

HIGH PRESSURE MELTING OF H-CHONDRITE: A MATCH FOR THE MARTIAN BASALT SOURCE MANTLE. C. B. Agee and D. S. Draper, Institute of Meteoritics, Dept. of Earth and Planetary Sciences, MSC03 2050, Albuquerque, NM 87131, agee@unm.edu, david@draper.name.

Summary: Melting experiments on the Farmville H4 ordinary chondrite up to pressures of 9 GPa and temperatures of 1960°C produce silicate liquids that are remarkably good matches for the major element composition of the martian basalt (shergottite) source region. A precise and simple mass balance shows that a Martian mantle with a bulk silicate composition similar to H4 ordinary chondrite can produce primitive shergottite magmas such as the calculated parent liquids of shergottites ALH 77005, LEW 88516, EETA 79001A and the magma represented by Yamato 980459. The mass balance is interpreted as a simple two stage process: 1) partial melting of H-chondrite-like source region at high pressure (~9 GPa) in the deep Martian mantle and 2) fractionation of olivine ± orthopyroxene at lower pressures. This is the first experimental study to show that shergottite parent magmas can be derived from a martian mantle having a chondritic major-element composition by equilibrium magmatic processes. Furthermore, these new experiments are in agreement with our hypothesis [1] that the martian mantle has an Mg# (molar Mg/Mg+Fe) = 80, higher than the widely accepted value of Mg# = 75 proposed by Dreibus and Wänke [2] (DW hereafter). This finding is also in accord with inferences made from recent geochemical modeling [3, 4].

Background: Extending the earlier work of Bertka and Holloway [5] and Longhi [6] to higher pressures, we have been searching for experimental conditions under which it may be possible to derive Martian basalt parent magmas from model Martian mantle compositions. Our recent paper [1] on high pressure melting of Homestead L-chondrite (very similar in composition to DW model mantle) showed that although the superchondritic CaO/Al₂O₃ of shergottites can be produced from a DW model mantle at pressures of 5 GPa, the very high FeO/MgO and FeO contents of these melts are completely inconsistent with shergottite compositions. We concluded that there appears to be no simple or multi-stage equilibrium process whereby shergottite parent magmas can be produced from a DW model mantle. On the other hand, our experiments also led us to speculate that there may be compositions within the range of chondrites that are different enough from DW that they could produce matches to shergottite parent liquids when melted at mantle pressures in the presence of olivine (ol), orthopyroxene (opx), and garnet (gt). We noted that a composition with a lower

FeO content, like H-chondrite (Mg#=80) might produce liquids at high pressure having a closer resemblance to shergottite parent melts calculated by a range of authors (see [1] for these references). Thus we embarked on a search for an alternative Martian mantle composition by performing a series of melting experiments on the Farmville H4 chondrite. Note that the silicate fractions of Homestead and Farmville are identical except for their FeO and MgO contents, and hence Mg#'s (Farmville has ~13.3 wt% FeO and 30.5 wt% MgO with Mg# 80.4 and Homestead has ~16 wt% FeO and 29.4 wt% MgO with Mg# 76.6). Here we present the first results from this investigation.

Experimental Results: All experiments were performed using a multi-anvil device at the High Pressure Laboratory, Institute of Meteoritics, University of New Mexico. Experimental procedures are the same as described in Agee and Draper [1]. The starting material was a finely ground aliquot of the Farmville H4 ordinary chondrite obtained from the Institute of Meteoritics' Meteorite Collection. Experiments were carried out at pressures from 5.5 to 9.0 GPa and temperatures of 1850 to 1960°C. These conditions were selected to target the P-T intervals where silicate melt is likely to coexist with ol, opx, and gt. Our initial experiments were run at 5.5 GPa, a pressure close to those of our melting experiments on L-chondrite. At this pressure, Farmville's solidus is at 1850°C, with a trace of melt (too small to analyze with the electron microprobe) coexisting with ol, opx, and gt. Just 25°C hotter, Farmville is ~60 wt% melted and garnet is absent, consumed by the initial stages of melting. Therefore we ran subsequent experiments at higher pressures where the stability field of garnet in this composition was expected to expand, as it is difficult to achieve temperature intervals narrower than 20-25°C using the multianvil. Several scoping experiments at 7-9 GPa led us to the optimum conditions of 9 GPa and 1960°C where we produced a significant (~80 wt%) silicate melt pool coexisting with ol, opx, and majoritic gt (3.24 Si and 1.34 Al per 12-oxygen formula unit). Figure 1 summarizes the CaO-Al₂O₃ and FeO-MgO of average melt compositions from these experiments along with those of 5 GPa melts of Homestead [1], compositions of the starting materials, several calculated shergottite parent liquids, and Yamato 980459, a recently recovered olivine-phyric shergottite that appears to represent a primitive shergottite liquid [7].

Mass Balance and a Match for the Martian Basalt Source Mantle: Figs. 1a and 1b show that the combination of partial melting of H-chondrite at 9 GPa and lower pressure fractionation of olivine (arrows on plots) is also consistent with the FeO-MgO and Mg# of shergottite parent melt compositions. Fig 1c shows

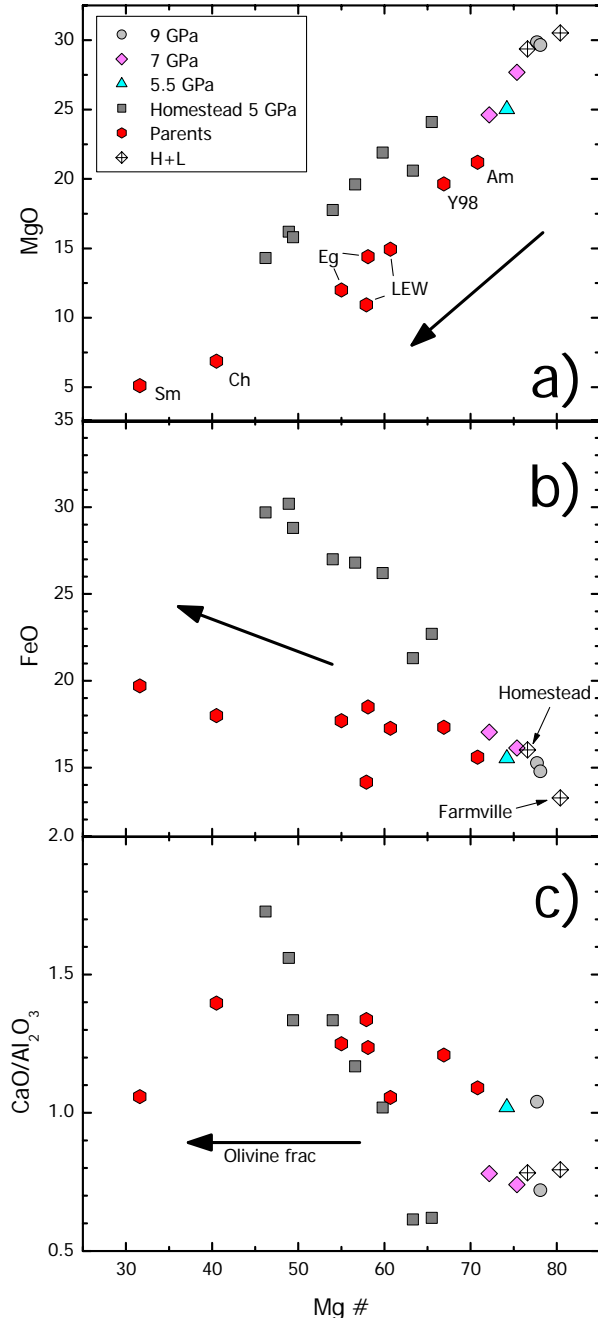


Figure 1. Melt compositions from Farmville compared with previous results on Homestead and with proposed SNC parent melts. See text for discussion

that the CaO/Al₂O₃ of our experimental H-chondrite melts is within the range of calculated martian parent liquids (1.0-1.5). This match suggests that it is possible

to derive superchondritic CaO/Al₂O₃ in martian basalt parents from an H-chondrite-like martian mantle by partial melting at depths of ~750 km (P=9 GPa). The CaO and Al₂O₃ contents of martian parent liquids are all higher than H-chondrite partial melts. This apparent discrepancy can also be explained by the subtraction of olivine during a second stage of magmatism.

This inference is further supported by least-squares mass balance modeling. We found that 9 GPa H-chondrite melt can be expressed as linear combinations of olivines (Fo₈₅₋₈₈) and putative shergottite parent liquids. The calculations yielded surprisingly precise major element mass balances. For example, we calculate (1.01) H-chondrite melt = (0.65) Yamato 980459 + (0.36) Fo₈₈ olivine with sum $r^2=0.73$. Thus, the Yamato 980459 magma could be derived by melting H-chondrite at 9 GPa and then subtracting 35% Fo₈₈ olivine via lower-pressure fractionation. We obtain similar best fit matches for the calculated parent liquids of ALH77005, LEW88516, and EETA79001A, using 9 GPa H-chondrite melt and amounts of subtracted olivine (Fo 85-88) ranging from 25 to 45%.

Discussion: We interpret the physical meaning of these mass balances as a simple two stage magmatic process that produces shergottite parent magmas via partial melting of an H-chondrite-like source region at depths of ~750 km in the Martian mantle, followed by lower-pressure fractionation of olivine (and perhaps opx). Geophysical constraints such as Mars' moment of inertia factor are satisfied equally well by silicate fractions of both L and H chondrites. The H-chondrite-like mantle can be envisaged, in turn, as the product of wholesale crystallization of an extensive, early magma ocean on Mars, for example as proposed in recent geochemical models [3,4]. Thus, the shergottite source regions undergo the "processing" required to impose isotopic and trace element features as measured and inferred from martian meteorite studies, while maintaining an appropriate major element bulk composition to account for the major element compositions of shergottites and their putative parent liquids. The mechanism by which the parent melts are generated from the martian mantle may well resemble the plume-like mechanisms recently modeled by Kiefer [8].

References: [1] Agee C. B. and Draper D. S. (2004) *EPSL*, 224, 415-429. [2] Dreibus, G. and Wänke, H., (1985) *H. S. Festschrift*, 20, 367-381. [3] Borg L. E. and Draper D. S. (2003), *MAPS*, 38, 1713-1731. [4] Draper D. S. et al. (2005), this meeting. [5] Bertka C. M. and Holloway J. R. (1994), *CMP*, 115, 323-338. [6] Longhi J. (1995), *GCA*, 59, 2375-2386. [7] McKay G. A. et al. (2004), *LPSC XXXV*, 2154. [8] Kiefer W. S. (2003), *MAPS* 38, 1815-1832.