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IDENTIFICATION OF LITHOLOGICAL UNITS USING GEO-ELECTRICAL METHOD, OLABISI ONABANJO UNIVERSITY CAMPUS, SOUTHWESTERN NIGERIA

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ABSTRACT

The study presented the results obtained from estimation of the depth to the bsement bedrock (overburden thickness) in Olabisi Onabanjo University, Ago-Iwoye using two configurations of electrical resistivity methods. The study was aimed to delineate the stratigraphy and thicknesses of the subsurface layer present in the study area for comprehensive study of the lithostratigraphic information of the area. Vertical Electrical Sounding (VES) and 2-D Horizontal Electrical Profiling (HEP) techniques were used to obtain 1-D and 2-D subsurface resistivity images of the study area. The VES data were plotted manually on the Bi-log graph. The curve obtained was partially curve – matched to obtain the layer resistivities and thicknesses for further iteration. The 2-D resistivity imaging data were analyzed and processed to obtain the inverted (true) resistivity image. From the results, five (5) VES type curves were delineated. These includes H, HA, QH and KH type. The geoelectric sections and 2-D resistivity images showed three to four geoelectric layers. These layers are topsoil/laterite, weathered basement, partly weathered/fractured basement and fresh basement. The study showed that materials with resistivity values that ranged between 10 and 298 Ωm and 152 and 589 Ωm representing clayey weathered layer and partly weathered/fractured basement were delineated beneath some sounding points. The clayey and weathered layer are indicative of soil formations that are inimical to foundation of civil engineering structure. Likewise, they can serve as reservoir for groundwater potential (if the porosity and permeability are high). Due to this, detailed lithostratigraphic evaluation through petrophysical analysis is encouraged for the purpose of mapping and correlation of the rock units before embarking on any engineering construction in the study area. The study concludes in providing assistance to subsequent research on the stratigraphic related studies in the area.

Keywords: Geo-electric , Stratigraphy, Lithology, Layer,

INTRODUCTION

Geophysical studies can be used to determine the nature of overburden materials subsurface structures such as sinkholes, cavities and faults and to determine the depth to basement rock (overburden thickness) (Muhamad *et al.*, 2017). Geophysical investigation is also one of the most appropriate means of understanding the lithology of a study area. Knowledge of the engineering properties and thicknesses of subsurface soils and depth to bedrock are required in the design and construction of foundations of civil engineering structures and buildings

(Groves *et al.*, 2011). The discovery of structures in the subsurface using geophysical methods has gained wide interest in the past few decades. Geoelectrical methods of investigating the subsurface is a non-invasive, cheaper and **time effective** method that can be used to identify and characterise the subsurface thus revealing its features (such as lateral contact) within the bedrock when compared to soil sampling methods.

The conventional soil sampling method involves the drilling of boreholes at selected spacing to generate a model of soil layers (Groves *et al.*, 2011). The drilling of a sufficient number of boreholes to adequately establish a subsurface model is often constrained by limited budget, restricted access of drilling equipment, environmental regulations among others. Soil samplig and drilling techniques are also point specific and cannot image beyond the sampled/drilled points. Geophysical techniques the other hand, can be obtained in continuous form and in 2 to 3-dimensions to image the subsurface in both the horizontal and vertical dimensions. The sub-surface stratigraphy was assesed within the study area in order to unravel the contrast in the merials composition with respect to depth and thickness with improved in accuracy and resolution with geophysical survey techniques.

Results from the electrical resistivity method can be related and use to map variation in sub-surface material properties such as texture, water content, salinity and so on. Groves *et al.* (2011) reported that electrical resistivity imaging technique is the most effective for locating boundaries and detecting changes in sediment type.

Bayewu *et al.* (2012) and Adekoya *et al.* (2019) presented the effectiveness of electrical resistivity method, adopting the 2-D profiling technique, for site characterization, while Badmus *et al.* (2012) and Groves *et al.* (2011) showed the possibility of using multidimensional electrical resistivity method for subsurface characterization and depth determination. Therfore, this study is aimed at delineating the subsurface layers and determine their thickness and the depth to the basement around the Olabisi Onabanjo University using Vertical electrical sounding (VES) and 2-D electrical resistivity imaging (ERI) techniques as a means of unravelling the presence of weak earth materials and basement bedrock structures which might be inimical to founding of civil engineering structures and favorable to ground water exploration.

Description and Geology of the Study Area

The study area is situated within the equatorial belt of Nigeria within geographical of longitude $3°51'30'' - 3°53'15''E$ and latitude $6°55'00'' - 6°56'15''N$ Figure 1. It is about 100 kilometres east of Abeokuta, the Ogun State capital and is accessible from all parts of Ogun State and Nigeria through road network. The two major access roads are the Sagamu-Benin expressway through Ilisan and Irolu to the campus, and also the Ijebu-Ode to the University road. Ago-Iwoye falls within the tropical rain forest with wet and dry season. These seasons prevail from April to October and November to March, respectively. The predominant winds are the south-west moisture laden trade wind during the rainy season and the north-east harmattan trade wind during the dry season

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(Onakomaya *et al.,* 1992). Temperature ranges between 24℃ around August during the rainy season and 39℃ at the peak of the dry season in March. The mean net radiation is 70 Kg/cm^2, with substantial cloud cover during the raining season. Evapotranspiration is the highest during the dry season, the period with the greatest discomfort to plants and human beings.

Badmus *et al.*, 2012 reported that the geology of Ogun State, within which the study area is located is made up of both sedimentary and basement complex rocks. The sedimentary rock underlies approximately three quarters of the whole area of the state, stretching from the northwest to the southwest while the basement complex rocks underlie the remaining one quarter of the surface area of the state. Ago-Iwoye is situated in the Precambrian basement complex area of the state. It comprises of both the migmatite gneiss complex and the older granite, which shows evidence structural disposition. Other important rock units are the schists, made up of biotite schist, quartzite schist talk-tremolite schist, and the muscovite schists (Oyinloye, 2011) porphyroblastic gneisis, Banded gneiss and Biotite-hornblende granite (Baiyewu *et al.*, 2014). The study area was reported by Baiyewu *et al.* 2018 to consist of four distinct rock units which are porphyroblastic (augen) gneiss, hornblende-biotite gneiss, banded gneiss and quartz schist (Figure 2).

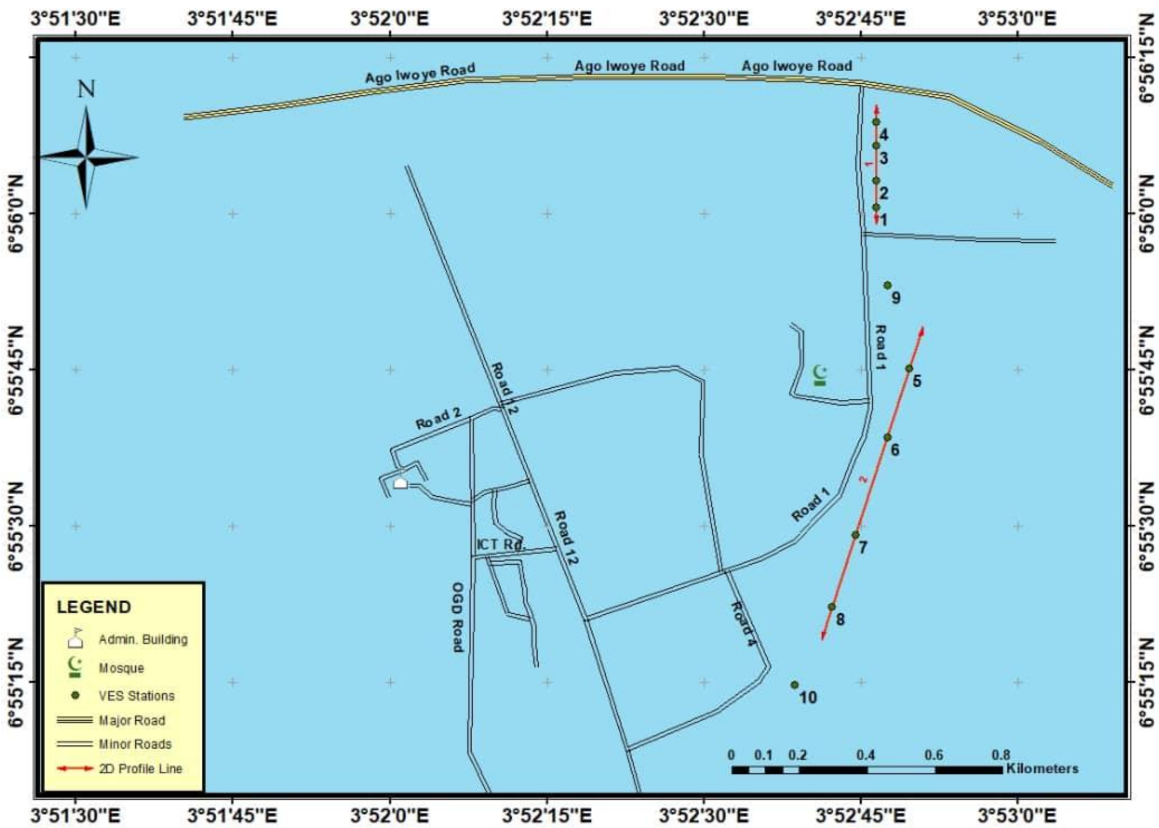

Figure 1: Location Map of the study area

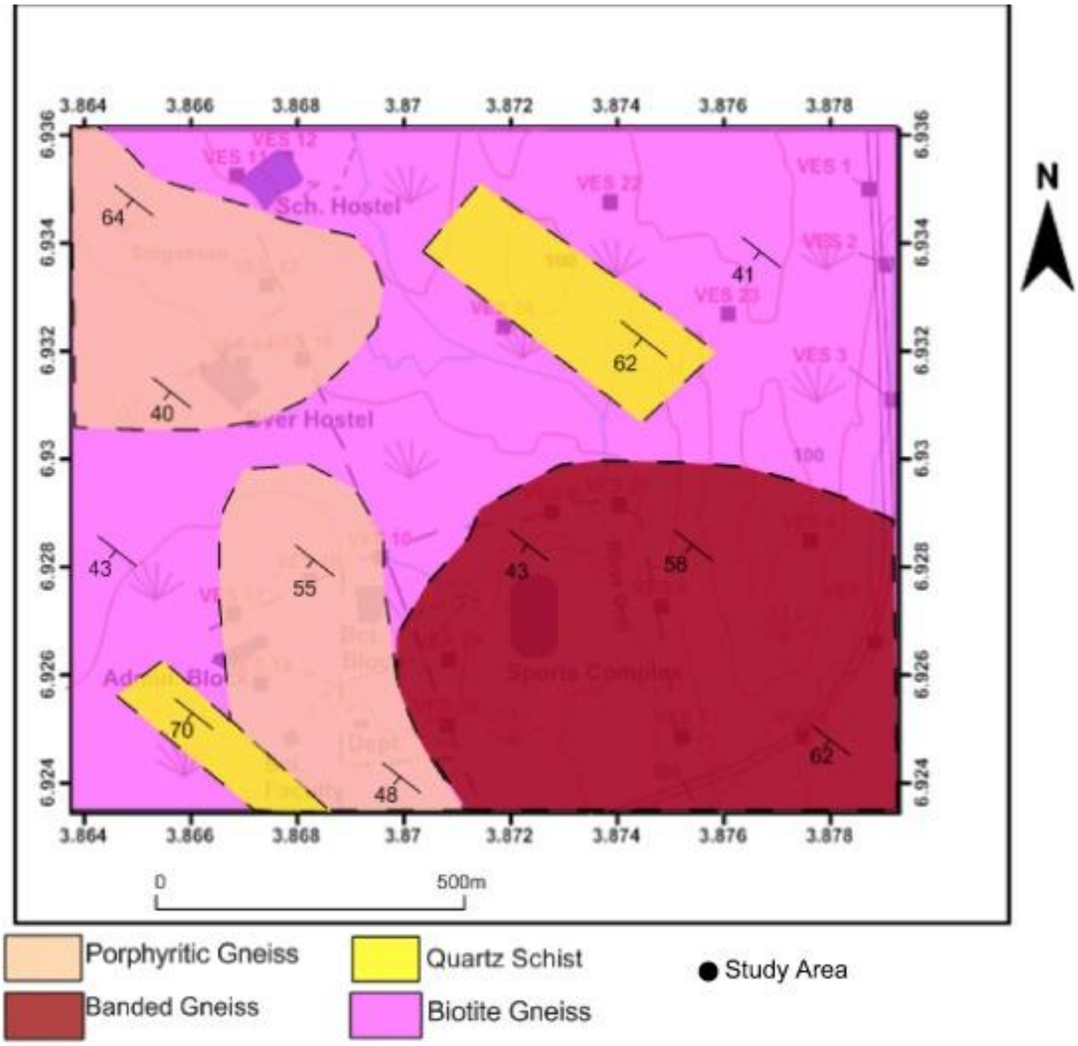

Figure 2: Geological map of the study area (modified after Baiyewu *et al.*, 2018)

MATERIALS AND METHODS

The electrical resistivity method is based on introducing electrical current into the subsurface through two current electrodes (Muhamad *et al.*, 2017) and measuring the resulting potential difference at different points on the ground surface through two potential electrodes. Information is gathered on the nature and electrical properties of subsurface heterogeneities through the patterns of recorded potential differences (Forthingham, 2013). According to Keary *et al*. (2002), the resulting resistivity (ρ) of the subsurface material between the two inner electrodes measuring the potential difference is given as equation 1

$$\rho = \frac{2\pi\Delta V}{I\{[(1/r_{c_1p_1}) - (1/r_{c_2p_1})] - [(1/r_{c_1p_2}) - (1/r_{c_2p_2})]\}} \quad (1)$$

Where $r_{c_1p_1}$, $r_{c_2p_1}$, $r_{c_1p_2}$ and $r_{c_2p_2}$ are the positions of the electrodes relative to each other.

The spacing of the electrodes is adjusted to generate resistivity profile of the targeted stratigraphy (Telford *et al.*, 1990).

A more accurate model of the subsurface is a two-dimensional (2-D) model where the resistivity changes in the vertical direction, as well as in the horizontal direction along

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the survey line. In this case, it is assumed that resistivity does not change in the direction that is perpendicular to the survey line. However, at the present time, 2-D surveys are the most practical economic compromise between obtaining very accurate results and keeping the survey costs down (Dahlin 1996). 2-dimensional electrical imaging/tomography surveys are usually carried out using a large number of electrodes, that are connected to a multi-core cable (Griffiths and Baker, 1993). A laptop microcomputer together with an electronic switching unit is used to automatically select the relevant four electrodes for each measurement (Figure 3). At present, field techniques and equipment to carry out 2-D resistivity surveys are fairly well developed (Loke and Baker 1996a).

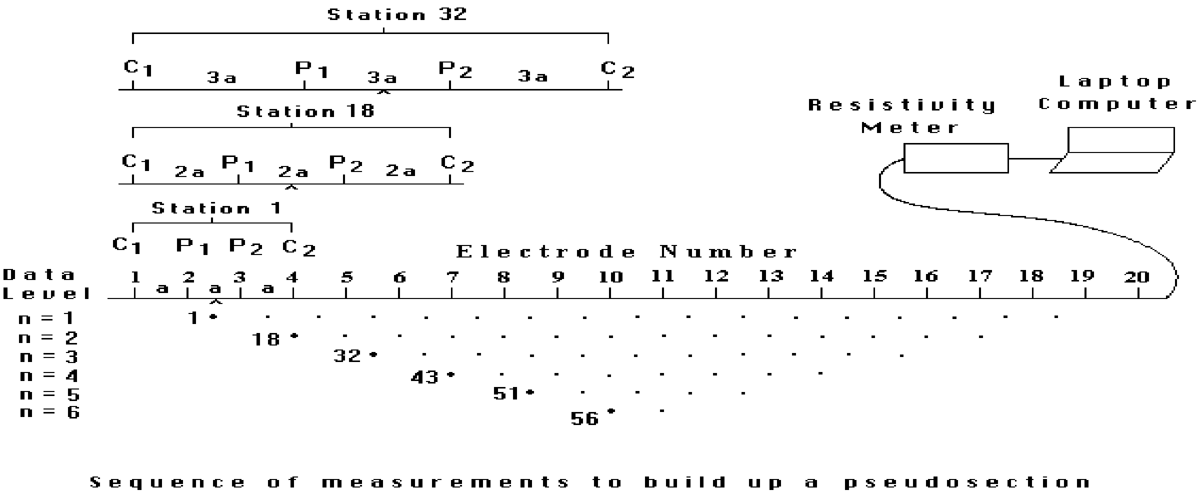

Figure 3: Illustration of 2-D electrical imaging set-up

The two kinds of electrical resistivity techniques used for this research work are the Vertical Electric Sounding (VES) and 2-D electrical resistivity imaging techniques. The VES technique adopted the Schlumberger electrode configuration and was used to investigate the subsurface geologic layers, fracture faults and joints delineation. The half maximum current electrode spacing (AB/2) range between 80 m and100 m depending on space constraint encountered on the field. A total of 10 VES points were established at the study area.

The 2-D electrical resistivity imaging survey was done long two profiles **(Fig. 1).** The dipole-dipole electrode array with dipole spacing of 5m was utilized for the 2D resistivity survey, along profile lines of 190 m total length extent. VES 1, 2, 3, and 4 were located at different positions along profile one while VES 5, 6, 7, and 8 were occupied along profile two. VES 9 and 10 fall outside the profiles.

The VES data were plotted on the bi-log graph and the resulting curves were partially curve –matched using the master and auxiliary model curve to obtain the starting parameters used for (layer resistivities and thicknesses) used for iteration on the Winresist software to obtain the better and refined layer resistivities and their corresponding thicknesses. The 2-D ERI data were analyzed and processed using the DIPRO computer software to obtain the inverted section**.**

RESULTS AND DISCUSSION.

The summary of the VES interpretation results is given in Table 1. The type curves identified from the VES datainterpretation include H ($\rho_1 > \rho_2 < \rho_3$), HA ($\rho_1 > \rho_2 < \rho_3 < \rho_4$), two (2) QH ($\rho_1 > \rho_2 > \rho_3 < \rho_4$) and KH ($\rho_1 < \rho_2 > \rho_3 < \rho_4$).

From the result, VES point 1, 3 and 6 are curve type HA, VES points 2, 9 and 10 are curve type KH, VES points 7and 8 are curve type H and VES points 4 and 5 are curve types K and QH model respectively. The interpreted result showed 3 to 4 inferred geoelectric layers as presented in table one below. The inferred geoelectric layers are topsoil, weathered basement, fractured basement and fresh basement.

Table 1: Summary of Interpretation of VES

VES Number	Layer Number	Type Curve	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	1	HA	407	2.0	2.0	Topsoil
	2		85	7.0	9.0	Clay weathered layer
	3		420	16.0	25.0	Partly weathered layer
	4		1120			Fresh Bedrock
2**	1	~~K~~H	359	2.5	2.5	Topsoil
	2		88	4.0	6.5	Weathered Layer
	3		235	5.5	12.6	Weathered Layer
			1403			Fresh basement
3	1	HA	393	1.5	1.5	Topsoil
	2		139	7.1	8.6	Weathered Layer
	3		589	2.1	10.7	Partly weathered layer
	4		2229			Fresh Bedrock
4	1	H	400	2.1	2.1	Topsoil
	2		36	7.8	9.9	Clay weathered Layer
	3		152			Partly weathered layer
5	1	QH	646	3.2	3.2	Top Soil
	2		104	3.5	8.5	Weathered Layer
	3		63	10.8	17.5	Clay weathered Layer
	4		284			Partly weathered/fresh basement
6	1	HA	442	1.6	1.6	Topsoil
	2		16	11.1	12.7	Clay weathered Layer
	3		479	11.7	24.4	Partly weathered layer
	4		986			Fresh Basement
7	1	H	314	2.1	2.1	Topsoil
	2		298	13.2	15.3	Weathered Layer
	3		1355			Fresh Bedrock

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8	1	H	118	1.5	1.5	Top Soil
	2		10	10.5	9.0	Clay weathered Layer
	3		101			~~Weathered~~ Fresh Basement
9	1	KH	215	0.8	0.8	Topsoil
	2		765	4.6	5.4	Lateritic soil
	3		65	31.1	36.5	Clay weathered Layer
	4		821			Fresh Basement
10	1	KH	169	1.1	1.1	Topsoil
	2		1545	1.1	2.2	Lateritic soil
	3		40	10.5	12.7	Clay weathered Layer
	4		2896			Fresh Bedrock

From Profile 1, Four (4) Vertical Electrical Sounding (VES) were established, designated as VES1, VES2, VES3 and VES4. The profile describes four (4) geo-electric layers within VES1, VES2 and VES3, however, three (3) geo-electric layers were illustrated in VES4 (Figure 4). The top layer depicted from the figure has a thickness values ranging from 1.5 – 2.1 m with resistivity values varying from 358 – 407 ohm-m.

The second layer mapped along profile 1 has a layer thickness values that range between 4.0 to 7.8 m with apparent resistivity values that loiters around 36 – 139 ohm-m. This layer is characterized as clay weathered layer. Likewise, the third layer illustrated along the profile has thickness values that vary from 2.1 to 16.0 m. The apparent resistivity values described in this profile vary between 139 – 420 ohm-m depicting partly weathered layer. The thickness value ranges from 2.1m to16m for VES 3 and VES 1 respectively and to a continuous depth beneath VES 4 as the last layer.

The fourth geo-electric layer represent the infinite continuous layer along the profile with high apparent resistivity values but terminates beneath VES 3. The layer has resistivity value ranging from 1119 – 2289 ohm-m characterizing the fresh basement along the profile.

However, VES5, VES6, VES7 and VES8 were established along Profile 2. The profile depicts four (4) geo-electric layers within VES5 and VES6, whereas three (3) geo-electric layers were illustrated in VES7 and VES8 (figure 5). The top layer inferred from the figure has resistivity value ranging from 118-646 ohm-m with thickness value ranging from 1.5 – 3.2 m.

The second layer depicted along profile 2 has a layer thickness values that range between 3.5 to 13.2 m with apparent resistivity values that loiters around 16 – 299 ohm-m. This layer is characterized as clay weathered layer. Likewise, the third layer illustrated along the profile has thickness values of 10.8 m and 12.3 m. The apparent resistivity values corresponding to this layer in this profile is 105 and 479 ohm-m depicting partly weathered layer. This layer terminates at a depth of 12m in VES6 thinning out along the NS direction. This layer does not elongate to VES 4.

The fourth geo-electric layer represent the infinite continuous layer along the profile with high apparent resistivity values. The layer has resistivity value ranging from 509 – 1357 ohm-m characterizing the fresh basement along the profile.

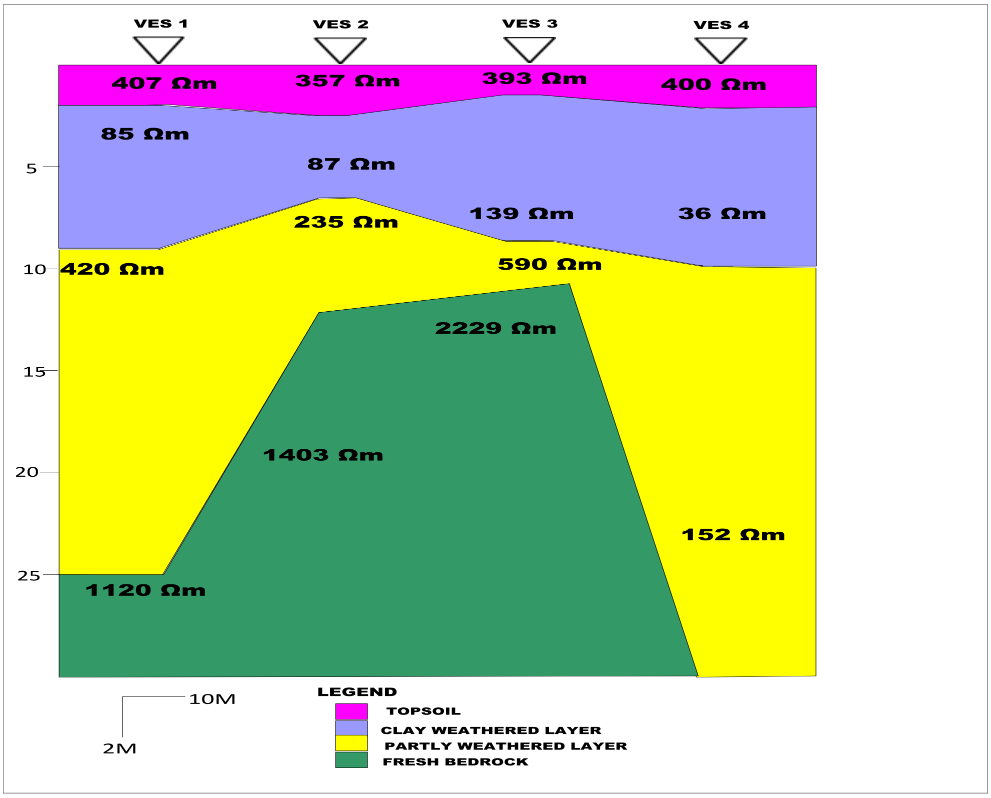

Figure 4: Geoelectric section of Profile one

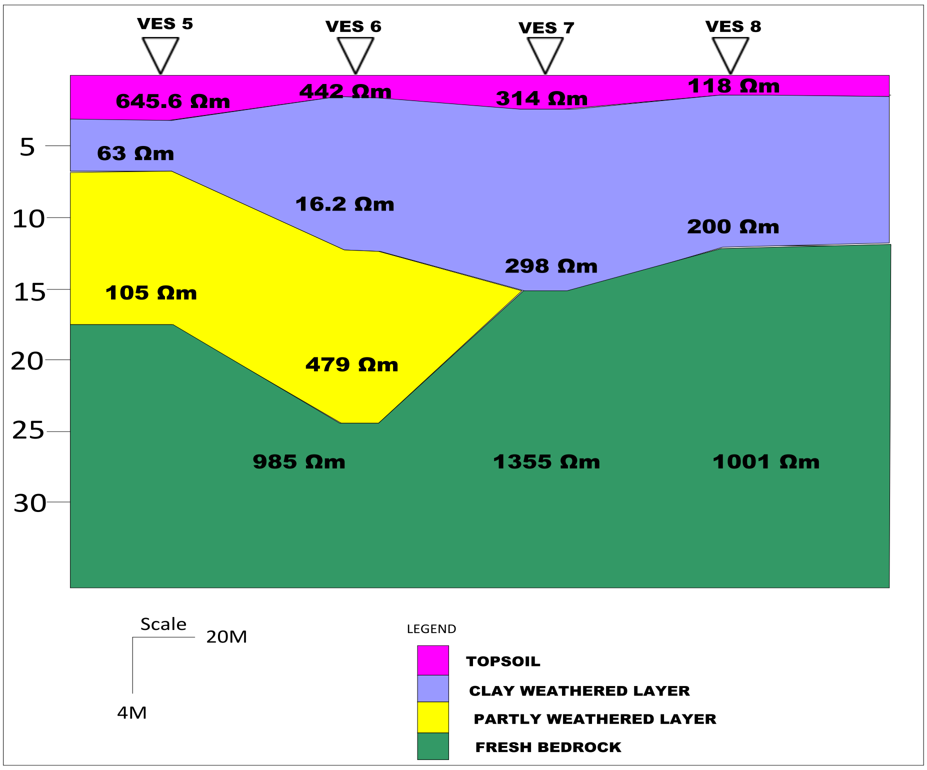

Figure 5: Geoelectric section of Profile two.

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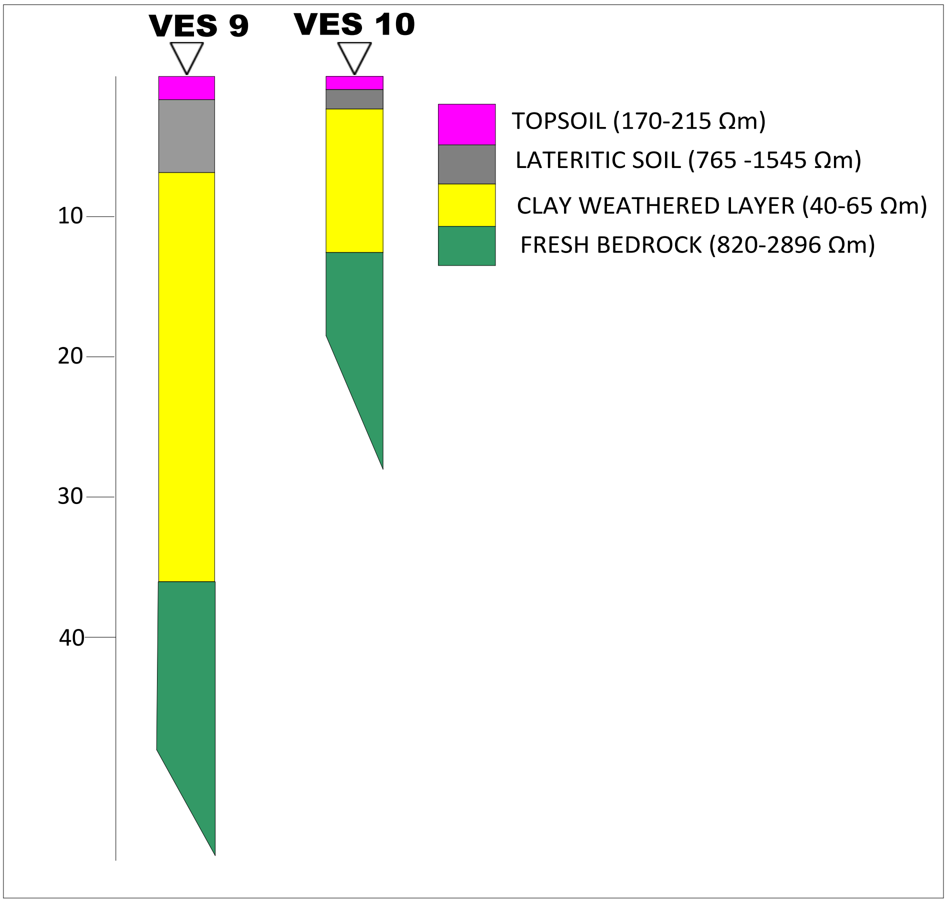

Figure 6: Geoelectric section of VES 9 and 10

From VES9 and VES10, four (4) geo-electric layers were delineated from the processed apparent resistivity values figure 6, namely; topsoil, lateritic layer, weathered layer and fresh basement. The topsoil has resistivity values that range between 169 – 215 ohm-m with thickness of 0.8 and 1.1 m respectively. The second geo-electric layer are described with apparent resistivity values of 764 and 1591 ohm-m. This layer is characterized as lateritic layer with thickness of 4.6 and 1.1 respectively. Similarly, weathered layer was outlined in the third geo-electric layer with apparent resistivity values of 65 and 40 ohm-m with corresponding thickness values of 31.1 and 10.5 respectively. This layer is asymptomatic of good aquiverous units which will tend to produce high groundwater yield. Conversely, this geo-electric layer is unfavorable for situating of founding layer of engineering structure. The fourth geo-electric layer signify the infinite continuous layer with apparent resistivity values of 820 and 2896 ohm-m characterizing the fresh basement along the profile.

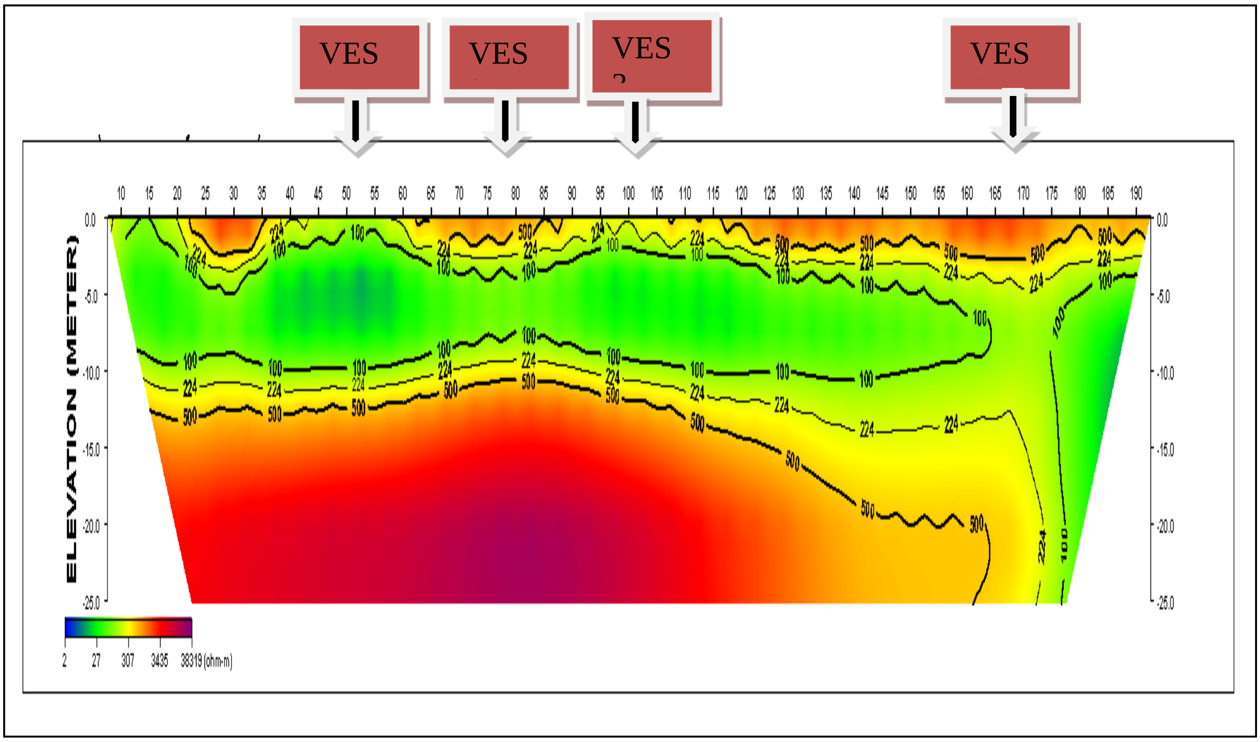

Figure 7: **Pseudosection of image line one**

Two Dimensional Imaging Profiles

The corrected lithologic units obtained from the 2-D resistivity structure showed that the profile 1 has 3 - 4 geologic layers. These layers are medium dense topsoil (1.5 – 2.1 m as thicknesses; 100 - 500 Ωm as resistivities), clay (4.0 - 7.8 m as thicknesses; 36 - 100 Ωm as resistivities), partly weathered (2.1 – 5.1 m as thicknesses; 139 - 500 Ωm as resistivities) and fresh basement (12.6 – 25.0 m as overburden thickness/depth to basement rock; 589 - 1484 Ωm as resistivities). These results correlate with the 2D images in Figure 6.

The corresponding lithologic units unraveled as obtained from the 2-D resistivity structure of profile2 describes the presence of 3 - 4 geo-electric layers. These layers are topsoil (1.5 – 3.2 m as thicknesses; 118 - 646 Ωm as resistivities), clay (3.5 – 11.1 m as thicknesses; 16 - 63 Ωm as resistivities), partly weathered (10.5 – 13.2 m as thicknesses; 105 - 478 Ωm as resistivities) and fresh basement (m as overburden thickness/depth to basement rock; 985 - 1355 Ωm as resistivities). These results correlate with the 2D images in Figure 7.

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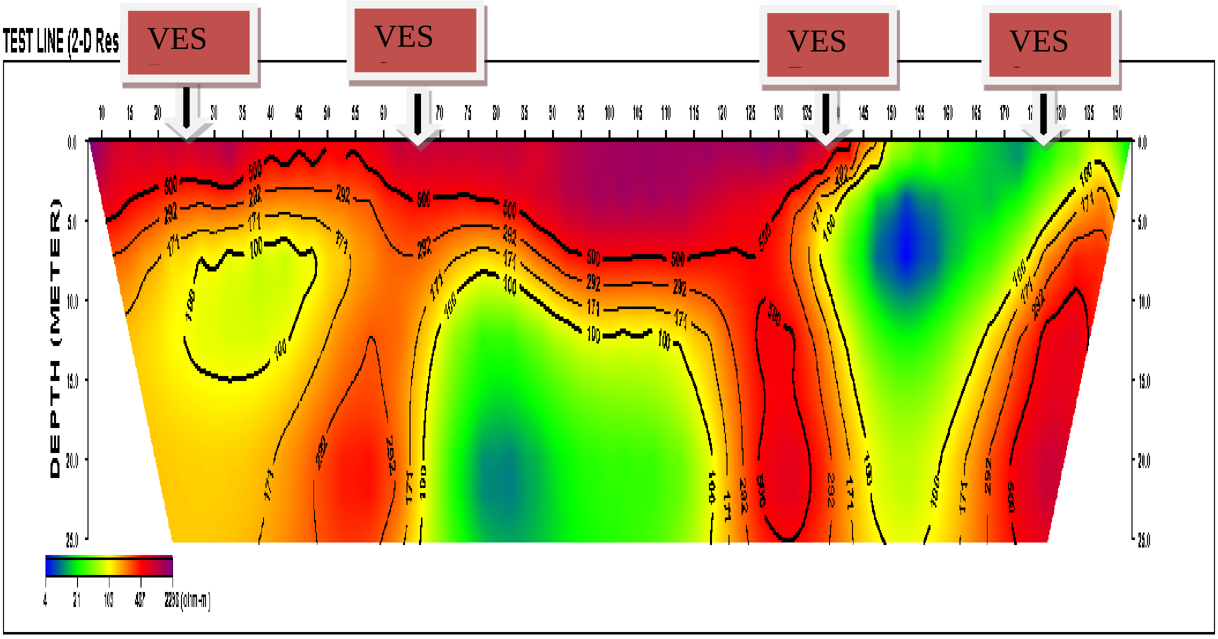

Figure 7: Pseudosection of Profile image line two

CONCLUSION

The study has aided the delineation of the subsurface of OOU Ago Iwoye using geo-electric parameters. The integrated configuration of the VES and HRP of electrical resistivity method facilitated the imaging of the subsurface information in 1- and 2- dimensions respectively. Conclusively, the study showed that the underlying formation has undergone uneven weathering process resulting in obtaining 3 to 4 geolectric layers along the same profile. This prodigy require proper characterisation, so as to circumvent its bad contribution during exploration or engineering process. For instance, the partly weathered layer delinetaed as the third geologic layer portrays good aquiver characteristics, showing that high yield of groundwater are likely to be present. Contarily, the clay weathered soil underlying the topsoil, is an indication that high rise building within the area require thorough geotechnical investigation. The foundation layer must not be erected on clayey layer.

However, the results obtained from the study area agrees with the geology of the area with little modification with a report of more weathering phenomenon. The recent human activities around the area might be responsible for this deviation. More geological investigation in form of petrophysical and thin-section analysis are hereby recommended to give the recent mineral composition of the the weathered layer.

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