THE PUNTA DEL COBRE BELT, NORTHERN CHILE: INTRUSION-RELATED MID-CRETACEOUS Cu(-Fe) MINERALIZATION

Robert MARSCHIK and Lluís FONTBOTÉ

Département de Minéralogie, Université de Genève, Rue des Maraîchers 13, 1211 Genève 4, Switzerland

The Punta del Cobre belt is located about 15 km south of Copiapó, northern Chile. The belt comprises several Cu(-Fe) deposits in the Punta del Cobre (e.g., Carola, Resguardo, Santos, Socavón Rampa, and Trinidad mines) and southern Ladrillos districts (Mantos de Cobre mine), east of the Copiapó river, as well as the new La Candelaria deposit (Ryan et al., 1994) in the Ojancos Nuevo district west of the river (Fig. 1). The Cu(-Fe) deposits are hosted by the largely volcanic pre-upper Valanginian Punta del Cobre Formation, which is exposed in the core of the Tierra Amarilla anticline. The lower part of the Punta del Cobre Formation in the districts Punta del Cobre and Ladrillos, consists of altered calc-alkaline andesitic (Lavas Inferiores, Kpcli) and dacitic ("Albitófiro", Kpcfa) volcanic rocks (Fig. 1). Above a red, in the lower part volcaniclastic, breccia (Basal Breccia, Kpcsb) follows a mainly continental sedimentary sequence consisting essentially of siltstone, chert, and limestone (Trinidad Member, Kpcs). Basalts to basaltic andesites, in part with chemical affinities to mid-ocean ridge basalts, tuffs, and reworked tuffs form the upper part of the formation (Lavas Superiores, Kpcls). In the southern part of the study area the Punta del Cobre Formation is represented by the Quebrada Los Algarrobos Sequence (Kpcla), consisting of volcaniclastic rocks, basaltic andesites and andesites, and the Lavas Superiores (Marschik et al., 1994).

The Punta del Cobre Formation is overlain by Neocomian limestones of the Chañarcillo Group, which were deposited in the marine Andean backarc basin. Continental conditions established in middle Cretaceous as a result of regional uplift. Middle Cretaceous intrusive rocks of mainly dioritic, granodioritic, and quartz monzonitic composition, which form the batholith in the Copiapó area, were emplaced into the Neocomian rocks in the western part of the belt causing intense contact metamorphism (Tilling, 1963, 1976).

Contact metamorphism is expressed in the volcanic rocks of the Punta del Cobre Formation as parallel largely overlapping alteration zones (Fig. 2) that are characterized, from west to east, by the alteration mineral assemblages: (a) Ca-amphibole ± biotite ± sericite, (a) biotite ± chlorite ± sericite ± epidote (discontinuous zone), and (c) epidote-chlorite ± quartz, ± calcite. These three zones are superposed on pre-existing centers of alkali metasomatism, in which an early episode of sodium metasomatism was locally followed by potassic alteration. Mineralization is spatially associated with alkali metasomatism, in particular with potassic alteration (Marschik and Fontboté, 1994, in press).

Copper is mined in the Punta del Cobre belt from breccia bodies, veins, stockworks, and concordant lens-shaped bodies (mantos). The mineralization is characterized by a simple hypogene mineral assemblage of chalcopyrite, pyrite, magnetite, and hematite. Average Cu grades are between 1.1 and 2% and may reach more than 8% in veins. Massive magnetite occurs as veins and irregularly shaped bodies. In the Punta del Cobre and Ladrillos districts the mineralization is controlled by NNW to NW-trending structures.

Sulfur isotope ratios from chalcopyrite and pyrite show a narrow range in $\delta^{34}S$ values between -0.7 and +1.1 ‰ (Fig. 3). These data suggest that sulfur was leached from the underlying igneous rocks or contributed by magmatic fluids (R. Marschik, in press).

A $^{40}Ar/^{39}Ar$ incremental-heating experiment on hydrothermal biotite, interpreted to have formed synchronous with the Cu(-Fe) mineralization, yielded an inverse isochron age of 114.9±0.5 Ma (Marschik et al., 1996). This age is consistent with field evidence (Ryan et al., 1994) that suggest that mineralization predates batholith emplacement (K/Ar hornblende age 109.6±1.7 Ma, K/Ar biotite age 97.9 ±1.5 Ma, Farrar et al., 1970; ages converted following Dalrymple, 1979).

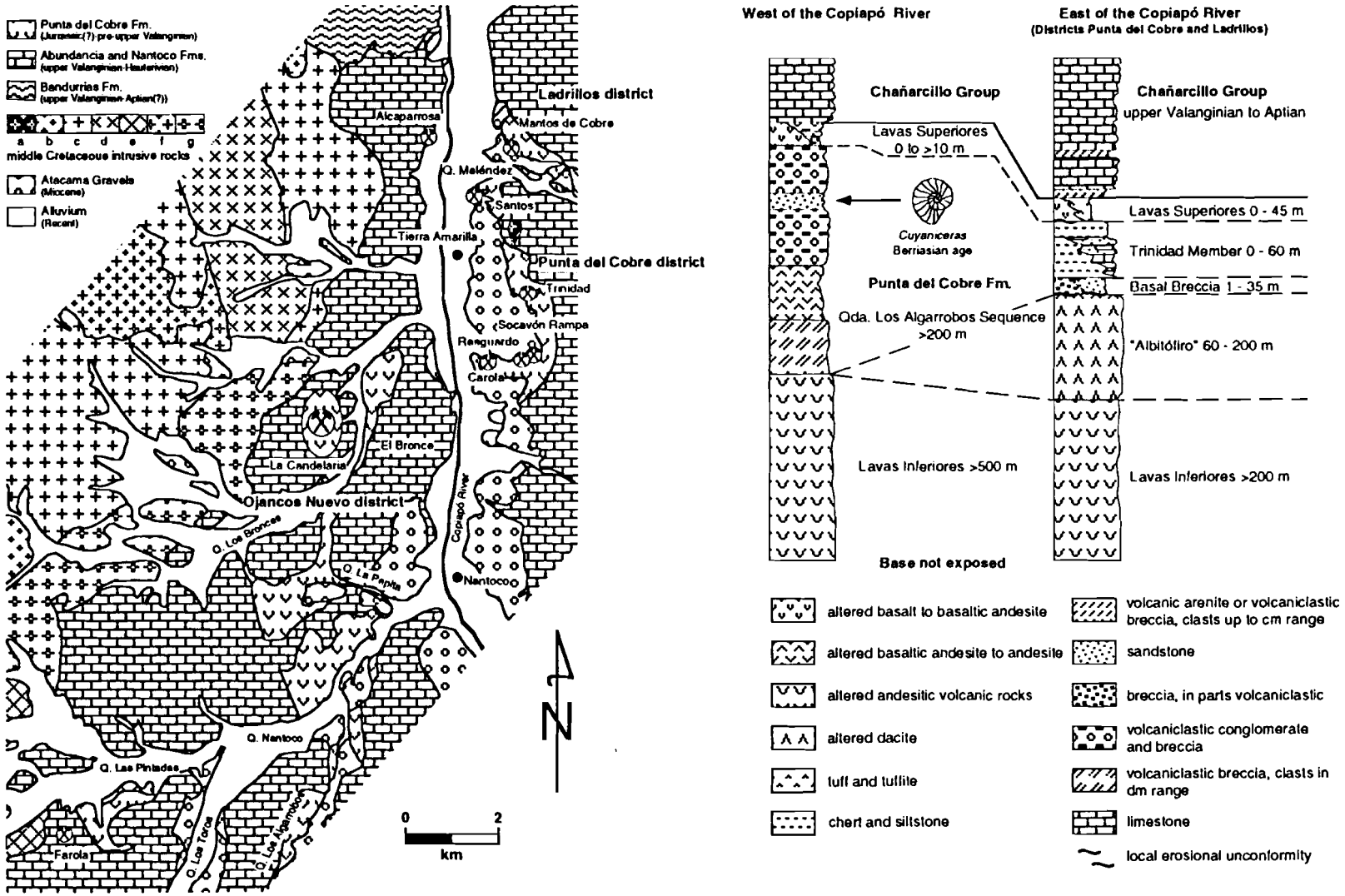

Figure 1. Geologic map of the main part of the Punta del Cobre belt (geology modified from Tilling, 1976; a) lamprophyre, b) meladiorite, c) diorite, d) leucodiorite, e) tonalite, f) quartz monzonite, g) albite granite). The Stratigraphy of the Punta del Cobre Formation east of the Copiapó river (Punta del Cobre and Ladrillos districts) and west of the river (Ojancos Nuevo district, Quebradas Nantoco, Los Algarrobos, and Los Toros) is summarized in two schematic sections.

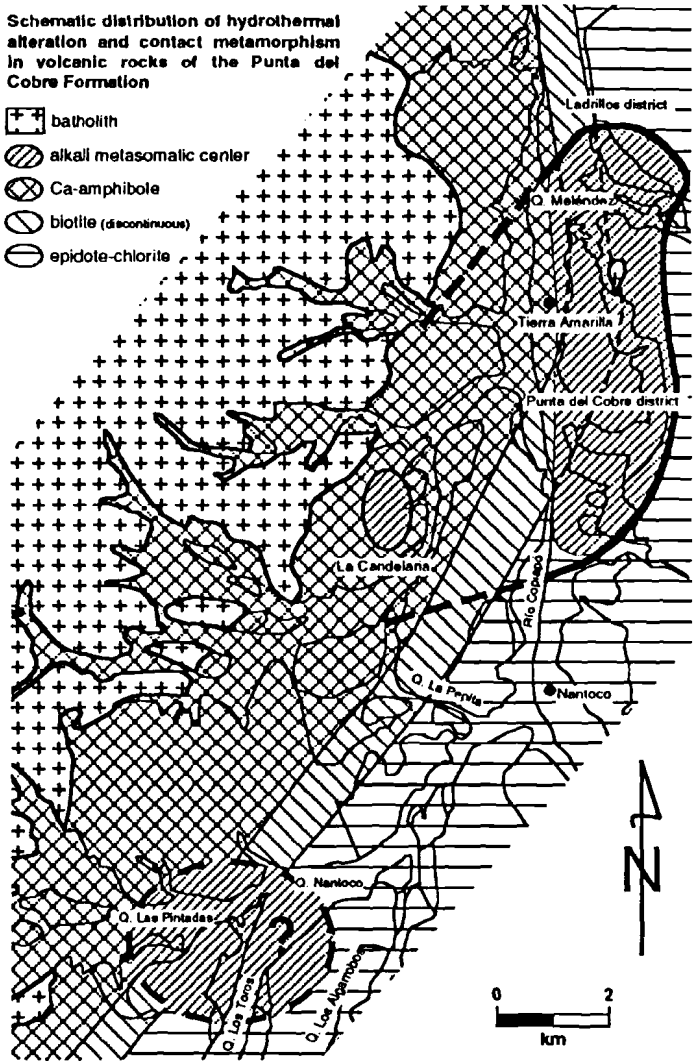

Figure 2. Limits of diagnostic minerals in the volcanic rocks of the Punta del Cobre Formation marked on the geologic map of Figure 1. Outlines of alkali metasomatic centers are also shown.

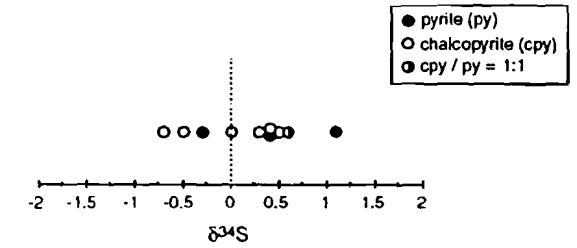

Figure 3. Sulfur isotope ratios of chalcopyrite an pyrite from the mines Santos and Socavón Rampa, Punta del Cobre district.

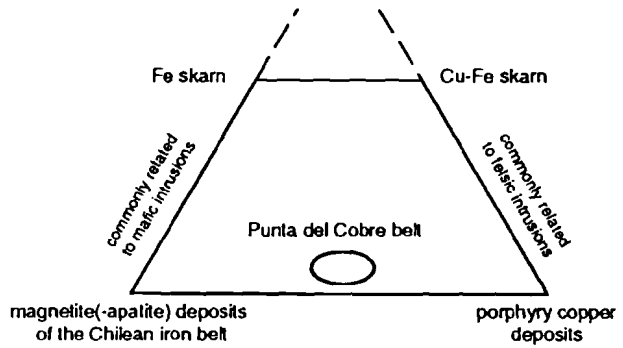

Figure 4. Schematic representation of the Punta del Cobre belt in comparison to other Andean intrusion-related deposit types.

Fluids in inclusions hosted by postore calcite have salinities between 29.2 and 33.6 wt.% $NaCl_{equiv.}$ and contain 12 to 24 wt.% NaCl and 13 to 23 wt.% $CaCl_2$. Assuming burial between 2 and 3 km in the mid-Cretaceous, the corrected formation temperatures for postore calcite lie between 122° and 174°C, and 149° and 203°C for hydrostatic and lithostatic pressure conditions, respectively (Marschik, in press).

The alteration pattern, geometry of the orebodies, ore formation temperatures of about 400° to 500°C (Hopf, 1990), and the age of potassic alteration point to a mineralization event associated with deep-seated magmatic intrusion(s) that predates emplacement of the middle Cretaceous batholith. The sulfur isotope compositions of chalcopyrite and pyrite and saline fluid inclusions of post-ore calcite may indicate that these intrusion(s) not only provided heat but also contributed with magmatic fluids. Not excluding that the Punta del Cobre belt could represent an external part of a system similar to those known from porphyry coppers, the large amounts of magnetite found in the deposits of the Punta del Cobre permits a comparison with the magnetite(-apatite) deposits of the "Chilean iron belt", which show similar mineralization temperatures and ages, and are hosted by Neocomian rocks in the vicinity of mid-Cretaceous intrusives. These magnetite(-apatite) deposits are frequently characterized by the presence of skarn parageneses. In a scheme considering porphyry copper deposits, magnetite(-apatite) deposits, and Fe and Cu-Fe skarns as endmembers, the Punta del Cobre district is interpreted to genetically occupy a transitional position between the "Chilean iron belt" and Andean porphyry copper deposits (Fig. 4; Marschik and Fontboté, in press).

References

Dalrymple, G.B. 1979. Critical tables for conversion of K-Ar ages from old to new constants. *Geology*, 7, 558-560.

Farrar, E., Clark, A.H., Haynes, S.J., Quirt, G.S., Conn, and H. Zentilli, M. 1970. K-Ar evidence for the post-Paleozoic migration of granitic intrusion foci in the Andes of northern Chile. *Earth and Planetary Science Letters*, 10, 60-66.

Hopf, S. 1990. The Agustina Mine, a volcanic-hosted copper deposit in northern Chile. In Fontboté, L., Amstutz, G.C., Cardozo, M., Cedillo, E., and Frutos, J., eds., Stratabound ore deposits in the Andes. *Springer*, Berlin-Heidelberg, 421-434.

Marschik, R. Cretaceous Cu(-Fe) mineralization in the Punta del Cobre belt, northern Chile. *Terre et Environment*, Univ. of Geneva, in press.

Marschik, R., Fontboté, L., and Delaloye, M. 1994. Volcanic rocks of the Lower Cretaceous Punta del Cobre Formation: Petrology and implication for its paleotectonic setting. *Congreso Geológico Chileno*, 7th, Concepción, 1994, Actas, 2, 1110-1114.

Marschik, R., and Fontboté, L. 1994. Potassium and sodium alteration related to Cu-mineralization in the Punta del Cobre Formation, northern Chile. *Congreso Geológico Chileno*, 7th, Concepción, 1994, Actas, 2, 1591-1595.

Marschik, R., Singer, B.S., Munizaga, F. Tassinari, C., and Fontboté, L. 1996. Age of Cu(-Fe) mineralization and Cretaceous to Paleocene Thermal evolution of the Punta del Cobre district, northern Chile. *Brazilian Geological Congress*, 39th, Bahia, 1996.

Marschik, R. and Fontboté, L. Copper(-iron) mineralization and superposition of alteration events in the Punta del Cobre belt, northern Chile. *Economic Geology*, Special Publication No. 4, in press.

Ryan, P.J., Lawrence, A.I., Jenkins, R.A., Matthews, J.P., Zamora, J.C., and Marino, E. 1994. The Candelaria copper-gold deposit, Chile. *Congreso Geológico Chileno*, 7th, Concepción, 1994, Actas, 2, 1616-1617.

Tilling, R. 1963. Disequilibrium skarns of the Tierra Amarilla aureole, Atacama province, Chile. *Geological Society of America*, Special Paper 76 (abst.), 167.

Tilling, R. 1976. El Batholito Andino cerca de Copiapó, Provincia de Atacama. Geología y Petrología. *Revista Geológica de Chile*, 3, 1-24.