

EXPERIMENTAL DETERMINATION OF DEGASSING PATH OF VOLATILES FROM LUNAR MAGMAS: NEW INSIGHTS FROM TIME STUDIES G. Ustunisik¹, H. Nekvasil¹, and D. H. Lindsley¹,
¹Department of Geosciences, Stony Brook University, Stony Brook, NY 11794-2100, Gokce.Ustunisik@stonybrook.edu, Hanna.Nekvasil@sunysb.edu.

Introduction: An essential part of the current lunar paradigm is that the lunar mantle contains very little water [1-4]. The primary line of reasoning behind this acceptance was perfectly consistent with the high-temperature, Moon-forming giant impact event [e.g., 5-7] until the recent evidence for water in the lunar interior by analysis of pyroclastic lunar glasses [8] as well as apatite grains in a variety of lunar lithologies [9-12]. These careful determinations have challenged the old paradigm of a “dry” mantle and opened the possibility that the strongly volatile depleted feature of lunar samples may not be correlated to volatility during the Moon-forming phase, but rather may have arisen by secondary magmatic processes at a much later stage.

Even though analysis of lunar apatites has provided invaluable information on instantaneous magmatic volatile contents, using this information to extract parental magmatic volatiles contents and source region volatile contents is not straightforward because apatite is commonly a late-crystallizing mineral and may reflect late-stage open system processes that have perturbed the magmatic volatile content. Therefore, the direct use of the inferred instantaneous volatile content of magmas co-existing with apatite to assess the bulk volatile content of the source regions was questioned by [13, 14] based on a set of mass balance calculations for the KREEP-bearing samples analyzed by [11]. These computations showed that the apatites record a degassing process that resulted in both loss of magmatic volatiles and in significant changes in the relative volatile contents of the residual liquids, which affected the composition of the apatites forming.

Recent degassing experiments [15,16] were conducted to determine the absolute and relative changes in abundance of volatiles (Cl, F, OH, and S) in the melt during the ascent of a lunar magma from 100 km depth to the surface without crystallizing. Based on the initial and final values for Cl, F, H₂O, and S (wt%), degassed samples with initially 2.2 and 2.5 wt% water lost 99-100% water, 89-84% Cl, 60-61% F, and 94-92% S. This percentage loss also affected the relative volatile contents of the melt with a strong decrease in water content and an increase in F:Cl ratio. In reflection of changes in melt volatile contents, hypothetical computed apatite compositions also show a strong reduction in OH content and a decrease in Cl:F ratio. While computed apatites from the initial (undegassed) magma had 20% Cl, 48% F, and 32% OH, computed apatites from degassed melts showed 10% Cl, 90% F, and 0% OH.

The mass balance computations of [13, 14] also indicated a two-stage degassing path consistent with the alkali halide-water systems in which a water and Cl-rich fluid vapor and aqueous liquid is lost first, followed by a more Cl-rich assemblage. Cl and F contents of apatite vary according to their lithologic type and these variations are not random but show a systematic path. The degassing experiments of [15,16] were designed to determine the composition of the bulk vapor and saline liquid assemblage from a synthetic 14053 composition [17] with added water, F, Cl, and S. However, these experiments did not provide insights in to the pathways taken by degassing. New experiments were designed as time studies and implemented to assess potential information on the degassing pathways.

Experimental Design and Details: The experiments are similar to those discussed by [15, 16, and in submission] but were designed to monitor changes in relative volatile content during successive intervals of low pressure degassing of a synthetic melt of 15043 with 0.5 wt% Cl, 0.5 wt% F, and 0.3 wt% S and 2.5 wt% water. The volatile-bearing glasses are prepared at 0.5 GPa in piston-cylinder apparatus then placed in Fe^o-capsules inserted into a long silica tube. After evacuation, the tubes are sealed and suspended by a Pt-wire into a vertical furnace and heated above the liquidus T for 2, 4, and 6 hours before quenching. Both the starting hydrous glasses and the degassed glasses at the end of each degassing interval are analyzed optically as well as by electron microprobe (at the AMNH) and by micro-FTIR (for water) at SUNY Stony Brook. The results of these experiments will be presented at the conference.

References: [1] Taylor, S.R. et al. (2006) *New Views of the Moon*, 657-704. [2] Fegley, B. and Swindle, T.D. (1993) *Resources of Near-Earth Space*, 367-426. [3] Papike et al. (1998) *Lunar Samples in Planetary Materials*, 5-1 - 5234. [4] Taylor (1992) *Solar System Evolution, A New Perspective*, 307p. [5] Albarede, F. (2009) *Nature*, 461, 1227-1233. [6] Canup, R. M. (2004) *Annu. Rev. Astron. Astr.*, 42, 441-475. [7] Lucey, P., et al. (2006) *Min. Soc. Am.*, 83-220. [8] Saal A. E. et al. (2008) *Nature*, 454,192-195. [9] Greenwood J. P. et al. (2011) *Nature Geosciences*, 4, 79-82. [10] McCubbin F. M. et al. (2010) *Am. Min.*, 95. [11] McCubbin F. M. et al. (2010) *PNAS* 107, 11223. [12] Boyce J. W. et al. (2010) *Nature*, 466, 466-469. [13] Nekvasil et al. (2010) *AGU*, P41A05. [14] Nekvasil et al. (2011) *LPSC XLII*, 2240. [15] Ustunisik et al. (2010) *AGU*, P41A04. [16] Ustunisik et al. (2011) *LPSC XLII*, 2643. [17] Willis J. P. et al. (1972) *LPSC III*, 1269-1273.