Geology and Ore Deposits of the Peruvian Andes

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Peru is one of the largest mineral producers of the world and is a preferred destination for mineral exploration investment (6th position in 2011 according to Metals Economics Group world ranking). The mining investment in 2011 amounted to US$7.2 billion and the Ministry of Energy and Mines has identified a mining portfolio of 48 projects that will receive an investment of US$53 billion in the next 10 years. As recently estimated by the Instituto Peruano de Economía (2012), this investment will increase the annual exports of the country by US$30.3 billion and the gross product by US$44.5 billion, create 2.4 million new direct and indirect jobs, and raise government tax revenues by more than US$9 billion per year.

Most ore resources presently being mined and/or explored in Peru belong to the following three main ore deposit categories:

1. More than 100 million ounces of gold has been discovered (and half of it mined) since 1985 in the more than 2,000-km-long Neogene volcanic belt occurring in the higher parts of the Peruvian Andes. Disseminated gold (+silver) is contained in altered volcanic rocks developed beneath extinct hot spring zones at epithermal depths. Preferred host rocks are coarse-grained or lapilli tuffs, acidic flow domes, and hydrothermal breccias. Economic ore is commonly related to porous silicic alteration (vuggy or sugary quartz); by contrast, other voluminous alteration, such as advanced argillic, argillic, and propylitic, is generally subeconomic or barren. Structural control of silicic alteration is strong, and relates to dilatant second and third order structures associated with major underlying crustal structures.
2. The Peruvian Andes also host various porphyry copper belts containing reserves and resources of over 90 million tons of fine copper and variable amounts of gold, silver, and molybdenum. These porphyry belts are associated with intrusive systems of Paleocene, Eocene-Oligocene, and Miocene age. These deposits are commonly related to isolated, multiphase stocks within, or associated with, large batholiths; there are no preferred host rocks. Widespread hydrothermal alteration is emplaced within, and around, the porphyritic stock, and it is associated with disseminated and stockwork-type sulfide mineralization. Belts of porphyries are related to thicker continental crust and possibly are associated with evolved magmas that have interacted with the crust. Large, deep crustal fractures are one of the main controlling factors, but arc-oblique accommodation faults may have localized the major districts.
3. Current reserves and resources of other metals in the Peruvian Andes include >8 million tons of fine lead, 19 million tons of fine zinc, and 3.7 billion ounces of silver (world's largest silver resource). Triassic to Cenozoic sedimentary rocks, particularly carbonate-rich facies, display a number of mineral occurrences due to metasomatic replacement by Neogene magmatic-hydrothermal fluids in various settings. All

deposits of this style are spatially associated with Neogene intrusive sills, dikes, flow domes, or explosive vents. Low-temperature alteration (epithermal style) of associated intrusives or domes is common. Deposits are inferred to lie in the roof zone, or on the edges, of major underlying intrusive complexes, comprising skarn, distal skarn, and replacement bodies, partly superimposed on porphyry alteration and mineralization. Lateral zoning from Cu-Au–rich proximal parts to Zn-Pb-Ag–rich distal parts is common in these replacement deposits. Magmatic heat and fluid components are supplied by stocks or subvolcanic assemblages of calc-alkaline composition (alkaline magmatism has also been reported more recently from mineral deposits in central Peru); most formed during the Miocene epoch. Major crustal structures and their higher order structures (as in the case of the porphyry systems) channel magma and fluids to shallow depths via steeply dipping fault zones (dip-slip) and outward along layering when a reactive host is encountered.

The spatial and genetic link between these three deposit categories has been intensively investigated by researchers and explorers, with evidence strongly indicating an overall "porphyry system" or "intrusive centered" model. This model is being used as an effective exploration tool to assess the porphyry, skarn, replacement, and epithermal potential of the overall magmatic system (refer to Sillitoe, 2010; Catchpole et al., 2011; Hedenquist, 2012).

Besides the bulk-tonnage mineralized systems described in previous paragraphs, other deposit types, including iron oxide copper-gold, volcanic-hosted massive sulfide, Mississippi Valley-type zinc, and mesothermal vein deposits, occur in the Peruvian Andes and contribute to Peru's mining production, with significant amounts of iron ore, copper, gold, silver, lead, zinc, tin, tungsten, and other metals.

The overview offered in this paper on the ore deposits of the Peruvian Andean territories and their geologic framework highlights Peru's mineral potential and the need for a more consistent and systematic exploration effort.

References

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