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Constraints of depth on hydrothermal fluid evolution in porphyry deposits

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Formation depths of porphyry-Cu (Mo-Au) deposits are typically inferred to be in the range of 1 to 6 km, although root zones of these hydrothermal systems show porphyritic intrusions merging down into the porphyritic copula at depths of over 10 km. The permeability of the brittle crust is capable of maintaining hydrostatic pressure at up to 10 km deep or more over the times scales of 10 to 1000 years, allowing for fluid circulation, vein formation, wall rock alteration, and potential ore-mineralization at depths of up to 9 km. Coexisting halite-bearing and vapor-rich fluid inclusions are observed in most porphyry systems, indicating that the evolution paths of hydrothermal fluids overlap largely with the fluid unmixing domain in the H_2O-NaCl (-CO_2) system. However, deep veins in some systems, that form at depths greater than 5 to 6 km lack unmixed fluid inclusion populations and are dominated by single-phase low-salinity (sometimes CO_2-bearing) fluids (e.g., Trout Lake, British Columbia; Butte, Montana; Dabaoshan, China). Therefore, formation depth of a porphyry ore system exerts significant control on hydrothermal fluid properties, evolution, and mineralization zonation in porphyry-type ore deposits.

Pressure decreases that trigger fluid unmixing in porphyry systems can occur either by fluid ascent, or by the transition from lithostatic pressure to hydrostatic pressure during which the loss of >60 % of pressure can be obtained. However, the relative contribution of either trigger is not well documented in most porphyry systems. We have conducted a comprehensive comparison of fluid evolution in porphyry deposits formed at various depths. Combined with the numerical simulation, we conclude: 1) for porphyry deposits formed at <2 km, fluid ascent is capable of breaching the V-L surface of the H_2O-NaCl (-CO_2) system and triggering fluid unmixing even under lithostatic pressure; 2) for porphyry deposits formed at 2~5 km, fluid ascent is not capable of triggering fluid unmixing under lithostatic pressure, instead, the transition from lithostatic pressure to hydrostatic pressure is required to provide sufficient pressure drop for hydrothermal fluid to breach the V-L surface; and 3) for porphyry deposits formed at depth greater than 5 or 6 km, the occurrence of hydrostatic pressure is transient, especially in the early high-temperature stage. Therefore, the extent of fluid unmixing is limited and the single-phase low-salinity (sometimes CO_2-bearing) parental magmatic fluids dominate in these deep deposits.