

D/H RATIOS OF THE LUNAR VOLCANIC GLASSES. A. E. Saal¹, E. H. Hauri², J. A. Van Orman³, M. J. Rutherford¹. ¹Department of Geological Sciences, Brown University, 324 Brook St., Box 1846, Providence, RI, 02912. ²Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Road, NW Washington, DC 20015. ³Department of Geological Sciences Case Western Reserve University, Cleveland, OH 44106.

Introduction: Water is perhaps the most significant molecule in the solar system, and understanding the origin and distribution of water in planetary interiors has important ramifications for understanding the evolution of planetary bodies. The general notion that water (hydrogen) was completely evaporated away during the single or series of catastrophic heating events that formed the Moon has changed [1, 2, 3, 4, 5]. These results represent the best evidence for the presence of a deep source within the Moon relatively rich in volatiles, especially water. Here we report the first in-situ measurements of the isotopic composition of hydrogen dissolved in primitive volcanic glass and their melt inclusion samples recovered from the Moon by the Apollo 15 and 17 missions.

Samples and Analytical Techniques: The studied samples (74220; 15426; 15427) are all samples chosen for their high concentrations of volcanic glass spheres (~90%). The glassy spherules range in size from ~100 to ~1 mm, while the olivine-hosted melt inclusions range from 10 to 40 μm . Lunar volcanic glass beads and melt inclusions were individually handpicked, mounted into indium metal contained in an aluminum metal disc, and were then sectioned and polished in such a way as to attempt to expose the precise geometric center of as many beads as possible. The sample mount was polished to 1 μm quality with diamond paste, cleaned with distilled water, dried in a vacuum oven for a week, then coated with a 200 nm layer of gold. The abundances of volatiles and D/H ratios dissolved in the interior of the lunar picritic glasses were measured by SIMS using a Cameca IMS 6F and NanoSIMS at DTM, CIW, employing methods recently developed for the microanalysis of trace amounts of H₂O, CO₂, F, S, Cl and D/H ratios in glasses and nominally anhydrous minerals [6, 7]. For the analyses reported here, we obtained data in two different modes of operation: standard Dynamic SIMS, and Scanning Ion Imaging SIMS. Analysis of 74220 matrix glasses and glass beads, and all glass bead analyses from samples 15426 and 15427 were performed using standard Dynamic SIMS. For the measurements of 74220 melt inclusions, only Scanning Ion Imaging SIMS was used. Our new SIMS detection limits (~0.13 ppm C; ~0.4 ppm H₂O, ~0.05 ppm F, ~0.21 ppm S, ~0.04 ppm Cl by weight determined by the repeated analysis of synthetic forsterite located on each sample mount), represent at least 2 orders of

magnitude improvement over previous analytical techniques.

Results: δD measured in ~65 lunar glass beads range from +161‰ to +542‰, and thus, are indisputably fractionated from terrestrial values. δD is inversely correlated with water content, and part of the D enrichment is the result of in situ spallation during interactions with solar and galactic cosmic rays. The cosmic ray exposure ages of individual lunar volcanic glasses from the samples examined in this study have an average of 283 ± 51 Myr for A15 glasses [8] and 30 ± 10 Myr for A17 glasses [9]. Interestingly, the average δD of the highest-H₂O glass bead is +340‰ (+180‰/-240‰), not that different from the reported $\delta\text{D} +680$ (± 350) of lunar apatites from Mare basalts (Greenwood, et al. 2011). However, it is very likely that the original pre-eruptive δD value of these lunar magmas was significantly lower, and that D/H fractionation has resulted in preferential loss of H during magmatic degassing and eruption. A simple kinetic degassing calculation suggests that the δD of the lunar glasses might not have been that different from that of terrestrial basalts. A notable feature of the highest-H₂O lunar glasses after spallation correction is that they exhibit a much smaller range in δD values than the overall data. The average δD of the five highest-H₂O glasses is +340‰ (+180‰/-240‰). It is very likely that the original pre-eruptive δD value of these lunar magmas was significantly lower, and that D/H fractionation has resulted in preferential loss of H during magmatic degassing and eruption.

Conclusions: Our δD results, after spallation and degassing corrections for the highest-H₂O glasses, suggest a D/H ratio slightly heavier than that of the terrestrial mantle.

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