3D ZTEM Inversion: Application to Mt. Milligan

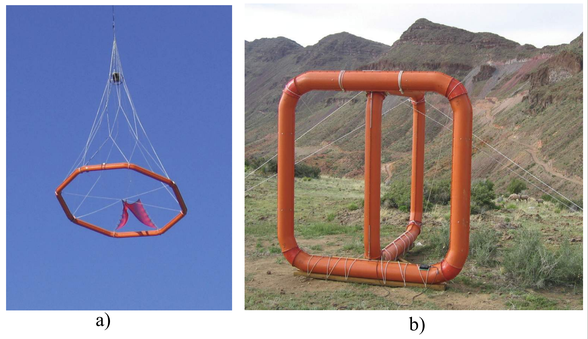
Elliot Holtham, Douglas Oldenburg

University of British Columbia, Geophysical Inversion Facility

Introduction

In an effort to develop an airborne electromagnetic system that utilizes the depth of investigation advantages offered by natural sources, the Z-Axis Tipper Electromagnetic Technique (ZTEM) was developed by Geotech.

In ZTEM, the vertical component of the magnetic field is recorded above the entire survey area, while the horizontal fields are recorded at a ground-based reference station. The result is a cost effective procedure for collecting natural source EM data that provide information about the 3D conductivity structure of the earth.



a) b)

Figure 1. a) Airborne helicopter system towing the coil used to measure the vertical component of the magnetic field. b) Set of orthogonal coils used to measure the horizontal fields at the base station.

Inversion Algorithm

ZTEM data can be interpreted using a 3D inversion algorithm to recover a conductivity model. The inversion algorithm is implemented by minimizing the an objective function.

Minimize $\phi = \phi_d + \beta \phi_m$

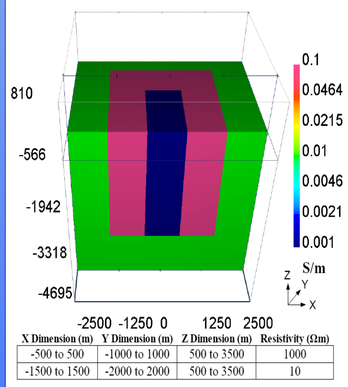
where

$$\phi_d = \left\| \mathbf{W_d}(F[\mathbf{m}] - \mathbf{d}^{obs}) \right\|^2, \quad F[\mathbf{m}] = f(\mathbf{Qu})$$

$$\phi_m = \left\| \mathbf{W}(\mathbf{m} - \mathbf{m}_{ref}) \right\|^2$$

β: Regularization parameter
$\mathbf{Q}$: Projection matrix
$\mathbf{u}$: Fields
$\mathbf{d}^{obs}$: Observed data
$\mathbf{m}, \mathbf{m}_{ref}$: Model and Reference model
$\mathbf{W_d}, \mathbf{W}$: Data error, model weighting

Synthetic Inversion Model



X Dimension (m)	Y Dimension (m)	Z Dimension (m)	Resistivity (Ωm)
-500 to 500	-1000 to 1000	500 to 3500	1000
-1500 to 1500	-2000 to 2000	500 to 3500	10

Figure 2. Synthetic Model

- Data computed at 1, 3.2, 5.6, 10, 18, 32 Hz
- Reference Station: (-3000, -3000, 0)m
- Data collected at a constant height of 100m
- Data collected over an area of 5000 x 5000m
- 10m data spacing and 50m line spacing

Synthetic Inversion Results

The 6 frequencies of synthetic data were inverted. The predicted data fits the observed data very well.

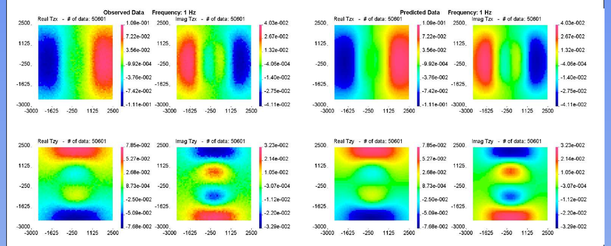


Figure 3. Observed and predicted data for 1 Hz.

Inverted Model

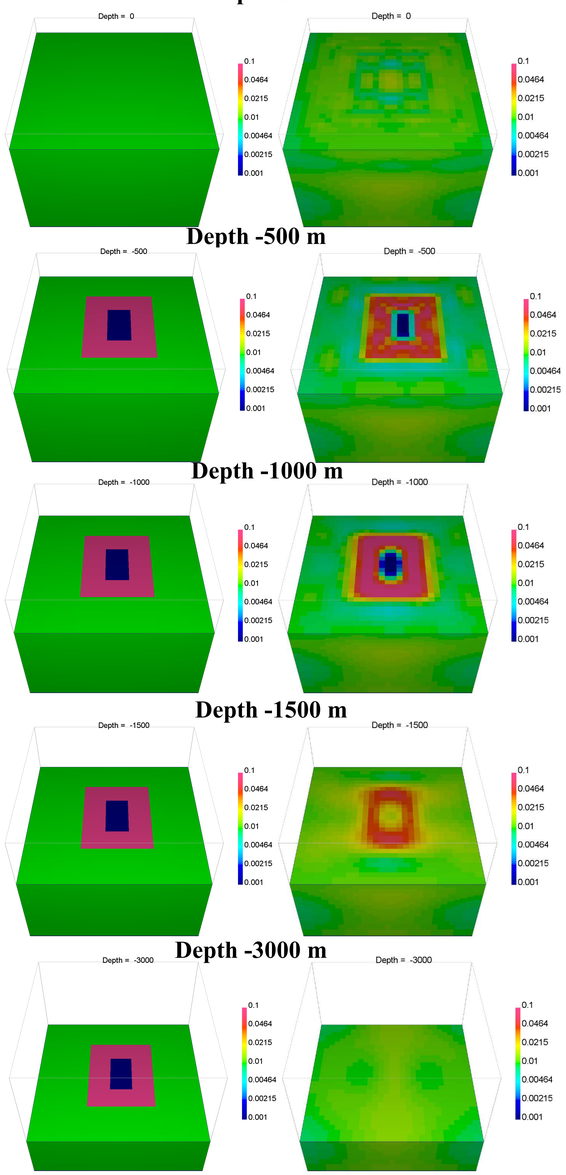
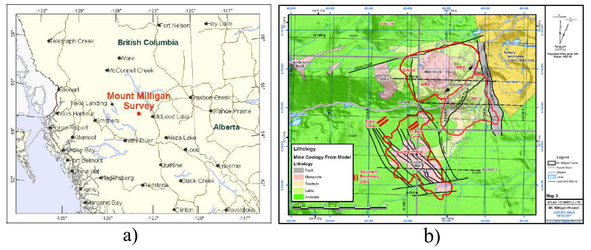


Figure 4. Horizontal slices at various depths through the synthetic model (left hand figures) and inverted model (right hand figures).

Mt. Milligan - Porphyry deposit



a) b)

Figure 5. a) Location of Mt. Milligan. b) Deposit zones.

The Mt. Milligan deposit is a porphyry deposit located in northern British Columbia. This deposit is a perfect case study because significant geologic information is known from multiple drill programs and many data sets are available from multiple geophysical surveys. We get consistent results by inverting three different electromagnetic surveys (ZTEM, DC resistivity, VTEM)

ZTEM Data

- 30, 45, 90, 180, 360 Hz data
- 250 m flight line spacing
- 25 lines
- 200 line-km of data
- 6 x 8 km area
- 18 000 data

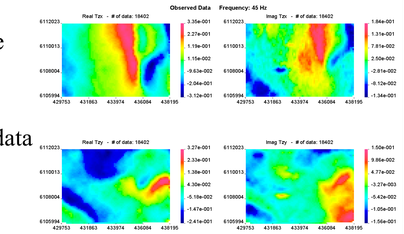


Figure 6. Data at 45 Hz.

ZTEM Inversion

The data from the ZTEM survey was inverted. There is good agreement between the inverted model and deposit zones.

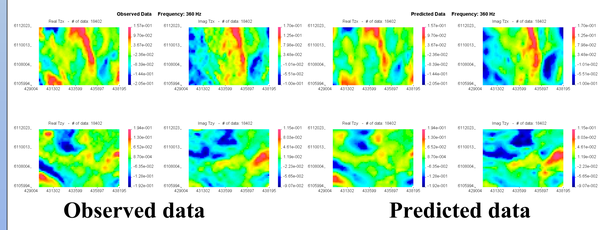


Figure 7. Observed and predicted data at 360 Hz.

Recovered Models

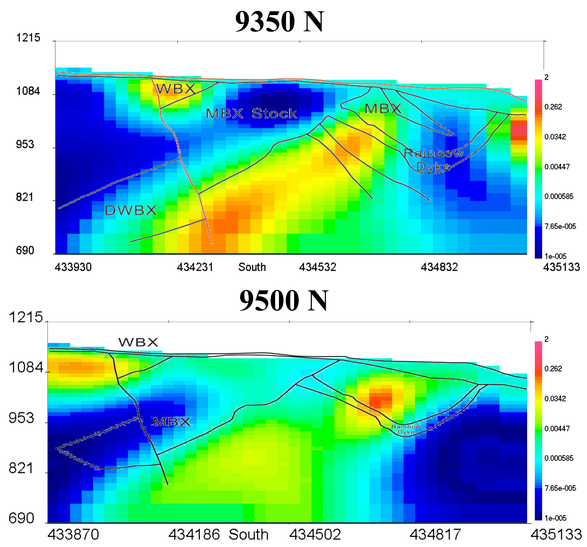


Figure 8. Recovered conductivity and geologic zones along the 9350N and 9500N cross sections.

DC Resistivity

Archived DC resistivity data was re-inverted using a newer 3D inversion code. The pole-dipole survey was collected with N=1:4 and a=50m

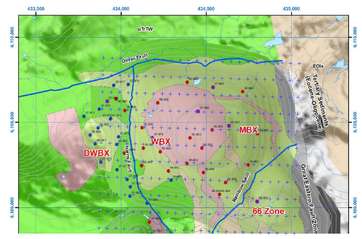
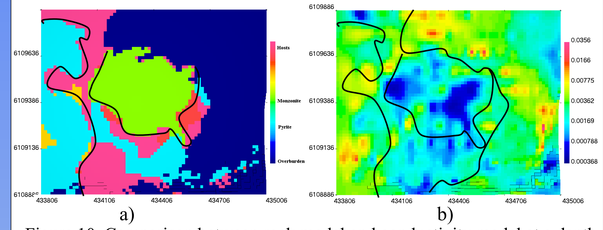
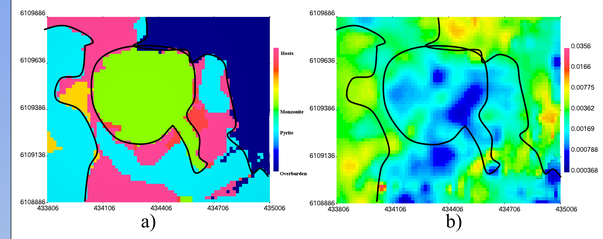


Figure 9. Measurement locations for DC resistivity survey



a) b)

Figure 10. Comparison between rock model and conductivity model at a depth of 1095m (~45m below the surface). a) Rock model. b) Conductivity model



a) b)

Figure 11. Comparison between rock model and conductivity model at a depth of 1065m (~75m below the surface). a) Rock model. b) Conductivity model

VTEM Inversion Results

The VTEM system is a time domain electromagnetic system. 28 soundings were inverted (Yang, D., Oldenburg, D., BC Geophysical Society Workshop, 2009) using a 3D time domain inversion code. The recovered model shows large scale agreement with the known rock model. Inverting additional transmitters may recover a better model.

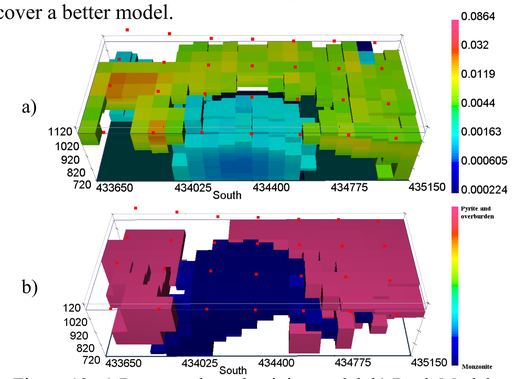


Figure 12. a) Recovered conductivity model. b) Rock Model

Conclusions

The ZTEM technique is a promising method to cost effectively explore for large-scale targets at depth limits that are extremely difficult to reach with traditional exploration techniques. We developed a 3D inversion algorithm for ZTEM data and demonstrate the effectiveness on a synthetic test model. We use the Mt. Milligan deposit as a case study to investigate 3D inversion of multiple electromagnetic data. Each data set yields reasonable and consistent results.

Acknowledgement