Late-Stage Cu and Ag Replacement at the Greens Creek Massive Sulfide Deposit, Alexander Terrane, Southeast Alaska

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The Late Triassic Greens Creek massive sulfide deposit, located in southeast Alaska within the allochthonous Alexander terrane, is the top silver-producing mine in the United States and one of the most significant massive sulfide deposits in the world. Massive sulfide lenses occur along with black dolostone and rift-related conglomerate at the base of a thick sequence of Late Triassic graphitic argillite, and unconformably overlie a footwall of altered Carboniferous mafic metavolcanic rocks intruded by mafic-ultramafic rocks.

The current genetic model is a hybrid VMS-SEDEX-style hydrothermal system driven by shallow mafic-ultramafic hypabyssal intrusions below a major seafloor detachment. The deposit has a combined resource of approximately 24.2 Mt grading 13.9% Zn, 5.1% Pb, 658 g/t Ag, and 5.1 g/t Au. Not included in the resource is an average of approximately 0.5% Cu, typically as chalcopyrite and tetrahedrite-tennantite. Silver is most commonly within tetrahedrite-tennantite and to a lesser extent proustite-pyrargyrite, but may occur as gold-rich electrum within late veins and fractures. Ore at Greens Creek is divided into five distinct end-members: three "white" ores and two massive sulfide ores. The white ores are dominated by gangue and comprise carbonate-rich, barite-rich and quartz-rich end-members. The massive sulfides are divided into pyrite-dominated and base metal-dominated ores. The topological relationships between the ore types are complex and vary through the deposit. Intense, polyphase deformation, multiple rheologically contrasting ore types and low-grade metamorphism have created a wide range of sulfide textures.

Local discordant concentrations of bornite, chalcocite, and stromeyerite have overprinted recrystallized and remobilized galena and sphalerite within the white ores. This Cu- and Ag-rich assemblage replaced galena in late, F_2-related tension veins within more brittle ore types (carbonate-rich and quartz-rich ores), and replaces disseminated sphalerite and galena in more annealed, ductile ore types (barite-rich ores). The preservation of delicate replacement and exsolution textures suggests that remobilization of Cu and Ag occurred late-stage and post-dated the major metamorphic recrystallization and remobilization event. Recrystallization and deformation of gangue and ore minerals at Greens Creek probably occurred during mid-Cretaceous accretion of the Alexander terrane to North America and was related to F_2 folding. Bornite, chalcocite and stromeyerite most likely formed late- to post-F_2 folding and may be related to later folding (F_3 or F_4), faulting (D_5), or shearing events ($D_{2.5}$).