Two-phase geodynamics of subduction tectonics and magmatism

Overview
Subduction zones host the vast majority of Earth’s subaerial volcanism and pluton emplacement. The magmatic system that feeds arc volcanoes and plutons remains poorly understood. Geodynamic models of subduction zones have typically neglected magma entirely. The few models that do incorporate magmatism have prescribed the kinematics of the subducting slab on the basis of seismic observations. But the dynamics of the slab and the magmatism it promotes are coupled: slab density and strength is affected by dehydration, which is controlled by the pressure—temperature path it takes as it sinks. Magmatism is a consequence of slab dehydration and affects the strength of the mantle wedge. How these processes interact has not been considered by any study and yet there are indications that the interactions exert a leading-order control on the dynamics. Coupled models may help to explain a range of observations and change our understanding of the tectonic and volcanic evolution of subduction systems from inception to maturity.

Figure showing output from a two-phase flow model of subduction with prescribed slab kinematics. Left panel shows temperature and solid flow lines; right panel shows melt fraction and liquid flow lines (in the wedge only).

Methodology
This project will use a new geodynamic code that is under active development by a group at Oxford. The code uses a mixture of finite element and semi-Lagrangian numerical methods to simulate the dynamics of partially molten rocks in subduction zones. This tool is providing an entirely novel geodynamic perspective on subduction magmatism but at present it relies on a simple, kinematic prescription for the subducting slab. This project will extend the model to allow for a dynamic slab that founders and subducts due to its own negative buoyancy. The project will develop the code to incorporate the rheological complexity of the slab: elastic and brittle deformation. The student will work with the partial differential equations and constitutive laws, computational software and simulation results. Therefore a background in applied mathematics, continuum physics or geodynamics will be helpful.

Timeline
Year 1: DTP training courses, literature review, independent study of two-phase fluid dynamics and rheology, introduction to code use.

Years 2 and 3: code development, systematic testing and investigation, comparison with simpler models and available data.

Year 4: Data integration, thesis completion, papers for international journals/conference presentation.
Training & Skills
As part of the Environmental Research DTP cohort, you will receive one term of intensive training in mathematical and computational methods for geoscientific research, plus a variety of short courses to increase the breadth of your knowledge.

The supervisory team in Oxford are leaders in the use of scientific computing and the application of two-phase physics to geodynamic problems of partially molten rocks. You will join a group of other students and postdocs who are developing expertise in these areas. The supervisors will provide training in aspects of the software development, underpinning mathematics, and associated physics. You will learn to visualise and postprocess the software output for comparison with observations. You will attend at least one summer school in fluid dynamics or geodynamics, as appropriate to your background.

References & Further Reading


Further Information
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