Mostly Wet Apatites on a Mostly Dry Moon

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Lunar apatites are far too H-rich for their volatile-depleted hist rocks. Several hypotheses have been invoked to explain this paradox: One is that the Moon is far more H-rich than would be indicated by depletion of other moderately to highly volatile elements. However, it is also possible that the H content of apatite (H_{ap}) is not a suitable proxy for the H content of melt (H_{melt}), or is poorly understood.

It has been argued that the partitioning of H, Cl, and F between apatite and melt can be adequately described by independent linear ("Henry's Law") partitioning relationships. However, this model is only appropriate for one element if the others are invariant in the melt.

A more general formulation considers the H-F-Cl exchange reactions between apatite and melt, andequilibrium constants like $K^{F\text{-}H} = (F_{melt}/F_{ap})/(H_{melt}/H_{ap})$. Thus, the H content of apatite in equilibrium with melt will depend on $K^{F\text{-}H}$, F_{melt}, and H_{melt}. At equilibrium, low F_{melt} can lead to high H_{ap}, and estimates of H_{melt} that are higher than the H_{melt} implied by Henry Law models.

Heterogeneous apatites [1, 2] and populations of apatites from single samples [2] indicate that apatites are not universally in equilibrium (i.e., substantial variation in F:Cl:OH is observed). These variations have been interpreted to be the result of competing processes of fractional crystallization (FC) and degassing. However, FC of nominally anhydrous minerals does not result in significant changes to H:F:Cl. Adding apatite to the FC assemblage results in bulk compatibility of F. This sequesters F in early growing apatite, resulting in melts with high H/F and Cl/F. Apatites growing late will have elevated H and Cl, and if P/F ratios are high enough, Cl can be consumed leaving only H to make apatite. There are several testable predictions of this model that appear to have been confirmed.

[1] McCubbin, F.M., *et al* 2010, Proceedings of the *National Academy of Sciences*, **107**, 11223-11228 [2] Greenwood, J.P., *et al* 2011, *Nature Geoscience*, **4**, 79-82