



Chapter 13

Wealth Creation through Exploration in a Mature Terrain: The Case History of the Centinela District, Northern Chile Porphyry Copper Belt

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Abstract

The Centinela district is a 40-km-long segment of the late Eocene to early Oligocene porphyry copper belt of northern Chile. The main mineralization styles in the district include porphyry copper and associated skarns with gold and molybdenum credits, oxide copper in the form of either exotic deposits or in situ oxidation zones, and supergene copper sulfide enrichment blankets.

Structurally controlled, district-wide porphyry copper mineralization formed between 44 and 41 Ma, contemporaneously with transpressional tectonism along the regional-scale Centinela-Limón Verde fault zone, a splay of the major Domeyko fault system. The Domeyko fault system accommodated tectonic uplift of the Cordillera de Domeyko during early stages of the middle Eocene Incaic orogeny. Several productive porphyry copper systems in the district were emplaced syntectonically along reverse- and oblique-slip faults that controlled the shape and attitude of both the dominantly dike-like intrusions and associated alteration mineralization.

All the porphyry copper deposits in the district evolved from early potassic alteration with copper mineralization present as chalcopyrite and bornite, through sericite-chlorite alteration with chalcopyrite and pyrite, to late, overprinting pyritic sericitic alteration. Some systems developed advanced argillic lithocaps in their upper parts. Much of the copper was introduced with the potassic alteration, and all the gold-rich deposits display abundant hydrothermal magnetite and a positive correlation between copper and gold.

Supergene processes gave rise to oxide copper zones above pyrite-poor, chalcopyrite- and bornite-bearing protore and to chalcocite blankets over less reactive, sericitic zones containing pyrite and chalcopyrite. Coeval regional uplift, erosion, and exhumation resulted in widespread piedmont gravel deposition broadly contemporaneous with the supergene activity, with formation of exotic copper deposits alongside the shallow, actively oxidizing, pyritic parts of porphyry copper deposits.

A long exploration history characterizes the Centinela district, from initial prospecting in the 1870s to formal exploration programs by major mining companies approximately 100 years later. However, initial appreciation of the district potential resulted from the discovery of the El Tesoro and Tesoro NE exotic copper deposits between 1990 and 1993 and was confirmed with the discovery of the Esperanza and Telégrafo porphyry copper-gold deposits in 1999 and 2001, respectively. Approximately 18 years of persistent exploration by Antofagasta Minerals resulted in an order-of-magnitude expansion of the district mineral inventory from an original 120,000 metric tons (t) of contained copper at El Tesoro in 1990 to the presently known resources of ~20 Mt of contained copper and ~560 t (18 Moz) gold in the several main deposits. Commercial copper production commenced at the El Tesoro SX-EW plant in 2001, with a cumulative output through 2009 of 790,000 t of cathode copper. With production start-up at Esperanza in late 2010, the district is expected to produce an additional 195,000 t Cu, 7 t (225,000 oz) gold, and 35 t (1,130,000 oz) silver per year in concentrates, whereas Mirador will contribute an additional 95,000 t of cathode copper upon attaining full production in 2012.

Early stages of exploration within the district targeted exposed mineralization that had undergone historic, small-scale surface mining. The more recent exploration incorporated geologic mapping and conceptual modeling to test for both extensions to the known mineralization and new deposits as the company's land holdings expanded. Recent efforts successfully targeted blind mineralization under extensive postmineralization gravel cover through interrogation of comprehensive data sets, use of empirical geologic models, and incorporation of conventional and relatively new geophysical tools to assist with modeling of bed-rock geology. However, the most recent discoveries employed information from nearby drill holes that were completed by previous explorers more than 23 years earlier. Discovery and wealth creation in the Centinela district are considered as products of the company's long-term commitment to exploration and the exploration team's view that the district had unfulfilled potential. Persistence overcame at least two cycles of economic turmoil. The most recent discoveries occurred approximately 17 years after initial discovery of El Tesoro and more than 25 years after formal exploration by major mining companies commenced in the district.