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Chemical differentiation, magma transport and formation of multiple mush reservoirs beneath caldera volcanoes.

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For over a century, our understanding of magma storage and differentiation has been based on the concept of a high melt fraction ‘magma chamber’. However, geophysical data do not image these chambers beneath active volcanoes and geochemical data shows that crystals within erupted magma are often stored ‘cold’ at a low melt fraction. Yet many volcanoes erupt low crystallinity magma. Numerical modelling has shown that transient, high melt fraction layers can form within long-lived ‘mush’ reservoirs within the mid to lower crust. The model includes repeated intrusion of mafic sills into initially solid crust to create and grow the reservoir, transport of heat by conduction and advection, plus transport of mass by reactive flow of buoyant melt and compaction of the crystal mush. Here we further develop the model to include rapid upwards transport via dykes of buoyant magma formed in the deeper mush reservoir to a shallower subvolcanic reservoir.

The aim of the work is to investigate (i) formation of multiple sub-volcanic mush reservoirs that coexist at various depths throughout the crust and (ii) mush reservoir processes that produce observed characteristics of volcanism at two caldera volcanoes of contrasting size: Santorini (an island in the southern Aegean Sea) and Yellowstone (Rocky Mountain region, United States). Preliminary results show that a mid-to-lower crustal mush reservoir can deliver significant quantities of low crystallinity magma to the upper crust, but that the creation of a persistent upper crustal mush reservoir is highly dependent on the rate of magma delivery, the composition of the magma delivered, and the relative lateral extent of the lower and upper crustal reservoirs.

The rate and composition of magma delivered to the upper crustal reservoir is dictated by processes occurring in the deeper reservoir and is decoupled from occurrences of mafic magma intrusion into this reservoir. There is significant variability in the composition of magmas delivered from the lower crustal reservoir, which affects the formation and longevity of the upper crustal reservoir, because a batch with low silica content injects more heat into the upper crust than a batch that has higher silica content. We do not see evidence of significant further differentiation of magma in the upper crustal reservoir; the primary reservoir controlling the rate and composition of magma delivery is in the deeper crust.