ASEG-PESA 2013
'THE EUREKA MOMENT'
11-14 AUGUST 2013 • MELBOURNE, AUSTRALIA

Passive and active helicopter EM survey comparisons over 501 Project Cu-Zn volcanogenic massive sulphide at McFauld's Lake, northern Ontario

Marta Orta	**Jean M Legault***	**Alex Prikhodko**	**Geoffrey Plastow**	**Shengkai Zhao**	**Chad Ulansky**
Geotech Ltd.	*Geotech Ltd.*	*Geotech Ltd.*	*Geotech Ltd.*	*Geotech Ltd.*	*Metalex Ventures Ltd.*
Aurora CAN	*Aurora CAN*	*Aurora CAN*	*Aurora CAN*	*Aurora CAN*	*Kelowna CAN*
marta.orta@geotech.ca	*jean@geotech.ca*	*alexander@geotech.ca*	*geoffrey@geotech.ca*	*shengkai@geotech.ca*	*culansky@metalex.ca*

SUMMARY

Helicopter AeroTEM, VTEM and ZTEM surveys were flown over the 501 zone in the McFauld's Lake area, northern Ontario. The 501 zone is a relatively small VMS deposit that appears to respond well to all three active and passive airborne EM systems that have surveyed the property. Comparisons between these data sets and the geology are showcased using 1D-2D-3D EM inversion modeling.

Key words: AeroTEM, VTEM, ZTEM, VMS, Inversion.

INTRODUCTION

The 501 project, belonging to joint-venture partners Metalex Ventures Ltd. and White Pine Resources Ltd. is a high grade Zn-Cu-Pb-Ag mineralized, Mattagami-Noranda style volcanogenic massive sulphide (VMS) deposit that is situated in the northern extension of the Ring of Fire region of McFauld's Lake, northern Ontario. It hosts significant intersections of massive and semi-massive sulphide, which have been delineated over a 200m NS strike length and to a vertical depth of 275m from surface (www.whitepine resources.ca).

The 501 zone was discovered in 2008 following drilling of AeroTEM airborne electromagnetic and follow-up ground magnetic and horizontal loop HLEM survey program in 2007 (www.whitepineresources.ca). In fall 2008, as part of a larger, more regional survey, the deposit and surrounding area was flown with the VTEM helicopter EM system. And in summer 2009, the area was flown with the ZTEM passive helicopter EM system. The objectives of the VTEM survey was to provide greater depth of investigation, below the conductive alluvial and sedimentary cover, and for the ZTEM survey to provide indications of possible extensions of mineralized zones at depth.

Airborne EM, both passive and active, are known to be very useful tools for copper exploration – albeit respectively for disseminated copper porphyries and Cu-bearing volcanogenic & magmatic massive sulphide (MS) deposits. Although, in exploration settings, passive and active AEM surveys are rarely both flown over the same property, several joint ZTEM-VTEM test case studies for massive sulphides have been presented, notably the Axis Lake (Legault et al., 2009), Eagle's Nest (Legault et al, 2010), Nebo-Babel (Legault et al., 2012), and Mayville (Orta et al., 2012) magmatic Cu-Ni deposits, as well as the Lalor Lake Cu-Au VMS deposit (www.geotech.ca). However, in nearly all instances these have all been relatively large/long strike-length orebodies, which are well-suited to ZTEM's large footprint and large depth of penetration. Smaller MS deposits, such as East Bull Lake (Legault et al., 2011) and Forrestania (Sattel et al., 2010), have not always responded as well to ZTEM (Smith, 2012). However, at approximately 200 x 250m, the 501 zone is a relatively small VMS deposit that appears to respond well to all three active and passive airborne EM systems that have surveyed the property. As a result, this aspect is explored further in this case-study.

Property Geology

In general, the geology is poorly known due to extensive swamps and deep overburden (10 to 20 m deep) that severely limit any outcrop exposure. The area lies within the Precambrian rocks of the Superior province, Neo-to-Meso-Archean. Figure 1 shows the locations of current airborne surveys over the bedrock geology map. The 501 zone occurs along a NW-SE trending mafic to intermediate metavolcanics contact with foliated tonalite intrusive rocks.

The 501 zone dips steeply at 75 degrees to the east and has a steep 65 degree plunge to the south. Horizontal widths can reach up to 22m. Drill intersections average 7.6% Zn, 0.35% Cu, 0.26 Pb and 4.6 g/t Ag (www.whitepineresources.ca).

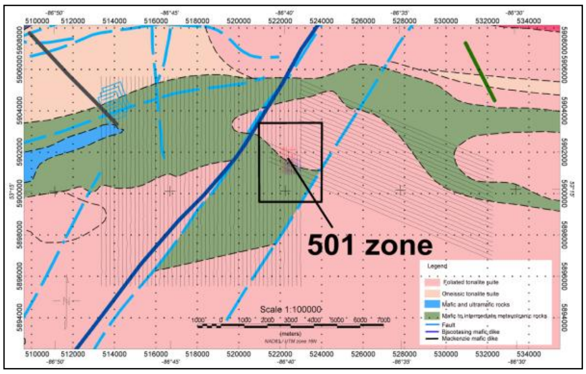

Figure 1 – Flight path of airborne surveys over bedrock geology, highlighting the 501 zone.

AIRBORNE SURVEY RESULTS

During January-February, 2008, AeroTEM time- domain helicopter EM (Huang et al, 2008) surveys were flown over multiple blocks that included the 501 zone. After the 501 discovery, a few months later between June-August, 2008, VTEM (versatile time-domain electromagnetic; Witherly et al., 2004) surveys were also flown over multi blocks, including the 501 zone. This was subsequently followed by a ZTEM (z-axis tipper electromagnetic; Lo and Zang, 2008) helicopter AFMAG (Ward, 1959; Labson et al., 1985) survey in August, 2009.

The objective of the VTEM survey was to provide greater depth of investigation, below the conductive alluvial and sedimentary cover, and for the ZTEM to provide indications of possible extensions of mineralized zones at depth.

Aeromagnetic Results

Figure 2 presents a color-shadow image of the total magnetic intensity (TMI) from the ZTEM survey, with flight paths of the three survey coverages. AeroTEM is shown in red, VTEM in blue and ZTEM in black. The 501 zone is highlighted as a magnetic high anomaly in the central survey region. The peak magnetic high of about 800nT over the magnetic background is attributed to the presence of magnetite mineralization.

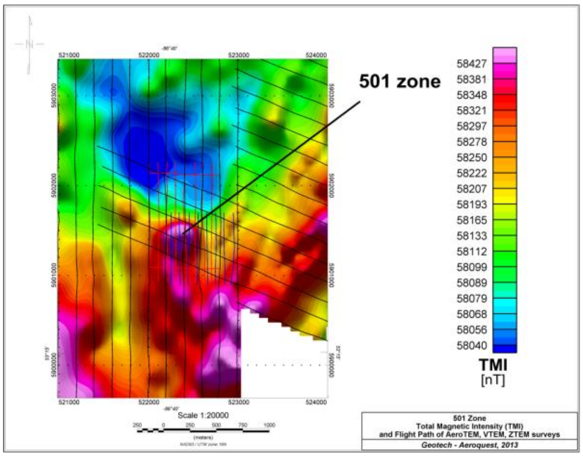

Figure 2 – Detailed view of color-shadow TMI image, highlighting the 501 mineralized zone.

AeroTEM Survey Results

The 2008 AeroTEM survey consisted of 4102 line-km flown over multiple blocks along 100m spaced NS lines, with EM and magnetic sensors at 26m and 50m average elevation, respectively, using a 90Hz base-repetition rate.

The AeroTEM Time-constant (Tau) image and contours of the calculated vertical magnetic gradient (CVG) over the 501 zone are presented in Figure 3a. The EM Time-constant (Tau) was obtained from the Z-coil, off-time dB/dt response. The "sliding Tau" method calculates the slope of the late-time EM decay above the chosen EM noise threshold level (I. Johnson, pers. comm., 2008). The Tau image clearly identifies the 501 zone response in Figure 3a.

The RDI resistivity depth imaging technique, that is based on the apparent resistivity transform of Meju (1998), has been is used to rapidly convert AeroTEM vertical component EM decay profile data into equivalent resistivity versus depth cross-sections (A. Prikhodko, pers. comm., 2009).

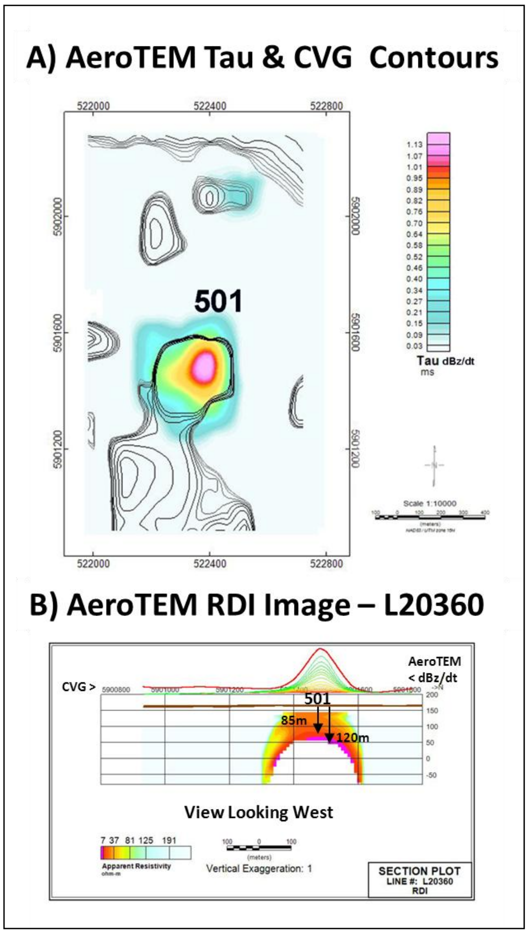

Figure 3 - AeroTEM results over the 501 zone; A) Tau image and CVG contours; B) Resistivity-depth image for L20360.

Figure 3b represents the RDI for AeroTEM line L20360 directly over the 501 zone, highlighting the top of the anomaly at 85 metres depth, reaching a 7 ohm-m minimum resistivity, with an estimated depth of investigation of approx. 120m within the zone.

Maxwell (Electromagnetic Imaging Technology, Midland, WA) EM plate modeling was performed on the AeroTEM response along L20360 that intersects the mineralized 501 zone. A south-dipping, 150x150m conductive plate was modeled at 85m depth with a conductance of 38 Siemens.

VTEM Survey Results

The 2008 VTEM survey consisted of 801 line-km flown over multiple blocks along 100m spaced traverse lines and 1km spaced tie-lines, oriented in different direction to meet geological specifications of the survey area. EM and magnetic sensors were positioned at 42m and 57m mean elevation AGL, respectively. The VTEM survey measured off-time data in the 0.12-6.58msec range, using a 30Hz base-repetition rate.

The VTEM Time-constant (Tau) image for the off-time dBz/dt response and contours of the calculated vertical magnetic gradient (CVG) over the 501 zone are presented in Figure 4a. Over the 501 zone, the low values of Tau (1.9ms in L36890) are consistent with a mod-weakly mineralized conductor closer to surface. Figure 4b represents the RDI of VTEM line

L36890 highlighting the top of the anomaly at 98 metres depth, reaching a 6 ohm-m minimum resistivity, and an estimated depth of investigation of 130m below the 501 zone.

Maxwell EM plate modeling for the VTEM response along L38690 over the 501 zone gives a south-dipping, 150x150m conductive plate is modeled at 98m depth with a conductance of 150 Siemens – slightly deeper than the AeroTEM model and with 4x greater conductance.

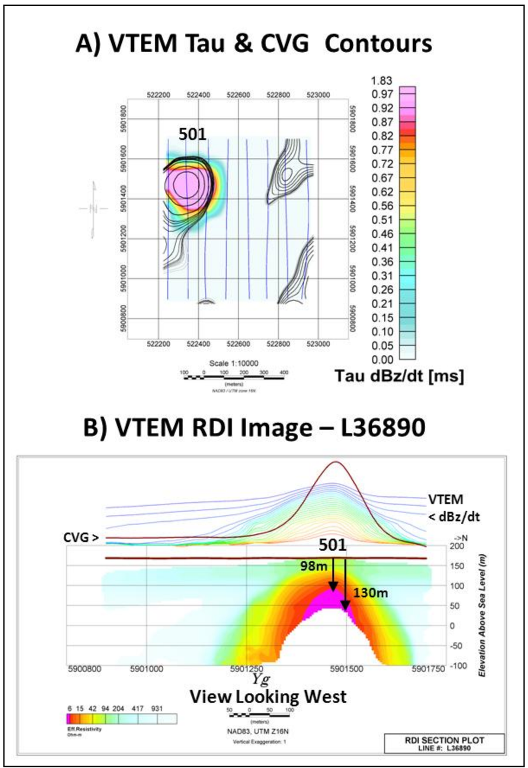

Figure 4 - VTEM results over the 501 zone; A) Tau image and CVG contours; B) Resistivity-depth image for L36890.

ZTEM Survey Results

The 2009 ZTEM survey consisted on 730 line-km flown over two blocks spaced at 200m. ZTEM lines were orientated NS and NW-SE with the purpose of better intersecting the mineralized 501 zone and other anomalies of interest. The EM and magnetic sensors were at 81m and 94m mean elevations AGL, respectively. The ZTEM survey measured In-line and Cross-line tippers between 30-360Hz.

Figure 5 presents the ZTEM tipper results in plan shown as Total Phase Rotation (TPR) images that convert the tipper cross-overs into peak responses while preserving long waveform information (Lo and Zang, 2008). The In-Phase TPR at high (360Hz) and low (30Hz) frequencies are both presented for depth-comparison purposes, based on relative skin depth. The circular elongated shape of the anomaly is well defined at high frequencies (Figure 5a), suggesting a near surface source-depth and corroborating the previous AeroTEM and VTEM results. At lower frequencies, the anomaly, although diminishing in strength and size, is still well defined (Figure 5b) potentially suggesting good vertical depth extent. The 501 anomaly also lies on a NNE-aligned conductive trend that cross-cuts the apparent geologic strike and is unexplained, but nevertheless subparallels known aeromagnetic and geologic structural lineaments (Figure 1).

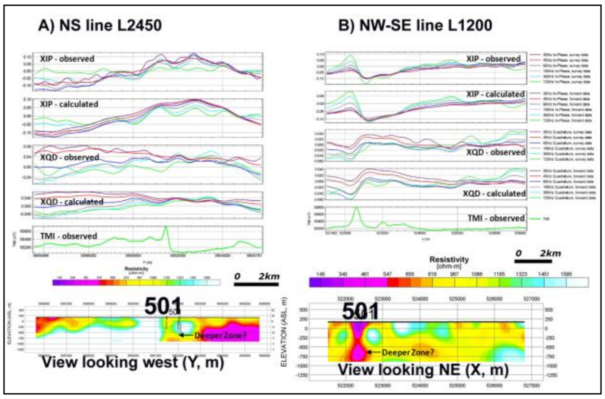

Figure 5 - ZTEM Total Phase Rotation (TPR) of In-Phase Tipper at; A) 360Hz (shallower) and B) 30Hz (deeper), highlighting the 501 mineralized zone.

ZTEM 2D and 3D Inversion Results

Two-dimensional (2D) inversions of the ZTEM data were calculated using the Geotech Av2dTopo code (*ref.* Orta et al., 2012). The inversion used the in-line (Tzx) component, in-phase and quadrature data for all five frequency (30, 45, 90,180, 360 Hz) data in the calculation. A 1,000 ohm-m half-space model apriori was chosen based on model-testing.

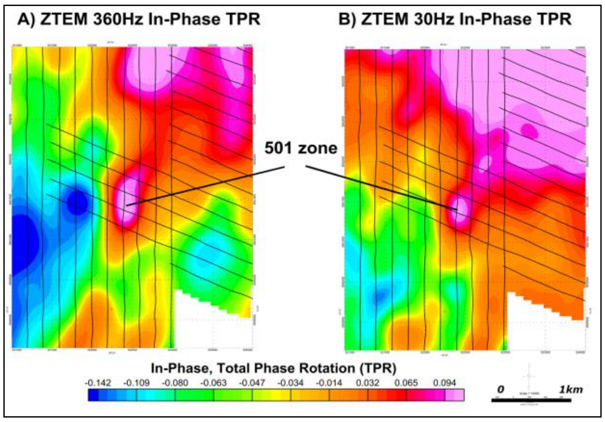

Figure 6 - ZTEM 2D inversions highlighting the 501 mineralized zone; A) north-south line L2450; B) NW-SE line L1200.

Figure 6 presents 2D inversion results for the NS L2450 (left) and the NW-SE L1200 (right) that pass directly over the 501 zone. As shown, the line flown in NW-SE orientation displays the more conductive response, suggesting that target main orientation is more NS; whereas the ZTEM response is weaker for the NS orientated line (Figure 6a), suggesting a shorter EW dimension. This is also reflected in the survey data profiles, with better defined cross-overs in the NW-SE lines (Figure 6B, profiles on top), relative to the NS lines. More importantly, as shown 6, in addition to defining the subcropping 501 zone to 350-500m depths, both 2D inversions give indications of potentially deeper conductivity, at >750m depths below the deposit response. Clearly, though, the 3D geometry of the 501 requires that these features be validated using more advanced 3D inversion instead of 2D.

A three-dimensional (3D) inversion of ZTEM data was performed using the UBC MT3Dinv software. The 3D inversion code, based on the algorithm developed by Holtham and Oldenburg (2008), utilizes the multi-frequency In-phase and Quadrature data for both the Tzx and Tzy components.

Figure 7 presents a voxel view generated by the 3D inversion performed with 46x54x50 cells with dimensions 100x100x100m and 1,000 ohm homogeneous half-space starting model. The 100 ohm-m iso-surface shown (Figure 7b), taken from the 3D inversion resistivity voxel, that roughly approximates the 501 zone conductivity anomaly, has dimensions of 500m NS x 200m EW x 190 m vertical – extending 95m below the surface to 285m depth. Hence, although, the 3D ZTEM model exceeds the VTEM-AeroTEM NS and EW dimensions, its vertical depth extent approximates the known 501 sulphide orebody. Equally important, unlike the 2D inversion models, additional zones of increased conductivity are not indicated in the 3D model at greater depth below the known 501 zone.

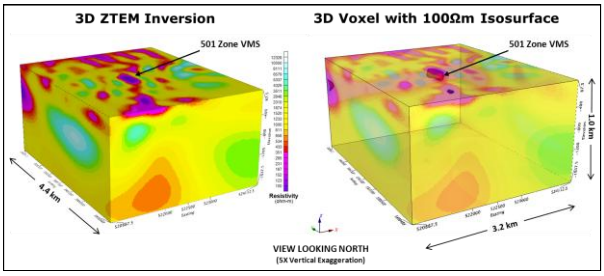

Figure 7 - 3D ZTEM inversion results; A) voxel view of the complete range of resistivity values; B) view of the 100 ohm-m iso-surface, highlighting the 501 zone.

CONCLUSIONS

Helicopter-borne active source AeroTEM and VTEM surveys and passive natural field ZTEM survey results over the 501 project have identified conductive signatures associated with the known VMS type Zn-Cu-Pb-Ag 501 mineralized zone, located in the northern extension of the Ring of Fire region of McFauld's Lake, northern Ontario. The 501 zone is distinguished by the fact that, in spite of its relatively small size and near-surface depth, in addition to AeroTEM and VTEM, this VMS deposit appears to respond well to ZTEM.

2.5D-3D inversion modeling have shown that each system identifies the same target, with markedly higher conductances obtained from VTEM relative to AeroTEM - mainly due the lower base-repetition rate, longer pulse width, larger dipole-moment and longer delay times. The ZTEM 3D inversion improves the discrimination of 501 zone over the 2D inversion and field results. However, the 3D model has overall dimensions which are larger than VTEM and AeroTEM and also extend to greater depth. The results also indicate that 501 zone also occurs along a prominent weakly conductive NNE feature that extends from surface to great depths. The ZTEM response may be enhanced by the increased footprint from the surrounding lower resistivity corridor.

REFERENCES

Holtham, E., and D.W. Oldenburg, 2008, Three-dimensional forward modelling and inversion of Z-TEM data, SEG, Expanded Abstracts, **27**, 564-568.

Huang, H. and Rudd, J., 2008, Conductivity-depth imaging of helicopter-borne TEM data based on a pseudolayer half-space model, Geophysics, **73**, 115-120.

Labson, V. F., Becker A., Morrison, H. F., and Conti, U. , 1985, Geophysical exploration with audio frequency natural magnetic fields, Geophysics, **50**, 656-664.

Legault, J.M., Fisk, K., and Fontura, C., 2010, Case study of ZTEM airborne tipper AFMAG results over a magmatic nickel deposit at Forrestania, West Australia, 4th Brazilian Geophysics Symposium, SBGF Expanded abstracts, 8 p.

Legault, J.M., Kumar, H, Milicevic, B, and Hulbert, L., 2009, ZTEM airborne tipper AFMAG test survey over a magmatic copper-nickel target at Axis Lake in northern Saskatchewan, SEG Expanded Abstracts, **28**, 1272-1276.

Legault, J.M., Orta, M., Kumar, H., and Zhao, S., 2011, ZTEM and VTEM airborne EM survey results over PGM-Cu-Ni targets at East Bull Lake anorthositic complex, Massey, Ontario, SEG Expanded Abstracts, **30**, 629-634.

Legault, J.M., G. Wilson, A. Gribenko, M. S. Zhdanov, S. Zhao, and K. Fisk, 2012, An overview of the ZTEM and AirMt airborne electromagnetic systems – A case study from the Nebo-Babel Ni-Cu-PGE deposit, West Musgrave, Western Australia, Preview, **158**, 26-32.

Lo, B., and Zang, M., 2008, Numerical modeling of Z-TEM (airborne AFMAG) responses to guide exploration strategies, SEG Expanded Abstracts, **27**, 1098-1101.

Meju, M.A., 1998, Short Note: A simple method of transient electromagnetic data analysis, Geophysics, **63**, 405–410.

Orta, M., Legault, J.M., Zhao, S., Izarra, C., Eadie, T., and Galeschuk, C., 2012, ZTEM and VTEM airborne EM survey results over the Mayville Cu-Ni-PGM intrusive system, southeastern Manitoba, SEG Expanded Abstracts, **31**, 1-5.

Sattel, D., Witherly, K. and Becken, M., 2010, A brief analysis of ZTEM data from the Forrestania test site, WA; 21ST ASEG International Geophysical Conference & Exhibition, Extended Abstracts, 5 p.

Smith, R.S., 2013, Electromagnetic methods in mining geophysics from 2008 to 2012, paper presented at the 21st Workshop on Electromagnetic Induction in the Earth, Darwin Australia, July 25-31, 2012, 61 p.

Ward, S. H., 1959, AFMAG - Airborne and Ground: Geophysics, **24**, 761-787.

Witherly, K., Irvine, R., and Morrison, E.B., 2004, The Geotech VTEM time domain helicopter EM system: SEG Expanded Abstracts, **23**, 1217-1221.