CONTINUED EVIDENCE FOR CHLORINE-RICH MARTIAN MAGMAS: CONSTRAINTS ON THE CHLORINE CONTENT OF THE MARTIAN MANTLE. J. Filiberto[1] and J. Gross[2], [1]Southern Illinois University, MC 4324, Carbondale, IL 62901. email: Filiberto@siu.edu, [2]The American Museum of Natural History, Dept. of Earth and Planetary Sciences, New York, NY 10024. Email: jgross@amnh.org.

Introduction: There is considerable debate about the pre-eruptive magmatic volatile (H_2O, F, and Cl) contents of Martian basalts and hence their source regions. The bulk water contents of the Martian meteorites are rather low compared to terrestrial basalts (< 350 ppm H_2O released at T>350 °C, [e.g., 3]), as are the magmatic water contents of glassy olivine-hosted melt inclusions in primitive basaltic shergottites (< 251 ppm H_2O, [9]). Comparable terrestrial basaltic rocks typically contain much higher concentrations of H_2O (~2,000–20,000 ppm, [e.g., 11, 12, 13]). Bulk fluorine and chlorine contents of the unaltered Martian basalts are similar to those of terrestrial tholeiites (29-41 ppm F and 14-137 ppm Cl) [4, 8, 14]. However, Martian magmas may have partly degassed upon eruption and lost water and/or halogens to the surface [e.g., 16]. Here we use apatite, amphibole, and the bulk chemistry of Martian meteorites to estimate the pre-eruptive chlorine concentration of Martian magmas and use this to calculate the chlorine content of the Martian mantle.

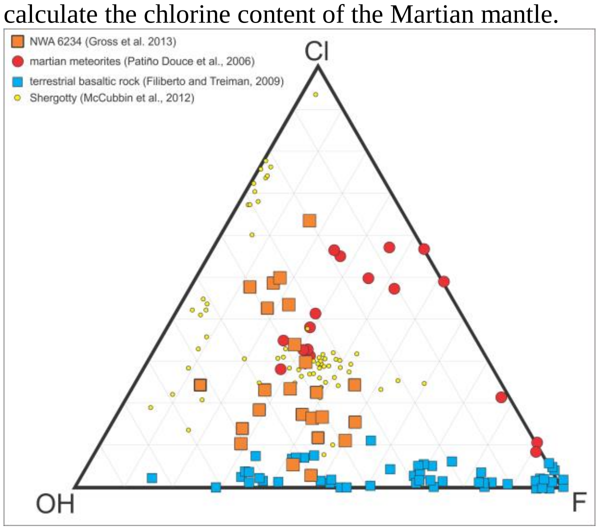

Figure 1. Martian apatite data modified from [2]. Data for apatite in NWA 6234 (orange) from [4], Shergotty [7, 8], Martian meteorites in general as in [15], compared with apatite in unaltered or metasomatised terrestrial rocks as in [1].

Apatite and Amphibole Chemistry: Many studies have focused on using the OH-bearing phases amphibole and apatite to constrain the Martian igneous volatile history and budget [e.g., 1, 7, 15, 17]. Apatite in Martian meteorites range from OH- bearing, F- apatite to almost pure end member Cl-apatite (figure 1) which suggests a range in volatile contents of primary magmas with some being potentially rich in H_2O [2, 7]. However, the majority of Martian apatite are chlorine-rich and typically plot in or near the field of chlorine-dominant parental magma (from [18]) suggesting that the majority of magmas that crystallized apatite are chlorine-rich and some may have chlorine as the dominant volatile (or at least co-dominant with H_2O). Further, recent investigations of apatite in lunar rocks showed that apatite is not a robust hygrometer and using the F:Cl:OH ratio of apatite to calculate the parental magma volatile concentration can over estimate the H_2O content of the parental magma [19].

Recently, there has been much less focus given to amphibole in Martian meteorites and there are few direct analyses of water in Martian amphiboles [20-22]. Kaersutite in Chassigny has 0.1 wt% Cl and 0.5 wt% F from EMP analyses, but SIMS analyses have yielded two distinctly different results for water content: 0.1–0.2 wt% H_2O and 0.41–0.74 wt% H_2O [20-22]. Kaersutite in the chassignite NWA 2737 has F and Cl concentrations (0.45-0.58 and 0.09-0.13 wt% by EMP) that are similar to those in Chassigny, and ~0.1 wt% H_2O measured by SIMS [22-24] but may have been affected by shock dehydrogenation [22]. Kaersutites in Zagami and Shergotty have ~0.1-0.2 wt% H_2O measured by SIMS but < 0.1 wt% F and Cl measured by EMP [25, 26].

Thus, there is a wide uncertainty, as well as variation, in volatile concentrations of Martian amphiboles and apatites, and therefore in volatile concentrations of Martian magmas.

Bulk Chemistry: Bulk chlorine contents of the unaltered Martian basalts are similar to those of terrestrial tholeiites (12-225 ppm Cl; fig. 2) which has been used to suggest that the Martian interior has bulk halogen contents similar to the Earth [4, 8]. However, in order to compare bulk composition of different planetary bodies it is not enough to just compare concentrations of elements. Instead, we must compare ratios of similarly incompatible elements which accounts for differences in magmatic processes such as partial melting and fractional crystallization [e.g., 14]. Comparing the Cl/La ratio of Martian basalts to terrestrial basalts (figure 2) shows that while Martian basalts have similar Cl concentrations to terrestrial basalts, they have lower La concentrations consistent with higher degrees of partial melting and/or smaller amounts of fractional crystallization. Further, the majority of Martian basalts fall along a line. Interestingly, Chassigny has a Cl/La ratio consistent with the Mars array and is suggested to represent the Martian interior, at least in terms of noble gas data [27]. By filtering the data to only the data that falls on the Mars array line, we calculate a Cl/La ratio for Martian basalts of 51 +/-17 ppm; however, there may be source regions with different Cl/La ratios.

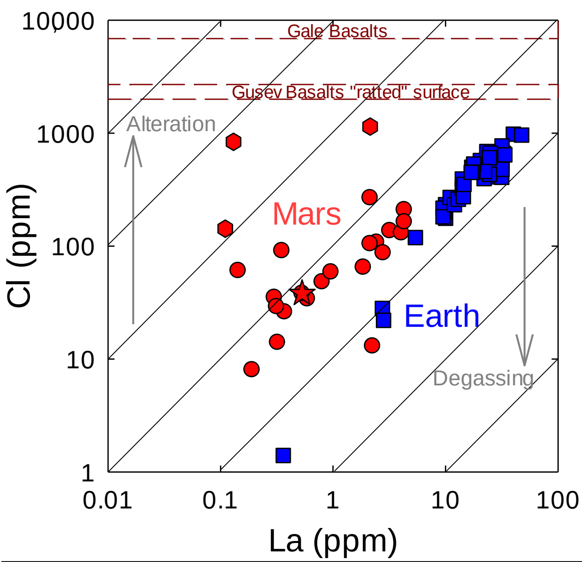

Figure 2. Bulk Cl (ppm) and La (ppm) values for Martian meteorites (red symbols) compared with terrestrial basalts (blue symbols). Updated from [1] with newer bulk chemical data [4, 5, 8]. Red star represents Chassigny bulk composition. Also shown for comparison are Cl data (brown boxes) for abraded rocks in Gusev Crater [6], and rocks from Gale Crater [10]. There are no La data for these rocks. Arrows show how alteration and degassing would affect the Cl/La ratio.

For the Earth, we calculate a Cl/La ratio of 21 +/-6 ppm. Comparing these rations, we calculate that Mars has a Cl/La ratio 2.5 (+/- 1.0) times that of the Earth consistent with previous notions that Mars is 2-3 times as enriched in Cl as the Earth [1, 14, 28]. We can now use this comparison to calculate the Cl concentration of the source region of the SNC meteorites. Using La value of 0.48 ppm [29], we estimate a bulk Cl abundance of 25 +/- 8 (ppm) which is significantly lower than the Cl abdunace calculated for the interior based on the crustal Cl/K ratio (390 ppm; [30]), and slightly lower than previous estimates based on the SNC meteorites 44 ppm [28]. Surprisingly, our new estimate is similar to estimates for the terrestrial enriched mantle (30 ppm) but an order of magnitude higher than estimates for the terrestrial depleted mantle (1 ppm) [13, 31, 32]. This may suggest a source region for the SNC meteorites with a chlorine content (and potentially other volatiles) similar to the enriched MORB-source.

References:

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