

Ore formation in a capsule: Experimental investigation of percolative reactive flow of fluid and melt

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Key words:	Experimental petrology, sulphides, metal mobilisation, porphyry copper deposits, magmatic systems
Research theme(s):	- Planetary Evolution and Materials - Earth Resources
Eligible courses for this project:	- DPhil in Earth Sciences (3-4 years) - Interdisciplinary Life and Environmental Science Landscape Award (ILES�A)

Overview

How are metals mobilised and transported through the Earth's crust to form economically important ore deposits? Porphyry copper deposits are among the world's most important sources of copper, yet the processes responsible for mobilising and concentrating metals within magmatic systems remain enigmatic. In particular, the role of percolative reactive flow of fluid or melt through crystal-rich magmatic systems in redistributing sulphides and their associated metals is poorly constrained.

This DPhil project will investigate a potentially important mechanism of metal mobilisation: **percolative reactive flow through crystal mushes in transcrustal magmatic systems**. As fluids and melts migrate through interconnected networks of crystals, they may react with surrounding minerals, potentially mobilising metals previously stored in sulphides and redistributing them within the magmatic system.

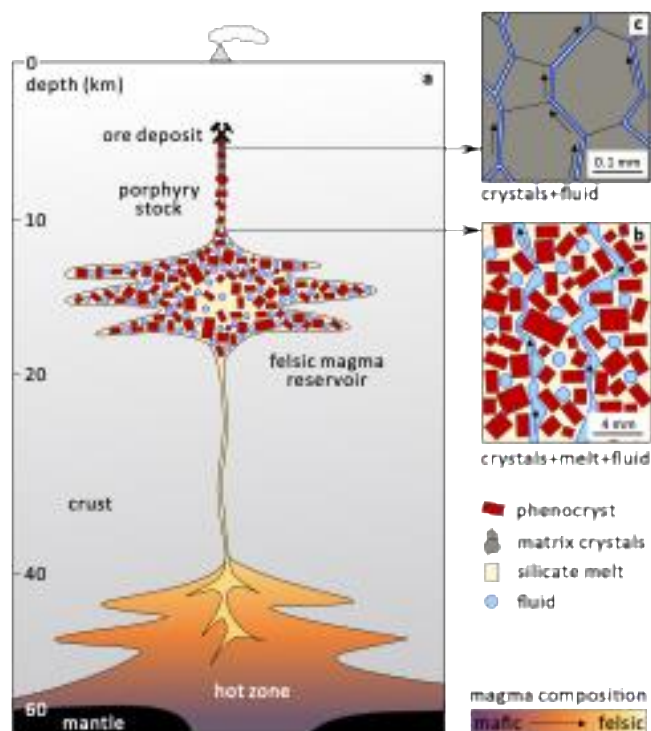
The student will use innovative high-pressure and high-temperature experiments to investigate the interaction of sulphide-bearing gabbroic rocks with two different transporting agents: **saline aqueous fluids and hydrous silicate melts**. By comparing their behaviour under controlled experimental conditions, the project will investigate the mechanisms controlling sulphide dissolution, reaction and redistribution, as well as the mobilisation and transport of associated metals. A central aim will be to establish the conditions under which each transporting agent is most effective.

Experimental results will be combined with petrographic observations, geochemical analysis and modelling to evaluate the role of percolative reactive flow in metal transfer through

crystal-rich magmatic systems.

Experimental findings will be compared with natural examples from exhumed magmatic arcs, including the Sierra Nevada (USA) or Famatinian arc (Argentina), providing an opportunity to link laboratory-scale processes with geological observations.

The project aims to establish the relative roles of saline fluids and hydrous silicate melts in sulphide and metal redistribution, providing new insights into the processes that may contribute to the formation of porphyry copper deposits.



Cartoons illustrating the preferred model of magma evolution, fluid exsolution, and fluid transport processes involved in the formation of porphyry-type Cu (Au, Mo) deposits in the Sanjiang region (not to scale). *From Chang et al 2025, Nature communications.*

Methodology

The project will combine high-pressure and high-temperature experiments with petrographic observations, geochemical analysis and modelling. Experiments will investigate the percolative reactive flow of saline aqueous fluids and hydrous silicate melts. By comparing the interaction of these two transporting agents with different gabbroic compositions, the student will investigate the mechanisms controlling sulphide dissolution, reaction and redistribution, as well as the mobilisation and transport of associated metals. Experimental products will be characterised using petrographic and microanalytical techniques, with particular emphasis on sulphide behaviour, mineral reactions and metal redistribution. Geochemical modelling will be used to interpret experimental results and assess their implications for natural magmatic systems. Potential fieldwork in exhumed magmatic arcs, such as the Sierra Nevada (USA) or Famatinian arc (Argentina), will provide opportunities to compare experimental findings with natural examples of reactive fluid and melt flow.

Timeline

Year 1: Literature review and training in high-pressure experimental techniques. Selection and characterisation of starting materials, development of experimental protocols and preliminary reactive-flow experiments.

Years 2 and 3: Experimental investigation of saline fluid and hydrous silicate melt interactions with sulphide-bearing gabbroic rocks. Characterisation of experimental products,

comparison of sulphide and metal redistribution mechanisms, and geochemical modelling. Potential fieldwork, conference presentations and preparation of research publications.

Year 4: Integration of experimental, analytical and modelling results. Evaluation of the implications for metal transport and ore-forming processes in magmatic systems. Thesis completion and publication of research findings.

Training & Skills

Training will be provided in high-pressure and high-temperature experimental petrology, petrography, geochemical analysis and modelling of mineral–melt–fluid interactions. The student will develop skills in experimental design, microanalytical techniques, trace element partitioning and interpretation of magmatic and ore-forming processes.

Additional training opportunities will include scientific computing, scientific writing and presentation of research findings. Regular supervisory and research group meetings will provide support throughout the project.

References & Further Reading

- [1] Holwell, D.A., et al. (2022). Mobilisation of deep crustal sulfide melts as a first order control on upper lithospheric metallogeny. *Nature Communications*, 13, 573.
- [2] Cashman, K.V., Sparks, R.S.J. and Blundy, J. (2017). Vertically extensive and unstable magmatic systems: A unifying view of igneous processes. *Science*, 355, eaag3055.
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- [7] Carter, L.C., et al. (2021). Crystal mush dykes as conduits for mineralising fluids in the Yerington porphyry copper district, Nevada. *Communications Earth & Environment*, 2, 59.
- [8] Chang, J., Audétat, A., & Pettke, T. (2025). Ten kilometers ascent of porphyry Cu (Au, Mo)-forming fluids in the Sanjiang region, China. *Nature Communications*, 16(1), 2330.

Further Information

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