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Research Article

A STUDY ON SUBSURFACE LITHOLOGY AT ANDHRA UNIVERSITY CAMPUS USING ELECTRICAL RESISTIVITY SOUNDINGS

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ABSTRACT
An attempt has been made in the present work to study the subsurface lithology using Vertical Electrical Soundings (VES) at Andhra University campus to observe the different layers of soil strata. It is a part of a research in which a study on groundwater flow dynamics with artificial recharging is aimed at. Subsurface lithology inferred from Vertical Electrical Sounding (VES) data indicated that the top soil is red sandy soil and its thickness varies from 7m to 20m. Weathered rock underlain to top soil and continued up to a depth of 25m to 40m. Fractured rock zone which is the water bearing zone/ aquifer is noticed between 25m/30m and 60m/80m depth. Hard rock is indicated below the fractured rock which is beyond 60m/80m depth.

Keywords: *Vertical Electrical Sounding (VES), Subsurface Lithology, Resistivity, Weathered Rock, Fractured Rock*

INTRODUCTION
Geophysical exploration is the scientific measurement of physical properties of the earth's crust for investigation of geologic structure. In recent years, refinement of geophysical techniques and their increasing recognition for groundwater exploration has gained importance. These techniques/methods are highly useful when supplemented by subsurface investigations. The electrical resistivity of a rock formation limits the amount of current passing through the formation when an electric potential is applied. Resistivities of rock formations vary over a wide range depending on the material density, porosity, pore size and shape, water content and quality, and temperature. There are no fixed limits for resistivity values of various rocks. However, in porous formations the resistivity is controlled more by water content.

Electrical resistivity of the soil can be considered as a proxy for the spatial and temporal variability of many other soil physical properties i.e. structure, water content, or fluid composition (Samouelian *et al*., 2005). The method is non-destructive and very sensitive, it offers a very attractive tool for describing the subsurface properties without digging. Electrical resistivity prospecting is a very attractive method for soil characterization. Contrary to classical soil science measurements and observations which perturb the soil by random or by regular drilling and sampling, electrical resistivity is non-destructive and can provide continuous measurements over a large range of scales. In this way, temporal variables such as water and plant nutriment, depending on the internal soil structure, are monitored and quantified without altering the soil structure.

A multi-electrode resistivity survey, carried out by Owen *et al.*, (2005) over meta-sedimentary strata and meta-volcanics in the Harare greenstone belt in northeastern Zimbabwe as part of a groundwater resources investigation, illustrates the ability of this technique to produce high-resolution images of the subsurface, which are useful for groundwater resources assessment. The multi-electrode method is successful in identifying potentially favourable zones for obtaining groundwater, such as areas with a maximum depth of weathered regolith, zones of fracturing and faulting, and high porosity and permeability zones associated with lithological contacts.

A resistivity survey was carried out by Arshad *et al*., (2007) in order to study groundwater conditions along the Jhang Branch canal, such as depth, thickness and location of the aquifer and the type of water. The resistivity data confirm that the aquifer consists of an alluvial aquifer. Interpretation of the VES tests indicates the presence of an alluvial aquifer that mainly consists of sand and clay. The resistivity of the aquifer between 30 to 140 m showed the increasing value, which indicated the existence of fresh groundwater. The groundwater after 140 m and up to 200 m possesses marginally fit quality having larger TDS values than the upper zone.

A geological survey using VES was carried out by Nejad *et al.,* (2011) in the Curin basin, Iran, applying Schlumberger array with quantitative and qualitative interpretations of data. From the quantitative interpretation high yield potential in the aquifer were determined.

Geophysical survey involving electrical resistivity methods has been carried out by Lateef (2012) in southwestern Nigeria with the view to delineate the geo-electric characteristics of the basement complex and evaluate its groundwater potential in the area. The schlumberger configuration was used for the data acquisition. The geo-electric section drawn from the results of the interpretation reveal five subsurface layer which comprises of the topsoil, lateritic sand, partially weathered, weathered and fractured basement. The weathered and fractured layers constituted the aquiferous zone in all the stations.

The Schlumberger array of the electrical resistivity method was used by Olawepo *et al.,* (2013) at University of Ilorin in Ilorin, Kwara State, Nigeria which indicated that the test site has at least four major Lithologic layers with the topmost layer (topsoil) majorly laterite, the second layer being clay/sand, the third being weathered basement and the fourth layer being fractured basement.

Akawwi *et al.,* (2014) carried out to assess the groundwater potential and its quality to explain the subsurface geological and structural conditions of subsurface geological layers to support the geological and environmental studies. Based on the correlation of VES data and available wells data, the types of layers present at different depths including water-bearing formation were identified.

Vertical Electrical method (VES) using Schlumberger array was carried out by Tahir *et al.,* (2014) and the results suggest that, three to four geoelecric layers exist in the study area. The weathered layer serves as an aquiferous zone; where it is extensively thick. Bedrock could also serves as an aquifer where it is extensively fractured.

Study Area

The study area, Andhra University is located in Visakhapatnam, Andhra Pradesh. It lies between latitude 17º43'5.38''N and longitude 83º19'17.61''E with an area of 422 acres and a varying elevation from 10MSL to 62.5 MSL. The average annual rainfall is 955mm and the mean annual temperature and humidity are23.7ºC and 67 to 78% respectively.

MATERIALS AND METHODS

Methodology

Resistivity Sounding (VES)

Resistivity sounding is a technique of studying the vertical (depth) variations of subsurface resistivity through an estimation of the resistivities and thickness of various subsurface layers. The centre of the configuration is kept stationary and the measurements are made for each of the progressively increasing electrode spacing. In Schlumberger array all the four electrodes are kept in a line but the two inner electrodes (Potential electrodes) are kept closer. For increasing the depth of investigation the current electrodes are moved from each other symmetrically about the centre point, keeping the potential electrodes fixed. The potential electrode separation is increased only when the potential difference becomes low i.e. below the measurement accuracy of the instrument. Whenever, the potential electrodes are shifted, measurements are repeated for a few of the previous current electrodes separations. The apparent resistivity ($\rho_{a)}$ for each electrode separation is calculated by multiplying the resistance value by Schlumberger configuration factor. Conventionally, the plot between apparent resistivity and half current electrode separation in the case of Schlumberger configuration (K) is used for analysis of thickness and resistivites of the subsurface layers.

The Schlumberger array is the most widely used array in electrical prospecting. The four electrodes (A,M,N,B) are placed along a straight line symmetrically over centre point O. the separation between potential electrodes (MN) is kept small when compared to the electrode separation AB. Current is sent through the outer electrodes AB and potential across MN (inner electrodes) is measured using the following equation:

L = AB/2 and l = MN/2 the configuration factor for Schlumberger array is
$K = \pi(L^2 - l^2)/2l$
and the apparent resistivity is calculated with the formula: $\rho_a = K \times R$

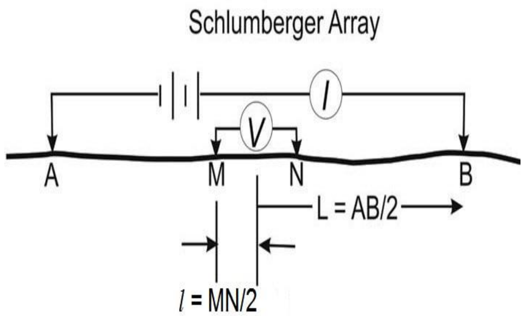

Figure 1: Schlumberger Electrode Array

Interpretation of Resistivity Sounding Data

The interpretation of resistivity sounding data is done in two stages - Processing of data to get the geoelectric parameters in terms of resistivities and depths/thickness and using these parameters to infer the nature of subsurface formations on the basis of geological knowledge and correlative studies.

When the subsurface is a single homogeneous layer, the apparent resistivity equation gives the same value of "ρ" for all separations equal to the true resistivity of the formation. However, if the subsurface is a layered medium, the apparent resistivity values obtained will be close to that of the top layer for small current electrode spacing and as the current electrode spacing increases the influence of lower layers starts contributing.

Hence, the computed resistivity which is termed as the "Apparent Resistivity", depends on the electrode spacing and subsurface layer distribution. The study of variation of apparent resistivity with increasing electrode spacing will provide information regarding the resistivities of subsurface layer distribution.

Curve Matching Technique

The first step in curve matching method is the preparation of field curve. In electrical resistivity sounding apparent resistivity values are obtained for different values of increasing electrode spacings. These apparemnt resistivity values are plotted on log-log scale as ordinate against AB/2 (half current electrode spacing) as abscissa in the case of Schlumbereger configuration.

This curve is called VES field curve. The actual procedure requires that the field curves be drawn on a transparent bi-logarthmic paper of the same modulus as used for the Master Curves. When we carry out Schlumberger sounding, we will be changing MN, the potential electrode separation, due to low potential measurements.

It is possible that when we shift these electrodes, there could be a shift in the sounding curve itself. We will be getting a number of segments of the field curve depending upon the potential electrode shifts. A smooth curve should be reconstructed from these segments.

RESULTS AND DISCUSSION

Subsurface lithology inferred from interpretation of resistivity sounding data is listed below. Data interpreted from the resistivity data is synthesized with geological and hydrogeological observations and lithological layers are designated. As a part of a research project, to establish piezometers and monitor the water table fluctuations and to know the impact of rainwater harvesting structures in the entire Andhra University campus, the locations of aquifers are to be identified. The results indicate that an aquifer zone can be identified between 40m and 80m depth and the depth of occurrence is variable as per the surface topography as well geological structural control. Aquifer zone is of semi-confined nature and the water table varies between 25 and 40m.

Table 1: Geographical Coordinates of VES Locations

VES No.	Layer	Thickness(m)	Resistivity (ohm-m)	Expected Lithology
VES- 1	1	0.0 – 7.0	75	Red sandy soil
	2	7.0 – 22.0	120	Boulders& pebbles
	3	22.0 – 40.0	60	Weathered rock
	4	40.0 – 80.0	45	Fractured rock
	5	80.0 onwards	High	Hard rock
VES- 2	1	0.0 – 25.0	75	Red sandy soil
	2	25.0 – 40.0	45	Weathered rock
	3	40.0 – 70.0	25	Fractured rock
	4	70.0 onwards	High	Hard rock
VES- 3	1	0.0 – 7.0	75	Red sandy soil
	2	7.0 – 30.0	35	Weathered rock
	3	30.0 – 70.0	25	Fractured rock
	4	70.0 onwards	High	Hard rock
VES- 4	1	0.0 – 13.0	75	Red sandy soil
	2	13.0 – 35.0	45	Weathered rock
	3	35.0 – 70.0	55	Fractured rock
	4	70.0 onwards	High	Hard rock
VES- 5	1	0.0 – 10.0	65	Red sandy soil
	2	10.0 – 25.0	45	Weathered rock
	3	25.0 – 60.0	55	Hard Fractured rock
	4	60.0 onwards	High	Hard rock

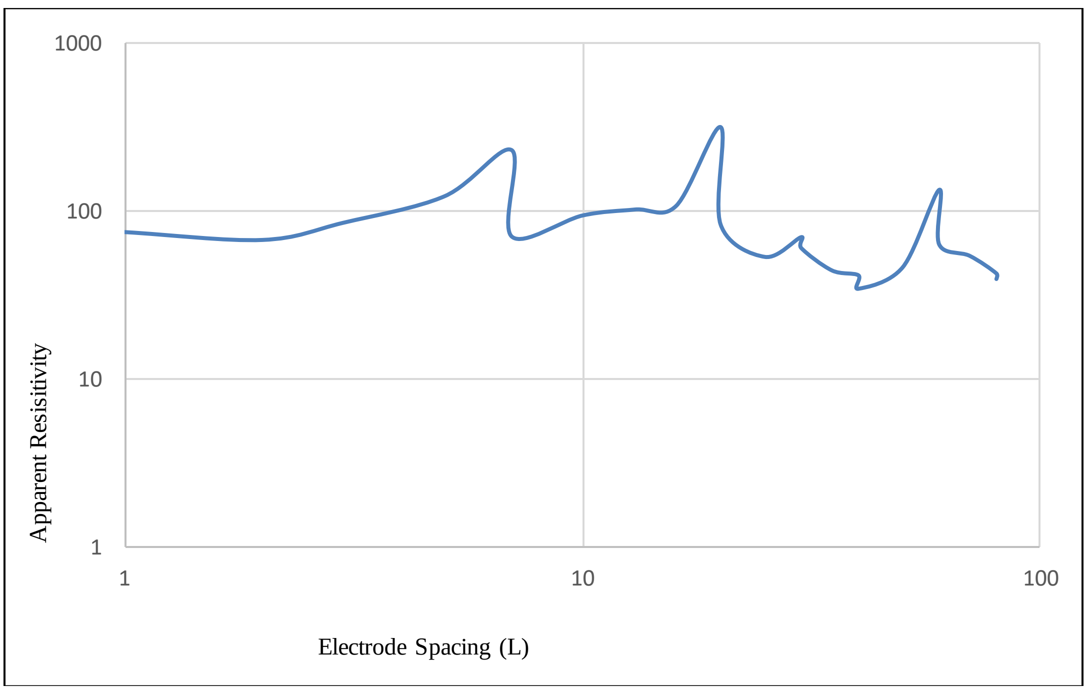

Figure 2: Resistivity Soundings at NCC Office, AU

Table 2: Resistivity Soundings Conducted at Various Places in University

Electrode Spacing (L=AB/2) (mts)	Apparent Resistivity (ρ_a)				
	NCC Camp Office	CSE Department	Samatha Hostel	Dispensary, AU South Campus	Assembly Hall
1	75.47	190.38	130.69	84.25	138.532
2	67.73	69.67	108.39	42.87	83.40
3	85.73	29.78	95.37	37.37	70.89
5	123.62	15.55	48.30	38.09	67.64
7	232.78	18.37	36.49	19.90	58.19
7	71.06	31.66	34.99	18.09	49.00
10	94.85	55.98	21.13	23.32	43.54
13	102.91	52.77	17.05	26.38	42.22
16	108.14	56.07	18.20	24.03	40.05
20	319.63	62.67	15.44	25.06	37.60
20	83.97	80.86	15.92	34.21	40.43
25	53.65	87.79	13.89	28.14	39.01
30	70.37	98.51	18.71	14.07	42.22
30	60.64	125.96	23.26	13.99	37.32
35	44.56	114.60	25.32	12.73	38.20
40	41.65	108.29	16.49	8.33	41.65
40	34.63	94.01	19.27	9.89	39.58
50	46.65	93.30	17.57	10.10	38.87
60	134.77	112.31	19.36	8.98	33.69
60	63.74	127.49	37.73	13.54	39.84
70	54.42	130.62	74.70	21.77	32.65
80	42.75	96.91	55.56		
80	39.58	106.87	67.85		
90		123.14	101.20		
100		35.76	84.81		

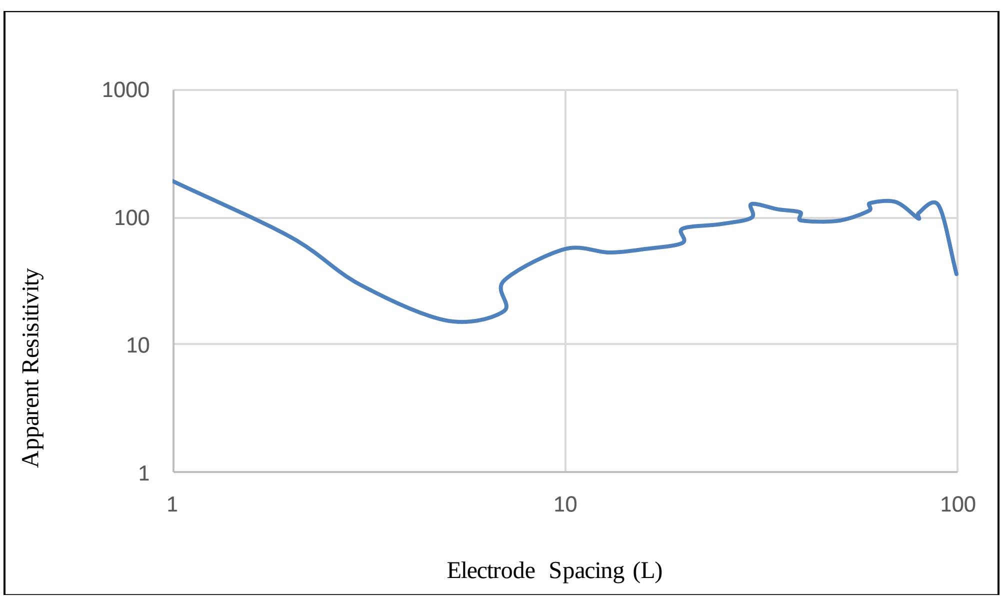

Figure 3: Resistivity Soundings at CSE Department, AU

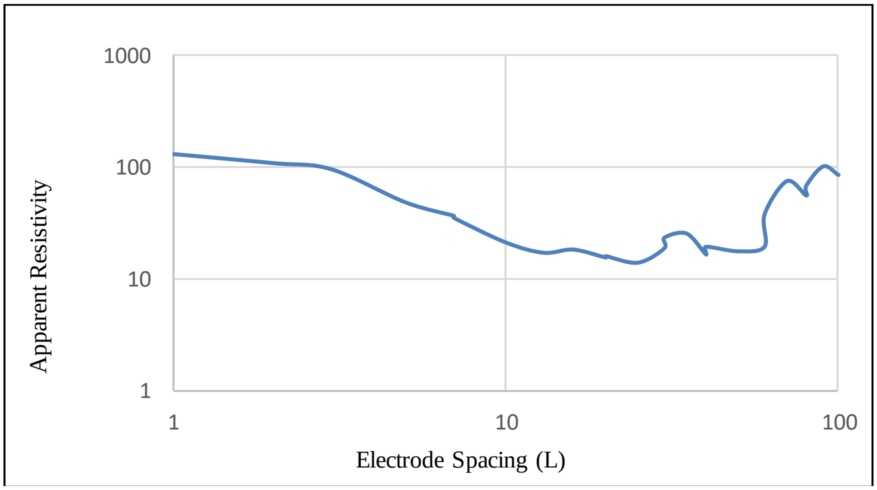

Figure 4: Resistivity Soundings at Samatha Hostel, AU

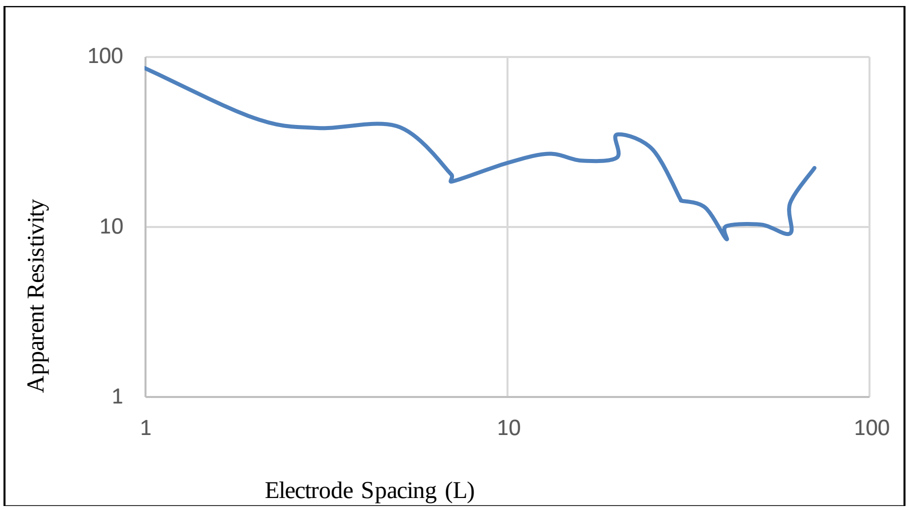

Figure 5: Resistivity Soundings at Dispensary, AU

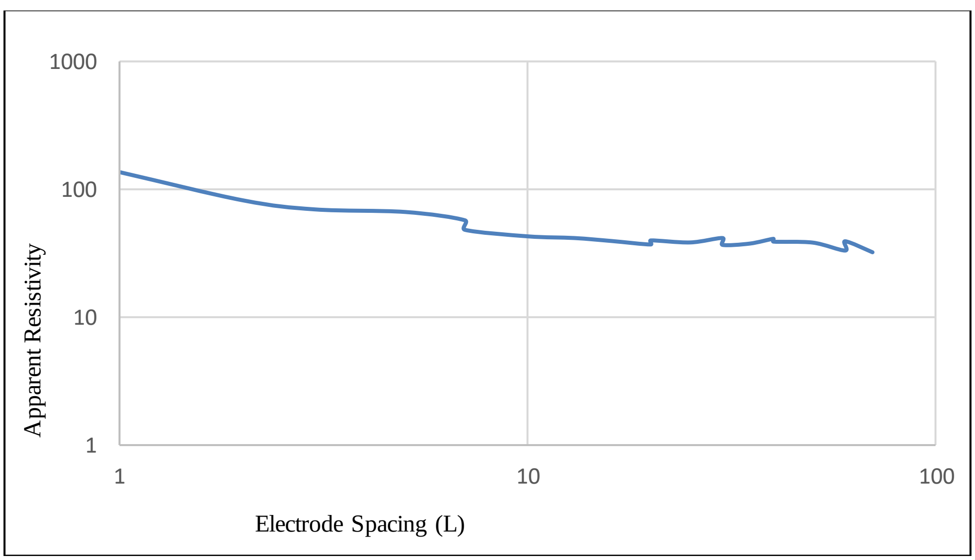

Figure 6: Resistivity Soundings at Assembly Hall, AU

Conclusion

Subsurface lithology inferred from Vertical Electrical Sounding (VES) data indicated that the top red sandy soil thickness varies between 7m and 20m and its resistivity varies between 65 ohm-m and 75 ohm-m. Weathered rock underlain to top soil continued up to 25m to 40m depth and its resistivity variable between 35 ohm-m and 45 ohm-m. Fractured rock zone which is the water bearing zone/ aquifer noticed between 25m/30m and 60m/80m depth and its resistivity varies between 25 ohm-m and 55 ohm-m. Hard rock is indicated below fractured rock which is beyond 60m/80m depth.

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