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Porphyry-Style Alteration and Mineralization of the Middle Eocene to Early Oligocene Andahuaylas-Yauri Belt, Cuzco Region, Peru

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Abstract

Originally known for its Fe-Cu skarn mineralization, the Andahuaylas-Yauri belt of southeastern Peru is rapidly emerging as an important porphyry copper province. Field work by the authors confirms that mineralization in the belt is spatially and temporally associated with the middle Eocene to early Oligocene (~48–32 Ma), calc-alkaline Andahuaylas-Yauri batholith, a composite body with an areal extent of ~300 × 130 km emplaced into clastic and carbonate strata (e.g., Yura Group and Ferrobamba Formation) of Jurassic to Cretaceous age. Batholith emplacement included early-stage, mafic, cumulate gabbro and diorite between ~48 and 43 Ma, followed by pulses of granodiorite and quartz monzodiorite at ~40 to 32 Ma. Coeval volcanic rocks make up the middle Eocene to early Oligocene Anta Formation, a sequence of >1,000 m of andesite lava flows and dacite pyroclastic flows with interbedded volcaniclastic conglomerate. Sedimentary rocks include the red beds of the Eocene to early Oligocene San Jerónimo Group and the postmineralization late Oligocene to Miocene Punacancha and Paruro formations. Eocene and Oligocene volcanic and sedimentary rocks are interpreted to have accumulated largely in both transtensional and contractional synorogenic basins. New and previously published K-Ar and Re-Os ages show that much of the porphyry-style alteration and mineralization along the belt took place during the middle Eocene to early Oligocene (~42–30 Ma). Thus, batholithic magma emplacement, volcanism, and sedimentation are inferred to have accompanied a period of intense deformation, crustal shortening, and regional surface uplift broadly synchronous with the Incaic orogeny. Supergene mineralization is inferred to have been active since the Pliocene on the basis of geomorphologic evidence and a single K-Ar determination (3.3 ± 0.2 Ma) on supergene alunite.

The belt is defined by 31 systems with porphyry-style alteration and mineralization, including 19 systems grouped in 5 main clusters plus 12 separate centers, and by hundreds of occurrences of magnetite-rich, skarn-type Fe-Cu mineralization. Porphyry copper stocks are dominated by calc-alkaline, biotite- and amphibole-bearing intrusions of granodioritic composition, but monzogranitic, monzonitic, quartz-monzonitic, and monzodioritic stocks occur locally. Hydrothermal alteration includes sericite-clay-chlorite, and potassic, quartz-sericitic, and propylitic assemblages. Calcic-potassic and advanced argillic alteration associations are locally represented, and calc-silicate assemblages with skarn-type mineralization occur where carbonate country rocks predominate.

Porphyry copper deposits and prospects of the belt range from gold-rich, molybdenum-poor examples (Cotabambas), through deposits carrying both gold and molybdenum (Tintaya, Los Chancas), to relatively molybdenum-rich, gold-poor end members (Lahuani). Gold-only porphyry systems are also represented (Morosayhuas). Gold-rich porphyry copper systems are rich in hydrothermal magnetite and display a positive correlation between Cu and Au in potassic alteration. The bulk of the hypogene Cu (-Au, -Mo) mineralization occurs in the form of chalcopyrite and bornite, in intimate association with early-stage potassic alteration which, in many deposits and prospects, is variably overprinted by copper-depleting sericite-clay-chlorite alteration.

Most porphyry copper systems of the belt lack economically significant zones of supergene chalcocite enrichment. This is due primarily to their relatively low pyrite contents, the restricted development of quartz-sericitic alteration, and the high neutralization capacities of both potassic alteration zones and carbonate country rocks as well as geomorphologic factors. Leached cappings are irregular, typically goethitic, and contain copper oxide minerals developed by in situ oxidation of low-pyrite, chalcopyrite (-bornite) mineralization. Porphyry copper-bearing stocks emplaced in the clastic strata of the Yura Group and certain phases of the Andahuaylas-Yauri batholith may develop appreciable supergene chalcocite enrichment in structurally and lithologically favorable zones.

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A model for the region suggests that the calc-alkaline magmas of the Andahuaylas-Yauri batholith and subsequent porphyry-style mineralization were generated during an event of subduction flattening which triggered the crustal shortening, tectonism, and uplift assigned to the Incaic orogeny. Shortening of the upper crust would have impeded rapid magma ascent favoring storage of fluid in large chambers which, at the appropriate depth in the uppermost crust, would have promoted large-scale porphyry copper emplacement. Geodynamic reconstructions of the late Eocene to early Oligocene period of flat subduction in the central Andes suggest that emplacement of the Andahuaylas-Yauri batholith took place at an inflection corridor in the subduction zone broadly coincident with the position of the present-day Abancay deflection. Similarly, evidence from southeastern Peru suggests that the Andahuaylas-Yauri belt may be continuous with the late Eocene to early Oligocene porphyry copper belt of northern Chile and that the process of subduction flattening in southern Peru also may have taken place in northern Chile between ~45 and 35 Ma.