On the longevity of large upper crustal silicic magma reservoirs

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Understanding the timescales and processes involved in the formation and maturation of upper crustal magma reservoirs, ultimately sourcing the largest volcanic eruptions on Earth, is one of the most fundamental goals of volcanology. While such reservoirs are known to assemble incrementally over extended periods of time, debate persists regarding the timescales of melt preservation in the cold upper crust. If rapid cooling individually freezes incoming replenishing intrusions, accumulations of eruptible magma are impossible, precluding caldera-forming eruptions for all but the highest magma emplacement rates. Recent numerical thermal models have been used to assess the viability of upper crustal silicic magma survival, and have suggested that supervolcanic reservoirs must form in geologically short timescales with anomalously high injection rates, and subsist only ephemerally, making them less predictable. Motivated by geological observations suggesting the contrary, we have improved upon these models by incorporating two fundamental features of natural systems not previously considered: (1) a non-linear crystallization-temperature relationship adapted for upper crustal silicic magmas and (2) a temperature-dependent thermal conductivity. We demonstrate that the incorporation of both of these properties can allow an upper crustal reservoir to remain above its solidus for hundreds of thousands of years, on par with estimates from zircon crystallization histories, when fed by magma fluxes typical of large magmatic provinces. While the crystallization-temperature path plays the most significant role in maintaining a large pool of eruptible magma, the incorporation of temperature-dependent thermal properties, together with a deeper emplacement level, significantly extends the lifetime of such reservoirs. These results provide strong support for long-lived upper crustal mushes as a staging ground for accumulation of highly eruptible, crystal-poor silicic magmas, and further assert the evolutionary link between volcanic and plutonic systems