Using Low Frequency Ground and Downhole TDEM to explore for Massive Sulfide Mineralisation in the Carajás Mineral Province

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SUMMARY

The Carajás Mineral Province in Brazil hosts the highest concentration of major IOCG deposits in the world. Airborne and ground electromagnetic (EM) methods are frequently applied when exploring for these deposits using relatively high operating frequencies (25Hz - 30Hz). This frequency range limits the survey to effectively detect shallow, weakly to moderately conductive sources.

An airborne EM survey (VTEM) using a 30Hz base frequency has been flown by Falconbridge Ltd over the Pedra Branca deposit in 2005, identifying two discrete anomalies in the area. The high frequency nature of the VTEM system did not provide good depth resolution of the anomalies and follow-up ground EM surveys were conducted.

An orientation fixed loop EM (FLTEM) survey was carried out at Pedra Branca to compare the effectiveness of using lower frequency (2Hz) ground EM against existing VTEM and previous high-frequency ground EM surveys. The application of EM methods using frequencies of 2Hz and below enables the detection of late time conductors by recording much later in time compared to high frequency systems. These typically detect stronger, deeper conductors which are commonly related to higher grade and/or thicker massive sulfide mineralisation.

The results of this new survey significantly increased the resolution of the conductor. Modelling of the FLTEM data shows excellent correlation with the high-grade mineralisation surface, down to a depth of approximately 550m.

An FLTEM survey was also completed over the Azevedo prospect and provided a significant improvement in resolution compared to the historical, poorly defined VTEM anomaly. The FLTEM data provided an 80m lateral adjustment to the initial anomaly, allowed detailed modelling, and reduced drill testing uncertainty.

Ground and downhole EM surveys at lower frequencies are now being used extensively to effectively explore for massive sulfides with a greatly increased depth of investigation compared to historical airborne and ground EM surveys.

Key words: Carajás Mineral Province, FLTEM, VTEM, IOCG

INTRODUCTION

The Carajás Mineral Province (CMP) is located in the south-eastern section of the Amazon Craton in northern Brazil (NetunoVillas & Santos, 2001). The mineral province hosts the highest concentration of major IOCG deposits in the world, collectively producing approximately 2 billion metric tons of Cu-Au ore (Xavier et al., 2012).

Avanco Resources Ltd (AVB Mineração Ltd) is the second-largest landholder in the CMP behind major miner Vale. Their tenure includes the high-grade copper-gold mine Antas Norte and the larger undeveloped Pedra Branca deposit. In 2006, an airborne electromagnetic (EM) survey (VTEM) successfully detected what is now known to be the shallow portion of the Pedra Branca mineralisation (Figure 1). Data was collected using a base frequency of 30Hz and identified clear anomalies over the deposit. Due to the high frequency of the system, the depth resolutions of these anomalies are limited.

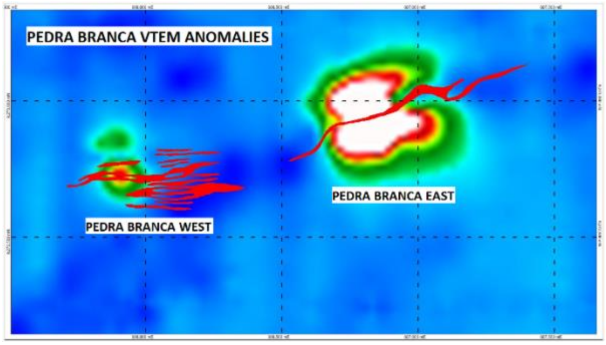

Figure 1. Airborne electromagnetic survey (VTEM) image (0.3 msec) over the Pedra Branca deposits (mineralisation in red)

To better characterise the VTEM anomalies, an orientation fixed loop EM (FLTEM) survey was carried out over the Pedra Branca deposit using a base frequency of 2Hz. This frequency is considered unconventional in the area where historical ground EM survey data are typically acquired using a 30Hz base frequency. This higher frequency has been traditionally used in the area due to the relatively resistive host rocks and thin cover which results in the primary excitation field travelling quickly through the ground. This is in contrast to more conductive environments where the EM fields travel slower and require longer detection windows. A 2Hz base frequency was used in this instance to resolve the response from stronger and deeper conductors that are detected in the late channels of the detection window.

The results of the orientation survey improved the resolution of the conductor significantly both laterally and vertically, compared to the previous VTEM survey (Figure 2) and displayed excellent correlation with the existing high-grade mineralisation surface to a depth of 550m below surface.

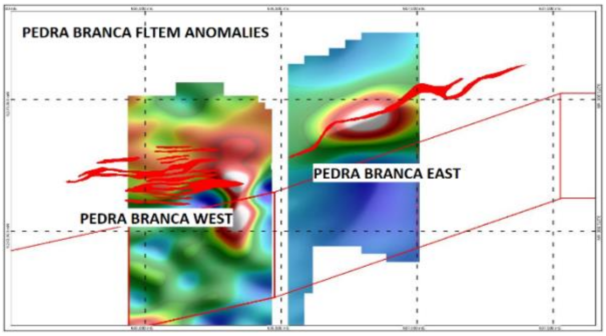

Figure 2. Fixed Loop TEM surveys over Pedra Branca deposits. Image is of B-field X component (6.093 msec). Mineralisation is in red and loops are shown as thin red lines

GROUND SURVEYS

A FLTEM survey was then commissioned over the Azevedo prospect, a satellite deposit located roughly 1 km north of the existing Antas Norte copper-gold mine. This followed a scout drilling campaign where use of the historic VTEM survey data operating at 30Hz was unsuccessful at intersecting modelled conductors. Using a base frequency of 2Hz together with a station spacing of 25m, Avanco were better able to resolve the EM response and model the conductor position, which was approximately 80m east of the modelled VTEM conductor position. The increased resolution afforded by the ground EM system allowed the detailed modelling of narrow, steeply dipping, yet highly conductive sulphide mineralisation and ultimately more effective drill targeting (Figure 3).

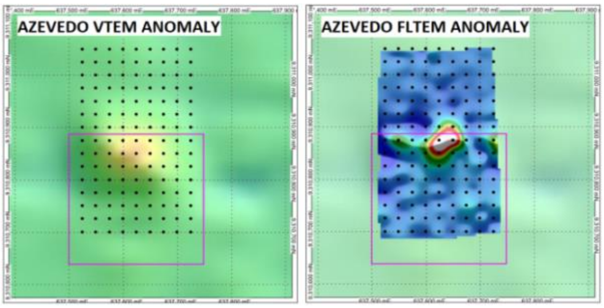

Figure 3. Historic VTEM survey on the left over the Azevedo prospect, New FLTEM survey showing improved spatial resolution on the right

DOWNHOLE SURVEYS

The benefits of a low frequency DHTEM survey at the Pedra Branca deposit can be seen in Figure 4 where field data acquired using a 2Hz base frequency was compared against the same data which had been re-processed to simulate the acquisition using a 30Hz base frequency.

In the data acquired at 30Hz, the signal was only able to be recorded to a time of 6.56ms. In doing so, a moderate conductor at a depth of around 325m was identified. In contrast, the field data acquired using a 2Hz base frequency was able to record to a time of 101.9ms. This allowed for the detection of the conductor at 325m, as well as from a larger, more conductive and distal target at a depth of 425m which would not have been identified in the 30Hz survey.

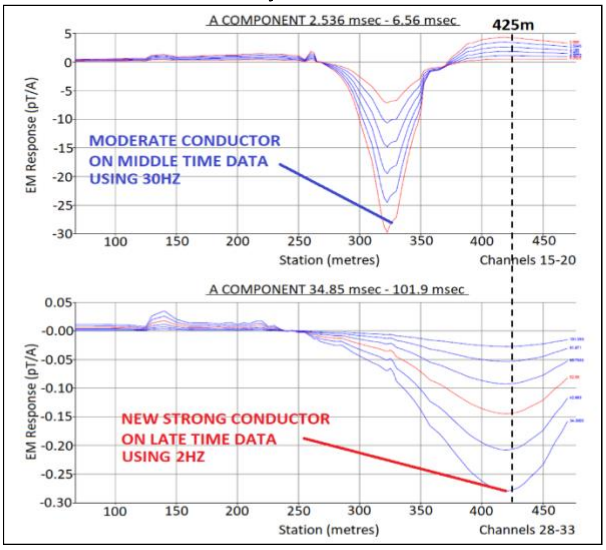

Figure 4. DHTEM data comparison of historic 30Hz survey (top) and more recent 2Hz survey (bottom) showing the associated new late time anomaly at 425m

PLATE MODELLING

Forward modelling of the recent low frequency FLTEM and DHTEM surveys has been undertaken at the Pedra Branca deposit using Maxwell, a proprietary software by EMIT, designed to read and model electromagnetic data. This improves the accuracy of follow up drill targeting beyond simple qualitative anomaly identification. The forward models of DHTEM, FLTEM and VTEM conductivity plates are shown in Figure 5.

Looking at the Pedra Branca East deposit, a large improvement on the position, dip and plunge of the plate models can be seen when comparing between the VTEM plate and the FLTEM and DHTEM plates. The initial VTEM plate is modelled near to surface as an elongate near-vertical conductor with no dip. The FLTEM and DHTEM plates have a much larger depth extent with a dip angle which correlates strongly with that of the known mineralisation. In addition, the DHTEM data also provided sufficient resolution to discriminate and model discrete mineralised lenses at depth.

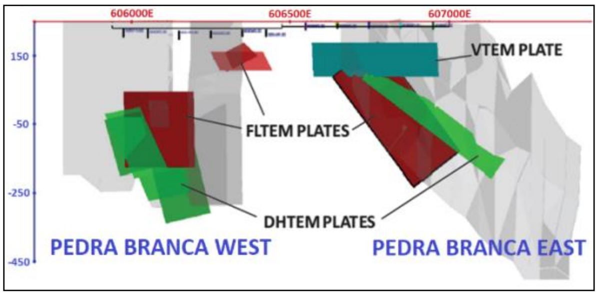

Figure 5. Long Section of the Pedra Branca deposits (grey surface) showing the improved spatial resolution provided by the FLTEM and DHTEM modelling, over the VTEM modelling

CONCLUSIONS

Modelling and analysis of historical airborne and ground electromagnetics with high frequencies compared with more recent low frequency ground electromagnetics over the Pedra Branca and Azevedo deposits has displayed a clear and tangible improvement in determining the location, size and depth of IOCG deposits in the CMP. Electromagnetic surveys in the past have typically used a frequency range around 30Hz which works well for areas where there is relatively resistive cover since the EM signal is able to be transmitted and received quickly with little attenuation. This is not the case in more conductive environments where the EM signal remains in the near surface for longer, and receiving a signal from deeper bodies requires longer periods of detection. The change also increases the effective depth penetration and detection radius for deeper or more distal and highly conductive targets in ground and borehole EM surveys.

ACKNOWLEDGMENTS

The authors would like to acknowledge Avanco Resources for the permission to present and publish this information. We would also like to acknowledge Owen Hatton for his support and contribution to the project.

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