

Geologic Setting, Mineralogy, and Geochemistry of the Early Tertiary Au-Rich Volcanic-Hosted Massive Sulfide Deposit of La Plata, Western Cordillera, Ecuador

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Abstract

La Plata is, economically, the most important of several volcanic-hosted massive sulfide (VHMS) deposits of the Western Cordillera of Ecuador, with preliminary estimated reserves of 840,000 metric tons (t) at 4.8 g/t Au, 54 g/t Ag, 4.1 percent Cu, 0.7 percent Pb, and 4.2 percent Zn. Like the other VHMS deposits of the Western Cordillera, it is hosted by the Early Tertiary Macuchi unit, which represents an oceanic island-arc sequence, composed of submarine volcanic and volcanoclastic sequences of basaltic to andesitic compositions, accreted to the continent along the Chimbo-Toachi shear zone in the late Eocene.

La Plata displays a typical VHMS vertical zonation, from bottom to top, of a pyrite stockwork, disseminated sulfides, massive sulfide lenses, and a thin red jasper bed with exhalative-sedimentary textures. The massive sulfide lenses are located within footwall andesitic volcanic and volcanoclastic rocks that are pervasively altered to a quartz-pyrite-sericite assemblage, and immediately below a hanging-wall sequence consisting of at least two basaltic to basaltic-andesitic lava flows, each capped by autoclastic breccia intervals. The hanging-wall rocks, especially the autoclastic breccias, are hematite altered up to 300 m above the ore level. Hanging-wall volcanic rocks have geochemical features typical of arc tholeiites. Dolerite dikes in the hanging wall have middle-ocean ridge basalt (MORB)-type geochemical features likely indicating deposit formation in an intra-arc extensional environment.

The massive sulfide lenses are situated mainly on the eastern side of an antiform with footwall rocks at the core and hanging-wall rocks on both flanks. Lithologic contacts, volcanic strata, and axial planes of folds have a consistent north-south strike. Footwall rocks at the core of the antiform are locally affected by meter-thick, north-south-trending subvertical shear bands that result in an intense tectonic foliation. Deformation structures are absent in the hanging-wall rocks suggesting that the footwall rocks, due to a different rheology, were ductile during deformation. Centimeter- to decimeter-sized massive sulfide clasts are incorporated into a mylonitic matrix of altered footwall rocks within these shear bands that contain dextral movement indicators. The larger massive sulfide lenses (up to 100 m long) probably result also from tectonic dismembering, within the footwall rocks, of a former, larger, massive sulfide body. The deformation is probably related to the Chimbo-Toachi dextral shear zone situated a few kilometers to the east of La Plata.

The main ore minerals are pyrite, chalcopyrite, sphalerite, bornite, and galena, with minor tennantite and digenite. The gangue minerals are barite, quartz, and sericite. Mineralogical banding, defined by chalcopyrite-rich layers alternating with pyrite- and/or sphalerite-rich layers, is mostly the result of tectonic injection of ductile chalcopyrite, bornite, and galena within shear bands of cataclastic pyrite and sphalerite. Pyrite and sphalerite also show mild recrystallization textures. Deformation is heterogeneous as a consequence of strain partitioning, resulting in portions of the massive sulfide lenses being essentially undeformed and preserving primary VHMS textures, such as framboidal pyrite. Ag-poor gold is microscopically visible and can reach dimensions of few hundreds of microns. Whereas it is likely that some gold at La Plata has been reprecipitated during the shear event, the lack of gold in structural positions indicating an epigenetic origin with respect to the VHMS sulfides (e.g., in veins), suggests that gold was present in the original VHMS ore.

Sulfur isotope compositions of the sulfides are homogeneous and consistent with sulfur derivation from leaching of the host volcanoclastic sequence, although a direct magmatic contribution cannot be ruled out. Strontium and sulfur isotope compositions of the late-stage barite are consistent with mixing between hydrothermal fluid and seawater.

The very low Fe contents of sphalerite (0.27 ± 0.40 mol % FeS) suggest precipitation from fluids characterized by high a_{S_2} and a_{O_2} . Because gold solubility as a bisulfide complex is higher in fluids with high a_{S_2} and a_{O_2} , this might explain the Au-rich nature of the La Plata VHMS deposit. Additionally, the association of La Plata with magmatic rocks derived from a depleted mantle could indicate primary enrichment of gold in the source rocks.

These characteristics resemble those of Au-rich VHMS deposits and submarine vents of the southwestern Pacific, including the occurrence within an intraoceanic island arc, a similar fluid chemistry and sulfide paragenesis, in contrast to other VHMS deposits of the Central Andes. This may have ultimately resulted from the Mesozoic to Cenozoic geodynamic evolution of the Northern Andes, which differs from that of the Central Andes and, being characterized by multiple accretions of both oceanic plateaus and island arcs, is similar to that of the southwestern Pacific region.

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