The deep interior of Mars

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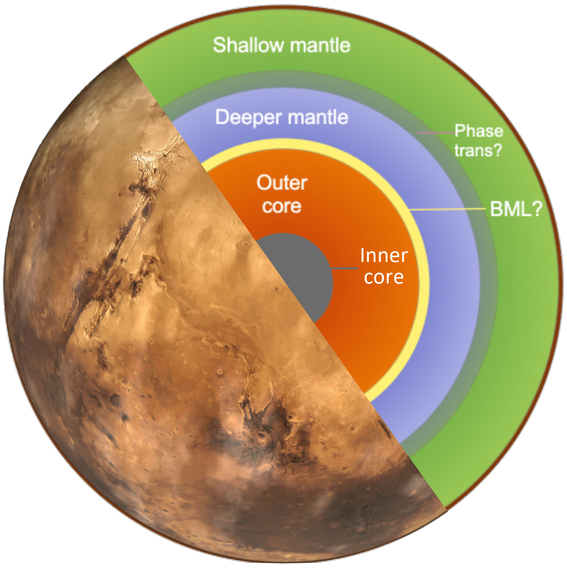

Fig 2: A possible interior structure for Mars

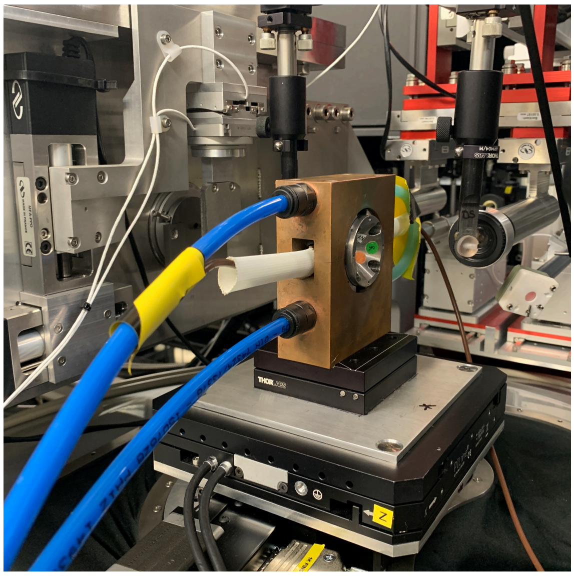

Fig 2: An in situ laser-heated diamond anvil cell experiment at the UK x-ray synchrotron, Diamond.

Project Background

The Martian seismic data collected during the NASA InSight mission (Banerdt et al., 2020) has provided an unprecedented view into the planet's deep interior. Some of the interpretations from InSight remain highly controversial, including the proposed existence of both a solid inner core and a basal magma layer (BML) directly above the core (Fig. 1; Samuel et al. 2023). Determining whether a BML exists on Mars would place powerful constraints on the composition, structure, and thermal history of the red planet.

The successful applicant to this PhD project will collect experimental data to test whether a BML is physically and chemically feasible. Using the unique high-pressure research facilities operated by the Petrology Group in the School of Earth Sciences at the University of Bristol, we will examine whether a basal molten layer could have formed early in Mars' history and whether it could persist to the present day. BMLs can only remain stable over a particular compositional and temperature range, as they must remain simultaneously molten and denser than the overlying mantle. As the planet evolves, these conditions may change, causing a BML to freeze and/or become buoyant.

Project Aims and Methods

In this project you will:

1. Determine the melting phase relations of a range of plausible Martian mantle and basal magma ocean compositions.
2. Measure the density of the resulting melts at high pressure to assess whether they could form a stable layer at the base of Mars' mantle.

To achieve this, the project will use diamond anvil cells (DACs), which routinely reach pressures comparable to those at the Martian core–mantle boundary (~25 GPa). A range of heating methods will be employed, including:

- Laser heating,
- External resistive heating, where the heater surrounds the gasket and diamond anvils (Louvel et al. 2020)
- Internal resistive heating, a new technique developed in Bristol (Heinen et al., 2021), capable of reaching ~65 GPa and ~4000 K for long durations and with minimal thermal gradients.

These experiments will be conducted at x-ray synchrotron user facilities, including Diamond Light Source, enabling *in-situ* X-ray diffraction (XRD) measurements while the samples are at high pressure and temperature. This data will allow us to identify mineralogical changes with pressure and temperature and to determine the conditions at which liquids first appear.

After quenching the experiments, melt compositions will be measured using advanced analytical methods, including electron-probe microanalysis (EPMA; University of Bristol) and synchrotron-based X-ray fluorescence measurements.

Once melt compositions are determined, a second experimental campaign will measure liquid densities as a function of pressure. Two complementary methods will be tested:

- Large-volume press experiments, in which a marker sphere of known density sinks or floats in the melt, constraining melt density;
- In situ synchrotron-based density measurements, using XRD-derived liquid structure and direct tomographic imaging to determine melt volume and density.

The resulting phase relations and density data will then be incorporated into 1D thermal and compositional models of planetary evolution, and 2D geodynamic simulations (Cheng et al., 2025) using ASPECT (Dannberg et al., 2021) to assess the evolution of molten layers at the Martian core–mantle boundary. Depending on the interests of the applicant, these thermal and compositional models could also be used to conduct seismic simulations for comparison with the InSight data.

Candidate

The successful applicant should have a background in either Earth Sciences or a related physical science, preferably to MSc/MSci/MRes level. A strong interest in Earth or planetary sciences is essential, as is an enthusiasm for practical, laboratory work and careful, analytical investigation.

Training

The applicant will be trained in a range of micro-fabrication and synthesis techniques required to make experiments in DACs and large volume presses including glass making by aerodynamic levitation, laser and mechanical machining, sputter coating, grinding and polishing, laser heating and electrical heating. Experiments of this type almost always require a degree of technique development, leading to skills in the design and manufacture of new equipment and integration at synchrotron facilities. *In situ* and *ex situ* experimental analysis will require training in Raman, fourier-transform infra-red and photo-luminescence spectroscopy, electron-probe micro-analysis and x-ray diffraction. Generating geodynamic models will lead to skills in numerical modelling and code development. The candidate will gain a variety of transferrable skills through training offered by the School and the wider University , and will have the opportunity to present their work at international conferences and write articles for internationally renowned academic journals.

References / Reading List

- Banerdt, et al.. (2020). Initial results from the InSight mission on Mars. *Nat. Geosci.*
- Samuel, H. et al. (2023). Geophysical evidence for an enriched molten silicate layer above Mars's core. *Nature*
- Cheng, K. W. et al. (2025). The impact of a long-lived basal magma ocean on the thermochemical evolution of Mars. *J. Geophys. Res.: Planets*
- Dannberg, J. et al. (2021). The morphology, evolution and seismic visibility of partial melt at the core-mantle boundary: Implications for ULVZs. *Geophys. J. Int.*
- Heinen, B. J., et al. (2021). Internal resistive heating of non-metallic samples to 3000 K and >60 GPa in the diamond anvil cell. *Rev. Sci. Instrum.*
- Louvel, M. et al. (2020). The HXD95: a modified Bassett-type hydrothermal diamond-anvil cell for in situ XRD experiments up to 5 GPa and 1300 K. *J. Synchotron Radit.*

Application deadline: 14.00 GMT, 25th Feb 2026

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