**HYDROGEN VARIATIONS IN LUNAR GLASS BEADS: ERUPTIVE DEGASSING IN ANGSA SAMPLES.** E.M. Recchuiti[1], M.C. McCanta[1], M.D. Dyar[2], E. C. Sklute[2], and A. Lanzirotti[3]. [1]Dept. of Earth and Planetary Sciences, Univ. of Tennessee Knoxville, TN, 37996 (erecchui@vols.utk.edu), [2]Planetary Science Inst., 1700 East Fort Lowell Rd., Suite 106, Tucson, AZ 85719, [3]Center for Advanced Radiation Sources, The Univ. of Chicago, Argonne, IL, 60439.

**Introduction:** Many of the lunar samples returned by the Apollo program contained picritic glass beads interpreted to result from explosive volcanism like terrestrial fire-fountain eruptions [1]. Because they are rapidly quenched material, these primitive glass beads provide a unique opportunity to analyze the volatile contents of lunar melts, as well as to evaluate the amount of volatiles lost during degassing prior to and during eruption [2, 3]. The beads represent the only direct samples of internal lunar $H_2O$ available for analysis. High-resolution measurements of $H_2O$ in these glasses are needed to constrain lunar volatile evolution.

The oxidation fugacity ($f_{O2}$) of a system can be correlated with the H content and therefore facilitate additional assessment of melt $H_2O$ concentration [4]. In-situ analysis of both the $H_2O$ and $f_{O2}$ of volcanic glasses thus allows for evaluation of the processes related to and degree of volatile degassing on parent bodies. To interpret such measurements, readily available terrestrial analogues can be used to better understand diffusive $H_2O$ loss during eruption. The resultant understanding of processes and rates of volatile loss can then constrain the initial $H_2O$ content of the lunar interior.

Measurements by the ANGSA-funded SCARAB (Spectroscopy Consortium Addressing Redox Acquired by Beads) team seek to constrain the initial $H_2O$ content of the lunar interior and $H_2O$ loss during eruption, in combination with measurements of $Fe^{3+}$. This abstract focuses on H mapping in lunar glass beads.

**Samples:** Two lunar glass beads from Apollo 15 (15427,83) and several glass beads from the Apollo Next Generation Sample Analysis (ANGSA) core 73002 were analyzed. Sample 15427,83 is a regolith breccia thin section that contains several clasts as well as glass beads and shards. The ANGSA beads were individually mounted in epoxy in 1-inch rounds that were polished. They include beads within the space weathered and pristine portions of the core.

**Methods:** Fourier transform infrared (FTIR) analyses were performed using both a Bruker Vertex 70 with a Hyperion 3000 microscope (UMass, Amherst) equipped with an mercury cadmium telluride (MCT) point detector and a 64×64 pixel focal plane array (FPA) detector, as well as using the Bruker Lumos II equipped with a 64×64 pixel FPA detector at (Bruker Demo Laboratory, Billerica, MA). All samples were lightly polished directly prior to analysis to remove possible surface $H_2O$. Coarse MCT maps at higher spectral (4 $cm^{-1}$) but lower spatial resolution were made to guide FPA image acquisition. Once obtained, each group of spectra was offset-normalized to the baseline value between 4000-3990 $cm^{-1}$. Noisy pixels were manually removed in each FPA image prior to binning. Binning was used to increase the signal-to-noise ratio (SNR); 2×2, 4×4, and 8×8 bins were compared to find the maximum possible spatial resolution that provided an adequate SNR. Hydrogen maps were made by applying a peak area integration (OPUS B class integration) of the broad hydration feature from

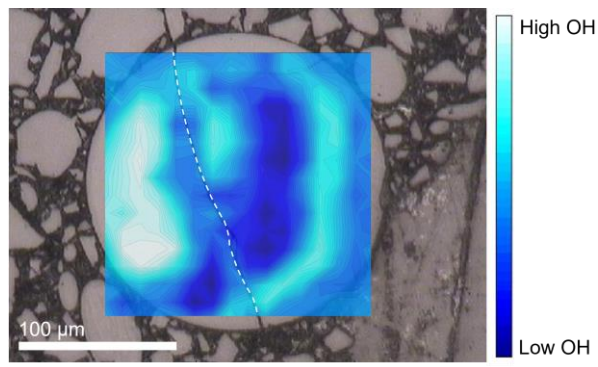


**Figure 1.** Hydrogen abundance map with 4x4 binning and hydration feature integration overlain a reflected light image of lunar bead 2 from sample 15427,83. The dotted line indicates the location of the cross cutting fracture.

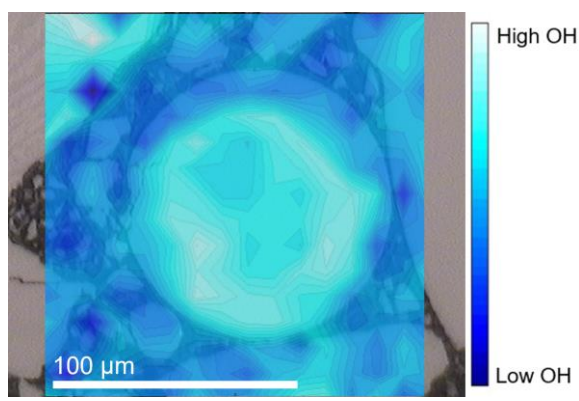


**Figure 2.** Hydrogen abundance map with 4x4 binning and hydration integration overlain a reflected light image of lunar bead 4 from sample 15427,83.

~3800-3000 $cm^{-1}$, which has been shown to be due to OH in mineral structures [5], and to correlate to hydrogen concentrations [6,7]. End-points of integration were chosen to avoid the epoxy-associated feature near 2990 $cm^{-1}$ and appropriately average out thin-sample sinusoidal interference. The unscaled integration areas provide a qualitative assessment of hydrogen distribution across a sample.

**Data:** Preliminary FTIR data for lunar beads 2 and 4 from sample 15427,83 are shown as hydrogen maps for select beads in thin section 15427,83 (Figs. 1 and 2). While the absolute value in the color scale has no specific meaning for these plots, the qualitative distribution of hydrogen in the sample can be visualized. Depletion of H within the beads differs between beads 2 and 4. Lunar bead 2 shows a depletion pattern that, compared with the backscatter electron image (BSE) of the bead, appears to coincide with the fractures in the bead (Fig. 1). It is inferred that the fracture created a pathway by which H could readily exit the glass, though the enrichment near the fracture indicates that the degassing was not complete. In bead 4, there is no fracture to provide a pathway for degassing, so hydrogen diffuses from core to rim (Fig. 2). This results in the observed bullseye pattern of enrichment in the center grading into a steady depleted rim on the bead.

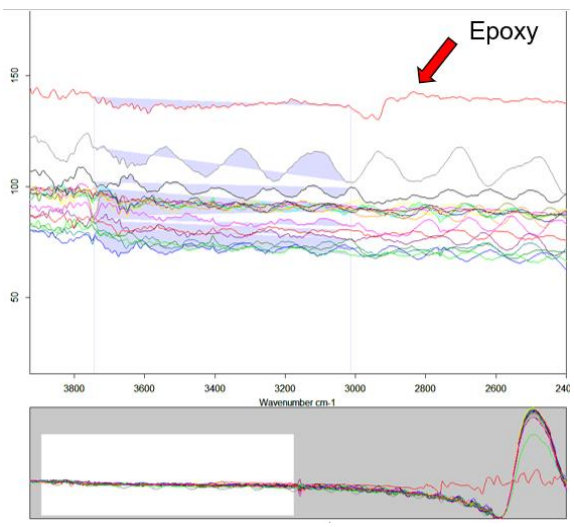


**Figure 3.** Sample spectral data. The red line offset at the top is from an epoxy-rich pixel. The blue shaded area indicates bounds of integration for hydration.

FTIR data often show contamination from the mounting epoxy (Fig. 3); its interference is observed as the blue and red lines that diverge from the clear Si reflectance feature that spans from ~1200 $cm^{-1}$ to the end of the spectral range. Epoxy can be mapped using a clear organic feature ~2950 $cm^{-1}$. Generally, epoxy maps are inversely correlated with Si maps, indicating that admixing of the two spectral components occurs at the edges of the sample where the bead thickness is decreasing. Thus, any zoning seen at the edges is interpreted to be due to thickness effects. Our preparation of these ANGSA beads minimizes the epoxy interference and thin-sample sinusoidal interference by using carefully prepared thicker sections.

**Summary and Future Work:** Understanding the amount of H lost during degassing and eruptive processes can aid in allowing for estimation of primary volatile content in a melt. Preliminary data indicate that H loss is associated with fractures and core-to-rim degassing. Those data do not show epoxy contributions in the center of the bead where the sample is thickest, though the thinner edges suggest some interference (Fig. 4).

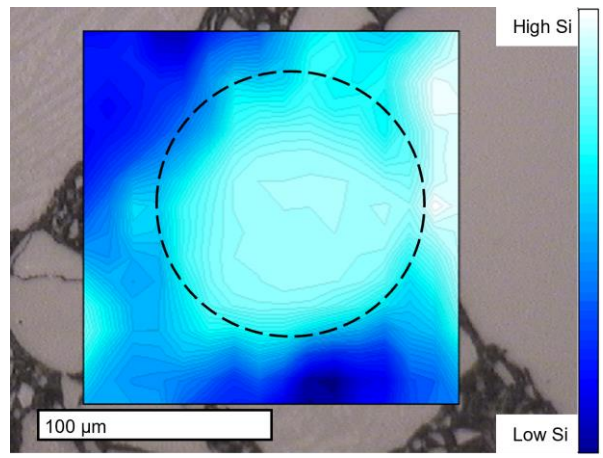


**Figure 4.** Si abundances for lunar bead 4 with integration (1155-751 $cm^{-1}$) and 4×4 binning. The dashed circle indicates the edge of the bead and the radial Si pattern indicated that the center of the bead is returning data representative of the sample.

As we acquire data on additional samples, comparisons can be made to infer the degree of degassing that occurred during lunar eruptions. This will allow for constraints to be placed on the similarities and disparities between lunar and terrestrial explosive basaltic volcanism and its subsequent volatile loss, as well as allowing for primary abundances to be estimated [9, 10].

**References:** [1] Heiken et al. (1991) *Lunar Sourcebook*, Cambridge Univ. Press. [2] Hauri et al. (2015) *Earth & Planet. Sci. Let.* 409, 252-264. [3] Saal et al. (2008) *Nature* 454, 192-196. [4] Hauri et al. (2011) *Science* 333, 213-215. [5] Bell & Rossman (1992) *Science* 255, 1391-1397. [6] Johnson & Rossman (2003) *Am. Min.* 88, 901-911. [7] Seaman et al. (2006) *Am. Min.* 91, 12-20. [8] Lanzirotti et al. (2018) *Am. Min.* 103, 1282-1297. [9] Recchuiti et al. (2021) *LPSC* 52, #1299. [10] Recchuiti et al. (2020) *AGU* V013-0009.