Magnetite clusters on vesicle walls: Evidence for pre-eruptive bubbles in the early-erupted Bishop Tuff, CA

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Despite the importance of volatiles in controlling most properties of magmas, little is known about the distribution of bubbles in pre-eruptive magma. Melt inclusions permit constraining the abundance of dissolved volatiles; however, they give very limited information on the presence and size of bubbles. We have used vesicle size distributions to argue that large vesicles in early-erupted Bishop Tuff correspond to pre-eruptive bubbles. Our new evidence supports this conclusion.

We are studying pumice clasts from units F7 and F8 of the Bishop Tuff using x-ray tomography. Data were collected at the GSECARS beamline at APS, Argonne National Laboratory, using a monochromatic 22 keV x-ray beam. Imaged samples are cylinders with approximately 1 cm in diameter and height. The resulting images correspond to 3D maps of the linear attenuation coefficient – a function of the mean atomic number and density. Magnetite, sanidine, quartz, glass and vesicles (in this order of decreasing brightness in the images) can be identified.

The most crystal-rich sample of our current collection (F8-15, 13 wt. % crystals) shows a large vesicle whose walls have abundant magnetite crystals attached to it, which results in a higher concentration of magnetite in this sample (4 vol. %) than in other samples (< 1.2 vol. %). We envision two plausible scenarios for the origin of such clusters. (1) Experiments have shown that magnetite crystals are favorable sites for the nucleation of bubbles; collision of magnetite-bubble pairs would cause bubble coalescence, which could result in large bubbles with many magnetite crystals attached to their walls. (2) Even if the bubbles are initially magnetite-free, crystals could become attached to the bubbles after collisions; surface-energy considerations suggest that magnetite crystals are more likely to be attached to the bubble-melt interface than other minerals. In any case, it seems very unlikely that features like this could be formed during magma ascent and eruption. During eruption, bubble growth is fast and this limits relative movement which could facilitate bubble coalescence and/or accumulation of magnetite crystals onto rising bubbles. Thus, this vesicle is probably a pre-eruptive bubble. Importantly, the presence of pre-eruptive bubbles is evidence that the magma was gas-saturated, and that it indeed contained mm-sized bubbles.

Open-system processes and rhyolites: What isotope systems can we trust, and for what?

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Constraining the timescales for genesis and storage of large volumes of silicic magma has long been a challenge facing volcanologists and geochemists. A broad range of radiogenic isotope systems have been applied to a variety of materials including whole rocks and common and trace phenocryst phases. Many results to date have been controversial, depending on the targeted isotope system and material analyzed; in particular, linear trends that remain on isochron diagrams after eruption-age correction have been assigned significance for magma storage times. Such trends can however be produced by open-system processes such as magma mixing and crustal contamination. In addition to generating linear trends that mimic aging, these processes may otherwise leave only very subtle signatures of their operation in rhyolitic magmas. The high-silica rhyolite Bandelier Tuff (1.6 Ma, Valles caldera) is an example of such a case. Only through detailed multi-isotopic phenocryst and groundmass studies were the effects of open-system processes identified, and model-dependent magma storage "ages" discounted. In this example, high precision Pb isotope ratios were critical to identifying subtle open-system modifications. Very young rhyolites (<100 ka) are additionally accessible to U-series investigations, but debate is also growing about the validity of U-series isotope ages. Unfortunately, few large-volume rhyolites are young enough to apply U/Th isotopes, and far fewer are young enough to apply Ra isotopes (e.g., Olkaria volcanic complex and Baitoushan volcano). In these systems, an expanded suite of isotopes on a wide range of materials (groundmass and phenocrysts) will be required to address whether a system is closed, and thus what is being dated. In this light, we will review the available data on open-system isotope characteristics in both older and younger rhyolitic magmatic systems.