# ABSTRACT


This thesis embodies the results of certain aspects of one dimensional magnetotelluric modelling and magnetotelluric field investigations in certain areas of the Singhbhum Orissa Iron Ore Craton and the adjoining Proterozoic mobile belts in eastern India.

## Part A

The important points of principle obtained from 1D magnetotelluric modelling can be summarised as follows

1. Magnetotelluric signals can feel the presence of a target bed even when it lies at a depth greater than the skin depth. For a certain class of models the skin depth at $f_c$r (crossover point frequency) are roughly equals to the depth to the top of the second layer (target bed).

2. For a certain class of $H$ type models there is a linear relation between the first and second layers for the same percentage anomaly. For every 1 km increase in the depth of the target bed, its thickness must increase by 6.8, 11 and 19 m for 3%, 5% and 8% anomalies. The relation between $f_{min}$ and $h_2$ is also linear.

3. Resolution is very poor when a resistive target is embedded in between two conductive beds. It is observed that for a certain class of models the resolution is totally lost. In general a contrast beyond 100 times ($\mu_2 \geq 100$) for a $K$ type model is difficult to resolve by MT.

4. The wavelength of an MT signal at the perturbation centroid frequency is several order magnitude higher than the target bed thickness. For certain class of $K$ and $H$ type models (tested in the thesis), the ratio $h_2/\lambda$ is found to be $10^3$ to $10^5$. The ratio $h_2/\lambda$ has inverse relation with the resistivity contrast and is independent of whether the target is more resistive or more conductive in comparison to the host rock so long as $\rho_2/\rho_1$ in one case is equal to $\rho_1/\rho_2$ in the other.

5. MT soundings for studying the crust and upper mantle should be taken right over the hard rock areas. Two kilometers of conductive sediments in a continental crust and upper mantle earth model can significantly reduce the sensitivity of the magnetotelluric response down to 400 km. The depth limit for the sensitivity will depend upon all the layer resistivities and thicknesses.

6. The Probability for detection of Moho by magnetotellurics in practically nil. There may be say 5% chances for its detection. If the structure is nearly one dimensional and if the contrast in the electrical conductivity of the lower crustal and upper most mantle rocks is more than an order of magnitude, the moho will be reflected. Presence of one dimensional structures, suitable combination of lower crustal and upper mantle silicates, presence of fluids in the lower crust, suitable thickness of the lower crust and upper mantle may increase the possibility of detection of 'Moho'. Moho can not be detected in the subduction and other tectonically disturbed zones. It is an highly debatable issue. The general consensus is " Moho can not be detected by MT".

7. Magnetotelluric method is a powerful tool for studying the area covered with flood basalts. This topic has greater relevance in the Indian context, because a large part of our country (about 30%) is covered with flood basalt. The author modelled the approximate geology of the three areas, viz, Deccan Syneclise, Saurashtra basin and Cambay basin. The problem was to examine the possibility of detection of Mesozoic sediments below the pre-Tertiary volcanic traps. One dimensional modelling reveals that thickness of Quaternary and Tertiary sediments above the Deccan basalt will be the crucial factor. It will be easier to detect the Mesozoic sediments below the Deccan Syneclise and Saurashtra basin area. Detailed mapping of the Mesozoic sediments will be possible in the Deccan Syneclise area where the basalts are exposed on the surface or are covered with relatively thin black cotton soil. Any detailed subsurface mapping of the Mesozoic sediments in the Cambay basin area is ruled out, where 3 to 4 km of Quaternary and Tertiary sediments are present. Even the detection of sediments may turn out to be difficult.

## Part B

**(A)** Single site magnetotelluric field survey was conducted across the Singhbhum granite batholith from Bangriposi to Keonjhar. MMS02E system (Metronix, Germany) was used for the field observations. MMS02E system, has a frequency range of 4.0 to

1/4096 Hz. Induction coil magnetometer and silver–silver chloride non polarisable electrodes are used for measuring the magnetic field and electric fields respectively. Softwares supplied by Metronix, developed by author and other scientists are used for analysis and interpretation of the MT data. The data analysis revealed the following points.

1. Singhbhum granite Phase II (SBG-A) is much more resistive than the Singhbhum granite phase III (SBGB). Resistivities of SBGA is of the order of $18000\Omega - m$ and above and that of phase III (SBG-B) is of the order of $3500\Omega - m$ to $7000\Omega - m$.

2. Singhbhum granite phase II (3300 my) is more deep rooted than the SBGB, the Singhbhum granite phase III (3140 my). SBGA is 22 km deep whereas SBGB is 3 to 4 km deep.

3. MT 2D models based on 1D inversion and 2D inversion show that SBGA is more resistive than the SBGB. Thinning of the electrical lithosphere below the station Nuvagaon leads to the opinion that mantle plume exists below the Singhbhum granite phase III. The structure is more prominent in the 2D inverted model. Bouguer gravity map show high gravity anomalies over the proposed mantle plume. However integrated approach including detailed heat flow, deep seismic soundings, gravity and geodetic studies will be necessary for further progress in interpretation.

4. Thickness of the lithosphere below Keonjhar is estimated to be 130 to 140 km from 2D inversion and 80 km from the 1D inversion. There is a significant discrepancy between these two results. Near Bangriposi on the other side of the profile 2D and 1D inverted lithospheric thicknesses are respectively 70 km and 60 km. Author is attaching more weightage to the results obtained by 2D inversion.

5. Published high pressure temperature laboratory measured electrical conductivity data of crust mantle silicates have been used to estimate the present day asthenospheric temperature below the Singhbhum granite batholith. The estimated temperature ranges from $1000^0$ to $1400^0$.

6. Lower crustal conductor, which was so prominent in the 2D model obtained by 1D inversion appeared only in small patches in 2D the model obtained by 2D inversion. Therefore not enough weightage could be given at this stage on the presence of lower crustal conductor below the singhbhum granite batholith.

7. The author has written 1D inversion code using (i) Weighted ridge regression approach, (ii) Backus – Gilbert approach and (iii) simulated Annealing approach.

Schmucker's $\rho^* - g^*$ algorithm was supplied by Manufacture of the MT equipment. All the four approaches gave reasonably consistent result about the presence of the lower crustal conductor and the underlying resistive uppermost mantle below the station Tangavilla. nature of the Backus-Gilbert averaging kernel and spread function and Backus-Gilbert model are presented for the field data just for academic interest.

**(B)** Magnetotelluric traversing along the western end of the Singhbhum shear zone is done using the same MT equipment. With upgradation of the equipment and better processing software, all the elements of the impedance tensor were available for analysis and interpretation. The Goilkera area of the western Singhbhum, Bihar, is geologically very disturbed and difficult for the magnetotelluric survey also, due to high cultural noise(the busy electrified Calcutta–Mumbai railway which passes almost parallel to the Singhbhum shear zone marked by geologists. Dense network of the the high tension power lines is present in the area. 2D inversion of the Kuira–Kundpai profile data reveals the signature of a nearly vertical contact and a high conductive zone below the MT site Kuira. A sharp contrast in resistivity exists below the station Nuvagaon and Gotampa. The contact may be the extension of the shear zone on the western side. Some aspect of the rotation invariant analysis is included in this section. Berdichevsky's averages apparent resistivity and phases (($\rho_D$, $\phi_D$), ($\rho_B$ and $\phi_B$) and Lilley's central apparent resistivity and phases($\rho_C$ and $\phi_C$) are presented along with Bahr's telluric decomposition results. The effective or determinant average $\rho_D$ and $\phi_D$ pseudosection appeared to be quite informative.

**(C)** A magnetotelluric traverse was taken across the Sukinda thrust, the contact of the northern margin of the Eastern Ghats and the southern margin of the Singhbhum Orissa iron ore craton, near Kamakhyanagar, Dhenkanal district, Orissa. The same instrument was used. In place of silver silver chloride electrodes cadmium–cadmium chloride electrode are used. Noise level was less and data with reasonable error bar could be collected for the entire period range of the equipment (0.25 sec to 4096 sec), thus data analysis and interpretation could be done in greater detail. Rotation invariant parameters along with the conventional MT analysis is done. Tensor decomposition results with Egger's eigen state formulation, Yee and Paulson's canonical decomposition and Bahr's telluric decomposition are presented along with Berdichevsky's averages and Lilley's central impedances.

Following MT parameters are presented particularly for MT site 18, univariate and bivariate coherency, amplitude spectra of all the five components recorded, magnetic transfer functions, amplitude and phases of the induction arrows, tipper and tipper skew, Swift's skew and Bahr'skew, Swift's and Bahr's rotation angle, real and imaginary impedance tensor elements, apparent resistivity and phases for the diagonal and off diagonal elements of the impedance tensor, Swift rotated apparent resistivity and phases, real and imaginary telluric vectors, telluric apparent resistivities and phases. Results are also presented along the profile in pseudosection form and/or as surface plots for TE, TM, TE & TM, apparent resistivity and phase, $\rho_D$ and $\phi_D$, $\rho_B$ and $\phi_B$, $\rho_C$ and $\phi_C$, $\rho_{\lambda^+}$ and $\phi_{\lambda^+}$, $\rho_{\lambda^-}$ and $\phi_{\lambda^-}$, $\rho_{\sigma_1^2}$ and $\phi_{\sigma_1^2}$, $\rho_{\sigma_2^2}$ and $\phi_{\sigma_2^2}$, $\rho_{T1}$ and $\phi_{T1}$, $\rho_{T2}$ and $\phi_{T2}$, $\Sigma$, $\mu$, $\eta$, and "error" is included (these terminology are explained in the text). Telluric vector $e_X$ and $e_Y$ and induction arrows are presented for this profile for a period range from 0.25 sec to 256 sec.

2D inverted models for the collision zones of the Eastern Ghats and Singhbhum Archaean craton upto a depth of 180 km are presented for the TE mode, TM mode, TE+TM mode data. 2D inverted models using the rotation invariant parameters ($\rho_D$,$\phi_D$), ($\rho_B$, $\phi_B$) and ($\rho_C$, $\phi_C$) are also presented.

Data analysis reveal the following facts

1. The signal with 4096 sec could see the crust mantle upto 180 km from the surface. More weightage is given to the TE and TE+TM mode data. it is observed that the thickness of the lithosphere is about 130 to 150 km.

2. A conducting pocket in the mantle is located below the Sukinda thrust.

3. Resistivity of the thrust zone or the collision zone or the shear zone is significantly lower than the quartzite/granodioritic block present just north of the collision zone. With all the surface apparent resistivity plots, Sukinda thrust is a flat plateau extending from the surface to the great depth. The thickness of the plateau is about 4 km. Actual thickness of the Sukinda thrust is more than 4km in the Kamakhyanagar area. The northern margin is established more observations are required to establish the southern margin. Sharp contrast in the resistivity between the southern margin of the Archaean craton is well established through the many MT parameters.

4. Pseudosections based on TE mode, TM mode , TE+TM mode, ($\rho_D$, $\phi_D$), ($\rho_B$, $\phi_B$) and ($\rho_C$, $\phi_C$) data reveal the many faults present just north of the thrust plane. It is in agreement with the surface geological findings. Signature of the collision tectonics are reflected in these pseudosections.

5. TE, TM, ($\rho_B$, $\phi_B$) and ($\rho_C$, $\phi_C$) 2D inverted model show the signature of a conducting body in the upper mantle below the Sukinda thrust or collision zone. Signature of the collision zone are present in the granitic body of Sukinda areas.