The University of Oxford Department of Earth Sciences

EARTHSCIENCES

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A hidden water reservoir in the continental lithosphere

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Key Words	**Metamorphism, mineralogy, fluid–rock interactions, continental lithosphere**

Overview

The water content of metamorphic rocks in the continental crust and underlying lithospheric mantle controls many of their key petrophysical properties, such as melting temperature, electrical conductivity, and rheology (Jones et al., 2015). In the middle and upper crust, H_2O is mostly contained within hydrous minerals, such as mica and amphibole, although these phases become unstable at elevated pressure (*P*) and temperature (*T*) conditions (Palin et al., 2016). Nonetheless, mass balance models of volatile transport into the deep Earth coupled with a range of geophysical and geochemical observations suggests that the lower crust and upper mantle are hydrated – so where is this water?

Recent studies have shown that nominally anhydrous minerals (NAMs), such as garnet, pyroxene, and olivine, can host ~100–1000 ppm H_2O at lower crust/upper mantle *P*–*T* conditions (Kumamoto et al., 2017), although the water-carrying capacity of synthetic forms of these minerals differ from measurements made on natural examples (e.g. Hirschmann et al., 2005).

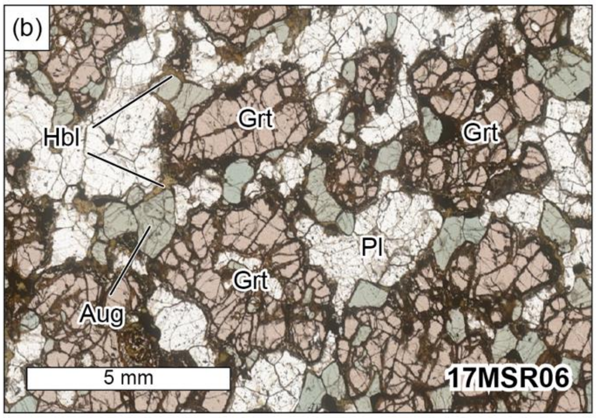

Figure: Plane-polarised light photomicrograph of a metasomatised mafic granulite xenolith from the Colorado Plateau lower crust. Aug = augite, Grt = garnet, Hbl = hornblende, Pl = plagioclase.

This project will utilise a lithologically diverse suite of crustal and mantle xenoliths exhumed during Miocene volcanism on the Colorado Plateau. Petrographic and petrological analysis of 'fresh' and metasomatized parageneses will allow direct quantification of the H_2O-carrying capacity of common metamorphic minerals at different *P*–*T* conditions within the continental lithosphere. These results will be compared to the results of high-pressure experiments and data documented in the literature. The results of this study will provide important new linkages between petrology, fluid–rock interaction, and large-scale tectonics (e.g. Hernández-Uribe and Palin, 2019), and have critical implications for understanding the volatile budget of the bulk Earth.

Methodology

Petrographic and petrological analysis of crustal and mantle xenoliths will utilise optical microscopy and electron-beam micro-analysis. Mineral compositions will be used to constrain *P*–*T* conditions of equilibration within the lithosphere via various forms of thermobarometry. Water contents in NAMs will be constrained via secondary ion mass spectrometry. Petrological modelling will be employed to parameterize relationships between *P*, *T*, and H_2O content.

A student working on this project will gain direct experience in the following tools and techniques:

- X-ray fluorescence (XRF)
- Scanning-electron microscope (SEM)
- Electron probe micro-analysis (EPMA)
- Secondary ion mass spectrometry (SIMS)
- Petrological modelling software (Perple_X)

Timeline

Year 1: Doctoral training courses, literature review, sample characterisation, and laboratory training.

Years 2 and 3: Petrographic and microanalytical work (XRF, SEM, EPMA), in-situ analysis of NAM H_2O contents (SIMS), and petrological modelling. Data compilation and interpretation. Presentation of results at the Geological Society of London 'Metamorphic Studies Group' and 'Tectonics Studies Group' annual meetings.

Year 4: Data integration, thesis completion, write papers for international journals, presentation of results at an international conference.

Training & Skills

An ideal student for this project would have a keen interest in mineralogy and petrology, and how they influence our understanding of broad-scale tectonics. They will learn how to process and analyse samples in the laboratory and be trained on a range of micro-analytical equipment. They will be trained how to apply phase equilibria calculations to natural samples and how to interpret the results within the framework of an initial hypothesis posed. The student will also be mentored on how to prepare scientific results for presentation at international conferences and how to write papers for publication in high-profile, international journals.

References & Further Reading

Hernández-Uribe, D. and Palin, R.M., 2019. A revised petrological model for subducted oceanic crust: insights from phase equilibrium modelling. Journal of Metamorphic Geology, 37, 745–768.

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Kumamoto, K.M., Warren, J.M. and Hauri, E.H., 2017. New SIMS reference materials for measuring water in upper mantle minerals. American Mineralogist, 102, 537–547.

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Further Information

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