Apatite as a monitor of late-stage magmatic volatile processes at Volcán Irazú, Costa Rica

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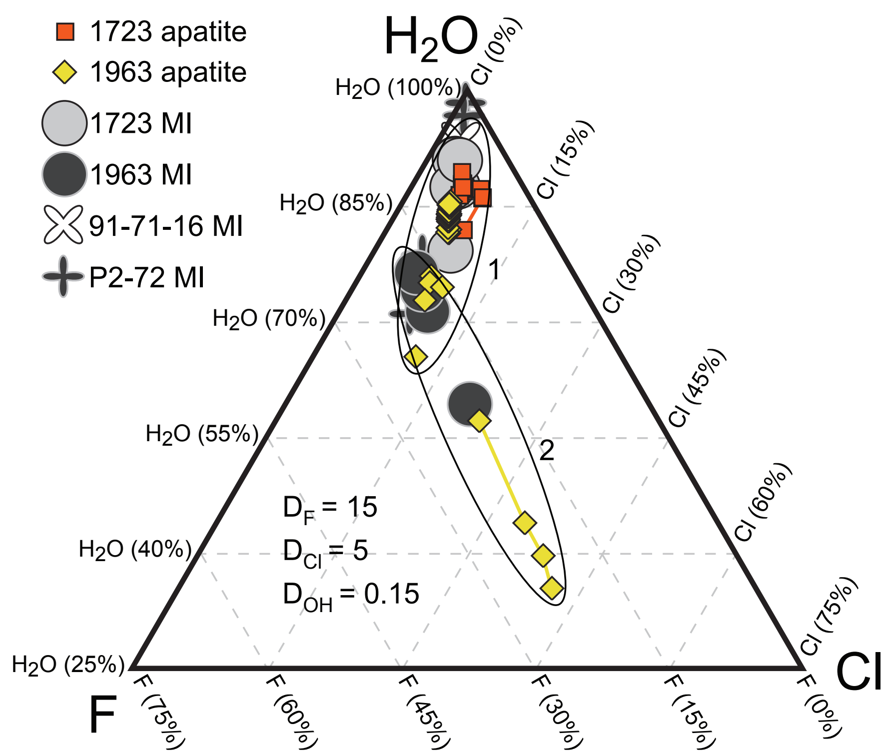
For the 1723 and 1963 eruptions of Volcan Irazú (Costa Rica), we measured F, Cl, and H in apatite phenocrysts, and compared those measurements with the record of the same elements in olivine- and clinopyroxene-hosted melt inclusions (Benjamin et al., 2007)*, for the same hand samples (Boyce and Hervig, 2008b). The agreement between the two data sets is quite good (Figure), with the volatile zoning in apatite crystals reproducing the inflection in the magma chemistry trend revealed by melt inclusions. Heterogeneous apatite populations and internally heterogeneous apatite crystals from the 1963 eruption, combined with published diffusion coefficients for halogens in apatite (Brenan, 1993)* require fairly late-stage magmatic processes (such as mixing) to have occurred prior to the 1963 eruption, and suggest that the remnants of the 1723 magma may have served as a precursor to the 1963 magma. Core-to-rim compositional variations observed in one crystal from 1963 suggest that a Cl-rich component was added to the evolved 1723 remnant magma, with the apatite (originally from this Cl-rich environment) recording partial equilibration with more Cl-poor compositions in the hybrid/contaminated magma. NSF MARGINS support for this project has generated a new and invaluable tool for studying magmatic processes: Our data indicate that in the absence of appropriate melt inclusions and in combination with independently determined partition coefficients, apatite can reflect the volatile chemistry of magmas with the added bonus that known diffusion coefficients provide relative constraints on the timing of processes affecting magmatic volatiles. Future studies enabled by this research include magma dynamics in a variety of arc and other volcanoes as well as in extraterrestrial apatites.

Figure: Relative abundances of OH, F, and Cl in Irazu magm as as reflected by direct measurements of trapped melt inclusions (data from Benjamin et al., 2007; Clark et al., 1998*; Sadofsky et al., 2008*), plotted with volatile compositions in the same magmas predicted from apatite compositions (this work) using estimated partition coefficients: DF = 15, DCl = 5, and DOH = 0.15. Note that the pattern of apatite and MI data are quite similar, suggesting that the two data sets record compatible volatile histories (with two trends, labeled 1 and 2). Partition coefficients were estimated by taking the ratio of the mean apatite F, Cl, and OH concentrations to the mean melt inclusion F, Cl, and H2O for only the 1723 eruption. These values were then applied to the entire data set, resulting in model magma volatile concentrations.*



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*References listed in appendix A.