

Reconciling warm and cold storage of silicic magma: $^{40}\text{Ar}/^{39}\text{Ar}$, U-Th disequilibria, and eruption temperatures constraints on the post-74 ka supereruption magma dynamics at Toba Caldera, Indonesia

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Toba Caldera, located in Sumatra, Indonesia, last erupted ~74 ka, depositing the climactic Youngest Toba Tuff (YTT). This was followed by resurgent uplift forming Samosir Island and associated volcanism, in the form of lava domes extruded along caldera related faults. Obtaining ages of the lava domes help constrain the process and time scale of resurgence at Toba. Four lava dome localities were selected for geochronology: two lava domes on Samosir Island (North Samosir and Tuk Tuk Samosir) and two lava domes found in the southern half of the caldera (North and South Pardepur). Combined U-Th-disequilibrium/(U-Th)/He zircon geochronology have yielded eruption ages ranging from 69.7 ± 4.5 ka to 56.9 ± 3.9 ka (all errors 2 s.d.). These eruption ages imply that resurgent volcanism started soon after the caldera-forming eruption and continued for ~20 kyrs after. However, $^{40}\text{Ar}/^{39}\text{Ar}$ dating of sanidine and plagioclase crystals from three of the lava domes return ages contemporaneous with the climactic eruption, between 74.5 ± 6.7 and 73.8 ± 0.9 ka. The fourth lava dome, North Pardepur, returned $^{40}\text{Ar}/^{39}\text{Ar}$ crystallization ages on plagioclase of 57.0 ± 10.2 ka. The discordance between the (U-Th)/He and $^{40}\text{Ar}/^{39}\text{Ar}$ ages imply a complex thermal history of the post-74 ka magma and provides the potential to constrain the physical conditions and time scales of storage and eruption. A simple diffusion model using closure temperatures of He-in zircon, Ar-in sanidine, 190 and 350°C respectively, in combination with Fe-Ti oxide equilibration temperatures from these lava domes, has been used to create a conceptual model for resurgence at Toba Caldera. Combined with previously measured eruption temperatures for the Samosir lava domes and the YTT caldera-forming eruption, the model reveals that the lava domes represent small volumes of remobilized, cool (below 350°C) margins of the much larger, warmer remnant magmatic system beneath Toba Caldera. While equilibration temperatures of fast diffusing species like Fe-Ti oxides indicate temperatures as high as 800°C or more, our model suggests that the erupted magma could only have resided above the Ar-closure temperature for approximately 700 to 1400 years. This allowed antecrystic sanidine and plagioclase crystals within the erupted remnant melt to retain their argon signatures from the YTT eruption, while the helium signatures in zircons record the eruption age of the lava domes, and the Fe-Ti oxides record transient local temperatures as high as and above 800°C. This work reveals the potential of multiple methods to unravel details of pre-eruptive magma storage and dynamics that help inform a more complete understanding of the “cold mush” versus “warm magma” dichotomy.

Keywords: Toba Caldera, U-Th disequilibria, $^{40}\text{Ar}/^{39}\text{Ar}$, Geochronology, warm and cold storage, supervolcano