Magmatic connections: The interplay of magmatic systems with their crustal containers

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Magmatic systems develop on many different temporal and spatial scales and are influenced by internal process such as magma chamber convection, phase change, melt composition evolution and associated physical property changes, as well as external controls such as larger scale stresses and hydrothermal systems. The geophysical and geochemical datasets that describe these systems also focus on different aspects of their spatio-temporal histories and are often treated in isolation. Here we present a modeling framework to describe these coupled systems in order to integrate and interpret these perspectives and datasets. The magmatic model accounts for the following set of processes and the coupling between them: 1. Deformation of host rocks in response to pressure variations in the chamber. 2. Heat transfer from the magma chamber to the wall rocks and growth or decline of a viscoelastic shell around the magma body. 3. Crystallization and accumulation of crystals in different portions of the chamber in response to cooling which affects the mineral and melt compositions as a function of time and space.

The stress that a magma body imposes on its crustal container is an important indicator of changes in magma chamber conditions that can influence the surrounding crustal environment and produce measurable signals at the surface including ground deformation, changes in hydrothermal circulation and focusing of dikes toward the chamber, and importantly can also impact phase equilibria. The phase equilibria determines the latent heat contribution, and ultimately influences the thermal viability, convective vigor, magmatic timescales, melt-crystal separation and overpressure of the system.

We use a multiphase approach to compute extraction in magmatic systems. Each phase, melt or crystal, is represented by conservation equations for the mass, momentum and enthalpy. Enthalpy closure is determined from a version of MELTS with callable library functions that provide phase equilibrium results to the fluid dynamics code. This method accounts for the partitioning of latent and sensible heat in complex geochemical systems. Chemical species for each phase have separate transport equations permitting the exploration of fractionation behavior as well as providing detailed geochemical information that can be used to compare to field observations. We describe those regimes that can lead to sustained overpressure in a magmatic system, potentially making them more prone to erupt, and predict both petrologic and geophysical conditions accompanying these magma chamber conditions.