DEVELOPING GARNET AND EPIDOTE AS MINERAL INDICATORS OF PORPHYRY-SKARN ORE SYSTEMS

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Project available for funding through the NERC "TARGET" Centre for Doctoral Training (see target.le.ac.uk)

Project Highlights:

- First baseline study of garnet and epidote chemistry in mineralized and barren porphyry-skarn systems utilising NHM mineral collections
- Building an understanding of the controls on major and trace element compositions of skarn minerals using experimental studies
- Development of mineral proxies using data analytics and machine learning to discriminate barren from fertile porphyry-skarn systems

Overview

Porphyry systems represent the world's principal source of copper and molybdenum and are major repositories of gold and silver (Cooke et al., 2014a). In some cases, associated skarn deposits provide additional high-grade resources and can contain exotic critical metals. These linked deposits originate from huge volumes of metal-bearing hydrothermal fluid that exsolved from crystallising crustal magma reservoirs, with carbonate host rocks favouring skarn development through magmatic fluid-rock interaction. This project seeks to understand the growth and composition of epidote and garnet in skarns using a combination of analysis of natural specimens and experimental modelling, growing skarn asssemblages under controlled laboratory conditions. The results will be used to develop mineral chemistry tools for porphyry-skarn exploration.

Figure 1: Large, zoned garnet from unmineralized endoskarn, central Pyrenees

Key research questions:

This project aims to answer the following key research questions:

(1) What is the typical paragenesis of garnet and epidote in skarns?
(2) What controls the major and trace element compositions of garnet and epidote that form in skarn settings?
(3) Are the signatures of fertile mineralizing fluids preserved in garnet and epidote and can these be developed into a tool to discriminate mineralised from barren settings using detrital grains?

Methodology:

A literature review will establish current understanding of the formation of garnet and epidote in skarns and their compositions. Laboratory studies will first utilise samples from the NHM collections to develop a baseline understanding of the paragenesis of garnet and epidote in diverse skarn settings and

to characterise their textural and compositional variability. We anticipate that the sample set will be extended to include material collected from selected field sites.

Analysis will involve conventional wholerock multielement lithogeochemistry (where possible), mapping of sections in PPL, XPL and RL using a Zeiss Axioimager and mineral mapping using a TESCAN TIMA automated SEM to define paragenetic relationships and identify mineral grains for analysis by SEM-EDS/microprobe and LA-ICP-MS.

Piston-cylinder experimental studies will grow skarn assemblages under controlled P-T; run products will be analysed using the same methods outlined above. Results will be used to understand reactions leading to mineral growth and determine controls of trace element partitioning. Results from natural samples will be interrogated using a variety of data analytics and machine learning approaches to develop tools for discrimination of garnet and epidote from skarn origins and to discriminate between barren and mineralized settings.

Possible timeline:

Year 1: Literature review, development of skarn geology understanding, compilation of existing data on garnet and epidote multielement chemistry from skarns and other settings. Selection of samples from the NHM collections and submit for sample preparation. Initial petrographic work using Axioscan and automated SEM. Report on petrographic study at conference 1.

Year 2: Major analytical phase, including the majority of imaging and mineral chemistry analysis. Select samples for trace element mapping. Carry out gap analysis of sample suite and identify potential field areas to supplement the database. Report on mineral chemistry results at conference 2.

Year 3: Carry out fieldwork to collect additional samples and complete the analytical programme. Explore different analytics and machine learning approaches to select optimum for discrimination tools. Test against detrital sample set from an area of known geology. Report on main findings of research at conference 3. Plan thesis structure and begin write-up.

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.

At NHM, the student will receive training in lab safety and occupational health, sample preparation and instrumental methods. Optional courses in transferable and various technical skills including use of software and coding, and public engagement opportunities, will be available. At Imperial College, courses provided by the graduate School will be available, as well as technical training in machine learning methods. Training in fieldwork and porphyry/skarn geology will be done by Wilkinson, attendance on field training courses (e.g. SEG) and by Rio technical staff. Training in rock petrography and mineral analysis will be mainly completed at the NHM using instruments in the Imaging and Analysis Centre supervised by Wilkinson and the lab support team. Bromiley will provide training in experimental petrology and characterisation of run products in Edinburgh.

Partners and collaboration (including CASE):

The student will be based primarily at Imperial College London and the Natural History Museum within the LODE research group but will work with the co-supervisor and other collaborators at the University of Edinburgh and the CASE partner as appropriate. They will be part of the PhD student cohorts both at NHM and Imperial. Demonstrating opportunities for undergraduate classes at Imperial will also be available. It is expected that the student will attend a placement and present the results of the research at a workshop for technical teams within Rio Tinto at their research labs in Melbourne, Australia.

Possible timeline:

Year 1: Online kick-off meeting with stakeholders, including UK-based Rio Tinto staff. Training in lab methods with diverse range of scientists at NHM and in-house LODE group activities.

Year 2: Placement time spent with CASE partner team in Melbourne. Interaction with diverse scientists and the LODE research team at NHM.

Year 3: Collaboration with AI experts at Imperial. Online workshop reporting on results to CASE partner staff.

Requirements: Applicants should have a First Class or good Upper Second Class Msci/MGeol degree or BSc + relevant Masters in geology/geoscience, with particular interests in mineralogy, geochemistry and microanalytical methods, and a passion for mineral exploration and ore genesis.

Further reading:

Cooke, D.R., Hollings, P., Wilkinson, J.J., and Tosdal, R.M. (2014a). 'Geochemistry of porphyry deposits' in Holland, H.D., and Turekian, K.K., eds., Treatise on Geochemistry, 2nd Edition, v. 13, Oxford, Elsevier, pp. 357-381.

Meinert, L.D., Dipple, G.M. and Nicolescu, S. (2005). 'World skarn deposits', Economic Geology 100th Anniversary Volume, pp. 299-336.

Wilkinson, J.J., Cooke, D.R., Baker, M.J., Chang, Z., Wilkinson, C.C., Chen, H., Fox, N., Hollings, P., White, N.C., Gemmell, J.B., Loader, M.A., Pacey, A., Sievwright, R.H., Hart, L.A., and Brugge, E.R. (2017). 'Porphyry indicator minerals and their mineral chemistry as vectoring and fertility tools', in McClenaghan, M.B. and Layton-Matthews, D., eds., Application of indicator mineral methods to bedrock and sediments: Geological Survey of Canada, Open File 8345, 2017, pp. 67-77, DOI: 10.4095/306305.

Meinert, L. (2023). Exploration for skarn deposits, GeoHug presentation, https://www.youtube.com/watch?v=POIRpmVaom0

Further details:

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To apply, please go to: https://target.le.ac.uk/how-to-apply/

A separate application will subsequently need to be made for entry as a student to Imperial College London at:

https://www.imperial.ac.uk/study/apply/postgraduate-doctoral/application-process/