INTERNATIONAL JOURNAL OF LATEST TECHNOLOGY IN ENGINEERING, MANAGEMENT & APPLIED SCIENCE (IJLTEMAS)

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIII, Issue V, May 2024

Correlation of Schlumberger Array Geoelectric Log with Borehole Lithologic Log in Ekiti State University Campus, Ado Ekiti, Ekiti State, Nigeria.

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DOI : https://doi.org/10.51583/IJLTEMAS.2024.130510

Received: 24 March 2024; Revised: 03 May 2024 Accepted: 08 May 2024; Published: 11 June 2024

Abstract: Correlation of the schlumberger array geoelectric logs interpreted from Vertical Electrical Sounding (VES) data acquired in Ekiti State University Campus with borehole litholigic logs from the same area was done with the aim of establishing a mathematical relationship between the two logs. The study area is located within the basement complex of southwestern Nigeria, where occurrence of groundwater is limited to specific localized and enclosed regions within the weathered or fractured zones. Therefore, thorough geophysical surveys before drilling become necessary. The availability of borehole data in this area reduces the risk of data interpretation errors and enables prediction through statistical analysis. The Vertical Electrical Sounding data acquired from five stations within the campus were processed and interpreted using WINRESIST interpretation software. The results from the 2-D interpretation of the VES data were used to prepare five geoelectric sections which were compared with the borehole litholigic logs obtained from the same VES points using regression analysis. Depth to bedrock from Geoelectric log was correlated with the depth to bedrock from Lithologic log. The correlation coefficient gave a positive value of 0.9, which indicated a high degree of correlation between the geoelectric log and the borehole logs. The regression analysis equation obtained was y = 1.14x + 2.48. The equation is useful in converting the geoelectric logs to drilling logs in any location within the study area.

I. Introduction

Electrical resistivity method involves introducing artificially-generated electric currents into the ground and measuring the resulting potential differences at the surface with the aim of determining the distribution of electrical resistivity within the subsurface. Electrical resistivity data acquisition either in the form of vertical electrical sounding or electric mapping has been in vogue in Nigeria for long but precision in the interpretations of such data have been taking for granted (Olasehinde and Taiwo, 2000). The electrical resistivity method, employing vertical electrical sounding (VES) technique, is increasingly being used in geophysical investigations related to environmental studies, groundwater exploration, and engineering activities (Afolayan *et.al.*, 2004; Abubakar and Auwal 2012; Adepelumi *et al.*, 2013; Ochuko 2013; Okogbue and Omonona 2013; Oladunjoye *et al.*, 2013; Akande *et al.*, 2016; Bienibuor *et al.*, 2016; Kumar *et al.*, 2016; Nicholas *et al.*, 2016), especially in basement complex terrain where groundwater prospecting can be very challenging due to the complex nature of the geological formations (Wannamaker *et al.*, 2016; Sunmonu *et al.*, 2018).

The electrical resistivity method is significantly useful in studying hidden subsurface structures and rock types (Ojo *et al.*, 1990 and Olayinka, 1996); however, much work has not been done in comparing the interpreted results with drilling logs (Ojo and Ademilua, 2013). This could be as a result of lack of follow-up drilling exercises due to economic reasons (Olasehinde and Taiwo, 2000). The determination of the litholigic layer from geoelectric data is not direct since the immediate aim of electrical prospecting is the study of the geoelectic layer. It is necessary to reconstruct the geoelectric layer from the interpreted resistivity data, utilizing well-established relations for a given region, thus effecting the transformation from geoelectic layer to lithologic layer. The use of borehole data to complement the electrical resistivity data in delineating subsurface lithology reduces the possibility of interpretation errors that relying solely on VES data could cause (Claris *et al.*, 2022)

The present study is aimed at correlating the Schlumberger array geoelectric logs interpreted from VES data using iterative computer modeling with borehole litholigic logs and to determine the mathematical relationship between the two for the purpose of making predictions about the subsurface lithology within the area of study. In this work, geoelectic sections and borehole lithologic sections were generated for five resistivity stations within the Ekiti State University campus.

II. Location and Geology of the Study Area

Ekiti State University which is the study area is located in Ado Ekiti along Iworoko road in Ekiti Srate (Figure 1). Ado Ekiti is located between latitude $7^0\ 33'$ and $7^0\ 42'$ N and longitude $5^0\ 11'$ and $5^0\ 20'$ E, Southwest, Nigeria on a low-land surrounded by

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIII, Issue V, May 2024

several isolated hills and inselbergs. The study area is located within the Basement Complex made up of the Precambrian Crystalline Rocks which forms the rocks of the South Western Nigeria and consisting mainly of gneisses, migmatites and granites and vast areas of Schists, Phylites and Quartzites and more occasionally Amphibolites, Diorites, Gabbros and Pegmatites (Talabi and Tijani, 2011).

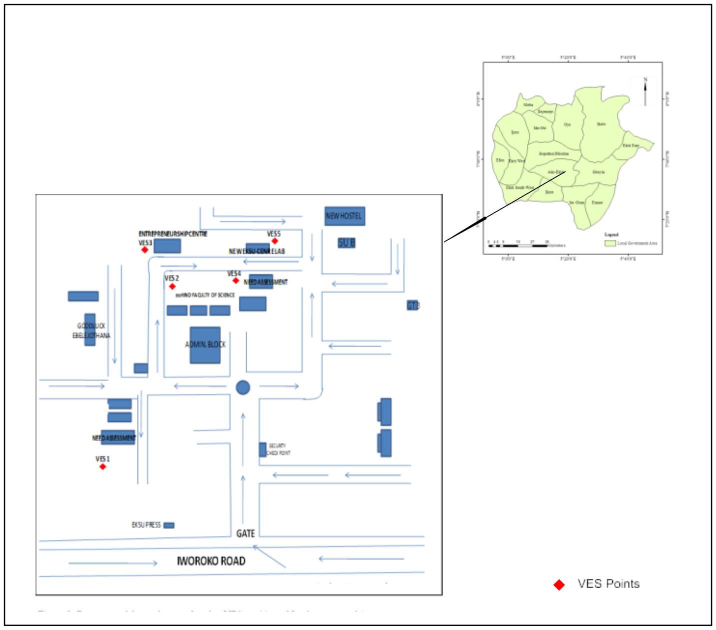

Figure 1: Base map of the study area showing the VES points

III. Methodology and Instrumentation

The site investigation involved Vertical Electrical Sounding (VES) and direct boring (borehole) methods. The vertical electrical sounding (VES) was carried out using Campus Omega Resistivity meter, four electrodes, measuring tape and hammers. The Vertical Electrical Sounding (VES) technique involving Schlumberger array was adopted with maximum half current electrode spacing (AB/2) of 100m. A total of five (5) VES stations were occupied at the logged borehole locations. The apparent resistivity data obtained were plotted against half current spacing (AB/2) on a bi-log graph to determine the number of subsurface layers, their resistivities as well as thicknesses using manual partial curve matching method with the aids of two layer model curves. The initial model parameters resulting from the curve matching procedures were then fed into the computer for iteration processing using WINRESIST software to obtain the final curves as well as the final model parameters (figure 2).

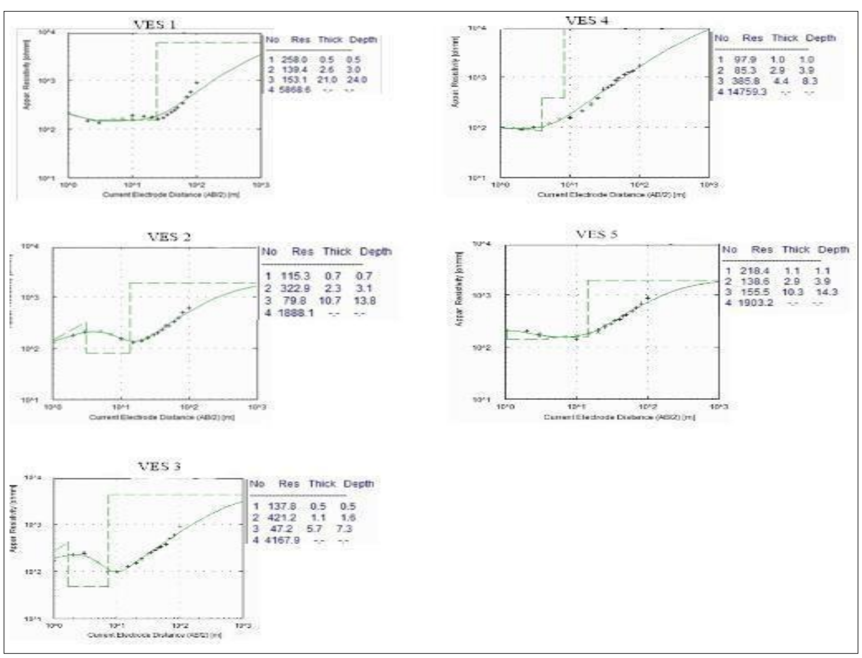

Figure 2: Electrical Resistivity Sounding Curves

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IV. Results and Discussion

Table 1 shows the results of the interpreted VES curves while figure 3 shows the geoelectric logs prepared from the results of the vertical electrical sounding. The borehole litholgic logs are presented in figure 4.

4.1 Vertical Electrical Sounding

Two types of curve – HA and KA, and four major layers consisting of topsoil, lateritic clay, weathered basement and presumably fresh bedrock were identified from the VES curves in study area. The resistivity of the topsoil ranges from 97.9 ohm-m to 258 ohms-m and its thickness varies from 0.5 - 1.1 m. Lateritic clay has resistivity values ranging from 85.3 ohm-m to 421.2 ohm-m with thickness variation of 1.1 – 2.9 m. The resistivity of weathered basement ranges from 47.2 ohm-m to 385.5 ohm-m with thickness between 4.4 – 21 m. The presumably fresh bedrock has resistivity values ranging from 1888.1 ohm-m to 14759.3 ohm-m. These high resistivity values confirm the non-fractured and non-conductivity nature of the bedrock. The low values of resistivity in the weathered layer are indicative of the presence of weathering agent which is likely to be water.

4.2 Borehole Lithologic Log

The borehole lithologic data of the Five VES points in the study area were obtained from the drilling company. The total number of layers in the lithologic log agrees with the number of layers in the geoelectric log. The lithologic log shows that the thickness of topsoil varies from 0.5 m to 1.1 m while the thicknesses of lateritic clay and weathered basement range from 1.4 m to 4.0 m and 7.0 m to 25.5 m respectively. The drilling extended to different depths, ranging from 16.8 m to 66 m, in the fresh basement at the VES points but the thickness of the fresh basement in the geoelectric log is infinity.

Table 1: Summary of VES Analysis

VES No	Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Resistivity curve type	Lithology
1	1	258.0	0.5	0.5	HA	Topsoil
	2	139.4	2.6	3.1		Lateritic clay
	3	153.1	21.0	24.1		W/basement
	4	5868.6	∞	∞		Fresh basement
2	1	115.3	0.7	0.7	KH	Topsoil
	2	322.9	2.3	3.1		Lateritic clay
	3	79.8	10.7	13.8		W/basement
	4	1888.1	∞	∞		Fresh basement
3	1	137.8	0.5	0.5	KH	Topsoil
	2	421.2	1.1	1.6		Lateritic clay
	3	47.2	5.7	7.3		W/basement
	4	4167.9	∞	∞		Fresh basement
4	1	97.9	1.0	1.0	HA	Topsoil
	2	85.3	2.9	3.9		Lateritic clay
	3	385.8	4.4	8.3		W/basement
	4	14759.3	∞	∞		Fresh basement
5	1	218.4	1.1	1.1	HA	Topsoil
	2	138.6	2.9	3.9		Lateritic clay
	3	155.5	10.3	14.3		W/basement
	4	1903.2	∞	∞		Fresh basement

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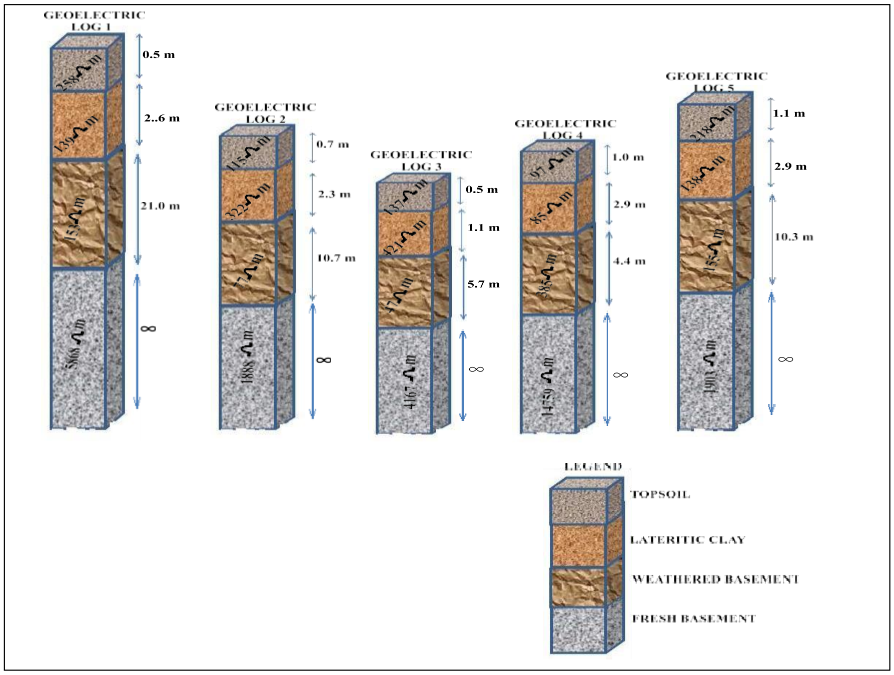

Figure 3: Geoelectric logs

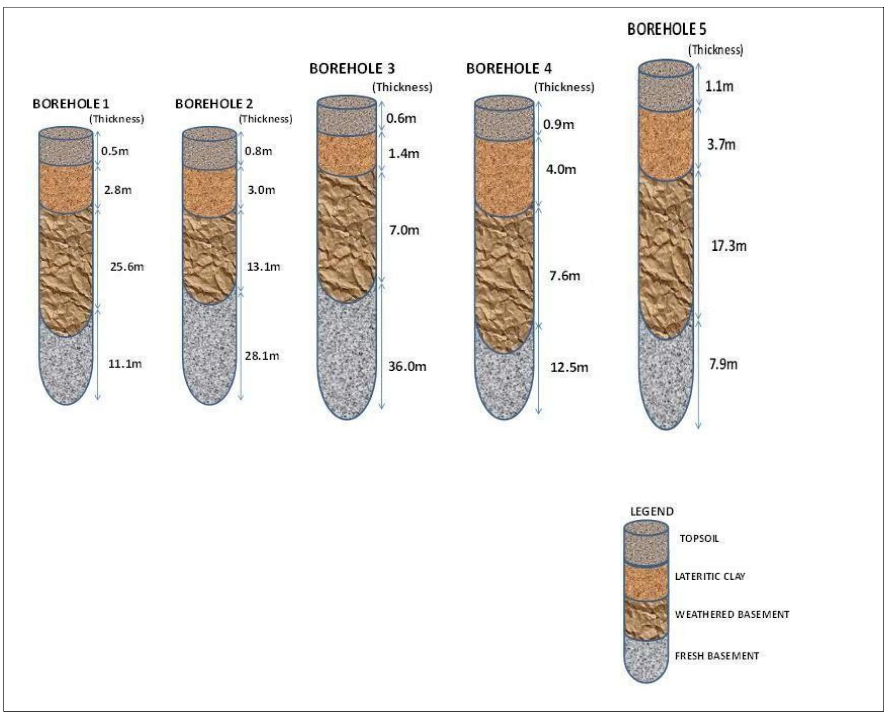

Figure 4: Borehole lithologic logs

4.3 Correlation and Regression Analyses of Geoelectric and Borehole lithologic logs

The correlation between the predicted depth to the basement derived from the VES study and the actual depth to basement from the borehole logs (Table 2) has been computed using correlation and regression analyses.

Erricaker (1971) provides the expression for correlation coefficient as:

$$\Gamma xy = \frac{Cov\ (x,)}{\delta x \delta y} \quad \text{where} - 1 \leq \Gamma xy \leq 1 \qquad (1)$$

Cov (x,y) is covariance of variables x and y; and δx and δy are standard deviation of x and y, respectively.

The regression analysis is defined by the following equations:

$$Y = a + bx \qquad (2)$$

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$$\sum y = na + b\sum x \quad (3)$$

$$\sum xy = a\sum x + b\sum x^2 \quad (4)$$

Where 'a' and 'b' are constants, 'n' represents the number of items, and 'y' and 'x' denote variables, specifically, the actual depth to the basement and the predicted depth to the basement, respectively, in this context (Table 3).

Table 2: Depths to bedrock from VES data and borehole data

VES No	Predicted Depth to Basement from Geoelectric Log (m)	Actual Depth to Basement from Borehole Lithologic Log (m)
1	24.1	28.9
2	13.8	16.9
3	7.3	9.0
4	8.3	12.5
5	14.3	22.1

Table 3: Analysis table for the depths to bedrock from VES data and borehole data

n	x	y	x^2	xy	$x - x$	$y - y$	$(x - \bar{x})(y - \bar{y})$	$(x - \bar{x})^2$	$(y - \bar{y})^2$
1	24.1	28.9	580.81	696.49	10.54	6.22	696.49	111.0916	38.6884
2	13.8	16.9	190.44	233.22	0.24	-4.08	233.22	0.0576	16.6464
3	7.3	9.0	53.29	65.7	-6.26	-10.58	65.7	39.1876	111.9364
4	8.3	12.5	68.89	103.75	-5.26	-9.58	103.75	27.6676	91.7764
5	14.3	22.1	204.49	316.03	0.74	-3.58	316.03	0.5476	12.8164

The graphical relationship between the predicted depth to basement from the geoelectric log and the actual depth to basement from the borehole lithologic log in the study area was obtained using excel statistical tool (figure 5). A positive correlation coefficient, Γxy, of 0.9 was obtained from the correlation coefficient analysis of the data and the regression analysis produced a regression equation of y = 1.14x + 2.48.

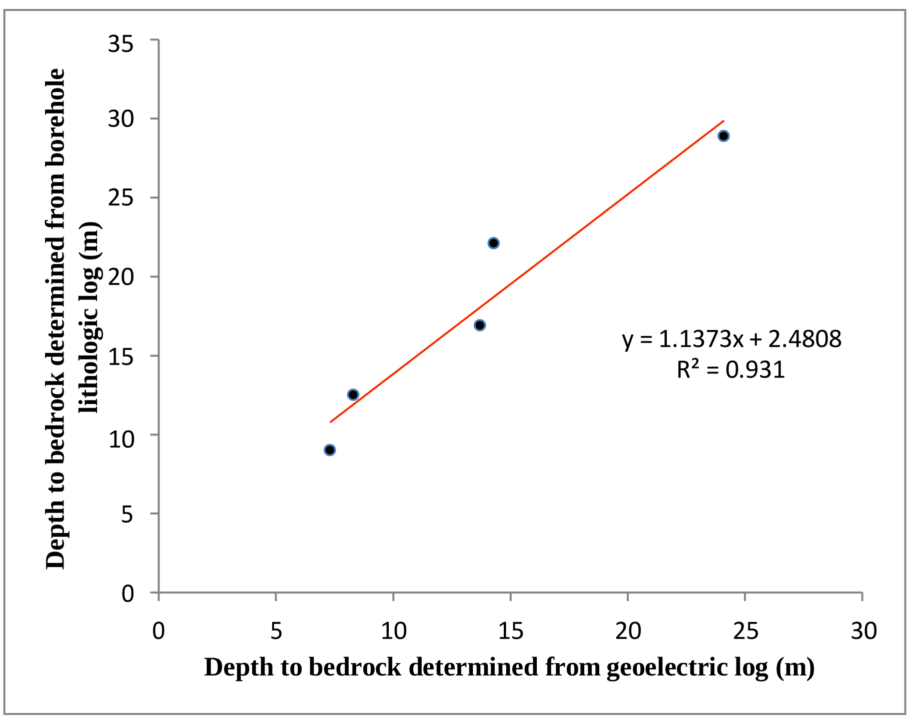

Figure 5: Relationship between depths to bedrock from borehole and geoeletric logs

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V. Conclusion

Vertical electrical sounding (VES) technique has been proven to be a reliable technique in electrical resistivity method to give information about the subsurface geology. The processes involved in generating geoelectric log is less expensive than drilling to produce borehole lithologic log. The predicted depth to the basement as determined by the VES study has been compared with the depth to basement from borehole logs within the study area, employing correlation and regression analyses. The correlation coefficient value indicates a good level of correlation between the two set of data. Therefore, the obtained regression equation can be used to generate borehole lithologic log from the geoelectric log within the study area. Using regression analysis, the geoelectric log produced from the result of an electrical resistivity survey can be converted to a borehole lithologic log with a high level of accuracy, under the assumption that there is no significant variation in the subsurface lithology within the study area.

Acknowledgements

The Authors of this study acknowledge with thanks Jadeko Geosciences Nigeria Limited for supplying information about the boreholes.

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