PUBLIC CUSTOMIZED TRAINING COURSE ON
The chain of processes forming porphyry-type and epithermal ore deposits

The **International School for Geoscience Resources** of KIGAM presents an intensive training course on **the chain of processes forming porphyry-type and epithermal ore deposits** led by Christoph A. Heinrich from ETH Zurich, Switzerland. The course will take place at the Ara room of International School for Geoscience Resources of KIGAM in Daejeon (Korea) in **17th-20th of August, 2015** and will include the following topics.

Topics	Date	Instructor
Day 1. Outline, rock samples and geology Topic 1. Magmatic-hydrothermal resources Topic 2. Geology of porphyry Cu-Mo-Au Topic 3. Practical study of ore samples	Aug. 17	Prof. Christoph A. Heinrich (ETH Zürich, Switzerland)
Day 2. Lithosphere scale processes Topic 1. Large scale tectonics Topic 2. Generation of fertile magmas Topic 3. Recognissing fertile magmas	Aug. 18	
Day 3. Sub-solidus fluid evolution Topic 1. Magma evolution and ascent Topic 2. Fluid-producing magma chambers Topic 3. Making an effective ore fluid	Aug. 19	
Day 4. Alteration and ore metal precipitation Topic 1. Fluid ascent and phase separation Topic 2. Alteration & Cu-Mo-Au precipitation Topic 3. Synthesis: porphyry to epithermal	Aug. 20	

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Ministry of Science, ICT and Future Planning

COURSE INFORMATION

Agenda

- With this interactive course, I wish to explain at the state of current research in my group and worldwide, how the chemical elements that eventually become enriched in an economic ore deposits can be followed through a chain of geological – geochemical processes. These processes overlap in time and in space, but occur at very different scales: from million years and lithospheric scale, to days or less at the scale of small veins and contained fluid inclusions.
- An active course with student interaction and practical exercises using rock samples and thin sections (if possible).

Course Covered

- The course will focus on basic science, in particular geochemistry and hydrothermal reactions, but will include some practical exercises with rock samples and (if possible) some microscopy exercises.
- The contents follow the process chain, leading from lithosphere-scale preparation of ore-foring provinces to the precipitation of high-grade ores in veins.

Course Requirements: Prerequisite

- Geological background at MSc level, recognition of rocks and minerals and general background of tectonics, magmatism, ore types.
- Knowledge of basic chemistry: balancing stoichiometric reactions, understanding the concept of an equilibrium constant, reading a phase diagram.
- Bring along hand-lens, scratcher, any own samples you would like to discuss

Who should Attend?

- Any geoscientist interested in basic process of magmatic-hydrothermal ore formation and is happy to participate actively in class communication.

Summary of topic contents and learning objectives

Learning objectives:

- Recognize and interpret ore-forming processes in hand samples.
- Understand the processes that contribute to metal enrichment mainly along active plate margins, from lithosphere dynamics through magma evolution, fluid separation, sub-solidus fluid evolution, and alteration and mineral precipitation by interaction of magmatic fluids with country rocks and the hydrosphere.
- Understand to use simple chemical concepts like equilibrium constants to predict behaviors of ore-forming fluids.
- Understand connection to active volcanism and geothermal processes.
- Obtain an insight into modern research approaches including field mapping, analytical techniques and simple chemical thermodynamics.

Day 1. Outline, rock samples and geology

On the first day we will start by introducing the economic significance of magmatic-hydrothermal systems, and then describe the basic geological features of porphyry – epithermal systems worldwide. We will look in groups at rock samples that I will bring along, sample we hopefully will collect during the preceding field trip with Dr. J. H. Seo, and samples that he has in his collection at Inha University.

Day 2. Lithosphere scale processes

We will discuss the plate-scale prerequisites that generate the right tectonic conditions for partial melting and formation of fertile magmas, using empirical observations of the provinciality of ore deposits and the relatively restricted metallogenic epochs that generated them. After learning about the geochemical criteria for recognising fertile porphyry copper and gold magmas, we will discuss the conditions of magma ascent that will favour the formation of large but non-erupting magma chambers in the upper crust. Presenting the role of magmatic sulphides, using Alumbrera Bingham as examples, is the basis for understanding fluid exsolution and the transfer of chloride, sulfur and metals to make an effective ore fluid.

- **Day 3. Sub-solidus fluid evolution**

  After an introduction into the principles of fluid inclusion study, I hope to do a practical exercise of looking at fluid inclusion sections in the microscope (or alternatively do it with photomicrographs). With this I show the participants the evidence for fluid phase separation as a key process in the evolution of magmatic fluids on ascent from a magma chamber to the surface. A key message is that simple petrographic observation of fluid inclusions allows depth estimation. Depth in turn predicts the selective precipitation of Cu and Au and even allows prediction of the likely Au/Cu ratio of porphyry-type ore deposits. This requires understanding NaCl – H2O fluid phase diagram, which I will introduce with exercises.

- **Day 4. Alteration and ore metal precipitation**

  Study hydrothermal alteration, hopefully again in thin section, and achieve a basic undertanding of the relationship between hydrothermal alteration of wall rocks and precipitation of ore mineral in veins. Use tin deposits as starting example, then progress to porphyry copper ± molybdenum ± gold, with Bingham Canyon as type example. Geology of epithermal ore deposits and their two main types defined by alteration and fluid chemistry. Conclude by integrating ore-forming systems from magma chamber though porphyry deposits to epithermal ore deposits, all driven by magmatic fluids interacting with meteoric fluids that mainly act as cooling mechanism. Discuss time scales of ore formation, emphasising complementary role of geochronology and physical modelling of fluid & heat transfer. Outlook to exploration applications, general discussion, feedback by participants.

About the instructor – *Prof. Christoph A. Heinrich*

Chris Heinrich is Professor of Economic Geology at ETH Zurich, since 1994, after an early research career in Australia. His teaching and research concentrates on fluid processes in the Earths interior, including metamorphic fluid generation, ore-formation by magmatic fluids, and mass and heat transfer in deep geothermal systems. He leads the Fluids and Mineral Deposits group at ETH Zurich, which is particularly known for pioneering fluid inclusion micro-analaysis, for modeling chemical and hydrological processes in ore-forming hydrothermal systems, and for high-precision geochronology. These lab studies complement quantitative field-geological obsevations, commonly made in cooperation with international mining companies. Further information including group publications see http://www.geopetro.ethz.ch/research/orefluids

A synopsis of this course and its philosophy is contained in the magmatic-hydrothermal section of the following review paper:

Heinrich CA, Candela PA (2014) Fluids and Ore Formation in the Earth's Crust. In: Holland H.D. and Turekian K.K. (eds.) Treatise on Geochemistry, Second Edition, vol. 13 (S. D. Scott, ed.), pp. 1-28. Oxford: Elsevier.