Numerical modelling of igneous processes

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Magma matters. From magmatism facilitating the differentiation of terrestrial planets into core, mantle and crust, to the magmatic activity that modulates plate tectonics and deep volatile cycles to maintain a habitable Earth, to volcanism that causes terrible hazards but also provides rich energy and mineral resources - igneous processes are integral to Earth and other planets. Our understanding of volcanoes and their deep magmatic roots derives from a range of disciplines including field geology, petrology and geochemistry, and geophysical imaging. Observational and experimental studies, however, are hampered by incomplete access to processes that play out across scales ranging from sub-micron size to thousands of kilometres, and from seconds to billions of years. Computational modelling provides tools 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 such as mineral grains, melt films, and vapour bubbles. This approach has been used successfully to model both porous flow of melt percolating through compacting partially molten rock, as well as suspension flow of crystals settling in convecting magma bodies. My recent work has introduced a new modelling framework to bridge the porous and suspension flow limits, and to extend beyond solid-liquid systems to multi-phase systems including several solid, liquid, and vapour phases. These advances provide new insights into the dynamics of crustal mush bodies, the outgassing and eruption of shallow magma reservoirs, and the generation of mineral resources by exsolution of exotic magmatic liquids.