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Numerical modelling of igneous processes

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Magma matters. From magmatic differentiation of terrestrial planets into core, mantle and crust, to magmatism modulating plate tectonics and deep volatile cycles that maintain a habitable Earth, and volcanism causing terrible hazards but also providing rich energy and mineral resources – igneous processes are integral to the evolution of Earth and other terrestrial planetary bodies. Our understanding of volcanoes and their deep magmatic roots derives from a range of disciplines including field geology, experimental petrology, geochemical analyses, geophysical imaging, and volcano monitoring. Observational and experimental studies, however, are hampered by incomplete access to processes that play out across scales ranging from sub-millimetre size to thousands of kilometres, and from seconds to billions of years. Computational modelling provides a tool kit for investigating igneous processes across these scales.

Over the past decade, my research has been focused on advancing the theoretical description and numerical application of multi-phase reaction-transport processes at the volcano to planetary scale. Mixture theory provides a framework to represent the spatially averaged behaviour of a large sample of microscopic phase constituents including mineral grains, melt films, fluid droplets, and vapour bubbles. The approach has been used successfully to model both porous flow of melt percolating through compacting rock, as well as suspension flow of crystals settling in convecting magma bodies. My recent work has introduced a new modelling framework that bridges the porous to mushy and suspension flow limits, and extends beyond solid-liquid systems to multi-phase systems including several solid, liquid, and vapour phases. Igneous process modelling can thus provide new insights into the generation and extraction of mantle melts, the dynamics of crustal magma processing, the outgassing and eruption of shallow magma reservoirs, and the generation of mineral resources by exsolution of enriched magmatic liquids.