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Magma-Chronology: High Silica Rhyolite

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Rhyolitic magmas yield the largest explosive eruptions on the planet but the way in which they accumulate remains the subject of considerable debate. Central to this controversy is uncertainty in the duration of magma accumulation: estimates range from tens of thousands of years to more than a million years and are not readily correlated to the volume of erupted material. We used the ion microprobe to obtain *in situ* ^{230}Th-^{238}U ages for allanite and zircon from a high silica (>74 wt% SiO_2) rhyolite (HSR) associated with the Youngest Toba Tuff (YTT) of Sumatra. The duration of accessory phase crystallization provides insight into the longevity of crystal residence and the chemical evolution of this voluminous rhyolite, the most recent of four ash flow tuff eruptions associated with Toba.

Because the HSR we studied is more evolved than the thermochemical conditions for initial saturation with zircon and allanite in YTT magmas, ages of these two accessory phases might be expected to be synchronous and to provide minimum estimates for the timing of differentiation of this magma. It should be borne in mind, however, that complicated age spectra might be produced if the genesis of HSR occurred by amalgamation of magmas derived by multiple evolutionary pathways. The results of our analyses show that, rather than dating a single episode of allanite saturation, the allanites range in age from that of eruption to more than 150 ka before eruption. Nonetheless, the majority of these ages are conspicuously younger than those of the zircon analyzed. Most zircon spot analyses could represent a single episode of zircon growth ca. 140 ka before eruption, appreciably older than the mean age of allanite. Radial distributions of ages obtained by depth profiling of grains demonstrate that zircon crystallization was protracted, ranging from 50 to more than 250 ka before eruption.

The protracted crystallization histories of single Toba zircon grains show that individual crystals may have long residence times. A zeroth-order conclusion is therefore that the HSR cannot simply be the product of remelting of multiple young intrusions that cooled and crystallized rapidly. The onset of zircon and allanite crystallization could delimit the relative timing of differentiation of the YTT magmas to at least (rhyo)dacite and high silica rhyolite, respectively. It seems likely therefore that the YTT represents a new episode of rhyolite differentiation since eruption of the middle Toba Tuff ca. 0.5 Ma ago. The different age distributions for allanite and zircon suggest further that, rather than growth solely in HSR, the crystal record is the superimposed effects of crystal growth and stochastic crystal loss, and that at least some of the zircons may have been inherited from a less evolved magma. Some portion of the magma that evolved to HSR must have differentiated to (rhyo)dacite at least 250 ka before eruption; differentiation to HSR began by 170 ka before eruption. Episodes of HSR crystallization continued up to the time of eruption, but further work is needed to determine whether these represent discrete episodes of differentiation or simply a punctuated cooling history.