Why are barren porphyry systems unmineralized?

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Co-supervisors: Natural History Museum

Project Highlights:

- First detailed case study characterization of a well-drilled but barren porphyry centre
- Identification of key process differences between barren and mineralized systems
- Development of mineral proxies to discriminate barren from fertile porphyry 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). These deposits originate from huge volumes of metal-bearing hydrothermal fluid that exsolved from crystallising crustal magma reservoirs. Recent studies have shown that igneous accessory minerals such as zircon and apatite can retain critical chemical information that allows us to distinguish magmas that are predisposed to form porphyry ore deposits (e.g. Loader et al., 2017; Nathwani et al., 2020, 2021). However, we do not really understand processes operating at the deposit level that result in the failure of a mineralizing system to develop, even when the right type of magmas are involved. The aim of this project is to identify which part(s) of the porphyry mineral system are the root cause of the failure of economic mineralization to form in altered but barren systems. Possible reasons include: (1) igneous infertility (insufficiently oxidized or hydrous magmas), lack of metals, sulfur or Cl in the source magmas; or (2) potentially fertile magma but ineffective hydrothermal processes, e.g. weak melt-fluid partitioning of ore-forming components, lack of effective sulfide trap mechanism in terms of temperature gradient, pH buffering and/or reductant. We believe that the geochemical signature of minerals in the 'barren system' will, because of one or more of these factors, differ from the equivalent minerals in well-endowed porphyry deposits, allowing for the development of discrimination tools.

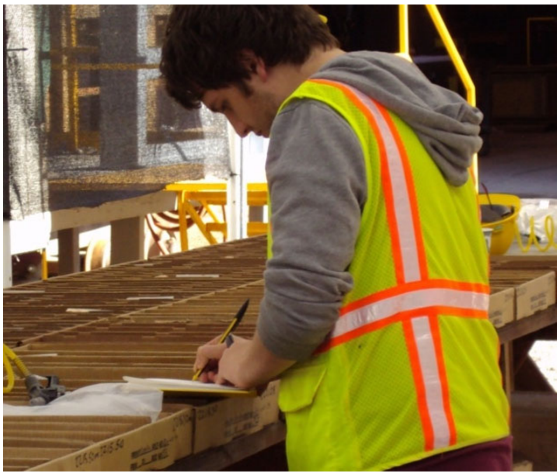

Figure 1: Logging drillcore at the giant Resolution porphyry-Cu deposit, Arizona, USA

Methodology:

Fieldwork will be carried out on a case study site where 3D sampling can be done on a barren porphyry system that bears all the typical hallmarks in terms of geology and alteration of mineralized centers. Drillcores will be logged in detail to identify intrusive units, describe contact relationships and define a vein and breccia – and associated alteration – chronology.

Analysis will involve conventional wholerock multielement lithogeochemistry, mapping of sections in PPL, XPL and mineral mapping using automated SEM to define paragenetic relationships and identify grains for analysis. SEM-EDS, microprobe and LA-ICP-MS will be used for multielement mineral chemistry of igneous minerals that contain "fertility" signatures (zircon, apatite, titanite) and hydrothermal minerals (apatite, rutile, APS minerals, muscovite, chlorite) where existing comparator datasets from well-endowed porphyry systems exist. Representative samples of key stages will be used for fluid inclusion microthermometry to constrain fluid properties and P-T conditions. Geochronology of targeted phases will be carried out to constrain timing and duration of hydrothermal activity.

Results will be compared with relationships and parameters derived from well-studied porphyry deposits as published in the literature. Phases identified as potential proxies for key processes (or lack thereof) will undergo further analysis to build a sufficient dataset for the development of machine learning algorithms for system discrimination.

Possible timeline:

Year 1: Literature review, development of porphyry geology understanding, possible field training course (SEG or other). Main field campaign, start to put samples through the preparation workflow and initial petrographic work. Report on petrographic study at conference 1.

Year 2: Major analytical phase, including the majority of imaging and mineral chemistry analysis. Identify samples for fluid inclusion study and get sample preparation underway, plus initial cathodoluminescence and fluid inclusion analyses. Identify samples for geochronology and initiate study. Report on mineral chemistry results at conference 2.

Year 3: Complete fluid inclusion microthermometric study and analyse selected inclusion samples by LA-ICP-MS. Complete geochronology. Extend database on target minerals and develop discrimination tools. 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, instruction in porphyry geology, geochemical interpretation using ioGAS and technical training in machine learning methods will be provided. Training in fieldwork and porphyry geology will be done by Wilkinson, attendance on field training courses (e.g. SEG) and by CASE partner technical staff. Training in mineral analysis will be mainly completed at the NHM using instruments in the Imaging and Analysis Centre supervised by the NHM co-supervisor and the lab support team.

Partners and collaboration (including CASE):

The student will be based jointly at Imperial College and NHM as part of the student cohorts both at Imperial and NHM, and will work with the CASE partner as appropriate. Demonstrating opportunities for undergraduate classes at Imperial will be available. It is expected that the student will present the results of the research at a workshop for technical teams in the CASE partner company/ies in person at their head office, as well as to the case study area local technical teams in-country. Fieldwork will be carried out with the student embedded in the local exploration teams. Regular (quarterly) meetings will be held between the student, supervisory team and technical advisors from the CASE partner(s)

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.

Loader, M.A., Wilkinson, J.J., and Armstrong, R.N. (2017). 'The effect of titanite crystallisation on Eu and Ce anomalies in zircon and its implications for the assessment of porphyry Cu deposit fertility', Earth and Planetary Science Letters, 472, pp. 107-119, DOI: 10.1016/j.epsl.2017.05.010

Nathwani, C.L., Loader, M.A., Wilkinson, J.J., Buret, Y., Sievwright, R.H. and Hollings, P. (2020). 'Multi-stage arc magma evolution recorded by apatite in volcanic rocks', Geology, 48, DOI: 10.1130/G46998.1

Nathwani, C.L., Simmons, A.T., Large, S.J.E., Wilkinson, J.J., Buret, Y., and Ihlenfeld, C. (2021). 'From long-lived batholith construction to giant porphyry copper deposit formation: petrological and zircon chemical evolution of the Quellaveco District, Southern Peru', Contributions to Mineralogy and Petrology, 176, 12, DOI: 10.1007/s00410-020-01766-1

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.

Further details:

Please visit https://target.le.ac.uk/ for additional details on how to apply.

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https://www.nhm.ac.uk/our-science.html