MELTING OF MODEL MARTIAN MANTLE AT HIGH-PRESSURE: IMPLICATIONS FOR THE COMPOSITION OF THE MARTIAN BASALT SOURCE REGION. C. B. Agee and D. S. Draper, Institute of Meteoritics, University of New Mexico, Albuquerque NM 87131, agee@unm.edu.

Summary: High-pressure melting experiments on the Homestead L5 ordinary chondrite were performed at 5 GPa in a multi-anvil device over a temperature interval that ranged from near solidus to near liquidus conditions. Near solidus silicate liquids of Homestead have higher CaO/Al_2O_3 and lower Mg# compared to solidus liquids of terrestrial peridotite (e.g.: KLB-1) at this pressure. The silicate portion of Homestead is similar to proposed model Martian mantle compositions and therefore these experiments may place constraints on the nature of melts derived from the Martian interior at high pressure. For example, the super-chondritic CaO/Al_2O_3 of several proposed shergottite parent magmas fall within the range of the experimental Homestead melts, however the CaO and Al_2O_3 contents of the shergottite parent magmas are higher than Homestead melts. Thus a model Martian mantle composition can produce shergottite CaO/Al_2O_3 by partial melting at a depth of ~425 km, however a second stage of shallow level magmatism with olivine (± low-Ca pyroxene) fractionation is required to match CaO and Al_2O_3 values. FeO content of Homestead partial melts at 5 GPa are much higher than are those of shergottite parent magmas, implying that the shergottite source mantle could be lower in FeO than the Dreibus and Wanke [1] Martian mantle composition (DW hereafter).

Background: The main goal of this study is to use high-pressure, high-temperature melting experiments to determine if it is possible to derive the major element abundances of Martian basalts (shergottites) or their parent magmas from a model Martian mantle composition. Earlier melting experiments on FeO-rich bulk compositions [2-6] similar to the composition in our current study have cast some doubt on the feasibility of generating shergottite parent magmas by near-eutectic melting in the incipient garnet stability field. These studies showed that shergottite-like magmas, with super-chondritic CaO/Al_2O_3, cannot be produced by partial melting in the pressure range 1.5-3.0 GPa (~150-300 km depth in Mars). However, it is well established from numerous phase equilibrium studies at P>3 GPa on chondritic compositions and on Earth mantle peridotites [7-9] that increasing pressure up to ~15 GPa continuously expands the stability field of garnet at the expense of all other crystalline phases, and decreases garnet solubility in silicate melt. Hence, it can be expected that partial melts at P>3 GPa will be characterized by increasing CaO/Al_2O_3, approaching values observed in shergottites. Therefore we were motivated to determine if the partial melting of a model Martian mantle composition at higher pressures could give rise to shergottites or their parent magmas.

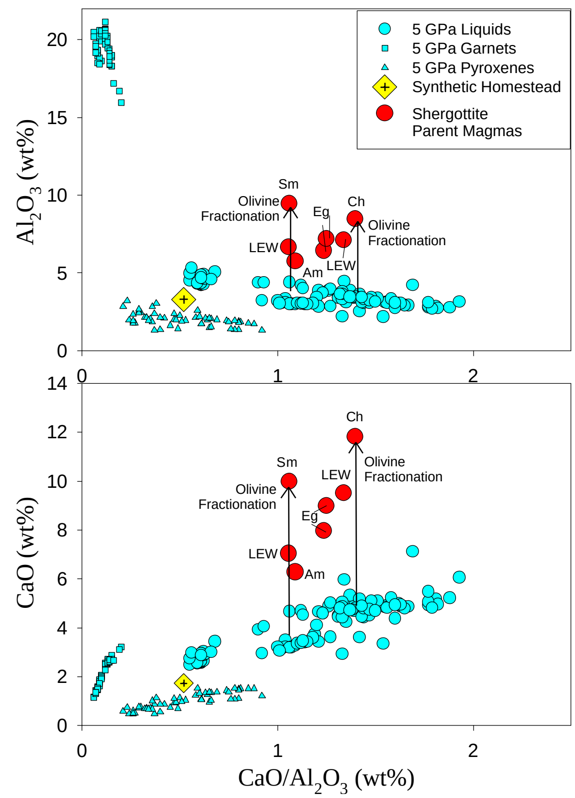

Figure 1. $CaO-Al_2O_3$ compositions of 5 GPa Homestead melts and calculated Martian parental melts. *Sm,* Shergotty [10]; *Ch,* Chassigny [11]; *LEW,* LEW88516 [12]; *Eg,* EETA79001A [13, 14]; *Am,* ALH77005 [15].

Experimental Results: Figure 1 summarizes $CaO-Al_2O_3$ of liquids and crystals coexisting at temperatures (1770-1860 C) between the silicate solidus and liquidus at 5 GPa from nine experiments on synthetic Homestead L5 chondrite. The major element composition of the synthetic mixture [Draper et al., PEPI, in review] is similar to the silicate fraction of natural Homestead and to the DW Martian mantle composition [1]. Liquidus phases plotted are garnet and low-Ca pyroxene (blue squares and triangles). Olivines (blue diamonds) are not plotted here, but are found in figure 2. Partial melts of Homestead are shown as blue dots in both figures. Near-solidus melts are characterized by high CaO/Al_2O_3, approaching a value of ~2 at the eutectic temperature. Melts formed at higher than solidus temperatures trend to lower CaO/Al_2O_3 in figure 1, with near-liquidus melts plotting close to the synthetic Homestead bulk composition. Also shown in figure 1 are several possible Martian parent magma compositions [10-15]. The CaO/Al_2O_3 of Martian parent magmas fall within the range of intermediate temperature melts from Homestead. This match suggests that it is possible to derive the CaO/Al_2O_3 of these Martian basalt parent magmas from a model Martian mantle composition by partial melting at depths of ~425 km (P=5 GPa). Figure 1 also shows that the CaO and Al_2O_3 content of Martian parent magmas are all higher than Homestead partial melts. This apparent discrepancy can be explained by the subtraction of olivine during a second stage of magmatism (arrows in figure 1). More evolved magmas (Sm and Ch) with higher CaO and Al_2O_3 contents could have fractionated relatively high amounts of olivine, while more primitive magmas (Am) could have fractionated relatively low amounts of olivine. Thus we envisage at least two stages in the petrogenesis of shergottite parent magmas. The first stage would be a deep level partial melting process at pressures greater than 3 GPa, consistent with experiments at 5 GPa, in equilibrium with garnet, low-Ca pyroxene and olivine. The second stage would require transport of the partial melts to shallow mantle or crustal magma chambers where variable amounts of olivine fractionation could occur. Fractionation of olivine leaves the super-chondritic CaO/Al_2O_3 unperturbed, although the concentrations of CaO and Al_2O_3 in the melt will increase.

FeO content of the Martian Basalt Source Region: Figure 2 demonstrates that there is a significant FeO mismatch between Homestead partial melts and Martian parent magmas. For a given Mg#, Homestead melts are more FeO-rich than are calculated Martian parental magmas. The mismatch is greatest for evolved magmas Sm and Ch that require the most olivine fractionation. Olivine fractionation increases the FeO content of the melt and decreases the Mg# (arrows in figure 2). These large differences in FeO content appear to be inconsistent with high-pressure derivation of shergottite magmas from the Homestead ordinary chondrite or other FeO-rich compositions such as the DW [1] Martian mantle. A possible remedy for this inconsistency would be to lower the FeO content and raise the Mg# of the model Martian basalt source region. This would likely shift the partial melt FeO-MgO values to approximate coincidence with the Martian parent magmas. Such mantle source region compositions could be intermediate between FeO-rich Mars mantle models and MgO-rich Earth mantle models (e.g.: KLB-1), and these unexplored compositions should be candidates for future experimental melting studies.

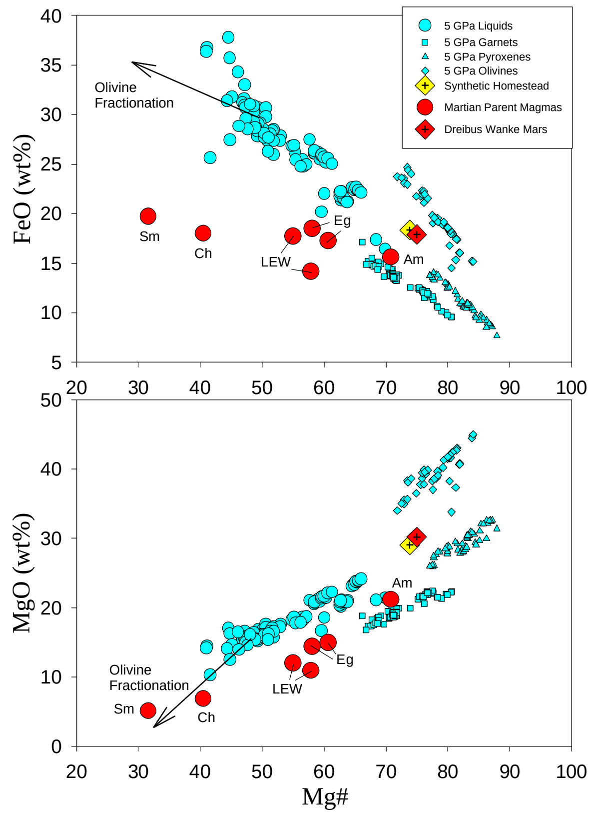

Figure 2. Fe-Mg compositions of 5 GPa Homestead melts and calculated Martian parental melts. Symbols as in figure 1.

References

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