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Insights into the poroelastic mechanical behaviour of a crystalline magma reservoir and its influence on modelling volcano surface deformation

Rami Alshembari[1], James Hickey[1], Ben Williamson[1], and Katharine Cashman[2]
[1]Camborne School of Mines, University of Exeter, Penryn, Cornwall, TR10 9FE, UK
[2]School of Earth Sciences, University of Bristol, Wills Memorial Building, Queens Road, Bristol BS8 1RJ, UK

Understanding the physical properties of magma reservoirs and their fluid/mechanical behaviour is crucial for improving geophysical models. New evidence suggests that large bodies of magma are difficult to maintain for an extended time period and that melts may instead reside within crystal-mush reservoirs which consist of variably packed frameworks of crystals and interstitial melt. Most existing volcano deformation models assume a pressurized cavity embedded in a homogeneous or heterogenous elastic half-space and therefore ignore the presence of crystals and the possible poroelastic mechanical response to melt intrusion or withdrawal. Here, we consider the magma reservoir to be entirely porous, comprising melt distributed between solid crystals. We investigate the influence of poroelastic mechanical behaviour on reservoir pressure development and resultant spatio-temporal surface deformation. We examine the post-intrusion and post-eruption time-dependent pressure evolution in the magma reservoir due to melt diffusion in the porous domain. Unlike the classic (cavity) models for volcanic surface deformation, an observable post-eruptive or post-intrusion time-dependent inflation can occur without an additional mass change if the reservoir is sufficiently permeable. Post-intrusion and post-eruption timescales vary depending on the porosity of the mush (melt fraction), permeability and magma viscosity. Our study confirms that reservoir inflation and surface deformation can occur without an intrusion or withdrawal of melt but are instead controlled by the mush's poroelastic behaviour.