Evidence for the Giant Impact Model from D/H of Water in Lunar Melt Inclusions and Apatite

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In the past six years, the idea of a completely dry lunar mantle has been swept aside by the preponderance of evidence to the contrary beginning with [1]. In fact, the high levels of indigeneous water found in lunar samples has led to questioning of the Giant Impact model for the Moon's formation, since a major line of evidence for this event was the formerly dry lunar interior. In order to understand the meaning of water and D/H in lunar samples, we have begun a study of olivine-hosted melt inclusions and apatite in the Apollo 12 olivine basalt suite. The Apollo 12 olivine basalt suite is believed to be a consanguineous suite, differing mostly by cooling history, from olivine vitrophyres (12009) to olivine cumulates (12040).

We have analyzed ten melt inclusions (MIs) in 12009 and 12004 for D/H and/or OH and find that water contents are mostly <100 ppm H_2O. We analyzed apatite in more slowly cooled samples of the suite (12006, 12018), and it is much higher in water (688-3164 ppm H_2O), with δD values typical of lunar apatite (δD: +868±122‰ to +1439±104‰ (2σ). The δD of the melt inclusions range from +31±275‰ to +1219±173‰ (2σ). The MIs are on average lower in D/H than lunar apatite, but are better described as overlapping the range in D/H exhibited by lunar apatite, but at *much lower water contents*. This suggests that D/H was likely set before crystallization of olivine in these samples.

We propose that the lunar mantle D/H is elevated with a δD of ~+200-300‰, as the most water-rich melt inclusions of [2] and plutonic apatite of 14305 [3] have identical δD within error. These two sample sets are the best samples currently available for assessment of the lunar mantle D/H. As the Moon is the only planet with Cl and Zn isotope anomalies, we propose that H, Cl, and Zn isotopes were fractionated during hydrodynamic escape of hydrogen in the aftermath of the Giant Impact.

[1] Saal A. E. *et al* (2008) *Nature,* ***454****,* 192-196. [2] Saal A. E. *et al* (2013) *Science* doi:10.1126/science.1235142. [3] Greenwood J. P. et al (2011) *Nature Geosci.,* ***4****,* 79-82.