

EXPERIMENTAL INVESTIGATION OF GEOPHYSICALLY-CONSTRAINED MARTIAN MANTLE COMPOSITIONS. M.E. Minitti¹, Y. Fei² and C.M. Bertka³, ¹Center for Meteorite Studies, School of Earth and Space Exploration, Arizona State University, Tempe, AZ, 85287-1404 (minitti@asu.edu). ²Geophysical Laboratory, Carnegie Institution of Washington, Washington, DC, 20015. ³Directorate for Science and Policy Programs, AAAS, Washington, DC 20005.

Introduction: A fundamental goal in the study of Mars is understanding its accretion, differentiation and evolution. From a petrology standpoint, much of this research has been focused on trying to recreate the lithologies represented by the Martian meteorites from various model Martian interiors [1,2,3]. However, the ever-increasing amount of data about the composition of Martian surface materials coming from orbiters and landers has expanded the range of compositions available for testing Martian mantle melting models to new mafic compositions that are not necessarily reminiscent of the Martian meteorites (TES [4], picritic basalts from Gusev, [5]) to andesitic compositions apparent in flows [6] and even quartzofeldspathic lithologies [7]. Studies that have tried to recreate various Martian igneous lithologies have met with varying degrees of success [1,2,3,8].

The goal of this study is to recreate the range of currently known Martian igneous lithologies by melting Martian mantle compositions constrained by geochemical and geophysical data. Geophysical data provide real and meaningful constraints on the composition of the Martian interior, as detailed by the studies of [9] and [10]. The two most relevant parameters are moment of inertia [e.g., 11] and crustal thickness, for which the Mars Global Surveyor mission provided a global average of 50 km [12]. [9,10] demonstrated that these two parameters constrain the Mg# (73-79) of the Martian mantle and the bulk Fe (23.10-24.20) and Fe/Si of Mars (1.319-1.495). This suite of values requires that Mars is a product of a mixture of chondrite compositions rather than a single chondrite composition.

We combined pairs of chondrites in a series of mixing calculations to yield Martian mantle compositions allowed by the geophysical constraints. We selected two compositions (CM+L and H+L, Table 1) for experimental study. Table 1 compares these new mantle compositions to previously studied Martian mantle compositions [13,14]. The subtle differences in major element concentrations of the mantles translate into meaningful differences relative to the parameters constrained by the geophysical data. Our hypothesis is that these compositional differences will allow the new mantles to better reproduce Martian igneous lithologies than previously studied compositions.

	CM+L	H+L	DW [13]	AD [14]
SiO ₂	46.9	47.6	44.5	47.0
Al ₂ O ₃	3.1	2.8	3	2.7
FeO	30.7	30.0	30.2	30.5
MgO	15.1	15.6	17.9	13.3
CaO	2.5	2.2	2.5	2.1
Na ₂ O	0.4	0.5	0.5	1.1
P ₂ O ₅	0.3	0.3	0.2	0.3
Cr ₂ O ₃	0.4	0.4	0.5	0.4
MnO	0.7	0.7	0.8	0.7
Proportions	CM:L = 42:55	H:L = 34:67	na	na
Bulk Fe (wt%)	23.1	24.07	27.8	27.34
Bulk Fe/Si	1.34	1.31	1.71	1.63
Mantle Mg#	78.4	77.5	75	80.3

Experimental: We synthesized the CM+L and H+L compositions by mixing oxide, carbonate and phosphate powders and then thoroughly grinding them in an agate mortar and pestle under ethanol. We reduced the powders to near the IW oxygen buffer to reflect the reducing character of the Martian mantle [15]. All experiments were conducted in 0.5" piston cylinder assemblies in either the non-end-loaded apparatus of the Depths of the Earth Laboratory at ASU or in the endloaded apparatus of the Geophysical Laboratory. We have run experiments at 20 kbar, roughly equivalent to 150 km deep in the Martian mantle, and between 1300-1600 °C. 1300 °C is near the solidus of the two compositions and 1600 °C approaches the point where all the orthopyroxene is melted out of the mantle. For the experiments, the starting material powders were packed into a graphite crucible with a lid and the crucibles were placed in either the same (GL) or different (ASU) Pt capsules. The unsealed Pt tube was stored in a drying oven for at least 24 hours and then the Pt was welded shut. In the ASU experiments, the individual Pt capsules with the CM+L and H+L compositions were loaded simultaneously into the piston cylinder assembly so that both compositions experience the same conditions. Runs lasted from 8 to 72 hours, with shorter times associated with higher temperatures.

Results: Figure 1 shows the melt compositions resulting from a portion of the CM+L (pink squares) and H+L (blue circles) experiments in comparison to Martian meteorite parent magma compositions [red diamonds, as compiled by 3], compositions of rocks from Gusev crater [yellow triangles, 5] and the composition of the terrestrial basalt that serves as a spectral analog to the Surface Type 1 basalt identified by TES [cross, 16]. The experimental melt compositions do a good job of reproducing the Fe and Mg character of many of the Martian meteorite parent magmas (Fig. 1). However, olivine fractionation from the experimental melts and/or experiments yielding smaller degree melts than those plotted would be necessary to produce the most Fe-rich Martian meteorite parent melt compositions. Melting of our mantle compositions at different conditions and/or fractionation of the melts produced in this study are likely required to produce both the Mg and Fe characters of the Gusev and TES basalts.

The experimental products are less successful at reproducing Ca and Al signatures of Martian meteorite basalts (Fig. 1). It may be possible to reproduce the $\text{CaO}/\text{Al}_2\text{O}_3$ of the Martian meteorite parent magmas with higher pressure experiments; however, the effect on the Mg and Fe character of the resulting melts might adversely affect the ability of the experiment products to reproduce the Mg and Fe contents of the meteorite parent magmas. We plan to investigate higher pressure melting (35 kbar) to see if it improves the ability of the CM+L and H+L mantles to yield all of the Martian meteorite parent magma characteristics. The experiment products are better able to lead to the Ca and Al signatures of the MER and TES basalts. Olivine fractionation from the melts of this study would appropriately raise the Al and Ca concentrations to those of the MER and TES basalts.

Overall, the data demonstrate that the meteorite, MER and TES lithologies are likely not the products of a single melting and fractionation pathway, but need different conditions (e.g., depth of initial melting, degree of olivine fractionation) to yield the different classes of basalts.

References: [1] Bertka C.M. and Holloway J.R. (1988) *PLPSC* 18:723-739. [2] Longhi J. et al. (1992) *Mars*, 184-208. [3] Agee C.B. and Draper D.S. (2004) *EPSL* 224:415-429. [4] Bandfield J.L. et al. (2000) *Science*, 287, 1626-1630. [5] McSween H.Y., Jr. et al. (2006) *JGR*, doi:10.1029/2005JE002477. [6] Ruff S.W. and Christensen P.R. (2003) *LPSC XXXIV*, Abstract #2068. [7] Bandfield J.L. et al (2004) *JGR*, doi:10.1029/2004JE002290. [8] Monders A. et al. (2007) *MaPS*, 42, 131-148. [9] Bertka C.M. and Fei Y. (1998) *EPSL* 157:79-88. [10] Bertka C.M. and Fei Y. (1998) *Science*, 281, 1838-1840. [11] Sohl F. et al. (2005) *JGR*, 110, doi:10.1029/2005JE002520. [12] Zuber M.T. et al., (2000) *Science*, 287, 1788-1793. [13] Dreibus G.

and Wänke H. (1985) *Meteoritics* 20:367-382. [14] Draper D.S. et al. (2005) *LPSC XXXVI*, Abstract #1429. [15] Wadhwa M. (2001) *Science*, 291, 1527-1530. [16] Wyatt M.B. et al. (2001) *JGR*, 106(E7), 14,711-14,732.

