PHD PROJECT: Fluid dynamics of magma reservoirs

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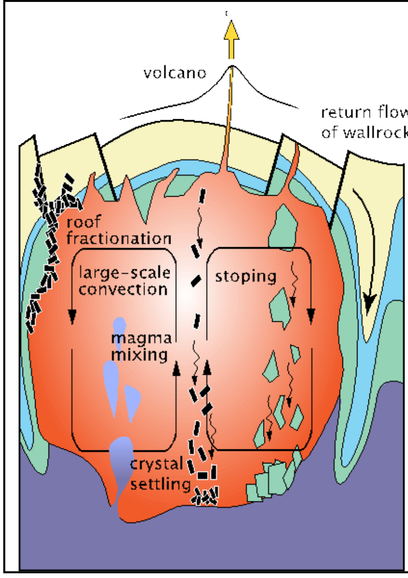
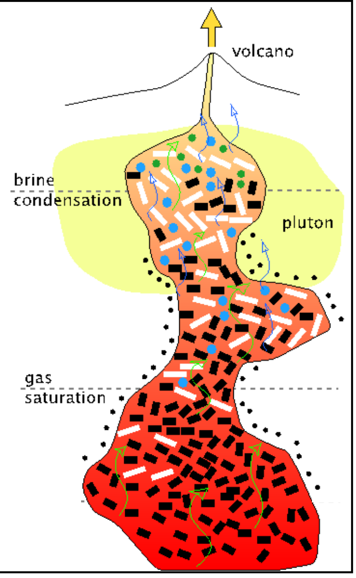
Magma reservoirs are zones in the crust where magma accumulates and chemically evolves. The classical model of a magma reservoir is a chamber of molten rock occupying a void space in the crust. The chemical composition of the magma evolves as it cools, because the crystals which form during cooling are denser than the surrounding liquid, so they settle out of suspension under gravity in a process termed fractional crystallisation. The remaining magma is periodically drained from the chamber via fractures, moving upwards to shallower levels in the crust where it may accumulate in another magma chamber, or be erupted at the surface.



Classical magma chamber concept. Key fluid dynamical processes:
1. Convection and conductive heat transport
2. Mixing of new and existing magmas and crystals
3. Phase change and crystal settling
4. Melting of wall rock ('stoping')
5. Eruption (driven by?)

New magma reservoir concept. Key fluid dynamical processes:
1. Porous media flow of melt (green lines) and volatiles (blue lines)
2. Phase change and chemical reaction between melt and crystals
3. Volatile release from melt
4. Compaction of mush
5. Convective overturn of mush
6. Melting of wall rock
7. Eruption (driven by volatile expansion?)



The concept of a large, liquid-rich magma chamber has been widely accepted for over a century and is used ubiquitously to explain the chemical evolution of igneous rocks. However, geophysical surveys have failed to identify large chambers of molten rock beneath active volcanoes; moreover, thermal models and chemical data suggest that the magma spends most of its life as a liquid-poor 'mush' (a pile of crystals with liquid present in the pore spaces) rather than a liquid-rich 'slurry' (a liquid containing suspended crystals). The data suggest that traditional, liquid-rich magma chambers are at best a transient, short-lived feature: long-lived magma reservoirs are dominated by liquid-poor mushes. The challenge now is to understand the fluid dynamics of these magma reservoirs, which remains almost entirely unexplored. Numerous key questions remain unanswered, including (1) How does melt present in the pore-spaces of a magma mush collect to form an eruptible magma? (2) How does the chemical composition of the melt evolve to match erupted magma compositions? (3) What processes control the key rates, time-scales and length-scales? These questions are fundamental to understand why and when magma is delivered to volcanoes.

The aim of this project is to investigate and model the fluid dynamics of magma reservoirs. The project will involve the development and application of new computational fluid dynamical models of magma reservoirs, building on novel methods developed in our open-source reservoir simulation software (IC-FERST). The models will be tested and calibrated against data collected from ancient magma reservoirs now exposed at the surface, and modern magma reservoirs such as those below Mount St. Helens and Santorini, imaged using geophysical techniques. The CFD models developed will capture a wide range of fluid dynamical processes in magma reservoirs, including multi-phase porous media flow of melt and volatiles such as water, heat transfer and phase change, reactive flow, and compaction and buoyant overturn of the mush.

Applicants should have a good degree in an appropriate subject (e.g. earth science, physics, mathematics, or engineering) and a strong interest in computational modelling. The project is hosted by the highly successful NOvel Reservoir Modelling and Simulation (NORMS) group, a broad, cross-disciplinary group developing, and applying, novel methods in computational fluid dynamics. **The research will deliver fundamental new understanding of volcanic processes, and also contribute to the development of new tools and techniques in CFD**.

Further information about the project can be obtained from Professor Matthew Jackson (m.d.jackson@imperial.ac.uk).