Linking ground deformation to magma injection and volatile exsolution in a rapidly evolving magma chamber

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Rapid pressurization due to late-stage volatile exsolution is often cited as a triggering mechanism for the eruption of shallow magma chambers. The relationship between the injection of new melt and volatile saturation during periods of prolonged crystallization has been illustrated in previous geochemical investigations and suggests a link to magma chamber pressurization that should be observable as ground surface deformation. However, there are many examples where eruption occurs without precursory deformation signal. As such, several critical gaps remain in our understanding of how volatile saturation impacts the eruption potential of long-lived magma systems, including: how pressures build-up and dissipate in time; how the wall rock responds to variations in magma reservoir volume promoting either storage or eruption; and how the resultant volume change due to volatile saturation is manifested in surface uplift, if it is at all. Thermal mechanical finite element models of an evolving magma reservoir are used to conduct a series of numerical experiments to test the predicted surface uplift and reservoir stability during magma injection and volatile saturation due to protracted crystallization. Specifically, we present a two-stage model that tracks the deformation signal due to the injection of new magma into a stable reservoir and then tracks the subsequent evolution of the system as it cools and becomes volatile saturated. To provide a first-order approximation of a complex, multi-phase system, an analytical approximation of reservoir volume change during volatile exsolution is used. Compressibility of the melt and volatile phases are estimated to provide end-member approximations for volume change. Brittle and ductile failure, as well as tensile failure along the reservoir boundary, are tracked to estimate reservoir stability as the system evolves. Our new approach provides a framework for coupling more complex magma chamber models with the thermomechanical models in future studies.