Multi-dimensional Modelling of RMT Data Observed in a Mining Environment in Kiruna, Sweden

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Introduction

Radio Magnetotellurics technique (RMT) was conducted in the northern most town of Sweden (Kiruna), a very prominent mining city as a result of the presence of vast mineral deposits. The basis of this survey was to model the multi-dimensional nature of the subsurface and also to detect the width of these electrically conductive structures over the survey location. The mineral deposits (anomalies) are as a result of the past tectonic activities experienced by the research location . These conductive anomalies are good target for electromagnetic induction method.

The RMT soundings was done using the RMT-F device[3]. Three RMT profiles spanning an approximate total distance of 5 km was covered. Sounding stations spacing was 10 m and 20 m respectively.

Research Location

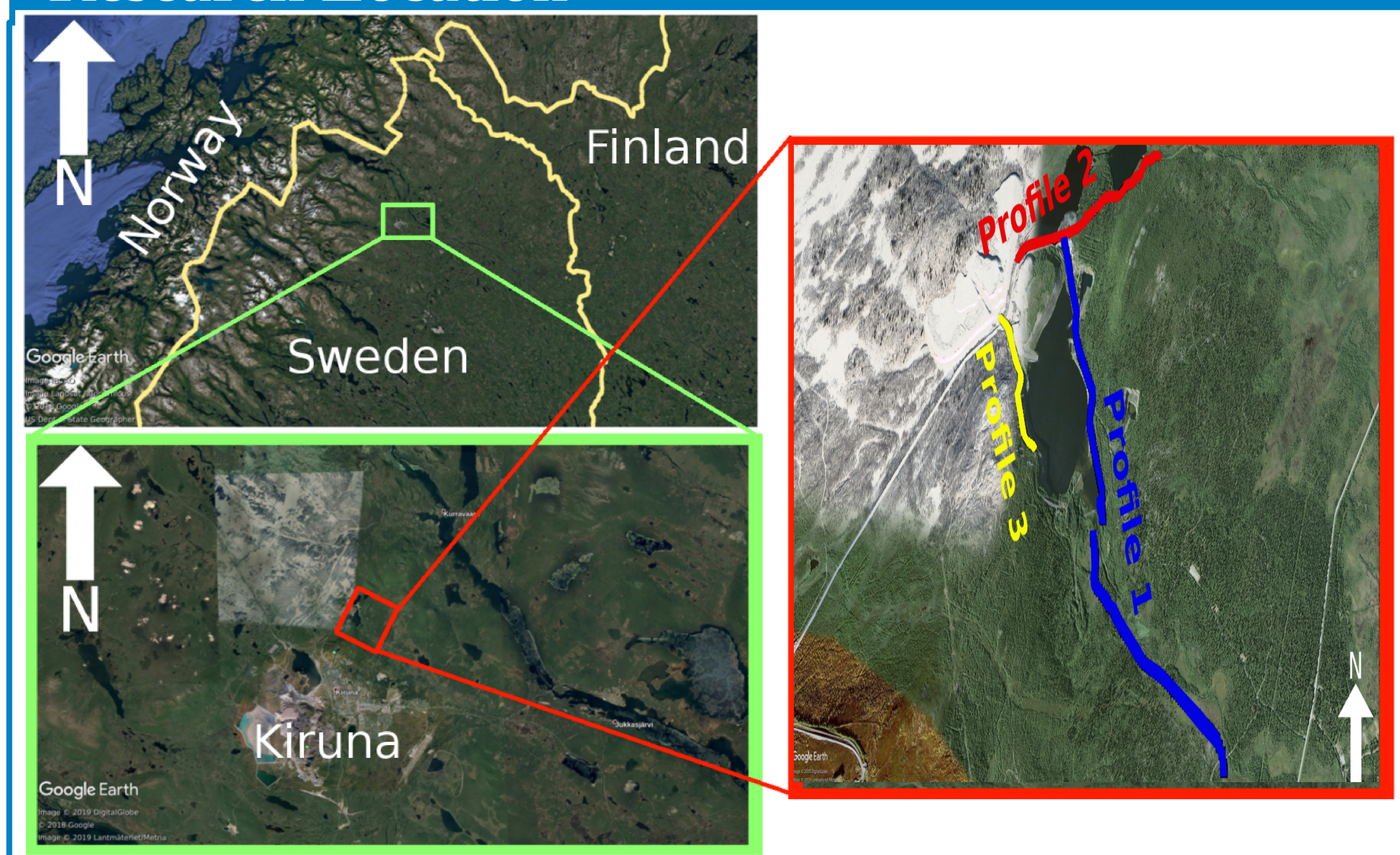

Fig 1: Yellow colour indicate international boundary of Sweden, Norway and Finland, green box signifies the Kiruna district and the red box indicates the survey area with all three different RMT profiles (blue = profile one, orange = profile two and the yellow = profile three).

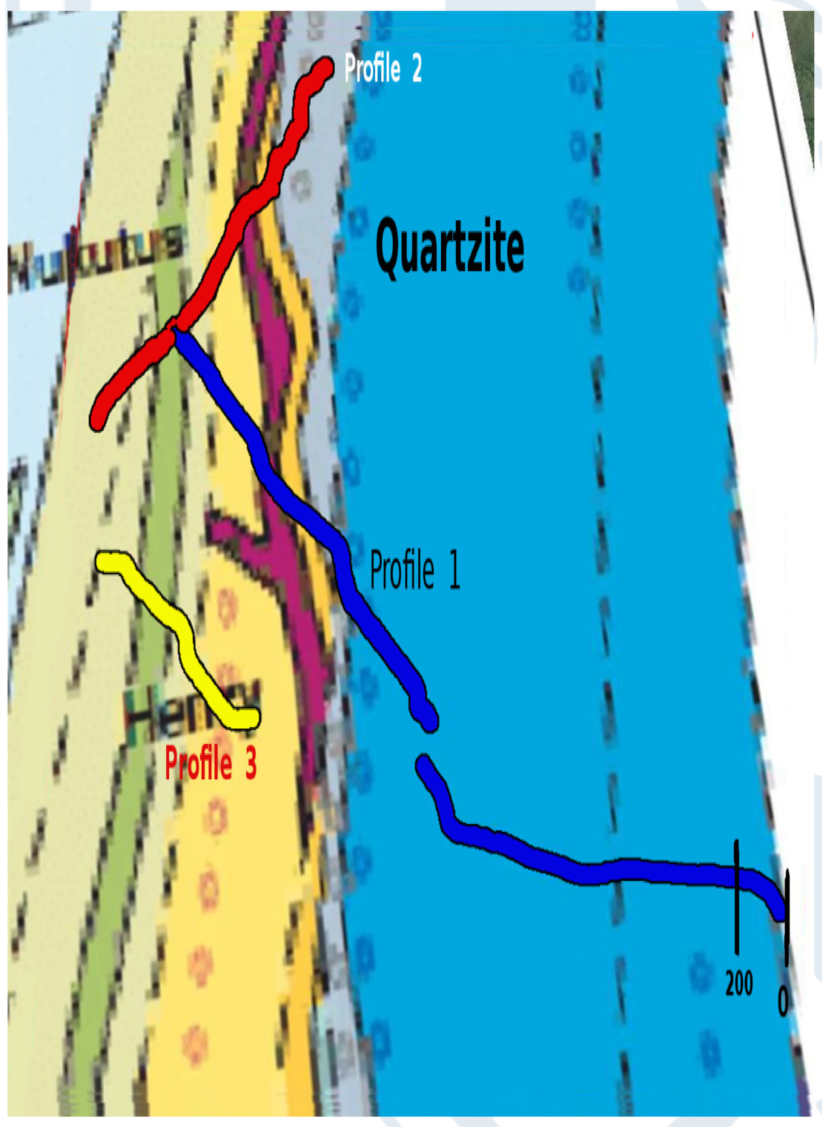

Fig 2: RMT profiles overlay on geological map of survey area.

As observed from the geological map of the survey area, the RMT profiles cut across several geological structures. The dashed lines in the geological map indicates fracture/deformation zones, the small circles present on some of the geological figures are the conglomerates, the blue structure is the quartzite formation, the greyish structure is the metagreywacke formation, the yellowish structure is the metarhyolite and bordering, the pinkish structure is the hematite ore formation, the lite yellowish structure is the metarhyodacite formation, the fainted green structure is the metatrachyandesite, the greenish structure is the metabasalt and lastly the lite blue structure is the metaconglomerate.

Data Acquisition

The data was collected using the RMT-F device which is a five channel electromagnetic induction device with two component electric field sensors (Ex and Ey), and three component magnetic field coils (Hx, Hy and Hz) for a duration of 5 non-consecutive days[3]. Total of 338 soundings could be realized. The frequency range observed in Kiruna was from 16 kHz to 360 kHz.

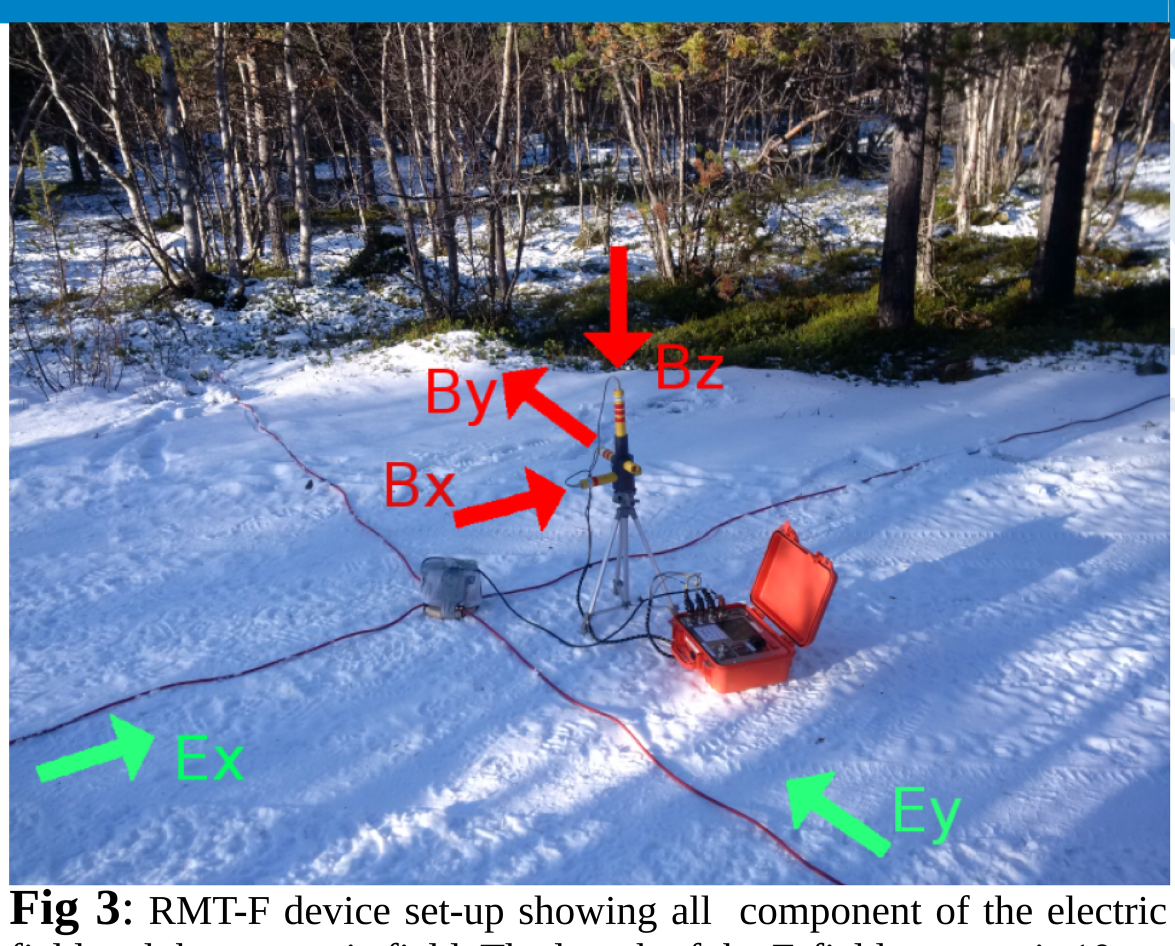

Fig 3: RMT-F device set-up showing all component of the electric field and the magnetic field. The length of the E-field antenna is 10 m

Data Processing

In processing the data obtained, the RMT profiles were broken down in to smaller profiles for less complicated inversion process.

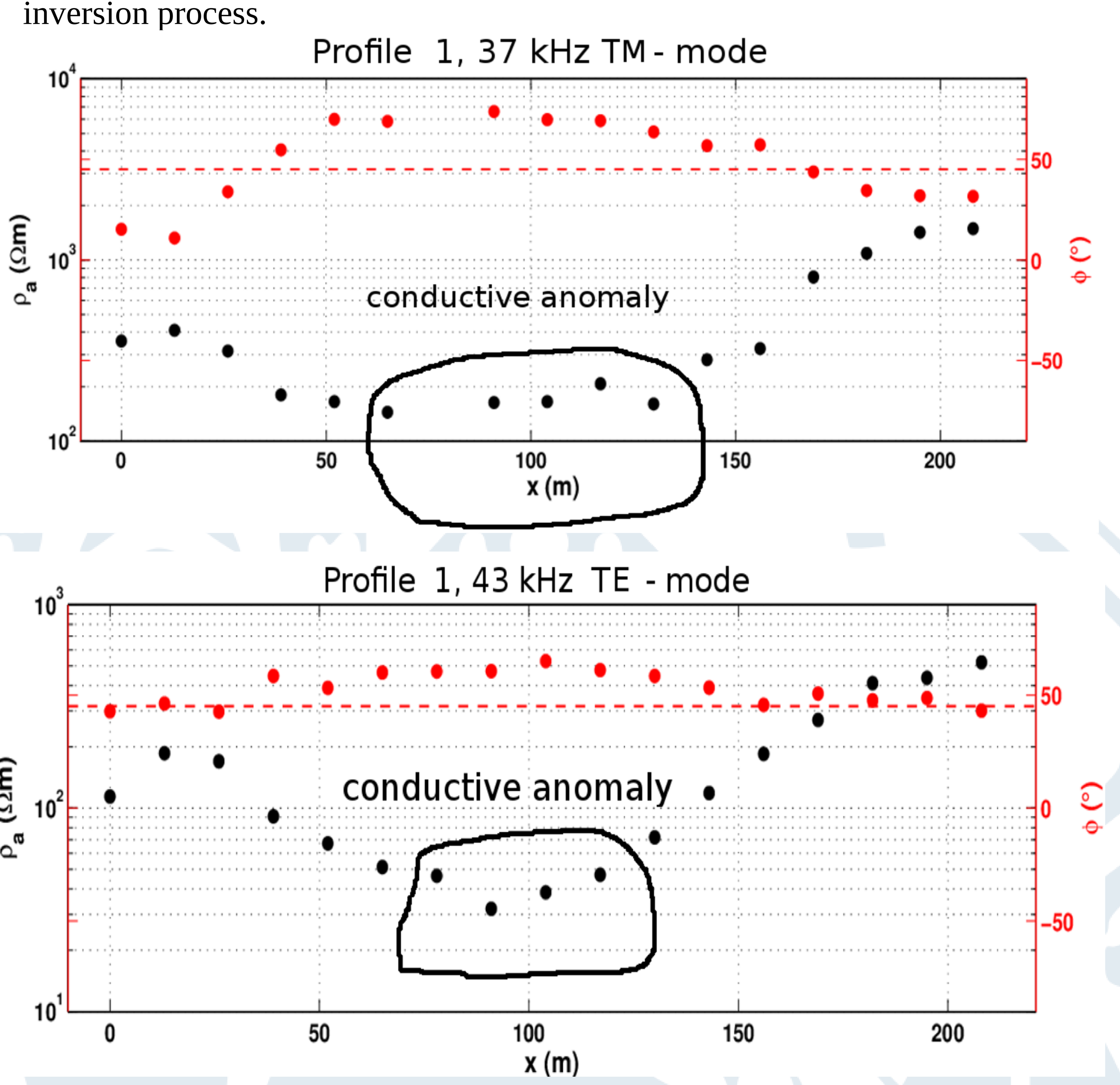

Fig 4: Plot of measured apparent resistivity (black) and phase (red) for the first 17 stations from profile one for frequencies 37 kHz and 43 kHz respectively.

The SM25 software was used to analyze the observed electric and magnetic field time series and export the files from the device. Further processing was done using matlab scripts to plot and edit the data. The observed apparent resistivity and phase angle as calculated from the impedance tensor corresponding to f = 37kHz for the transverse magnetic mode (TM-Mode) and f = 43 kHz for the transverse electric mode (TE-Mode). From both modes and frequencies, it is observed that the phase angle increase from less than 45^0 to above 45^0 at station 4 and this correspond to the drop in apparent resistivity.

2D Inversion results

The data was inverted using the 2D magnetotellurics inversion code by Rodi and Mackie were the Tikhovnov regularization parameter is applied[2]. The algorithm is a formulation of the Maxwell`s equation applying the finite difference scheme and using the the non linear conjugate grtate gradient (NLCG) to minimize the objective function TE, TM and TE - TM joint inversion are realized. Fig 5 shows the TM mode of the inversion of profile 1 for the data shown in fig 4.
Inversion error floor for apparent resistivity = 5.0 %
Inversion error floor for phase = 2.5 %
Depth of investigation was estimated with the z^* equation of Schmucker[1].

$$z^* = \sqrt{\frac{\rho_a}{\omega\mu_0}} sin\phi$$

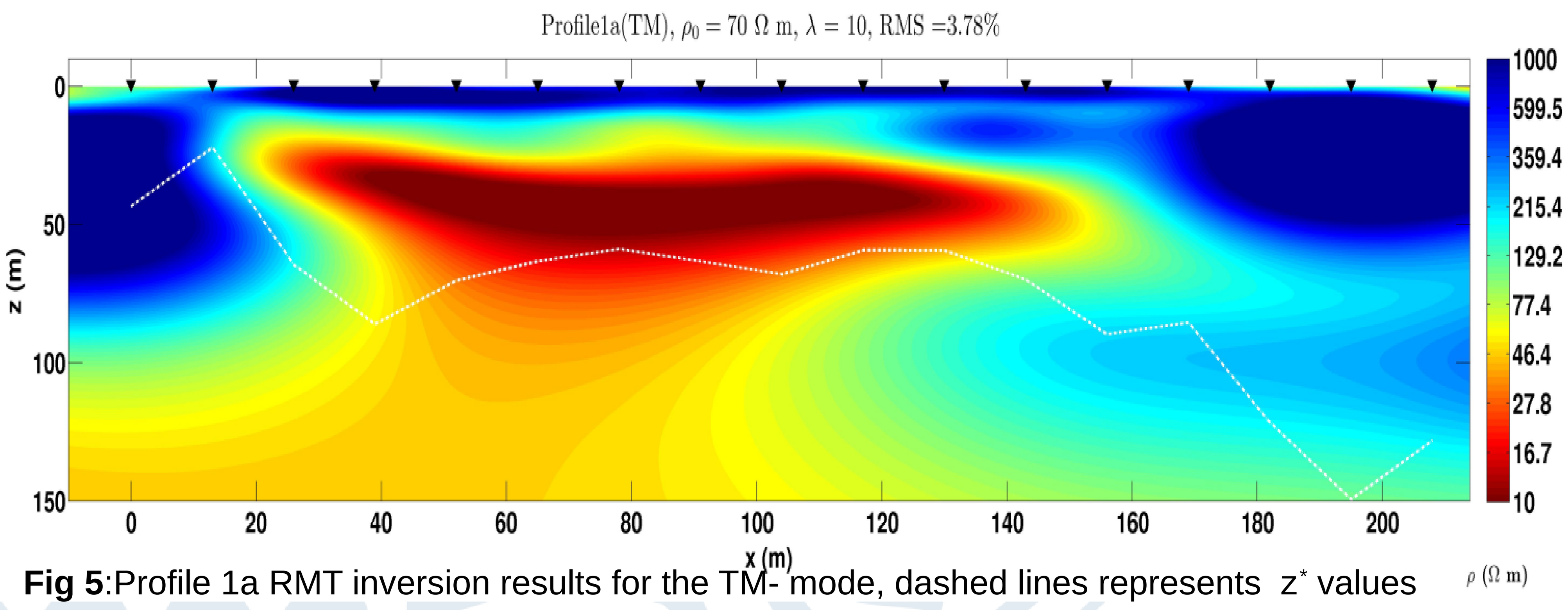

Fig 5:Profile 1a RMT inversion results for the TM- mode, dashed lines represents z^* values as calculated using the lowest observed frequency of 16 kHz.

Conclusions

From the inversion results, a conductive anomaly is detected along profile 1a (first 17 stations of profile 1) by both TE and TM-mode. The conductive body lies below an approx 10 m thick resistive top layer. We could also deduce that the conductive anomaly might possibly have originated from a greater depth considering the shape and probably got trapped few meters below the subsurface. The conductive anomaly is a graphite body already detected by a previous unpublished survey trapped in the quartzite formation is further validated by the 2D RMT data inversion.

References – size 40

[1] Schmucker, U. (1987). Substitute conductors for electromagnetic response estimates, in pure and applied geophysics 125.2-3, 341–367.

[2] Rodi, W. and R. L. Mackie (2001). Nonlinear conjugate gradients algorithm for 2-D magnetotelluric inversion, in Geophysics 66.1, 174–187.

[3]Tezkan, B. and A. Saraev (2008). A new broadband radio-magnetotelluric instrument: applications to near surface investigations, in Near Surface Geophysics 6.4, 245–252.