Fe isotopic composition of Martian meteorites and some terrestrial analogues

Conference or Workshop Item

FE ISOTOPIC COMPOSITION OF MARTIAN METEORITES & SOME TERRESTRIAL ANALOGUES

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Introduction

Recent Spacecraft and Lander missions have reinforced the earlier suggestions that Mars was once a warmer and wetter place [e.g., 1]. These missions have also highlighted the presence of diverse rock types on the surface of Mars. Martian landscape is increasingly thought to have been shaped by processes similar to those operating on our own Earth. Such developments have highlighted the importance of sample return missions to fully understand the Martian petrologic and hydrologic (biologic?) processes. However, until such return sample missions from Mars take place, 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 present study is the continuation of our Fe isotope work to understand the action and effects of water on Mars by using fractionation of iron isotopes, which can be significant during low-temperature alteration processes.

Methodology and Samples: The goals of the project are to study bulk, elemental and isotopic composition of components within Martian meteorites. Iron is an important constituent of the rock-forming minerals that are produced at 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 other stable isotopes. Iron isotopes have also been shown to be fractionated by biological processes, and thus have potential in providing biosignatures in a sample [2]. 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 δ^{56}Fe and δ^{57}Fe. Previously, we reported our first Fe isotope results [4] on six Martian meteorites (Shergotty, Zagami, Los Angeles, Sah Al Uhaymir 005, Nakhla and Chassigny). We have further analyzed 7 more Martian meteorites (Governador Valadares, Lafayette, MIL 03346, Y000593, Y980459, Dar Al Gani (DaG) 476), a range of terrestrial samples including basalts, granites and Antarctic sandstones which may be considered Martian analogues. The sample preparation and ion-exchange chromatography methods are same as in [5]. Fe-isotope compositions (δ^{56}Fe and δ^{57}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 [5]. 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}Ar^{16}OH background at mass 57 is reduced by analyzing solutions at approximately 5-10ppm concentration and sample and standard solutions are concentration matched to within 5%. Typical errors are less than 0.1 per mil (2 sigma) in most cases.

Fe-isotope Fractionation: All of the Martian meteorites analysed so far plot within a restricted range on a 3-isotope plot (diamond symbols in Fig. 1). The Figure 2 shows the spread in the measured δ^{56}Fe and δ^{57}Fe ratios in our samples with 2 sigma error bars. The grey circles in Figure 1 represent Fe isotope data available on various planetary materials that have been compiled from various sources [2-14]. The majority of Martian meteorites display a restricted range in Fe-isotopic composition between -0.01 to 0.04 ‰ for δ^{56}Fe and from -0.02 to 0.07 ‰ for δ^{57}Fe (Table 1, Fig 1), with a mean value only slightly lighter than the average of 9 Proterozoic basalts from Southern India analyzed in this study. However, Martian meteorite, Y 000593, has significantly heavier Fe isotope signature compared to other Martian samples and terrestrial basalts. However, the precision on Fe isotope measurement in this sample is bit poor, making it difficult to reliably assess the cause of its heavier Fe isotopic signature. The two Precambrian granite samples (SiO_2 – 69-70% and MgO – 0.9-1.6%) have the heaviest Fe isotope values, similar to those reported by [15]. The two Antarctic sandstones, MM45 and VH-59 (both are feldspathic sandstones), analyzed have different Fe isotopic signatures. Fe isotopic composition of MM45 is similar to the mean of Martian meteorite values whereas VH-59 has heavier isotopic values (Table 1, Fig. 2). Furthermore, the Fe-isotope data for all the samples analyzed in this study fall on the mass fractionation line already described for a range of other solar system samples [2-14]

(Fig 1). The mean of δ^{56}Fe and δ^{57}Fe values from the 13 Martian meteorites appear to be slightly lighter than the mean of terrestrial basalts analyzed in our study. However, given the uncertainty of 0.1 per mil on our measurements, it is not possible to conclusively establish the difference between the Martian and terrestrial basalts.

References: [1] Squyres et al. (2004), *Science*, 306, 1698-1703. [2] Beard et al (1999), Science, 285, 1889-1892. [3] Poitrasson et al., (2004) *Earth Planet. Sci. Lett*. 223, 253-266. [4] Anand et al., (2005) LPSC XXXVI, Abs. #1859. [5] Mullane et al. (2003) In: Holland & Tanner (Eds.) Plasma Source Mass Spec., Royal Soc. Chem. 351-361. [6] Mullane et al. (2003) LPSC XXXIV, Abs. #1027. [7] Zhu et al. (2001) Nature 412: 311. [8] Mullane et al. (2004) LPSC XXXV, Abs. #1015. [9] Mullane et al. (2004) Met Soc, Abs. #5147. [10] Mullane et al. (2004) Met Soc, Abs. #5148. [11] Mullane et al. (2003) LPSC XXXIV, Abs. #1027. [12] Wiesli et al. (2003) *Earth Planet. Sci. Lett.* [13] Zhu et al. (2000) *Earth Planet. Sci. Lett.* 200, 47-62. [14] Beard et al (2003) Chem. Geol., 195, 87-117. [15] Poitrasson et al. (2005) Chem. Geol., 222, 132-147.

Table 1

Sample	δ 56 Fe(‰)	+/- (2 SD)	δ 57 Fe(‰)	+/- (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	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
Governador Valadares	0.02	0.02	0.07	0.05
Lafayette	-0.02	0.02	0.04	0.05
MIL 03346	0.02	0.02	0.06	0.07
NWA 1183	0.02	0.02	-0.01	0.07
Y980459	0.03	0.06	0.02	0.09
DaG 476	0.07	0.06	0.06	0.08
Mean	0.03	0.04	0.04	0.06
1.9Ga Basalts (Mean of 9 samples)	0.05	0.05	0.07	0.07
Precambrian Granites (Mean of 2 samples)	0.28	0.11	0.45	0.16
Antarctic sandstone MM45	0.01	0.05	0.01	0.04
Antarctic sandstone VH59	0.14	0.05	0.2	0.07

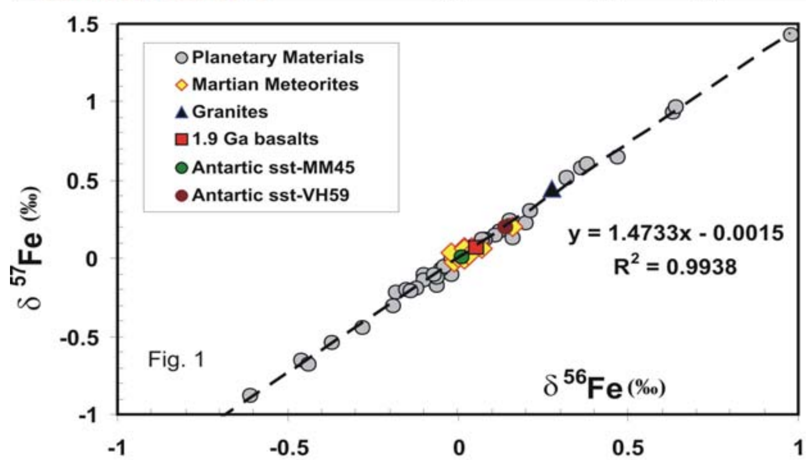

Fig. 1

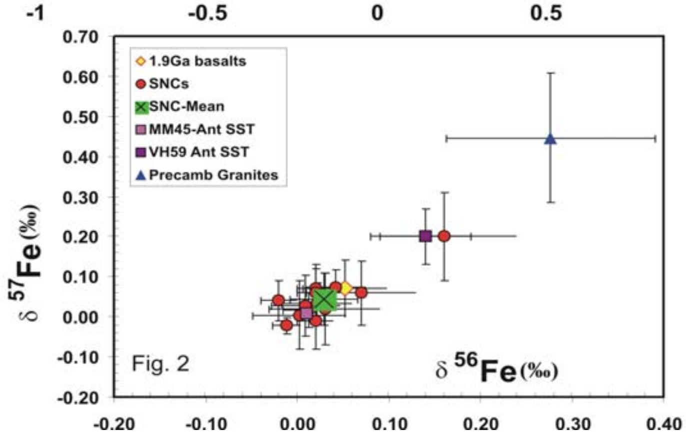

Fig. 2