Comunicaciones Nº 45 (1994): 87-92

CARACTERISTICAS GEOQUIMICAS Y ESTRUCTURALES DE LOS DEPOSITOS METALIFEROS EN EL NORTE DE CHILE

GEOCHEMICAL AND STRUCTURAL CHARACTERISTICS OF ORE DEPOSITS IN NORTHERN CHILE

W.C. Williams

Western Mining Exploration, S.A.
Las Nieves 3331, Santiago, CHILE

INTRODUCTION

In northern Chile, magmatism and its related ore deposits migrated eastward from the Jurassic to the Oligocene. Characteristic of this spatial and temporal migration is the crude correlation of decreasing grade, increasing tonnage, and increasing contained copper of deposits associated with magmatic arcs. Whereas geochemical differences implicate a crustal influence, the most distinguishing feature of these deposits is their structural geometry and therefore the tectonic regime under which they formed.

GEOCHEMISTRY

The metallogeny of northern Chile is characterized by three longitudinal belts: 1) the Jurassic Cu-Ag manto and vein deposits; 2) the Paleocene-Eocene polymetallic vein and breccia deposits; and 3) the Oligocene porphyry copper deposits (Fig. 1). Besides the distinguishing traits of deposits in each belt (Table 1), the La/Yb ratio increases with time, influenced only by subdued HREE values, and Nd/Sm and Rb/Sr isotopic values evolve along the mantle array, with few exceptions, in time (see Williams, 1992). The most discerning geochemical trait, however, is the range of lead isotopes.

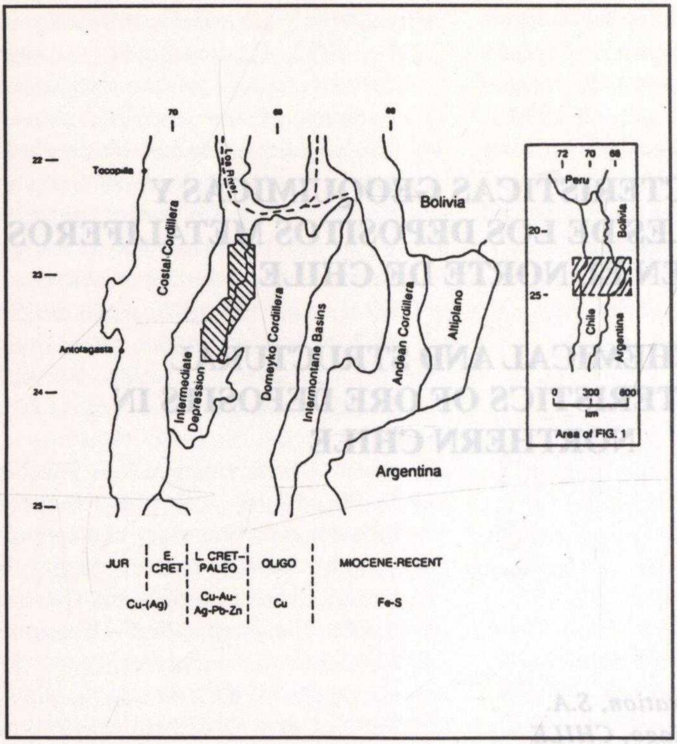

Figure 1. Metallogenic belts in northern Chile. Stippled area studied in detail by Williams (1992).

Within the transect shown in Figure 1, values for Jurassic sulfides and Paleocene-Eocene sulfides/rocks define a steep-line mixing trend. End members are a high-μ rock, most likely a late Paleozoic-early Mesozoic felsic rock, and a lower-μ source, perhaps enriched mantle lithosphere and/or lower-crustal rocks (Figure 2). The field represented by the Eocene-Oligocene porphyry copper deposits defines a more subdued mixing trend and is located within the aforementioned field of mixing. The field defined by the Eocene-Oligocene PCD's has been considered to be representative of a well-mixed, homogeneous, enriched mantle lithosphere (Tilton, et al., 1981). On the other hand, the more radiogenic values of the Eocene-Oligocene rocks/sulfides may represent the local mid- to lower crustal composition. The values of the Paleocene rocks presented here may be more representative of a lower lithospheric source. In this case, a mix between this source and ^{206}Pb-depleted rocks, as in southern Peru (Mukasa, 1986), is a plausible explanation for the signatures of the Eocene-Oligocene PCD's.

If the Pb-isotopes are defining local crustal compositions, crustal provenance is empirically related to copper-deposit size. Furthermore, crustal blocks may not be oriented longitudinally parallel to the magmatic and metallogenic belts. Figure 3 shows available Paleocene Pb-isotope data from northern Chile; data are separated at 26ºS latitude. The most notable feature is the restricted range of Pb values of southern block galenas, whereas the northern block galenas not

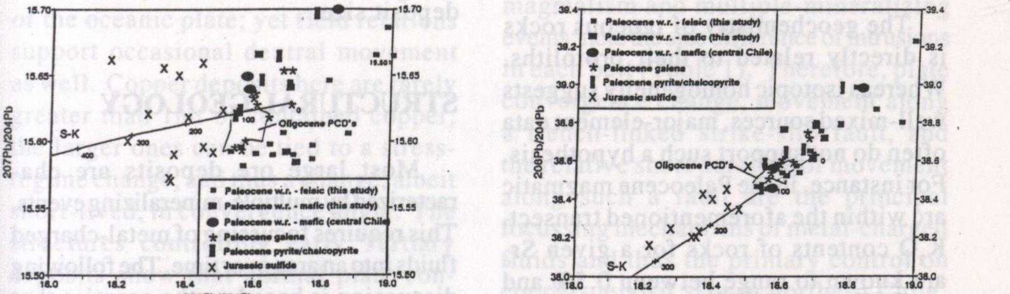

Figure 2. Lead isotope data from northern Chile (McNutt, et al., 1979; Tilton, et al., 1981; Puig, 1988; Zentilli, et al., 1988; Fontboté, et al., 1990; this study).

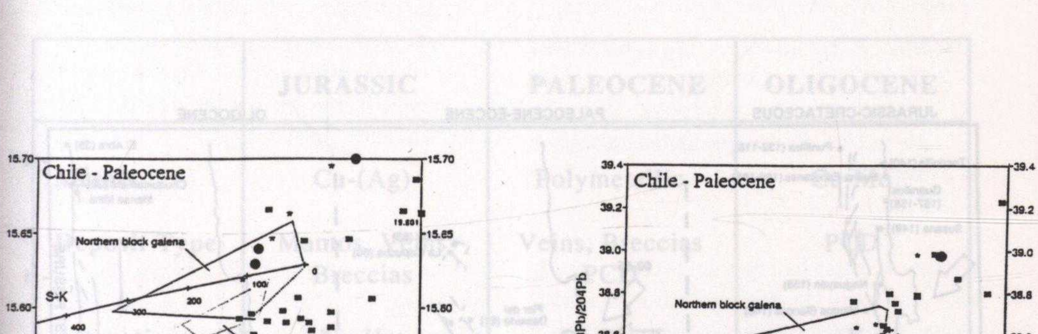

Figure 3. Lead isotope data from Paleocene rocks and sulfides, northern Chile. *- chalcopyrite (Tilton, et al., 1981); • - rocks (McNutt, et al., 1979); ■- rocks (this study). Galena fields defined by data from Puig (1988), Zentilli, et al. (1988), and this study.

only show an influence of a high-μ source, but of a ^{206}Pb-depleted source as well. Thus, crustal segmentation, and possibly crustal thickness, across longitudinal boundaries may not only constrain metallogeny, but most importantly help understand the early crustal history of the South American western margin.

The geochemistry of igneous rocks is directly related to their protoliths. Whereas isotopic homogeneity suggests well-mixed sources, major-element data often do not support such a hypothesis. For instance, in the Paleocene magmatic arc within the aforementioned transect, K_2O contents of rocks for a given Sr_o are known to range between 0.5% and 8% (Williams, 1992). Therefore, protoliths may be isotopically homogeneous but compositionally heterogeneous.

In summary, isotopic and other geochemical data show that Chile can be segmented into tectonic blocks with a characteristic crustal composition, albeit heterogeneous. The boundaries of these blocks are not clearly defined but they appear to crosscut traditional longitudinal belts. In this light, crustal provenance and metallogeny are related. Notwithstanding, hydrothermal processes rather than metal sources are the principal petrogenetic controlling factors of ore-deposit size.

STRUCTURAL GEOLOGY

Most large ore deposits are characterized by multiple-mineralizing events. This requires focussing of metal-charged fluids into an area over time. The following discussion is based on the premise that continental structures are strain indicators of regional stress regimes and thus can be used to constrain the convergence angle of the oceanic plate through time. The western margin of Chile is ideal for such an application since eastward-

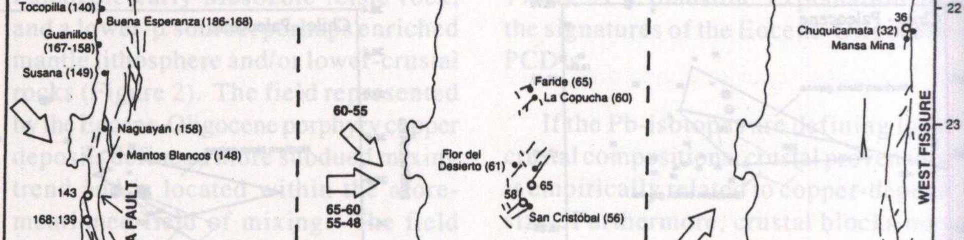

Figure 4. Mesozoic and Cenozoic tectonic and metallogenic evolution of northern Chile (after Williams, 1992).

dipping subduction has occurred here for nearly the last 200my.

In the Coastal Cordillera, the Atacama Fault, a trench-linked strike-slip fault, was the site of transcurrent movement for at least 100my during the Jurassic and Cretaceous (Boric, et al., 1990) (Figure 4). Sinistral movement prevailed and is directly tied to southeast convergence of the oceanic plate; yet field relations support occasional dextral movement as well. Copper deposits here are rarely greater than 1mt of contained copper; the larger ones can be tied to a stress-regime change, and thus a change, albeit short-lived, in convergence angle. The structures controlling early Tertiary deposits show that normal plate convergence was dominant; larger deposits correlate with a short-lived change to oblique convergence, but no trench-linked strike-slip fault developed (Williams, 1992). The Oligocene deposits are spatially related to the West Fissure, another trench-linked strike-slip fault that was active during oblique convergence. The short duration of transcurrent movement along this fault relative to that of the Atacama Fault focussed magmatism and multiple-mineralizing events; note the size difference of intrusions in each belt (Table 1). Therefore, plate convergence change, movement along a trench-linked strike-slip fault, and the relative short duration of movement along such a fault are the principal focussing mechanisms of metal-charged fluids and thus the primary control on copper-deposit size in northern Chile.

TABLE 1

	JURASSIC	PALEOCENE	OLIGOCENE
Metals	Cu-(Ag)	Polymetallic	Cu-Mo
Deposit Type	Mantos, Veins Breccias	Veins, Breccias PCD	PCD
Alteration	Na-Hm	Ad-Ser/K	K
Sulfur	Poor		Rich
Intrusions	Batholiths		Stocks
Country Rock	Jur. andesites	e.K-e.T volcanics	l.Pz-e.Mes felsics
Structure	Atacama Fault		West Fissure

ACKNOWLEDGEMENTS

This summary was an outgrowth of my Ph.D dissertation guided by J. Guilbert and funded by La Compania Minera El Bronce and J. David Lowell. Lead isotopes were analyzed by R. Bouse-Schaeneman at the USGS laboratory in Menlo Park. This is a contribution to IGCP # 342.

REFERENCES

Boric, R., Díaz, F., y Maksaev, V., 1990. Geología y yacimientos metalíferos de la región de Antofagasta: Servicio Nacional de la Geología y Minería (Santiago), Bol. 40, 246p.

Fontbotě, L., Cálvez, J. Y., Pincheira, M. and Wolf, F., 1990. Geotectonic position and metal sources of stratabound ores in the central Andes - Lead isotope constraints: Symp. Int. Géodynamique Andine, Grenoble, 347-350.

McNutt, R. H., Clark, A. H., and Zentilli, M., 1979. Lead isotopic compositions of Andean igneous rocks, latitudes 26° to 29°S: Petrologic and metallogenic implications: Econ. Geol., 74, 827-837.

Mukasa, S. B., 1986. Common Pb isotopic compositions of the Lima, Arequipa and Toquepala segments in the Coastal Batholith, Perú: Geochim. Cosmochim. Acta, 50, 771-782.

Puig, A., 1988. Geologic and metallogenic significance of the isotopic composition of lead in galenas of the Chilean Andes: Econ. Geol., 83, 843-858.

Tilton, G. R., Pollak, R. J., Clark, A. H., and Robertson, R. C. R., 1981. Isotopic composition of Pb in central Andean ore deposits: Geol. Soc. of America, Memoir 154, 791-816.

Williams, W. C., 1992. Magmatic and structural controls on mineralization in the Paleocene magmatic arc between 22°40' and 23°45' south latitude, Antofagasta, II Region, Chile: Unpub. Ph.D. thesis, Tucson, University of Arizona, 182p.

Zentilli, M., Doe, B. R., Hedge, C. E., Alvarez, O., Tidy, E., y Daroca, J. A., 1988. Isótopos de plomo en yacimientos de tipo pórfido cuprífero comparados con otros depósitos metalíferos en los Andes de Chile. V Cong. Geol. Chileno, B331-B369.