Large silicic eruptions, episodic recharge, and the transcrustal magmatic system

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Large silicic eruptions, although rare, are some of the most catastrophic natural hazards known. Understanding how eruptible silicic reservoirs are built is thus essential for volcanic hazard prediction. Magma input into the eruptible silicic reservoir is generally attributed to extraction from a large underlying crystal-rich source mush, but how these viscous melts are extracted is unclear. Here, we use time series data of temperature and composition of magmas erupted in the Taupo Volcanic Zone (TVZ), New Zealand over the last 25 thousand years (kyr) to constrain the temporal variation of magma input rate into the silicic reservoir. The TVZ was characterized by the Oruanui eruption, a major rhyolitic eruption 25 kyr ago. Small volume magmas reflecting the evolution of the silicic reservoir after the major eruption document a gradual cooling and increase in silica content. We show that the most important factor controlling the thermal budget of the silicic magma reservoir is the ratio of magma input into the silicic reservoir to heat loss through the overlying crust. In order for the silicic reservoir to cool, our model requires that the rate of magma input must decay. Our models, as constrained by the cooling history recorded in the post-Oruanui magma series, require peak magma input rates at the time of the Oruanui event to be $>3\times10^{-9}$ m/s and up to 10^{-6} m/s, decaying to $\sim1\times10^{-9}$ m/s within 10 kyr. The initial pulse of magma input could be in the form of buoyancy driven porous flow or hindered settling in a mush of melt fraction of >20% and up to 70%. We propose that the incursion of deep-seated mafic magmas into the crystal-rich source mush could produce a short-lived increase of porosity in the mush, perhaps by disaggregation of the mush. This would allow for rapid, but ephemeral, expulsion of silicic melts into the overlying silicic reservoir, which in turn could trigger an eruption. Our model suggests massive eruptions followed by a long interval of quiescence during which the eruptible silicic reservoir re-builds may be a natural consequence of episodic pulses of magma from the deep crust or mantle.