Evolution of VTEM – technical solutions for effective exploration

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SUMMARY

The helicopter borne time-domain VTEM system has been in constant development since 2002 through complex and multicomponent technical improvements in an effort to satisfy exploration and mining industry requirements.

Progress in the geoelectrical informational level of data obtained with different VTEM systems is illustrated with the results of test surveys over the Caber VMS deposit. Forward plate modeling with different systems for the Caber deposit geometry target with changing conductance, as well as resistivity-depth transforms of the real data, both serve to illustrate significant broadening of the conductance aperture and increasing depth of investigation over time. Most of all the increasing sensitivity of the VTEM system is highlighted.

Key words: VTEM, electromagnetic, airborne.

INTRODUCTION

The helicopter-borne Versatile Time Domain Electromagnetic (VTEM) System (Witherly et al, 2004) is a geophysical instrument which has been in continuous development, utilizing most recent advances in digital electronics and signal processing, guided by practical experience (Kuzmin and Morrison, 2009, 2010).

Since its inception in 2002, more than 1 200 000 line kilometers have been flown around the world, in widely diverse geological environments and spanning a broad spectrum of exploration tasks. The continuous technical development of the system is firmly based on the combination of survey practice, new electronic and schematic achievements, requirements of exploration and mining industry. It stands firmly on the principle of implementing upgrades that contribute to noise reduction, increasing dipole moment, waveform optimization, increasing time-width of decay measurement, and increasing precision of the data acquisition system.

There are several standard performance measures for transient electromagnetic systems and one of the most important is the signal to noise ratio (S/N). Other technical aspects in terms of responsibilities are:

- Dipole moment which principally affects depth of penetration of transmitted currents, while the achieved depth depends also on the geoelectrical environment;
- Waveform (width and area of the transmitted pulse) determines induced and off-time residual currents and so the response;
- Off-time width is responsible for the observable range of conductance of the TEM response.

The S/N ratio is determined by all these factors and the physical and electrical characteristics of the target, as these determine the signal level. Therefore an increase in the signal strength by simply increasing the transmitter dipole moment is not in itself sufficient to improve the maximum depth of investigation of the system.

Using the example of Caber volcanogenic massive sulphide deposit and modeling results, we demonstrate the progress of the VTEM system sensitivity from 2003 until present.

TEST AND MODELING RESULTS

The evolution in performance of the system is best demonstrated by comparative survey tests, new and previous, over known mineral deposits and naturally occurring geologic targets that can be quantified directly using modeling and depth imaging with VTEM historical specifications for varying characteristics of geological environment. One such example of direct survey comparisons is the Caber Zn-Cu-Ag volcanogenic massive sulphide deposit (Gingerich and Allard, 2001) in northern Quebec (Figure 1).

Geotech Ltd. has carried out test surveys over the deposit between 2003-2009 with different VTEM systems – in 2003 with the VTEM 18m diameter system; in 2005 and 2007 with the VTEM 26m system, and in 2009 with VTEM 35m system. Figure 2 presents the 3D EM plate model that describes the Caber deposit (i.e., 150 m depth to top, 200 m strike-length, 150 m depth extent, 82.5 degree South dip, 120 siemens conductance) and the corresponding VTEM observed and forward model responses.

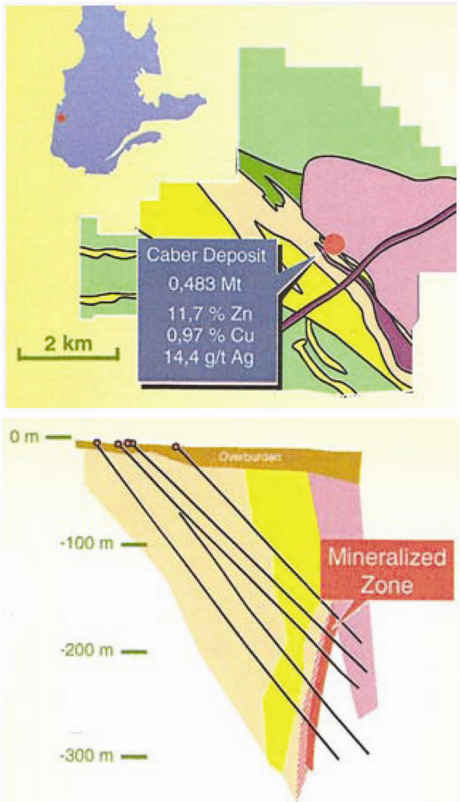

Figure 1: Caber VMS deposit location and geologic cross-section (after Gingerich and Allard, 2001)

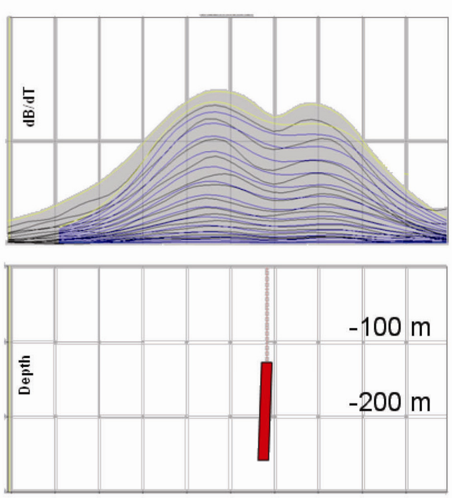

Figure 2: Maxwell plate model for Caber deposit with late-time dB/dt anomaly (observed=grey, calculated=blue)

The results of the modeling are presented in the form of nomograms in Figure 3 where the VTEM dB/dt amplitude response for the different time delay-channels after the transmitter current is switched off is plotted against plate conductance.

The technical specifications of the various VTEM systems which determine the signal to noise ratio are shown in the table below:

	2003	**2005**	**2007**	**2009**
Transmitter coil diameter (m)	18	26	26	35
Base freq. (Hz)	30	30	30	30
Peak current (A)	110	180	200	230
Dipole moment (NIA)	148000	380000	425000	866000
Noise level (pV/(A*m^4))	0.01	0.0015	0.0009	0.0003

The nomograms in Figure 3 illustrate very clearly the benefit of improved S/N ratio in broadening of conductance aperture.

The transformation scheme (Meju, 1998) $\mathbf{D}_{eff}(\boldsymbol{\rho}_{app}, \mathbf{t})$, where the $\mathbf{D}_{eff}$ – effective depth of investigation, $\boldsymbol{\rho}_{app}$ – apparent resistivity, $\mathbf{t}$ – time after turn-off transmitter current, provides resistivity depth sections from time-domain data.

The results of the transformation depend only on:

1. Off-time width of the response registration and
2. Level of noise

Results of this resistivity-depth transformation for successive VTEM surveys over Caber between 2003 and 2007 are presented in Figure 4. These results also illustrate the effect of the S/N ratio and the progressive improvement in the sensitivity of VTEM system in terms of depth of investigation.

CONCLUSIONS

Real data examples, from the 2003-2009 VTEM surveys over the Caber deposit in the Matagami area and off-time anomaly amplitude nomograms calculated using the Caber deposit model with different conductance, demonstrate significant improvements of the VTEM system leading to the present.

One of the key technical advances is in the sensitivity of the system which is achieved by noise reduction, and optimization of transmitter current waveform along with dipole moment increases.

The low level of noise of VTEM system significantly extends conductance aperture and conductance discrimination.

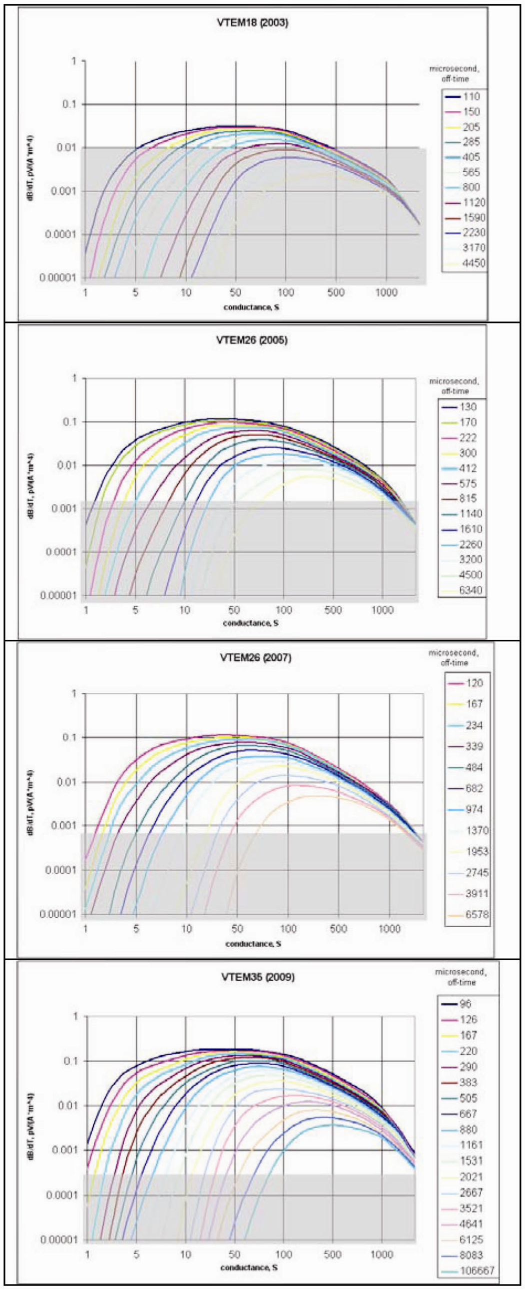

Figure 3: Off-time anomaly amplitudes, for respective 2003-2009 VTEM systems, calculated for a 200 m length, 150 m depth extent, 82.5 degree South dipping plate at 150 m below surface as a function of its conductance. Amplitudes in the grey zones are below late time noise level estimated from actual surveys

REFERENCES

Gingerich, J., and Allard, M., 2001, VHMS Exploration Matagami District Geophysics: Presented at PDAC International Convention and Tradeshow, Toronto, ON, Canada.

Kuzmin, P., and Morrison, E., 2009, Large airborne time-domain electromagnetic transmitter coil system and apparatus: Patent Application Publication No.: US 2009/0212778 A1, August 27, 2009.

Kuzmin, P., and Morrison, E., 2010, Bucking coil and B-field measurement system and apparatus for time domain electromagnetic measurements: US Patent Application 20100052685, Published March 4, 2010.

Meju, M.A., 1998, A simple method of transient electromagnetic data analysis: Geophysics, 63, 405-410.

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

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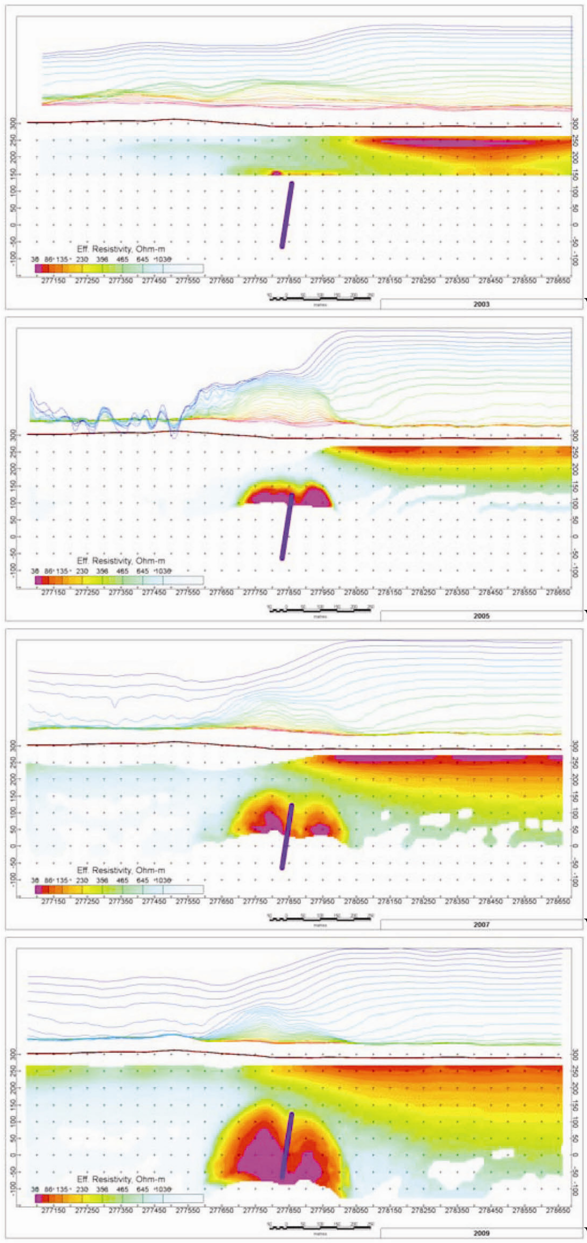

VTEM18; 2003

VTEM26; 2005

VTEM26; 2007

VTEM35; 2009

Figure: 4. Resistivity-Depth Sections for 2003-2009 VTEM data over the Caber VMS deposit

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