The internal trigger test: Mapping overpressure regimes for giant magma bodies

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Determining eruptibility of silicic magma bodies is important in understanding and predicting how ancient and modern-day magmatic systems can evolve. The goal of this project is to determine if supereruptions have the potential to naturally evolve and internally trigger eruption or if an external trigger is necessary. We use whole-rock compositions from the Oruanui Tuff (New Zealand) and the early and late-erupted Bishop Tuff (California) to model magma evolution using rhyolite-MELTS. Under the assumption of closed-system crystallization, volatile exsolution leads to expansion of a magma body, eventually resulting in overpressurization of the system. We use isenthalpic simulations (constrained enthalpy steps and constant pressure) to estimate the overpressure. The minimum crystallinity (or, similarly, porosity) that leads to overpressures sufficient for internal triggering is observed for melts initially saturated in water (or, more generally, fluids). Comparison of observed crystallinity (or porosity) and expected critical overpressure (for initially H_2O-saturated conditions) leads to the recognition of three overpressure regimes. (1) Systems whose observed crystallinity is lower than the critical crystallinity are interpreted to require an external trigger to erupt. (2) Systems whose crystallinity match the critical crystallinity are interpreted to be initially fluid-saturated with potential to be internally triggered. (3) Systems whose crystallinity is higher than the critical crystallinity can also be internally triggered, but they are interpreted to have been initially volatile-undersaturated. Our results show that the Oruanui Tuff and the Early Bishop Tuff were likely initially volatile saturated and were capable of internal triggering. The Late Bishop Tuff could also have been triggered internally, but it was likely initially volatile-undersaturated. In contrast, our results for Toba Tuff suggest that either an external trigger was needed for eruption, or that the crystallization pressure (~300 MPa) we employed is overestimated or it varied over the course of crystallization. The results from these models can be used to assess the potential roles of external versus internal triggering of other silicic magma bodies at upper crustal depths considering a variety of volatile saturation conditions.