WATER IN THE MOON: EVIDENCE FROM HYDROGEN ISOTOPE COMPOSITIONS OF LUNAR APATITE.
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Introduction: Since the discovery of trace amounts of water in lunar fire-fountain glasses in 2008 [1], several groups have more recently reported on the existence of copious amounts of water in lunar apatite [2-5], with maximum values of 6050 ppm determined from mare basalt 12039 apatite [5]. Modeling of these results to determine the original content of water in the lunar mantle is fraught with difficulties and unknowns in key parameters [2,3]. We have recently reported the first D/H measurements of lunar water from ion microprobe measurements of D/H in apatite from Apollo rock samples [5]. Here we summarize and discuss key results of our research.

Results and discussion: Results of our ion microprobe spot analyses of H_2O and D/H of lunar apatite are shown in Fig. 1. A histogram of our D/H results are shown in Fig. 2.

D/H of the Moon. The mean and standard deviation of δD analyses of mare basalts 10044, 12039, and 75055 are +681±132‰ (n=27) (Fig. 2). That the D/H of these 3 mare basalts from different landing sites should be so similar argues that the mare source region is also similarly elevated in D/H.

The δD of apatite from an intrusive highlands alkali anorthosite clast (14305,303) is also elevated relative to Earth (δD=+238±72‰; +341±53‰), but less so than mare basalts 10044, 12039, and 75055. The elevated D/H for this intrusive sample seems to rule out assimilation of regolith material (derived from comets or asteroids) by the extrusive mare lavas to explain the elevated D/H of the Moon.

Degassing of H_2. The mean and standard deviation of δD of pigeonite basalt 12039,43 are +698±61‰ (n=9). This is almost identical to the mean δD of 12039,42 (mean δD=+689±180‰ (n=13) [5]), but with much less variability. We have analyzed 13 apatite grains in 12039, and these grains exhibit a 6-fold change in water content and almost no change in D/H. This argues strongly against a model of degassing of H_2 from lunar magmas with Earth-like D/H *during apatite crystallization* to explain the elevated D/H of 12039 apatite. Our results do not rule out degassing of H_2 *prior to apatite crystallization* to explain elevated D/H of mare basalts.

References: [1] Saal A. E. et al. (2008) *Nature 454,* 192-196. [2] McCubbin F. et al. (2010) *PNAS 107,* 11223 [3] Boyce J. et al. (2010) *Nature 466*, 466. [4] McCubbin F. et al. (2010) *Am. Min. 95* 1141 [5] Greenwood J. P. et al. (2011) *Nature Geosci.* doi:10.1038/NGEO1050.

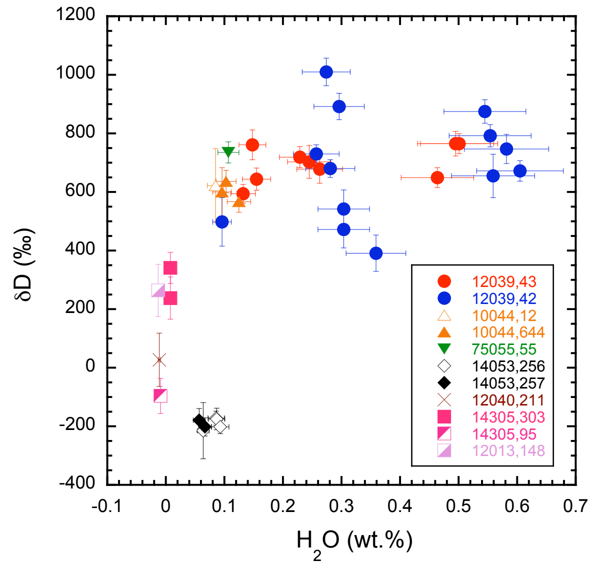

Figure 1. δD vs. H_2O (wt.%) plot of apatite from lunar samples collected during the Apollo programme.

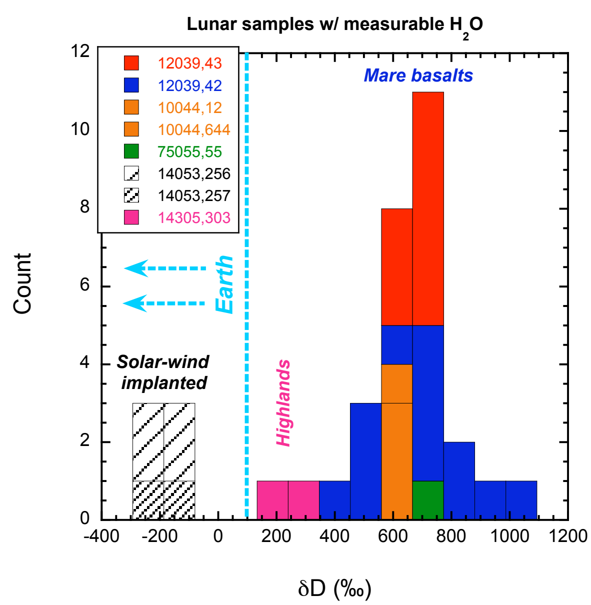

Figure 2. Histogram of δD analyses of lunar samples with measurable water.