

STABLE IRON ISOTOPE ANALYSES OF METAL GRAINS IN ORDINARY CHONDRITES BY MC-ICP-MS. K. J. Gildea¹, R. Burgess¹, I. C. Lyon¹ and D. W. Sears², ¹School of Earth, Atmospheric and Environmental Sciences, The University of Manchester, Manchester, M13 9PL, UK. (karen.j.gildea-1@postgrad.manchester.ac.uk). ²Arkansas Center for Space and Planetary Science, University of Arkansas, Fayetteville, Arkansas 72701, USA

Introduction: Stable iron isotope measurements of metal grains from ordinary chondrites have been carried out in order to explore the processes involved with their formation, their early history and subsequent alteration. Metal/silicate fractionation, chondrule formation, metamorphism, aqueous alteration and other processes have probably all influenced the Fe in chondrites. We have analysed the iron isotope ratios of the metallic iron grains of 18 H, L and LL chondrites representing petrographic types 3-6, including falls and finds.

Samples and preparation: The samples had been crushed and magnetically separated during an earlier study [1]. Initial analyses were carried out by dissolving (mg) samples of the magnetic separates in 10% HNO₃. However, significant amounts of magnesium from intergrown silicates were present which caused matrix effects and also indicated the possible presence of Fe leached from the silicate. Thus, the samples were crushed further under acetone and the iron grains hand picked under a microscope. The samples were once again dissolved in a 10% solution of HNO₃ and left to re-flux until fully dissolved. They were then diluted and re-analysed to confirm that the amount of magnesium had been reduced to insignificant levels.

Mass Spectrometry: Measurements were made on a Nu Instruments double focusing multiple-collector ICP-MS. The instrument was operated in pseudo high resolution with sample solutions being introduced by a Nu Instruments DSN-100 Desolvating Nebuliser. The nebuliser is designed to minimise isobaric interferences resulting from ArN, ArO and ArOH which interfere with ⁵⁴Fe, ⁵⁶Fe and ⁵⁷Fe respectively. In this way the iron isotopes and the isobaric interferences are sufficiently resolved and appear as a flat topped peak with an iron 'shoulder' [2].

Reproducibility and accuracy were determined over a two year period by multiple measurements of an in-house Johnson-Matthey (JM) iron standard using the sample standard bracketing (SSB) technique and the IRMM014 iron isotope standard (JRC Reference Laboratory for Isotopic Measurements). The results have been calculated using the standard delta notation: $\delta^{56,57}\text{Fe} = \left[\frac{({}^{56,57}\text{Fe}/{}^{54}\text{Fe})_{\text{sample}}}{({}^{56,57}\text{Fe}/{}^{54}\text{Fe})_{\text{IRMM014}}} - 1 \right] * 1000$. For the JM standard we found that $\delta^{56}\text{Fe} = 0.34 \pm 0.03\%$ and $\delta^{57}\text{Fe} = 0.52 \pm 0.04\%$, in good

agreement with accepted values. Each measurement cycle, including the meteorite samples, consisted of a single block of 30 readings typically repeated 3-6 times and bracketed each time with IRMM014. Quoted uncertainties are to $\pm 1\sigma$.

Results: Isotopic data are given in Table 1 where each value is the average and standard deviation of 6 repeat analyses. In addition, some of the samples have been duplicated at different times to assess long-term reproducibility. In this case the result given is the average of the two or more separate measurements and is indicated in the table with an asterisk. The data are plotted in Figures 1-5.

Table 1: Isotopic data for iron grains in ordinary chondrites, all values are in ‰ relative to IRMM014.

Meteorite Sample	$\delta^{56}\text{Fe}$	1σ	$\delta^{57}\text{Fe}$	1σ
Abee EH*	0.03	0.08	0.02	0.05
Bremervörde H3	-0.01	0.09	-0.02	0.13
Clovis (no.1) H3*	0.02	0.04	-0.02	0.09
Faucett H4*	0.07	0.07	0.12	0.11
Beaver Creek H4*	0.08	0.06	0.15	0.12
Elm Creek H4**	0.13	0.04	0.20	0.08
Jilin H5*	0.09	0.04	0.21	0.07
Plainview (1917) H5*	0.10	0.03	0.19	0.08
Gilgoon H5	0.12	0.04	0.15	0.04
Acme H5*	0.14	0.07	0.18	0.10
Kernouve H6*	-0.02	0.02	-0.01	0.12
Estacado H6	0.13	0.08	0.21	0.13
Crumlin L5*	0.13	0.06	0.25	0.12
Etter L5	0.19	0.06	0.36	0.05
Calliham L6	0.19	0.05	0.38	0.06
De Nova L6	0.21	0.03	0.32	0.11
Barwell L6*	0.24	0.08	0.38	0.17
Aldsworth LL5	0.24	0.09	0.42	0.11

* sample was measured on two separate occasions.

** Elm Creek was measured on three separate occasions.

The isotopic values are plotted in Figure 1. The H, EH, L and LL chondrites produce a positive correlation with the classes showing an enrichment of the heavier iron isotopes with increasing oxidation states, H/EH → L → LL. The reduced H chondrites have a $\delta^{56}\text{Fe}$ value of -0.02‰ up to 0.14‰, while the L chondrites range from 0.14‰ to ~0.21‰ and the LL sample (and one L

chondrite sample) have a $\delta^{56}\text{Fe}$ value of 0.24‰. These figures are within previously published data [3,4].

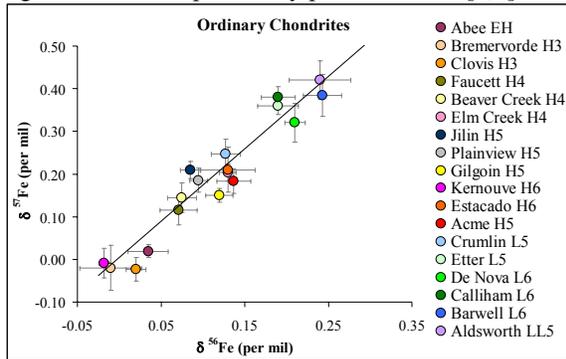


Figure 1. Fe isotopic fractionation variation from IRMM014 standard of metal iron grains from ordinary chondrites (data given in table above). Within the experimental uncertainties, the data plot along the mass fractionation line shown.

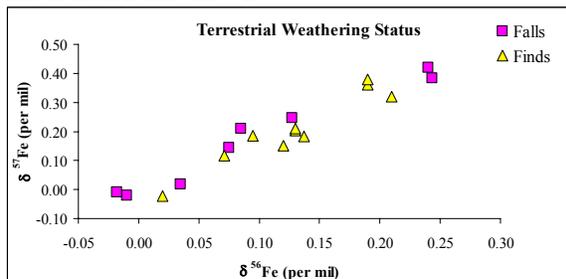


Figure 2. Meteorite samples separated into falls and finds suggests that the falls and finds cannot be distinguished in terms of their Fe isotope compositions.

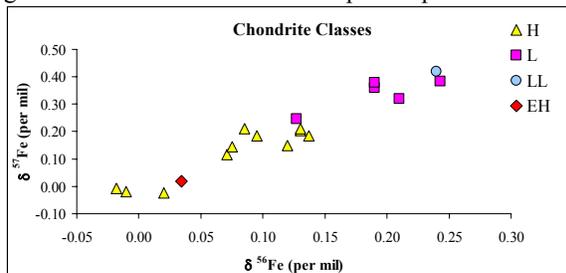


Figure 3. The data sorted by meteorite class i.e. H (n=10), L (n=5), LL (n=1) and EH4 (n=1). It appears that heavy isotope enrichment occurs along the series H/EH \rightarrow L \rightarrow LL.

The data in Fig. 4 display a positive correlation (with a slight overlap) between intensity of metamorphism and enrichment in the heavier isotopes. The obvious exceptions are the type 6's which seem to span the entire range. Kernouve is also exceptional in that it is an H6 but appears to be isotopically lighter than the H3's.

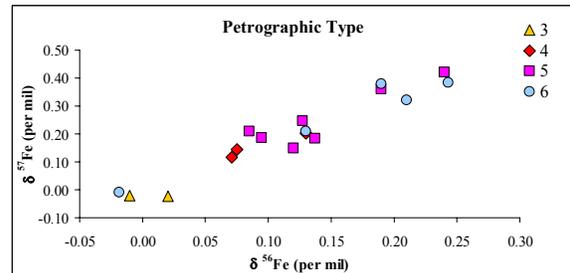


Figure 4. Samples are plotted according to petrographic types. The circular data point at the bottom left of the graph is Kernouve (H6). Kernouve aside, heavy isotope enrichment also appears to increase along the petrographic type series 3 \rightarrow 4 \rightarrow 5 \rightarrow 6, but with less discrimination than class (Fig. 3).

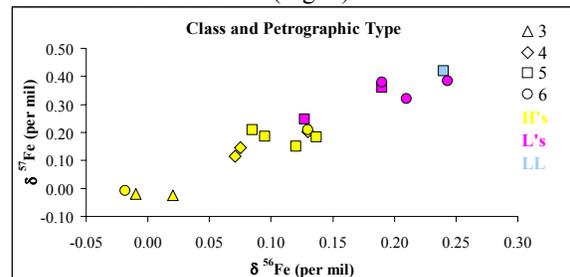


Figure 5. Data sorted by class and petrographic type.

Discussion: There is no evidence in the data for a significant effect from terrestrial weathering (Fig. 2). However, there is a relationship between chemical class (Fig. 3), petrographic type (Fig. 4) and Fe isotopes, with higher types and more oxidized classes being enriched in heavy isotopes. Disentangling the relationship between chemical class, petrographic type, and Fe isotopes will require more work. The apparent relationship between type and Fe isotopes might be an artifact of our sample selection, we have more low H types than we have low L types (see Fig. 5 above). The relationship between Fe isotopes and chemical class (Fig. 3) suggests fractionation during the process that determined oxidation state, which is usually assumed to be pre-accretionary and probably associated with chondrule formation. Mullane et al, [5] has also suggested that short lived high temperatures during formation (i.e. during chondrule formation) pushed the iron isotope ratios towards heavier compositions.

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References: [1] Sears D. W. & Axon H. J. (1976) *Nature* 260, 34-35. [2] Weyer S. & Schweiters J.B. (2003) *Int. J. of Mass Spec.*, 226, 355-368. [3] Kehm K. et al (2003) *GCA*, (67) 15, 2879-2891. [4] Zhu X. K. et al (2001) *Nature* 412, 311-312. [5] Mullane E et al., (2005) *EPSL*, 239, 203-218.