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Inferring Magma Ascent Times and Reconstructing Conduit Processes in Rhyolitic Explosive Eruptions Using Reentrant H_2O and CO_2 Gradients

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Important clues to processes in the initiation and early behavior of large (super-sized) eruptions lie in the records of degassing during magma ascent. However, there is currently a shortage of geochemical methods for (a) assessing the processes that initially drive magma from its long-term storage region into the conduit(s), and (b) recording the magma residence time during ascent in the conduit system(s). To quantify these events, we apply an diffusion-based volatile method in quartz crystals from the initial fall deposits of three supereruptions that show field evidence for contrasting opening behavior: (1) Bishop Tuff, Long Valley (650 km3, 0.76 Ma), (2) Oruanui eruption, Taupo (530 km3, 25.4 ka), and (3) Huckleberry Ridge Tuff, Yellowstone (2,500 km3, 2.1 Ma).

During magma ascent, decompression causes volatile exsolution from the host melt into bubbles, leading to H_2O and CO_2 gradients in quartz-hosted melt reentrants (REs; unsealed inclusions). These gradients are modeled to estimate ascent timings, and hence rates. We present best-fit modeled ascent rates for H_2O and CO_2 profiles for REs in early-erupted fall deposits from Bishop (n = 13), Oruanui (n = 9) and Huckleberry Ridge (n = 9) deposits. Using a Matlab script that includes an error minimization function, Bishop REs yield ascent rate estimates of 0.6-13 m/s, overlapping with and extending beyond those of the Huckleberry Ridge (0.3-4.0 m/s). Reentrants in Oruanui quartz crystals from the first two eruptive phases (of ten) yield the slowest ascent rates (0.06-0.48 m/s) which then transition to more uniformly higher rates (1.4-2.7 m/s) in phase three, with a field-verified marked increase in eruption intensity.

For all three eruptions, interiors of most REs appear to have re-equilibrated to lower H_2O and CO_2 concentrations when compared to co-erupted, enclosed melt inclusions in quartz. Such reequilibration implies the presence of an initial period of slower ascent, likely accompanying movement of magma from its long-term storage region into a developing conduit system, prior to the faster, final ascent of magma to the surface. This slower initial movement represents hours to several days of reequilibration, invalidating any assumption of constant decompression conditions from the storage region. However, the number of REs with deeper starting depths increases with stratigraphic height in all three deposits (particularly the Bishop Tuff), interpreted to reflect 'maturing' of the conduit system(s) and removal of any initially sluggish ascent behavior. Our results agree well with ascent rates from theoretical approximations and numerical modeling for plinian rhyolitic eruptions (0.7-30 m/s), but overlap more with the slower estimates.