The Volatile Input to Volcanoes and Eruptions

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As of this writing, eighteen volcanoes are in a state of eruption or unrest; seventeen of those are on a convergent plate margin. The eruption of basalt to andesite at arc volcanoes is the most common global event, and yet little is understood of what controls their eruptive vigor. The obvious driver of explosivity is the volatile fuel, with H_2O being the most abundant species. This plenary talk will present data on the parental abundances of H_2O, and its degassing rate, as recorded in melt inclusions and chemical diffusion profiles in crystals and melt. The last fifteen years have seen intensive study of magmatic volatiles through the analysis of melt inclusions trapped largely in olivine crystals from airfall deposits. The unexpected observation is the uniformity in the water concentration of parental arc magmas: 4 +/ -1 wt% H_2O (n~60 volcanoes) [1]. Given the 4-5 orders of magnitude in eruptive intensity that produced these deposits, it does not seem likely that such a small range in H_2O is the driving factor. Instead, magma decompression rate may affect explosive behavior through its control on bubble-melt separation, bubble-crystal nucleation, and/or magma supply rate. Several chronometers have been developed over the past years that capture the minutes-to-hours of magma decompression prior to explosive eruption using the diffusion of H_2O in and through olivine, clinopyroxene and melt. The greatest uncertainty in this approach lies in the diffusivity of water through olivine and cpx, which varies by 5 orders of magnitude depending on the site occupancy of the hydrogen and abundance of other cations [2]. The simultaneous application of multiple chronometers to the same eruptions provides permissible diffusivities, and demonstrates that water diffusion through olivine and cpx phenocrysts occurs at the rates comparable to the fastest measured in the laboratory, generally associated with exchange between Fe^{3+} and H^+. Although this is bad news for the preservation of primary water in nominally anhydrous minerals, it is good news for eruptive chronometers. The application of diffusion chronometry to several eruptions thus far demonstrates a relationship between decompression rate and eruptive vigor, with magma ascending in minutes from 5-10 km depth magma storage regions in VEI 4-5 eruptions.

[1] Plank, et al. (2013), EPSL 364, 168-179.
[2] Ferriss, Plank, Walker (2016) CMP, in press.