

INVESTIGATION OF THE EFFECTS OF WATER ON A MARTIAN MANTLE COMPOSITION. H. A. Dalton, T. G. Sharp, and J. R. Holloway, School of Earth and Space Exploration, Arizona State University Box 871404, Tempe, AZ 85287-1404 (heather.dalton@asu.edu)

Introduction: Experiments using hydrated terrestrial compositions have been performed by many [1] to determine the effect of water on melt compositions, but few have utilized Martian compositions with small amounts of water. Médard and Grove [2] conducted experiments to study the effects of water on the Dreibus and Wänke modeled Martian mantle composition [3]. However, recent studies using moment of inertia data have shown that this modeled composition might not be correct [4, 5], and therefore, experimental results using the Dreibus and Wänke composition with water may not be representative of what has occurred on Mars.

The best compositions to use for experiments to study the Martian mantle are the SNC meteorites, specifically primitive SNCs, because they are known mantle melt compositions rather than modeled compositions. Yamato 980459 (Y98) is an olivine-phyric basaltic shergottite. It is composed of 48% pyroxene, 26% olivine, 25% mesostasis, and 1% other minerals and is the most primitive Martian meteorite collected thus far [6]. Experiments performed using an anhydrous Y98 synthetic composition have determined that a multiple saturation point for olivine and pyroxene exists, suggesting Y98 is a primary melt of the Martian mantle and not a cumulate [7]. Because it is a primitive mantle composition, Y98 is a good starting composition for experimental petrology concerning the Martian mantle. These experiments used a synthetic Y98 composition with 0.5 weight percent H₂O added to determine the effect of water on a Martian mantle composition with various degrees of melting.

Experimental Methods: A synthetic composition was created using an average of two reported compositions of Y98 [8, 9] with 0.5 weight percent H₂O added (Table 1). Oxides and carbonates were ground together using an agate mortar and pestle under ethyl alcohol for 15 minutes, then left to dry. Two platinum crucibles containing the dry starting material powder were placed into a box furnace where the temperature was raised to 1000°C over three hours. The powder was removed from the furnace and dry-ground with the agate mortar and pestle. The starting material was then placed into a one-atmosphere gas-mixing furnace at 1000°C with a CO/CO₂ ratio of 3/2 for two hours, removed from the furnace, quenched in water, and reground to ensure homogeneity. This was done twice with a resulting f₀₂ of IW + 0.7 log units. After dry-

ing in a 100°C oven overnight, brucite (Mg(OH)₂) was substituted in for a portion of the MgO in the starting material to add 0.5 weight percent H₂O to the composition. The method of [10] was used to control the oxygen fugacity. The starting material with a preset f₀₂ was inserted into a graphite capsule; the oxidation reaction of C forming CO₂ affected the f₀₂, keeping it at IW + 0.7 log units.

Oxide	Y 980459 [8]	Y 980459 [9]	Target comp	Comp as weighed
SiO ₂	49.40	48.70	49.050	49.049
TiO ₂	0.48	0.54	0.510	0.510
Al ₂ O ₃	6.00	5.27	5.635	5.635
Cr ₂ O ₃	0.71	0.71	0.710	0.709
FeO	15.80	17.32	16.560	16.560
MnO	0.43	0.52	0.475	0.475
MgO	18.10	19.64	18.870	18.872
NiO	0.03	0.03	0.030	0.032
CaO	7.20	6.37	6.785	6.785
Na ₂ O	0.80	0.48	0.640	0.640
K ₂ O	0.02	0.02	0.020	0.021
P ₂ O ₅	0.31	0.29	0.300	0.301
S	0.07			
FeS	0.19	0.26	0.226	0.225
H ₂ O	0.00	0.00	0.500	0.500
Total	99.54	100.15	100.311	100.314

Table 1: Experimental starting material. The first column lists the oxides in the composition. The second and third columns are published values of the Y98 meteorite composition [8, 9]. The fourth column, the target composition, is an average of the two published compositions. The fifth column is the composition as it was weighed before mixing.

High-pressure experiments were conducted using the QuickPress non-end-loaded piston cylinder in the Depths of the Earth lab at Arizona State University. The assemblies consisted of a graphite inner sample capsule with a platinum outer capsule, Al₂O₃, pyrex, and NaCl inner parts, and an NaCl salt sleeve. Temperature was monitored using a C-type (W5Re/W25Re) thermocouple. Temperature and pressure ramps were done using the “hot piston out” method: ramping the pressure up to 10% above run pressure, ramping the temperature up to run temperature over about 30 minutes, and then lowering the pressure to run pressure. The runs were performed at pressures of 8, 12, 15, and 17 kbar, temperatures ranging between 1350°C and 1550°C, and durations of 30

minutes to 1.5 hours. The results of the experiments were analyzed using the JEOL JXA-8600 Superprobe at Arizona State University.

Results: The run conditions and the results of the experiments are shown in Table 2 below. Three phases are present: 1) melt, 2) olivine + pyroxene + melt, and 3) pyroxene + melt.

Run	Pressure (kbar)	Temp (°C)	Duration	Results
y-15-2	15	1550	30 min	glass
y-15-4	15	1500	35 min	glass
y-12-7	12	1550	30 min	glass
y-8-16	8	1450	45 min	glass
y-8-14	8	1350	1.5 hrs	ol + pxn + glass
y-12-9	12	1450	45 min	ol + pxn + glass
y-12-10	12	1350	1.5 hrs	ol + pxn + glass
y-15-6	15	1400	60 min	pxn + glass
y-17-11	17	1550	30 min	pxn + glass
y-17-12	17	1450	45 min	pxn + glass
y-17-17	17	1350	1.5 hrs	pxn + glass

Table 2: Experimental run conditions and run products. Ol = olivine and pxn = pyroxene.

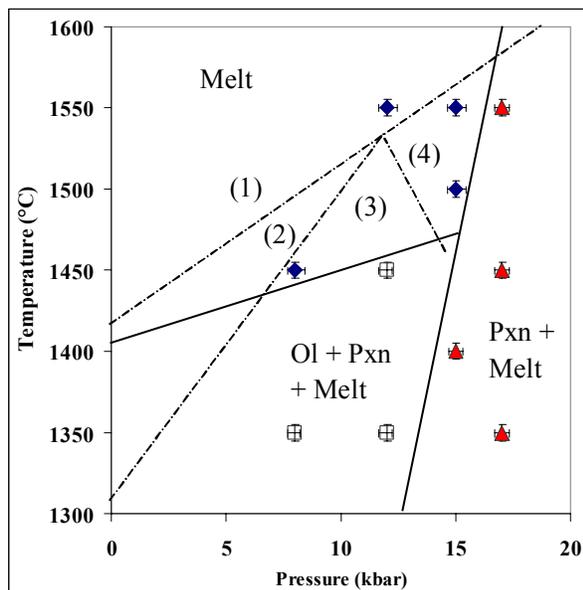


Figure 1: Experimentally-determined phase diagram of the Y98 + 0.5 weight percent H₂O. Solid diamonds represent runs that produced only glass, solid triangles produced pyroxene + glass, and open squares produced olivine + pyroxene + glass. The solid lines between phases were determined from the run data. The dashed lines indicate the phases produced in the anhydrous Y98 experiments [7].

Experimental results from this study and [7] are plotted on the chart above (Figure 1). The data points and solid lines are from this study with the three phases labeled. The dashed lines are from [7] and

identify four phase fields: (1) melt, (2) olivine + melt, (3) olivine + pyroxene + melt, and (4) pyroxene + melt.

The runs closest to the melt field but still containing crystals had the crystals clustered near the sample capsule lid, while lower-temperature runs produced crystals throughout the capsule. The runs that produced only glass typically had a thin layer of quench crystals all the way around the inner edge of the capsule, indicating a very small, if any, thermal gradient was present or that the entire capsule was at higher than the liquidus temperature.

Discussion: The phase diagram from this study is quite different from that of the anhydrous meteorite composition [7]. Most notably, the olivine + melt phase (2) has disappeared, and the pyroxene + melt field has intersected the anhydrous liquidus. In addition, the line separating the olivine + pyroxene + melt (3) and the pyroxene + melt (4) fields has changed directions. The liquidus temperature has also decreased by about 50°C, and the slope of the liquidus line has decreased. The multiple saturation point has moved from 12 kbar and 1540°C to 15.5 kbar and 1490°C. The pyroxene compositions in the hydrous samples are more calcium- and aluminum-rich than in the Y98 experiments. Additionally, the olivine core Mg# (MgO/(MgO + FeO)) has decreased from 0.86 in the anhydrous samples to between 0.68 and 0.72 in these recent experiments. These data are consistent with a less primitive melt composition, which was created with the addition of 0.5 weight% H₂O to the meteorite composition. A cumulate formed from this melt would be more evolved than the primitive meteorite. This work has shown that a small amount of water added to a very primitive Martian composition has a large effect on the phases present, the liquidus temperature, and the multiple saturation point.

References: [1] Gaetani G. A. and Grove T. L. (1998) *Contrib. Mineral. Petrol.*, 131, 323-346. [2] Médard E. and Grove T. (2006) *LPS XXXVII*, Abstract #1762. [3] Dreibus G. and Wänke H. (1985) *Meteoritics*, 20 (2), 376-381. [4] Bertka C. and Fei Y. (1998) *Science*, 281, 1838-1840. [5] Agee C. B. and Draper D. S. (2005) *LPSC XXXVI*, Abstract #1434. [6] Mikouchi et al. (2003) International Symposium. *Evolution of Solar System: A New Perspective from Antarctic Meteorites*, 82-83. [7] Musselwhite et al. (2006) *Meteorit. Planet. Sci.*, 41 (9), 1271-1290. [8] Greshake A. (2004) *Geochim. Cosmochim. Acta*, 68, 2359-2377. [9] Misawa K. (2003) International Symposium. *Evolution of Solar System: A New Perspective from Antarctic Meteorites*, 84-85. [10] Kress V. C. and Carmichael I. S. E. (1988) *Am. Mineral.*, 73, 1267-1274.