NOMINALLY HYDROUS MAGMATISM ON THE MOON. F. M. McCubbin[1,2] A. Steele[2], E. H. Hauri[3], H. Nekvasil[4], S. Yamashita[5], R. J. Hemley[2] [1] Institute of Meteoritics, Department of Earth and Planetary Sciences, University of New Mexico. Albuquerque, New Mexico 87131 (fmccubbi@unm.edu) [2]Geophysical Laboratory, Carnegie Institution of Washington, 5251 Broad Branch Rd., N.W, Washington, DC 20015 [3]Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Rd., N.W, Washington, DC 20015 [4]Department of Geosciences, Stony Brook University, Stony Brook, NY 11794 [5]Institute for Study of the Earth's Interior, Okayama University, Misasa, Tottori 682-0193, Japan

Introduction: One of the first scientific discoveries resulting from the Apollo missions was the pervasive waterless nature of the Moon and its rocks. Moreover, the subsequent forty years of lunar sample analysis have only supported and strengthened the idea that indigenous water was nearly absent from the Moon's interior, and this conclusion has been incorporated into many petrologic and geophysical models constructed to aid in our understanding of lunar formation and lunar geology. The bulk water content of the Moon was recently estimated to be less than 1 ppb [1], which would make the Moon at least six orders of magnitude drier than the interiors of Earth and Mars.

Facilitated by advancements in analytical detection sensitivities for water, several recent discoveries have indicated that the story of water on the Moon is far from complete. Evidence for hydroxyl/water on the lunar surface has been detected using remote sensing data from the Moon Mineralogy Mapper (M^3) instrument on board the Chandrayaan-1 space craft [2-4]. Moreover, evidence for water within the lunar interior has been reported through ongoing lunar sample analysis efforts. Specifically, up to 46 ppm water has been directly measured in some pyroclastic lunar glasses [5], and hydroxyl has been qualitatively identified in fluorapatite grains (fluorapatite is a calcium phosphate mineral depicted as [$Ca_5(PO_4)_3F$]) from Apollo 15 mare basalt 15058 [6]. Significantly higher water contents of the lunar interior could hold profound changes in our understanding of the Moon's geologic history, from models of lunar formation to our understanding of its thermal and magmatic evolution.

In the present study, apatites from three different lunar samples were analyzed for hydroxyl using secondary ion mass spectrometry (SIMS). The samples analyzed are from rock types that have not been previously analyzed for water. The samples investiengated include a high-Al basalt (14053,16), a clast-bearing impact melt rock (15404,51), and an olivine-gabbro cumulate lunar meteorite (Northwest Africa 2977). We also note that 2 other ongoing studies report the water contents of lunar apatite [7-8]

Results: All of the apatites analyzed in this study had measurable water, and the water contents ranged from about 100-3700 ppm H_2O. the water contents for all the apatite analyzed are reported in table 1.

Table 1. SIMS analyses of lunar apatite

Sample*	F (wt%)†	Cl (ppm)†	OH (ppm)†
14053_1	2.48 ± 0.03	4,660 ± 50	2,700 ± 400
14053_2	2.70 ± 0.06	4,300 ± 200	1,700 ± 300
14053_3	2.83 ± 0.08	4,570 ± 80	1,400 ± 200
14053_4	2.9 ± 0.1	1,730 ± 50	1,300 ± 200
15404_1	2.47 ± 0.04	11,600 ± 200	1,000 ± 300
15404_2	2.62 ± 0.03	9,340 ± 20	300 ± 200
15404_3	2.54 ± 0.06	10,770 ± 40	220 ± 40
NWA 2977_1	2.7 ± 0.2	2,100 ± 100	7,000 ± 1,000
NWA 2977_2	2.7 ± 0.4	330 ± 50	4,000 ± 700

*Numbers next to the sample refer to the analysis number indicated on the respective BSE image.
†All reported uncertainties are 2σ.

Discussion: Using the analyses from table 1, we can bracket the lower limit water content of the magmatic source region from which the magmas parental to these samples originated. In order to make this estimation, a few assumptions must be made. 1) apatite did not enter the phase assemblage until 99% crystallization. 2) There was no flux in the water budget of the system and apatite was the first OH-bearing phase to form. 3) The parental melt resulted from low degrees of partial melting (3%) of the lunar source (higher degrees of partial melting result in higher source region water contents).

Using these assumptions, the minimum water contents of the lunar magmatic source regions range from 64 ppb to 5 ppm H_2O. This lower limit range of water contents is at least two orders of magnitude greater than the previously reported value for the bulk Moon (<1 ppb), and the actual source region water contents could be significantly higher. However, the lower limit values alone do not cause a complete re-write of the current theories for lunar formation and its subsequent magmatic evolution.

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