# Geophysics over the Boa Esperança Copper-Cobalt deposit, Carajás Province, Pará State, Brazil.

Eduardo Ferreira Henrique, Reconsult Geofísica Ltda.; Paulo José Mena Barreto de Andrade, MBA GEO Exploração Mineral Ltda.; and José Guilherme Xenofonte Pereira Valle, Mineração Caraíba S/A.



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## Abstract

**This paper shows and discusses the results of the airborne (magnetics and gamma ray) and ground geophysics (magnetics, gravity, induced polarization and DC resistivity) methodologies applied over the mineralizations of the Boa Esperança deposit located in the south portion of Carajás Province, Pará State, Brazil.**

## Introduction

The Boa Esperança Copper-Cobalt deposit is located 180 km southwest of the Carajás Village, nearby Tucumã town, State of Pará, Brazil.

Due to the absence of gold and presence of cobalt, Boa Esperança cannot be classified as a typical IOCG class of deposit, despite alteration and mineralization styles are quite similar to important IOCG deposits of the Carajás Province, such as Alemão, Sossego and Alvo 118.

The deposit was discovered by CODELCO in late 2003 by drilling, after a field check done in 2002 of a magnetic anomaly detected in a poor quality regional airborne survey. In 2007, the Boa Esperança Deposit was sold to MINERAÇÃO CARAÍBA S/A, that is nowadays starting development.

Boa Esperança is related to hydrothermal alteration, which includes several stages of IOCG type and is restricted to an opening space structure, such as a dilatational jog of NE direction. The main alteration is a strong K-metassomatism which makes a wide regional granodiorite becomes locally granite (*lato sensu)*. Sharp contact relationships are not observed to classify the granite as an intrusive body.

As intense as the potassic alteration (K feldspar, biotite and minor sericite), there is a Fe metassomatism, represented by magnetite at a deep level and hematite at shallower ones. Chloritization is also present at more than one stage. Carbonatization usually represents the latest stage of alteration.

Copper-cobalt hipogenic mineralization occurs mainly in breccia, quartz veining and in altered granitoid, replacing previous alteration assemblages or, in some cases, infilling them within silica.

Mineralization comprises more than one pulse of sulphidation, including at least one pyrite stage, which hosts cobalt and is partially overprinted by chalcopyrite from the center to the deposit border, characterizing the copper ore zone.

Airborne and ground geophysics were applied over the mineralized area to help the deposit evaluation and delineation. The magnetic, gravity and induced polarization methods were able to detect mineralizations mainly due to its association with magnetite and sulphides.

## Airborne geophysics

A fixed wing airborne magnetic and gamma survey was conducted using lines 250 metres apart, at a nominal survey altitude of 100 metres. The lines direction was N30$^{o}$.

The airborne magnetic survey delineated a clear magnetic source that is related to the mineralization (see figure 1). The deposit is coincident with a reverse magnetic dipole anomaly with amplitude of more than 1,000 nT. The circular magnetic source is about 1,500 metres west of a NNW regional magnetic structure.

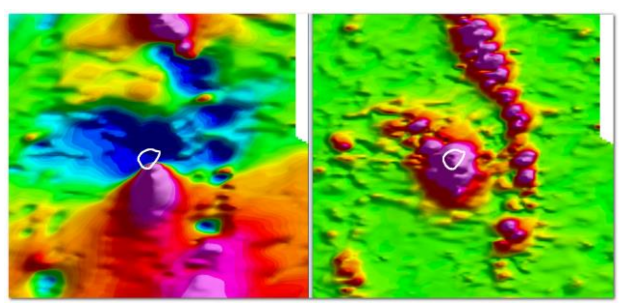

**Figure 1** Airborne magnetic images over the deposit (white polygon). Left, the total magnetic intensity image. Right, the analytic signal of the magnetic data.

The airborne gamma ray survey also was able to detect the deposit. As many IOCG deposits around the world, the Boa Esperança is clearly associated to a circular uranium anomaly (see figure 2). The potassium and thorium images did not reflected the deposit.

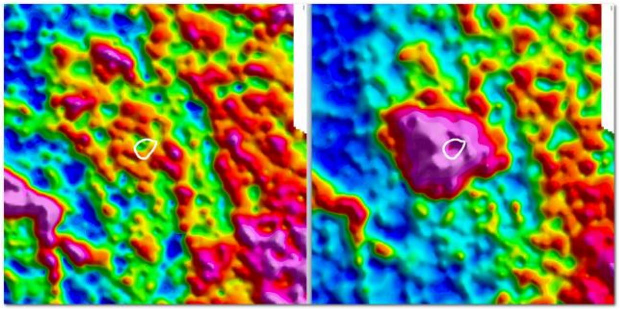

**Figure 2** Airborne gamma ray images over the deposit (white polygon). The potassium distribution image (left). The uranium distribution image (right).

It is important to note that the region of the airborne survey was intensely deforested by cow farmers in the last decades; the ground was exposed, increasing the geological mapping capability of the gamma ray methodology.

## Ground geophysics

### Gravity and Magnetics

A total of 450 gravity stations and 70 km of ground magnetics were collected over the deposit in 2004. The line direction of the ground grid was N30$^{o}$W. The gravity was acquired in stations separated by 50 metres in lines 100 to 300 metres apart. The magnetic data was acquired at interval of 10 metres using the same line separation.

The figure 4 shows the final magnetic and gravimetric images of the ground surveys. The magnetic data, as expected, showed with more resolution the airborne anomaly associated to deposit. The anomaly amplitude is about 4,000 nT. The gravity data processing included a complete Bouguer correction to eliminate the influence of the Boa Esperança hill. Even after the topographic correction, the positive gravity anomaly was coincident with the topography due to the fact that the topography is also reflecting geology as the gravity.

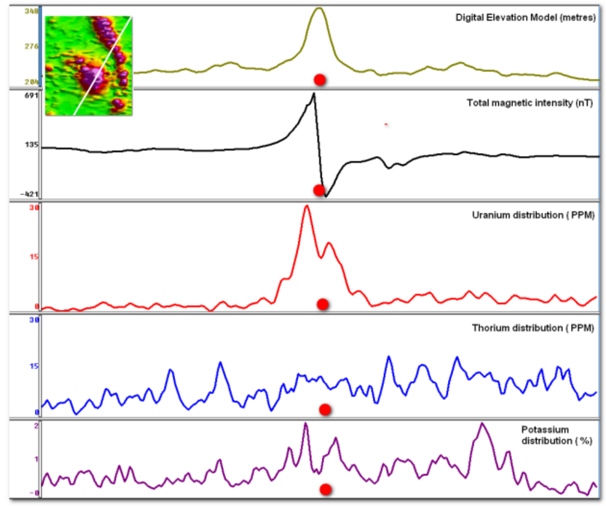


**Figure 3** Summary of the Boa Esperança airborne geophysical signatures through profile views right over the deposit (red dots).

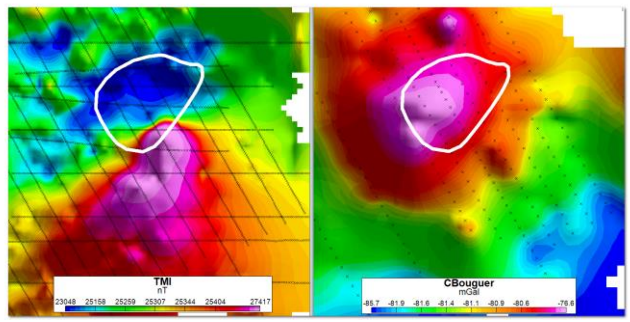


**Figure 4** Ground magnetic (left) and gravity (right) of the deposit (with polygon). The reading points are represented as black crosses.

A gravity-magnetic simultaneous tridimensional modeling was conducted to estimate the geometry and depth of the causative dense and magnetic body. See figure 5. The gravity data was modeled using a density contrast of 0.46 g/cm$^3$. Remanent magnetization parameters were used to model the magnetic data. The modeling results suggested that the source is outcropping, plunges with 70$^{o}$/315$^{o}$ and has a cylinder shape with a diameter of 350 metres.

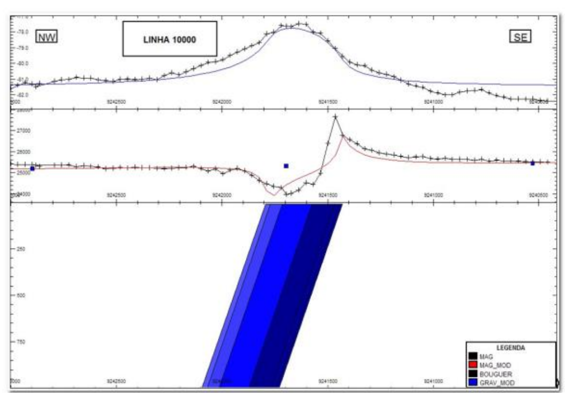


**Figure 5** Results of the gravity and magnetic simultaneous modeling.

<u>Induced polarization and DC resistivity</u>

Induced polarization (IP) and resistivity data were acquired over a least ten lines over the deposit. The line directions were EW and N30$^{o}$W separated by 200 or 300 metres. Dipole-dipole and pole-dipole arrays with different dipole sizes were tested. All surveys were conducted using time-domain receptors, using square waves with frequency of 0.125 Hz.

The inversion of the IP and resistivity data was fundamental due to topography. The best results were obtained in the EW lines using a 40 metres dipole. The interpretation revealed that the IP and resistivity methodologies were able to detect the sulphides, mainly pyrite and chalcopyrite, associated to the mineralization. The figure 6 shows an example of the east-west line 41600 (40 metres dipoles). Under the hill is detected a polarizable body (up to 30 mv/v) and a conductor (bellow 75 ohm.m).

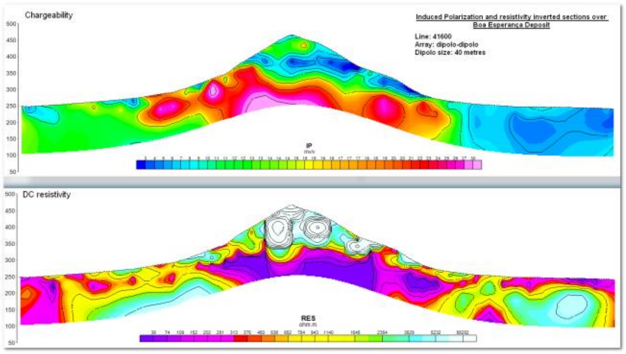


**Figure 6** IP (top panel) and DC resistivity inverted sections right over the middle of the deposit.

## Conclusions

The Boa Esperança “IOCG like” deposit located in the Carajás Region has clear geophysical signatures from the air and ground. The similarities of the airborne geophysical signatures of the Boa Esperança and Alemão (Barreira et al. 1999 and Barreira, 2006) deposits, both in Carajás region, are beyond the expectations. The deposits are coincident with magnetic and associated to uranium highs as many IOCG deposits around the world.

The analysis of the regional airborne magnetic and gamma ray information during the evaluation of an IOCG prospect in Carajás region is relevant to achieve a correct exploration decision.

## Acknowledgments

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