Airborne IP: Drybones kimberlite VTEM data Cole-Cole inversion

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SUMMARY

A VTEM survey was flown over the Drybones kimberlite in 2005, followed by a ZTEM survey in 2009. These data sets were inverted on multiple previous occasions using various 1D, 2D, 3D and plate modelling algorithms. VTEM data showed AIP effects, manifested as negative voltages and otherwise skewed transients. This created artefacts in conventional inversions of VTEM data, which showed some inconsistencies with ZTEM inversions, as well as with the known geology. In 2015 the VTEM data were transferred to Aarhus Geophysics, reprocessed and reinverted using the modified “AarhusINV” code with Cole-Cole modelling. The results are presented in current abstract, they appear to be more interpretable and provide better data fit, than previous inversion attempts.

Key words: Airborne IP, Time Domain EM, Inversion, Kimberlite, VTEM

INTRODUCTION

Figure 1: Location of Drybones kimberlite, NWT, Canada

Drybones kimberlite is located in northern Canada, approximately 45 km SE from Yellowknife, NWT (Figure 1). Geology of Drybones kimberlite has been described in Kretchmar (1995); Dunn et al. (2001) and Kerr et al. (2001). The kimberlite is situated under 35- 40 meters of lake waters and under 75 – 85 meters of clayish lake sediments.

The kimberlite was subject for multiple geophysical studies, including airborne EM surveys. A VTEM survey was flown in 2005, followed by ZTEM survey, flown in 2009 (Kaminski et al, 2010). The data from these airborne surveys were inverted at the University of British Columbia using 3D time domain inversion algorithm (Oldenburg et al, 2013) for inversions of VTEM data and 3D MT/ZTEM inversion algorithm (Holtham et al, 2010) for the ZTEM data (Kaminski and Oldenburg, 2012). There is however some discrepancy between the results of 3D time domain inversion and 3D ZTEM inversion. The discrepancies may be explained by presence of IP effect in the VTEM data, which is often recorded in TDEM data, collected over kimberlites and may be responsible for artefacts in conventional inversions results (Kamenetsky et al., 2014; Kaminski and Viezzoli, 2016; Viezzoli et al., 2013; Viezzoli et al., 2016).

IP EFFECTS IN VTEM DATA AND SCI INVERSION

In 2015, the VTEM data acquired over Drybones kimberlite were transferred to Aarhus Geophysics and inspected for presence of IP effect. The inspection revealed moderately strong IP effect over the central part of Drybones kimberlite (Figure 2).

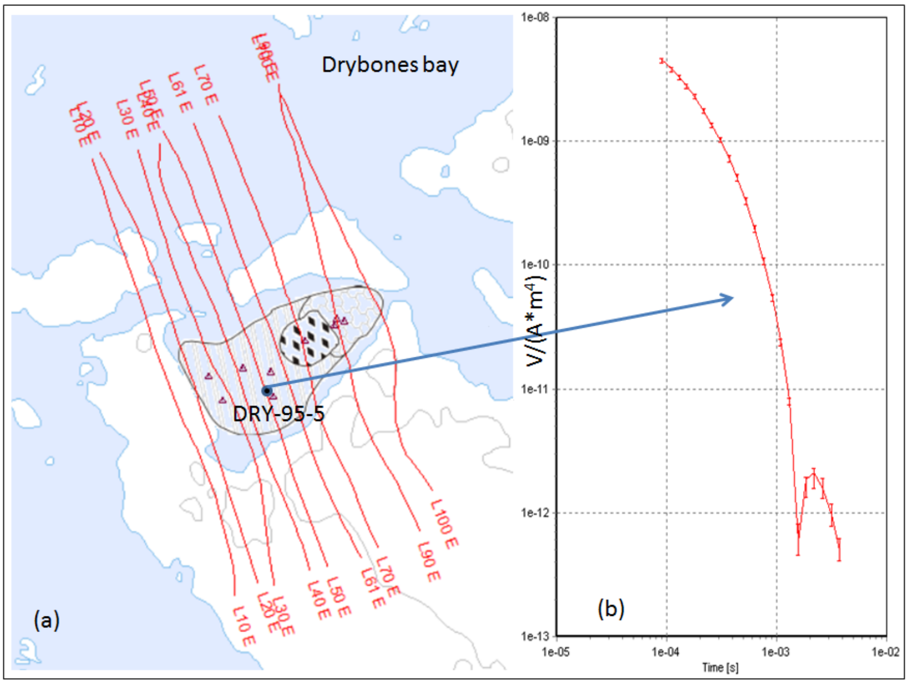

Figure 2: (a) VTEM flight planning over Drybones kimberlite; (b) IP effect in transient measured over drill hole DRY-95-5 (observed vs predicted).

As it can be seen from Figure 2b, there is notable IP effect present in late times. The VTEM sounding shown in Figure 2b is coincident with one of the boreholes (DRY-95-5). Data set had to be reprocessed, implementing advanced data processing techniques, discussed in Kaminski and Viezzoli (2016).

Then, the reprocessed data were inverted, using a Spatially Constrained Inversion (SCI) approach (Viezzoli et al., 2008) implemented in a modified "AarhusINV" code with capability of Cole-Cole modelling (Cole and Cole, 1942; Fiandaca et al., 2012). The following starting model was used for the Cole-Cole inversion: $\rho = 300$ Ohm m; $m_0 = 100$ mV/V; $\tau = 10^{-3}$ s; $C = 0.5$.

The inversion converged in 14 iterations to an average misfit of 1.29 (normalized by standard deviation), showing good overall data fit (Figure 2b) and producing 3D distributions of electrical resistivity, chargeability, time constant and frequency parameter.

RESULTS AND DISCUSSION

The results of SCI inversion with Cole-Cole modelling were verified against drilling. In Figures 3, a 1D model is shown for the station, coinciding with drill hole "DRY-95-5". As it can be seen in the figure, the most chargeable and electrically conductive part marks the lake sediments, not the lake waters, as it was previously suggested by Kaminski and Oldenburg (2012). The results achieved in current paper actually are in better agreement with both our understanding of geology and results of 3D inversion of ZTEM data (Kaminski and Oldenburg, 2012).

In order to study the correlation better, the results of SCI Cole-Cole inversion were interpolated to populate 3D volume and further imaged against the results of Kaminski and Oldenburg (2012). These interpolated resistivity values are shown in Figure 4. As it can be seen in the figure, there is some contradiction between the historic ("non-IP") 3D inversion of VTEM data and the SCI inversion in "IP mode", based on Cole-Cole modelling. Furthermore, the results of the SCI inversion in "IP mode" (with Cole-Cole modelling) are in better agreement with the geological information, as well as with the 3D ZTEM inversion results (Figure 5).

The latter can be attributed to the fact that in Kaminski and Oldenburg (2012), AIP effect was disregarded in the 3D inversion of TDEM data, and 3D ZTEM inversion recovered results in better agreement with geology, being a passive source EM system and not susceptible to AIP effects, as much as VTEM data.

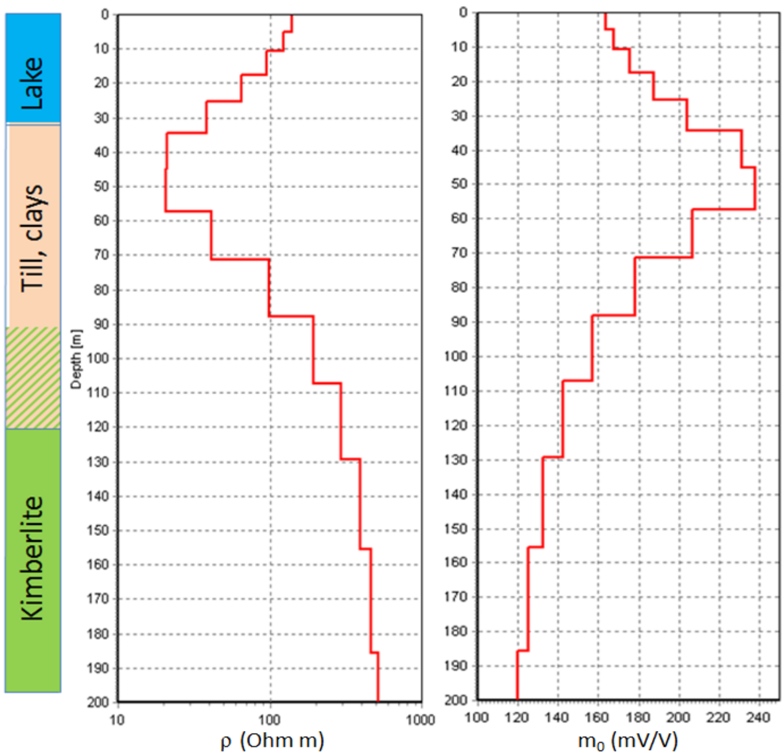

Figure 3: 1D resistivity and chargeability models recovered over drill hole "DRY-95-5".

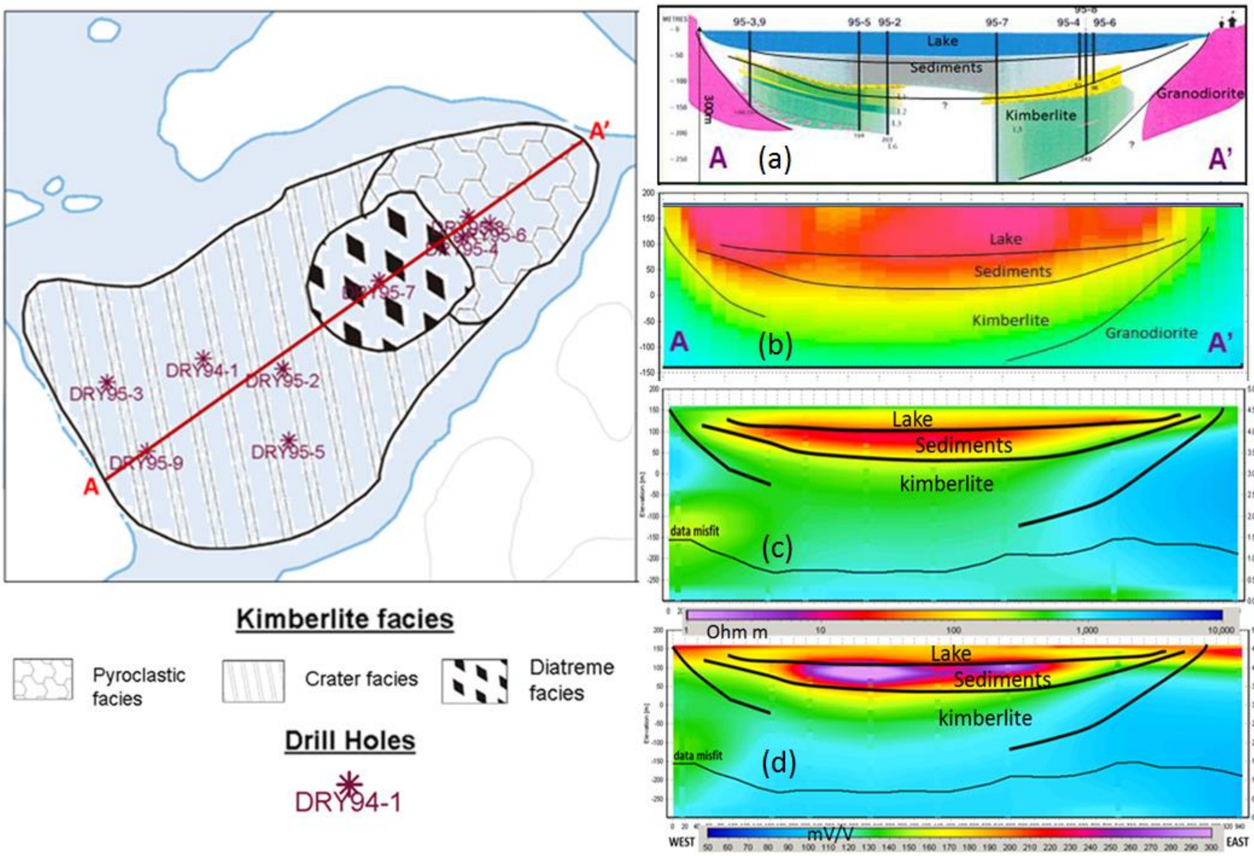

Figure 4: Comparison of SCI Cole-Cole inversion results with historic 3D VTEM inversion results. (a) Geological cross-section over Drybones kimberlite, based on drilling information. (b) Electrical resistivity section of historic 3D VTEM inversion results (adapted from Kaminski and Oldenburg, 2012). (c) Interpolated electrical resistivity, recovered by SCI "IP-mode" inversion (with Cole-Cole modelling). (d) Interpolated chargeability, recovered by SCI "IP-mode" inversion (with Cole-Cole modelling).

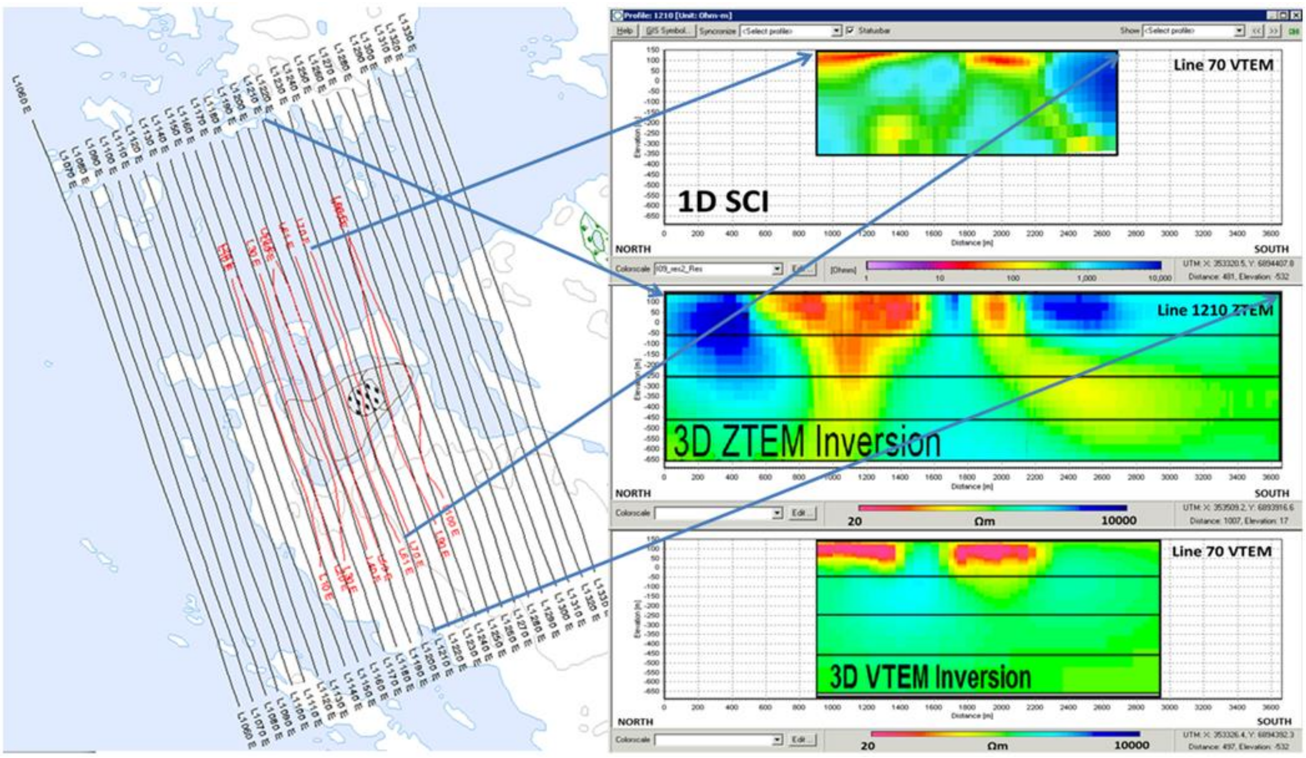

Figure 5: Comparison of inversion results over VTEM (red) line 70 and ZTEM (black) line 1120 (adapted from Kaminski and Viezzoli, 2016).

CONCLUSIONS

In became conclusive that inversions of TDEM data, based on Cole-Cole modelling carry great potential for providing improved recovery of physical parameters, including electrical resistivity and chargeability. In current study, the new approach, based on Cole-Cole modelling allows recovery of improved near-surface resistivity section over Drybones kimberlite. The latter is supported by drilling and by comparison with 3D inversion results of ZTEM data, which were not affected by IP.

Inversions in "IP-mode" (with Cole-Cole modelling) may become a powerful and effective tool, especially in kimberlite exploration, since this approach allows extraction of chargeability information, which historically has played an important role in mapping crater facies of kimberlites and clay alteration zones, which may be associated with kimberlites.

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