# Geology of the Pebble Porphyry Cu-Au-Mo Deposit, Southwest Alaska

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The Pebble Cu-Au-Mo deposit in southwest Alaska is one of the largest porphyry deposits known with a total resource of 10.9 billion tonnes. It comprises the East and West zones, with slightly lower grade mineralization in the center of the deposit where the two zones merge.

The oldest rocks in the Pebble district are gently folded, Jura-Cretaceous andesitic flysch with subordinate basalts and gabbroic intrusions. Alkalic intrusions and related breccias were emplaced between 99 and 96 Ma. Broadly contemporaneous granodiorite and diorite sills also intruded the flysch at this time. Subalkalic hornblende granodiorite of the Kaskanak batholith was emplaced at ~90 Ma, followed by two stages of granodiorite stocks and dikes related to Cu-Au-Mo mineralization dated at ~89.5 Ma by Re-Os on molybdenite. An E-thickening wedge of volcanic and clastic sedimentary rocks overlies the East zone and was deposited between 67 and 58 Ma. Eocene igneous rocks occur east and southeast of the Pebble deposit, and unconsolidated glacial sediments are widespread.

The East and West zones represent two coeval hydrothermal centers within a single system. The West zone is centered on four granodiorite porphyry plugs emplaced into flysch, diorite, and granodiorite sills, and alkalic intrusions and breccias. The higher-grade East zone is hosted by a larger, composite granodiorite porphyry pluton and adjacent granodiorite sills and flysch. These five stocks cut or are apophyses from underlying equigranular Kaskanak batholith. On the east side of the deposit, high-grade mineralization has been dropped into the NE-trending East graben, where the deposit remains open.

Variations in hypogene grade and metal ratios reflect multiple stages of metal introduction and redistribution. Prehydrothermal hornfels formed above the Kaskanak batholith. Most Cu-Au-Mo mineralization, dominated by chalcopyrite ± bornite, formed with potassic and sodic-potassic alteration in the East and West zones, respectively. Weakly mineralized sodic-calcic alteration underlies potassic alteration in the East zone. Younger quartz veins introduced additional molybdenum. Illite ± kaolinite alteration overprinted potassic and sodic-potassic alteration throughout the deposit and variably redistributed copper and gold. High-grade Cu-Au mineralization is related to advanced argillic alteration, which comprises a core of pyrophyllite alteration associated with chalcopyrite, bounded to the west by an upward-flaring zone of sericite alteration which introduced hypogene bornite, digenite, covellite, and trace enargite and tennantite. Advanced argillic alteration was controlled by synhydrothermal brittle-ductile deformation and overprinted early potassic and sodic-calcic alteration. Grade-destructive but auriferous quartz-sericite/illite-pyrite alteration surrounds and is locally preserved at the top of the deposit and yields outward to propylitic alteration. Molybdenite contains high concentrations of rhenium. Elevated palladium occurs in pyrophyllite alteration. Thin zones of leached capping and supergene chalcocite and covellite occur in the West zone.