Deciphering pre-eruptive thermal histories using coupled Ar/Ar and (U-Th)/He thermochronometry and Bayesian inference: Toba Caldera, Sumatra

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Understanding pre-eruptive thermal histories at volcanoes is an imperative for understanding magmatic history, eruption initiation, and assessing volcanic hazard and risk. To date, technical and methodological challenges have limited progress. We have joined this challenge to address the pre-eruptive magma dynamics of post-supereruption recovery at Toba caldera, Sumatra, the site of the greatest volcanic catastrophe of the last 100 kyrs; the ca. 74 ka, Youngest Toba Tuff (YTT).

We compare single-crystal feldspar Ar/Ar data for post-74 ka lava domes to zircon (U-Th)/He ages. Then, we utilize a novel Bayesian statistical analysis to evaluate differences between the corresponding Ar/Ar and (U-Th)/He datasets and demonstrate that the observed subtle differences in age are statistically credible. Finally, we employ inverse thermal history modelling based on coupled Ar/Ar and (U-Th)/He diffusion models that allows us to place constraints on time-temperature conditions of pre-eruptive storage. Our results indicate storage durations of up to ~13 kyrs at temperatures between ~275°C and ~500°C, and raise the intriguing possibility that the domes, represent samples of the cold "halo" around the warm remnant Toba magma, and could have been erupted under sub-solidus conditions.

This study demonstrates exciting potential of the coupled thermochronometry in tandem with Bayesian inference to address complex pre-eruptive magma dynamics in silicic magma systems and help resolve the debate about warm versus cold pre-eruptive storage of magma.