

An experimental crystallization study of a proposed high-Fe, low-Al Martian parental liquid at elevated pressure. J Filiberto,¹ H. Nekvasil¹ and D.H. Lindsley¹ ¹Department of Geosciences, Stony Brook University, Stony Brook, NY 11790-2100 email: Jfiliber@ic.sunysb.edu

Introduction: Recent discoveries have led workers to start to question the assumption that high-Fe, low-Al compositions characterize all Martian magmas.

- The MER rover Spirit data suggest a much more terrestrial Al/Si ratio and lower Fe contents than previously observed (in the SNC meteorites) [1].
- MER rover Spirit basaltic rocks, after correction for 25% olivine phenocrysts (Fo₇₀-Fo₃₀) [2] as possible cumulate material, have residual bulk compositions similar to terrestrial tholeiites.
- Recent work [3] has suggested that liquid parental to the Chassigny meteorite could be similar to terrestrial hawaiiite. The experiments upon which this was based showed that at pressures above 4.3 kbar and water contents greater than 0.4 wt% the assemblage olivine, augite, orthopyroxene, kaersutite, (Ti-biotite), apatite, ilmenite, and plagioclase crystallized. This assemblage is consistent with the cumulate and melt inclusion assemblages of Chassigny.
- The recent finding of a new shergottite meteorite, Yamato 980459 [4, 5], the “most primitive” shergottite meteorite. The Yamato 980459 meteorite contains olivine cores of Fo₈₄ composition, which is the most magnesium olivine found in any of the SNC meteorites [4, 5]. Fo₈₄ is similar to olivine in terrestrial mantle xenoliths and suggests that the Martian mantle may have a Fe/Mg ratio similar to Earth.
- Melting experiments on melt inclusions from the Shergottite ALH77005 [6] produced liquids with Al₂O₃ contents of 13-14 wt% and FeO contents of 15-16 wt% [6]. Previous workers [7] also obtained similar bulk melt inclusion compositions, but then modified those to high-Fe, low-Al compositions through the addition of olivine host.
- Researchers [8] using a high-Fe, low-Al “parental” liquid (A*) performed crystallization experiments at low pressure to attempt to produce the Mars Pathfinder “sulfur-free” rock composition. This work [8] did not produce the assemblages of the SNC meteorites.

Perhaps high-Fe, low-Al magmas are rarer on Mars than previously assumed. In fact, to date, no experiments on any high-Fe, low-Al parental liquid have produced kaersutite which is commonly seen in the melt inclusions in Martian meteorites or replicated

satisfactorily the SNC assemblages. However, all experiments on high-Fe low-Al compositions have been conducted only at low pressures. Perhaps experiments at elevated pressures could result in more similar mineral phase assemblages to the SNC’s. The possibility of high pressure evolution has been suggested by [9] who evaluated Ba partitioning between biotite and silicate liquid. In addition, [3] concluded that at elevated pressures hawaiiite could produce the Chassigny assemblage.

We have conducted experiments at 4.3 kbar (~35 km depth on Mars) and at 9.3 kbar (~70 km depth on Mars) in order to assess phase relations of high-Fe, low-Al magmas at elevated pressures.

Experimental Technique: A synthetic high-Fe, low-Al starting composition similar to A* composition of [7, 8] was used for this study. The powder was made from a mix of powdered oxides and synthetic gels. Powder and capsules were dried either in the presence of an Fe^o oxygen getter at 800°C in vacuum, for 20 minutes to remove all structurally bound water, or dried at 150°C for 15 minutes to drive off all adsorbed water. [These will be referred to as “Dry” and “NVA” (no volatiles added) experiments, respectively] Other experiments were done with water added to reach desired water contents.

All experiments were conducted in a piston-cylinder apparatus using BaCO₃ sleeves with exterior Pb liners and graphite furnaces. Temperature was measured using a Pt-Pt₉₀Rh₁₀ thermocouple. Experiments were carried out using a piston-out procedure (i.e. pumped to two kilobars above pressure and then brought down to pressure). Samples were melted for 2 hours above the liquidus temperature and then rapidly cooled to the final crystallization temperature, where they remained for ~2 days.

Experimental run products were analyzed at SUNY Stony Brook using a Cameca Camabax Microprobe for major element abundances of the residual liquid as well as the crystal phases.

Preliminary Results: Our experimental results indicate that at 4.3 kbar, in the presence of water (0.2 wt% bulk water), the assemblage is pigeonite-dominated with olivine, subcalcic-augite, plagioclase, and ilmenite as additional crystallizing phases (Figure 1). Dried experiments (0.05 wt% water) produce the same assemblage, although plagioclase crystallizes at higher temperatures. This assemblage differs markedly from that of the Chassigny cumulate and melt inclusion assemblage. It is more similar to that of the

Shergotty. Although there is overlap, it is clear that the earliest (least evolved) ferromagnesian phases produced from A* are distinctly more Fe-rich than the least evolved Shergotty minerals (Fig. 1).

At 9.3 kbar the assemblage continues to be pigeonite-dominated, with plagioclase and minor subcalcic augite. Ongoing experiments are evaluating the direct role of water in affecting the mineral assemblages.

Summary: The assemblages at either 4.3 kbar or 9.3 kbar at 0.2 wt% water and lower do not produce the cumulate assemblage seen in the Shergotty and Chassigny meteorites. The phases produced are enriched in Fe compared with those seen in the meteorites; this suggests that the Shergotty and Chassigny cumulate assemblage were produced from a liquid with lower Fe contents, and higher Mg contents. Furthermore, since the assemblages do not contain kaersutite, apatite, biotite, or low-Ca pyroxene, they differ markedly from the melt-inclusion assemblages of the Chassigny meteorite. Thus, to date no experiments on any high-Fe, low-Al parental liquid have produced the Chassigny and Shergotty mineral assemblages.

References: [1] McSween H.Y. et al. (2004) *Science*, 305, 842-845. [2] Morris R.V. et al. (2004) *Science*, 305, 833-836. [3] Nekvasil H. et al. (2003) *Sixth International Conference on Mars*, CD abstract 3041. [4] Greshake A. et al. (2004) *GCA*, 68, 2359-2377. [5] McKay G. et al. (2004) *LPS*, XXXV, Abstract # 2154. [6] Calvin C. and Rutherford M.J. (2004) *LPS*, XXXV, Abstract #1371. [7] Johnson M.C. et al. (1991) *GCA*, 55, 349-366. [8] Minitti M.E. and Rutherford M.J. (2000) *GCA*, 64, 2535-2547. [9] Righter K. et al. (1997) *LPS*, XXVIII, 1362. [10] Floran R.J. et al. (1978) *GCA*, 42, 1213-1229. [11] Stolper E.M. and McSween H.Y. (1979) *GCA*, 43, 1475-1498.

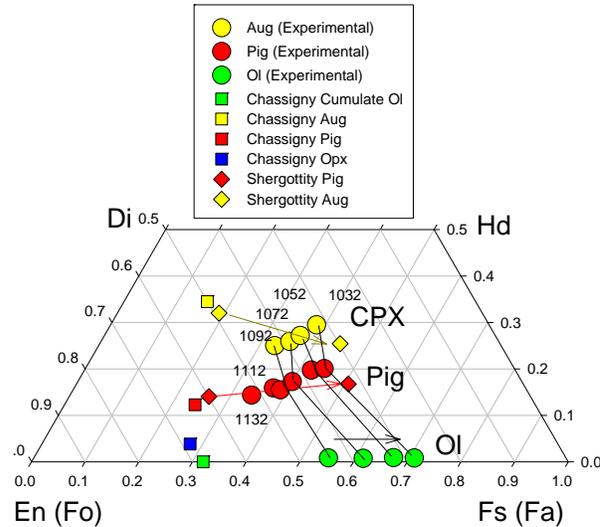


Figure 1. Pyroxene quadrilateral for experiments at 4.3 kbar and 0.2 wt% bulk water. Circles are experimental data: yellow: augites, red: pigeonites, green: olivines. Tie lines are drawn for coexisting phase compositions. Squares are data for Chassigny [10], colors are same as above. Diamonds are data for Shergotty [11], colors are same as above, arrows are drawn from cores to rims.