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Modeling overpressure regimes for large, upper crustal magma bodies: Triggering of Taupo Volcanic Zone flare-up explosive volcanism.

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Understanding silicic eruption triggers is paramount for deciphering explosive volcanism and its potential societal hazards. We use phase equilibria modeling to determine the potential role of internal triggering – wherein magmas naturally evolve to a state in which eruption is inevitable – in rhyolitic magma bodies. The goal of this project is to determine the conditions under which an external trigger (i.e. a tectonic perturbation) is necessary for eruption. We use whole-rock compositions to model magma evolution using rhyolite-MELTS. Under the assumption of closed-system equilibrium crystallization, volatile exsolution leads to expansion of a magma body, resulting in an overpressurization of the system; eruption will occur if the overpressure of the system exceeds the strength of the surrounding wall rock. We use isenthalpic simulations (constrained enthalpy steps and constant pressure) to track overpressure as a system loses heat, crystalizes, and evolves. The minimum conditions (crystallinity, porosity) that lead to overpressures sufficient for internal triggering are obtained for melts initially saturated in water. 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 or to have partially degassed. We focus on compositions of the Taupo Volcanic Zone (TVZ) flare-up, particularly on four very large (>50 km3) eruptions that took place within 40 ka. We use crystallization pressures previously determined using rhyolite-MELTS geobarometry using measured glass compositions in pumice. Our results show that the last two eruptions (Ohakuri, Mamaku) were likely initially volatile saturated and were capable of internal triggering. The first two eruptions (Pokai, Chimpanzee), in contrast, are too crystal poor to have been internally triggered, suggesting an external trigger. External triggering is consistent with the close interplay between tectonism and volcanism in the central TVZ – an actively rifted arc. It is interesting that external triggering is required early in the evolution of the TVZ flare-up, when there is evidence that magma plumbing systems were less extensive vertically. The results from these models can be used to assess the potential for determining external and internal triggering of other silicic magma bodies at upper crustal depths considering a variety of volatile saturation conditions and may aid in deciphering the onset and evolution of flare-up magmatism.