MAGNETIC PROPERTIES OF LA NEGRA FORMATION (CHILEAN COASTAL CORDILLERA): COMPARATIVE ANALYSIS BETWEEN ZONES WITH AND WITHOUT COPPER MINERALIZATION

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INTRODUCTION

We present a characterization of the magnetic properties of La Negra Formation, the most important geological unit of the northern Chile Coastal cordillera. This formation corresponds to a nearly 7.000 m thick sequence of basalts to andesites that were deposited in an island arc to back arc position at Jurassic times. Contemporaneous intrusions (tonalite to granodiorite) cut the volcanics. Regionally distributed very low-grade metamorphism affects the lava flow sequence at different stages. La Negra Formation is the host unit of numerous Cu stratabound deposits [Boric et al., 1990], that provide the second source of Cu production in Chile. This metallogenic belt is the object of mineral exploration supported by high-resolution aeromagnetic data. However the interpretation and the modelization of magnetic anomalies usually do not rely on direct knowledge of the magnetic properties of the underlying rocks. The aim of the present study is to present an extensive characterization of La Negra Formation magnetic properties in areas with and without copper mineralization. The second objective is to use paleomagnetism in mineralized rocks to provide additional insights on mineralization processes, especially about the timing of mineralization events and the behavior of magnetic minerals upon increasing degrees of mineralization.

SAMPLING AND RESULTS

We have selected four areas along the Coastal cordillera between 22° and 25°S that allow us to obtain a regional characterization of the magnetic properties of different rock types from La Negra Formation. From north to south, these areas are (1) Tocopilla, (2) Carolina de Michilla mining district (3) Antofagasta and (4) Paposo (Figure 1). Areas 1, 3 and 4 correspond to non-mineralized sections of the

volcanic sequence. Sampling of rocks affected by hydrothermal alteration and copper mineralization was made in the stratabound deposits that characterize the Michilla district.

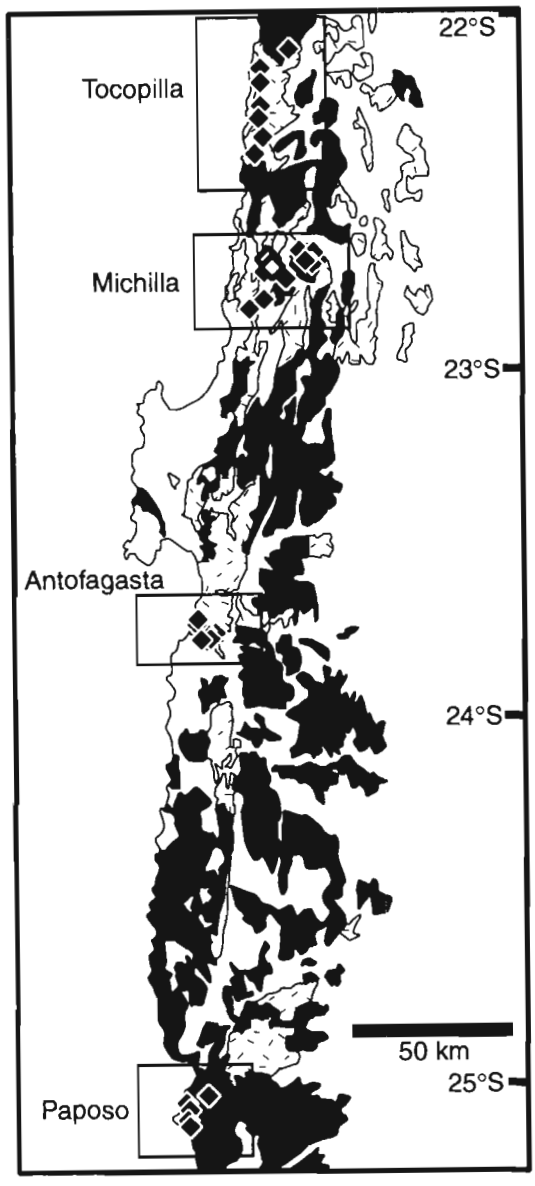

Figure 1: Paleomagnetic sampling in the coastal area of the Antofagasta region.

The paleomagnetic sampling corresponds to 13 sites in Tocopilla area, 9 at Paposo and 17 at Antofagasta, most of them in lava flows and a few in subvolcanic granodioritic to dioritic bodies. Near Antofagasta the paleomagnetic sampling was distributed along a 3000 meters thick profile in the type section of the Formation, "Quebrada La Negra". Evidence of low-grade metamorphism, characterized by the association epidote-clorite-calcite-chalcedonite-zeolites-prehnite-pumpellite is widespread, especially in the brecciated levels of the lava flows. This metamorphism appears more important near Antofagasta than near Tocopilla. In the Carolina de Michilla mining district region, we have taken 250 samples in 2 mining cores 250 and 350 meters long respectively. These cores cut orthogonal the lava flows and related intrusives affected by hydrothermal alteration and Cu-oxides mineralization. Ore bodies present vertical zonation from chalcopyrite-pyrite-magnetite at deeper zones to chalcosine-coveline-hematite to the surface with increasing quantities of Cu oxides.

MAGNETIC PROPERTIES

Magnetic susceptibility of the lava flows for all areas is usually high, ranging from 0.01 to 0.1 (S.I. units) (Figure 2). The highest values are found near Tocopilla, a feature that correlates with the minor amount of low-grade metamorphism. Intensities of magnetic remanence are distributed between 0.06 to 0.6 A/m, with rare values above 1 A/m.

Primary magnetization are found in most sites of the Tocopilla area, while secondary partial to total magnetic overprints characterized most samples collected in the Antofagasta and Paposo areas. As seen in figure 2, the distribution of the magnetic susceptibility versus intensity of remanent magnetization

for samples taken from the cores is roughly similar to the distribution found at other locations in rocks from La Negra Formation. Near Tocopilla, large crystals of magnetite are often seen and laboratory experiments indicate multidomain magnetites as the magnetic carrier.

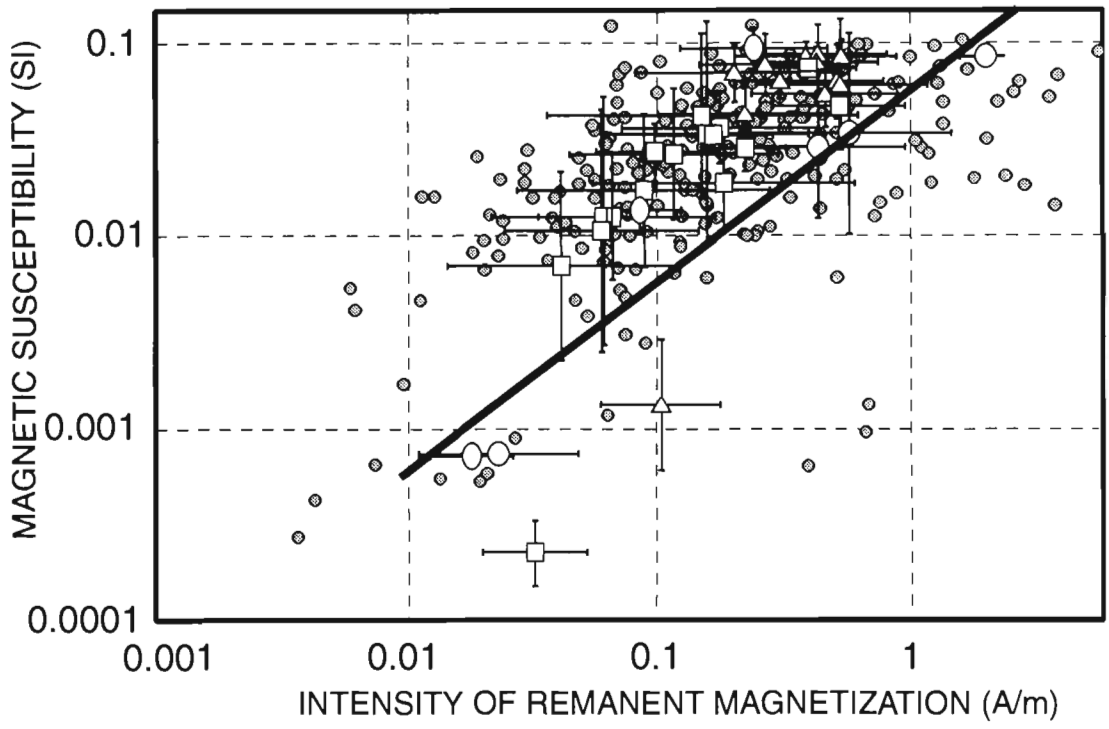

Figure 2: Log-Log plot of the magnetic susceptibility (K) versus intensity of remanent magnetization (J_{NRM}). The thick line corresponds to a Koenigsberger ratio (J_{NRM} /KH) of one. (H is the intensity of the Earth Magnetic Field in northern Chile (~21A/m)) . Data above this line correspond to rocks with an induced magnetization greater than the remanent magnetization. Filled circles are individual samples from the mining cores. White triangles, squares and circles with associated standard deviation are geometric mean site values from Tocopilla, Antofagasta and Paposo areas.

The low magnetic stability of multidomain grains explains why the intensity of natural remanent magnetizations is relatively low. The Koenigsberger ratio is significantly less than one and remanent magnetizations will not contribute much in producing strong magnetic anomalies (Figure 2). Magnetite and maghemite are the principal carrier of the magnetic susceptibility. The presence of maghemite was essentially deduced from the sharp drop in susceptibility during laboratory heating in the temperature range 300°-350°C. Maghemitization due to low-temperature oxidation of magnetite is widespread in these andesitic lavas, probably related to low grade metamorphism. The similar susceptibility of both minerals permits however to maintain a relatively high bulk susceptibility for these rocks. As seen in figure 3, samples with a high maghemite content have the same range of susceptibilty values than those containing magnetite. Maghemitization affects essentially the lavas and not the intrusive bodies.

Maghemization is however a significant factor in reducing the initial remanent magnetization acquired during the emplacement of the volcanic rocks.

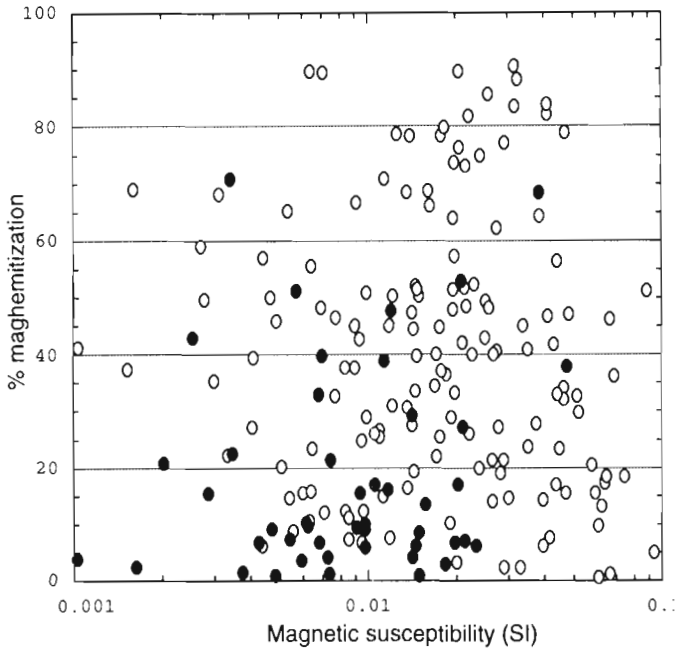

Figure 3: Importance of the maghemitization (defined by the decrease of magnetic susceptibility between 250°C and 350°C) with respect to initial magnetic susceptibility. Samples from the two mining cores.

There is no significant difference between the magnetic properties of non-mineralized areas and the two drill cores from Michilla district (Figure 2). At the regional scale of an aeromagnetic survey, Cu metalogenic processes do not generate relevant changes in magnetic properties of La Negra rocks that would be useful as prospective keys in magnetic surveys. There is however complete destruction of primary magnetic mineralogy only at metric scales where an important concentration of chalcosine and coveline is observed.

In this case, low magnetic susceptibility indicates that hematite is the dominant magnetic carrier. It is interesting to note that these mineralized rocks have stable univectorial remanent magnetizations. Further work is in progress to relate the paleomagnetic information contained in these rocks with the hydrothermal processes

CONCLUSIONS

Magnetic properties of La Negra Formation are characterized by high magnetic susceptibility and relatively low magnetic remanence, consequence of relict primary mineralogy and secondary effects related to very low grade metamorphism. These characteristics are not affected at district to regional scales by Cu stratabound metallogenic processes. At these scales there is no contrast in terms of magnetic susceptibility between mineralized and non-mineralized zones, that could generate a significative magnetic anomaly. Only at local (metric) scales would be seen in very high-resolution magnetic survey some anomalies related to small intrusive bodies with low total magnetization and mineralized bodies with very low susceptibility linked to chalcosine-coveline-hematite. Conclusions, drawn in this paper, are obviously related to the type of mineral deposits observed in the Michilla district and may not apply to other environments.