

## Fluid evolution at the Bingham Cu-Au-Mo-Ag porphyry deposit

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The Bingham Canyon Cu-Au-Mo porphyry deposit (Utah) is one of the largest and best exposed magmatic-hydrothermal orebodies in the world. Intimately related intrusive and hydrothermal veining events, the timing of mineralization and the distribution of the copper-gold-molybdenum ore over a 2 km vertical section are well established. Our current research collaboration aims at understanding the relative importance of magmatic and hydrothermal processes in controlling the metal budget of this and other large porphyry-style ore deposits.

Fluid inclusions are studied by microthermometry and Laser-Ablation ICPMS analysis. Detailed petrographic mapping with the help of cathodo-luminescence imaging allows textural correlation between successive quartz generations, sulfide deposition and fluid inclusion assemblages. Inclusions trapped in quartz veins in the deep parts of the system record a single-phase CO<sub>2</sub>-bearing fluid of intermediate salinity (2–7 wt% NaCl eq.) and near-critical density (homogenizing around 370 °C), containing ~8000 ppm Cu. This intermediate-density fluid may represent the most pristine magmatic fluid. On ascent to shallower parts of the deposit, this fluid underwent phase separation to a CO<sub>2</sub>-rich vapor phase and a brine phase. Phase separation occurs approximately 400 m below the base of the high-grade copper-gold orebody, and temporally prior to copper precipitation. Copper-rich brine inclusions (over 10'000 ppm Cu and salinities >45 wt% NaCl eq.) homogenize around 400 °C. Brine inclusions trapped after chalcopyrite and bornite precipitation homogenize around 350 °C, have salinities between 38 and 43 wt% NaCl eq., but low copper concentrations of ~1'000 ppm. These inclusions are considered as samples of the 'spent' ore fluid.

Ongoing studies examining samples from the entire deposit aims at a better understanding of the fluid-compositional evolution in space. Quantitative understanding of fluid evolution paths should clarify the relative importance of input composition of fluids and their magma source (Ulrich et al. 1999; Halter et al., this Issue), and of the precipitation mechanisms at the deposit scale (Simon et al. 2000) — the two currently debated factors that may control metal ratios in porphyry-style ore deposits.

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## Controlling Arsenic Concentrations in Buried Uranium Mill Tailings

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At the McClean Lake Mill in northern Saskatchewan Canada, grinding, acid leaching and oxidizing the uranium ore produces high As concentrations (140-2400 mg/l) in resultant acid raffinate solutions. Extensive study shows that As levels can be reduced to <2 mg/L if the molar Fe/As ratio of the raffinates is increased (if necessary) to about 3 by adding ferric sulfate before lime addition to attain a nominal pH of 8 (cf. Langmuir et al., 1999). With increasing pH most of the As in raffinates precipitates in poorly crystalline Al scorodite (approx. Fe<sub>0.9</sub>Al<sub>0.1</sub>AsO<sub>4</sub>·2H<sub>2</sub>O) and annabergite (approx. Ni<sub>2.3</sub>Mg<sub>0.7</sub>(AsO<sub>4</sub>)<sub>2</sub>·8H<sub>2</sub>O). In ten-month aging tests the amount of Al scorodite increased with time while the amount of annabergite decreased. Consistently, solution analyses showed Ni increasing from 1 to 3 mg/L, whereas As declined from 4-6 mg/L at 5 months to 1-2 mg/L after 10 months. A separate study indicated that adsorption is a minor sink for arsenic: only ~0.2% of total As was exchangeable.

Government regulators have questioned whether the lab results for As would be borne out in the Tailings Management Facility. In June 2001, after two years of operation, tailings and pore waters were sampled from six bore holes in the TMF. With increasing depth (and tailings age) As concentrations peaked at <5-6 mg/L at 10 ft, decreased to <2 mg/L at about 35 ft and to ~1 mg/L at 65 ft depth. Crystalline Al scorodite had a saturation index (SI) of +0.21-0.97, whereas the SI for annabergite was -7.64-1.14, probably reflecting crystallization of Al scorodite at the expense of dissolving annabergite. Al scorodite is thermodynamically stable in the TMF relative to hydrous ferric oxide which remains amorphous and has an apparent pK<sub>sp</sub> of 35.8.

### Reference

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