Short course SC6: Porphyry copper-gold deposits in the circum-Pacific and elsewhere

Presenter

Steve Garwin, email: sgar@iinet.net.au

Date: Saturday 6 April – one-day; 9:00 am - 5 pm

Short course description

This workshop will consist of two major parts. The first describes the tectonic and regional controls to copper and gold mineralization in the circum-Pacific region with a focus on the magmatic arcs of Southeast Asia, Western Pacific, Peruvian Andes and Ecuador. The relationships of mineralization to subduction-slab geometry, varying deformational styles, cross-orogen structures, heat- and fluid-flow focussing mechanisms and other controls will be discussed.

The second part of the course will present the geological setting, geochemical signature and geophysical expression of porphyry copper-(gold) systems on the district-scale and provide several global examples. This presentation will cover the key geological ingredients and physical constraints that make for productive porphyry systems. General geochemical zoning, hydrothermal alteration models and geophysical signatures will be presented. Examples from continental and island arc settings will include deposits formed from oxidized magmas in Indonesia, Ecuador and elsewhere, and more reduced magmas in Nevada, with comparisons drawn to the intrusion-related gold deposits in Alaska-Yukon. Exploration models will be discussed for porphyry deposits in different geological settings, erosion levels and weathering environments.

Course Presentation Components:

1. Tectonic and regional controls to copper and gold mineralization in the circum-Pacific;
2. General description of geology, geochemical expression and geophysical signatures of porphyry deposits, including an introduction and examples of oxidized systems — Batu Hijau and Elang, Indonesia;
3. More examples of oxidized systems – Alpala - Cascabel, Ecuador; Kharmagtai, Mongolia and Bajo de la Alumbrera, Argentina
4. Examples of reduced systems – Elder Creek and Fortitude, Nevada and comparison to intrusion-related gold deposits (IRGD) in Alaska, USA and the Yukon, Canada

Steve Garwin

Steve has more than 30 years of experience as an exploration geologist with large and small mining companies. He has participated in the gold and copper projects of more than 26 clients in over 16 countries. He worked with Newmont Mining for ten years, including two years as Chief Geologist in Nevada. Steve is a fellow of the Society of Economic Geologists, fellow of the Australian Institute of Geoscientists and a fellow of the Australian Institute of Mining and Metallurgy.

Steve is one of the leading authorities on porphyry, epithermal and Carlin-style mineralization in the circum-Pacific region. He has been involved in several, major exploration and mining projects, including the Batu Hijau porphyry mine in Indonesia, the mines of the Carlin and Battle Mountain Trends in Nevada, and the recently discovered world-class Alpala porphyry deposit in Ecuador.

Steve is an independent consultant based in Perth, Australia. He obtained his B.Sc. in geology from Stanford, M.Sc. from the University of British Columbia and Ph.D. (distinction) from the University of Western Australia. He is an adjunct research fellow at the Centre for Exploration Targeting at UWA. Steve is chief technical advisor to SolGold Plc. (SOLG:L and SOLG:TSX-V) and technical advisor to Japan Gold Corp (JG:TSX-V).

Included:
- Morning and afternoon tea, coffee and accompanying snacks
- Electronic version of speaker’s presentation and hard-copy print outs of presentations.

Not included:
- Lunch (bring your own lunch or purchase during the 1 hour lunch break)

Minimum number of participants: 15

Cost: To be notified. Cost includes morning and afternoon coffee/tea, but not lunch.

Further information: Email Steve Garwin at sgar@iinet.net.au
Regional Controls, Geology, Geochemical Signature and Geophysical Expression of Porphyry Systems

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Grasberg open pit (circa 1995)

Post-meeting short course - PACRIM 2019
Auckland, New Zealand 6th April 2019

SE Asia – W Pacific Tectonic Elements, Cenozoic Magmatic Arcs and Large Gold and Copper Deposits with Sea-floor Bathymetry and DEM

Garwia, (2013)
**Indonesian Region – Tectonic Elements**

- Greater than 10 M Oz Au Resource
- Greater than 5 M Oz Au Resource

**INTRUSION-RELATED MINERALIZATION & TECTONICS**

Crustal-scale arc-transverse fault system occurs in the arc above a kink, or tear, in the subducting slab.

Rapid rise of asthenospheric melts and efficient release of mineralizing fluids at high crustal-levels.
Historic views of magma-chamber geometry

After Jon Blundy, Bristol (Seminar at ETH Zürich, July 2017)

The old view?
"Magma Chamber"

Specific physical requirements?

The modern view?
"Trans-crustal Mush"

Fluid & metal dispersion is the rule

ETH Thermis, 2017
Vertical geochemical dispersion model in porphyry Cu-(Mo-Au) systems

Summary of MDRU-study (Cohen, 2011 and Halley et al., 2015)

There is a consistent element distribution in global porphyry systems. Local discrepancies in metal sequence may reflect late argillic overprints or varying H2O:CO2:S proportions of the ore fluid. Distribution of Au-Ag varies and is partially controlled by oxidation / sulfidation state, temperature and metal complex speciation.
Alpala – Cascabel, northern Ecuador
Section Interpretations – Geology and Mineralization

Cross-section 82950 m N, showing geological interpretations, copper-equivalent shells of 0.9% and 0.3% and molybdenum in drill-core (window ± 50 m) as of June 2018

Garwin et al., 2018

Alpala - Cascabel vein types

Photographs of drill-core from the Alpala deposit: a) Prismatic quartz showing unidirectional solidification texture (UST), cut by a chalcopyrite-rich C-vein, b) intrusive contact between late Q020 and early D10, showing truncation of early B-veins and a late CD-vein that cross-cuts the contact, c) Chalcopyrite vein and late-stage bornite along fracture surface, d) Magnetite-bearing B1 quartz vein stockwork with clots of chalcopyrite (cp), e) late-stage pyritic D-vein with selvage of quartz-sericite.

Garwin et al., 2017
Battle Mountain District, Nevada
Geology, Deposits and Metal Inventories

- Unconsolidated deposits (Quaternary)
- Rhyolite rocks (Penstock)
- Late-alpine plutonic rocks (Pine). M aps, to up to 0.06 g/t Au and 0.04 g/t Ag
- Geologic deposits (esp. chalcopyrite): locally distributed of 0.18-1.0 g/t Cu and 0.10-0.50 g/t Au
- Schist and metamorphic rocks (Penstock)
- Contact: high-grade orebody (kinked and folded)
- South: orebodies (kinked and folded)
- Fault: high-grade orebodies (kinked and folded)
- North: orebodies (kinked and folded)
- South: orebodies (kinked and folded)
- Middle: orebodies (kinked and folded)
- South: orebodies (kinked and folded)
- North: orebodies (kinked and folded)

District Total: > 25 Moz Au & 2.0 Blls Cu
(70% past production + current resources)
Southern Lewis Property - Nevada
View to the north from the Fortitude open-pit

Battle Mountain Gold, 2016

Looking northwards into the southern part of the Lewis property from the Fortitude open-pit. The approximate claim boundary (BMG / NMC), historic Buena Vista Mine, Fortitude dump and major faults are indicated. The top of the Antler Limestone, which lies beneath the Golconda Thrust and hosts the upper part of the Fortitude Au-Ag-Cu deposit, is also shown.

Tintina Gold Province Deposits
Hart (2007)

Figure 1. Distribution of the Tintina Gold Province (TGP) across Alaska and Yukon as shown in yellow. Individual Au deposits (large circles), notable occurrences, and those mentioned in the text (small circles) are shown. Not all Au mineralization in the TGP represents Rb-Sr. Gold deposits and occurrences considered to be Rb-Sr are shown in red, those that are ambiguous or controversial in origin are highlighted in black, and those dominated by W, but associated with the same geologic event as Rb-Sr, are shown in purple. The Rb-Sr half value of the Tintina Gold Belt (shown as pink) underlies central Yukon; its western extent has been offset along the Tintina Fault and displaced to its present location, where it forms part of the Faribanks district. Notably, the TGP is composed of numerous different Au districts with varying deposit types and ages of mineralization, but reduced strain-related Au systems are mostly limited to the Tintina Gold Belt. Ph = Fairbanks, D = Dawson, M = Mayo, W = Whitehorse.