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ON STRATIFORM COPPER DEPOSITS OF CHILE (*)

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(1 fig. dans le texte)

ABSTRACT

Stratiform copper deposits are abundant in Mesozoic and Cenozoic volcanic and sedimentary rocks of Chile and, in some way, are related to calc-alkaline volcanism that has been active in this region during both Eras.

There are also stratiform deposits of manganese, of Paleozoic, Cretaceous and Pleistocene age, wich are also related to volcanism, and iron deposits of Paleozoic and Pleistocene age. The last ones correspond to El Laco magnetite flow, emplaced in a modern andesitic volcanic system in the Altiplano region of the Antofagasta province.

The highly specialized copper-rich metallogenesis of the base metal stratiform deposits of Chile is pointed out.

Although stratiform deposits of manganese and iron were mentioned in the abstract, this paper deals only with stratiform or « manto » type deposits of copper which, with mineralization of « porphyry » and vein type, define a very important and highly specialized metallogenic province. Most stratiform deposits of Chile contain approximately 1-2 millions tons of ore, assaying 2 to 5 % Cu, the only significant exception being El Soldado (32° 39/71° 7′) whose reserves are estimated to be over 10 millions ton at 2.2 % Cu. However, unpublished work by Bassi (1958) indicates that this deposit may be sort of transition to « porphyry » type mineralization.

Even though the relatively simple structural environment, together with the general lack of strong alteration and metamorphism favor their study, very little detailed work has been undertaken. The main object of this paper is thus to attract the attention of specialists who may be interested in this field of research.

Ruiz (1965) distinghished five types of « manto » copper deposits, on the basis of their relationship to the following rock types : a) continental clastic sedimentary rocks, — being divided into 1° sulphide bearing deposits (Cretaceous) and into 2° oxidized and native copper bearing deposits (Tertiary), b) marine limestones, c) metamorphosed marine limestones; and d) andesite flows and ignimbrites.

Stratiform deposits in continental clastic rocks of Cretaceous age (a_1) have a low temperature sulphide assemblage consisting of pyrite, chalcopyrite and bornite, the last mineral being abundant in the central parts of the deposits, and pyrite in the fringes. Mineralized strata are andesitic pyroclastic or fine to medium grained rocks. The groundmass or cement material of the latter is black or green in colour

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and may be indicative of a reducing or slightly reducing depositional environment. Among the principal deposits of this type are Cerro-Negro-Pirquitas (32° 34′/70° 5′) emplaced in green breccias of Upper Cretaceous age, and Veta Negra (32° 39′/71° 6′) emplaced in black shale.

Deposits in Tertiary continental clastic formations (a_2) include mineralization similar to the Coro-Coro (Bolivia) type, as in San Bartolo (22° 44′/68° 14′) and also some « exotic » copper deposits. The principal examples are Sagasca (20° 12′/69° 21′) and Exótica (22° 18′/68° 55′) in which colloform chrysocolla acts as a cement to poorly sorted conglomerates which were deposited by floods in a semi-arid environment. Copper, derived from the weathering, oxidation and leaching of porphyry copper deposits in the vicinity, some kilometers from its source, was precipitated with silica gel derived from the destruction of silicates by highly acid copper bearing solutions.

Copper deposits within Lower Cretaceous marine limestones (type b) are related to a narrow North trending Titonian-Neocomian basin, and possibly also, to Cenomanian plutons which intersect this basin in the provinces of Atacama and Coquimbo (Frutos and Oyarzún, 1973). Generally, the mineralization has the same paragenesis and mineralogical zoning as the Cretaceous continental deposits, possible pointing to a similar genesis. Stratigraphic cross-sections of some mines in the Aconcagua province (Rusa mine : 32° 31′/71° 5′) indicate the formation of limestone reef facies in a mobile marine environment in which volcanic islands existed.

Where these Neocomian limestone formations are affected by contact metamorphism (garnet-actinolite facies) related to Cenomanian plutonism, a different mineral association is found in the stratiform deposits (type c), which consists of hematite, magnetite, pyrite, chalcopyrite and bornite. Chalcopyrite predominates over bornite and the sulphide textures are coarser (Ruiz, 1965).

If a syngenetic origin were accepted for the stratiform deposits in unmetamorphosed limestone, then those in the metamorphic equivalents could be explained in terms of addition of iron from the intrusions, and by recrystallization of sulphide minerals. However, it may be simpler to consider both types of deposits and those in continental Cretaceous formations, as related to plutonic activity (telethermal or contact metamorphic, according to distance).

Stratiform deposits in volcanics (type d) are mainly restricted to rocks of andesitic composition. However some ignimbritic flows of the Hornitos Formation (Senonian to Eocene) do contain disseminated chalcocite.

The principal deposits in rhyolitic ignimbrites lie between lat 27°-28° S and long. 69°-70° W. Mineralization is in the upper portions of the flows and in the overlying clastic sediments. It is interesting to note that El Hinnawi et al (1969) detected some anomalously high copper values in Chilean ignimbrites. Near to these mineralized ignimbrite flows there is a porphyry copper deposit (El Salvador, 26° 15′/69° 24′), — which is related to sub-volcanic thyodacitic porphyries emplaced in the Hornitos Formation.

Most of the stratiform deposits in the volcanic are within andesite flows. Ruiz (1965) considered them as syngenetic, because of the lack of strong hydrothermal alteration, the scarcity of the gangue minerals and the lack of structural control. The deposits, according to Ruiz, were formed because the andesitic magma had unusually high concentration of copper. Ruiz estimated that the copper content in these rocks was 200-300 ppm, that is about 4-6 times higher than the normal average copper content of andesites.

However, more recent analyses gave lower average values for copper in andesites. Siegers et al (1969) found 47 ppm in Quaternary andesites of Northern Chile. Nesterenko and Cháves (1971) gave 40 ppm for andesites of the Arqueros Formation (Lower Cretaceous), Oyarzún (1971) determined 66 ± 52 ppm in Cretaceous, 46 ± 38 ppm in Tertiary and 61 ± 29 ppm in Quaternary andesites from different formations and locations. Losert (1972) estimated 50 ppm as the copper concentration of unaltered andesites in La Negra Formation (Middle to Upper Jurassic) from the Buena Esperanza mine area, but found much lower values in those which had undergone regional propylitization.

Therefore, if Chilean andesites do not have abnormal copper content, and if they are, in some way, the source for stratiform copper mineralization, genetic mechanisms other than magmatic sulphide segregation have to be considered. In this respect the studies of Nesterenko and Cháves (1971), and Losert (1972), are very interesting.

Nesterenko and Cháves studied the El Soldado deposit (33° 44′/70° 58′), emplaced in andesites of the Veta Negra Formation (Lower to Middle Cretaceous) and intruded by diorites that generate a 130 m wide metamorphic zone. The deposits are 500-700 m away from the contact and include 11 mineralized monoclinal andesitic flows striking North and dipping 30° East. Bornite and chalcocite are mostly in vesicles in the upper part of the flows. Each flow is separated by a breccia zone 10 cm thick that the authors considered as due to tectonism and circulation of hot water.

The above authors concluded that the mineralization is post tectonic and due to the leaching and redeposition of sulphides disseminated in the andesites by meteoric waters which infiltrated through the volcanic series. These waters were heated, as in some geothermal fields, by the emplacement of syntectonic intrusive bodies.

Losert (1972) studied the geology and geochemistry of the Buena Esperanza deposit (22° 11′/70° 14′). The mineralization is emplaced in 28 monoclinal (N-S/30° E) andesitic flows of La Negra Formation, which is about 5-10 Km thick and wich has a fairly homogeneus andesitic lithology, with minor ignimbritic and sedimentary intercalation. La Negra Formation was deposited in the eugeosynclinal environment of the Jurassic basin.

The copper sulphides bornite and chalcocite occur in vesicles in the upper part of the flows and also as disseminations in the groundmass. The rocks are regionally altered by low-grade metamorphism (greenschist facies), and mineralization is related to localized alteration (K — feldspar, secirite, quartz and calcite). A gabbroic intrusive is emplaced in the mine (probably a volcanic neck) and granodiorite intrusives occur nearby.

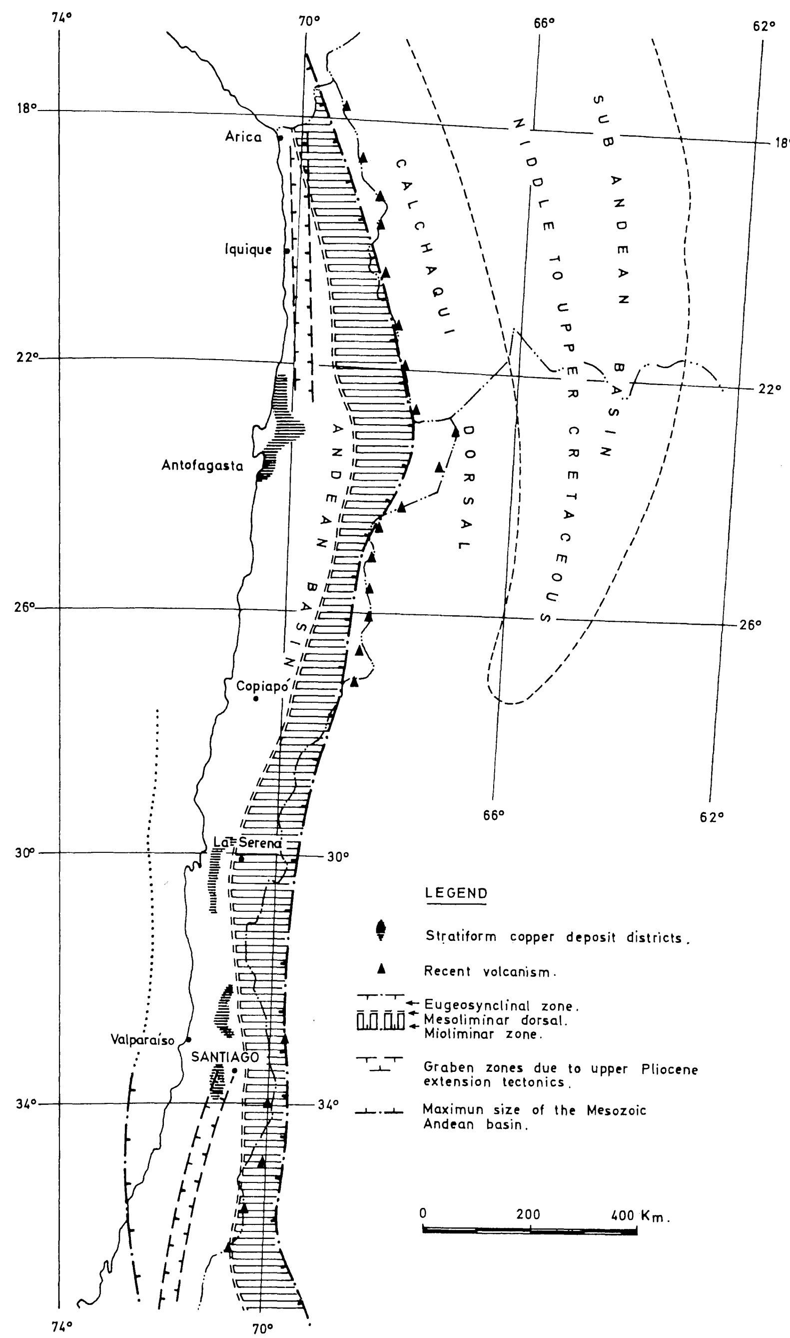
The mineralization, considered by Losert to be epigenetic, lies stratigraphically above a 100 m thick epidotized horizon, in which both copper and sulphur are highly depleted. Losert postulated that copper was removed from andesites during the regional alteration that transformed the andesites into epidotites, and deposited as sulphide by replacing iron from pyrite formed during the earlier more localized alteration. Estimations of the amount of copper leached from the epidotized andesites agree with estimations of the amount precipited in the mineralized flows (about 100.000 tons).

Whether the stratiform deposits of Chile, like those of the rest of the world, are syngenetic and related to volcanism or sedimentation, or are epigenetic and associated with regional alteration and plutonism, is debatable. It is interesting to note, however, that although copper, zinc, lead and other metals have normal concentrations in Chilean volcanic and plutonic rocks (Oyarzún 1971), only copper is found in significant amounts in the stratiform deposits.

LOCATION OF PRINCIPAL STRATIFORM COPPER DEPOSIT DISTRICTS

MESOZOIC CENOZOIC PALEOGEOGRAPHY AND TECTONICS From Frutos, Tobar 1973

LOCATION OF DISTRICTS From Ruiz 1965



Polymetallic vein mineralization is connected with the Andean Geosyncline development in Chile, but only silver is of economic significance. Most of the lead-zinc mineralization is emplaced in volcanic rocks, instead of the carbonate rich Jurassic or Lower Cretaceous mioliminar facies (Fig. 1). This may point to a juvenile, sub-volcanic origin for the sulphide mineralization in Chile, unlike that postulated for deposits associated with marine sedimentary rocks surrounding old crystalline massifs, for example the Massif Central of France, (Cevennes) or for the Mississipi Valley deposits, which seem to have a crustal origin.

REFERENCES

Bassi, H., 1958. — Informe sobre el Mineral de Cobre « El Soldado ». Santiago, *Cía. Minera Disputada de las Condes*. Unpublished Report.

El Hinnawi, Pichler, H. and Zeil, H., 1969. — Trace Element Distribution in Chilean Ignimbrites. *Contr. Mineral. Petrology*, **24**, p. 50-62.

Frutos, J. and Oyarzún, J., 1973. — Mapa Metalogénico del Norte de Chile. II Congreso Latinoamericano de Geología. In print.

Losert, J., 1972. — Genesis of Copper Mineralization and Associated Alterations in the Jurassic Volcanic Rocks of the Buena Esperanza. Mining Area. Dept. Geología. Univ. of Chile, Santiago. 104 p.

Nesterenko, G. and Cháves, L., 1971. — Génesis de Yacimientos de Cobre Tipo Manto de Chile. Dept. Geología. Univ. of Chile, Santiago, 17 p.

Oyarzún, J., 1971. — Contribution à l'Étude Géochimique des Roches Volcaniques et Plutoniques du Chili. Thèse. Univ. Paris. 195 p.

Ruiz, C., 1965. — Geología y Yacimientos Metalíferos de Chile. Inst. Invest. Geológicas Santiago. 305 p.