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Crustal-scale magmatism and its control on the longevity of magmatic systems

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Constraining the duration and evolution of crustal magma reservoirs is crucial to our understanding of the eruptive potential of magmatic systems, as well as the volcanic:plutonic ratios in the crust, but estimates of such parameters vary widely in the current literature. Although no consensus has been reached on the lifetime of magma reservoirs, recent studies have revealed about the presence, location, and melt fraction of multi-level (polybaric) storage zones in the crust. If magma accumulates at different crustal levels, it must redistribute significant enthalpy within the crustal column and therefore must influence the lifetime of magma plumbing systems. However, an evaluation of the mass and heat budget of the entire crustal column is lacking. Here, we use a two-dimensional thermal model to determine the thermal conditions under which both lower and upper crustal magma bodies form. We find that large lower crustal mush zones supply heat to the upper crust and reduce the amount of thermal energy necessary to form subvolcanic reservoirs. This indicates that the crust is thermally viable to sustain partially molten magma reservoirs over long timescales (>10^{5}-10^{6} yr) for a range of magma fluxes (10^{-4} to 10^{-2} km^{3}/yr). Our results reconcile physical models of crustal magma evolution and field-based estimates of intrusion rates in numerous magmatic provinces (which include both volcanic and plutonic lithologies). We also show that young magmatic provinces (< $\sim$10^{5} yr old) are unlikely to support large upper crustal reservoirs, whereas longer-lived systems (>$\sim$10^{6} yr) can accumulate magma and build reservoirs capable of triggering supereruptions, even with intrusion rates as low as $\leq$10^{-2} km^{3}/yr. Hence, the total duration of magmatism is critical in determining the size of the magma reservoirs, and should be combined with the magma intrusions rates to assess the capability of volcanic systems to form the largest eruptions on Earth.