OXYGEN ISOTOPE COMPOSITIONS OF MINERAL SEPARATES FROM SNC METEORITES: CONSTRAINTS ON THE PETROGENESIS OF MARTIAN MAGMAS.

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Introduction: Martian (SNC) meteorites are igneous rocks that range from a reduced, trace-element depleted end member to an oxidized, trace-element enriched end member [1-3] (Figure 1). One interpretation of this trend is that relatively reduced, depleted magmas are partial melts of a reduced peridotitic mantle, whereas more oxidized, enriched magmas are mantle-derived magmas contaminated by oxidized, aqueously altered crustal rocks. In this case, the compositional trend defined by SNC meteorites would be a record of crustal assimilation processes and could be used to constrain the average composition of the Martian crust [4, 5]. Alternatively, the two end members could reflect partial melting of two (or perhaps more) compositionally distinct mantle components (e.g., enriched, oxidized domains entrained in the ambient depleted mantle [6, 7]; the enriched mantle domains might be products of early differentiation of the Martian mantle).

Oxygen isotope geochemistry has the potential to discriminate between these alternate hypotheses. On Earth, oxygen isotope ratios (i.e., $^{18}O/^{16}O$) of mantle peridotites differ systematically from crustal materials (mainly as a consequence of aqueous alteration in the shallow crust) [8 and references therein]. This contrast in oxygen isotope composition has been used to constrain crustal assimilation processes in the differentiation of terrestrial igneous rocks and to identify subducted crust in the sources of mantle-derived magmas [9]. It is conceivable that this approach can be applied to understanding similar processes for Mars. Oxygen isotope compositions of whole rock samples of the SNC's appear to correlate with oxygen fugacity [7] (as well as various other correlated properties; Figure 1). This relationship has been interpreted as evidence that martian magmas are derived from a depleted, reduced mantle followed by variable amounts of contamination by oxidized, ^{18}O-rich, aqueously altered crust. However, there are two reasons why the available oxygen isotope data may not simply reflect the $\delta^{18}O$ values of Martian magmas: (1) Many SNC's contain high-$\delta^{18}O$ alteration phases from martian and/or terrestrial weathering. And, (2) many SNC's are cumulates that would not be expected to match compositions of the magmas from which they accumulated. This study examines mineral separates subjected to various pre-treatment procedures in an effort to reconstruct the $\delta^{18}O$ values of melts.

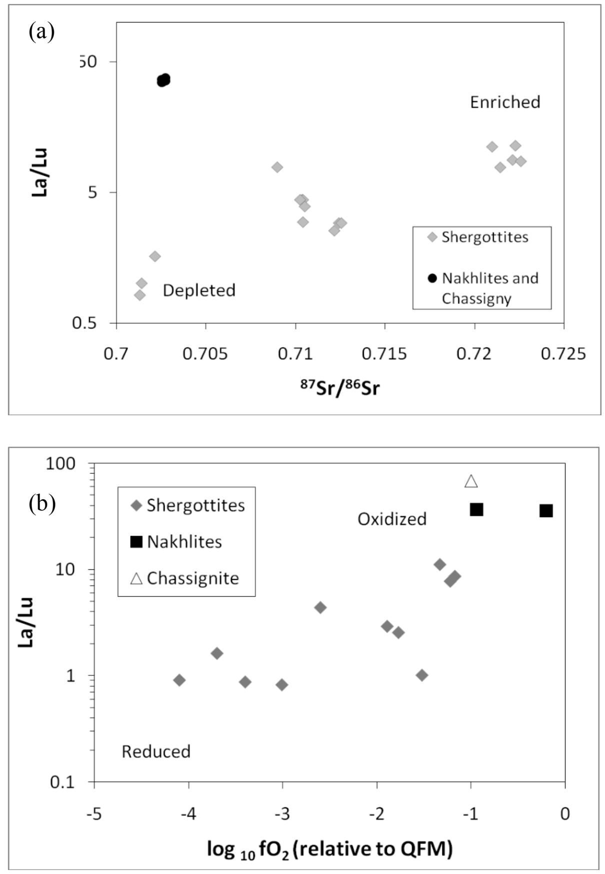

Figure 1. (a) Shergottites define a trend between enriched and depleted endmembers. (b) All SNC's define a similar trend between oxidized and depleted endmembers. Both plots are reproduced after [3].

Methods: Oxygen isotope compositions of olivine and pyroxene separates were measured at Caltech using CO_2 laser fluorination. Detailed methods are described in [10, 11]. The separations were done by hand under a binocular microscope; the phases were verified using Raman spectroscopy (particularly the early separates). Aliquots of pyroxene separates from sample NWA 998 (a highly weathered sample) were washed in 2.5M HCl for 20 minutes at 90 ˚C, and a subset of these aliquots were washed in 5% HF for 10 minutes at room temperature then rinsed with 2.5M HCl and again with deionized water (all were dried prior to analysis). The isotopic compositions of melts coexisting with the monomineralic separates were calculated with methods described in [8] assuming a magmatic temperature of 1350 ˚C.

Results: Twenty-five measurements were made on olivine and/or pyroxene separates from four SNC samples (Table 1). Samples ALHA 77005 and NWA 1950 are both lherzolitic shergottites, while Lafayette and NWA 998 are both nakhlites. Washed and unwashed pyroxene separates from sample NWA 998 yielded results with no greater than 0.13 per mil difference.

Table 1. Data obtained from this study.

Sample	Mineral	$\delta^{18}O$ (‰)
ALHA 77005	Ol	4.21±.13
		Calculated Melt: 4.76
NWA 1950	Cpx	4.60±.11
	Ol	4.37±.02
		Calculated Melt: 4.88
Lafayette	Cpx	4.77±.10
	Ol	4.44±.16
		Calculated Melt: 4.99
NWA 998	Unwashed Cpx	4.93±.03
	HCl washed Cpx	4.86±.06
	HF washed Cpx	4.80±.10
	Average Cpx	4.87±.09
	Olivine	4.34±.16
		Calculated Melt: 4.99

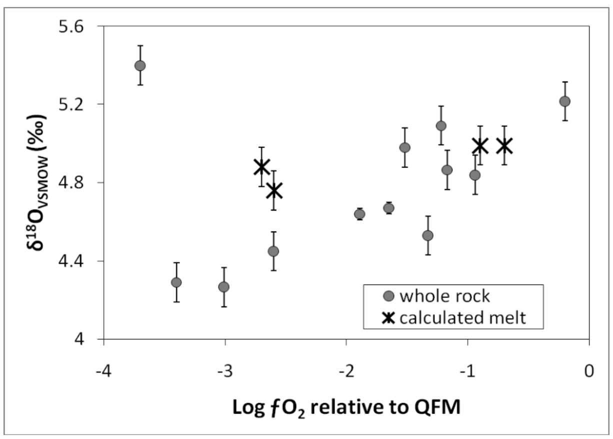

Figure 2. The whole rock oxygen isotope data come from [12-16], and do not include measurements made by conventional fluorination. Where errors were not reported, a value of 0.1 was assigned (a typical value). The oxygen fugacity data come from [17-19]. Three of the calculated melt samples are plotted using estimated oxygen fugacity data by using numbers from other martian meteorites that have similar $^{87}Sr/^{86}Sr$ and/or La/Lu values. This plot is reproduced after [7].

Discussion: Our results suggest that liquids from which the SNC's crystallized vary in $\delta^{18}O$ by significantly less than previously inferred from whole-rock measurements. Moreover, they suggest that the correlation between $\delta^{18}O$ and oxygen fugacity for whole rocks (dots in Figure 2; see [12-16]) relates to systematic differences in average mineralogy between reduced and oxidized samples rather than to differences in their parent magmas (Figure 2). Our data set is not yet large enough to conclude whether assimilation of ^{18}O-rich materials influences martian magmas generally, but the differences between our mineral-separate data and previous whole-rock data urge caution. Our leaching experiments suggest that alteration of the SNC's has little effect on their average $\delta^{18}O$ values.

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