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Boiling, condensation and vapour contraction in magmatic-hydrothermal Cu-Au ore systems

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A re-assessment of phase stability relations in the salt-water fluid system [1] combined with thermodynamic modelling of minor solutes based on fluid inclusion microanalyses [2] and a comprehensive new experimental data set for gold solubility across a large pressure and temperature range [3,4] indicate that very high concentrations of gold can be efficiently transported from magmas through porphyry-style ore deposits to sites of high-grade gold enrichment in epithermal deposits. The key physical process is the *contraction* of a magmatic vapour phase to an aqueous liquid. This process can be achieved, without crossing of any phase boundary, by fluid cooling in a confined pressure environment, possibly near the lithostatic – hydrostatic interface. An essential chemical requirement for concentrated gold transport is an excess of sulphide over copper and iron in the low-salinity magmatic fluid. This chemical requirement can best be met by initial *condensation* and physical separation of some Fe-K-Na-chloride rich brine from the vapour, before this Fe-depleted but sulphur (H₂S, SO₂) enriched low-salinity fluid cools and ascends to the epithermal deposit. Fluid inclusions show that the process of brine condensation is ubiquitous in porphyry deposits. Acid neutralisation by feldspar destructive alteration further helps maintaining high gold concentrations in the fluid, up to several ppm, indicating that the common quartz – sericite – pyrite veins in many porphyry deposits are the likely gold-transporting fluid pathways towards epithermal gold deposits.

Fluid modelling and published field observations lead to a simple geological model that links porphyry-style and epithermal ore deposits to the cooling of a hydrous magmatic pluton as their common fluid source. As the magmatic systems cools, the melt interface and surrounding isotherms retract downward, while fluid exsolution continues. This shifts the region of brine – vapour coexistence to increasing depth and leads to the typical, ‘telescoped’ overprinting of porphyry-style ores by epithermal veins.

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