STATIC COMPRESSION OF HYDROUS FE-RICH ULTRABASIC LIQUID AND DENISTY CROSSOVERS IN THE MARTIAN MANTLE C. B. Agee, Institute of Meteoritics, Dept. of Earth and Planetary Sciences, MSC03 2050, Albuquerque, NM 87131, agee@unm.edu

Summary: High pressure sink/float experiments have been performed on a komatiite/fayalite liquid mixture with 5 wt% added H_2O in order to investigate the effect of water on magma density at high pressure and to determine if density crossovers between equilibrium liquidus crystals and hydrous magmas can exist in a FeO-rich Martian mantle.

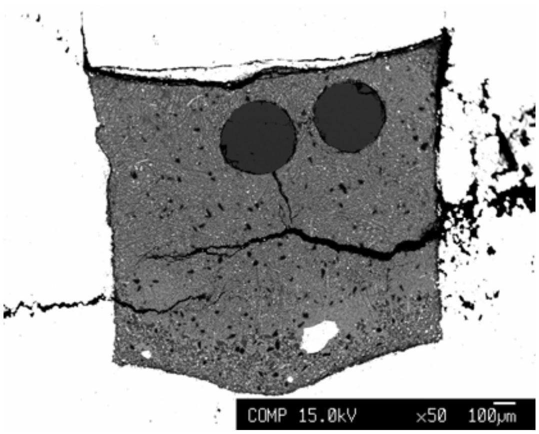

Figure 1. Backscatter electron image of a quenched experiment that has been sectioned to reveal the position of garnet spheres at the top of the capsule indicating a "float" during the superliquidus run. Conditions of the experiment: P=80 kilobars, temperature 1750°C. The initial configuration was one garnet sphere at the top of the capsule and one at the bottom of the capsule, packed in starting composition powder. Liquid is now quench crystals and glass. Cracks are due to decompression.

Experimental Methods: The starting composition is a mixture of 50 wt% komatiite and 50 wt% fayalite with 5wt% water added to the total in the form of brucite. This composition has been previously studied using sink/float experiments under anhydrous conditions (Agee and Walker, 1988). The starting material was a mechanical mixture consisted of powdered komatiite, fayalite, brucite and reagent oxides of SiO_2, Al_20_3, and CaO. Samples were contained in compression-sealed molybdenum capsules. Liquid densities were measured by the sink/float method (figure 1). Sink/float marker spheres implemented were gem quality San Carlos olivine Fo91, and garnets Py69Al17Gr14, Py65Al27Gr08, and Py63A33,Gr03. Experimental run times were 30 seconds, thus minimizing sphere-liquid reactions and liquid reaction with capsule and pressure media. All experiments were carried out in a Walker multi-anvil apparatus at the Institute of Meteoritics, University of New Mexico.

Experimental Results: The komatiite/fayalite + 5 wt% H_2O liquid density was bracketed at 1500°C by a float of olivine Fo91 at 40 kilobars and a sink at 30 kilobars. The liquid density was also bracketed at 80 kilobars by a float of garnet with composition pyrope (Py) 69 almadine (Al) 17 grossular (Gr) 14, a sink of garnet (Py65Al27Gr8) at 79 kilobars, and a sink of garnet (Py63Al34Gr3) at 81 kilobars. Figure 2 summarizes these results. Best fit of these data to the Birch-Murnaghan equation gives an isothermal bulk modulus (K_T) of 116 kb at 1500°C and 101 kb at 1750°C, assuming dK/dP=4, and adopting the 1-bar partial molar volume of H_2O from Ochs and Lange (1999). These values are consistent with a negative value for dK/dT.

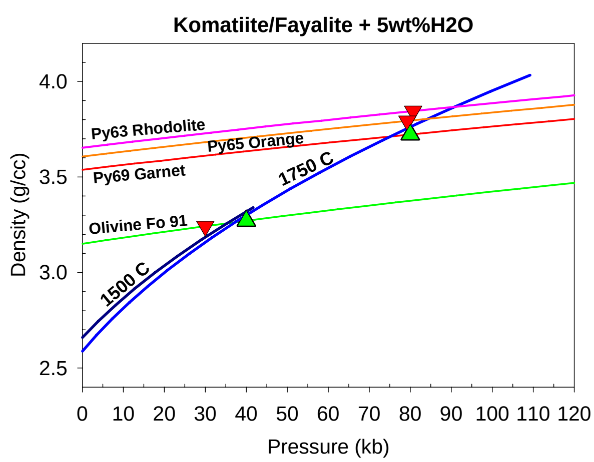

Figure 2. Pressure versus density diagram summarizing the preliminary results of sink/float experiments on a liquid of 50 wt% komatiite and 50 wt% fayalite composition with 5 wt% H_2O added. Red arrowheads down are the observed sinks and green arrowheads up are the observed floats. The calculated compression curves of the olivine and garnet marker spheres are shown. Also shown are two best fit compression curves for the experimental liquid at 1500°C and 1750°C.

Figure 3 illustrates that the compressibility of the hydrous experimental liquid is greater than the anhydrous case. The anhydrous komatiite/fayalite liquid is estimated to have an isothermal bulk modulus of approximately 250 kb assuming dK/dP=4. This is reflected in the shallower compression curve slope in figure 3. The steeper compression curve of the hydrous steeper compression curve of the hydrous liquid is consistent with a very high compressibility of the water component in magma. The partial molar volume of water in this silicate liquid is therefore assumed to decrease very rapidly with pressure in the range 0-40 kb. At 80 kilobars the density difference between hydrous and anhydrous liquids is significantly reduced.

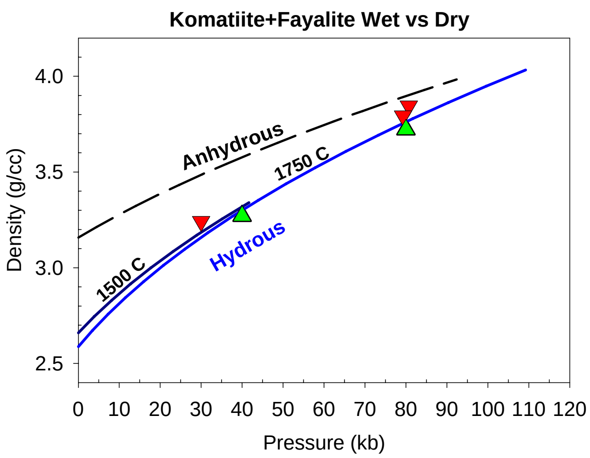

Figure 3. Density versus pressure diagram comparing the compression curve of hydrous versus anhydrous liquids of the composition measured in this study. The anhydrous (dashed line) is derived from experiments by Agee and Walker (1988).

In figure 4 the compressibility of measured liquid densities from previous studies are compared with our hydrous komatiite/fayalite liquid. It can be seen that from this comparison that hydrous silicate liquids are much more compressible than their anhydrous counterparts. For example anhydrous liquid fayalite and komatiite have shallower compression curve slopes in figure 4, while komatiite with 3 wt% H_2O has a steeper slope indicating higher compressibility, and komatiite/fayalite with 5 wt% H_2O has an even steeper slope and the highest compressibility.

Discussion: Earlier experimental work on magma compressibility showed that crystal-liquid density crossovers can exist in the Earth, Moon, and Mars (Agee and Walker, 1988,1993; Circone and Agee, 1996, Ohtani et al. 1995). Such density crossovers may have been important in trapping dense silicate liquids at depth in planetary mantles during early differentiation. Previous studies have focused primarily on anhydrous magmas, however it is possible that deep melting may have included hydrous conditions, especially in a volatile-rich planet such as Mars. Ohtani et al. (1995) carried out high pressure sink/float experiments on an anhydrous FeO-rich ultrabasic silicate liquid analog for Martian mantle melt. They calculated that a density crossover between Martian mantle melt and equilibrium liquidus olivine would occur at approximately 600 km depth in the Martian interior. We apply our current results to a hypothetical early Martian mantle with 5 wt% H_2O and conclude that the density crossover between hydrous mantle melt and liquidus olivine will still occur, but at a deeper level than 600 km. In anhydrous melting it is likely that a density crossover between Martian mantle melt and equilibrium liquidus garnet will occur at ~1500 km depth. It is unclear whether there is a garnet density crossover at deeper levels under hydrous conditions, and this will be explored by future experiments at higher pressures.

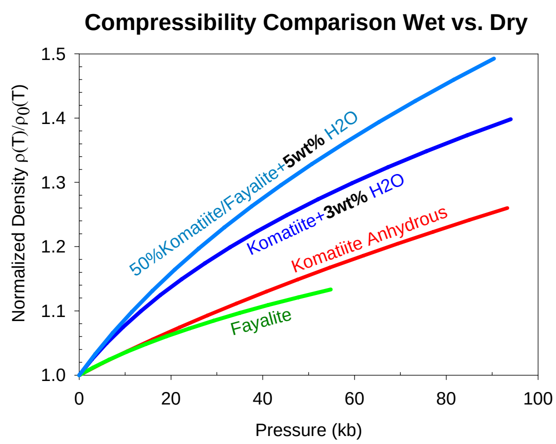

Figure 4. Normalized density versus pressure diagram comparing the compressibility of anhydrous liquid fayalite (Agee, 1992), anhydrous komatiite (Agee and Walker, 1993), hydrous komatiite with 3 wt% H_2O (Agee, 2005), and komatiite/fayalite liquid with 5 wt% H_2O (this study). The compression curve densities are normalized by dividing the liquid density measured at temperature (T) by the 1-bar reference liquid density at T.