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LMCE-Mediated Nanoscale Au-Ag Enrichment in Magmatic-Hydrothermal Porphyry Systems

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Porphyry copper systems host approximately 20% of global gold and significant silver production. In subduction-related settings, high fO_2 suppresses early sulfide saturation, allowing chalcophile metals to remain in the melt until halogen-rich fluids sequester and buoyantly transport them. While this model explains large-scale enrichment, it does not resolve microscale Au–Ag concentrations, particularly the enrichment role of low-melting chalcophile elements (LMCEs).

The Late Triassic Pulang and Lannitang porphyry Cu–Au deposits in the Zhongdian terrane, SW China are compared. Although both formed in a similar subduction setting, Pulang represents a deeper preserved structural level of the magmatic–hydrothermal system, whereas Lannitang represents a shallower and more strongly overprinted level.

At Pulang, Au nuclei (~1 nm) occur within rooseveltite and abundant gold nanoparticles (AuNPs, ~3–10 nm) within arsenopyrite. These AuNPs, initially metastable, later coalesce into stable, well-structured crystals, contributing to gold nugget formation; this process is driven by surface energy minimization and involves repeated aggregation and coarsening. These gold nanoparticles are spatially associated with diverse LMCE-bearing minerals, suggesting that LMCEs played a key role in scavenging and stabilizing gold at high-T close to the magmatic–hydrothermal transition. Silver shows a greater affinity for Te and Bi, forming hessite, volynskite, and associations with native bismuth, tetrahedrite–Zn, and galena. Although direct evidence of LMCE melts is lacking, the intimate association with LMCE minerals strongly implies that they mediated gold and silver enrichment at the nanoscale.

In contrast, Lannitang records stronger late-stage hydrothermal overprinting. Although early magmatic fO_2 was similarly high, deeper emplacement and extensive wall-rock interaction (hornfels and carbonate host rocks) facilitated remobilization of precious metals. Gold occurs as native grains in hornfels, suggesting liberation from earlier hosts during late fluid circulation. Silver is mainly present in tetrahedrite–Zn and cosalite with subeconomic grades.

We propose that LMCE-bearing phases act as nanoscale metal sinks during the magmatic–hydrothermal transition, locally enhancing Au–Ag concentration. However, preservation of this early enrichment depends on subsequent evolution: deeper preserved and sustained oxidizing conditions favor preservation, whereas shallower levels with stronger overprints experience redistribution. LMCE-mediated enrichment and subsequent preservation are critical for significant Au–Ag accumulation.