From Exploration to Mine Planning: Utilizing Shortwave Infrared Spectral Analysis of Exploration and Infill Drill Core to Map Hydrothermal Alteration and Geometallurgical Domains at the Pebble Cu-Au-Mo Porphyry Deposit, Alaska, USA

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The Pebble Cu-Au-Mo porphyry deposit, located approximately 320 km southwest of Anchorage, Alaska, is one of the world's largest porphyry copper deposits. The deposit contains 10.9 billion tonnes, including over 80 billion pounds copper, 107 million ounces gold and 5.6 billion pounds molybdenum. Multiple stages of hydrothermal alteration at Pebble strongly influence metal deportment, clay chemistry, and rock hardness which, in turn, directly affect the design of ore processing and recovery strategies. Porphyry alteration types are characterized by variations in fine-grained phyllosilicate mineralogy and can be challenging to distinguish visually. Shortwave infrared (SWIR) spectroscopy was used to evaluate the spatial distribution and metal associations of phyllosilicate alteration minerals at Pebble. These data were integrated with other types of drill hole data to produce a three-dimensional hydrothermal alteration model to assist mineral exploration and the definition of economically significant geometallurgical domains.

Six alteration domains were delineated at Pebble, based on the physical characteristics of drill core and on subtle shifts in the position of the AlOH spectral feature, located at ~2,200 nm wavelength, which can be related to white mica composition. The domains comprise the following: (1) sodic-potassic; (2) potassic; (3) quartz-illite-pyrite; (4) sericite; (5) quartz-pyrophyllite; and (6) quartz-sericite-pyrite. Samples dominated by sodic-potassic alteration display a spectral doublet near 2,200 nm, which is diagnostic of kaolinite. Spectra with the diagnostic, very sharp pyrophyllite absorption feature near 2,150 nm define the quartz-pyrophyllite alteration zone. Potassic, quartz-illite-pyrite, sericite, and quartz-sericite-pyrite alteration types have spectral features diagnostic of white micas, with absorption troughs between 2,190 nm and 2,220 nm; lower AlOH absorption values characterize illite, whereas higher values indicate sericite.

The SWIR results were used to map downhole variations in dominant phyllosilicate speciation and to more accurately define the spatial extents of the six alteration domains. The results of the integrated hydrothermal alteration model show that the distribution of metal grades is mostly controlled by hydrothermal alteration types rather than host rock. In general, highest deposit grades are associated with sericite and pyrophyllite alteration types, the lowest grades are coincident with quartz-illite-pyrite alteration and intermediate grades are associated with potassic and sodic-potassic alteration types.

At Pebble, the relationship of metal deportment and rock properties to the integrated alteration model informs both testwork and engineering parameters as they relate to design of comminution and flotation circuits and metal recovery. In particular, an extensive study of gold deportment at Pebble has shown large variations in the proportions of gold hosted by chalcopyrite and pyrite in different alteration types. The alteration model developed for Pebble delineates volumes of mineralization with internally consistent gold deportment characteristics, which could be expected to exhibit distinct recovery and processing behaviours. Similarly, the integrated alteration model can be linked to domains which influence geotechnical modelling, comminution studies, and mine planning. Because the alteration model directly reflects critical geometallurgical characteristics, it has been utilized to design testwork and to optimize recovery and processing circuit design at a relatively early stage in mine planning and economic forecasting.