Multiple F:Cl:OH Environments for Apatites from a Single Lunar Breccia

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Variations in volatile elements during igneous processes on the Moon are reflected by variations in F:Cl:OH ratios of apatites. In a set of lunar rocks dominated by Apollo samples, [1] found that lunar apatites are F-rich, but show some variations in F:Cl:OH: KREEP-rich and magnesian suite lithologies tend to be OH-poor and relatively Cl-rich, whereas mare basalts tend to be Cl-poor with variable OH.

In this study, we a find a range of apatite F:Cl:OH compositions similar to the results of [1], but our data are from a single lunar breccia, NWA 773. We used EPMA to determine concentrations of F and Cl and calculate OH based on stoichiometry. A low voltage (7 kV) was used to minimize effects of F- and Cl-loss during EPMA [2]. We collected analyses of apatites in diverse clasts and textural settings (see [3] for clast descriptions): (1) incompatible element-rich pockets in olivine cumulate gabbro (OC); (2) an inclusion in OC pyroxene; (3) alkali-rich phase ferroan (ARFe) clasts; (4) a combined symplectite/ARFe clast, (5) apatite mineral clast; (6) apatite+pyroxene clast.

We find three distinct compositions of apatite in the OC: (1) F:Cl:OH ~ 2:0:0 in one part of an incompatible pocket; (2) F:Cl:OH ~ 1.6:0.4:0 in another part of the pocket and (3) F:Cl:OH ~ 1.3:0.7:0 in an inclusion in pyroxene. Apatite in one ARFe clast is OH-poor and zoned in F:Cl, whereas apatite in the other ARFe clast is Cl-poor and zoned in F:OH. Apatite from the pyroxene+apatite clast is very OH-rich, with F:Cl:OH ~ 0.7:0.1:1.2. The other clasts have F-rich apatite, with Cl+OH < ~0.4.

Multiple F:Cl:OH patterns from the OC and zoned apatites from ARFe clasts are consistent with the prediction of [4] that apatite crystals in a single magmatic body can have different F:Cl:OH ratios; however, it is not clear if fractional crystallization alone accounts for the observed variations. The diversity of F:Cl:OH ratios in NWA 773 suggests that NWA 773 comes from a part of the Moon where mare and KREEP lithologies were well-mixed and/or that NWA 773 does not fit well in the F:Cl:OH patterns of mare vs. KREEP-rich rocks identified by [1].

[1] McCubbin F.M. *et al* (2011) *GCA* **75**: 5073-5093. [2] Stormer J.C. *et al* (1993) *Amer. Mineral.* **78**: 641-648. [3] Fagan T.J. *et al* (2014) *GCA* **133**: 97-127. [4] Boyce J.W. *et al* (2014) *Science* **344**: 400-402.