An assessment of ZTEM and time domain EM results over three mineral deposits

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SUMMARY

The ZTEM airborne EM system was introduced into commercial service by Geotech Ltd. in late 2007. ZTEM is unlike any other commercial EM system in that it relies on the measurement of natural occurring EM fields in the AFMAG frequency range of 25-720 Hz.

As a result of using natural EM fields that pass through the earth as plane waves, the ZTEM system response shares similarities and important differences to traditional inductive source EM systems such as VTEM or MegaTEM, used extensively by the minerals industry to explore for targets of high conductance. While ZTEM can detect discrete conductors like inductive systems, it also responds to bulk changes in resistivity and conductivity gradients that often characterize geological contacts or structures.

One of the key means assess how a new technology performs is to compare the new outcomes with results from well-understood techniques. In this review, ZTEM data will be compared with data from three different airborne TEM systems over three deposits.

Key words: AFMAG, ZTEM, airborne TEM, conductive mineral deposits.

INTRODUCTION

In the present study, the results of ZTEM surveys carried out over three mineral deposits are examined along with airborne TEM data obtained over the same locations. The three deposits are the Morrison porphyry copper-gold system in British Colombia, Canada, the Cinco de Mayo carbonate replacement deposit (CRD) deposit, Chihuahua Mexico and the Nebo Babel Ni-Cu-PGE deposit, West Musgrave, Australia. Only the Nebo Babel deposit could be considered to be 'classic' high conductance massive sulfide deposit but this is complicated by extensive development of conductive Tertiary channels in the vicinity of the deposit. At Morrison and Cinco de Mayo, while there are conductivity features associated with the deposits, the responses are complex and likely related to aspects of the geology not thoroughly understood at the present. Only in the case of Pozo Seco were the two surveys conducted by the same party and were intentionally designed to facilitate the intra-system comparison. At the other two sites, different line directions and spacings were employed which meant that comparisons were less exact. However, it was felt that there was sufficient overlap of results such that meaningful comparative outcomes were obtained.

THE SYSTEMS

The ZTEM system (built and operated by Geotech Ltd.) measures the AFMAG responses of naturally occurring subsurface currents, induced by distant lightning discharges. The vertical component is measured from a helicopter platform, while the horizontal components are recorded on the ground at a base station; data are typically acquired over a frequency range of 25-720 Hz. Various methods are used for the modeling and interpretation of ZTEM data, including 2D and 3D inversions, Karous-Hjelt filters and the derivation of apparent conductivity; these are discussed in Sattel et al. (2010).

The airborne TEM systems which generated data for the three sites were AeroTEM III (Morrison), VTEM (Cinco de Mayo) and Geotem (Nebo Babel). For all the airborne TEM results, the primary processing performed was 1D layered earth inversion (LEI) and time constant.

FIELD RESULTS

Morrison Deposit, British Colombia .

The Morrison deposit is porphyry copper-gold system located in central British Colombia. The deposit has a measured and indicated resource of 115.3 Mt @ 0.44 Cu and 0.20 % Au (Pacific Booker Minerals web site). In addition to the Morrison deposit, a second mineralized zone called Hearne Hill is located several kms. to the SE of Morrison. Hearne Hill is described as a breccia style deposit containing mainly copper mineralization. One geological assessment suggests Hearne Hill is the fault off-set lower part of the Morrison intrusive. An AeroTEM III survey was carried out over the property in October 2008 (Rudd and Sterritt 2009) and the ZTEM survey was carried out over the deposit in May 2010 (Legault 2010). An outline of the two surveys over the deposit area is shown in Figure 1.

Figure 2 shows the early time response from the AeroTEM III (left image) and the IP 360 Hz DT ZTEM result. The Morrison deposit is interpreted to lie within a graben structure bounded by two major NW-trending faults. Both the AeroTEM and ZTEM appear to capture the same overall

linear aspects of these structures but differ in the specific expression of the features.

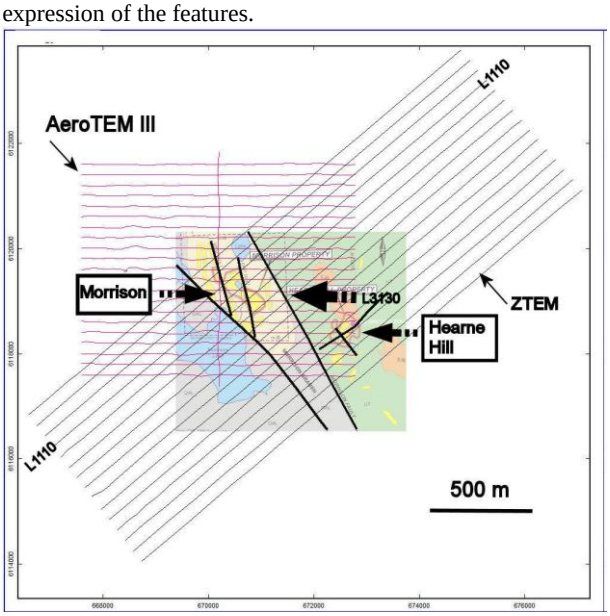

Figure 1: Location of AeroTEM III and ZTEM surveys over Morrison deposit.

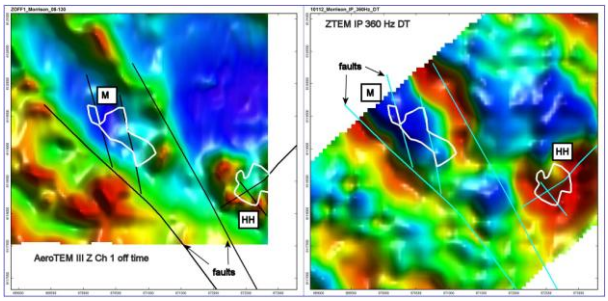

Figure 2: AeroTEM III Z Ch1 off-time and ZTEM IP 360 Hz DT.

With the AeroTEM, the western most structure is defined as the eastern edge of an elevated zone of conductivity whereas with the ZTEM, the structure appears as a discrete ridge of higher response. For the eastern graben structure however, both surveys produced similar looking responses. As well, both surveys suggest this structure has more complexity than has been mapped (i.e. a straight line). There are two sub-structures mapped with a NNW strike that off-set parts of the Morrison deposit. Neither the AeroTEM nor ZTEM surveys appear to detect these structures. However, both surveys do appear to show a possible structure that cuts off the SE end of the Morrison deposit.

The Hearn Hill deposit has a similar expression in both the AeroTEM and ZTEM but this looks very different than Morrison. The two surveys show the Hearne Hill deposit to sit within what appears to be a conductive annulus that is open to the NW.

Figure 3 shows the LEI result for the AeroTEM line over the Morrison deposit. The response of the Morrison deposit is not that clear. There are several zones of shallow resistivity high which could be the expression of the mineralized intrusions.

Figure 4 shows the 2D inversion of the ZTEM for L1100 directly over the Morrison deposit. The deposit itself appears as a modest shallow resistive zone.

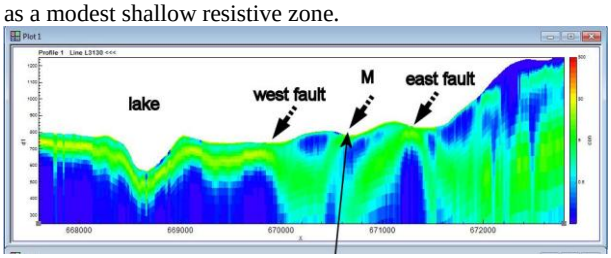

Figure 3: AeroTEM III LEI for L3130 over Morrison deposit (refer to Figure 1 for location).

The western graben fault is a major conductive structure whereas the eastern structure is a minor conductive zone.

The two airborne surveys at Morrison showed considerable similarity in outcomes, especially for the grid based results. In the depth inversions, the ZTEM results appeared to show the Morrison deposit and its bounding faults with better resolution than was obtained with the AeroTEM survey.

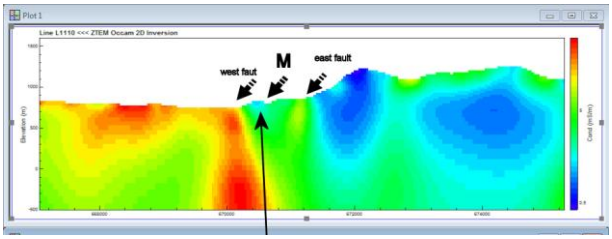

Figure 4: ZTEM inversion for L1100 over Morrison deposit (refer to Figure 1 for location)

Cinco de Mayo Property, Mexico

The Cinco de Mayo (CDM) property (Robertson and Megaw 2009) is located in north-central Chihuahua, Mexico. CDM is comprised of several different mineralized systems that are thought to be part of a CRD-style deposit. An idealized geological section through a CRD system is shown in Figure 5.

Two major zones of mineralization have been recognized Jose Manto and Pozo Seco. As well as two zones adjacent to Jose Manto, Pegaso and La Gloria have been recognized.

The Jose Manto zone has an Inferred Mineral Resources of 12.45 million tonnes at 132 g/t silver, 0.24 g/t gold, 2.86% lead, and 6.47% zinc. Pozo Seco is a structurally-controlled (occurs where three thrusts overlap) jasperoid 2,500 meters long, by 300 meters wide and 50 to 250 meters thick. Molybdenum mostly occurs on fracture surfaces as powellite (CaWO3) with later native gold. Pozo Seco has an Indicated Resource of 29 million tonnes averaging 0.147% moly and 0.25 g/t gold and another 23 million tonnes of Inferred (MagSilver Corp. web site).

VTEM and ZTEM were flown over the property in 2009. The location of the two surveys is shown in Figure 6. Figure 7 shows depth slices from the conductivity models for the VTEM and ZTEM surveys. The Jose Manto and Pozo Seco deposits are shown along with the TMI as contours. With the VTEM, at a shallow depth, the Pozo Seco deposit appears at the break in a linear trend. This feature is also apparent in the shallow ZTEM result. At greater depth, the VTEM response

dissipates but the linear high in the ZTEM persists. Overall as well at the greater depth, the VTEM response is quite limited to a conductive zone in the SW part of the survey block.

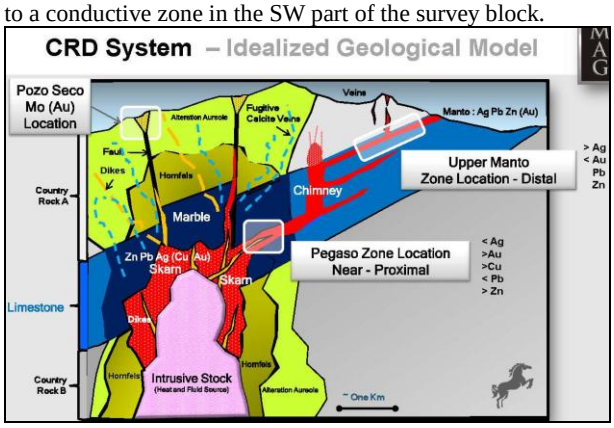

Figure 5: Cross section through idealized CRD system; geology from MagSilver web site.

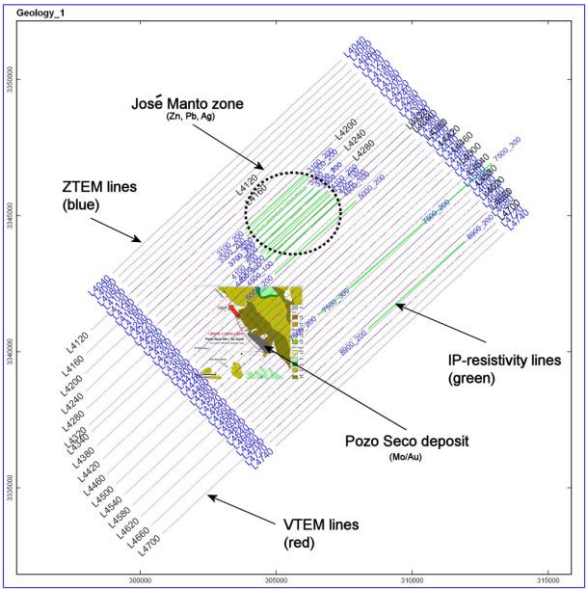

Figure 6: Outline of VTEM and ZTEM over Cinco de Mayo property; geology from MagSilver web site.

The ZTEM however, shows extensive conductivity over most of the survey area. The Jose Manto zone appears in a somewhat elevated conductivity zone in both the VTEM and ZTEM but is generally non-descript.

Figure 8 shows the conductivity depth section through the Pozo Seco deposit. The VTEM shows a clear anomaly under the deposit and could represent a conductive segment of one of the thrust faults. The ZTEM shows a conductor in the same location but as well shows a conductive zone with a shallow dip to the east.

The ZTEM however, produces far more character in low conductivity zones than the VTEM.

Nebo Babel Deposit Western Australia

The Nebo–Babel Ni–Cu–PGE sulphide deposit is located in the West Musgrave Block, Western Australia. The deposit is hosted within a concentrically zoned, olivine-free, tube-like (chonolithic), gabbronorite intrusion (Seat et al 2007). The Nebo and Babel occurrences are believed to have formed as one entity but faulting along the Jameson Fault has separated the two zones by approximately 1 km N-S and 800 m E-W.

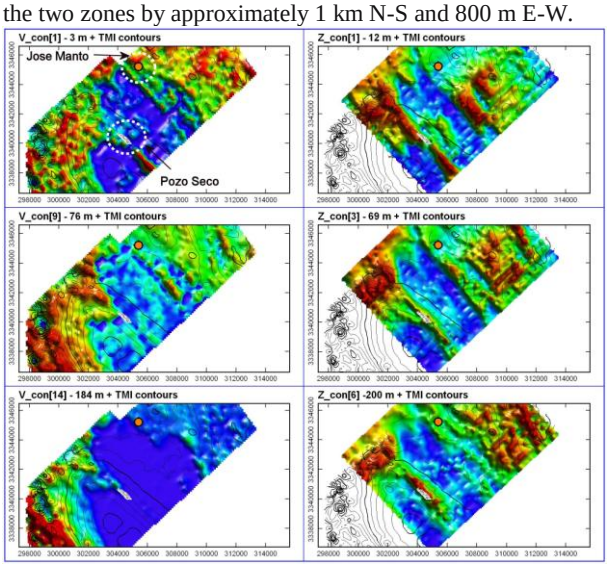

Figure 7: VTEM and ZTEM conductivity depth slices.

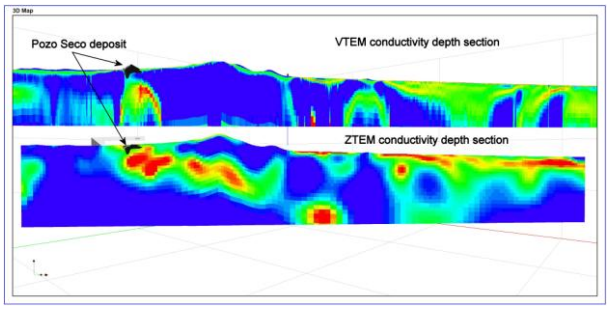

Figure 8: Conductivity depth sections for VTEM and ZTEM over the Pozo Seco deposit.

Figure 9 shows a perspective view of the deposit. The defined mineralization inventory is 392 Mt at 0.3 % Ni, 0.3 % Cu, 0.18 g/t PGE. Geotem was flown over the deposit in 2001 using a 200 m line spacing with N-S lines. ZTEM was acquired in 2010 in two directions (E-W 200 m spacing and N-S 400 m spacing). The various flight paths are shown in Figure 10. The deposit setting has extensive development of Tertiary channels that invariably contain conductive fill. This complicates the use of EM technology in general. One such channel follows the Jameson Fault that separates Babel from Nebo.

The Geotem late time (Ch. 20) with the discrete picks is shown in Figure 11. The discrete conductors are not totally within the gabbroic intrusions. This suggests that post-formational tectonic stress has resulted in the massive sulfides being squeezed out into the country rocks.

Figure 12 shows the ZTEM (N-S lines) 75 Hz IP DT response with the Geotem discrete conductors indicated. The strong overprint of the Tertiary channels is apparent in this image as well. The discrete EM picks determined manually from the Geotem are as well shown.

The ZTEM appears to show higher conductance responses associated with the Geotem anomaly picks for both Babel and

Nebo. There is reasonably close correlation between the deposit outline and enhanced conductivity in the ZTEM.

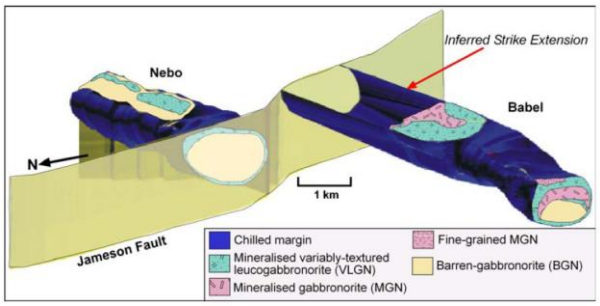

Figure 9: Perspective view of Nebo-Babel deposit; from Legault et al 2012.

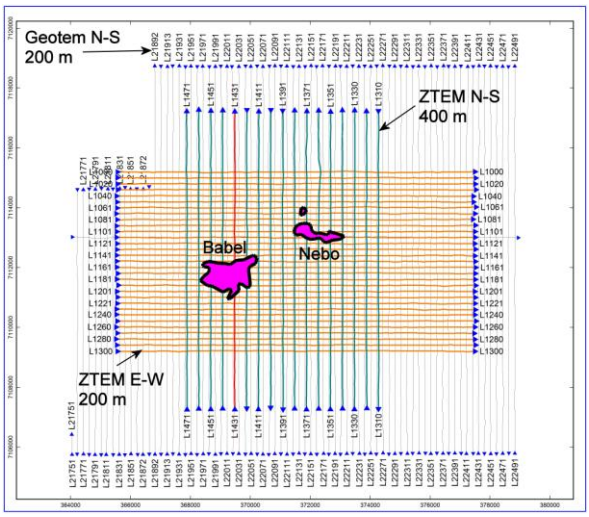

Figure 10: Outline of survey flight path for Geotem and ZTEM surveys.

As shown in Figure 13, the Tertiary channel response is also present in the ZTEM results.

Geotem and ZTEM surveys over the Nebo-Babel deposit both provide reasonably well constrained responses over the zones of known shallow mineralization. Both surveys also show the effects of prominent Tertiary channels systems in the area.

ACKNOWLEDGMENTS

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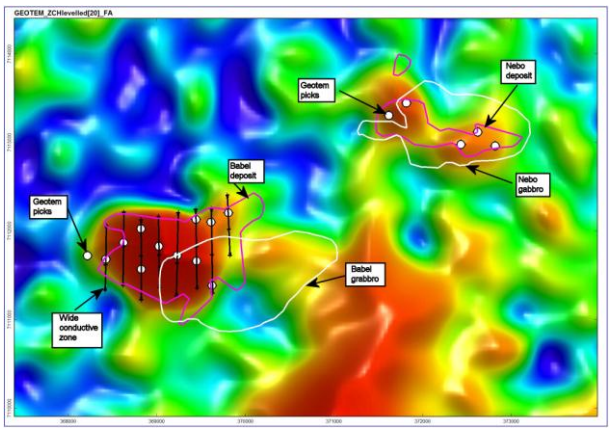

Figure 11: Geotem Ch 20 (late time) with discrete conductor picks.

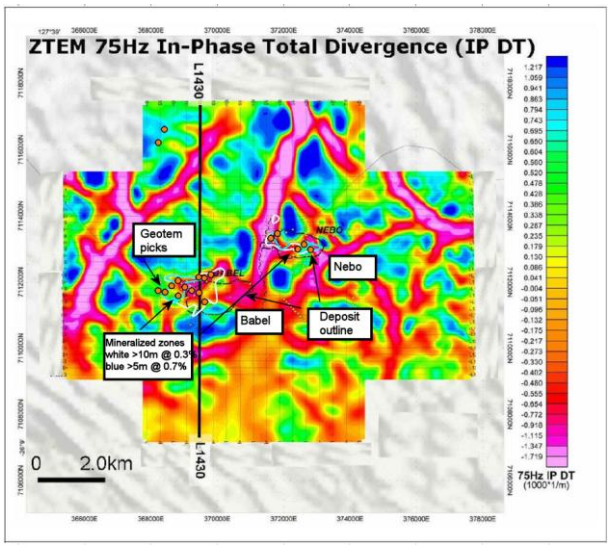

Figure 12: ZTEM N-S survey 75 Hz IP DT showing the effect of Tertiary channels.

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