The transport of metals through hydration in aqueous vapour-like fluids: Insights from quantitative modelling applied to porphyry Cu-Au-Mo deposits*

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The hypothesis that metals are transported by low- and intermediate-density aqueous fluids of magmatic origin to sites of ore deposition in many porphyry Cu-Au-Mo ore-forming systems is supported by fluid and vapor inclusion data. Recent experimental investigations have shown that metal fugacity increases with increasing water fugacity (i.e., density) due to the formation of hydrated gaseous metallic species, and that there is a solubility continuum between vapor- and liquid-like supercritical fluids. These experiments were carried out in batch-type Ti and Hastelloy autoclaves at temperatures between 300 and 500 °C and pressures up to 420 bar. Thermodynamic data derived from the experiments were used to model the transport and deposition of Au, Ag, Mo, and Cu by vapor and low- to intermediate-density supercritical fluids in the context of porphyry Cu-Au-Mo and epithermal Au-Ag ore formation using the GEM-Selektor software package. A major advantage of the new data set is that it allows for temperature- and pressure-dependent modeling of metal solubility in aqueous vapors at a variety of conditions important to understanding magmatic-hydrothermal systems, in which extreme pressure fluctuations are common.

The results of this modeling show that there is a strong compositional control (i.e., redox potential, sulfur and HCl content) on the Au/Mo ratio of the parental ore fluid, which can explain Au-Mo zonation in porphyry-epithermal deposits and the formation of Au-rich and Mo-rich porphyry deposit sub-types. High concentrations of gold are favored by high sulfur content, high contents of Ag by high HCl concentration and high contents of Mo by low sulfur content and intermediate density. The solubility of MoS_2 and Ag_2S is prograde with temperature and pressure, whereas gold/electrum solubility reaches a maximum between 320 and 450 °C. The deposition of molybdenite, argentite, and electrum leads to a zonation comparable to the metal zonation observed in Cu-Au(-Mo) porphyry deposits, where Au precipitates around the boiling/condensation horizon partially overlapping the deeper, higher temperature Mo ore shell. During cooling and decompression of a low-density magmatic fluid, phase separation occurs around 340 °C. At the onset of condensation Au and Mo partition preferentially into the vapor (90 mol%) and silver partitions into the liquid (10 mol%). In the case of a moderately saline fluid, in which the liquid fraction (40-50 mol %) equilibrates with the host rock causing pH neutralization and SO_2 and CO_2 to be sequestered into secondary minerals (anhydrite, calcite, etc.), Au, Mo and Ag partition preferentially into the liquid. The former helps explain ore formation in a high-sulfidation epithermal environment, in which the metals and volcanic acids (HCl, H_2S, CO_2) are transported there by the vapor from the deeper porphyry environment. Low-sulfidation epithermal ore formation, in contrast, is satisfactorily explained by the latter case, in which the metals are mobilized upwards by the liquid after fluid mixing and extensive fluid-rock interaction at depth.