PROJECT TITLE: Mantle melting and the deep Earth water cycle

University of Bristol Theme: Climate and Environment Research Challenge Area
Research Group(s): Petrology
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Project keywords: high-pressure, high-temperature, multi-anvil press, diamond anvil cell, mantle
Funder: University of Bristol Scholarship

Project Background: The habitability of our planet results from a fortunate balance of volatile exchange between the surface and the deep that has maintained clement surface conditions for 4 billion years\(^1\). Recently, there has been a huge effort to understand the reservoirs and fluxes involved in this exchange. We know that much of the water that is bound within the minerals of the oceanic lithosphere and that is subducted into the mantle is ‘baked out’ of the rocks and returns to the surface through volcanism. Recent seismic evidence suggests the presence of thin layers of melt immediately above and below the mantle transition zone (MTZ) that are interpreted to be hydrous\(^2\). This interpretation is logical if controversial\(^3\): olivine and bridgmanite, the major mantle minerals present above and below the MTZ cannot contain much water in their crystal structures. The major minerals within the MTZ (wadsleyite and ringwoodite), however, can contain significant water – up to 2\(^\%\) by weight. This means that if the rocks of the transition zone are wet, their water will be expelled as they pass out the top of the transition zone (when wadsleyite changes to olivine) or out the bottom (when ringwoodite changes to bridgmanite). From work done by the supervisors of this PhD project, we know the composition of hydrous melt at pressures and temperatures corresponding to the top of the MTZ in a simple chemical system\(^4\). We also know that this composition has a low density and a low viscosity – meaning that we expect it to rise rapidly to the surface\(^5\). However, to properly understand deep water cycling and its effect on Earth’s chemical evolution we need more information. We don’t yet know how much iron will dissolve into these melts, a key contributor to their density. We also lack information on the compositions of the melts that act to hydrate the MTZ, and the melt compositions released below it, in the lower mantle\(^6\). Finally, we don’t know whether these melts can ‘wet’ the boundaries between the crystals in mantle rocks. This is a key question, because if they can’t, they could, again, be trapped in the rocks in which they form. The answers to these questions have implications for our understanding of how water is cycled between the deep Earth and the surface, how much water is stored in the deep interior and for the geodynamic evolution of our planet.
**Project Aims and Methods:** In Bristol, we have all the experimental and analytical facilities necessary to solve these problems. You will use our multi-anvil presses and laser-heated diamond anvil cells (Fig. 1) to recreate the extreme pressures (up to 30 million atmospheres) and temperatures (up to 2000 K) found in the deep Earth. You will analyse these experiments using our state-of-the-art scanning electron microscope and electron probe micro-analyser (Fig. 2) to determine the conditions under which hydrous melts form, the compositions of the melts and the crystals they are in contact with and how iron partitions between them. We will use the same instruments to determine the ‘wetting angle’ between these melts and crystals, but we will also explore the use of a Plasma Focused Ion Beam (PFIB) instrument recently installed at Bristol to make 3-D images of the chemistry and textures of the experiments. We can adapt this project to your personal skills and interests: for example, we can explore the development of thermodynamic models to integrate our new experimental results with data from the literature or consider experiments using X-ray diffraction at the UK synchrotron, Diamond, to measure the density of these melts within the diamond anvil cell while they are held at high pressure and temperature. There will also be the possibility of running geodynamic simulations informed by your experimental results.

**Candidate:** Applicants must have a background in Earth Sciences or a related physical science (e.g., Physics or Chemistry) preferably to MSC/MSci level. A strong interest in Earth or planetary sciences is essential, as is enthusiasm for practical laboratory work and careful, analytical study.

**Training:** You will be trained in a range of experimental and analytical techniques, including the use of the multi-anvil press, diamond anvil cell, laser heating, and electron beam microanalysis. Cutting edge experimentation will lead to key skills in equipment design (including CAD software), engineering, microfabrication (including CNC machining) and plenty of problem solving. Your work will require sophisticated data analysis, providing opportunities to learn to code in MATLAB and Python. Presenting your work will provide you with excellent written and oral communications skills and the opportunity to travel to major international conferences.


**Useful links:** [http://www.bristol.ac.uk/earthsciences/courses/postgraduate/](http://www.bristol.ac.uk/earthsciences/courses/postgraduate/)

**Eligibility:** UK and International students are eligible for a University of Bristol Scholarship. UoB Scholarships are fully funded for 4 years and cover university fees, living expenses at the UKRI standard rate, and an allowance of £2000 per year towards research expenses.

**Application deadline:** Tuesday 16th January 2024, 23.59 GMT (Interviews are expected to take place in mid/late February)

**How to apply:** Applications are online only at: [http://www.bristol.ac.uk/study/postgraduate/apply/](http://www.bristol.ac.uk/study/postgraduate/apply/)

Please select “PhD in Geology” as the programme in the online application system.

Please specify the **project title and supervisors** for the project that you are applying for.

To ensure your application is considered under the University of Bristol Scholarship funding scheme you must complete the **Funding page** in your online PhD application as follows:

1. For “What is your likely source of funding?” select **Studentship**
2. For the free text field “Please give the name of your scholarship or studentship” enter **University of Bristol Scholarship**.
3. Set “Percentage from this source” to **100%**
4. Set “Is this funding already secured?” to **No**