

CARBON SOLUBILITY IN LUNAR MAGMAS. D. T. Wetzel¹, M. J. Rutherford¹, S. D. Jacobsen², E. H. Hauri³, and A. E. Saal¹, ¹Dept. of Geological Sciences, Brown University, Providence RI 02912 (Di-ane_Wetzel@brown.edu), ²Dept. of Earth and Planetary Sciences, Northwestern University, Evanston, IL 60208 (steven@earth.northwestern.edu), ³DTM Carnegie Institute of Washington, DC 20015 (hauri@DTM.ciw.edu).

Introduction: Available evidence suggests in the absence of water, carbon is the element responsible for generating the gas phase that drove lunar fire-fountain eruptions [1, 2]. The gas phase is generated by the oxidation of reduced C carried in the magma from depth [3]. Recent experiments have confirmed that C first forms a CO-rich gas phase in lunar picritic magmas at 40 MPa (~8.5km) [4]. A conduit flow model [5] predicted as little as 50 ppm C in the magma would create gas in sufficient quantities to drive the lunar eruptions. Recently, Saal et al. [6] identified indigenous H (H₂O), F, Cl, and S in a range of picritic glass compositions. Concentrations were found as residual diffusion-loss profiles in the lunar beads, which led to estimates for initial lunar volatile abundances. With new SIMS detection limits of 0.13 ppm C, Saal et al. [7] determined that picritic glass beads contained from 0-0.69 ppm C. Our study was designed to determine the solubility and speciation of C in H-bearing, graphite-saturated picritic lunar magmas, and the effect of H on the initial gas phase generated in these magmas at liquidus T's.

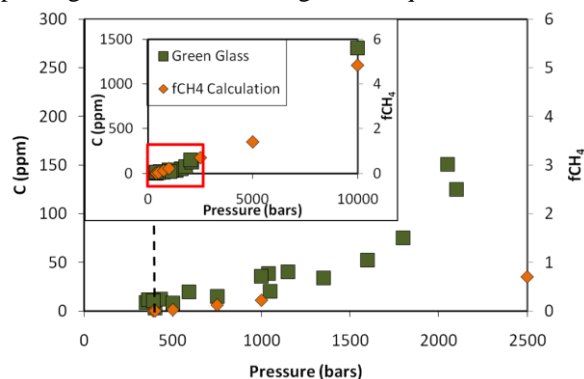


Fig 1: Carbon vs. pressure graph shows C increases with increasing P in the graphite-stable field at $f_{O_2} \sim IW$. C decreases with the generation of CO-rich gas at $P < 400$ bars (dashed line). CH₄ fugacity for the coexisting fluid phase was calculated [10].

Experimental and analytical methods: Experiments on synthetic A15 green glass compositions were carried out in an IHPV on pellets of powder, which were reduced to $f_{O_2} \sim IW$. Samples were run with excess graphite in sealed Pt tubes as described by [4]. Temperatures were 1465°C, or ~15°C above the green glass liquidus T, at lower pressures and 1500°C for higher pressures (1 GPa). Pressures ranged from 30-1000 MPa. Samples were quenched to a glass and analyzed by EMP, SIMS, FTIR, and Raman spectroscopy.

Results: Experimental samples pre-set at IW and enclosed in graphite contained a glass with lower FeO due to the formation of Fe-metal at pressures below 40 MPa. At pressures greater than 40 MPa, C in the green glass has a strong positive correlation with pressure (Fig. 1). Abundances were determined by SIMS for all of the glasses, resulting in 3-150 ppm C at lower pressures and up to 1400 ppm C for a 1 GPa experiment. Analyses also show a positive correlation between dissolved C and H₂O in the experimental glasses. Raman spectroscopy indicates CH₄ present in the melt, which confirms the observed trend between C and H₂O in the lower pressure glasses.

Discussion and Conclusions: Analyses of the natural lunar samples [2] and our experimental green glasses suggest the formation of a CO-rich gas phase via C-oxidation at $P < 40$ MPa due to Fe metal present in these melts. With hydrogen present, Raman spectroscopy indicates CH₄ is the dominant C species dissolved in the melt. (Depending on the relative abundance of C and H in the magma, there may or may not be reduced C with CH₄ in ascending magma). Therefore, the solubility of C in picritic melt (Fig. 1) is directly proportional to the concentration of dissolved CH₄ and increases with increasing f_{CH_4} . Experiments with water contents of 1000 ppm and excess graphite produced increasing maximum dissolved C in melts up to 1490 ppm at 1 GPa. Greater H₂O contents contribute to both CH₄ and water species (H₂O, OH, and H₂) present in the melt. If decompression-induced CH-gas saturation is reached at pressures greater than 40 MPa, methane could produce the first gas phase. These results are consistent with experiments on Na-silicate [8] and haplobasaltic [9] melts that indicate CH₄ dissolved in melts at $f_{O_2} \sim IW$. Thermodynamic models [10] predict a CH₄- and H₂-rich gas phase in equilibrium with a melt at higher pressures and CO-rich gas phase at lower pressures (near 40 MPa C oxidation reaction).

References: [1] Sato M. (1976) *PLSC 7th*, p.1323-25. [2] Fogel R.F. and Rutherford M.J. (1995) *GCA*, 59, 201-15. [3] Heiken G.H. et al. (1974) *GCA*, 38, 1703-18. [4] Nicholis M.G. and Rutherford M.J. (2009) *GCA*, 73, 5905-17. [5] Rutherford M.J. and Papale P. (2009) *Geology*, 37, 219-22. [6] Saal A.E. et al. (2008) *Nature*, 454, p.192-95. [7] Saal A.E. et al. (2009) *Goldschmidt*, A1139. [8] Mysen et al. (2009) *GCA*, 73, 1696-1710. [9] Ardia P. et al. (2011) *LPSC XLII*, Abst. #1659. [10] Zhang C. and Duan Z. (2009) *GCA*, 73, 2089-2102.