The physical and tectonic setting of Andean high-sulfidation epithermal gold-silver deposits and what it means for mineralizing processes and exploration targeting

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Gold and silver mineralization in the vast majority of Andean high-sulfidation epithermal Au-Ag deposits occurs at high elevations and typically 200-500 m below low-relief landforms situated at 3500 to 5200 m a.s.l. present day elevation. Stratovolcanoes, in contrast, are uncommon ore hosts. Most deposits are middle Miocene and younger and include (among others), El Indio, Tambo, Pascua-Lama, Veladero (El Indio belt, Chile/Argentina), Cerro de Pasco (Central Peru), Pierina, Lagunas Norte, Yanacocha (northern Peru), Quimsacocha (Ecuador), and the California-Vetas mining district (Santander, Colombia), jointly accounting for > 140 Moz Au resources. Slightly older examples are preserved in the Atacama Desert and include the middle Eocene El Guanaco and El Hueso and the late Oligocene/early Miocene La Coipa deposits. Mineralization coincides with transpressional tectonics and pronounced surface uplift, predominantly in segments of shallow angle subduction of the Nazca or Caribbean plate below the South American continent. However, near neutral stress regimes and syn-orogenic extension typically influence the structural style at the high elevations where epithermal mineralization is located.

Volcanic rocks coincident with mineralization are volumetrically restricted and in some cases lacking completely, although dacitic domes are important at, e.g., Yanacocha, Lagunas Norte and La Coipa. Mineralization is commonly located near the backscarp of pediments or head of valleys incising into the high-elevation, low relief surfaces. In the California-Vetas district and El Indio belt, hydrothermal alunite ages and mineralization become generally younger upstream along the incising valleys. This may be explained by the lowering of the water table and reduction of hydrostatic and lithostatic pressure at the headwalls of incising valleys; sites where erosion rates are highest and boiling or mixing of magmatic with meteoric fluids is enhanced.

The host rock composition, permeability and location of the water table control the distribution of alteration zones and ore. The surface-near steam-heated zone can attain a thickness of several hundred meters in dry climates (e.g. Veladero, Pascua-Lama, Tambo) but is typically less than 20-50 m thick in humid climatic zones. Intermediate volcanic rocks are the most common ore-hosts but they typically pre-date mineralization by several Ma. However, high-sulfidation epithermal mineralization can be hosted in any conceivable rock type including high-grade metamorphic rocks (California-Vetas mining district), significantly older plutonic rocks (Pascua-Lama) or quartzites (Lagunas Norte). In most deposits hydrothermal breccias are observed. Large vuggy quartz alteration zones and low grade - large tonnage mineralization are best developed in relatively permeable volcaniclastic rocks whereas coherent volcanic, plutonic, or metamorphic rocks may host fault and breccia controlled ore.
The physical and tectonic setting of high-sulfidation epithermal deposits is distinct from low-sulfidation epithermal districts such as those of Patagonia, El Peñón (Chile) or Fruta del Norte (Ecuador). The latter range to significantly older ages (Jurassic to early Eocene), occur at lower elevations and were emplaced in extensional settings. A temporal coincidence between uplift, erosion and mineralizing processes as well as a spatial and temporal association with porphyry style mineralization is not evident for low-sulfidation districts.