

**MAGMATIC VOLATILES IN LUNAR APATITE: A HEXAGONAL PRISM OF TRUTH OR A HOUSE OF CARDS?** F. M. McCubbin<sup>1</sup>, C. K. Shearer<sup>1</sup>, S. M. Elardo<sup>1</sup>, Z. D. Sharp<sup>2</sup>. <sup>1</sup>Institute of Meteoritics, University of New Mexico, Albuquerque, NM 87131. <sup>2</sup>Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131 ([fmccubbi@unm.edu](mailto:fmccubbi@unm.edu))

**Introduction:** Significant progress has recently been made in determining the nature of lunar indigenous hydrogen because recent SIMS analyses of lunar apatites have revealed that hydroxyl is structurally bound within apatite from a number of different lithologic types [1-4]. These studies, along with previous SIMS analyses of lunar fire fountain glasses [5], confirm that there is at least some hydrogen in the lunar interior. Although the absolute concentrations of hydroxyl that have been measured in lunar apatite are consistent among the various studies, there is some disagreement regarding what the analyses imply about hydrogen contents in the lunar interior, and there are also important questions regarding the sources and reservoirs of this H. The purpose of the present study is to review the required information, as well as the potential pitfalls, for using apatite to estimate the H content of a magmatic source region. Furthermore, we demonstrate that although the new findings of H in the lunar interior are potentially very exciting, there is considerable work ahead that is needed before we can fully understand the importance of lunar H with respect to the thermal and magmatic evolution of the Moon.

**Is apatite a reliable tool for probing the interior volatile contents of the Moon?** The absolute volatile abundances of a parental liquid (and hence the magmatic source region) are difficult to constrain from apatite volatile data alone. Even if one can discount the possibility of post- and pre-crystallization processes having disturbed either the parental magmatic volatile abundances or the volatile abundances in the apatites themselves, there are no apatite-melt partition coefficients for F, Cl, and OH for lunar compositions, and it is difficult to constrain the amount of crystallization that occurred before the start of apatite crystallization in each of the samples investigated. Both of these parameters must be known before any tight constraints can be placed on the H content of a lunar source region.

Given the very loose constraints that are currently available for the parameters discussed above, estimates of H in the lunar interior span several orders of magnitude from approximately 7 ppb to 1 ppm H [1,5,6], indicating the Moon is likely depleted in H relative to the interiors of Earth and Mars.

**Volatiles in the lunar interior: It gets more complicated/Fun.** The magmatic volatile abundances of apatite from several lunar lithologic types have been determined, and there are some striking differences in the volatile abundances that correlate to lithologic

type. Specifically, rocks from the highlands magnesian-suite, alkali-suite, and KREEP-rich impact melts, all of which are KREEP-rich lithologies, plot together in an OH-poor, relatively Cl-rich portion of the F-OH-Cl ternary. Furthermore, apatite from the various mare basalt compositions plot over a range of OH-rich to F-rich compositions that are consistently Cl-poor. Apatite from the single KREEP basalt sample that has been analyzed thus far, 15386, plot between the mare basalt and KREEP-rich highlands rocks portion of the ternary, although significantly more data is needed to confirm this observation (Figure 1). The difference between the Cl contents of the mare apatites versus the KREEP-rich lithologies' apatites indicate that there are significant compositional differences at the time of apatite crystallization in mare basalts versus KREEP-rich rocks that cannot be reconciled by post- or pre-crystallization secondary processes [7]. In fact, the compositional differences indicate there is a heterogeneous distribution of magmatic volatiles, including H, in the lunar interior. Therefore, all lunar lithologic types must be investigated before we can determine anything regarding the abundances of magmatic volatiles in the bulk Moon.

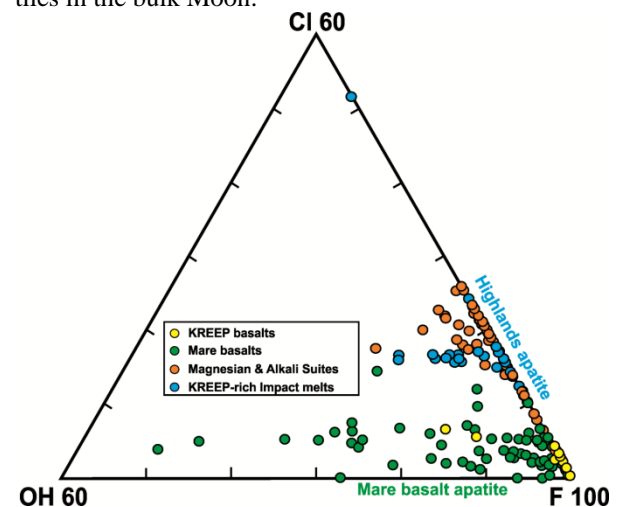


Figure 1. Truncated apatite ternary diagram of apatite volatile contents (F and Cl measured by EPMA, OH calculated by difference and has been generally confirmed by SIMS [1-4]) from several different lithologic types from the Moon.

**References:** [1] McCubbin et al. (2010) *Proc. Natl. Acad. Sci.* 27, 11223-11228. [2] McCubbin et al. (2010) *Am Min.* 95 1141-1150. [3] Boyce et al. (2010) *Nature* 466, 466-469. [4] Greenwood et al. (2011) *Nature Geoscience* 4, 79-82. [5] A. E. Saal et al., *Nature* 454, 192-195 (2008). [6] Sharp et al. (2010) *Science* 329, 1050-1053. [7] McCubbin et al. (Submitted) *GCA*.