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Gold and Copper Fertility in Porphyry Systems: Insights from Sulfide Inclusions

Ariadni A. Georgatou[1], Massimo Chiaradia[1], Andreas Audétat[2], Frances Jenner[3], Jung-Woo Park[4]
1. Earth and Environmental Sciences,University of Geneva, Geneva, Switzerland, 2. Bayerisches Geoinstitut, Universität Bayreuth, Bayreuth, Germany, 3. School of Environment, Earth and Ecosystem Sciences, The Open University, Milton Keanes, United Kingdom, 4. School of Earth and Environmental Sciences, Seoul National University, Seoul, Korea

Although Cu and Au porphyry deposits show similar mineralisation and alteration styles, they occur in different geodynamic situations, with Cu porphyries being mostly associated with subduction arc-magmas and Au-porphyries with post-collisional settings. As a result, both porphyry types are characterised by fundamental differences regarding the petrogenesis, geochemistry, and fertility of the associated magmas. A recent study shows that while Cu-rich deposits linked to high calc-alkaline magmas require large volumes of hydrous magmas to form, Au-rich porphyry deposits associated with alkaline rocks form due to a more efficient Au precipitation. Moreover, magma fertility in porphyry deposits has also been attributed to remobilization, assimilation, and dissolution of sulfide-rich cumulates stored at depth, leading to the release of metals in the later exsolving hydrothermal ore fluid. In fact, studies looking at whole-rock PGE, Cu/Au, and Cu/Ag show that it is possible to determine the timing of sulfide saturation and thus to track the evolution of Cu and Au in the residual magmas.

We studied magmatic sulfides occurring in volcanic rocks from different geodynamic settings of barren and mineralised areas hosting Cu or Au porphyry deposits in order to investigate the role of magmatic sulfide saturation with respect to the fertility of the ore-forming systems. The volcanic areas investigated are the Ecuadorian volcanic arc including (among other volcanoes) Yanaurcu and Pichincha and hosting the Llurimaga Cu-rich porphyry, the Western Anatolian volcanic belt including Beydagi and hosting the giant Au-porphyry Kışladağ, and Konya volcanic belt, hosting the high-sulfidation Au epithermal deposit of Inlice and Doğanbey Cu porphyry. The findings are compared to Kula-Western Anatolia and Nisyros-Greece barren volcanic areas, representing intraplate and subduction geodynamic settings, respectively. Our results indicate that magmas from all areas underwent sulfide saturation independently of geodynamic setting, magma composition, and whether the system produced an economic deposit. In addition, while early saturating sulfides hosted by early crystallising phenocrysts are found in all study areas and are characterised by low Cu and Au abundances (EPMA-$Cu_{(med)}$ = 0.46 wt % and LA-ICP-MS-$Cu_{(med)}$ = 1.3 wt %, $Au_{(med)}$ = 0.089 ppm), late sulfides ($Cu_{(med)}$ = 32-56 wt %) hosted exclusively by magnetite are observed only in andesitic–dacitic and oxidised lavas of Yanaurcu, Pichincha, Beydagi, and Konya. $Cu/Ag_{(med)}$ values of sulfides (LA-ICP-MS) and whole rock (ID-ICP-MS) in Konya are 2,580-7,830 and 450-475, respectively, with the latter being representative of continental crust values (ca. 500). Lastly, PGE contents of whole rock confirm that all areas are extremely depleted, with $Pd/Pt_{(med)}$ of Konya and Beydagi being 1.61 and 1.53, respectively (compared to Pd/Pt = 7-60 for porphyry Cu-Au). These results suggest that all areas are characterised by similar and low initial Cu, Au, and PGE contents, with no pre-enrichment at the source needed, and show no correlation with the type and extent of mineralization. Regardless of the low metal contents caused by either early metal removal in sulfide-rich cumulates or metal-poor magma sources, "normal" magmas with "normal" chalcophile element contents are capable to form an economic deposit.