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MAGNETOTELLURIC INVESTIGATIONS IN DECCAN TRAP COVERED AREAS OF NAGPUR-WARDHA REGION, INDIA

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Abstract

In the context of the efforts for identification and evaluation of hydrocarbon potential of different basins* in the country, Nagpur-Wardha is an important region in central India covered by Deccan volcanics. New directions in the exploration strategies need to be evolved to investigate the difficult and complex areas using judicious combination of conventional as well as non-conventional techniques like Magnetotellurics (MT) and other deep electromagnetic methods. With the support of Directorate General of Hydrocarbons (DGH), National Geophysical Research Institute (NGRI) has taken a lead in this direction to the application of MT, which is one of the most effective techniques, particularly in investigating areas covered by volcanics. This is because the target layer, a subtrappean Gondwana sedimentary column, in general has a marked resistivity contrast with the underlain basement as also to the overlying volcanic cover. The results of MT studies have demarcated the area of interest from the viewpoint of thick sediments, i.e.3-4km, in the region around Katol and Kondhali areas. In the present study, the efficacy of the approach in the estimation of the thickness of volcanic cover and subtrappean sediments and also the regional tectonics of northwest extension of Pranahita-Godavari graben are discussed.

Introduction

Identification and delineation of the hidden sediments buried below the Deccan trap covered areas is a difficult problem to conventional geophysical techniques. Among the various non-conventional geophysical methods, deep electromagnetic techniques, especially Magnetotellurics (MT) is known to be one of the effective techniques particularly in the areas covered by volcanic rocks such as basalt. This is because the buried sedimentary layer is significantly low resisitive as compared to underlying basement and also with the Deccan trap cover. The problem of the detection of subtrappean Mesozoic sediments under the volcanic cover can be seen in areas like Saurashtra in India and other similar areas elsewhere including Columbia River Basalt in States (Prieto et al 1985) and Parana basin in Brazil (Stanley et al 1985; Padila et al 1992).

With the support of OIDB, MT investigations in Deccan trap covered areas in Saurashtra peninsula have successfully identified and estimated the thickness of sediments (Sarma et al 1992). Subsequent, deep drilling (3.5km) has proved these results at Chandli near Lodhika in central Saurashtra (Srinivasan and Khar 1995).

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Apart from Saurashtra region, Nagpur-Wardha area in central India is believed to contain sediments buried below Deccan basalts, as this area is characterized by a prominent gravity low anomaly of the order of 60 to 70 mgal. Another reason for the suspected sediments beneath the Deccan trap cover is due to possible northwestward extension of Pranahita-Godavari graben. In view of this information and with the support of the Directorate General of Hydrocarbons, New Delhi, the present study aims at delineation of configuration of Gondwana basin covered by Deccan trap. Accordingly, the MT survey in Nagpur-Wardha area covering about 10,000 sq.km with the centres around Katol-Kondhali region has been taken up. In the present study, the results of MT investigation in Nagpur-Wardha region are presented.

Methodology

The magnetic pulsations generated due to interaction of solar wind with the earth's magnetosphere and of the magnetosphere with the Ionosphere and also due to Earth-Ionosphere cavity itself provides generation and transmission of signals produced through thunderstorm

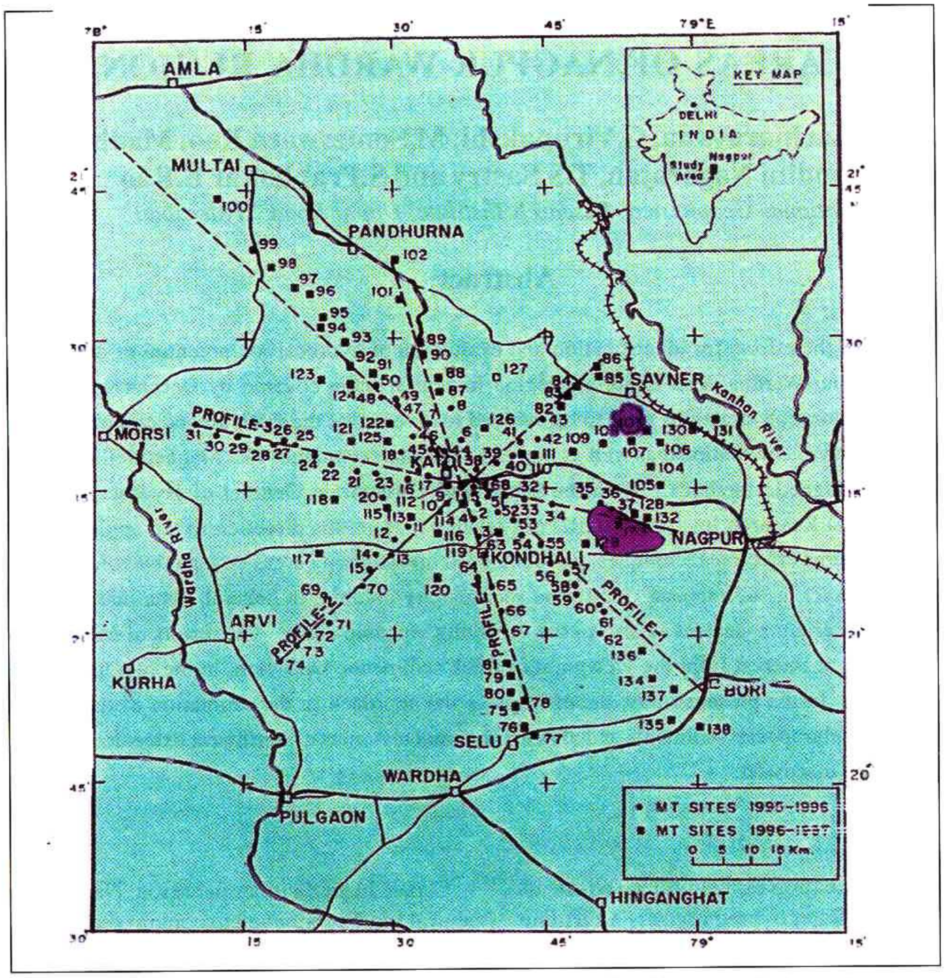

Fig.1. Location Map of MT sites in Nagpur-Wardha area, Maharashtra

activity. These magnetic field variations will cover wide band frequencies (few hundred of seconds to few kilohertz) and serve as MT source signals. In the magnetotellurics, the data has been obtained by measuring the simultaneous orthogonal components of natural magnetic and the corresponding induced electric field variations over a wide frequency range. This data in turn can be used to compute Earth's complex impedance as a function of frequency. The natural occurrence of MT source signals over a wide frequency band provides the subsurface information from a few tens of meters to more than a hundred kilometers. The depth of investigation increases with decreasing frequency of signal. The conductivity variation over a range of frequencies reflects variation of subsurface geoelectric structure at various depths. The subsurface model so derived will be integrated with other geological and geophysical information in order to refine the model so as to get a reliable subsurface structure.

Data Acquisition

Using the state-of-the-art digital data acquisition system, 138 stations were occupied in this area along radial profiles crossing near Katol. The location map of MT sites is shown in Fig.1. The equipment used is a portable system and powered with 12V battery and incorporates latest electronics. Magnetic field sensors consists of wide band induction magnetometer coils with very low noise. Three such sensors are used to measure the orthogonal components (Hx, Hy and Hz) of earth's magnetic field variation. The frequency band of signals ranges from 8kHz to 1/4096 Hz. The electric field sensors are non-polarizing electrodes with Cd-$CdCl_2$ and are used for measuring two orthogonal components (Ex and Ey) of telluric field.

The wide frequency range of measurement is divided into 5 bands, with each band of data selected at a time.

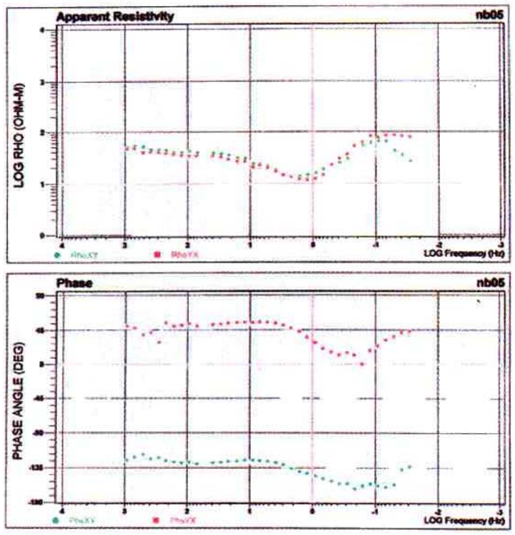

Fig.2.Examples of curves showing presence of sediments

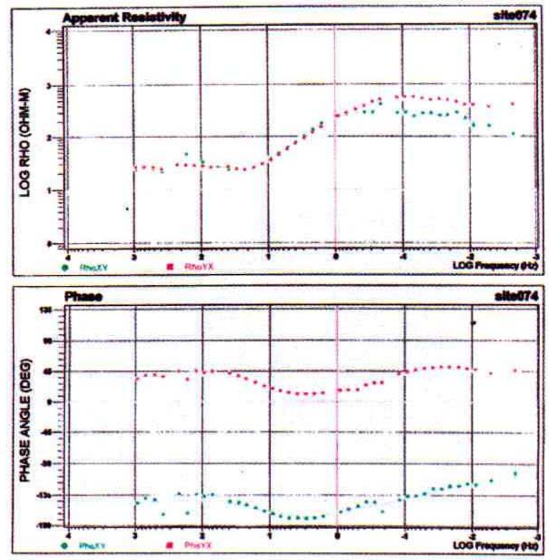

Fig.3. Example of curves showing absence or very thin layer of sediments

The in-built calibration facility makes the system more reliable in the sense that the calibration is carried out every time before acquisition of the data. The data is processed using classical tensorial technique (Vozoff, 1972) in order to obtain MT parameters such as apparent resistivity and phase curves as a function of frequency, which in turn gives the resistivity variation with depth by modeling techniques (Marquardt, 1963;Jupp and Vozoff, 1975).

Data Analysis

Fig.2 and 3 represents the results obtained after processing of MT data. As can be seen from these figures, the MT apparent curves shown in Fig.2 are distinct from that of Fig.3. The curves in Fig.2 in general show 'H' type indicating middle conductive layers (site 05). The resistivity of Deccan traps is of the order of 30-80 Ohm.m in the 10-100 Hz frequency range. The rising limb of the last part of the curve in the low frequencies (1.0 to 0.1 Hz) represents the electrical basement. It may be noted that the site 05 is located around Katol. The MT apparent resistivity curves in Fig.3 for the sites 74 located at the end of the profile 4, have shown in general 'A' type indicating thin or absence of middle conducting layer. The rising limb of the last part of the observed curve is in the frequency range 1 – 100 Hz indicating the shallow electrical basement, which is distinct from that of the curve shown in Fig.2. Consistent with apparent resistivity curves, the phase data (Fig.2,3) also show similar signatures.

Modeling

For quantitative interpretation/evaluation of MT sounding curves, it is required that the data is subjected to 1-D and 2-D modeling and inversion methods. In the present case, this has been carried out using "GEOTOOLS" integrated software package. This package consists of effective data storage, retrieval and display facilities and modeling tools. The MT data is presented in a standard format – The electromagnetic data interface (ED1). The data files are stored in relational database for efficient display, computation and for modeling purposes.

For ID modeling of MT data, the procedures described by Jupp & Vozoff 1975 Marquardt 1963, Occam (Constable et al 1987) and Fisher (Fisher et al 1981) linearized inversion schemes have been followed. The 2D modeling of data has been carried out using finite difference scheme of Jupp & Vozoff 1977 and Rapid Relaxation Inversion Technique developed by Smith and Booker, 1991.

Results

As mentioned before, a total of 138 MT stations were occupied in and around Katol, Kondhali, Arvi, Morsi, Multai, Pandhurna, Savner, Nagpur, Bori and Selu regions. Modeling has been carried out along the four major profiles namely, (i) Bori-Multai; (ii) Arvi-Savner (iii) Morsi-Nagpur, (iv) Selu-Pandhurna, and the results obtained along profile 2 are briefly described in the following.

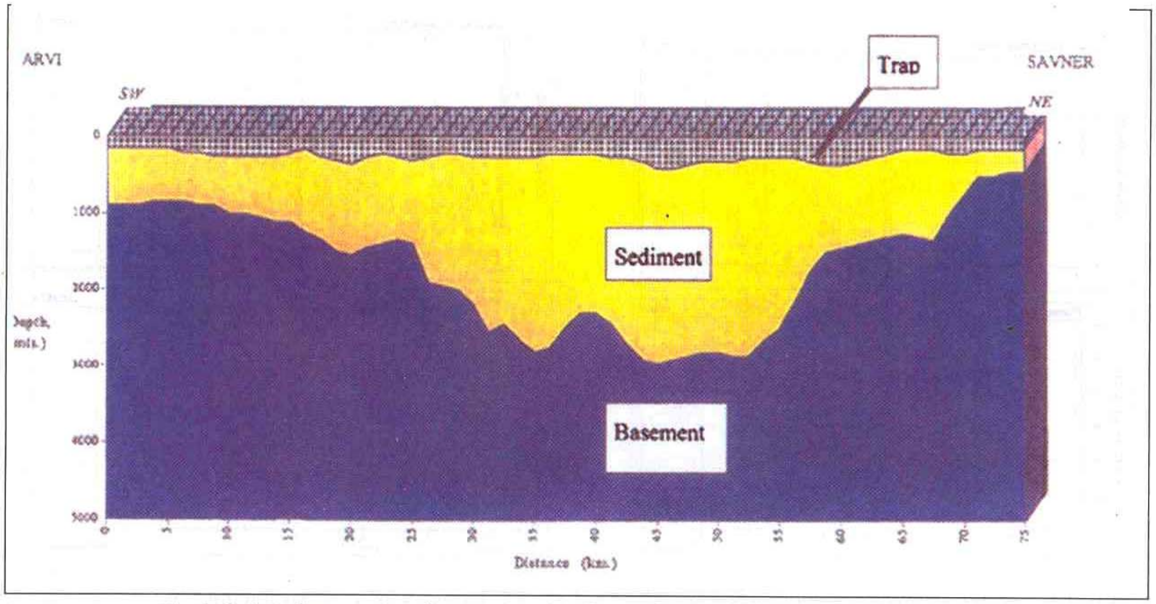

Fig.4. Subsurface section from magnetotellurics Arvi-Savner Traverse (Profile - II) Nagpur-Wardha Area

The first profile i.e. Bori-Multai is covered by 32 sites (120 km long) along the axis of the basin, from around Bori in the SE to Multai in the NW, through Katol. Towards Bori, the basement is shallow (1.0 to 1.5 km) whereas at the centre of the profile basement undulations are present reaching to a maximum depth of 4 km. The basement becomes shallow towards northwestern end of the profile. Arvi-Savner profile (II) is about 80 km in length oriented in NE-SW direction covering 22 sites, and cuts across the basin. The top layer exhibits resistivities of about 50 – 150 Ohm.m with a thickness in the range of 100-400 m representing basalts (Fig.4). This layer is underlain by a conductive layer with a resistivity of 10-15 Ohm.m with a thickness ranging from new hundreds of meters to more than 2.5 km. This layer is interpreted as Gondwana sediments. Basement depths along this profile from SW (Arvi) varies from few hundreds of meters to about 3 km.

Morsi-Nagpur profile (III) is covered by 20 MT sites over a length of 80 km. The top layer namely Deccan traps is represented with the layer resistivities of about 30-100 Ohm.m with a thickness of 100-300 m. The underlying layer is having resistivities of 4 to 20 Ohm.m represents Gondwana formation with a maximum thickness as much as 3 km (at the center of the basin). Selu-Pandhurna profile (IV) is about 90 km in length and covered by 20 sites. The top layer is similar to other profiles representing the Deccan traps (30-150 Ohm.m). Thick conductive layer having resistivity values varying from 10-20 Ohm.m represents Gondwana formation underlies top layer. The maximum basement depth observed on this profile is about 3.5 km.

Summary

Magnetotelluric studies were carried out in Nagpur-Wardha area using the wide band digital data acquisition system and occupied 138 MT sites along four radial profiles crossing near Katol. The data were subjected to 1D and 2D modeling using linearized inversion schemes. Results of the modeling of the data have indicated the presence of a major subtrappean sedimentary basin below the Deccan traps. The shape of the periphery of the basin and also its structure obtained indicates the northward extension of the Godavari graben. The study shows that the trap is thin with about 300-400 m thickness followed by large thickness of sedimentary column varying from a few hundred meters at the periphery of the basin to about 4 km at the centre of the basin. Results of modeling have also brought out the layering within the sedimentary column with moderately resistive sediments, which are interpreted to represent the possible coal bearing Barakars. The basement configuration derived from MT studies shows the presence of structural features like boundary faults, cross faults and ridges constituting the basic structural framework of the basin. The resistivity of the basement is only moderate indicating the possible presence of the fractured Proterozoic basement.

Acknowledgements

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