J. Ind. Geophys. Union (October 2015)
v.19, no.4, pp:433-446

Geophysical Investigations for Delineation of Gondwana Sediments below Deccan Trap beyond the Western Limit of Wardha Valley Coalfields, Yeotmal and Wardha Districts, Maharashtra-*a comprehensive analysis of case studies*

D.C. Naskar* and D.K. Saha

Geological Survey of India, Geophysics Division, ER, Kolkata, India
*Corresponding Author:dcnaskar@yahoo.com

ABSTRACT

The present work in Wardha valley in Central India is an effort in identification and evaluation of concealed Gondwana (coal bearing at places), under the Deccan trap cover, using geophysical inputs. The geophysical exploration was done by using magnetic (VF) and electrical surveys in three blocks in and adjoining part of Wardha valley, which hither to was not explored using Geophysical investigations. The presence of drilling data was an added advantage for correlation of geological litho packages vis-à-vis resistivity data interpretation.

The result of Resistivity Sounding (RS) data interpretation shows mainly four interfaces: top soil/ alluvium, Deccan trap, Gondwana sediment and basement of high resistivity. The resistivities of trap rock vary from 50-300 Ohm-m, with thickness in the range of 20-210 m. The Gondwana shows resistivity in the range of 6-120 Ohm-m with thickness variation ranges from 76-560 m. The geo-electric section in Block I indicate a fault zone in Mangli-Sindhi segment, due to appreciable large variation in basement depth (871 m and 313 m) in two adjoining RS locations. The geo-electric section in Block II indicates high resistivity basement (461-1628 Ohm-m) at a relatively shallow depth (102-218 m) southwest of Wardha River, whereas the same occurs at a greater depth (329-455 m) northeast of Wardha river. The basement has come up to a level of 75 m in the region immediate northeast of Wardha River. The course of the Wardha River is coincident with a postulated fault plane.

The magnetic map shows the presence of fluctuating high amplitude long wavelength anomalies due to the presence of a thick blanket of trap lying above the Gondwana sediments. These magnetic anomalies did not show the basement configuration appropriately due to an overlying blanket of trap. The highly fluctuating anomalies due to the trap overshadow the basement effect. The map, however, approximately indicates the fault zone through the change in the wavelength character of the magnetic anomalies.

INTRODUCTION

Identification and delineation of the hidden sediments under the cover of Deccan trap is a difficult problem in geoscientific exploration. Exploration for additional coal measures in the known Gondwana basins and their covered extensions need immediate attention to supplement to energy basket. In this context, delineation of Gondwana sediments below Deccan trap assumes greater significance. To achieve these objectives, certain areas of south-western part of the Wardha valley, Maharashtra (Fig. 1) have been selected for electrical survey employing Schlumberger sounding as well as magnetic surveys. Kailasam et al. (1973) demarcated a gravity low anomaly zone to the northwest of Godavari graben between Nagpur and Amravati and interpreted it to be due to the possible presence of Gondwana below the traps. This inference has further been substantiated by an indication of occurrence of a thick conductive layer, probably representing presence of Gondwana below traps based on deep electrical resistivity soundings (Reddi et al. 1975). Geological Survey of India had earlier taken up investigations employing deep electrical soundings and magnetic surveys in the Wardha-Pranhita trough and indicated the presence of highly conductive formation of considerable thickness at depth which was inferred as Lower Gondwana (Venkateswaralu et al. 1981). Joga Rao et al. (1984) under Project Deep Geology, based on regional gravity survey and the resistivity soundings, around Kouthurla, Sindi, Mangli and Hinganghat in the Wardha valley, have demarcated the presence of sediments (Gondwana) below the Deccan traps at depth. Sarma et al. (2004) based on magnetotelluric studies in the Wardha valley, have demarcated a major subtrappean sedimentary basin below the Deccan traps. Reddi (2015) succinctly pointed out the significant efforts made by GSI Geophysicists during 1970s and 80s in mapping the floor of the trap both for its economic and fundamental scientific implications. He stated that special purpose DC resistivity device with higher power supply capabilities helped in carrying out sub-trappean structural imaging studies. The studies turned out to be astoundingly successful for mapping sub-trappean geology in general and unveiling sediments with fossil fuel potential.

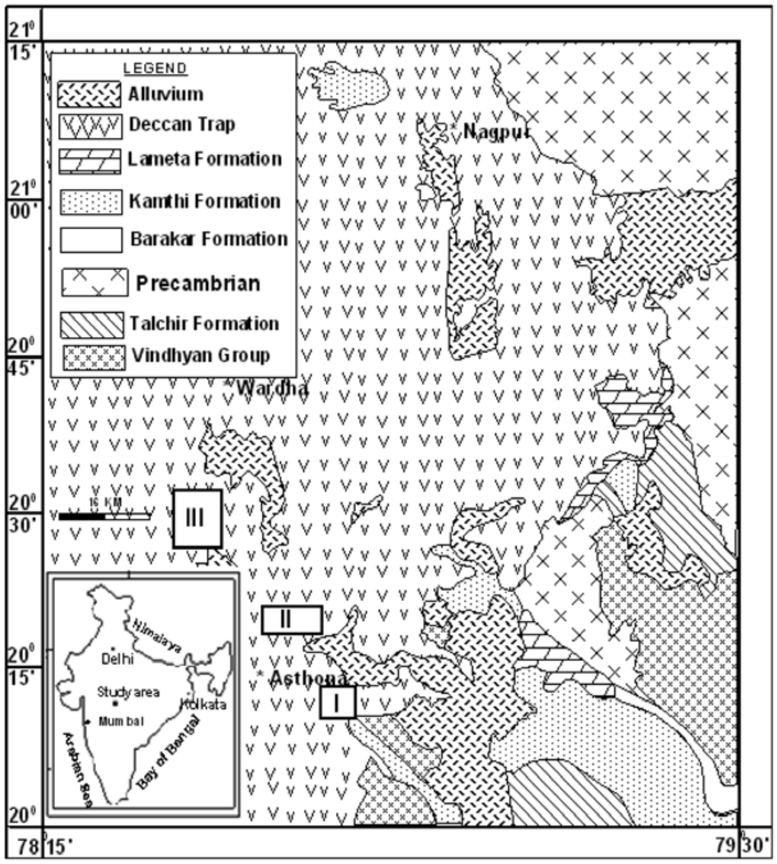


Figure 1. Geological map of Wardha valley coalfields showing the areas of investigations, Maharashtra.

These significant studies enthused the subsequent generations GSI geophysicists to carry out focused scientific endeavours to unravel hidden economic resources. The present study is part of such an endeavour.

Geology

The geology of Wardha district basically consists of Deccan trap lava flows of Cretaceous-Palaeocene age are mainly exposed in the area (Fig. 1). The flow rocks are basaltic or doleritic, medium to fine grained, porphyritic and non-porphyritic. It is known that in the northern parts of the Godavari graben, the Gondwana sediments are disposed in three sub-parallel troughs, the western most of which is the main Pranhita-Godavari (Wardha) trough. Most of the major coal reserves of south and central India are located in this area. The central trough is denoted by the Umrer basin. These sub-parallel troughs are separated by the intervening Precambrian formations. The postulated presence of Gondwana sediments below trap cover by the aforesaid geophysical inferences are the possible extensions of these three troughs under trap cover. The geological sequence of the various formations and their stratigraphy are as follows:

Formation	Age
Alluvium	Recent
Deccan trap	Upper Cretaceous
Lameta formations	Upper Cretaceous to Eocene
Kamthi formations	Upper Carboniferous to Permian
Barakar formations	Upper Carboniferous to Permian
Talchir formations	Upper Carboniferous to Permian
Vindhyan group	Precambrians
Precambrians	

The older rock, the Archaeans and Precambrians form the basis of deposition of rocks of Gondwana. The alluvial deposits are restricted to the bank of Wardha river and its tributaries. The thickness reported varies from 15-20 m.

GEOPHYSICAL STUDIES

The purpose of the geo-electrical survey is to determine the subsurface distribution of the resistivity-thickness parameters. This can well be related to the physical conditions of the underlying geological formations.

Magnetic survey was carried out using a Vertical Force (VF) MFD-2 Fluxgate Magnetometer in three blocks (Fig. 1). A total of 439 observations were taken. All observations were taken with N-S orientations and as such heading error

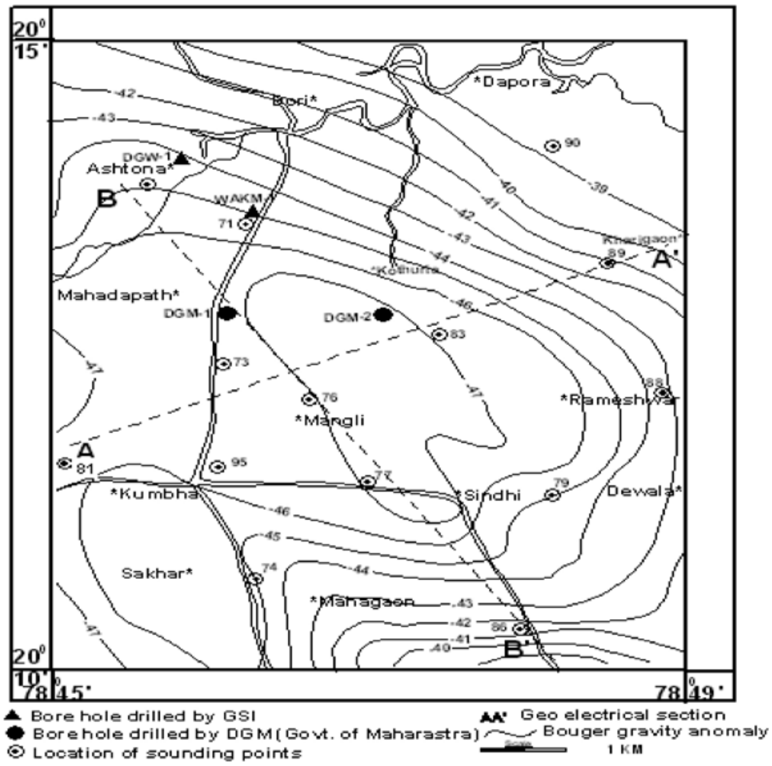


Figure 2. Location map along with Bouguer anomaly map (after Joga Rao, et al. 1984) in block-I: Kumbha area, Maharashtra.

was negligible. Resistivity survey was carried out using a TSQ-3 Transmitter and RDC-10 Receiver. 95 Resistivity Soundings (RS) were taken using Schlumberger array with a maximum current electrode separation (AB) equal to 4 km.

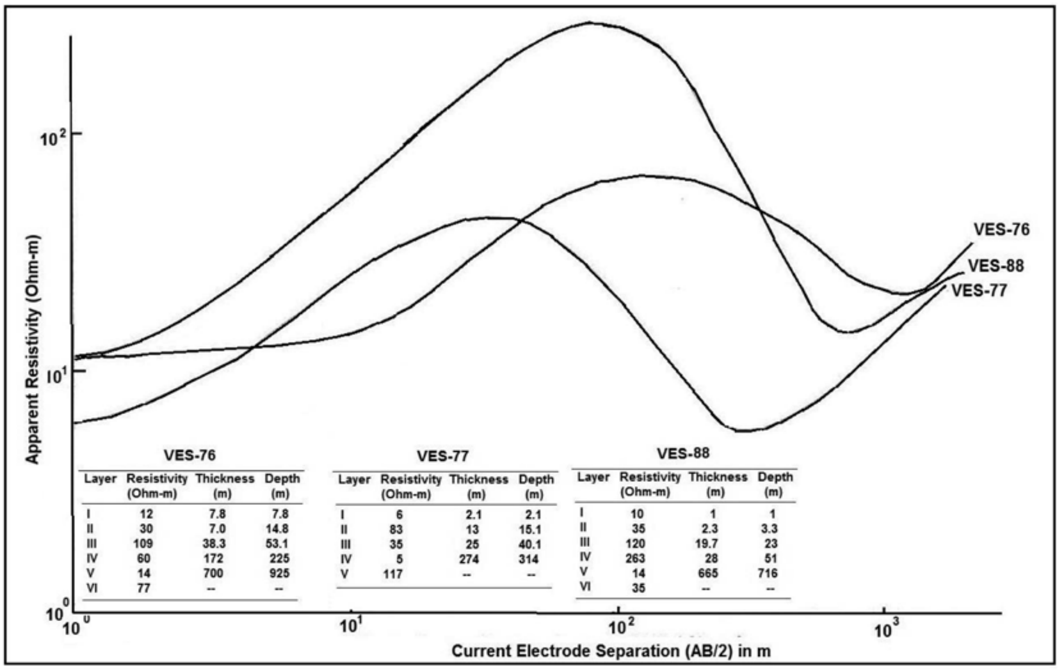
In the present study over an area of 310 sq km in three blocks (I, II, III), ninety five Schlumberger soundings with a maximum current electrode separation (AB) of 4 km have been carried out (Fig. 1). The length of the current and potential dipoles are increased keeping MN≤1/5 AB, where AB is current dipole length, MN is potential dipole length. On correlating interpreted resistivity data with boreholes litho logs drilled by the Directorate of Geology and Mining (DGM) Maharashtra, a relationship has been obtained between range of resistivity and the various subsurface formations. Details are given below:

Geological Formation	Resistivity (Ohm-m)
1. Alluvium/top soil/Weathered trap	up to 25
2. Deccan trap	50-300
3. Sub-trappean formations	15-80
4. Gondwana	6-120
5. High resistivity zone (basement/bedrock)	> 300

Nayak (1990) and Naskar (2005) had earlier reported similar characteristic resistivity values of the different rock formations in the Son- Narmada lineament area. It may be noted that there is an overlapping resistivity range for the Deccan trap and Gondwana sediments, which make it difficult to mark the interface between them. Demarcation of the Precambrian morphology, however, has been possible by the resistivity survey results, because of high contrast between the Deccan trap/Gondwana sediments and the Precambrian rocks.

Resistivity Interpretation

The field data, so obtained, are interpreted by 1D inversion technique. For this purpose, computer software RESIST (Vander Velpen, 1988) is used. Preliminary values of the model parameters, as obtained by manually matching the VES field curves with the theoretical master curves (Orellana and Mooney, 1966) and auxiliary point charts are subsequently used as input starting model in RESIST for further refinement of results by 1D inversion algorithm. The degree of uncertainty of the computed model parameters and the goodness of fit in the curve fitting algorithm are expressed in terms of standard deviation and residual error, respectively. The resistivity of different layers and the corresponding thickness are reproduced by a number of iterations until the model parameters of all the VES curves are totally resolved with minimum standard deviation and residual error. 1D interpretation is not always able to properly present a realistic resistivity



VES-76

Layer	Resistivity (Ohm-m)	Thickness (m)	Depth (m)
I	12	7.8	7.8
II	30	7.0	14.8
III	109	38.3	53.1
IV	60	172	225
V	14	700	925
VI	77	--	--

VES-77

Layer	Resistivity (Ohm-m)	Thickness (m)	Depth (m)
I	6	2.1	2.1
II	83	13	15.1
III	35	25	40.1
IV	5	274	314
V	117	--	--

VES-88

Layer	Resistivity (Ohm-m)	Thickness (m)	Depth (m)
I	10	1	1
II	35	2.3	3.3
III	120	19.7	23
IV	263	28	51
V	14	665	716
VI	35	--	--

Figure 3. Representative resistivity sounding curves along with interpreted layer parameters in block-I: Ashtona-Kumbha area, Maharashtra.

model because of the high degree of misfit between field data and model response. Therefore, 1D interpretation for these data is done by omitting the artificial layers, i.e. by truncating the data up to the acceptable limit. Only those estimated models were accepted whose RMS variation was less than 2.0. Resistivity of these geophysical models was finally interpreted in terms of lithology. 1D inversion reserves its importance and utility, as the interpreted model parameters can serve as starting models for 2D and 3D approaches for better approximation of the subsurface geology (inhomogeneities, lateral contacts, such as joint, fracture zone, dyke, vein, and fault or shear zone) of an area. In such cases, 1D interpretation is usually found to be fairly consistent with those observed in 2D and 3D inversions.

Block I (Ashtona-Kumbha Area)

Location of resistivity soundings along with Bouguer anomaly map (Joga Rao et al. 1984) is shown in Fig. 2. Some representative sounding curves of the area along with interpreted layer parameters are presented in Fig. 3.

The obtained apparent resistivities for half the current electrode separation (AB/2) beyond 100 m show a steep fall in resistivity value. The interpreted resistivity value for this conductive layer at depth varies from 5-18 Ohm-m. This conductive zone may be corresponding to the Talchir formations. Joga Rao et al. (1974), Subrahmanyam et al. (1975) and Chakraborty et al. (1976, 1977) have reported the same order of resistivities for Talchir formations southwest of the area. The details of some soundings along two sections AA' and BB' are also given in Fig. 4 and Fig. 5.

In view of obtaining a 2D idea of the area of study, two geo-electric sections (AA' and BB') were chosen taking gravity response into consideration (Fig. 2). The section AA' is taken from Kumbha in the NW to Khairgaon. The other section, almost orthogonal to the above has been designated as BB' (from Asthona to east of Mahagaon).

Along section AA' (Fig. 4), the top most layer characterized by resistivity value of 6-15 Ohm-m and thickness varying from 2-15 m corresponds to alluvium/ top soil, which is underlain by a layer having resistivity varying from 25-325 Ohm-m and of thickness varying from 50-80 m. This layer corresponds to Deccan trap. These are followed by a low resistivity zone 11-104 Ohm-m and of thickness 110-205 m representing sub-trappean formations Motur/Barakar. A thick conductive zone of resistivity varying from 6-18 Ohm-m and thickness varying from 340-700 m representing Talchir is interpreted all along the section. The high resistivity zone (69-500 Ohm-m) representing basement is inferred at deeper level. The results of resistivity soundings are in agreement with the gravity results along the section. Basement depression is found to lie in the central portion of Bouguer anomaly map. Along section BB' (Fig. 5), the top most layer characterized by resistivity value of 4-22 Ohm-m and thickness varying from 2-10 m corresponds to alluvium/top soil. The Deccan trap having resistivity in the range from 40-203 Ohm-m and thickness varying from 26-79 m lies below top soil/ alluvium. These are followed by a low resistivity zone

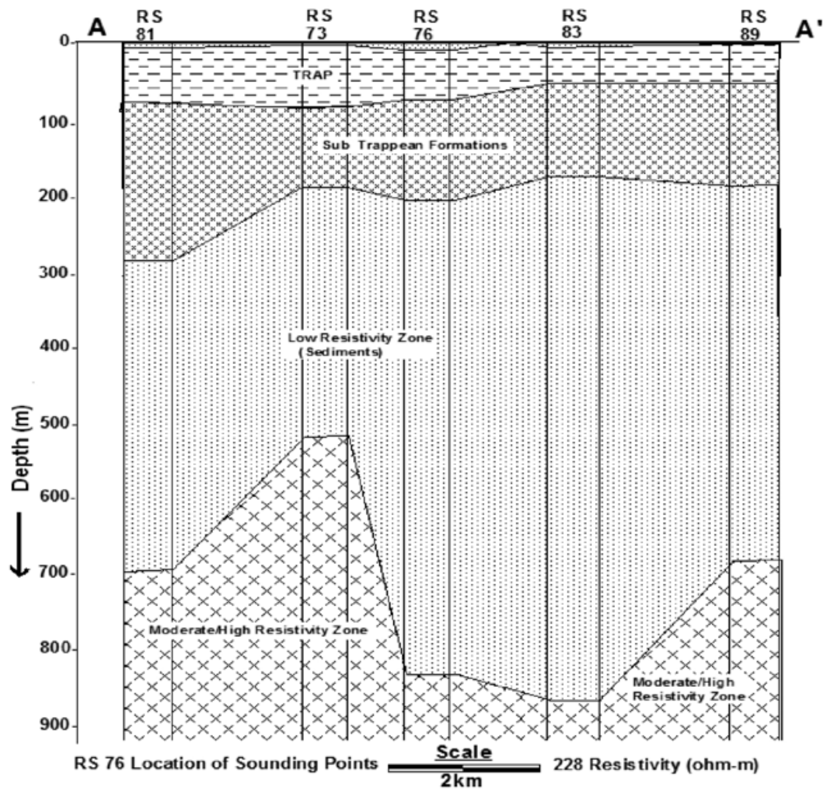


Figure 4. Geo-electrical section along AA' in block-I: Ashtona-Kumbha area, Maharashtra.

(22-60 Ohm-m) of thickness 24-143 m, representing sub-trappean formations Lameta, Kamthi and Motur. A thick conductive zone of resistivity varying from 5-16 Ohm-m and thickness varying from 106-700 m is inferred all along the section. The basement has been identified below this conductive layer. Interpretation of sounding curves in general reveals that high resistivity basement is present at greater depth of 871 m in RS 76 in Mangli-Sindhi area, whereas to the south of it (RS 77) the same occurs at a shallow depth of 313 m. The steep gradient could possibly be attributed to a fault zone (Naskar and Das, 2009). However, in gravity contour there is no indication of any upliftment of basement. The presence of fault may be due to variation of depth.

Correlation of the formations intersected in the boreholes and interpreted resistivity data is given below:

Borehole and associated sounding number	Observed lithology and depth range (m)	Interpreted resistivity (Ohm-m) of different layers from resistivity sounding data and depth range (m)
DGW 1 (RS 82)*	Deccan trap (0-55)	4 (0-1)
	Kamthi (55-145.45)	8 (1-3.8)
	Barakar (145.4-274.45)	40 (3.8-11.8)
	(Coal 170.87-180.08)*	200 (11.8-44.1)
	Talchir (274.45-356.2)	16 (44.1-594.1)
		119 (594.1-∞)
DGW 3 (RS 92)#	Deccan trap (0-59.4)	46 (0-1)
	Metamorphics (59.4-201.45)	92 (1-3.5)
		60 (3.5-10.8)
		136 (10.8-64.8)
		75 (64.8-378.8)
		175 (378.8-∞)
WAKM 1 (RS 71)	Deccan trap (0-69.7)	28 (0-1.8)
	Motur (69.7-287.6)	70 (1.8-9)
	Barakar (287.6-374.5)	203 (9-44)
		45 (44-134)
		8 (134-629)
		180 (629-∞)

Locations of sounding points are not very near to the borehole points.
* Thickness of coal horizon has not been detected by present resistivity sounding.

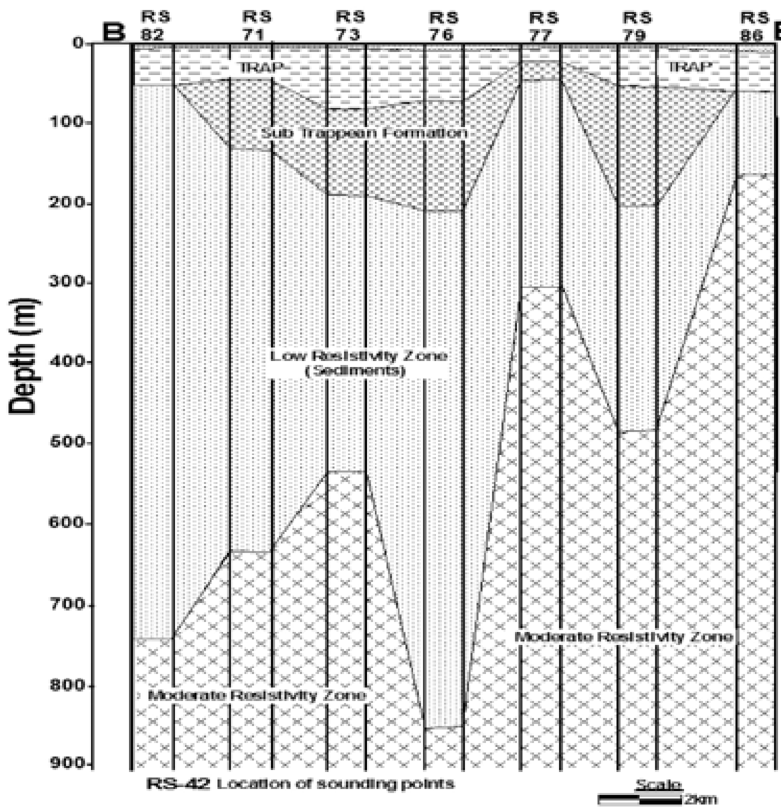


Figure 5. Geo-electrical section along BB' in block-I: Ashotna-Kumbha area, Maharashtra.

Block II (Wadhona-Pohna Area)

Location of resistivity sounding points is shown in Fig. 6.

Some representative sounding curves of the area along with interpreted layer parameters are depicted in Fig. 7.

The sounding curves have not indicated any characteristic conductive zone. The details of some soundings along geo-electrical section XX' across the Wardha river is also given in Fig. 8

The section has brought out a thick zone with variable thickness below the top layer. Thickness of this layer is found to increase towards NE as indicated in sounding numbers RS 15 and RS 16. A moderate/high resistivity zone (216-1628 Ohm-m) is reflected in the central part (RS 41, RS 63, RS 37), which however could not be correlated with the geological set up. It may be due to the presence of some intrusive body or basement high. The high resistivity basement (461-1628 Ohm-m) at a relatively shallow depth (102-218 m) southwest of Wardha river has been delineated. The basement, however, is found to be present at a greater depth (329-455 m) northeast of Wardha river. The basement has come up to a level of 75 m immediate northeast of Wardha river. The steep gradient could possibly be attributed to a fault zone (Naskar et al. 2008).

Block III (Ralegaon-Andori Area)

Location of resistivity sounding points is shown in Fig. 9. Some representative sounding curves of the area along with interpreted layer parameters are depicted in Fig. 10.

The details of some soundings along geo-electrical section PP' and QQ' are also given in Fig. 11 and Fig. 12.

The geo-electric section along PP' has brought out different subsurface litho interfaces in terms of resistivity and thickness parameters. The variation of resistivity values of subsurface layers/zones indicate that the area is structurally disturbed. At RS 87 the thickness of the second layer having resistivity of 150 Ohm-m is found to be 396 m, which is similar to that of trap. However, it is felt that such appreciable increase in thickness is not feasible as per available geological knowledge. Accordingly, in all likelihood it is due to the presence of some intrusive body or presence of formation having resistivity equivalent to trap. The increase in thickness may also be due to the presence of faults. Due to overlapping resistivity values, the individual thickness of trap and sedimentary column could not be identified in the area. However, depth to basement could be inferred. It is varying between 116 m to 450 m. The geo-electric section along QQ' has brought out different

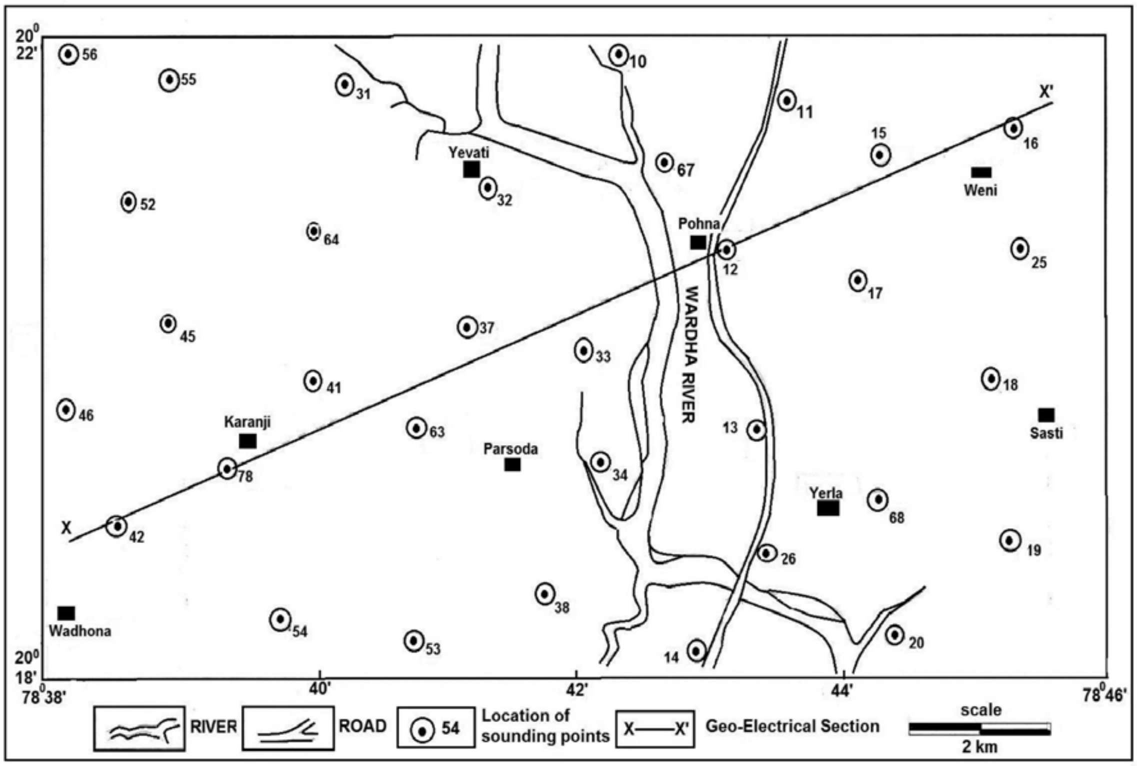


Figure 6. Location map along with resistivity sounding points and geoelectrical section in block-II:Wadki-Pohna area, Maharashtra

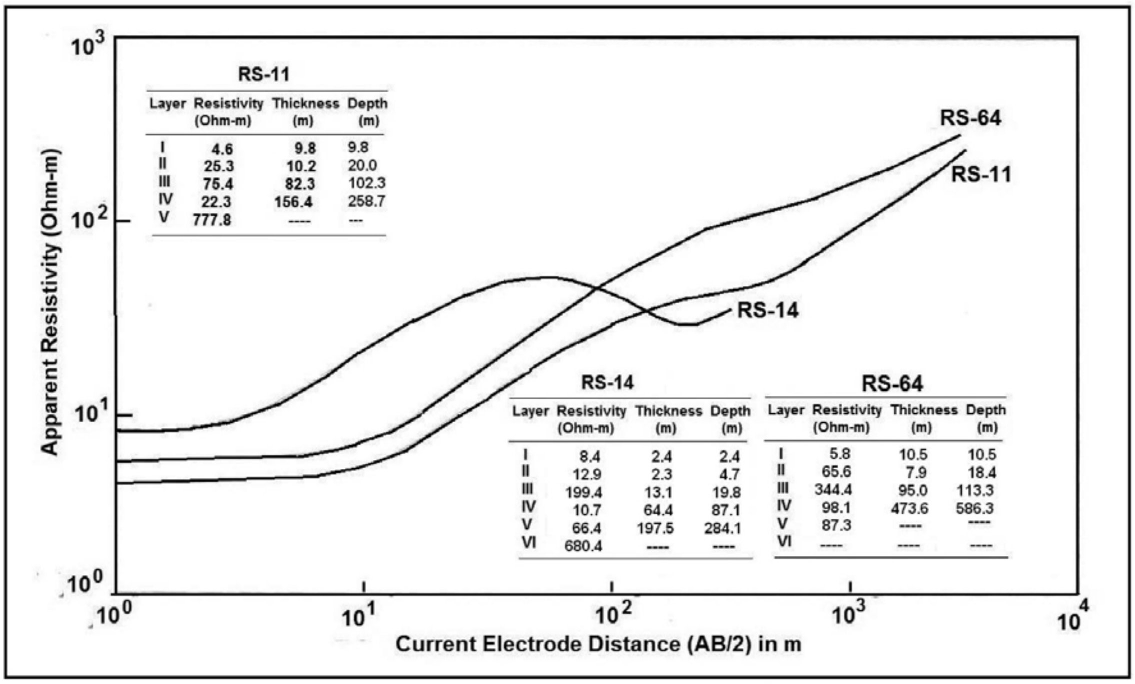


Figure 7. Representative resistivity sounding curves along with interpreted layer parameters block-II:Wadki-Pohna area, Maharashtra

subsurface layers characterized by different resistivity values. The first interpreted layer represents top soil/ alluvium. This is underlain by a layer having resistivity varying from 91-354 Ohm-m with thickness varying from 22-75 m. It is absent at RS 22.This is interpreted as Deccan trap. A low resistivity zone (13-53 Ohm-m) with

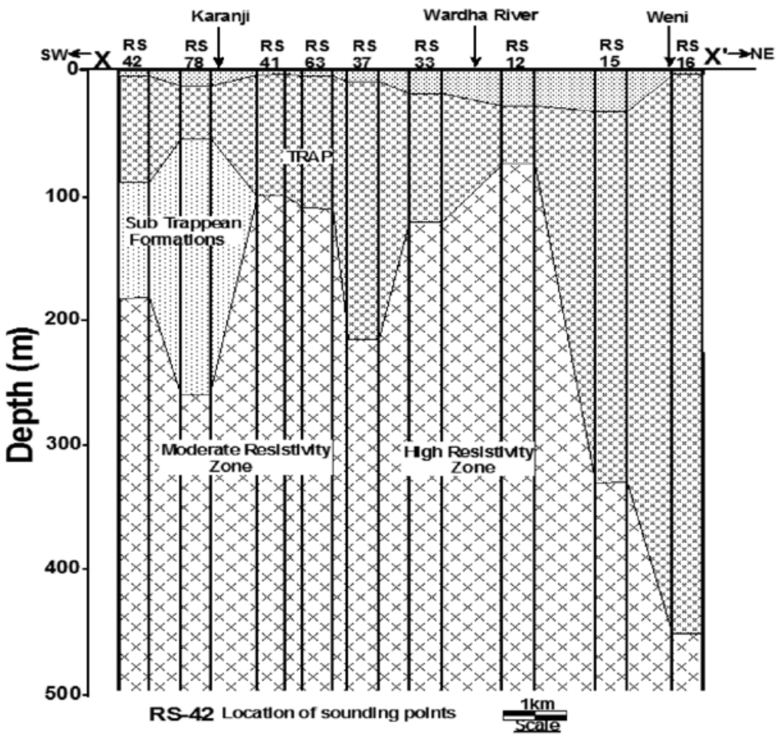


Figure 8. Geo-electrical section along XX' in in block-II:Wadki-Pohna area, Maharashtra

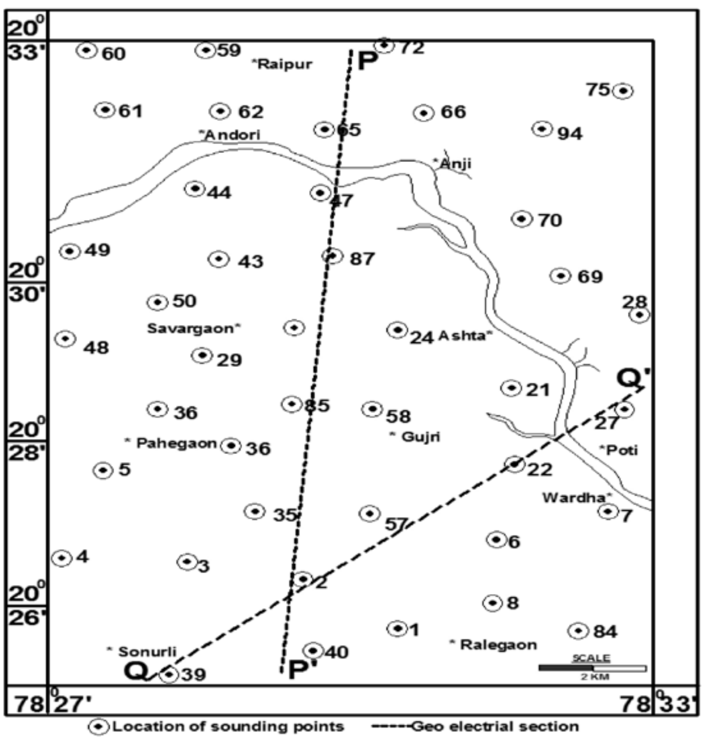


Figure 9. Location map along with resistivity sounding points and geoelectrical section in block-III: Ralegaon-Andori area Maharashtra.

thickness varying from 86-347 m, probably corresponding to sedimentary column, is inferred below the trap. A high resistivity zone representing basement is revealed all along the section, at depth of 116-370 m.

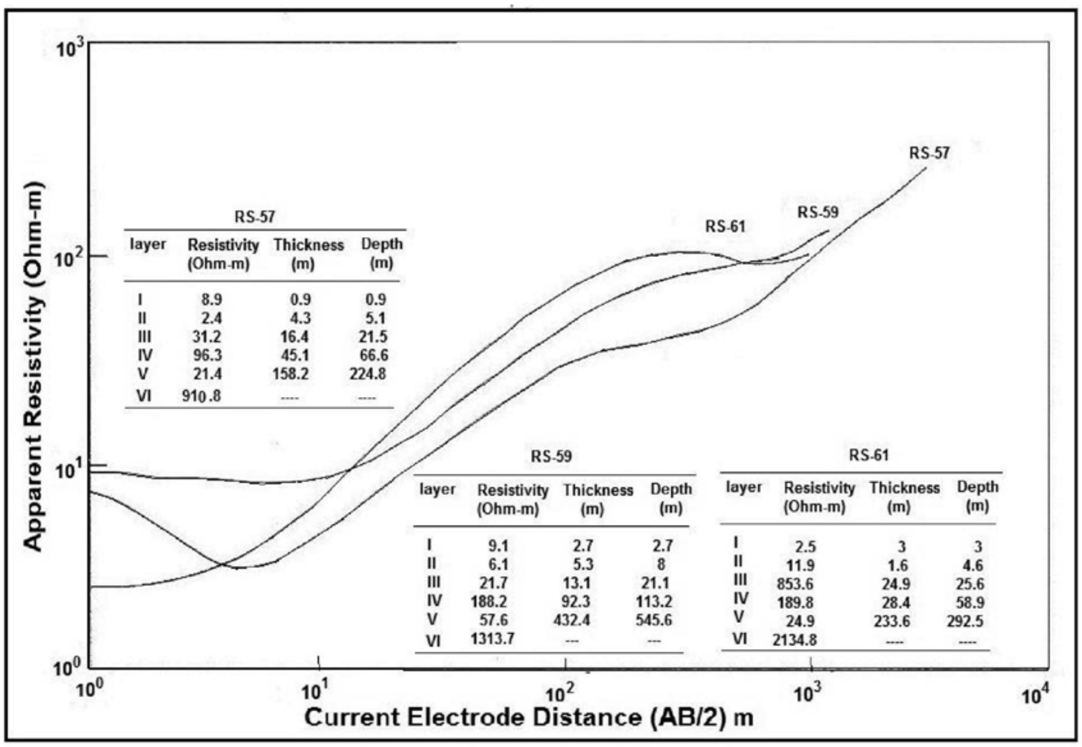


Figure 10. Representative resistivity sounding curves along with interpreted layer parameters block-III: Ralegaon-Andori area Maharashtra.

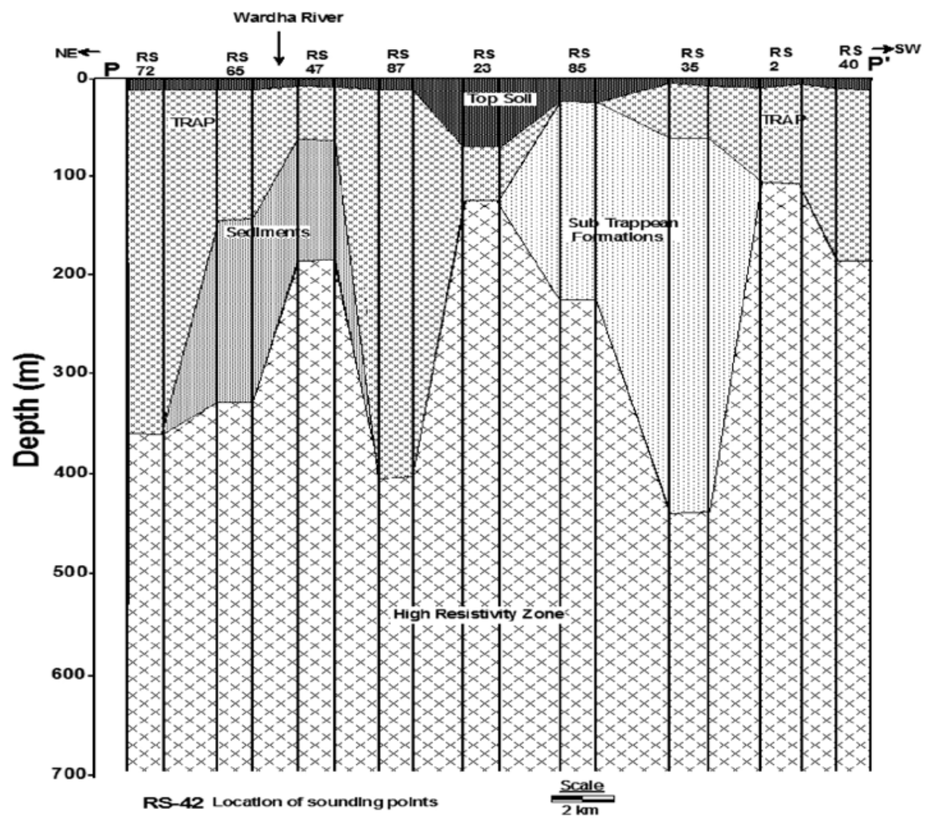


Figure 11. "Geo-electrical section along PP' in block-III: Ralegaon-Andori area, Maharashtra.

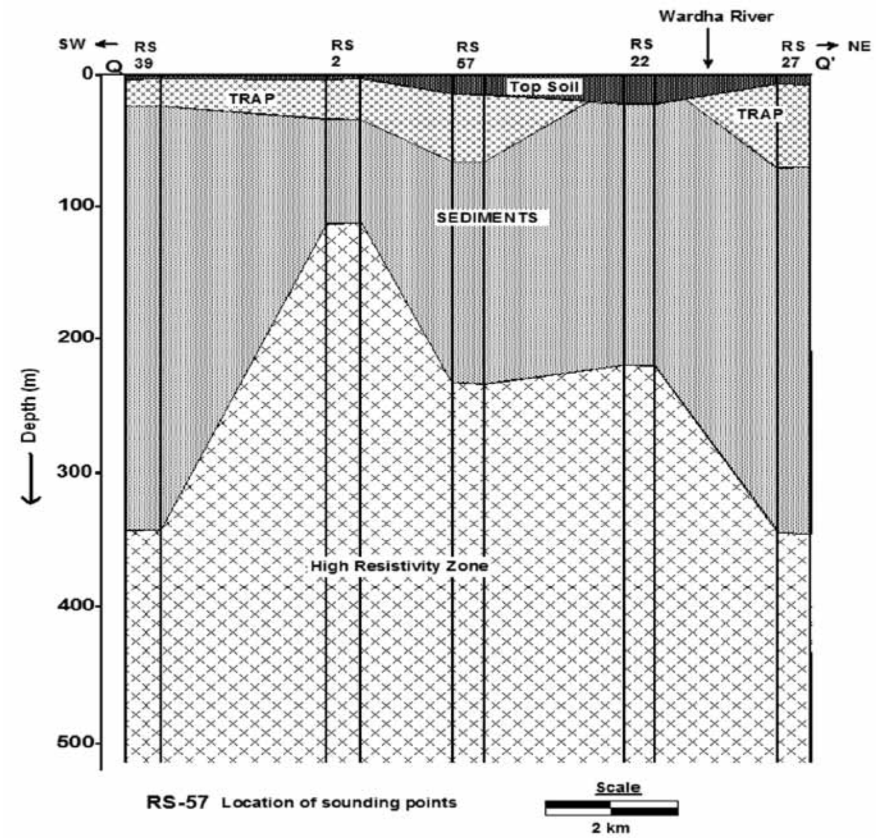


Figure 12. Geo-electrical section along QQ' in block-III: Ralegaon-Andori area Maharashtra.

Magnetic Survey

Spot magnetic observations (VF) were made at the resistivity sounding locations in three blocks as well as the adjoining areas. The magnetic anomalies (VF) are contoured and presented in Fig. 13, 14 and 15.

Ashtona-Kumbha Area (Block I)

Fluctuation of the magnetic anomalies could be due to the trap layer, overlying the Gondwana sediments. The distinct pattern and orientation of the contours indicate the occurrence of structurally controlled lava flow. The contours show localized anomaly closures of moderate wave number and amplitude (+400 nT) indicative of basement structure. The contour pattern of the magnetic anomalies showing a sharp magnetic gradient indicates a fault zone. This fault zone is running from NW-SE through east and southeast of Sindhi. This fault zone corroborates well with resistivity sounding results.

Wadhona-Pohna Area (Block II)

The contours show localized positive and negative closures associated with low and high wave number and amplitude. The contour trend varies from NE-SW to E-W, which is sympathetic to the Tapti and Narmada lineament. The high gradient of magnetic anomalies in the east suggests occurrence of the Deccan trap at shallow depth. Effects of the basement are not reflected in the magnetic anomaly map. Large amplitude of the magnetic anomaly north of Karanji and Parsoda, probably indicates that the trap lies at a deeper level. Sudden change in magnetic contour pattern running NNE-SSW to the east of Pohna is suggestive of a fault, which is well corroborated with resistivity sounding results (Fig. 6 and Fig. 8). The results of magnetic survey are compatible with the earlier gravity results (Joga Rao et al. 1984).

Ralegaon-Andori Area (Block III)

Magnetic map indicates E-W to NW-SE trend of the contours. Sharp gradient of contour in west central part suggests occurrence of Deccan trap at shallow depth. Amplitude of the anomaly varies from -1800 nT to +1000 nT, north of Dahegaon (Fig. 15) to the south of it. This high amplitude dipolar anomaly suggests either emplacement of basic bodies along some fault planes or the faults along which concentration of magnetite is a natural phenomenon. Relatively lower amplitude anomalies are observed in the

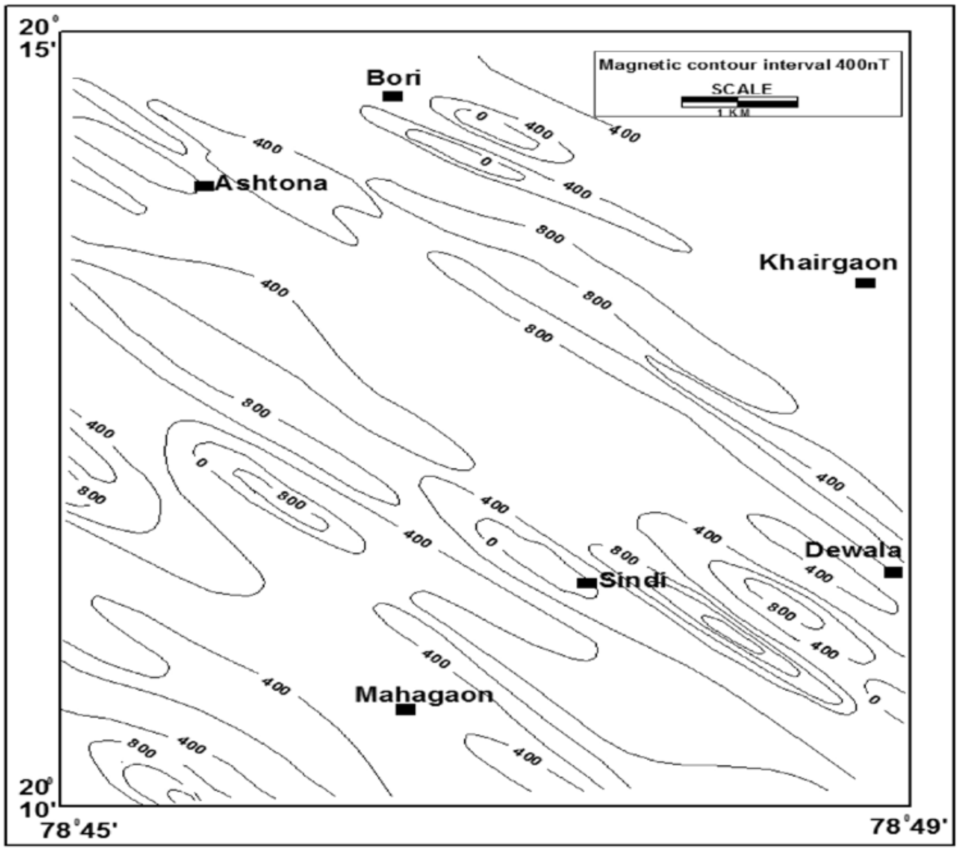


Figure 13. Magnetic (VF) contour map in block-I: Ashtona-Kumbha area, Maharashtra

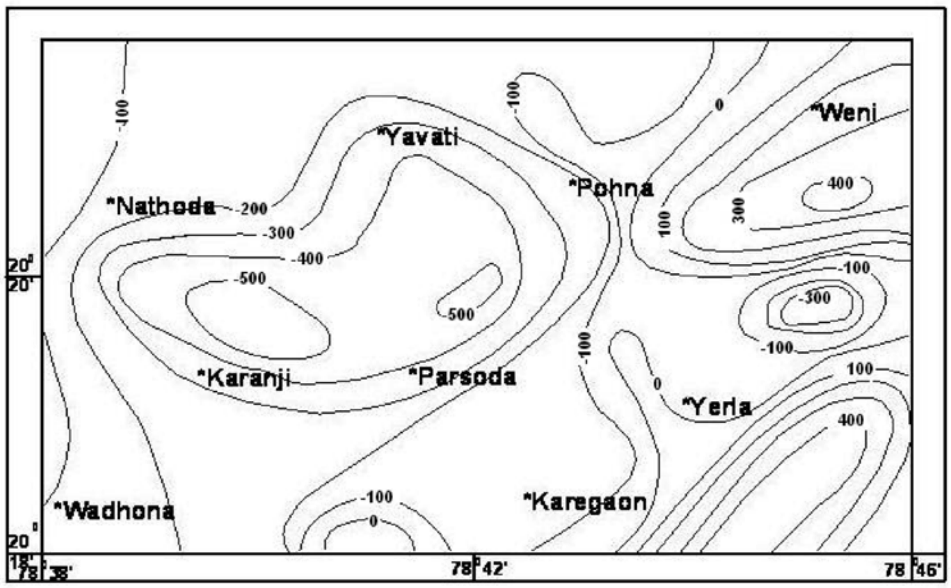


Figure 14. Magnetic (VF) contour map in block-II: Wadki-Pohna area, Maharashtra

northern, eastern and south-eastern parts. One significant feature of the map is a sharp change in gradient of magnetic field from western part to the eastern part, NW-SE of Valinagar. Gradient is high in the western part, whereas it is small in the eastern and south-eastern parts suggestive of deeper disposition of Deccan lava in the eastern part.

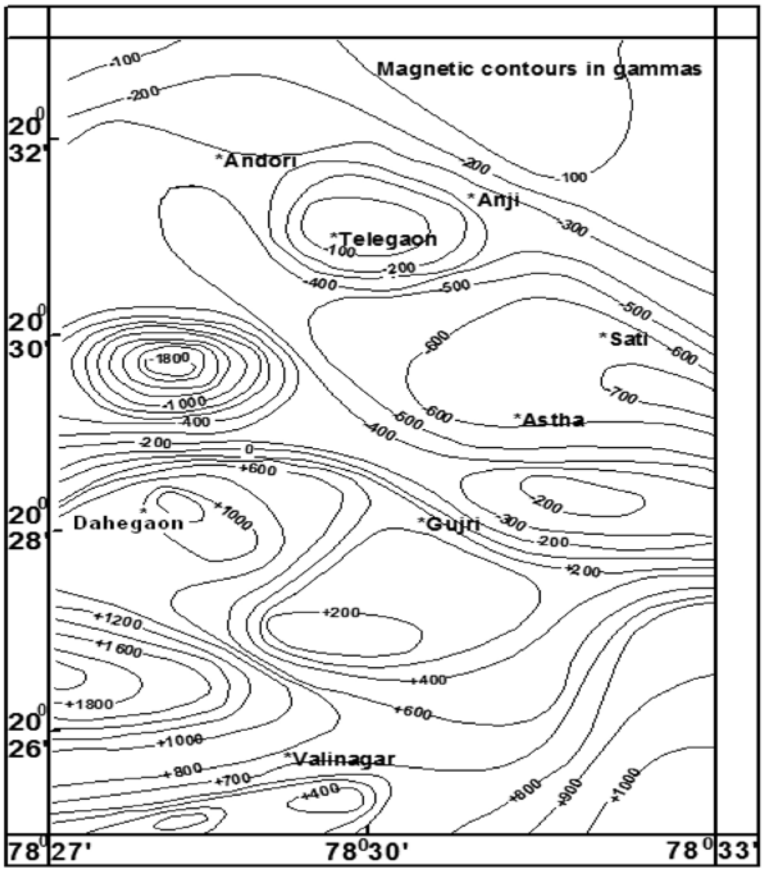


Figure 15. Magnetic (VF) contour map in block-III: Ralegaon-Andori area, Maharashtra

CONCLUSIONS

Usefulness of resistivity method in delineating sub-trappean Gondwana sediments has been established, way back in 1970s and 1980s. It`s efficacy and limitations vary from region to region, depending on subsurface geological milieu. As a part of exploration strategy, GSI has been carrying out integrated geological and geophysical investigations, in areas hitherto not been explored using a holistic approach. The present geophysical study based on resistivity survey, has brought out thickness and resistivity details of different subsurface layers comprising top soil, Deccan traps, sub-trappean formations, sedimentary column and also depth to the basement. The new data has been correlated with litholog information, available through exploration bore wells. While significant one to one correlation could be achieved in many parts of the 3 blocks, studied presently, however, at places the present investigation failed to resolve the thickness of individual layers due to absence of resistivity contrast. The present study, thus, has helped in obtaining new set of data that could be of use in adding to the existing knowledge, pertaining to the study area. It may be noted that even though scientifically nothing significant has been achieved; the study has generated useful data that could bring in to focus not only applicability of geophysical techniques but also their limitations. Pertinent details are listed below.

The high resistivity basement in Block I occurs at greater depth of 871 m in RS 76, whereas south of it (RS 77) the high resistivity basement occurs at a shallow depth of 313 m. The steep gradient could possibly be attributed to a fault zone. Presence of high resistivity basement (461-1628 Ohm-m) is inferred at a relatively shallow depth (102-218 m) southwest of Wardha River, whereas the same occurs at a greater depth (329-455 m) northeast of Wardha River. However, the basement has come up to a level of 75 m, immediate northeast of Wardha River. The steep gradient could possibly be attributed to a fault zone along section XX' in Block II.

The distinct pattern and orientation of the magnetic contours indicate the occurrence of structurally controlled lava flow. Fluctuations of the magnetic anomalies (low/high wave number and amplitude) are observed due to the trap layer overlying the Gondwana sediments. The magnetic anomaly map did not show the basement configuration appropriately due to an overlying blanket of trap. The highly fluctuating anomalies due to the trap overshadow the basement effect. The map, however, approximately indicated the fault zones, east and southeast of Sindhi in

Block-I and east of Pohna in Block-II, through the change in the wavelength character of the magnetic anomalies.

It is advisable to take up integrated geophysical studies involving magnetotellurics, seismic refraction and gravity investigations, in zones where poor correlation of resistivity results with sub surface lithology is noticed, to explicitly know the reasons for such an anomaly.

ACKNOWLEDGEMENTS:

The authors express their sincere thanks to the Director General, GSI, Kolkata for giving permission to publish the paper. Authors are also thankful to Dr. L.K. Das, Retd. Dy. Director General (Geophysics) for valuable suggestions and scrutinizing the GSI unpub. rep. Authors gratefully acknowledge the constant support, encouragement and guidance of Shri Shyamal De, Retd. Dy. Director General (Geophysics) all through the field investigation. Authors are grateful to anonymous reviewer and Editor for constructive suggestions.

REFERENCES

Chakraborty, R.N., Joga Rao, M.V., Sen, A.K., Sarkar, R.K., and Ghosh, D., 1976. Report on gravity, magnetic (VF) and deep electrical resistivity (DES) surveys for sub-surface structural features and associated coal in Chanda-Wardha valley, Chandrapur district, Maharashtra.GSI Unpub. Rep.

Chakraborty, R.N., Sen, A.K., Sarkar, R.K., Ghosh, D., and Benhur, K.S., 1977. Report on gravity, magnetic (VF) and deep electrical resistivity investigations for sub-surface structural features and associated coal seams in Chanda-Wardha valley, Chandrapur district, Maharashtra. GSI Unpub. Rep.

Joga Rao, M.V., Ghatak, S.K., and Ram Mohan, P.K., 1974. Progress report on reconnaissance gravity, magnetic and electrical resistivity surveys for coal in the Chanda-Wardha valley coal field area, Chandrapur district, Maharashtra. GSI Unpub. Rep.

Joga Rao, M.V., Sarkar, R.K., Ghatak, T.K., Saha, D.K., and Ghosh, D.C., 1984. Report on the geophysical investigations under Deep Geology Project for delineation of Gondwana sediments below Deccan traps in parts of Yeotmal district, Wardha valley coal field area, Maharashtra. GSI Unpub. Rep.

Kailasam, L.N., Pant, P.R., Murthy, B.G.K., Chanalu, A.Y.S.R., Lahiri, S.M., and Raju, V.L., 1973. Report on the geophysical investigations in Deccan trap areas of Maharashtra and Parts of Mysore, Andhra Pradesh and Gujarat. GSI Unpub. Rep.

Naskar, D.C., 2005. Structural studies of crust and upper mantle structures in parts of Madhya Pradesh and Maharashtra, Central India. Ph. D thesis, Jadavpur University, pp: 150.

Naskar, D.C., Das, L.K., Roy, K.K., and Singh, O.P., 2008. Structural studies of crust and upper mantle in parts of Madhya Pradesh, Central India. Spl. Publ. Geol. Surv. India, v.91, pp: 211-228.

Naskar, D.C., Das, L.K., 2009. Resistivity survey across the Narmada-Son lineament and along the Sanwer-Borgaon traverse, Madhya Pradesh, Central India. Bollettino di Geofisica Teorica ed Applicata, v.50 (x), pp:10-20.

Nayak, P.N., 1990. Deep crustal configuration of Central India. Geol. Surv. India Spec. Publ. v.28, pp: 67-98.

Orellana, E., and Mooney, H.M., 1966. Water table and curves for vertical electrical sounding over layered structures. Interetencia, Madrid, Spain.

Reddi, A.G.B., Joga Rao, M.V., Murthy, B.S.R., Venkateswarlu, P.D., and Rammohan, P.K., 1975. Report on the results of some deep resistivity surveys over the Deccan traps in parts of Maharashtra. GSI Unpub. Rep.

Reddi, A.G.B., 2015. A First Personal Account. The Jou.IGU, v.19, no.3, pp: 347 -349.

Sarma, S.V.S., Harinarayan, T., Virupakshi, G., Someswara Rao., M., Madhusudan Rao., Nandini Nagarajan., Sastry, T.S., S. and Prabhakar E. Rao., 2004. Magnetotelluric investigations in Deccan trap covered areas of Nagpur-Wardha region, India.

Subrahmanyam, B., Vaidyanathan, N.C., Sarkar, R.K., and Khotpal, A.S., 1975. Report on gravity, magnetic and electrical resistivity surveys for subsurface structural features and associated coal in Chanda-Wardha valley, Maharashtra. GSI Unpub. Rep.

Vander Velpen, B.P.A., 1988. A computer processing package for DC resistivity interpretation for a IBM compatibles. ITC Jour. 4, the Netherlands.

Venkateswarlu, P.D., Biswas, U.K., Roy, P.K., 1981. Report on the geophysical investigations for delineation of gondwana sediments below Deccan traps in parts of Yeotmal and Wardha districts. GSI Unpub. Rep.

Dr. D.C. Naskar received M.Sc. in Physics from Calcutta University and Ph.D from Jadavpur University. The results of his thesis has paved a way for application of deep geophysical technique in India, namely audio-magnetotellurics (AMT) and magnetotellurics (MT) – to understand the deep subsurface structure of the earth. He was conferred upon "H. S. Pareek Award for the best research paper on coal science published in the Journal of Geological Society of India" in 2008. In his 26 years of geophysical research, he has published 45 research publications in recognized national and international journals and 37 unpublished reports of mineral exploration, structural and tectonic studies, ground water investigations, environmental studies and geophysical mapping in different parts of the country.

Shri Dilip Kumar Saha completed his M. Sc., in Physics from North Bengal University in 1982 and joined Geological Survey of India in 1984. He has carried out geophysical investigations for various Geological and Geo-environmental problems. His significant works include applications of ground geophysical techniques for the first time in the highly conductive deltaic environment in greater Kolkata areas for ground water management and geo-environmental studies, geophysical mapping of Gondwana basins of Damodar Valley and Singhbhum Shear Zone. Deep crustal studies for delineation of weak zones in the areas of Shillong Plateau and Assam valley employing Magnetotelluric (MT) and Deep Resistivity surveys was a pioneering work in NE region. He has to his credit more than 30 publications in reputed National and International journals. He is a life member of the Mining, Geological and Metallurgical Institute of India (MGMI) and the Association of Exploration Geoscientists (AEG). At present, he is Deputy Director General (Geophysics) in Eastern Region, GSI, Kolkata.