Integrating zircon ages and geochemistry to investigate the volcanic-plutonic connection: A case study from the Lesser Antilles Arc

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Establishing genetic links between volcanic and plutonic rocks remains elusive, with current models ranging from exhaustive eruptive evacuation of magmatic reservoirs to only partial extraction of evolved melt from highly crystalline networks ("magmatic mushes"). The study of cognate plutonic xenoliths in volcanic deposits is uniquely suited for establishing volcanic-plutonic connections, but comparisons based on whole-rock chemistry are often limited by complex crystal origins and the effects of crystal accumulation which cannot always be reliably deconvolved. We have thus explored high-spatial resolution analysis of zircon in the search for direct evidence regarding the plutonic incubation of volcanic eruptions, and the link between erupted magma and its plutonic residues.

Volcanic deposits from the Quaternary Lesser Antilles arc have provided a remarkable suite of plutonic xenoliths. Here, we report SIMS zircon U-Th ages and trace elements from the ca. 14 ka Belfond dome, Soufrière, St. Lucia. Zircon rims from plutonic xenoliths (n = 7) record protracted crystallization and show characteristic differences between age spectra of individual xenoliths. Xenolith zircon rim ages range between ca. 20 and 200 ka, which in essence matches those from their host lava. Trace elements in xenolith and lava zircon rims become more variable within ca. 10 ka of the youngest zircon's crystallization which coincides with the last major explosive event at Soufrière, the ca. 20 ka Belfond Tuff eruption. Temperature-sensitive components in zircon (e.g., Ti, Hf) indicate excursions to elevated magmatic temperatures between ca. 20 and 30 ka. Collectively, this evidence suggests the presence of a long-lived (>200 ka) crystal mush undergoing re-heating episodes which possibly triggered explosive eruptions. Integrating the high temporal resolution record of U-series zircon ages with geochemistry is a powerful tool in deciphering the thermal and compositional evolution of magmas within a framework of absolute time.