by 0.2‰ than its olivine counterpart. There is thus a general tendency for minerals to show a heavier Fe isotope composition as the coordination number of the Fe site within the lattice increases, although troilite is an exception to this rule.

Discussion: Iron meteorites are classically considered as remnants of asteroid cores and pallasites as core-mantle interfaces. The simultaneous finding that the metal fraction of pallasite has a higher $\delta^{57}Fe/^{54}Fe$ signature than the coexisting olivines, and that the iron meteorites are slightly heavier than their putative starting material (chondrites) could be an indication that planetary core-mantle differentiation is accompanied by sizeable iron isotope fractionation. In this hypothesis, resultant planetary mantles should be isotopically ligher than the chondritic starting material to fulfill mass balance constraints. That is not observed, however, since all planetary mantles analyzed so far (from Vesta, Mars, Moon and Earth [4,5]) have $\delta^{57}Fe/^{54}Fe$ values equivalent to or heavier than those of chondrites. Furthermore, the noticeable spread observed among iron meteorites $\delta^{57}Fe/^{54}Fe$ signatures could result from the inadequate representativity of mg-sized aliquots taken for the analysis of samples which show taenite and kamacite mineral sizes of the meter-scale [9], and these phases fractionate $\delta^{57}Fe/^{54}Fe$ by up to 0.3‰.

The variable iron isotope fractionation observed between metal and olivine in different pallasites could be suggestive of disequilibrium. However, a correlation is observed between mineral modal abundances and the difference in $\delta^{57}Fe/^{54}Fe$ isotope composition between metal and olivine (Figure 1).

Secondly, the pallasite Marjalathi, which has metal and olivine abundance close to 50/50, yield an isotope metal-olivine difference of 0.07‰, that is similar to the metal-olivine fractionation calculated from [12] equations at the last presumed pallasite equilibration temperature of ~1000°C [13]. Lastly, recalculating bulk pallasite Fe isotope composition using published modal abundances [10,11] show much less variable $\delta^{57}Fe/^{54}Fe$ values than those found on minerals; they range to within ±0.05‰ relative to IRMM 14, i.e. very similar to bulk rocky meteorites. All this suggests that the variable metal-olivine isotope fractionation reflects equilibrium crystallization from a small, closed reservoir with a limited amount of Fe, such as an asteroid.

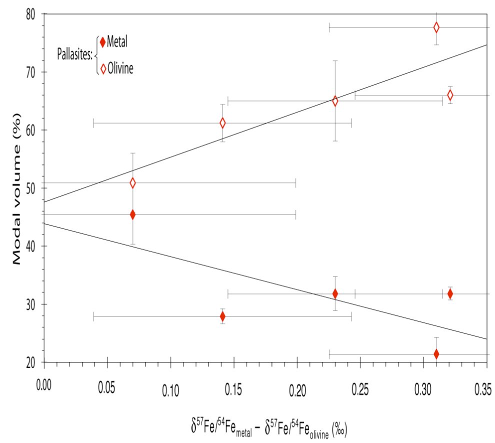

Figure 1. Difference between the iron isotope composition of metal against that of the neighbouring olivine in pallasites versus the modal abundance of these phases. Pallasite meteorites are, from left to right, Marjalahti, Springwater, Imilac, Eagle Station and Esquel. Modal abundances are from [10], except for Esquel that are from [11]. Iron isotope compositions for Imilac and Eagle Station are from [6]. Uncertainties are propagated 2SE.

Assuming that pallasites are representative of planetary mantle-core interfaces and extrapolating the results of Figure 1 to the mantle/core proportion of the Earth (which implies a planetary-scale equilibration), it is found that the Earth's mantle should be lighter than its core by 0.5‰ $\delta^{57}Fe/^{54}Fe$, thus about 0.4‰ lighter than its chondritic starting material to fulfill mass balance constraints. Mars, Vesta and the Moon, with smaller cores, should display an even lighter mantle Fe isotope composition compared to chondrites. Given that all this is not observed [4,5], it is concluded that the low temperature and pressure metal-silicate fractionation that occurred on pallasite parent bodies [9] is not transposable to planets as far as Fe isotopes are concerned. Instead, mantle-core differentiation/last equilibration of large planetary bodies is likely to be a high temperature (and presumably high pressure) event, in agreement with experimental evidence based on trace element partitioning [14]. Accordingly, metal-silicate iron isotope fractionation calculated at a terrestrial mantle-core differentiation temperature of ~2000°C [14] yield 0.024‰ between core and mantle, that leads to a mantle ~0.01‰ heavier in $\delta^{57}Fe/^{54}Fe$ than chondrites. This is clearly out of reach of current analytical precision for Fe isotope measurements.

Overall, the narrow range of $\delta^{57}Fe/^{54}Fe$ composition found among bulk rocky meteorites, irons and recalculated bulk pallasites is at stark contrast with the large, mass independent Fe isotope variations found in refractory inclusions, and also the significant mass dependent isotope fractionation measured in chondrules [1-3]. These new data support the idea of a major homogenization process occurring early in the solar system history, probably between refractory inclusion condensation and chondrite parent bodies accretion.

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