From source to deposit: Experimental and modelling constraints on copper mobilisation and deposition in sedimentary basins

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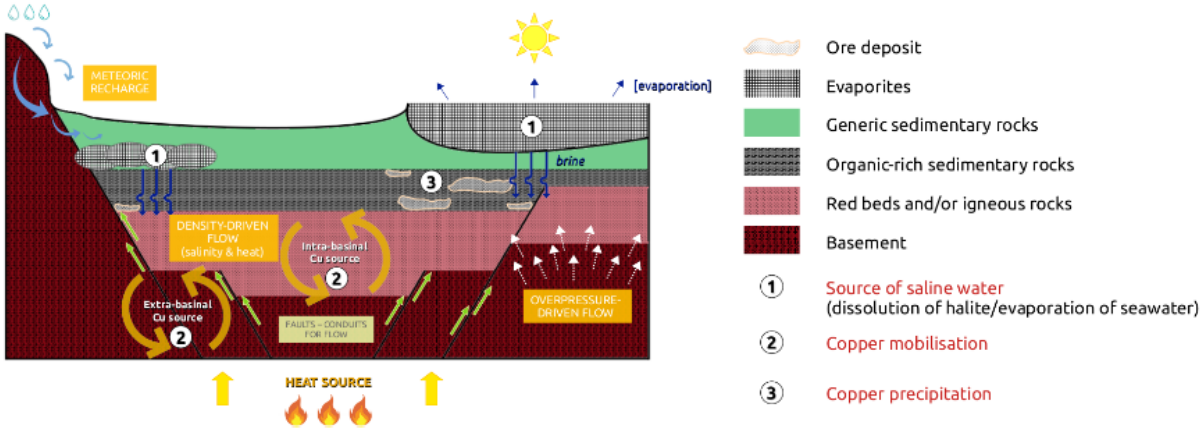
Project Highlights:

- Fundamental understanding of the mechanisms that control the formation of a key metal resource
- Results will inform exploration strategies in the mineral system framework
- Training in leading-edge numerical modelling techniques

Overview:

Sediment-hosted copper deposits account for approximately 23% of the world's discovered copper. Their global economic significance has stimulated over a century of research devoted to understanding their formation. This has demonstrated that most deposits were formed by leaching of copper and other metals from source rocks; transport of the metals in oxidising, chloride-rich brines as they flow through porous, permeable rocks or along faults, and precipitation of copper as sulphide minerals under reducing conditions.



Schematic of the basin processes that may produce a sediment-hosted copper deposit.

Although this general model for copper ore formation is broadly accepted, there are still major uncertainties and controversies concerning the timing of mineralisation, the source rock(s) from which copper and other metals are extracted, the efficiency with which brines can leach copper from the proposed source rock(s), the origin and composition of the brines responsible for metal leaching and transport, the temperatures and depths at which metals are leached and deposited, the forces that drive brine flow, controls on mineralisation, and whether mineralisation occurs during a single

pass of metal enriched brine, or during circulation of brine with multiple cycles of metal enrichment and mineral deposition. These knowledge gaps severely impact our ability to develop predictive models for copper localisation in basin systems and, more widely, the controls of basin metallogenic potential.

This project will investigate copper mineralisation in three different basins: (1) the Altiplano Basin, Bolivia; (2) the Neuquén Basin, Argentina; and (3) the Katangan Basin, Central Africa. These basins represent increasingly mature basin systems with different metal and petroleum endowments. They provide an opportunity to explore the role of contrasting geotectonic settings, basin fill and architecture, P-T-t evolution, and the timing and nature of mineralisation.

The project builds on methods and results developed in the NERC-funded CuBES project (Copper Basins Exploration Science), allowing rapid delivery of new results and insight. It is designed to address fundamental controls of sediment-hosted copper deposit genesis, including secular variations in seawater-derived brine chemistry, and paleoclimatic and geodynamic impacts on fertile basin fill and architectures. The results will have direct implications for better defining the exploration search space.

Methodology:

This project will constrain mechanisms of extraction, transport and deposition of copper using laboratory experiments combined with advanced, basin-scale numerical models built with georealistic geometries. The laboratory experiments will use an established methodology to determine the efficiency with which copper and other metals can be leached from potential source rocks by natural brines, incorporating secular variability in brine composition, at relevant conditions of temperature, pressure and oxidation state [1]. These new data will be used in an advanced numerical modelling tool [2] to explore: (i) the conditions and processes that lead to mobilisation and transport of copper in brines, including the control of heterogeneous stratigraphic architecture in terms of distribution of carbonate-bearing and reduced facies; (ii) the implications of potential interactions of such brines with petroleum during its generation and migration; and (iii) how copper deposition can be localised in such flow regimes in terms of structural geometries and stratigraphic architecture.

Possible Timeline

Year 1: Leaching experiments. Training in numerical modelling. Initial modelling of Katangan basin. First paper on leaching experimental results.

Year 2: Complete simulation work on Katangan basin; second paper on modelling results. Simulation work on Altiplano and Neuquén Basins.

Year 3: Complete simulation work; third and fourth papers on modelling results. Complete dissertation.

Training and skills:

TARGET researchers will participate in a minimum of 40 days training over the 3.5 years of study composed of:

- an annual one-week workshop dedicated to their year group, and tailored to that cohort's needs in terms of skills development – *for the first three years of their study*;
- an annual all-TARGET workshop with cross-year interactions, advanced training and opportunities to specialise in particular areas – *all years of study*;

- a number of one-day workshops;
- additional online events and in-person workshops attached to relevant conferences.
- bespoke training in advanced numerical modelling skills delivered through formal courses and on-the-job training supported by peers in our large and active research groups
- bespoke training in experimental skills

Partners and collaboration (including CASE):

The successful applicant will be based at Imperial but will spend time at the Natural History Museum using laboratory facilities to complete the experimental work and meeting with NHM staff including the project co-I, Prof. Richard Herrington. The applicant will leverage the project supervisors' outstanding links with academic research groups and industry partners within and outside the UK working in the basins of interest. Industry (CASE) support for the project is currently being sought. Visits and internships to spend time working with the project partner will be required as part of the CASE project arrangement.

Further reading:

1. J Woitischek, JJ Wilkinson, E Humphreys-Williams, MD Jackson, An experimental study of metal extraction from continental red-bed sandstones, Goldschmidt Conference, 2023

2. M Bahlali, J Woitischek, C Jacquemyn, M Purkiss, MD Jackson, Integrated Modeling of Cu-Rich Fluid Migration and Mineralization in the Katangan Basin, Central African Copperbelt: Insights from Numerical Experiments, European Geoscience Union Annual Meeting, 2024

Further details:

Please visit https://target.le.ac.uk/ for additional details on how to apply. If you have any questions about the project, please contact Matt Jackson at m.d.jackson@imperial.ac.uk. Further details about the research groups hosting the project can be found at https://www.imperial.ac.uk/earth-science/research/research-groups/norms/ and https://www.imperial.ac.uk/earth-science/research/research-groups/lode/.