THE MOON: GETTING WETTER ALL THE TIME (A SURVEY OF APATITE IN APOLLO 12 BASALTS).

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Introduction: How wet is the Moon? What is the origin of the Moon's water? How and when did the mare basalts obtain their water (during melting of a hydrous lunar mantle, or assimilation of volatile-rich lower or upper crustal materials, or assimilation of water-bearing exogeneous material on the lunar surface)? It is these questions that are driving the current research on the water and hydrogen isotope compositions of apatite in lunar rocks [1]. There is currently very little agreement on these questions in the lunar community, with magma ocean modeling [2] and extreme Cl isotope variations [3] pointing towards a generally dry Moon, while studies of lunar fire-fountain glasses [4,5] and apatite in lunar rocks [1,6,7] suggesting a 'damp' [6] or 'wet' [1,4,7] Moon.

Here we present new results on the water contents of seven Apollo 12 basalts. Hydrogen isotope results for these seven samples will be presented at the meeting. In our previous work [1] we had studied two Apollo 12 basalts, one slowly cooled olivine basalt (12040), wherein we found apatite to be essentially dry, and one slowly cooled pigeonite basalt (12039), which was the most water-rich sample from the Moon. In this work, we have looked at other members of the olivine (12006; 12018) and pigeonite basalt suite (12007; 12031), and also expanded our work to include members of the ilmenite basalt suite (12005; 12063) and a feldspathic basalt (12038).

Methods: Samples are first studied using optical microscopy, followed by low resolution Kα x-ray mapping to locate phosphate grains. Prior to ion microscope analysis, apatite grains are identified using the Wesleyan University JEOL SEM with an EDAX Genesis EDS system. Areas near grain edges or cracks are used for preliminary identification (areas deemed unsuitable for later ion or electron microprobe analysis due to cracks or grain boundaries).

Ion microscope analysis was conducted using the modified Cameca ims 1270 with SCAPS detector (Scanning CMOS-type Active Pixel Sensor) which allows 2D ion imaging at Hokkaido University. Ion probe spot analyses for ^{1}H and D and ^{1}H/^{18}O ratio measurements to determine D/H and OH of apatite, as well as SCAPS imaging, followed methods in [1]. After ion microscope analysis, apatite grains were measured using the JEOL Field Emission Gun (FEG) "Hyperprobe" at Yale University to determine major and minor element concentrations, especially of the halogens F and Cl.

Results:

Olivine basalts. We have now studied three of the Apollo 12 olivine basalts 12006, 12018, and 12040. According to Walker et al. (1976) [8], 12040 and 12035 are the slowest cooled members of the olivine basalt suite. In our previous study, apatite in 12040 was essentially dry [1]. Apatite in 12006 and 12018 were found to contain significant water. We studied two apatite grains in 12006, and found 4618 and 6328 ppm OH, respectively. In 12018 we analyzed one apatite grain and found 3978 ppm OH. In our previous work, we had suggested that the differences in olivine and pigeonite basalts [9] may be related to water content of the parent magmas. We see essentially no difference between water contents of apatite from some olivine basalts and pigeonite basalts, suggesting that water content alone is not a defining difference between these two important suites of Apollo 12 basalts.

Pigeonite basalts. 12007 is described as being very similar to 12039, thus we were excited to study this sample as 12039 had the most variability in water content and D/H in our previous work [1]. The sample of 12007 that we studied was surprisingly poor in apatite relative to 12039. We analyzed two apatite grains in 12007 and found them to contain 2316 and 3148 ppm OH. This is on the low end of OH contents for 12039 [1]. 12031 was originally classified as a feldspathic basalt [10], but was reclassified as a pigeonite basalt [9]. 12031 has a coarse-grained mesostasis, suggesting a slow cooling rate, similar to 12007 and 12039. Three analyses of apatite grains in 12031 ranged from 6292-9276 ppm OH.

Ilmenite basalts. Apatite in 12005 was dry, similar to that in olivine basalt 12040. This is now the 2nd mare basalt found to be dry. 12063 had water bearing apatite, but on the low end with only 864 ppm OH.

Feldspathic basalt. 12038 is the only surviving member of the feldspathic basalt suite (other members have been reclassified into the other three basaltic suites). Three apatite grains in 12038 had a large range in water content, ranging from 926-9276 ppm OH.

Discussion: The dry ilmenite basalt 12005 is a slowly cooled rock, similar in that regard to olivine basalt 12040. This suggests that the slowest cooled members of the olivine and ilmenite basalt suite lost their water during cooling after emplacement onto the lunar surface. This is very different than the pigeonite basalts, wherein the slowest cooled members of the suite are among the most water-rich samples from the Moon. This suggests a simple model, wherein the slowest cooled members of the olivine and ilmenite basalts were buried deeper than the slowest cooled members of the pigeonite basalt suite. This deeper burial and slower cooling of these members of the olivine and ilmenite basalt suite (12040 and 12005, respectively) suggests that these rocks underwent significant volatile loss in the near-surface lunar environment.

Regardless, all the Apollo 12 basalt types (olivine, pigeonite, ilmenite, and feldspathic) have evidence for significant water in apatite grains, strongly suggesting that none of these magmas were dry during early crystallization.

References:

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