MAGNETOTELLURIC STUDY TO CHARACTERIZE THE DEEP GEOELECTRIC CRUSTAL STRUCTURE OF THE SON–NARMADA-TAPTI LINEAMENT ZONE, CENTRAL INDIA

G. DHANUNJAYA NAIDU

NATIONAL GEOPHYSICAL RESEARCH INSTITUTE

HYDERABAD – 500 007, INDIA

THESIS SUBMITTED TO THE OSMANIA UNIVERSITY

FOR THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

GEOPHYSICS

2010

CERTIFICATE

This is to certify that the Thesis entitled**,** “Magnetotelluric study to characterize the deep geoelectric crustal structure of the Son-Narmada-Tapti lineament zone, central India” submitted for the award of the Degree of Doctor of Philosophy in GEOPHYSICS at Osmania University, is the bonafide research work carried out by G. Dhanunjaya Naidu, at NGRI, during the years 2007-2009 under my supervision. The work is original and has not been submitted earlier for any Degree at this or any other University.

Date:

(Dr. T. Harinarayana)
Research Supervisor,
Scientist – G,
NGRI,
Hyderabad – 500 007

DECLARATION

I, hereby declare that the thesis entitled, “Magnetotelluric study to characterize the deep geoelectric crustal structure of the Son-Narmada-Tapti lineament zone, central India” submitted for the Degree of Doctor of Philosophy in Geophysics of the Osmania University is original in its contents and has not been submitted before, either in parts or in full to any University for any research degree.

(G.DHANUNJAYA NAIDU)
Candidate

Dr. Y.J.Bhaskar Rao,
Director,
NGRI,
Hyderabad – 500 007,

Dr. T. Harinarayana,
Research Supervisor,
NGRI,
Hyderabad – 500 007.

ABSTRACT

A major portion of the Son-Narmada-Tapti (SONATA) lineament zone falls in the states of Maharashtra and Madhya Pradesh between lat. 20^0 and 25^0 N and long. 73° and 84° E. The area comprises different rock types ranging from Archean to recent.

Several geophysical studies were carried out in the NSL region to investigate the nature of the crust and upper mantle particularly in respect of density, velocity and related features of crust – mantle interaction. The Bouguer gravity map of the NSL region, compiled utilizing the data sets collected during CRUMANSONATA programme (Rao et al., 1982; Rao and Sastry, 1986) and during the upper mantle project (Kailasam, 1979), shows several high amplitude with long as well as short wave anomalies all along its length. While some of the major gravity lows have been attributed to the known sedimentary basins, viz. Vindhyans, Gondwanas, the gravity highs are interpreted in terms of heavier subsurface basic bodies in the crustal column. Five deep seismic sounding (DSS) traverses cutting across the NSL region were occupied and the results brought out anomalous crustal structure with the lower crust characterized by velocities in the range 7.0 - 7.5 km/s. These features are interpreted in terms of a transition zone (Kaila et.al., 1985). Major tectonic adjustments in various crustal blocks in the region are reported to occur during the Precambrian/Gondwana times. The observed block movements during the Precambrian and Gondwana times, existence of sedimentary basins below Deccan traps and the observed high density, high velocity material in the lower crust point out to the presence of deep seated tectonic activity in the region.

Though earlier geophysical studies conducted in the NSL region provided valuable data sets and new concepts on subsurface features (Mishra et al. 2001), keeping in view of the vast seismotectonic significance and map the details of anomalous features in the lower crust, wide band MT study has been undertaken along selected traverses cutting the NSL zone in central India region.

The main objectives of the present study are: (i) to delineate the subtrappean sediments (if any) across the NSL region along four different traverses, (ii) to understand the characterization of geoelectrical structure of the crust and examine the nature of geoelectrical signatures of the known faults, (iii) to integrate the results with other geophysical data such as seismics, gravity and heat flow in order to understand the tectonic scenario of the region.

MT investigations have been carried out over NSL region during 2004-2008 field campaigns along four different traverses, three in N-S direction and one is in E-W direction. These traverses are located across some of the gravity 'high' and 'low' axis in the NSL zone. State of the art wide band MT systems have been used for data collection and all the efforts made to maintain the quality of the data. The results of MT study along these four traverses are presented and discussed in the thesis.

The thesis consists of eight chapters. **Chapter I** provides an introduction, followed by details of the evolution of Son-Narmada-Tapti lineament zone, major lineaments, regional geology and tectonic frame work of the study area. Results of earlier geophysical studies in the region including regional gravity, deep seismic, MT and also geothermal studies are also compiled as a part of the present study in this chapter.

Chapter II presents the basic theoretical concepts of the magnetotelluric (MT) method. The method uses natural source electromagnetic fields that are generated due to the interaction of the varying intensity solar wind with outer magnetosphere boundary. Some of the particles from solar wind propagating through the magnetosphere generate the magneto hydrodynamic (MHD) waves. As they pass through ionosphere, electromagnetic waves are generated in different frequency ranges. Normally MT uses the frequency range from 10^3 Hz to 10^{-3} Hz. The source signals above 1Hz are caused by the worldwide thunder storm activity and the signals less than 1Hz are caused by the magneto hydrodynamic waves generated at the magnetospheric boundary. Details of these source field signals are described in this chapter. Processing of MT data results in deriving apparent resistivity/phase over a range of frequencies and several other response functions. The MT response functions such as impedance tensor, invariants, tipper, skew, polar diagrams and induction arrows are also described in this chapter. The concept of static shift effect, 3-D-galvanic effect and rotation of the impedance tensor are described in detail. The MT data when inverted would provide valuable information on the distribution of the electrical conductivity (or its reciprocal, electrical resistivity) with depth, which in turn may be interpreted in terms of subsurface structure, lithology and physical state of the earth’s interior. Modeling of geophysical data in terms of subsurface geology can be done in two ways: a direct way, the forward modeling, and an indirect one, the inversion. Some details of Non linear conjugate gradient (NLCG) inversion scheme used in the present study for 2-D modeling are also included in this chapter.

Chapter III describes the MT data acquisition procedures, instrumentation and some basic principles of the data processing in detail. Wide band magnetotelluric equipment ADU-06 has been used in the present study for data acquisition. This is the core unit of the Metronix multi-channel Geophysical Measurement System *GMS-06*. The electric and magnetic field sensors are connected directly to the *ADU-06*. Multiple *ADU-06* units can be connected in network using simple, light weight and inexpensive coax cable. The MT survey procedures include several steps to be implemented carefully and systematically in order to get good quality data. For e.g. selection of a suitable MT site is an important factor in any MT survey. After selecting a site, it has to be prepared for laying the electric and magnetic sensors. A specific configuration is followed while making a layout. The two horizontal electric field components are two orthogonal dipoles of 80-90m length, with porous pot electrodes containing $Cdcl_2$ electrolyte and Cd core. The horizontal and vertical magnetic field components are measured with induction coil magnetometers. All the data are processed using MAPROS (Metronix, Germany) software package. This processing facilitates robust single site estimates of electromagnetic transfer functions. Prior to conversion to the frequency domain the time series data of each of the electric and magnetic field components is manually edited by identifying and rejecting the bad segments containing spikes. The MT impedance tensor and magnetic transfer functions are calculated using the M-estimate regression scheme.

The MT survey has been carried out along the four different traverses in NSL region. The MT traverses occupied are; (i) a NE-SW trending Sanawad-Chopda traverse crossing major lineaments, (ii) two N-S trending traverses along Andharwadi-Balapur and Hoshangabad-Ner, (iii) E-W trending traverse passing from Galangi to Brahaman-wada in this region. The details of the modeling and interpretation of the data along these traverses are described in chapters IV to VII.

Chapter IV describes the results of MT studies along the NE-SW Sanawad-Chopda oriented traverse across Son-Narmada-Tapti lineament zone. Earlier geophysical studies gravity and seismics in particular brought out anomalous crustal structure in this region. This traverse mainly cuts across the satpura gravity high and covers mostly the region of exposed Deccan traps in the northern part and alluvial deposits in the southern part near Tapti River. This traverse crosses the major faults like Narmada south fault, Gavilgarh fault and Tapti north fault. 13 MT sites have been occupied at a station interval of 8-10 km along the traverse. The data have been edited and processed for obtaining apparent resistivity/phase as against frequency and the data inverted using NLCG inversion scheme. The impedance tensor data along the traverse are rotated to the regional strike direction of N70^{0}E and the rotated data in TE and TM mode are considered for modeling. The 2D modeling results from NLCG inversion scheme have brought out impressive structural features viz: two anomalous conductive features from mid to lower crustal depths and basinal like feature at shallow depths.

Chapter V describes the results of MT study along the Andharawadi-Balapur traverse. The N-S trending traverse is about 190 km long with a total of 14 sites. As described in the earlier chapter the Narmada-Tapti region is known to be dissected by several faults- the major ones being Narmada South fault, Tapti fault and Gavilgarh fault. Several geophysical studies were carried out earlier in the region to decipher the deep crustal structure and related features of crustal-mantle interaction under the project CRUMANSONATA. In order to gain further insights into the deeper structure of the region, the present study has been undertaken. The impedance tensor data rotated to the regional geological strike i.e. N75^{0}E and the rotated data are inverted to get geoelectric section along the traverse. The strike direction is close to the strike from previous traverse. The final inverted model brings out conspicuous horizontal conductive layer at upper to lower crustal depths associated with deep seated faults. The results clearly point out that these deep faults are associated with major subsurface linear conductive features. The model is correlated with the results from regional gravity, together with constraints from the nearby Ujjain-Mahan DSS traverse to get a more realistic subsurface model for this region. The results are discussed in relation to the seismotectonic significance and the intruded magmatic mafic material at deeper depths of the region.

Chapter VI infers to the details about the MT study along the Hoshangabad-Ner traverse which crosses the major lineaments, faults and different surface geological features. Majority of the stations cover the region of exposed Deccan traps with some stations covering alluvial cover near Tapti River. The northern part covers unclassified gneissic complex, terrestrial facies in a linear graben and alluvial cover near Narmada River. The 2-D MT geoelectric subsurface section brought out several interesting features viz: sedimentary basin like structure at shallow depths and anomalous high conductive feature on northern side of the traverse and is well correlated with the regional gravity anomaly.

Chapter VII describes the details about the MT study along the Galangi-Brahmanawada traverse. This is an E-W trending traverse of about 300 km length along the NSL zone. This traverse passes parallel to the Tapti and Gavilgarh faults. As described earlier, several geophysical studies were carried out earlier in the NSL region in Geological Survey of India to decipher the deep crustal structure and related features of crust-mantle interaction under the project CRUMANSONATA. The data are rotated to regional strike direction of $N75^0E$ for further 2-D analysis. The final inverted model brings out two vertical conductive features from upper to lower crustal depths associated with deep seated faults. The results clearly point out that these faults are associated with major subsurface linear conductive features. The subsurface model is integrated with the regional gravity to get a constrained subsurface model for the region. The results are discussed in relation to the seismotectonic significance and intruded magmatic mafic material at deeper depths of the region.

Chapter VIII infers to the significant results presented in chapters 4, 5, 6, 7 along four different traverses cutting across and along NSL region. Firstly, qualitative interpretation of the data is presented. The shallow resistive structure derived in NSL region is correlated with surface geological features. The thickness estimation of Deccan traps and sediments is also discussed. The deep crustal structure in the NSL region is analysed with more details. Some of the mapped faults in the region seem to have relation with anomalous conductive features indicating that these faults are not shallow and have relation to the features in deep crustal level. These major faults might have played a key role in the block movements and could have been cause for the development of seismicity in the region even today. The possible reason and correlation for the occurrence of various geothermal hot springs with the deep crustal anomalous conductive features is also discussed in this chapter. Finally, various factors for the existence of anomalous conductive features are also discussed.