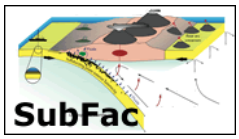
A New Method for Determining the Water Content of Magmas



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Although water is fundamental to magma genesis, evolution, and eruption, few direct measurements of magmatic H2O exist, as rocks found at the surface have extensively degassed upon eruption. Olivine-hosted melt inclusions provide a standard approach to measuring volatiles in undegassed magma, but many volcanic deposits (including many from Central America) do not contain melt inclusions large enough for analysis (>30µm), or olivine at all. In order to expand the database for Central American volcanoes in particular, we have developed a new method for calculating the H2O content of magmas based on direct measurements of H2O in clinopyroxene phenocrysts (Wade et al., 2008). We have tested this approach using phenocrysts from four arc volcanoes (Galunggung, Irazú, Arenal, and Augustine), which span the global range in H2O contents as measured in olivine-hosted melt inclusions (from 0.1 - 7 wt% H2O). The average and maximum magmatic H2O contents calculated from the clinopyroxene measurements shown good agreement (within 15%) with the melt inclusion values for most of the samples. The evolutionary paths recorded in H2O-Mg# variations overlap in some clinopyroxene and olivine-hosted melt inclusion populations, and in others, the clinopyroxenes record a larger portion of the liquid line of descent or a different portion of the magma system. Thus, the use of phenocrysts to estimate magmatic H2O contents creates a new and powerful tool in igneous petrology and volcanology, that complements the detailed work that has recently been done successfully for some volcanoes in Central America using melt inclusions (Roggensack, 2001a, b; Walker et al., 2003; Wade, et al., 2006; Benjamin, et al., 2007; Sadofsky et al., 2008*).

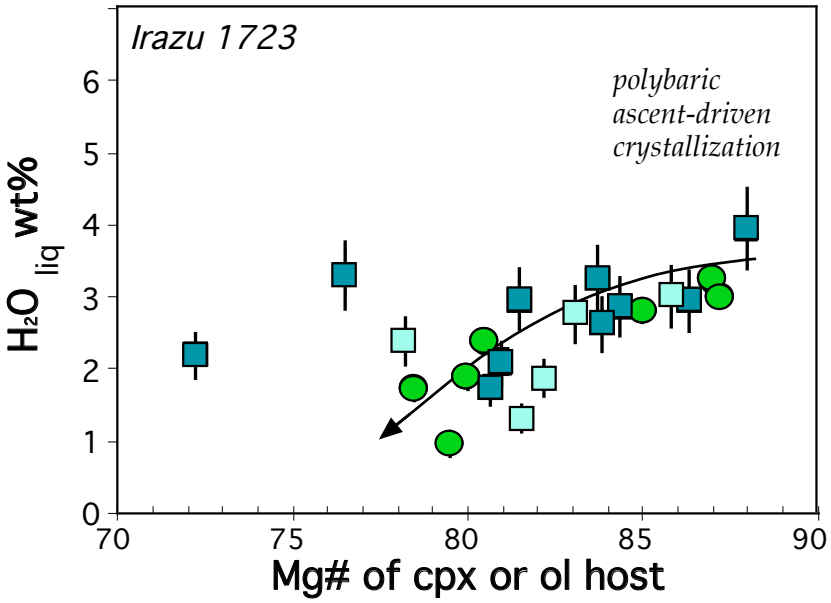

Figure: Comparison of clinopyroxene phenocryst (blue) and olivine-hosted melt inclusion (green) records of magmatic water content and evolution in the 1723 tephra from Irazu volcano, Costa Rica. Decreasing Mg# (molar ratio of MgO/[MgO+FeO]) reflects crystallization and magma evolution; co-crystallizing olivine and clinopyroxene (cpx) have similar Mg# (within a few Mg# units). H2O concentration in the liquid is as measured directly in melt inclusions (from Benjamin et al., 2007), and as calculated from H2O in cpx and cpx-liquid H2O partition coefficients (Wade et al., 2008). The 1723 scoria from Irazú olivine-hosted melt inclusions (green circles), cpx cores (dark blue squares), and cpx rims (light blue squares) reflect a similar degassing-crystallization path, consistent with that driven by magma ascent.

Benjamin, E.R., Plank, T., †Wade, J.A., Kelley, K.A., Hauri, E.H., Alvarado, G.E. (2007) High water contents in basaltic magmas from Irazu Volcano, Costa Rica. Journal of Volcanology and Geothermal Research, 168: 68-92.

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Walker, J.A., K. Roggensack, L.C. Patino, B.I. Cameron, and O. Matias, 2003. The water and trace element contents of melt inclusions across an active subduction zone. Contributions to Mineralogy and Petrology 146(1): 62-77.

*References listed in appendix A.