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On the formation and lifetime of large silicic magma chambers in the shallow crust

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Most large silicic intrusion are believed to have formed by repeated injections of smaller magma pulses that eventually constitute the whole pluton. Geochronology helps to calculate long-term average emplacement rates of intrusions that are in the order of few mm/a. However, numerical simulations showed that these rates are too low to create large magma chambers. The incremental emplacement style limits the size and lifetime of any large magma chamber because the earlier injected magma pulse would cool down below solidus temperature before the next pulse is injected.

To better constrain the formation of large-volume magma chambers, we investigate the influence of a changing emplacement rate over the lifetime of a composite plutonic body. That means that the emplacement rate can be temporarily high although the long-term average rate is low and is in agreement with the geochronological data. This is achieved by thermal modelling via an explicit finite difference scheme. The models calculate temperatures in the Earth's crust according to the equation of conductive heat transfer. They also take heat production of radioactive decay and phase changes into account.

The conditions necessary to form a magma chamber that is larger than one single magma pulse, in this case a sill intrusion, are investigated and applied to the Tuolumne Intrusive Suite. This granitic intrusion is part of the Mesozoic Sierra Nevada Batholith in California and covers an area of more than 1000 km^2. The Tuolumne Intrusive Suite is normally zoned with nested map units getting progressively younger and more evolved towards the centre. Data provided by U-Pb geochronology give an age range from 93.5 Ma for the outermost unit to 85.4 Ma for the core of the intrusive suite.

The modelling results show that specific conditions need to be fulfilled to form a magma chamber for the Tuolumne Intrusive Suite. For most models, one sill intrusion cools down before the emplacement of the next sill. Thus, no more melt than delivered by a single sill is present at any time of the model run. A transient emplacement rate of more than several cm/a sustained for more than 300 ka is necessary that eruptible volumes of magma with a melt fraction higher than 60% can accumulate.

The results suggest that processes like fractional crystallisation and settling of crystals which are believed to take place in magma chambers and can account for chemical and textural variations across a pluton, need to be reconsidered when looking at large silicic intrusions.