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DELINEATION OF SUBSURFACE GEOLOGICAL FORMATIONS USING ELECTRICAL RESISTIVITY METHODS IN DIFFERENT ROCK TERRAINS OF UDUPI, KARNATAKA STATE.

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Abstract

The purpose of the present work is to delineate the subsurface formations to a depth of approximately 100m (AB//2=100m). The study revealed the resistivity and thickness of the various subsurface formations through electrical resistivity methods has been attempted in and around Udupi, Karnataka state. 13 vertical electric soundings (VES) were conducted at certain locations. The VES data were interpreted by 'IPN2Win' software. The interpreted VES data and hydrogeological data were used to delineate subsurface geological formations. The range of resistivity values of various subsurface layers such as soil (98 to 1510 Ωm), laterite (753 to 14546 Ωm), lithomarge clay (9.45 to 249 Ωm), granitic gneiss (3408 to 21328 Ωm) and dolerite dyke (441 to 24421 Ωm) were estimated. Findings from the electrical resistivity study were used to identify potential underground aquifers.

Key words: Subsurface formations, Electrical resistivity, Groundwater potential aquifers

INTRODUCTION

Water being the elixir of life, search for this potential sustainable source in required quantity which satisfy the consumptive and conjunctive qualitative issues became difficult due to the dearth of trained and experienced personnel's in this field. Groundwater is a rich and reliable resource to meet domestic, industrial and irrigation water needs. Among the geophysical methods commonly employed in subsurface investigations, the electrical resistivity method has advantages in hydrogeology as it responds to variations in electrical conductivity of the groundwater bearing formations. Electrical resistivity method being a powerful tool is useful to investigate the nature of subsurface formations and its aquifer characteristics. Conducting electrical resistivity surveys involves evaluating the distribution of resistivity within the materials under examination. This is achieved by applying artificial electric currents and measuring the resulting potential differences. This method can be widely used in the field of groundwater exploration to locate groundwater bearing formations, estimation of depth to water table, thickness and lateral extent of aquifers, depth to bed rock, delineation of weathered zone, structures such as fractures, dykes etc., and

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stratigraphic condition. (Kearey et al., 2002; Abbey, M.E. and Digbani, T., 2018; Ahilan, J. and Senthil Kumar, G.R., 2011; Ariyo, S.O. and Adeyemi, G.O., 2009; Bhatnagar, S., Taloor, A.K., Roy, S. and Bhattacharya, P., 2022; Jamal, N. and Singh, N.P., 2020; Mohamaden, M.I.I., Hamouda, A.Z. and Mansour, S., 2016; Placide, U. and Kumar, G.S., 2018; S. Anbazhagan et al. 2015). The electrical resistivity method has gained considerable importance in the field of groundwater exploration because of its low cost, simple fieldwork of comparatively less time, easy operation and efficacy to detect the subsurface geological formations (Kearey and Brooks, 1991; Telford and Sheriff, 1990). A geoelectrical investigation at Nigeria College of Aviation Technology in Zaria, Kaduna State, used the D.C. electrical resistivity method, revealing two, three, and four geological layers. These include topsoil, weathered basement, partly weathered or fractured basement, and fresh basement. Qualitative interpretation of Vertical Electrical Sounding (VES) data suggests that some VES stations are ideal for borehole placement. These locations offer a significant thickness of weathered and fractured basement with enhanced groundwater permeability and storage due to structural features like fractures (Fadele et al., 2013). To rapidly assess the 0 to 200 m three-dimensional underground structure of Chengdu Bio-City, various geophysical exploration methods were tested, including ERT, micro-seismic exploration, and OCTEM. OCTEM was selected for its three-dimensional survey capabilities. Using resistivity structure data from OCTEM inversion and drilling exploration, a comprehensive three-dimensional geological model was created. The obtained electrical resistivity information from OCTEM's area exploration was integrated with on-site engineering geological data to construct a 3D model for the study area, spanning depths up to 200 m. (Wang et al., 2023). Depth of different rock types such as laterite, weathered shale, fracture share and limestone have been observed for the city of Raipur, Chattisgarh, India, by using Schlumberger Method and Geoelectrical imaging. In addition, Fracture locations, artificial recharge site identification and Ground water prospective zones have been identified. (Mondal et al., 2021). At Universiti Tun Hussein Onn Malaysia (UTHM), an electrical resistivity survey successfully detected potential shallow aquifers in the area. The data from spread lines indicated variations in groundwater depth or thickness, ranging from 7.5 m to 15 m. To enhance the identification of potential groundwater locations, an Induced Polarization (IP) survey was also conducted during data acquisition. This is crucial because resistivity alone may face challenges in distinguishing between clay and groundwater, especially in UTHM's marine clay region. (Riwayat et al., 2018)

In the present study, an attempt is made to identify the various underground geological formations in various terrains around Udupi, Karnataka State.

Study Area

The studies were carried out at different locations in and around Udupi viz., Manipal, Parkala, Arbi, Manipal lake, Nagarabettu, Ajjarakadu, Malpe beach, Hatrabailu, and Panchanabettu (figure 1). The study area locations are present in the Udupi district, Karnataka.

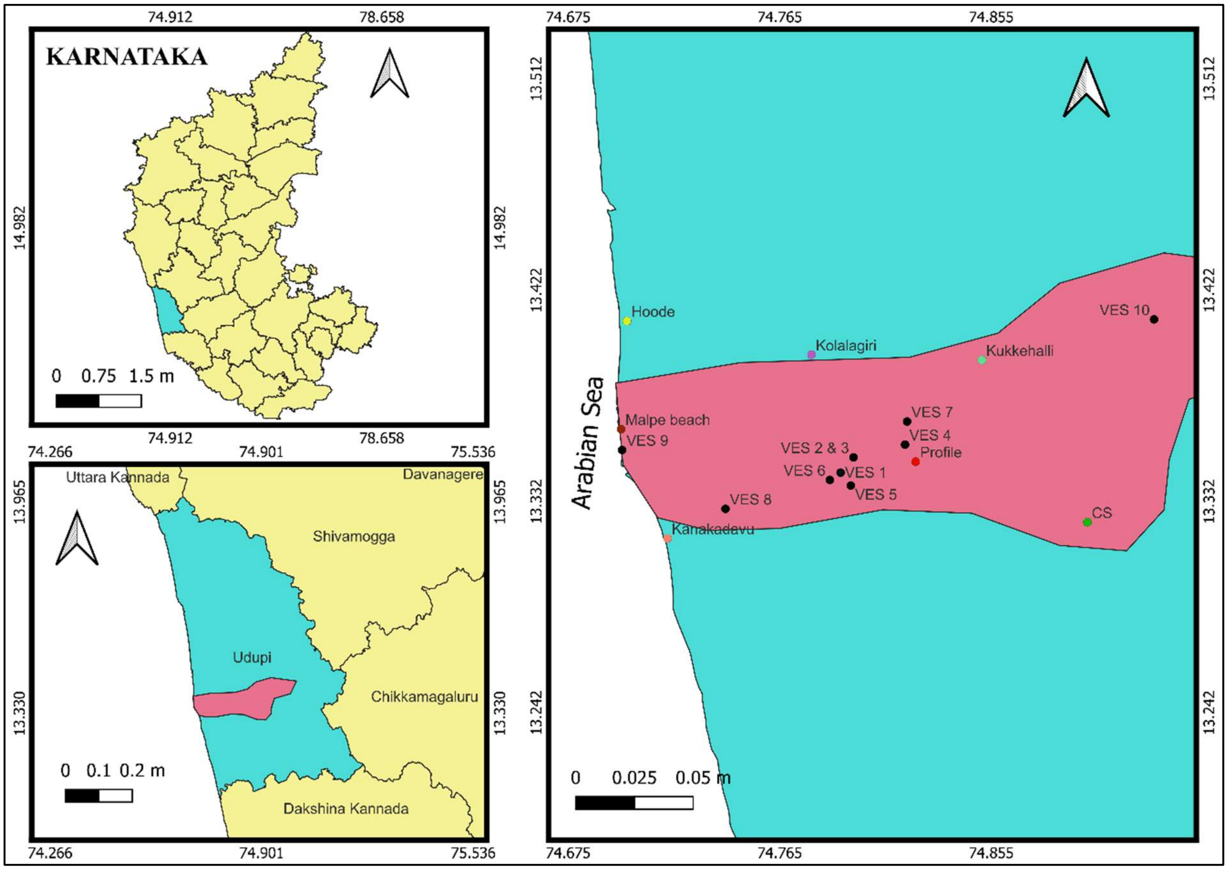

Figure 1: location map of study area

Vertical Electrical Sounding (VES) has been conducted in 10 different locations, in certain locations, the exposure of the hard rock and the dyke is observed. Archean craton in India consists of a Peninsular gneiss that has an isotopic age of 3.4 to 3.0 billion years (Hokada et al., 2013). It consists of numerous types of granites like closepet and some other types. The granite intrusion is dated back to 3.0-2.9 billion years. Most terrain comprises Gneissic rocks and meta basalts from the Bababudan Group. Because of the hot and humid weather in the coastal side of the Western Ghats, the iron-rich rocks are weathered and lateralized, forming the laterites, mostly dated the Early Cenozoic till recently (Jain et al., 2020). The western coastal area consists of sandy beaches, considered as the Quaternary deposits and recent coastal alluvium (Figure 2). However, most of the area is covered by red-colored, iron-rich laterite soil. Balasubrahmanyan (1975) estimated that the NW-SE dike east of Udupi was formed around 2200 Ma. The Tiruvannamalai dykes K/Ar whole-rock age is significantly younger than that of the Udupi dykes, although their palaeomagnetic directions are quite similar to one another.

MATERIAL AND METHODS

In this study, Vertical Electric Soundings (VES) were conducted at 10 different locations using the Schlumberger electrode configuration with a maximum of AB/2=100 mts. The Schlumberger configuration is widely used for electrical resistivity measurements in geophysical surveys due to its efficiency and minimal measurement errors (Susilo et al., 2020). It involves placing current and potential electrodes in a specific arrangement to measure subsurface electrical properties. Four electrodes are placed along a straight line from a reference point 'O'. The configuration includes closely spaced potential electrodes (M and N)

that accurately measure potential differences generated by injected current. To ensure deeper penetration, the current electrodes are placed at varying distances from the potential electrodes, allowing the current to spread radially beneath the surface (Reynolds, 2011). This arrangement creates a potential field that corresponds to the resistivity of subsurface materials. The separation between potential electrodes is kept small compared to the separation of current The area comprises the coastal beach, laterite capped pediplains and in few places' exposures of granitic gneisses and dolerite dykes. Sandy soil covering the beaches, adjoining stretches of yellow loamy soil and red lateritic soils are major types of soils in the region. Ground water in the region mainly occur in various geologic formations like beach alluvium, electrodes for good result. Bhimashankaram et al. (1969) have demonstrated certain practical, operational, and interpretational advantages of this method over other methods. The method used to compute apparent resistivity is given in the following equation:

$$\rho_a = \pi \left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \right] \frac{\Delta V}{I}$$ --[Eq. 1]

where AB and MN are the current and potential electrode spacing, respectively (Kearey et al. 2002). The VES curves were interpreted by using IPI2Win program. The resistances and thickness of the different layers were estimated (Table 1) considering local geology. For an electrical resistivity survey to function properly, a resistivity metre and four electrodes are needed. The resistivity metre is a device that can measure both voltage (V) and current (I), making it a dual-purpose voltmeter and ammeter. Using these values and the following formula, apparent resistivity is calculated:

$$\boldsymbol{\rho_a = \frac{KV}{I}}$$ --[Eq. 2]

Where, ρa = apparent resistivity k = geometric factor.

Depending on the geometry of each electrode spacing configuration, the geometric factor changes. The data for the current study is first collected as an apparent resistivity value, which is then evaluated to determine true resistivity.

Resistivity surveys can be broadly divided into Sounding and Profiling. Vertical Electrical Sounding (VES), a widely utilised geophysical technique, was applied to investigate the area in order to comprehend the groundwater potential zones. This approach is being utilised to comprehend how the resistivity of several layers varies vertically. This approach involves transmitting a known quantity of electricity through two iron rods to the Earth while measuring

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the potential difference between two additional places using two potential electrodes. In the current study, we are using Schlumberger array for carrying out the Vertical electrical sounding.
From the resulting VES data, the thickness, depth and resistivity of different layers were determined by direct or partial curve matching techniques. VES field curve is developed by plotting apparent resistivity against depth and created software based inverse model matching with the model curve in IPI2win (Lite) software (Fig 2.3), in which the data of current and potential difference are uploaded and this software interprets it and develops curve for further interpretation.

RESULTS AND DISCUSSION

Based on the interpreted results of the vertical electrical soundings in the study area, three to four layered subsurface geological formations have been deciphered. VES-1 to VES-8 were carried out in a lateritic terrain, shows topsoil, laterite, lithomargic clay and hard rock as litho-units. Individual soundings were done near the shore (VES 9), near to the dyke (VES-10), VES-9 indicated the presence of three layers of sand, salt water and hard stone. The apparent resistivities and the corresponding thickness of the layers of all vertical electric soundings are summarized in (Table 1).

The sounding data produced a total of 4 types of curves, among which K-type and KH type curves accounts for the maximum number, followed by A-type curve over H and HK-types in much of the studied region. The K-Type curve was shown by VES-3, VES-5, VES-I and VES-10. Type KH has been found in VES-1, VES-2, VES-4, and VES-8. Type A has been identified on VES-9, VES-II, and VES-III. The VES-6 was a Type H curve, and the VES-7 was a Type HK curve.

In the fig. 2 (a) and (b), type KH curve can be found with one complete peak and trough and another half peak, corresponding to resistivity value ρ1< ρ2 > ρ3<ρ4. The sounding curve exhibits a four-layered sequence Topsoil, Hard laterite, Lithomargic clay and Hardrock at depths of 0.61, 2.5 and at 17m and 0.274, 1.23 and 3m(ρ1< ρ2 > ρ3<ρ4), respectively.

Table 1: Summarized apparent resistivity data and corresponding thickness

VES No	Location	Layers	Apparent Resistivity *ρ* (Ωm)				Thickness *h* (m)				Total Thickness
			ρ_1	ρ_2	ρ_3	ρ_4	h_1	h_2	h_3	h_4	
1	MIT Manipal	4	232	14546	11.3	2103	0.61	1.89	14.5	-	17
2	Polytechnic ground	4	103	986	9.45	5784	0.959	4.07	3.42	-	8.45
3		3	428	5242	419	-	2	3	-	-	5
4	Parkala	4	1160	8263	249	24421	1.58	0.499	20.4	-	22.479
5	Arbi	4	608	1298	116	441	1.91	2.32	1.97	-	6.2

6	Manipal lake	4	431	5.14	139	1689	3.31	8.41	19.6	-	31.32
7	Nagarabettu	3	355	184	897	-	2	9.09	-	-	11.09
8	Ajjarakadu	4	348	976	59	2094	2	3.36	5.8	-	11.16
9	Malpe beach	3	0.143	0.804	828	-	0.17	9.2	-	-	9.37
10	Hatrabailu	4	721	3408	2774	1980	2	3	7.5	-	12.5

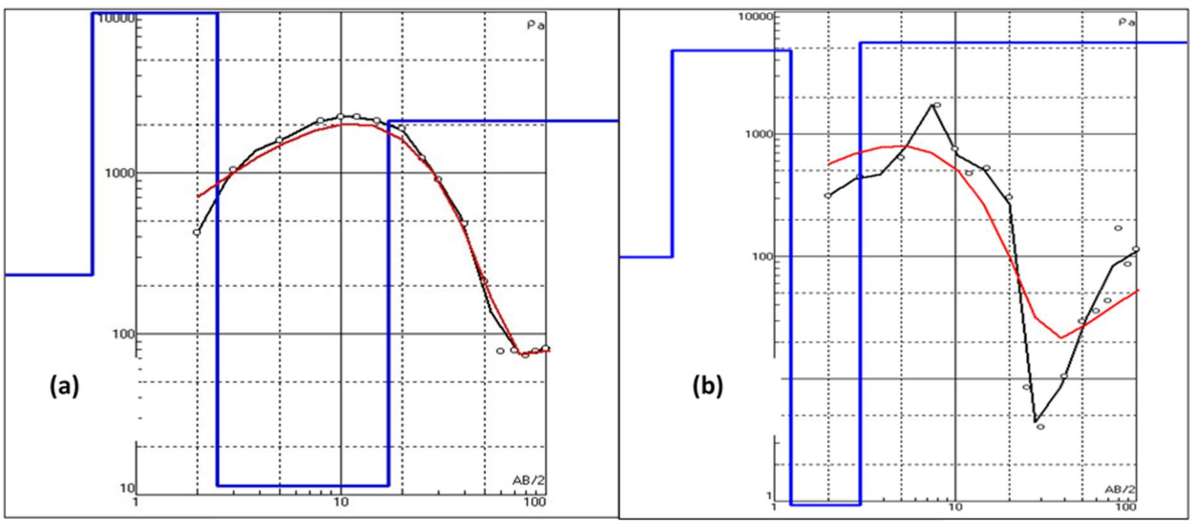

Figure 2: Sounding Curves obtained for VES-1 (a) and VES-2 (b)

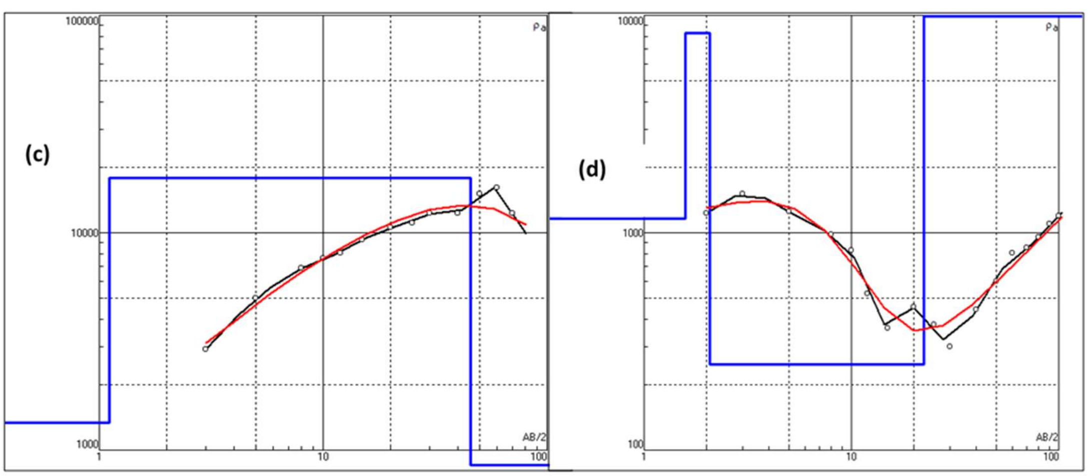

Figure 1: Sounding Curves obtained for VES-3 (c) and VES-4 (d)

Fig 3 indicates graph drawn for VES -3 and VES – 4, where K type (ρ1< ρ2> ρ3) and KH type (ρ1< ρ2 > ρ3<ρ4) can be observed. The depth of top soil, lithomargic clay and hard rock were 0.274, 1.23 and 3m and 1.58, 2.08, 22.5m, respectively.

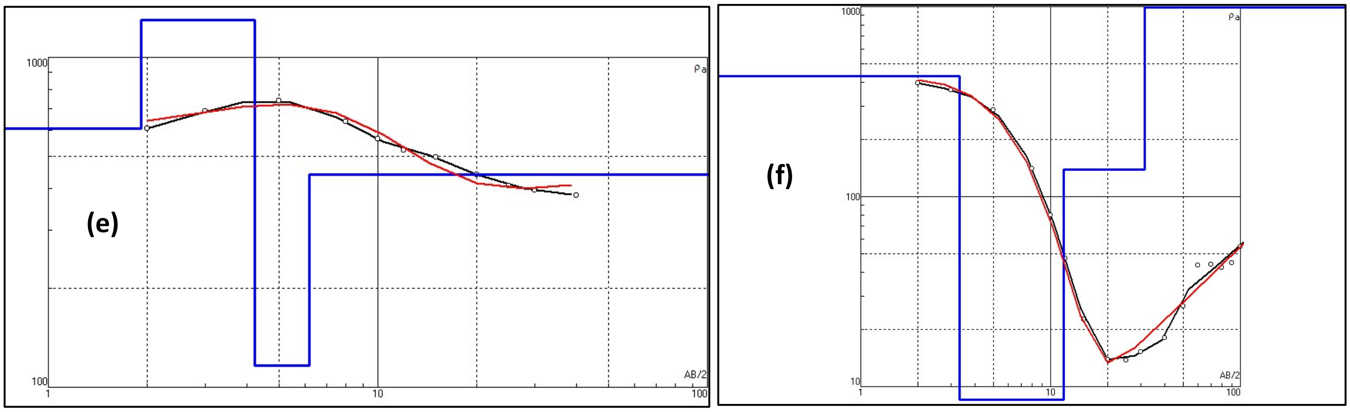

Figure 4: Sounding Curves obtained for VES-5(e) and VES-6 (f)

Fig 4 indicates graph drawn for VES -5 and VES – 6, where K type (ρ1< ρ2> ρ3) and H type (ρ1> ρ2< ρ3), which is a lake site (Mannapalla Lake, manipal) can be observed. The depth of top soil, lithomargic clay and hard rock were 1.91, 4.23, 6.2m and 3.31, 11.7, 31.3m, respectively.

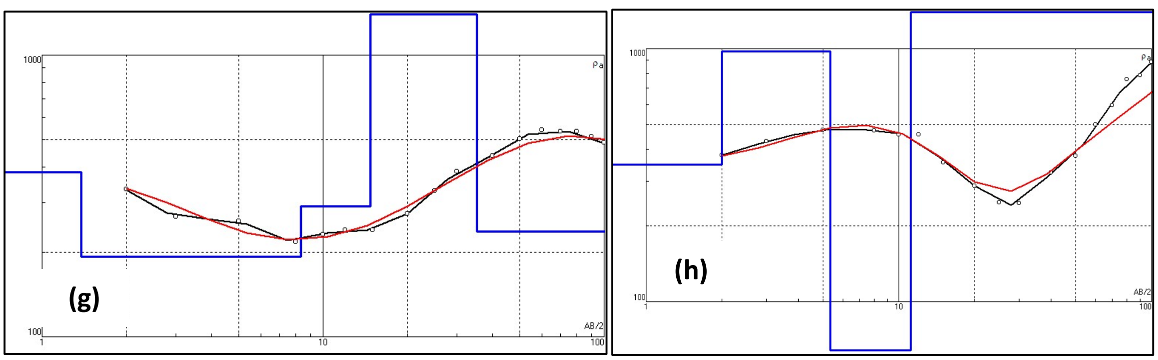

Figure 5: Sounding Curves obtained for VES-7(g) and VES-8 (h)

Fig 5 indicates graph drawn for VES -7 indicates HK type curve with ρ1> ρ2< ρ3>ρ4 and VES – 8, indicates the KH type curve with ρ1< ρ2 > ρ3<ρ4.. The depth of top soil, lithomargic clay and hard rock were 2, 11.09m and 2, 5.36, 11.2m, respectively.

Similarly, Fig 6 indicates graph drawn for VES -9 indicates A type curve with ρ1< ρ2< ρ3(Malpe beach) and VES – 10, indicates the K type curve with ρ1< ρ2> ρ3. The depth of top soil(sand) and salt water and hard rock were 0.19, 28.27m and depth of dolerite dyke, fractured dolerite, hard soil were 2, 5.12.5m, respectively.

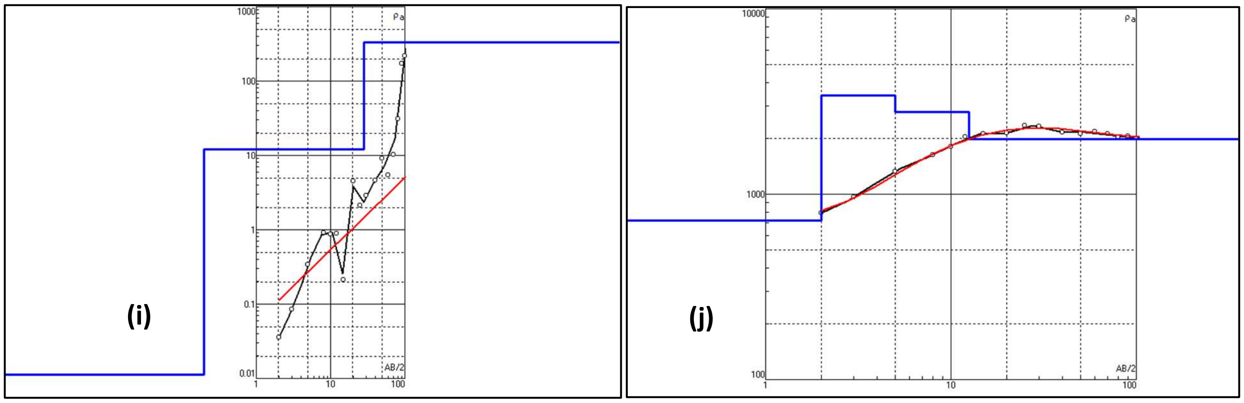

Figure 2:Sounding Curves obtained for VES-9(i) and VES-10 (j)

CONCLUSIONS

The study showed that electrical resistivity methods can be successfully used to decipher underground geological formations and thus potential groundwater aquifers. In this study attempt has been made to assess the thickness and resistivity ranges of various subsurface formations such as soil, laterites, lithomargic clay, depth to hard rock (granitic gneiss) and dolerite dykes.

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REFERENCES

1) Abbey, M.E. and Digbani, T., (2018) Determination of Ground Water Potential Using Electrical Resistivity Method. *International Journal of Science and Research*, *9*(4), pp.878-882.
2) Ahilan, J. and Senthil Kumar, G.R., (2011) Identification of aquifer zones by VES method: A case study from Mangalore block, Tamil Nadu, S. India. *Archives of Applied Science Research*, *3*(2), pp.414-421.
3) Ariyo, S.O. and Adeyemi, G.O., (2009) Role of electrical resistivity method for groundwater exploration in hard rock areas: a case study from Fidiwo/Ajebo areas of Southwestern Nigeria. *The Pacific Journal of Science and Technology*, *10*(1), pp.483-486.
4) Bhatnagar, S., Taloor, A.K., Roy, S. and Bhattacharya, P., (2022) Delineation of aquifers favorable for groundwater development using Schlumberger configuration resistivity survey techniques in Rajouri district of Jammu and Kashmir, India. *Groundwater for Sustainable Development*, *17*, p.100764.
5) Jamal, N. and Singh, N.P., (2020) Electrical resistivity in the delineation of groundwater potential zones: a case study from Kota, Rajasthan, India. *Arabian Journal of Geosciences*, *13*(15), p.697.

6) Keary, P. and Brooks, M. (1991) An Introduction to Geophysical Exploration. 2nd Edition, Blackwell Scientific Publications, Oxford, 254 p.
7) Kearey P, Brooks M, Hill I (2002) An introduction to geophysical exploration, 3rd edn. Wiley-Blackwell scientific publication, Oxford, 272p.
8) Mohamaden, M.I.I., Hamouda, A.Z. and Mansour, S., (2016) Application of electrical resistivity method for groundwater exploration at the Moghra area, Western Desert, Egypt. *The Egyptian Journal of Aquatic Research*, *42*(3), pp.261-268.
9) Placide, U. and Kumar, G.S., (2018) Electrical resistivity data interpretation for groundwater detection in Tittagudi taluk of Cuddalore district, Tamil Nadu, India. *Int J Res Eng Technol*, *4*(10), pp.228-233.
10) Telford, W.M., Geldart, L.P. and Sheriff, R.E. (1990) Applied Geophysics. 2nd Edition, Cambridge University Press, Cambridge, 770.
11) Balasubramaniam KS, Paropkari AL. (1975) Mineralogy and genesis of bauxites of Nagardaswadi plateau, Kolhapur district, Maharashtra State (India). The Canadian Mineralogist. Aug 1;13(3):222-6.
12) Reynolds, J. M. (2011). An introduction to applied and environmental geophysics. John Wiley & Sons.
13) Bhimasankaran, V.L.S., Murali, S. and Tarkhov, A.G. (1969) A comparative study of the wenner and schlumberger configurations in the electrical resistivity methods of prospecting, Bulletin of NGRI, v 7, pp.159-167
14) Hokada, T., Horie, K., Satish-Kumar, M., Ueno, Y., Nasheeth, A., Mishima, K., andShiraishi, K., 2013, An appraisal of Archaean supracrustal sequences in Chitradurga Schist Belt, western Dharwar Craton, southern India. Precambrian Research,v. 227, pp. 99– 119. http://dx.doi.org/10.1016/j.precamres.2012.04.006
15) Jain, A. K., Mukherjee, P. K., & Singhal, S. (2020). Terrane characterization in the Himalaya since Paleoproterozoic. *Episodes Journal of International Geoscience*, *43*(1), 346-357.
16) Riwayat, A. I., & Nazri, M. A. A. (2018, November). Hydrochemical characteristics of surface water and groundwater at Universiti Tun Hussein Onn Malaysia (UTHM) campus, Johor. In *AIP Conference Proceedings* (Vol. 2030, No. 1). AIP Publishing.
17) Mondal, K.C., Jhariya, D.C. & Mandal, H.S. Geoelectric Imaging to Assess Aquifer Conditions in Raipur City, Chhattisgarh, India, Using Schlumberger Method. J Geol Soc India 97, 943–950 (2021). https://doi.org/10.1007/s12594-021-1795-y
18) Wang, L., Dai, Y., Liu, B., Long, X., Lin, J., & Chen, X. (2023). Research on rapid detection of seawater intrusion based on opposing-coil transient electromagnetic method. *Progress in Geophysics*, *38*(3), 1397-1407.
19) Fadele, S. I., Sule, P. O., & Dewu, B. B. M. (2013). The use of vertical electrical sounding (VES) for groundwater exploration around Nigerian College of Aviation Technology (NCAT), Zaria, Kaduna State, Nigeria. *Pacific Journal of Science and Technology*, *14*(1), 549-555.