

CONSTRAINTS ON WATER CONTENTS OF MARTIAN MAGMAS: INFERENCES FROM THE CHASSIGNY METEORITE AND EXPERIMENTS ON BACKSTAY. S. Elardo¹, A. Harrington¹, H. Nekvasil¹, F. M. McCubbin¹, D. H. Lindsley¹, ¹Department of Geosciences, Stony Brook University, Stony Brook, NY 11794-2100, Hanna.Nekvasil@sunysb.edu

Introduction: The presence of dissolved water in martian magmas is evidenced by minerals in melt inclusions of meteorites such as the Chassigny meteorite. Recent SIMS analysis of Ti-biotite and kaersutite from melt inclusions in the Chassigny meteorite [1] indicate a significant amount of water in these minerals, equivalent to that found in such minerals on Earth. But constraining the actual magmatic water content from mineral assemblages has remained elusive. We compare here experimental mineral assemblages with natural assemblages to provide first-order constraints on magmatic water content, focusing on the melt trapped in melt inclusions of the Chassigny meteorite.

Using mineral assemblages to constrain water contents can only be done reliably if the compositional characteristics of the melt are known and some constraints on pressure are available. Work by [2] has indicated that melts residual to cumulus phase crystallization in the Chassigny meteorite likely had alkalic characteristics. They were able to reproduce the cumulus olivine composition and most of the mineral phases of the melt inclusions using a terrestrial silica-saturated hawaiite crystallized at a pressure equivalent to the base of the martian crust. In order for kaersutite to crystallize, however, a minimum of 0.6 wt% water was needed. This water content also ensured that crystallization produced melts tending towards silica-enrichment, that is, towards rhyolite. However, although the phases produced included kaersutite and Ti-biotite, the terrestrial hawaiite did not crystallize either chromite or pigeonite.

[3] noted that the rock Backstay analyzed by the MER Spirit had alkalic characteristics. As pointed out by [4], this rock showed strong compositional similarities to the terrestrial silica-saturated hawaiite that produced most of the minerals of the Chassigny cumulus and melt inclusion assemblages [2]. [4] experimentally investigated the phase relations of a melt of Backstay composition with 2 wt% water. This yielded not only Ti-amphibole but also olivine of the cumulus composition as well as chromite and a trace of pigeonite. These results suggest that the Backstay composition provides a reasonable proxy for the type of melt involved in the formation of the Chassigny dunite and through minor crystallization (<10 wt%) can produce the liquid trapped in the host olivines of the Chassigny meteorite.

Several lines of evidence, however, suggest that the trapped magma had a bulk water content lower than the ~2 wt% of the experiments of [4] for Backstay. First,

the Ti-content of the amphibole is too low to be kaersutite (Ti-contents in amphibole decrease with increasing water content). Second, only a trace amount of pigeonite is produced, but this mineral is found both within and outside of the melt inclusions of the Chassigny meteorite. Third, at none of the temperatures investigated was subcalcic augite observed, a part of the high-temperature pyroxene sequence in the meteorite.

In order to investigate the effect of lower water contents on phase relations of the Backstay composition, piston-cylinder experiments were conducted on Backstay with ~0.7 wt% added water. The results not only constrain the water content of the melt trapped within the melt inclusion, but also changes in liquid line of descent.

Experimental details: A starting mixture of oxides of the Backstay composition [3] was loaded into a large-volume graphite-lined Pt capsule into which 4 wt% water was added. This capsule was sealed and pressurized to 10 kbar nominal (9.3 kbar) and heated to 1350°C to ensure complete melting. The resulting glass was ground, dried at 175°C and mixed with an anhydrous powder of the starting mixture (dried at 800°C in the presence of an oxygen getter to prevent oxidation of the starting material) in the ratio needed to obtain 0.7 wt% water. This mixture was loaded into graphite capsules and used for the experiments. Crystallization experiments were conducted at 10 kbar nominal (9.3 kbar) by first melting and then rapidly cooling to the desired crystallization temperature. The fO_2 of these experiments lies between 1.5 and 2.5 log units below FMQ.

After quench, all experimental products were examined optically and analyzed by electron microprobe (at SUNY Stony Brook). Mass balance calculations were performed using the phase compositions obtained. These ensured that the analyses were reasonable and that no phase was overlooked during microprobing.

The water contents of select glasses were obtained by micro-FTIR analysis at the American Museum of Natural History.

Results: Table 1 summarizes the results and compares them with those obtained by [4] for 2 wt% water. At the lower water content both pigeonite and subcalcic augite appear after olivine and chromite, more in keeping with the observed phase relations in the melt inclusion and the interstitial regions of the Chassigny meteorite. However, plagioclase appears before Ti-

biotite or kaersutite, marking a major departure from the paragenetic sequence of the melt inclusions. This feldspar indicates that the amount of water is insufficient to effectively depolymerize the melt and destabilize plagioclase.

Table 1. Experimental phase assemblages of Backstay composition liquid crystallized at 9.3 kbar with 2 wt % bulk water content [4] and 0.7 wt% water (this work)

T °C	Phase assemblage (wt%)
	2 wt% bulk water
1330	gl (100)
1150	Ol (7.7) + chr (tr.) + gl (92.3) [s.s.r. 0.03]
1100	Ol (8.4) + chr (tr.) + pig (tr.) + Opx (9.2) + gl (82.4) [s.s.r. 0.05]
1050	ol (11.1) + chr (tr.) + opx (8.4) + Aug (5.5) + gl (75.1) [s.s.r. 0.04]
1000	ol (14.7) + opx (10.9) + pl (7) + Ti-amph (12.6) + ap (2.2) + gl (52.6) [s.s.r. 0.07]
980	ol (7.1) + opx (22.4) + pl (8.2) + Ti-amph (16.9) + ap (2.8) + gl (42.5) [s.s.r. 0.08]
	0.7 wt% water
1200	ol (2.2) + chr (0.4) + gl (97.4) [s.s.r. 0.2]
1125	ol (12.7) + pig [+ subcalcic aug.] (0.9) + gl (86.4) [s.s.r. 0.3]
1080	ol (4.4) + cpx (6.6) + opx (18.1) + pl (3.0) + gl (68.2) [s.s.r. 0.12]

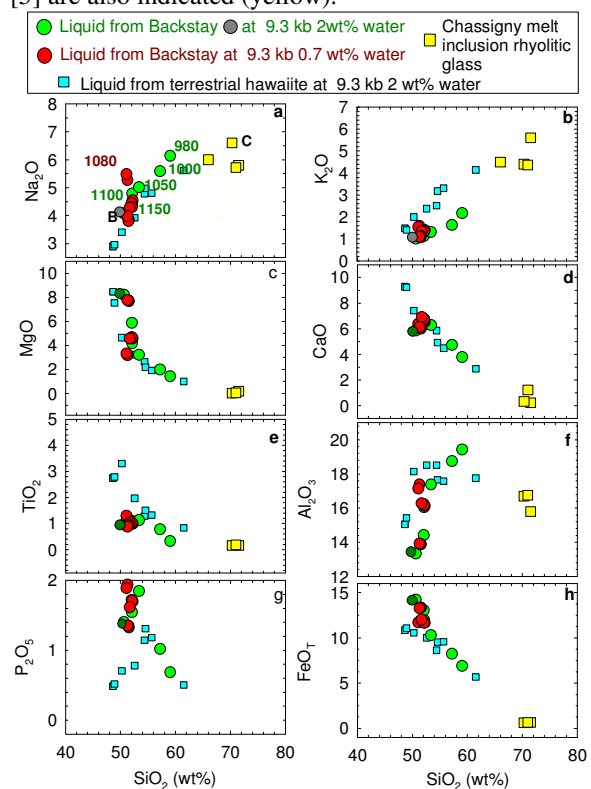
Symbols: ap-apatite; chr-chromite; gl-glass;
ol-olivine; opx-orthopyroxene; pig-pigeonite;
Ti-amph-Ti-amphibole
s.s.r.-sum of the squares of the residuals

Further indications that this water content (0.7 wt%) is too low can be seen by the liquid line of descent (Figure 1). By 1080°C for Backstay with 0.7 wt% bulk water content, plagioclase crystallization has commenced. This initiates residual melt evolution towards low silica contents and away from the quartz saturation and the composition of the rhyolitic glass of the melt inclusion [5]. This can be seen most readily in Fig. 1a.

Discussion: Experiments on Backstay composition crystallizing under the pressure conditions that can give rise to the Chassigny cumulus and melt inclusion assemblages can be used to constrain magmatic water contents. After about 10% crystallization, Backstay liquid crystallizes olivine of the composition present within the Chassigny dunite. The water content at this stage is ~ 2.2 for Backstay with 2 wt% starting water and ~.8 wt% water for Backstay with 0.7 wt% starting water. Early crystallization of plagioclase indicates that 0.8 wt% water is too low and 2.2 wt% is too high to produce the proper mineral assemblage. However, the combined phase relations are consistent with the proper

assemblage being produced at some intermediate bulk water content. These values provide the first constraints on martian magmatic water contents. Experiments are ongoing to constrain this further. Such water contents are consistent with water contents determined for terrestrial interplate magmas. Furthermore, they indicate that eventual crystallization and ascent will produce magmatic fluids that can interact with minerals in the martian subsurface.

Figure 1. Residual liquids from crystallization of Backstay composition melts at 9.3 kbar with 0.7 wt% water (red) compared with those from crystallization of Backstay with 2 wt% water (green)[4] and a terrestrial hawaiite from the Nandewar volcano (blue) [2]. Rhyolite glass analyses from Chassigny melt inclusions from [5] are also indicated (yellow).



References: [1] McCubbin F. M. et al. (in prep.)
[2] Nekvasil H. et al. (2007) *MAPS* 42, 979-992. [3] McSween H.Y. et al. (2006) *JGR Planets*, 111, E09S91. [4] Nekvasil H. et al. (2007) LPSC XXXVII Abstract No. 1312. [5] Johnson M. C. et al. (1991) *GCA* 55:349-366.