

**ORIGIN AND COMPOSITION OF LUNAR VOLCANIC GAS: THE PICRITIC GLASS MODEL.** M.J. Rutherford<sup>1</sup>, D. Wetzel<sup>1</sup>, E.H. Hauri<sup>2</sup>, and A.E. Saal<sup>1</sup>. <sup>1</sup>Dept. of Geological Sciences, Brown University, Providence RI 02912 (malcolm\_rutherford@brown.edu@brown.edu), <sup>2</sup>DTM Carnegie Institute of Washington, DC 20015 (hauri@DTM.ciw.edu).

**Abstract:** The composition and origin of the initial gas phase produced in the picritic lunar glass magma has been determined from analyses of the natural glasses and experiments. Partitioning of S, Cl and F into the CH<sub>4</sub>-bearing CO-rich gas has also been determined for a range of pressures up to 1000 MPa.

**Introduction:** The existence of a gas phase in lunar basaltic magmas is demonstrated by the ubiquitous presence of vesicles in returned samples (1). Additionally, the fine-grained glass bead deposits formed during eruption of the lunar picritic glasses (2,3) required a large (>90 v%) gas-bubble volume at the time of eruption (4). Theoretical studies (5) of the lunar picritic glasses suggest that in the absence of water, the only way to generate a gas phase at depth in the Moon is by the oxidation of reduced C, and the result would be a CO-rich gas containing anion species (S, Cl and F) and metals depending on the melt-gas partition coefficients. This theory has been confirmed by the analyses of the condensed coatings (Cu,Zn,Ga,Pb,S,Cl,B,F) on beads of the lunar orange and green picritic glass deposits (6). The process of generating a gas in ascending lunar, hydrogen-depleted, magmas depends fundamentally on the intrinsic oxygen fugacity ( $fO_2$ ) of the magma and the presence of carbon either dissolved in the magma, or as excess graphite in the magma. Because of the strong pressure dependence of the graphite C-O equilibrium (7), carbon (graphite) in ascending magma is oxidized to form a CO-rich gas at a pressure that depends on the intrinsic oxygen fugacity. For most lunar magmas, this oxygen fugacity is close to the Fe-FeO (IW) equilibrium. FeNi-metal grains in the picritic glasses, and trapped in olivine phenocrysts in the orange glass beads are interpreted as forming by C reduction (8). Experiments on the orange and green glass compositions (9,10) demonstrate that the Fe-rich metal is generated at a pressure of 40 MPa when the  $fO_2$  was at IW-1.0 log units. Trace amounts of Ni, S, F, Cl and F in the magma do not affect the 40 MPa pressure at which the CO-rich gas is formed (10).

**Water in the lunar picritic magmas:** Recently, (12,13) used SIMS to determine that water (H) is present in lunar glass beads; abundances of H<sub>2</sub>O ranging up to 100 ppm were identified at the center of beads, and diffusion loss profiles were determined in core to rim NANOSIMS profiles. Importantly, the H abundance is positively correlated with S, Cl, F and C abundances indicating that the volatiles including H (H<sub>2</sub>O) were dissolved in the melt at higher concentrations at the time the beads formed. Using available

diffusion rate data, (12) estimated that the original H concentrations in some beads were as high as 700 ppm. Graphite-saturated experiments on the A15 green glass composition indicate how this water would affect the origin and composition of the gas phase in the green glass magma (10). The results show that there is a strong positive correlation between the concentration of dissolved C and dissolved H (water) in the glasses for water concentrations up to 1500 ppm. The abundances of dissolved C and H also increase with increasing pressure, and many of the < 200 MPa experiments did contain an excess gas phase. We interpret these data as outlining the gas-saturated surface for C and H in the melt at graphite saturation for the lunar IW oxidation state. The correlation of C and H abundance with increasing pressure indicates the C is dissolved primarily as CH species at these reduced conditions, an observation constant with recent high-pressure results at the same oxidation state (13,14) where the C and H abundance was sufficiently high that CH species signatures were observed in Raman and IR spectra. Our experiments confirm this and yield data on the partitioning of S, Cl and F between the GG melt and the CH-CO vapor.

**Conclusions:** We conclude that ascending picritic lunar magmas containing H at 500 to 1500 ppm H<sub>2</sub>O concentration levels and graphite will produce small amounts of gas prior to reaching the graphite oxidation pressure where FeO is reduced to Fe-metal. The initial gas production is caused by the reduced CH-species solubility with decreases in pressure; in magmas without H, all of the gas phase would be produced in association with graphite oxidation at ~40 MPa or about 8.5 km depth in the moon. Cl and S partition modestly into the early forming CH-CO gas. This process of gas formation and FeO-reduction should have also operated during convection in the LMO that carried C and melt above ~8 km depth in the moon.

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