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Two-limit cases for the formation of magma bodies by discrete injections

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Magma reservoirs developing out of discrete magma injections may be generated in two different ways depending on the thickness of each injection and crystallization kinetics. In all cases, temperatures within the growing magma pile increase progressively with each injection. In kinetically-controlled conditions, successive magma injections initially do not crystallize completely and leave a glassy residue. Once temperatures within the storage zone exceed a certain threshold value, crystal nucleation and growth rates rapidly increase in a positive feedback loop involving latent heat release. Crystallization of the residual glass proceeds very fast as temperatures, leading to the rapid formation of evolved melt. In the other limit, crystallization kinetics are unimportant and, in initial stages, each successive injection crystallizes completely. With time, as temperatures rise within the storage zone, the amount of residual melt increases progressively.
The two scenarii exhibit contrasting evolutions. The kinetically controlled scenario involves two distinct phases. An initial phase with no evolved melt terminates with the sudden formation of a large body of differentiated magma, probably leading to a catastrophic eruption. The amount of evolved melt generated increases with decreasing injection rate in the kinetically-controlled case, in contrast to the other limit case which exhibits the opposite behavior. This initial phase is followed by a second one, in which successive magma injections occur in pre-heated rocks and follow a thermal path similar to that of the other scenario, with melts that become progressively more primitive with time. For a fixed injection rate, the kinetically controlled case leads to a sustained magma reservoir in a shorter time-interval and with a smaller amount of

magma injected than in the other limit case.
The kinetically-controlled scenario requires that magma pulses do not exceed a threshold thickness which is estimated to be about 4 m. We shall review evidence for kinetic controls on crystallization and for the formation of glass cooling magma bodies both in the laboratory and in the field, and discuss how they may account for important features of magmatic and volcanic systems.