Department of Earth Science and Engineering, Imperial College London and Department of Earth Sciences, Natural History Museum

PhD Project 2023

Residence and mobility of metals in the alteration zones of porphyry ore systems

AIM To understand the processes of mobilization and fixing of metals during progressive alteration in porphyry ore systems and relate these to the evolution of hydrothermal fluid chemistry.

BACKGROUND Porphyry systems represent the world's principal source of copper and molybdenum and are major repositories of gold and silver. These deposits originate from huge volumes of metal-bearing hydrothermal fluid that exsolved from crystallising crustal magma chambers. It is generally accepted that ore metals are derived from the magma at depth but the possibility exists that some components are leached from the host rocks during hydrothermal alteration. Furthermore, there is the likelihood that certain elements, including copper and molybdenum, that can be fixed in early hydrothermal alteration phases, may be remobilized during later alteration stages.

Isotopic evidence shows that magmatic Pb has been added to the alteration selvages of porphyry stage veins at Butte (Dilles & Kent, 2005) indicating that Pb may be fixed in early K-feldspar and/or biotite. Fluid inclusion compositional data from a number of porphyry systems suggests that Pb, Zn, Mn and Li are lost from fluids involved in copper deposition, implying that they are fixed in potassic and/or phyllic alteration phases. Later remobilization of Pb and other elements such as Zn and Mn would appear to be a prerequisite for development of the overprinting polymetallic vein systems that are observed in some porphyry systems, such as Butte. Release of elements such as Mn (and Li) will be favoured by acidic oxidising conditions, whereas large, highly charged elements (Mo, Sb, Ta, Nb) are more likely to be liberated by acidic, reducing conditions (Eugster, 1985), and potentially derived from the breakdown of magnetite which can sequester these metals. Remobilized elements may be redeposited down the flowpath associated with cooling and further reactions in a complexly evolving chemical system.

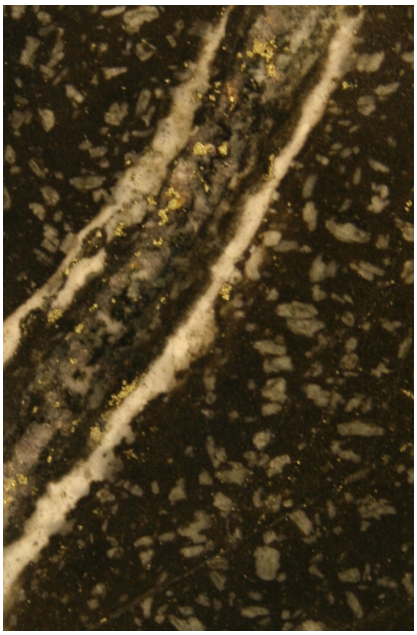
View of the giant open pit at the Bingham porphyry-copper deposit, Utah, USA

OBJECTIVES In order to understand the ultimate distribution of metals it is necessary to determine the mineralogical residence at each stage of alteration and to quantify the bulk element transfers in successive alteration steps. The corresponding behaviour of the fluid, which in a simple model may be expected to be inverse to changes experienced by the rock, can be tracked by the analysis of fluid inclusion compositions.

METHODS An initial literature review of alteration in porphyry systems will compile data on compositions of different alteration minerals and typical element dispersion patterns. Samples from existing suites plus additional sample collection in the field from specific alteration domains will form the basis of subsequent mineralogical and geochemical analysis. Samples will be studied using conventional microscopy, cathodoluminescence (CL) utilising the new CL-microscopy laboratory at Imperial College, and electron beam instruments housed at the Natural History Museum (NHM) in order to establish mineral assemblages and paragenesis. Whole rock geochemistry of major, minor and trace elements will be used to determine, quantitatively, the element transfers associated with successive alteration steps. Analysis of minerals by analytical SEM and laser ablation ICP-MS methods will determine the residence of major and trace metals and link metal fixing and release to specific mineral reactions.

WIDER IMPLICATIONS The research will provide new insights into element mobility in porphyry hydrothermal systems and establish the importance of metal sources and recycling in the evolution of porphyry ore deposits. New data on the mineralogical residence of trace metals such as As and Bi will be of relevance to mitigating problems associated with the presence of penalty elements in porphyry ores and to the wider understanding of trace element distributions in the Earth's crust.

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/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 are desirable. A desire for involvement with the Imperial Student Chapter of the Society of Economic Geologists and outreach activities will be beneficial.



Early biotite – chlorite – quartz vein containing minor chalcopyrite with plagioclase halo in porphyritic andesite host rock, El Teniente, Chile.

TRAINING The successful student will join the LODE research group in geochemistry and ore formation in the attractive environment of South Kensington, London, that includes researchers from 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 core logging and sampling, laboratory best practice, SEM techniques, laser ablation ICP-MS instrumentation and analysis, sample digestion and wholerock geochemistry , data reduction and statistical analysis methods. Attendance and presentation of results at major UK and international conferences will be supported in the research programme. All postgraduates in the Department of Earth Science and Engineering have access to workshops organised by the Graduate School of Engineering and Physical Science which include: personal organisation and effectiveness; thesis writing and completing the PhD; technical writing; teamwork; professional issues in science; research ethics; and presentation skills. There are also optional courses in career planning, IT skills, media and entrepreneurship. Attendance at regular seminars on ore geology, geochemistry and the wider Earth Sciences is compulsory.

FUNDING Funding for the project will be via a successful application by the student to the Imperial College London or Departmental scholarships programmes. Applications for additional 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

Dilles, J.H. and Kent, A.J.R., 2005. Isotopic Evidence for the Multiple Sources of Lead in Porphyry Cu - Mo and Base Metal Lode Ores at Butte, Montana. Geological Society of America Annual Meeting, Salt Lake City, Abstracts with Programs, 37: A315.

Eugster, H.P., 1985. Granites and hydrothermal ore deposits: a geochemical framework. Mineralogical Magazine, 49: 7-23.

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

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