

MARTIAN MANTLE PRIMARY MELTS: AN EXPERIMENTAL STUDY OF MELT DENSITY AND VISCOSITY AT 23 kb; C.M. Bertka* and J.R. Holloway, Department of Geology, Arizona State University, Tempe, AZ 85287; *also at the Geophysical Laboratory, Carnegie Institution of Washington, Washington D.C. 20008

Mantle compositions predicted for Mars are more iron-rich than those predicted for the earth (1). This difference will be reflected in both the compositional characteristics and the physical behavior of melts produced from the two mantles. Our previous experimental study (2) isolated the primary melt composition in equilibrium with a 23kb, volatile-free, iron-rich garnet-lherzolite source. The density and viscosity of this picritic-alkali-olivine-basalt (see Table 1) have been determined at the suggested source region pressure, 23kb, with the falling sphere technique.

The falling sphere method entails determining the velocity of two spheres of known radius and contrasting density in the melt at pressure. Density and viscosity values for the melt are then calculated from a simultaneous solution of the Stoke's equation for the two spheres (3,4):

$$V = (2 r^2 \Delta \rho g) / (9 Z)$$

V = velocity of sphere
r = radius of sphere
 $\Delta \rho$ = | density melt - density sphere |
g = gravity constant
Z = viscosity of melt

Experiments were performed in an end-loaded 0.75" diameter solid-media, high-pressure apparatus with a furnace assembly that included a tapered graphite furnace (5). The tapered furnace reduced the temperature gradient along the 5mm. diameter, 10mm. long sealed Pt capsule which contained the sample. Temperature, measured with a Pt-Pt90Rh10 thermocouple has an uncertainty of $\pm 10^\circ\text{C}$ and pressure $\pm 1\text{kb}$. Glass starting materials for the experiments were prepared from spec pure oxides reduced in a gas mixing furnace (1000°C , $f\text{O}_2$ at QFM -1) for 24 hours, then fired (1400°C , $f\text{O}_2$ at QFM -1) and ground to less than 10 microns. Natural olivine crystals, from a Red Sea olivine mg#=90 (mg#= atomic Mg/Mg+Fe) and a South African dunite mg#=94, were ground in a Bond apparatus (6) to 400 micron diameter spheres.

For each run, a single sphere was placed at the top center of the Pt capsule containing the glass starting material. This placement of the same size olivine spheres (± 15 microns) eliminated any wall correction from the density calculation. The charges were brought from an initial warming period below the solidus to 50° above the liquidus at a controlled rate of $400^\circ/\text{minute}$ and quenched at a rate of $55^\circ/\text{second}$. Three runs of varying duration were completed for both the dunite and Red Sea olivine at 1475°C , 23kb. The distance the spheres sank in each run was measured to ± 50 microns.

On a graph of distance sunk versus time (see Figure 1) the Red Sea olivine data plot on a straight line whose slope, the velocity of the spheres in the melt, has an estimated uncertainty of less than 2%. The dunite sphere data show a larger amount of scatter producing a velocity uncertainty of 18%. The melt density calculated from these velocities is $3.183 \text{ g/cc} \pm 0.35$. However, assuming similar starting positions for both sphere types at a run time of 120 seconds, an estimated 1% uncertainty on individual sphere radii, and a 1.5% uncertainty on calculated sphere densities, the calculated melt density is also 3.183 g/cc with an uncertainty of $\pm 0.07\text{g/cc}$. Additional data for the dunite may further lower this uncertainty. The calculated viscosity of the melt is 0.52 poise with a large uncertainty created by the similarity of melt and olivine sphere density. As such, a value of up to 2.62 poise is permissible. These viscosities are similar in magnitude to calculated 1 atm. values at the same temperature; 2.8 poise (7).

Stolper et al. (8) proposed that the greater compressibility of basaltic melts compared to mantle minerals will cause the density contrast between melt and residual source region minerals to decrease with depth. These workers also suggested that the increasing normative olivine content of terrestrial primary melts with depth is a factor in decreasing the density contrast between the melts and their source regions. Martian mantle garnet lherzolite minimum melts are more iron-rich and more olivine normative than their terrestrial counterparts (2). If Martian primary melts have compressibilities similar to terrestrial melts then we may expect a density inversion between melt and source region phases to occur at a lower pressure in the Martian mantle than in the earth's mantle. The density of mantle residual phases at source region P and T can be calculated from mineral endmember densities corrected for thermal expansion and compressibility. Melt densities at high pressure are more elusive because any calculation depends on a choice of expansion and compressibility factors that are model dependent

(9,10) (see Figure 2). Our present experimental estimate at 23kb is in good agreement with the melt density predicted from the Birch-Murnaghan equation by using 1 bar volume and compressibility data (10) and $K'=5$. Adherence to this model would result in a density crossover on Mars in the 45kb range, but the present uncertainty associated with the experimental estimate does not outlaw the compressibility behavior predicted by the other models. If the crossover does occur, then a lid may be placed on the maximum source region depth for partial melting products of an anhydrous iron-rich mantle. Above this depth the low viscosity of the melts, comparable to the 1 poise viscosity of olive oil, may begin to exert a stronger control on rheology and crystal fractionation events encouraging rapid separation of melt and liquidus phases.

References. 1) McGetchin, T.R. and Smyth, J.R. (1978) *Icarus* 34, 512-536. 2) Bertka, C.M. and Holloway, J.R. (1987) *Proc. Lunar Planet. Sci. Conf.* 18, 723-739. 3) Shaw, H.R. (1963) *Geophys. Res.* 68, 6337-6343. 4) Kushiro, I. (1976) *Carnegie Inst. Wash. Yearbk.* 75, 419-424. 5) Kushiro, I. (1976) *J. Geophys. Res.* 81, 6347-6350. 6) Bond, W.L. (1951) *Rev. Sci. Instrum.* 22, 344-345. 7) Shaw, H.R. (1972) *Am. J. Sci.* 272, 870-893. 8) Stolper, E., Walker, D., Hager, B.H. and Hays, J.F. (1981) *J. Geophys. Res.* 86 no. B7, 6261-6271. 9) Herzberg, C.T. (1987) In B.O. Mysen, Ed., *Magmatic Processes: Physicochemical Principles*. The Geochemical Soc., Spec. Pub. no. 1, 47-58. 10) Lange, R.A. and Carmichael, I.S.E. (1987) *Geochem. et. Cosmochem. Acta.* 51, 2931-2946.

Figure 1. Falling Sphere Experiments

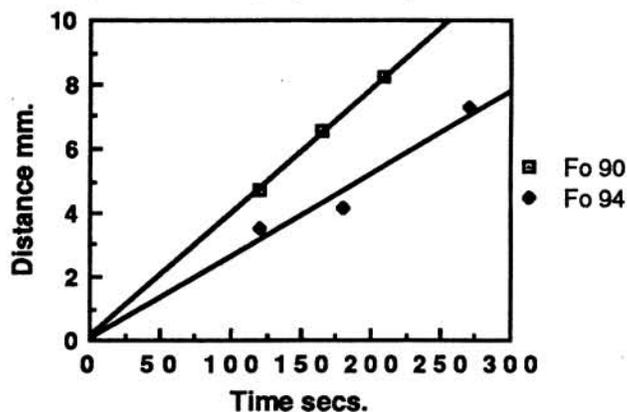


Table 1.
23kb Primary Melt
Composition

oxide	wt%
SiO ₂	41.9
Al ₂ O ₃	12.2
FeO	22.5
MgO	12.5
CaO	10.1
Na ₂ O	0.90
mg#	49.8

Figure 2. Calculated Melt Densities

