Delineation of Geometallurgical Domains in the Pebble Porphyry Cu-Au-Mo Deposit, Alaska

Cassady L. Harraden[1,]* and Melissa J. Gregory[2]

[1] CODES, ARC Centre for Excellence in Ore Deposits, Private Bag 79, University of Tasmania, Hobart, Tasmania 7001, Australia
[2] Mineral Deposit Research Unit, Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, 2020-2207 Main Mall, Vancouver, British Columbia V6T 1Z4, Canada

*E-mail, cassady.l.harraden@gmail.com

The Pebble porphyry Cu-Au-Mo deposit in southwestern Alaska has a total resource of 10.9 Bt that contains 81.63 Blb copper, 107.6 Moz gold, 5.6 Blb molybdenum, and 514 Moz silver. The deposit is related to ~90 Ma granodiorite intrusions associated with the Kaskanak batholith. Chalcopyrite-pyrite-(bornite)-molybdenite mineralization is hosted within the granodiorite intrusions and in surrounding clastic sedimentary and intrusive rocks. Most metal was introduced during early potassic (K-feldspar-quartz-biotite) and sodic-potassic (K-feldspar-albite-quartz-biotite) alteration. Younger illite-kaolinite alteration overprinted early potassic and sodic-potassic assemblages and effected local redistribution of metals. Sericite and pyrophyllite-quartz subtypes of advanced argillic alteration on the east side of the deposit represent a second major stage of metal introduction which formed the highest Cu-Au grades. Late, peripheral quartz-sericite-pyrite alteration destroyed preexisting Cu-Mo mineralization but retained strongly anomalous gold concentrations.

The Pebble deposit comprises several geometallurgical domains that manifest distinct patterns of metal recoveries. Domain characterization was based on detailed mineralogical assessment using SWIR to identify phyllosilicate mineralogy and QEMSCAN to assess metal deportment. The domains reflect specific types and combinations of alteration, the effects of which resulted in internally consistent characteristics of copper, molybdenum, palladium, and gold deportment. Geometallurgical domains at Pebble are therefore designated according to the key underlying alteration type.

Chalcopyrite is the dominant copper mineral in most alteration types and generally contains minor gold and silver inclusions. Partial overprinting of chalcopyrite by bornite, digenite, covellite, and trace enargite and tennantite occurs in the sericite domain. Chalcocite and lesser covellite form rims on chalcopyrite in the thin supergene zone in the western part of the deposit. Molybdenum occurs in molybdenite throughout the deposit. Elevated palladium concentrations occur in pyrite within the pyrophyllite-quartz domain.

Gold occurs predominantly as inclusions in chalcopyrite and pyrite and shows the most variability in deportment. The potassic domain contains gold as electrum inclusions in chalcopyrite. Gold within the sodic-potassic domain is evenly distributed among (1) high-fineness gold in pyrite, (2) electrum in chalcopyrite, and (3) inclusions within nonsulfide gangue minerals. Where illite overprinted the early potassic and sodic-potassic domains, electrum was commonly reconstituted to high-fineness grains in relict chalcopyrite and pyrite and in newly formed pyrite. High-fineness gold occurs in chalcopyrite in the sericite and pyrophyllite-quartz domains, accompanied in the sericite domain by gold-telluride inclusions. High-fineness gold and electrum in pyrite dominate the quartz-illite-pyrite domain. Gold in the quartz-sericite-pyrite domain is mostly contained within the pyrite mineral lattice.

Key influences of the three-dimensional geometallurgical domain model for Pebble have been on design of efficient metallurgical test work programs and, in turn, assignment of reproducible metal recovery factors to the economic block model. In particular, the distribution of gold hosted by pyrite relative to chalcopyrite varies greatly across the deposit; as a consequence, a flow sheet design and mine schedule can be developed to separately treat pyrite concentrates from selected parts of the deposit to materially increase the overall recovery of gold and improve projected cash flow. Most importantly, the early adoption of a geometallurgical characterization program at Pebble has enhanced project value and significantly reduced economic risk.