

SOLIDUS OF MARTIAN MANTLE CONSTRAINED BY NEW HIGH PRESSURE-TEMPERATURE EXPERIMENTS AT NOMINALLY ANHYDROUS CONDITIONS. S. Ding¹ and R. Dasgupta¹, ¹Department of Earth Science, Rice University, 6100 Main Street, MS 126, Houston, TX 77005, USA. (sd35@rice.edu.)

Introduction: Partial melting of mantle silicates is the most important process by which terrestrial planets continue to differentiate. Geochronology of Martian meteorites and cratering studies of lava flows in Tharsis and Elysium regions demonstrate that volcanic activity continued on Mars in geologically recent past [1,2], thereby suggesting partial melting of the mantle has been a key process over much of the geologic history of the red planet. The most critical information required to constrain partial melting processes of Mars is the location of the volatile-free solidus, but constraints on the solidus location and near-solidus melting systematics of low Mg# [molar $100 \times \text{MgO}/(\text{MgO}+\text{FeO})$] Martian mantle are limited [3-6].

The currently used Martian mantle solidus is based on experiments on a K-free composition derived from model Martian mantle of [7] at 1-3 GPa (BH solidus, [3]). Solidus brackets were strictly constrained only at 1-2 GPa in [3] while at higher pressures, the experimental data are scattered. Given the facts that the current estimate on total alkali of bulk silicate Mars range from 0.11 wt.% [8] to 1.2 wt.% ([9] model EH45: H55) and the onset of melting in the Martian mantle likely extends to much deeper depths, reliable experiments constraining solidus of K-bearing composition to higher pressures are needed. Moreover, the BH solidus appears too high to be consistent with the decreasing trend of isobaric solidus temperature with decreasing bulk Mg# of peridotite (filled symbols in Fig.1) as observed for terrestrial mantle peridotite compositions [10] and may be affected in part by poor detection ability of small melt pockets by EPMA imaging. However, K-free starting composition used in BH solidus experiment could have also resulted in higher solidus temperature than K-bearing mantle. With previous studies on terrestrial peridotite partial melting suggesting that both bulk alkali concentration and Mg# affect solidus temperature [10-12] it is important to constrain the mantle solidus and melting systematics in the presence of both Na and K and over the entire pressure range relevant for melting on Mars [13].

Here we present partial melting experiments at 2 to 5 GPa on one of the model Martian mantle compositions [14] (1) to constrain solidus temperature of K-bearing model Martian mantle from 2 to 5 GPa, (2) to discuss possible compositional (K_2O , Na_2O , Mg# etc.) effects on solidus temperature of Martian mantle by comparing available experimental data on both Martian and terrestrial compositions.

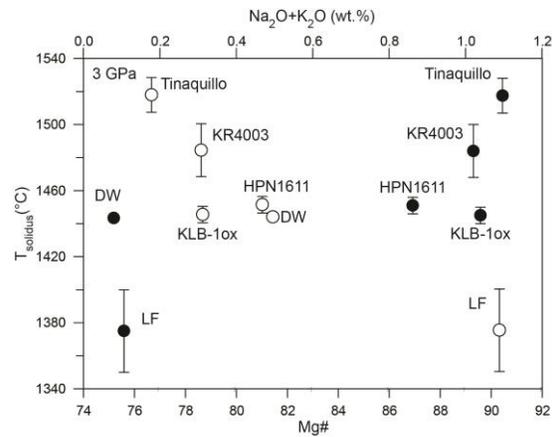


Figure 1. Isobaric solidus temperature of terrestrial and Martian mantle compositions at 3 GPa as a function of Mg# (filled symbols) and bulk alkali contents (open symbols). Tinaquillo: [15]; KR4003:[16]; KLB-1ox:[17]; HPN1611:[18]; DW: calculated by parameterization from [13] based on experiments of [3]; LF: This study.

Methods: Experiments were performed using a synthetic model Martian mantle composition from [14] (LF composition). LF composition is similar to the composition in [7] (DW composition) used in previous experimental studies [3,4] in most major elements and Mg# (~75), which is much lower than terrestrial mantle compositions (e.g., Mg#=90 for KLB-1). However, LF composition has higher K_2O , Na_2O and slightly higher P_2O_5 [14].

Experiments were performed using piston cylinder (PC) (2-3 GPa) and Walker-style multi anvil (MA) devices (4-5 GPa) at Rice University for duration varying from 12 to 48 h. Pt-graphite double capsules were used to (1) achieve experimental $f\text{O}_2$ below FMQ buffer; (2) to minimize Fe loss to the Pt capsules; (3) to minimize ingress of molecular water during the experiments. The homogeneous mixtures were loaded into 0.6 mm (MA) -1.0 mm (PC) thick walled graphite capsules surrounded by outer platinum capsules. Before the platinum capsules were welded shut, the loaded capsules were kept at 110 °C overnight to minimize water contamination.

The solidus temperature was bracketed by comparing the field emission electron microscope (FEI Quanta 400 at Rice University) images of a sequence of run products at each pressure. Temperature intervals of 30-

50 °C were used to bracket the solidus. Texture and major element phase compositions were analyzed using a Cameca SX50 electron microprobe.

Results: The stable subsolidus assemblage, determined at 2 and 3 GPa, is a spinel lherzolite: olivine + orthopyroxene + clinopyroxene + spinel; and a garnet lherzolite (olivine + orthopyroxene + clinopyroxene + garnet) at 4 and 5 GPa. Just above the solidus, small, glassy pockets of quenched partial melts were present in mineral triple-grain junctions while orthopyroxene was not present in these experiments (Fig.2).

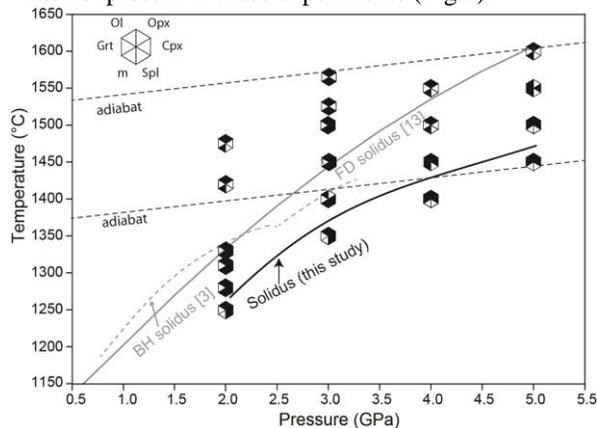


Figure 2. Pressure-temperature plot showing experimental conditions, resulting phase assemblages, and the estimated location of the solidus (black thick line) for the LF Martian mantle composition determined in this study. Also shown for comparison are the solidus estimates from [3] and [13].

Solidus temperatures were located between 1250 and 1280 °C at 2 GPa, 1350 and 1400 °C at 3 GPa, 1400 and 1450 °C at 4 GPa, 1500 and 1550 °C at 5 GPa (Fig.2).

Modes of orthopyroxene and basaltic partial melts increase and those of olivine, clinopyroxene and Al-bearing phases (spinel or garnet) decrease with increasing temperature and extent of melting. Al_2O_3 , TiO_2 , K_2O and Na_2O concentrations in the melt decrease as melt fraction increases. MgO and FeO^* concentration increase as melt fraction increases. CaO concentration first slightly increases then decreases after the consumption of clinopyroxene. Partial melts at 4 and 5 GPa have lower Al_2O_3 concentrations compared to those at 2 and 3 GPa because of presence of garnet in the former. Partial melts at higher pressures also have higher FeO^* concentration compared to those at 2 and 3 GPa as they are generated at higher temperatures.

Discussion and Implications: Experimental equilibria in all experiments were assessed by homogeneity of mineral phases in SEM images; spinel cores were

present in some of the garnet grains in subsolidus MA experiments, but these were volumetrically minor. For melt-present experiments, Fe/Mg exchange coefficient between olivine and melt ranged from 0.31 to 0.37, which is similar to the previously determined values in Martian systems [13].

Compared to the BH solidus [3,13] at a given pressure, solidus determined in this study is 50 to 100 °C lower (Fig. 1,2). Considering experimental isobaric solidi of both Martian and terrestrial peridotite, peridotite solidus temperature decreases with increasing bulk total alkali concentration and increases with increasing Mg# of starting composition (Fig.1). Our results agree with the discussion in [10] about the effect of total alkalis on mantle solidus. Though it is argued that isotope based estimate of bulk silicate Mars may be too enriched in volatile elements, including alkalis [19], our study likely provides a more appropriate solidus for nominally-volatile free, alkali-bearing mantle of Mars.

Application of our solidus results in an onset of decompression melting on Mars 1.3 GPa deeper for T_P of 1370 °C and could be as much as 1.5 GPa deeper for T_P of 1530 °C than previously obtained using the BH solidus (Fig. 2). The use of our solidus therefore suggests that greater extent of decompression melting would be relevant for at least early Mars magmatic events.

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