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PhD Project Description

Volatiles in zircon-hosted inclusions as indicators of porphyry copper fertility

Supervisors

Lead Supervisor: Dr. Chetan Nathwani

Co-supervisor(s): Dr. Yannick Buret (NHM), Prof. Jon Blundy (University of Oxford)

Research Group

The student will be based in the London Centre for Ore Deposits and Exploration (LODE) group at Imperial. They will also have access to world-class analytical facilities and collaborations with the Natural History Museum and the University of Oxford.

Project Summary

Magmas forming porphyry copper deposits are thought to have elevated volatile contents (water, chlorine and sulfur) relative to those forming unmineralised systems. This study aims to develop novel methodologies for probing the volatile and metal contents of magmas forming porphyry copper deposits, using melt inclusions and apatite inclusions shielded in zircon crystals. The workflow will include field sampling, electron microscopy, laser ablation, electron microprobe analysis and modelling approaches.

The developed methods will be applied to temporal sequences of arc magmatism culminating in porphyry Cu deposit formation to track magmatic volatile and metal budgets in the build-up to ore formation. This will test whether ore formation coincides with increased fluxes of magmatic volatiles such as chlorine and sulfur, and/or metals (e.g. Cu). The project will aim to provide a new method for mineral exploration that can efficiently identify porphyry-fertile magmas. The successful candidate will gain a wealth of expertise in economic geology and igneous petrology with a strong exposure to microanalytical geochemistry.

Research Context and Objectives

Porphyry copper deposits are the main source of society's copper and account for large amounts of molybdenum, gold and other metals. High concentrations of volatiles such as water, chlorine and sulfur are thought to play a key role in generating large porphyry deposits, as opposed to unmineralised magmatic systems (Grondahl and Zajacz 2022, Nathwani et al. 2024). This project will develop novel methods to constrain volatile and metal concentrations in porphyry-ore forming magmas using melt and apatite inclusions in zircon, which are shielded from hydrothermal alteration and can preserve important information on the evolution of porphyry-ore forming magmas (Nathwani et al. 2023, Butters et al. 2025). The new methods will be applied in a world-class porphyry Cu district case study site. The results will help identify the key magmatic ingredients responsible for forming porphyry deposits.

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Geochronology using LA-ICP-MS U-Pb dating of zircon will constrain the ages of the investigated sample suite. LA-ICP-MS methods will be developed in collaboration with the Natural History Museum to determine volatile and metal concentrations in zircon-hosted melt inclusions. These results will be complemented by electron microprobe analyses to determine volatile concentrations in apatite inclusions in zircon. Experimental facilities at the University of Oxford will be used to better understand the behaviour of melt inclusions during heating. The results of the study will be synthesised using models of volatile evolution and degassing from magmas, to test the scenarios that best reproduce the measured volatile and metal concentrations.

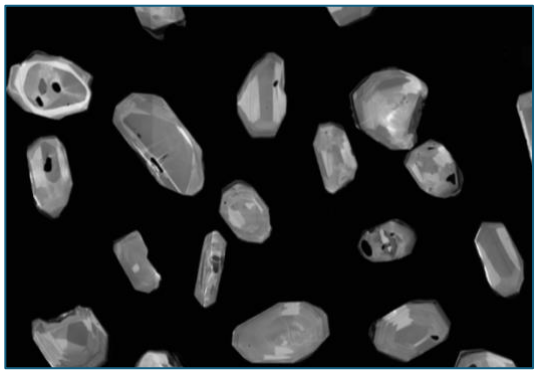

Figure 1: Zircon crystals from a porphyry copper deposit imaged using scanning electron microscope cathodoluminescence, showing frequent inclusions of melt and apatite within the crystals.

Collaborators and partners on the project:

This project will involve collaboration with our neighbours at the Natural History Museum, through training and use of world-class analytical facilities at the Imaging and Analysis Centre. Access and training to analytical and experimental facilities at the University of Oxford will also be available. Collaboration with mineral exploration companies is also expected, providing access to case studies sites and for valuable exchanges of ideas.

Further reading:

Butters, D. *et al.* (2025) 'Transcrustal, volatile-charged silicic melts revealed by zircon-hosted melt inclusions', *Earth and Planetary Science Letters*, 655, p. 119252. https://doi.org/10.1016/j.epsl.2025.119252.

Grondahl, C. and Zajacz, Z. (2022) 'Sulfur and chlorine budgets control the ore fertility of arc magmas', *Nature Communications*, 13(1), p. 4218. https://doi.org/10.1038/s41467-022-31894-0.

Nathwani, C. *et al.* (2024) 'A zircon case for super-wet arc magmas', *Nature Communications*, 15(1), p. 8982. https://doi.org/10.1038/s41467-024-52786-5.

Nathwani, C.L. *et al.* (2023) 'Apatite evidence for a fluid-saturated, crystal-rich magma reservoir forming the Quellaveco porphyry copper deposit (Southern Peru)', *Contributions to Mineralogy and Petrology*, 178(8), p. 49. https://doi.org/10.1007/s00410-023-02034-8.

Who are we looking for?

We are looking for motivated, hard-working students with a background in igneous petrology and/or economic geology, with the willingness to learn laboratory methods. Skills developed will include field sampling and a wealth of analytical/laboratory skills with extensive training provided. Participation in a training course (e.g. SEG) in field skills and porphyry Cu deposit geology will be strongly encouraged. Successful applicants should have a proven aptitude for analytical work and a genuine curiosity for research and applied geoscience. The candidate will have the opportunity to develop their career and profile by presenting at international conferences and publishing in recognised journals. The project involves interaction with other research groups within and beyond ESE, and industry partners.