

FE ISOTOPIC COMPOSITION OF MARTIAN METEORITES

M. Anand (M.Anand@nhm.ac.uk), S.S. Russell, E. Mullane, M.M. Grady

Department of Mineralogy, The Natural History Museum, Cromwell Road, London, SW7 5BD, UK

Introduction

The scientific community has actively debated for quite some time the possibility that conditions were once favorable for life to originate and evolve on Mars. However, as we know it, for life to survive, the presence of liquid water is essential. The present day climate on Mars is inhospitable for sustaining any life form. However, recent data from twin rovers, Spirit and Opportunity, and Mars Express spacecraft have strengthened previous interpretations and suggestions that Mars was once a warmer and wetter place [e.g., 1].

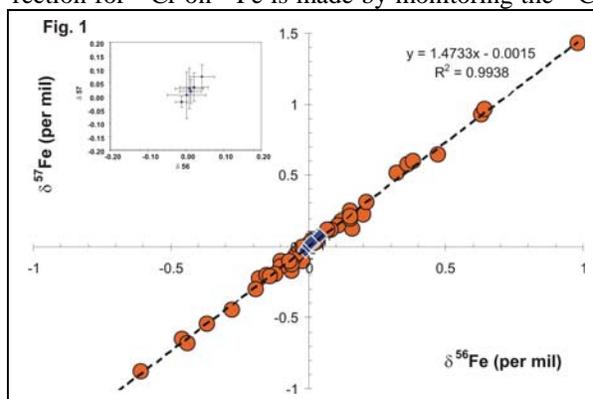
Until we have a returned sample mission from Mars, one of the ways to look for past evidence of aqueous activity on Mars is through mineral, chemical and isotopic studies of primary and secondary minerals in Martian meteorites. The focus of this research is on understanding the action and effects of water on Mars by using fractionation of iron isotopes (which can be significant during low temperature aqueous processes) to trace the alteration of primary to secondary minerals by water on Mars. Another key aspect of the project is to first establish a baseline Fe-isotope fractionation pattern in the case of high-temperature igneous rocks from Mars that are available to us in the form of Martian meteorites. Once the baseline Fe isotope fractionation in these rocks are established, it will be possible to determine any Fe isotopic variation because of low-temperature aqueous processes including biogenic activities. Previous research has recognized an evaporite sequence preserved within some of the Martian meteorites [e.g., 2]. This finding highlighted different alteration processes affecting Martian meteorites and Mars, and has important implications for the timing, extent and duration of hydrous activity at the planet's surface.

Methodology and Samples: The goals of the project are pursued through a detailed study of the bulk, elemental and isotopic composition of components within Martian meteorites. Iron is an important constituent of the rock-forming minerals that are produced at the elevated temperatures experienced during magma genesis. Iron has four stable isotopes (54, 56, 57 and 58) and is also an important constituent of secondary minerals produced by alteration of primary minerals, occurring in clay minerals and carbonates. Kinetic, equilibrium and nuclear processes fractionate the isotopes, in the same way as is commonly observed for light elements. Iron isotopes have also been shown to be fractionated by biological processes, and thus have potential in providing bio-signatures in a sample.

Previous to this study, a suite of 8 Martian meteorites were analysed for their whole-rock Fe isotope composition using an MC-ICP-MS technique, which indicated limited but distinct fractionation patterns compared to terrestrial and lunar samples [3]. In the present work, we have measured iron isotope compositions of a group of Martian meteorites to ascertain variation in

Sample	δ^{56}	+/- (2 SD)	δ^{57}	+/- (2 SD)
Los Angeles	-0.01	0.01	-0.02	0.02
Shergotty	0.02	0.04	0.03	0.05
Zagami	0.04	0.03	0.07	0.04
Sayh al Uhaymir 005	0.00	0.05	0.00	0.09
Nakhla	0.01	0.03	0.02	0.04
Chassigny	0.01	0.04	0.03	0.08
Mean (SNC)	0.01		0.02	
+/- (2 SD)	0.01		0.02	

$\delta^{56}\text{Fe}$ and $\delta^{57}\text{Fe}$. Six samples (Shergotty, Zagami, Los Angeles, Sah Al Uhaymir 005, Nakhla and Chassigny) were analysed. ~0.2g rock powder dissolution followed a two-step HF-HClO₄-HCl method [4]. Digests were purified using anion exchange chromatography, which separated out Fe, Cu and Zn. This procedure has been detailed elsewhere [4]. Fe-isotope compositions ($\delta^{56}\text{Fe}$ and $\delta^{57}\text{Fe}$) were measured on a fixed resolution ($m/m = 500$) MC-ICP-MS (IsoProbe, GV Instruments, U.K.) with respect to the Fe-isotope standard IRMM-014, using the sample-standard bracketing method [4]. Correction for ^{54}Cr on ^{54}Fe is made by monitoring the ^{53}Cr



signal and applying an on-line mathematical correction at mass 54. Blank subtraction is undertaken off-line. The effect of $^{40}\text{Ar}^{16}\text{OH}$ background at mass 57 is reduced by analyzing solutions at approximately 10ppm concentration and sample and standard solutions are concentration matched to within 5%. Typical errors are less than 0.05 per mil (2 sigma) in most cases.

Fe-isotope Fractionation: All of the Martian meteorites analysed plot within a restricted range on a 3-isotope plot (diamond symbols in Fig. 1). The inset in Figure 1 shows the spread in the measured $\delta^{56}\text{Fe}$ and $\delta^{57}\text{Fe}$ ratios in our samples with 2 sigma errors. The red circles in Figure 1 are all the Fe isotope data available on various planetary materials and have been compiled from various sources [3,4-14]. Figure 2 is a bar diagram illustrating the reported range in $\delta^{56}\text{Fe}$ among various planetary materials, including our data. The Fe-isotopic range in our samples is 0.00 to 0.02 ‰ for $\delta^{56}\text{Fe}$ and 0.00 to 0.04 ‰ for $\delta^{57}\text{Fe}$ (Table 1, Fig 1), similar to those reported for terrestrial igneous rocks [13]. Furthermore, the Fe-isotope data for Martian meteorites are tightly grouped and fall on the mass fractionation line already described for a range of other solar system samples [3,4-14] (Fig 1). The similarity and narrow range in iron isotope fractionation within the Martian meteorites, analysed in the present study, with terrestrial igneous rocks suggests that Earth and Mars were derived from a homogenous solar nebula with respect to Fe-isotope composition, consistent with

previous studies [6]. Further Fe-isotope measurement on primary and secondary minerals in the Martian meteorites is in progress. Suitable terrestrial analogues, such as some Proterozoic lava flows and sedimentary rocks, are also being studied for their Fe isotopic signatures.

References: [1] Squyres et al. (2004), *Science*, 306, 1698-1703. [2] Bridges J. C. and Grady M. M., (2000) *Earth Planet. Sci. Lett.* 176, 267-279; [3] Poitrasson et al., (2004) *Earth Planet. Sci. Lett.* 223, 253-266. [4] Mullane et al. (2003) In: Holland & Tanner (Eds.) *Plasma Source Mass Spec.*, Royal Soc. Chem. 351-361. [5] Mullane et al. (2003) LPSC XXXIV, Abs. #1027. [6] Zhu et al. (2001) *Nature* 412: 311. [6] Mullane et al. (2004) LPSC XXXV, Abs. #1015. [7] Mullane et al. (2004) *Met Soc*, Abs. #5147. [8] Mullane et al. (2004) *Met Soc*, Abs. #5148. [9] Mullane et al. (2003) LPSC XXXIV, Abs. #1027. [10] Wiesli et al. (2003) *Earth Planet. Sci. Lett.* [11] Zhu et al. (2000) *Earth Planet. Sci. Lett.* 200, 47-62. [12] Beard et al (2003) *Chem. Geol.*, 195, 87-117. [13] Beard et al (1999), *Science*, 285, 1889-1892.

