

**The Yamato 980459 Liquidus at 10 to 20 Kilobars.** J.R. Norris<sup>1</sup> and C.D.K. Herd<sup>1</sup>, <sup>1</sup>Department of Earth & Atmospheric Sciences, 1-26 Earth Sciences Building, University of Alberta, Edmonton, Alberta, T6G 2E3, Canada. [jrn4@ualberta.ca](mailto:jrn4@ualberta.ca).

**Introduction:** The Yamato (Y)980459 martian meteorite is the most magnesian and its bulk composition is representative of its parent melt [1]. It likely represents a primary martian melt, and is a good candidate for determining the phase relationships of the martian mantle. The phase relationships have been mapped to 15 kbar [2,3]. We carried out experiments in the 10-20 kbar range to extend the phase relationships to higher pressures.

**Experimental Methods:** A synthetic composition was prepared by the authors from reagent grade oxides to match the bulk composition [4] (Table 1). The synthetic composition of [2] was also provided to assist in interlaboratory comparison.

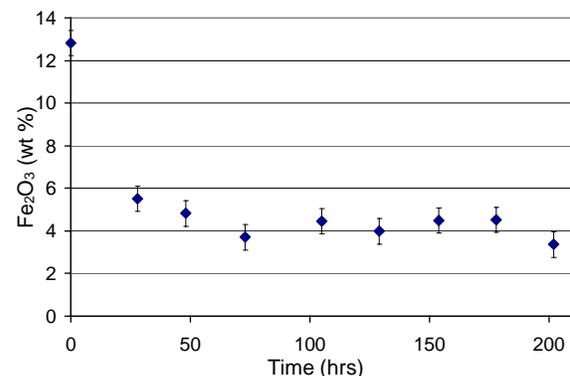
**Table 1.** Starting compositions with Y980459 bulk composition for comparison

Oxide	This Study	Synthetic [2]	Y980459 [4]
SiO <sub>2</sub>	46.89	50.20	49.40
TiO <sub>2</sub>	0.53	0.50	0.48
Al <sub>2</sub> O <sub>3</sub>	5.37	5.50	6.00
Cr <sub>2</sub> O <sub>3</sub>	0.54	0.66	0.71
FeO	17.96	15.82	15.80
MnO	0.48	0.49	0.43
MgO	19.76	19.35	18.10
NiO		0.01	0.03
CaO	6.28	6.97	7.20
Na <sub>2</sub> O	0.5	1.09	0.80
K <sub>2</sub> O	0.01	0.05	0.02
P <sub>2</sub> O <sub>5</sub>	0.26	0.36	0.31
S		0.01	0.07
FeS			0.19
Total	98.58	101.01	99.54

**Iron Reduction:** Dalton et al. [2] preset the ferric iron content of their starting material by placing it in a CO/CO<sub>2</sub> gas-mixing furnace at 800°C maintained at log  $f_{O_2}$  of -14.85 for 90 hours. Based on the calculations of [5] this should have resulted in a Fe<sub>2</sub>O<sub>3</sub> concentration of 1.07 wt %, corresponding to an oxygen fugacity of IW + 0.7 log units in their graphite capsule piston-cylinder runs. Following the procedure of [2] we placed our composition in a CO/CO<sub>2</sub> gas-mixing furnace at 900°C for 8 days (202 hours) to yield 1 wt% Fe<sub>2</sub>O<sub>3</sub> at IW + 0.7 log units. Fe reduction progress was tracked by taking samples every 24 hours, and measuring the ferric iron content using the micro-titration technique of [6]; results are plotted in Figure 1. Most of the reduction occurred in the first 24 hours. Over the first 6 days, the ferric iron content was reduced from 12.8 wt % to 4.5 wt%. Achieving 1 wt % Fe<sub>2</sub>O<sub>3</sub>

was difficult, even after further decreasing  $f_{O_2}$  of the CO/CO<sub>2</sub> furnace for the last 2 days, which yielded 3.4 wt% Fe<sub>2</sub>O<sub>3</sub>. There may be a lower limit to the amount of Fe reduction, possibly due to the kinetics of iron reduction. The composition of [2] had 3.7 wt % Fe<sub>2</sub>O<sub>3</sub>; therefore, it is possible that the experiments of [2] and those presented here ran at a higher  $f_{O_2}$  than expected. Work is underway to verify the ferric iron content after equilibration with the graphite capsule.

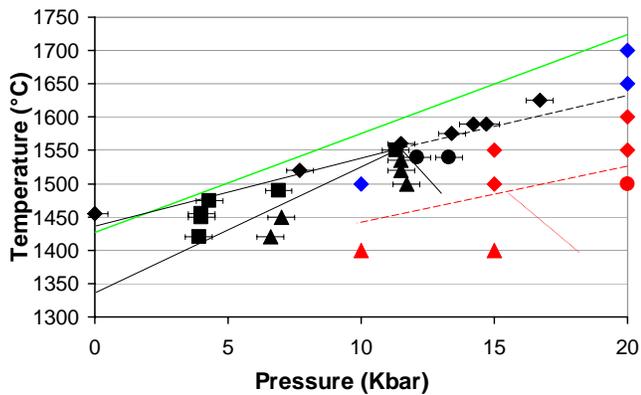
**Experiments:** Experiments were done in an end-loaded piston cylinder apparatus with a talc-Pyrex 1/2" pressure assembly of crushable ceramic and alumina parts. The sample was placed in a graphite capsule to prevent iron loss to the outer platinum capsule. Temperature was monitored using a W5Re/W26Re (Type C) thermocouple. Run conditions and products are shown in Table 2 and plotted in Figure 2. Products were analyzed using the JEOL-8900 electron microprobe at the University of Alberta.



**Figure 1:** Ferric iron reduction of the starting composition in a CO-CO<sub>2</sub> furnace at 900°C for 8 days.

**Table 2:** Run conditions and products

Run	P (kbar)	T (°C)	Duration (hours)	Product
JRN001	10	1500	6	glass
JRN006	20	1700	6	glass
JRN007	20	1650	6	glass
JRN009	20	1600	6	glass
JRN010	20	1550	6	glass
JRN011	20	1500	6	pxn+glass
JRN012	15	1500	6	glass
JRN013	15	1550	6	glass
JRN014	15	1400	6	ol+pxn+glass
JRN015	10	1400	6	ol+pxn+glass

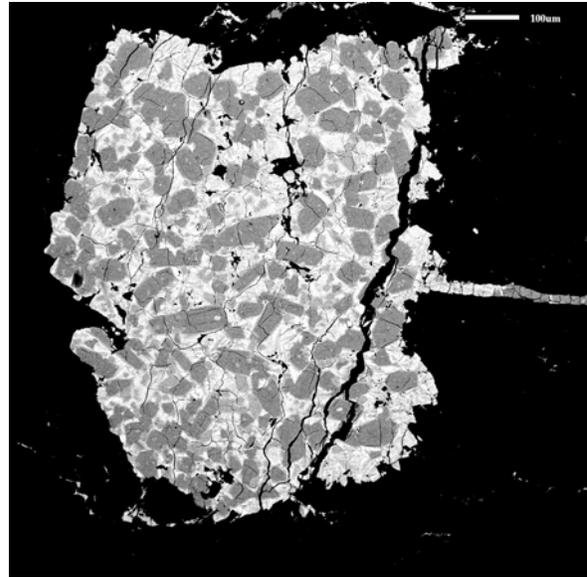


**Figure 2:** Experimentally determined phase relationships. Squares are experiments containing olivine and glass, triangles those with olivine, pyroxene and glass (Figure 3), diamonds those with only glass, and circles those with pyroxene and glass. Black symbols are results from [3], red symbols are from this study using the composition that we prepared, and blue symbols are from this study using the composition from [2]. The liquidus and phase boundaries have been sketched in. MELTS [7] calculated liquidus plotted for comparison.

**Discussion:** There is an obvious difference in the position of the liquidus from our experiments and those carried out by [3]. At 20 kbar our experimentally determined liquidus is at  $\sim 1525^{\circ}\text{C}$ , compared with  $\sim 1625^{\circ}\text{C}$  from [3]. At 15 kbar our liquidus is a maximum of  $\sim 1500^{\circ}\text{C}$ , compared with  $\sim 1580^{\circ}\text{C}$  from [3]. Overall there appears to be  $\sim 100^{\circ}\text{C}$  difference between our results and that of [3]. A pressure correction could not account for this large difference, as any correction should be small at these temperatures. Our pressure assembly was composed of talc (compared to  $\text{BaCO}_3$  [2,3]) and it is possible that hydrogen may have diffused into our sample and increased the  $\text{H}_2\text{O}$  content. According to MELTS [7] we would require  $\sim 3.5$  wt %  $\text{H}_2\text{O}$  in our sample to achieve a  $\sim 100^{\circ}\text{C}$  drop in the liquidus. It is unlikely that a talc assembly would result in this much water in the experiment. Work is currently underway to determine the  $\text{H}_2\text{O}$  content in the experiments using FTIR analysis of glass-bearing runs.

Further work will include experiments to better constrain the liquidus and phase relationships along with verifying the multiple saturation point found by [2,3]. We will also determine the ferric iron content of samples after they have run at pressures and temperatures to determine the  $f\text{O}_2$  conditions of the experiments.

Results from these experiments have implications for the thermal state of the martian mantle [3]. The lower temperature of the liquidus inferred by our results implies a cooler martian interior than modeled by [3].



**Figure 3:** Olivine, pyroxene and glass products of run JRN014.

**References:** [1] McKay G. et al. (2004) *Lunar Planet Sci.* XXXV Abstract #2154. [2] Dalton H.A. et al. (2005) *Lunar Planet Sci.* XXXVI Abstract #2142. [3] Musselwhite et al. (in press) *Meteor. Planet. Sci.* [4] Greshake A. (2004) *Geochim. Cosmochim. Acta* **68**, 2359-2377. [5] Holloway J.R. et al. (1992) *Eur. J. Mineral.* **4**, 105-114. [6] Yokoyama T. and Nakamura E. (2002) *Geochim. Cosmochim. Acta* **66**, 1085-1093. [7] Ghiorso M. and Sack R. (1995) *Contrib. Mineral. Petrol.* **119**, 197-212.

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