Department of Earth Science and Engineering, Imperial College London, London Centre for Ore Deposits and Exploration, Natural History Museum and University College London

PhD Project 2024

Detrital mineral records of magmatism and fertility in porphyry copper districts

Professor Jamie Wilkinson and Professor Pieter Vermeesch (UCL)

AIM The aim of the project is to examine and understand the mineral chemistry of igneous and alteration minerals from the mineralized centres of a major porphyry copper ore district and their transition, dilution and survival in drainage samples in order to develop effective exploration screening tools for porphyry ore systems.

BACKGROUND 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). Furthermore, the propylitic alteration halo – the most extensive zone of alteration associated with porphyry centres which can extend for more than 5 km from the ore deposit itself – also retains valuable mineral chemical information that relates to porphyry deposit potential (e.g. Cooke et al., 2014b; Wilkinson et al., 2015, 2017, 2020). Despite this new understanding, we still do not fully understand how such signatures develop over the multi-million year timescales of porphyry district evolution, nor how such signatures may be transferred and preserved in drainage catchments.

Logging drillcore at the giant Resolution porphyry Cu-Mo deposit, Arizona, USA

OBJECTIVES

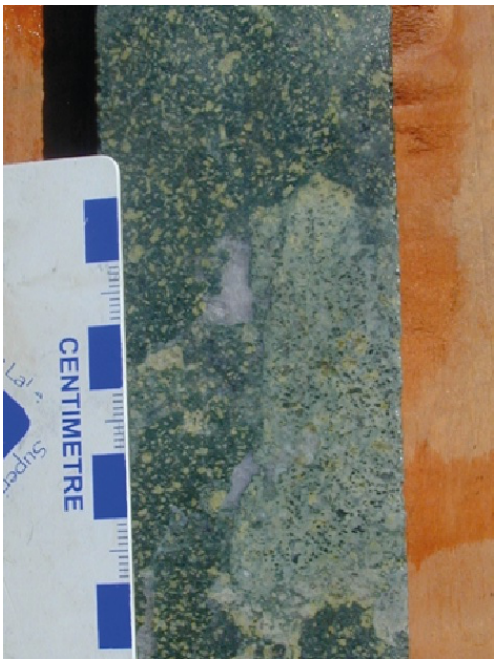
Key questions to be addressed in this research include: (1) Can district-scale detrital sampling give us deeper insights into the long-term temporal evolution of arc magmatic systems that generate fertile porphyry ore systems? (2) What are the characteristics of drainage minerals downstream of superior value mineralisation as opposed to smaller and less economic occurrences? (3) Can the effects of anthropogenic and mining related disturbances be compensated for during down-stream sampling? (4) What is an optimised workflow for drainage sampling, preparation and analysis to ensure that representative populations for key indicator minerals are obtained?

METHODS An initial literature review of igneous accessory mineral and propylitic mineral chemistry in porphyry systems will compile data on the scale, mineralogical zonation, geochronology and spatio-temporal mineral chemistry patterns. Fieldwork will involve mapping and sampling of igneous units and propylitically altered rocks in the selected case study district, and sampling of key drainage catchments. Where necessary, intrusions will be

dated using zircon U-Pb LA-ICP-MS in order to pin key geological events. Both in situ and drainage samples collected from across the district will form the basis of subsequent mineralogical, geochemical and

geochronological analysis. Samples will be studied using conventional microscopy, hot cathode cathodoluminescence (CL) and electron beam instruments housed at the Natural History Museum (NHM) in order to establish mineral relationships, textures and chemistry. Analysis of minerals by automated (TESCAN TIMA) SEM, analytical SEM, microprobe and LA-ICP-MS methods (including LA-ICP-MS mapping) will determine the residence of major and trace elements. Dating of rock-hosted and detrital zircon, apatite, titanite and epidote will be done using U-Pb geochronology by LA-ICP-MS.

WIDER IMPLICATIONS The research will provide new insights into the multi-million year and district scale evolution of igneous complexes that produce economic porphyry-copper deposits. The project will be of direct and immediate benefit to the CASE partner's exploration programmes globally. There are currently few case studies that look at the incorporation of mineral chemistry into the assessment of detrital mineral assemblages, and none that look at samples from a holistic perspective (they typically focus on one or a couple of minerals). The study will also provide a template for equivalent work that must be completed for other mineralisation styles where drainage sampling could be used to accelerate the path to discovery.



Intense chloritic alteration of matrix of volcanic breccia with preferential replacement of plagioclase phenocrysts by epidote. Patches and irregular veins of anyhydrite are also observed. Sample approximately 3.7 km from the El Teniente porphyry Cu-Mo deposit, Central Chile.

STUDENT PROFILE We are looking for a well-qualified and highly motivated Earth Sciences/Geology graduate who wishes to carry out a cutting edge PhD in economic geology/mineralogy/geochemistry and gain experience in a range of mineralogical and geochemical analytical methods. Excellence in geochemistry and mineralogy are essential; experience of microanalytical techniques and statistical data evaluation, including data analytics such as machine learning methods, are desirable. A desire for involvement with the Imperial Student Chapter of the Society of Economic Geologists and outreach activities will be beneficial.

TRAINING The successful student will join the London Centre for Ore Deposits and Exploration (LODE) research group in the attractive environment of South Kensington, London, that includes researchers from University College London, Imperial College London and the Natural History Museum. The student will have the opportunity to work in the state-of-the-art analytical suite at the NHM. The student will receive training in field mapping, core logging and sampling, detrital mineral sampling, laboratory best practice, mineral separation, SEM techniques, laser ablation ICP-MS instrumentation and analysis, geochronological methods, data reduction and statistical analysis. Attendance and presentation of results at major UK and international conferences will be supported in the research programme. All postgraduates have access to transferable skills workshops at UCL and additional professional development and public engagement opportunities at NHM. Attendance at regular seminars on ore geology, geochemistry and the wider Earth Sciences is required.

FUNDING Funding for the project scholarship will be via a successful application by the student to the NERC SSCP DTP, NERC TARGET Mineral Resources CDT or other scholarships programme at Imperial College London.

Additional research funding will be provided by the project partner. Applications for further support for conference and workshop attendance will be made to the Society of Economic Geologists student grant program.

FURTHER INFORMATION If you are interested in the project and would like to have further details please contact Jamie Wilkinson at j.wilkinson@nhm.ac.uk

REFERENCES

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, p. 357-381.

COOKE, D.R., BAKER, M., HOLLINGS, P., SWEET, G., CHANG, Z., DANYUSHEVSKY, L., GILBERT, S., ZHOU, T., WHITE, N., GEMMELL, J.B., AND INGLIS, S., 2014b, New advances in detecting the distal geochemical footprints of porphyry systems - Epidote mineral chemistry as a tool for vectoring and fertility assessments, in Kelley, K.D., and Golden, H.C., eds., Society of Economic Geologists, Special Publications, v. 18, p. 127-152.

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, 107-119.

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. https://doi.org/10.1007/s00410-020-01766-1

WILKINSON, J.J., CHANG, Z., COOKE, D.R., BAKER, M.J., WILKINSON, C.C., INGLIS, S., CHEN, H., AND GEMMELL, J.B., 2015, The chlorite proximitor: A new tool for detecting porphyry ore deposits: Journal of Geochemical Exploration, v. 152, p. 10-26.

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, 67-77. https://doi.org/10.4095/306305.

WILKINSON, J.J., BAKER, M.J., COOKE, D.R. AND WILKINSON, C.C., 2020, Exploration targeting in porphyry Cu systems using propylitic mineral chemistry: a case study of the El Teniente deposit, Chile. Economic Geology, 115, 771-791. doi:https://doi.org/10.5382/econgeo.4738

http://www3.imperial.ac.uk/people/j.wilkinson

http://www3.imperial.ac.uk/earthscienceandengineering/research/lode