ABSTRACT

This thesis contains the results of magnetotelluric field studies carried out around five base camps located at Khordha, Dhenkanol, Jiral, Kamakhyanagar and Keonjhargarh in Orissa, Eastern India, covering a profile of about 150 km in the north-south direction. This profile extends from the northern portion of the Proterozoic Eastern Ghats Mobile Belt (EGMB) to the southern portion of the Archaean Singhbhum craton across the Archaean-Proterozoic contact of the Sukinda thrust. The Sukinda thrust separates the high-grade granulitic terrain of the Eastern Ghats from the low-grade granites/granitoids and Iron ore group of rocks of the Singhbhum craton. The three base camps Khordha, Dhenkanol and Jiral are situated over the Eastern Ghats, Kamakhyanagar is situated over the Sukinda thrust or the Sukinda collision zone and Keonjhargarh is situated over the Singhbhum granite phase-II.

Various electric and magnetic field components have been recorded using the Metronix MMS02E single station equipment. Recording of two horizontal components of the electric field and three components (two horizontal and one vertical) of the magnetic field ranging in period from 0.25 second to 4096 second have been done continuously for more than 24 hours at a stretch in each site. Metronix PROCMT and EMPROG software have been used for data processing and data plots. The apparent resistivity and phase data obtained after processing have been inverted using the 2-D Rapid Relaxation Inversion (RRI), 2-D Reduced Basis Occam's Inversion (REBOCC) and 1-D Very Fast Simulated Annealing (VFSA) inversion algorithms in order to get the final subsurface geo-electric sections in TM, TE and TE+TM modes.

For this thesis, efforts have been directed in the following directions and results obtained in those directions have been presented. The major objectives of the thesis were as follows:

(i) electrical conductivity mapping of the upper crust, lower crust and the upper mantle of the study area extending for about 150 km in the north-south direction starting from Khordha, in the south up to Keonjhargarh in the north.

(ii) mapping the vertical discontinuities like the Mahanadi graben, Sukinda thrust and other tectonic faults to the south of the Sukinda collision zone.

(iii) delineating the horizontal discontinuities like the Moho and the Lithosphere-Asthenosphere boundary below the Eastern Ghats and the Singhbhum craton.

(iv) investigating the non-uniqueness in the subsurface geo-electric sections obtained from TM, TE and TE+TM mode inversion of magnetotelluric data using different 2-D inversion algorithms.

(v) studying some properties of the rotation invariant magnetotelluric parameters.

(vi) investigating the usefulness of the rotation invariant parameters in the interpretation of subsurface geology from magnetotelluric data. Mainly, three pairs of the rotation invariant parameters viz. determinant, central and average apparent resistivities and phases have been studied.

Chapter-1 contains a brief background of the subject Magnetotelluric method in Geophysics. The origin of the earth's natural electromagnetic field has been discussed. A brief outline about the history of gradual development of the subject Magnetotellurics starting from its origin to the present scenario is given. A few points about the application of the magnetotelluric method are discussed. A brief account of the problem dealt with in this thesis is given in this chapter.

Chapter-2 deals with the theoretical developments of the magnetotelluric method in brief. Chapter-3 contains the details of the procedures of data acquisition, processing and inversion taken up in the present work. Chapter-4 deals with the geology of the study area which includes two distinct geological terrains viz. the Proterozoic Eastern Ghats Mobile Belt and the Archaean Singhbhum craton. The contributions by the author in this thesis have been discussed from Chapter-5 to Chapter-8. The last chapter of this thesis, which is Chapter-9, contains the concluding remarks.

Chapter-5 deals with the data acquisition, data analysis and the results obtained from magnetotelluric survey along the three consecutive north-south extending profiles over the northern portion of the Eastern Ghats. Both 2-D RRI and

REBOCC inversion algorithms have been used in this sector to produce the TM, TE and TE+TM mode subsurface resistivity models. The results obtained from interpretation of the geo-electric models of the three sectors can be summarized as follows:

a) The high-grade granulite facies rocks in the northern portion of the Eastern Ghats Mobile Belt extend up to a depth of about 10 km from the surface.
b) Below about 10 km from the surface the lower crust is highly conducting and this highly conducting lower crust extend up to a depth of about 40 km from the surface.
c) Electrical resistivity increases with depth after about 40 km from the surface.
d) The lower crust and the uppermost mantle below the northern portion of the Eastern Ghats Mobile Belt are remarkably horizontal.
e) The Mahanadi graben does not extend beyond the depth of 7 to 8 km from the surface.
f) A sharp increase in resistivity has been observed below the Eastern Ghats at about a depth of 34 to 40 km, which may be the signature of Moho below the Eastern Ghats.
g) A break in electrical resistivity has also been observed at about a depth of 160 km, which may be the signature of the Lithosphere-Asthenosphere boundary.
h) Some major geologically established tectonic faults have been delineated to the south of the Sukinda thrust indicating the Sukinda thrust to be a collision zone.
i) The TM mode magnetotelluric data could resolve the Mahanadi graben better than the TE mode magnetotelluric data.
j) The subsurface resistivity models obtained using different inversion algorithms from the same set of data show some amount of non-uniqueness.

Chapter-6 contains the data acquisition, data analysis and the results obtained from magnetotelluric survey across the Sukinda thrust. The important findings from the interpretation of the TM, TE and TE+TM mode resistivity models of this sector obtained using 2-D RRI inversion algorithm can be summarized as follows:

a) The horizontality of the lower crust and upper mantle found below the Eastern Ghats started disappearing from a little south of the Sukinda thrust.
b) Sukinda thrust is a deep-seated feature. It extends up to the mantle.
c) Sukinda thrust is dipping towards south.
d) Highly conducting zone immediate south of the Sukinda thrust indicates that it may be a collision zone i.e., Proterozoic EGMB may have collided with the Archaean Singhbhum craton.

Chapter-7 contains the field-work, data analysis and interpretation of the resistivity models obtained from the magnetotelluric survey over the Singhbhum granite. The salient features obtained from the interpretation of the subsurface geo-electric sections of this sector can be summarized as follows:

a) The highly resistive Singhbhum granite is about 20 to 30 km thick below the entire profile across Keonjhargarh. It is about 25 km thick near Keonjhargarh.
b) A highly conducting zone exists below the Singhbhum granite batholith at lower crustal and upper mantle depth.
c) An increase in electrical conductivity at a depth of about 120 km may be the signature of the Lithosphere-Asthenosphere boundary below the Singhbhum granite.

Chapter-8 deals with the results obtained from the study of some properties of the rotation invariant parameters obtained from the field data collected over the Eastern Ghats and the Singhbhum craton. Their feasibility of being used in interpretation of the subsurface geology has also been investigated. The results obtained are as follows:

a) $\rho_{Frobenious}$, $\rho_{\beta+}$ and $\rho_{\lambda+}$ give apparent resistivities on the higher side and $\rho_{\beta-}$ and $\rho_{\lambda-}$ give apparent resistivities on the lower side of ρ_{TE} and ρ_{TM}. Only the three pairs of rotation invariant determinant, central and average apparent resistivities and phases i.e. (ρ_D,ϕ_D), (ρ_C,ϕ_C) and (ρ_B,ϕ_B), remain within the bounds of (ρ_{TM},ϕ_{TM}) and (ρ_{TE},ϕ_{TE}).

b) The TM and TE mode apparent resistivity and phase data obtained from the field are widely separated while the rotation invariant pairs (ρ_D,ϕ_D), (ρ_C,ϕ_C) and (ρ_B,ϕ_B) remain close to one another. Rotation invariant parameters show greater stability in apparent resistivity and phase plots.

c) In a complex plot the four components of the impedance tensor Z describe ellipses of the same size and ellipticity for 360^0 rotation even for field data having error bars. The Z_{xx} ellipse remains exactly superimposed over the Z_{yy} ellipse. But, the rotation invariant tensors (Z_D, Z_C and Z_B) are just points in a complex domain.

d) The rotation invariant parameters give an 1-D representation of the earth even when it is not at all 1-D. They generate 1-D type of approximate models of 2-D/3-D earth.

e) 1-D inversion of the rotation invariant parameters using VFSA algorithm clearly indicated a decrease in resistivity, which may be the signature of Lithosphere-Asthenophere boundary at a depth of about 120 km below the Singhbhum granite.

f) The rotation invariant parameters could also delineate the signature of Moho at a depth of about 40 km below the Singhbhum granite in a better way than the conventional TE and TM mode magnetotelluric data.

g) The geo-electric models obtained from the rotation invariant parameters are closer than those obtained from the TE and TM mode magnetotelluric data. The three pairs of rotation invariant apparent resistivities and their phases, i.e., (ρ_D,ϕ_D), (ρ_C,ϕ_C) and (ρ_B,ϕ_B) are better than conventional (ρ_{TE},ϕ_{TE}) and (ρ_{TM},ϕ_{TM}) for 1-D inversion.

h) The information content in the rotation invariant parameters is more than that in the conventional TE and TM mode magnetotelluric data.

i) When amplitudes of the seven impedance tensors are plotted for 360-degree rotation, four elements of the impedance tensor Z described polar diagrams and the rotation invariant tensors describe perfect circles.

j) The estimation of the Lithosphere-Asthenosphere boundary below the Singhbhum granite batholith has more weightage than that determined below the EGMB.