On the usefulness of high-resolution airborne magnetic and radiometric data in an area of sedimentary cover: Calama West, northern Chile.

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SUMMARY

In 1999 a non-exclusive airborne magnetic and radiometric survey of the Calama area, northern Chile was flown. The area is characterized by an active mining industry, mainly porphyry copper deposits. About 70% of it is under sedimentary cover. Magnetics and radiometrics proved to be very successful in providing important new information on the extent and lithology of the different volcanic and intrusive units. Extensive structural mapping was derived from the data, and a previously unrecognized SW-NE fault system, potentially an important mineralization control, was delineated.

INTRODUCTION

Paterson, Grant & Watson Limited (PGW) and Scintrex Survey & Exploration Technology (Scintrex) proposed and completed a non-exclusive airborne magnetic and radiometric survey of the Calama area, northern Chile (fig. 1). The area is characterized by an active mining industry, mainly porphyry copper deposits. The major objectives of the study were threefold, namely:

1. Prepare a geological interpretation map of the area outlining lithology, structure and intrusive activity based on enhanced products of the recently acquired aeromagnetic and radiometric data, combined with the published geology and satellite imagery.

2. Based on the geological interpretation, recognize signatures of the known mineral deposits in the area, and define areas with similar signatures.

3. From the radiometric data, define structures and correlate them with those defined by magnetic data. Identify probable alteration areas based on radiometric anomalies and the corresponding structural and lithological interpretation.

The survey was flown on N-S lines, with a nominal spacing of 500 m, at a constant nominal elevation of 100 m above the ground. The geophysical system incorporated a caesium vapour magnetometer, 256-channel gamma-ray spectrometer with a 33.6 l crystal pack and a differential GPS navigation system, mounted in a Piper Chieftain

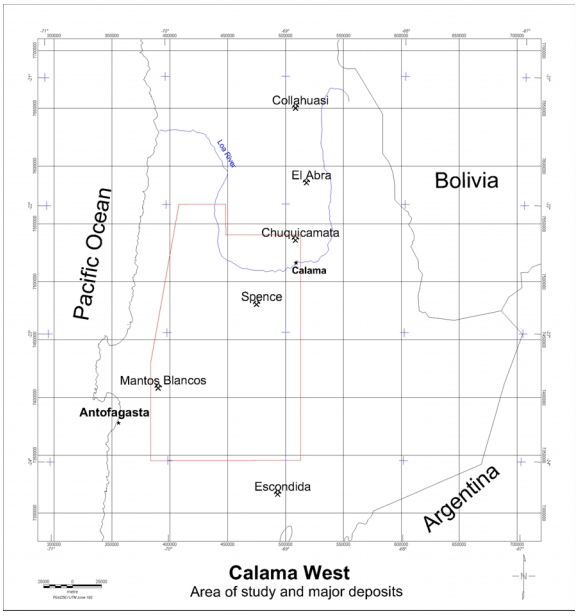

Figure 1: Area of study and major deposits

II. REGIONAL GEOLOGY

The Antofagasta region is a segment of the Central Andes, with a very rich potential for copper and related deposits. The age of the underlying rocks ranges from Upper Precambrian to Quaternary. The most important geological characteristic is that the majority of the outcropping rocks are of igneous origin (plutons & volcanics), showing that magmatic processes were dominant in Andean geological history, whilst metamorphic and sedimentary processes are subordinate.

The geological evolution of this Andean segment, at least since the Upper Carboniferous, essentially follows the type model for continental margin terrain (related to persistent

oceanic crust subduction). The consequent development of successive magmatic plutonic-volcanic arcs is associated with important metallic mineralization, mostly of hydrothermal origin. Sedimentation is restricted to associated fore-arc basins.

Within the Calama West area there are two major structural systems with metallogenic importance: the Atacama Fault System (AFS) and the Domeyko Fault System (DFS).

A) ATACAMA FAULT SYSTEM (AFS)

This regional structure strikes in a NS direction along the Coastal Cordillera between 20° and 27°. It includes vertical and sub vertical faults, sub parallel between them, oriented mainly NS and with branches striking NNE and NNW, in a belt up to 12 km wide.

Development of the AFS as a strike slip fault is associated with oblique convergence of the plates, at the beginning of the Cretaceous, when the mid-oceanic ridge in the Pacific had a direction SW-NE (Scheuber & Reutter, 1992), leading to a sinistral strike-slip fault. According to stratigraphic analysis, some vertical movements have also been detected. An uplift of the eastern block estimated in the thousands of meters, is attributed to compression and subsequent crustal thickening during Upper Cretaceous. There was an uplift of the western block in the Miocene, estimated at 300 m, and since then activity has decreased.

Within this region, the AFS does not have metallogenic importance and marks the eastern limit to the stratabound Cu deposits located in Jurassic rocks of the Coastal Cordillera. The only exception is Mantos Blancos, located east of the AFS.

B) DOMEYKO FAULT SYSTEM

This system is composed of faults that limit uplifted blocks along the Domeyko Cordillera, between 21° S and 26°30'S. The faults strike N5°E and dip vertical to sub-vertical. Generally, the eastern block is uplifted relative to the western one, but the opposite situation also appears.

Paleomagnetic measurements show that during the Oligocene, there was an oceanic ridge in the Southern Pacific with NW-SE orientation. The subduction of the Farallon Plate under the continent was oblique, SW-NE. In this circumstance, strike-slip faulting was produced at the location of the magmatic arc and the magmas were emplaced in extensional areas along the faults. The Domeyko Fault System (DFS), which had a dextral movement during the Oligocene, and the intrusions of Oligocene stocks along this system, suggest that this model was active throughout the region during this period.

The strategic importance of the DFS is that it controls the emplacement of the Oligocene intrusives, related to the biggest copper porphyry deposits (Quebrada Blanca, El\ Abra, Chuquicamata, Escondida).
Within the geological history of this segment, it is possible to distinguish seven stages, considering major regional discordances as a limit between them. Those discordances imply crustal tectonic movement periods, which produced important paleogeographic changes.

III. MAGNETIC INTERPRETATION

Interpretation was carried out at both the 1:250,000 and 1:100,000 scales. More detailed scale analysis is possible, but it was out of the scope of the project.

The structural interpretation was carried out using the total magnetic field and the first vertical derivative maps. For outlining the different units, both the analytic signal and the apparent magnetic susceptibility were used.

III.1 STRUCTURE

The major structural systems are well defined on the magnetics. The more outstanding features are:

1. The NNE branches of the AFS have a notable signature, defining two magnetic domains on both western and eastern sides. The DFS is also outlined, with its recognized control on the Oligocene intrusions.
2. An important set of SE-NW faults that cross the entire area of study. This system defines areas of deformation in between, with minor SW-NE, SE-NW and NS faults. Some strike-slip movement can be delineated in these blocks, controlled by the major SW-NE faults.
3. A remarkable SW-NE major fault system that crosses the entire area has also been defined. Its importance arises because it was not recognized on the mapped geology and because it may be an important control on the intrusive emplacements.
4. Intrusive emplacements are mainly fault controlled. Oligocene intrusives have a NS to NNE control, whilst Tertiary intrusives are related to NS to NNW structures. Cretaceous intrusives follow NW trends.
5. Jurassic volcanics follow a NW trend, outcropping in the west, producing a strong magnetic response in this area, and buried deeply in the east, where magnetic intensity tends to be reduced.

III.2 LITHOLOGY

With the magnetics it was possible to define the major lithologic units and to extend them under covered areas. The more outstanding signatures are:

1. The area has a vast incidence of volcanic units, of Jurassic, Cretaceous and Tertiary age. The more magnetic and extensive are the Jurassic. It was possible to extend their coverage to the east under the sedimentary cover. Cretaceous volcanics are less magnetic than Jurassic and with less extension. However, it is possible that there could be some Cretaceous volcanics overlying the Jurassic that was not mapped. Generally volcanic units have a signature of high frequency and widespread distributed anomalies, with amplitude depending on the lithology of the unit. Jurassic volcanics have a high amplitude, whereas the Cretaceous volcanics' amplitude is moderate.
2. Intrusives have a strong magnetic signature where they outcrop or are close to surface, generally high amplitude anomalies with circular shape. On the total magnetic field map they have strong dipolar signatures that distinguish them from the volcanics. Some of them were defined under the sedimentary cover or within the volcanics. It is significant that is possible to distinguish between various intrusives based on the magnetics. In some cases, the radiometric data provide a stronger indication of the lithology and/or boundaries of the intrusives than the magnetic data.
3. Sedimentary units were outlined according to weak, amorphous magnetic signatures. They are subordinate to the volcanic and intrusive units. Most of these areas are fault controlled and are related to basins delimited by vertical-movement faults.
4. Metamorphic units have little occurrence in the area.

IV. RADIOMETRIC INTERPRETATION

The radiometric interpretation was focused on outlining structures and contacts and on the delineation of radiometric signatures in areas defined as anomalous in terms of:

- the occurrence of radiometric anomalies defined from the ternary radiometric image
- coincidence of the above with intrusives mapped from magnetics, and/or the presence of faults controlling the intrusions, or crosscutting faults without a clear intrusion mapped

The structural mapping based on the radiometric data correlates well with the magnetic structural interpretation. It maps the major faults and also defines shallow contacts between some units. Although about 70% of the area is covered by sediments, radiometrics has proven to be extremely useful in structural and lithological mapping. The reason for this is the relative lack of transport of the sediments in the area, since the paleogeography has changed little since the Miocene. The radiometric responses are a good guide to the provenance of the sedimentary cover, which is useful for interpreting geochemical data.

V. CONCLUSIONS

The purpose of the Calama airborne geophysical survey was to provide a high-quality magnetic and radiometric dataset over an area within Chile's major copper producing region that has been underexplored due to the sedimentary cover.

The survey has been very successful in that:

1) the magnetic data provide important new information on the extent and lithology of the volcanic units;
2) numerous intrusives were newly or more fully characterized by the magnetic and radiometric data;
3) structure associated with the major fault systems is developed in considerable detail;
4) a previously unrecognized SW-NE fault system, which may be an important mineralization control, has been delineated; and
5) the magnetic and radiometric signature of the Oligocene intrusives, related to Chile's major porphyry copper deposits, has been determined and several new targets generated.

The success of this survey has lead to extensions to the south, west and north of the original survey area in 2000, including the Escondida deposit.

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