

## **Geology, Alteration, and Mineralization of Bayugo Porphyry Copper-Gold Deposit Surigao del Norte, Mindanao, Philippines**

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The Bayugo porphyry copper-gold deposit was discovered in 2003 in the Surigao del Norte district, Mindanao, Philippines. It is concealed by 100 to 300 m of Quaternary volcanics and lacustrine sediments. As of 2011, it had an estimated resource of 368 Mt at 0.38% Cu with 0.37 g/t Au at 0.2% Cu cutoff.

Copper and gold mineralization at Bayugo is centered on a multiphase intrusive complex emplaced into the volcano-sedimentary sequence of the Oligocene Bacuag Formation. There are seven discrete diorite phases identified—a pre-mineral family composed of the bird's eye porphyry, medium-grained (MGD) and fine-grained diorites, the synmineralization diorite 2 (DIO2), the intermineralization diorite 3 (DIO3), and fine to seriate diorite (FSD) and the post-mineralization diorite 4 dikes. In the absence of conspicuous intrusive contacts, these phases have been distinguished based on textural differences and variation in mineralization, alteration, and vein types. MGD is the principal host for mineralization. DIO2 and MGD are petrographically similar but the former has a higher density of quartz veins and contains more mineralization whereas MGD is only mineralized proximal to its contact with DIO2. DIO3 is distinctly coarse-grained, exhibits gradational contact with DIO2, and has relatively lower Cu-Au grades than DIO2.

At least three types of breccias are observed in Bayugo. Localized intervals of monomictic biotite ± magnetite-altered crackle breccia and magnetite ± K-feldspar ± chalcopyrite-cemented hydrothermal breccia are inferred to be temporally associated with DIO2. A postmineralization, oblate, east-trending polymictic sand-silt matrix breccia has rounded to subrounded clasts of all of the older intrusive phases. This breccia is located proximal to FSD and transition into a darker, FSD-cemented breccia at depth.

Intense biotite ± K-feldspar–magnetite alteration is well developed in DIO2. It is characterized by secondary biotite replacements of primary mafic minerals and K-feldspar groundmass replacements and vein halos. This assemblage has been overprinted by chlorite-sericite alteration. Chlorite has replaced secondary biotite and sericite replaced plagioclase phenocrysts. Sericite-quartz alteration is confined to thin halos around late pyrite veins, and to localized pervasive zones of leaching where there is a marked decrease in copper grades (pyrite >> chalcopyrite). Distal chlorite-epidote- calcite alteration has affected the outer margins of the Bayugo intrusive complex and the adjacent country rocks.

Copper mineralization in the hypogene zone strongly correlates with biotite ± K-feldspar + magnetite alteration and is characterized by chalcopyrite with localized minor bornite and covellite as rims on chalcopyrite grains. Pyrite is ubiquitous but is most intensely developed in the sericitic alteration zones.

Bayugo has a 50- to 100-m-thick supergene profile. A thin leached cap consisting mainly of Fe-oxides is underlain by a copper oxide zone dominated by cuprite, malachite, azurite, and chrysocolla with patches of native copper. This is underlain by a chalcocite enrichment blanket that overlies the hypogene copper sulfide zone. Copper minerals in both the supergene oxide and sulfide zones are associated with the quartz stockwork and altered wall rocks.