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Site Investigation of Subsurface Lithology of Ignatius Ajuru University of Education, Port Harcourt, Nigeria, Using Electrical Resistivity Methods

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ABSTRACT

This study was carried out to determine the subsurface lithology and possible depths for structural foundations in Ignatius Ajuru University of Education, Port Harcourt in southern Nigeria using electrical resistivity techniques of VES and borehole logging. Model ABEM SAS 300B Terrameter aided by SAS 200 log meter were used for the data collection while version IPWIN2 software was used for the processing of the VES data. Six profiles of different locations, using maximum current electrode spread of 200 m and maximum potential electrode spread of 30 m, were used to obtain resistivity range of 1.2 to 4335 Ωm for three to four geoelectric sections covering depth interval of 19.8 m in the area. The borehole data covered a depth range of 0 to 20 m. The results show lithostratigraphy sequence of silty sands, laterite, grain and coarse sands with resistivity values of 721 to 4000 Ωm. These soils can support structures with foundations as close as 0.5 m to 3 m or more below the earth surface because laterite and sandy soils have the ability of a firm grasp of structural foundations as they do not retain moisture that will cause foundational deformation and shifting that may eventually lead to collapse of the structures.

Keywords: Geoelectric Layers, Electrical Resistivity, Lithology, Apparent resistivity, Borehole Log, Schlumberger Array.

1. INTRODUCTION

Cases of building collapses have become frequent in Nigeria in recent times with some major incidents in Port Harcourt City and its environs. The reasons for these collapses have been attributed to a lot of factors and one of which is the building of structures on weak soils that cannot support structural foundations leading to their deformation and the eventual collapse of the structures. Soils that retain moisture and do not drain off water easily have been identified as risky soils for foundations. According to [1] two types of subsurface investigations can be carried out in a site to ascertain the composition, types and strength of soils before engineering structures can be built on them. These are the route selection study and detailed site characterization.

Route selection is usually by physical inspection, while site characterization is generally carried out through geophysical/geotechnical investigation and analysis. The geophysical methods that are frequently used include ground penetrating radar, seismic tomography, electrical resistivity, gravity and magnetics [2]. In all, the ground penetrating radar and electrical resistivity methods have advantage over the others because of their cost effectiveness, spatial resolution and target definition [3]. However, the uses of two or more methods give more confirmatory information about the subsurface.

The primary purpose of all site investigation is to determine the subsurface lithology and properties of soils which will aid developers on the choice of depth of foundations for structures and type of structures that can be built on them. Most information obtained usually includes the nature of the soil, configuration of the subsurface layers, bedrock topography, structural disposition and load bearing capacity [4]. Some of these properties can be determined by geophysical investigation. Theoretically, every geophysical technique detects discontinuities, which are differences between one layer from another in terms of a physical parameter, and it is this quantitative or qualitative (or both) analysis of this discontinuity that gives us our required information. With the upgrade of the Rivers State Collage of Education to a University by the Rivers State Government in 2008, the university has

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experienced influx of students and subsequent need for more structures and facilities. The authorities have taken up these challenges with plans to build the needed structures for use by the university community in different parts of the campus.

The university is located in the heart of a sedimentary basin and close to the creeks and there is the need to determine the types of soils within the upper subsurface of the university and its environs to aid in choice of sites and nature of structures in different parts of the community. The aim of the study therefore is to use the vertical electrical resistivity (VES) and borehole resistivity logging methods to identify the soil composition of the lithology in the upper subsurface of the university environment.

2. THE STUDY AREA

The study area is in the Obio/Akpor Local Government Area close to Port Harcourt City, the capital of Rivers state, Nigeria. It is south-south of the Niger Delta Sedimentary basin with GPS coordinates of 4.77742 N 7.0134 E (Fig. 1). The geological formations of the region consist of Quaternary deltaic sediments with top soils in most parts of the region identified as silty-sands, loamy soil, clay, lateritic, fine and coarse sands. The lithostratigraphy and geology of the Niger Delta has been discussed by several authors [5; 6; 7] and three major lithostratigraphic Formations have been identified. The top Formation is the Benin Formation which consists of sand and sandstones with depth of zero to more than 2000 m thickness in some regions. This formation is the aquiferous zone of the region. Water table depths range from 3 m to 15 m below the earth surface with existing boreholes within 15 m to 40 m [8;9].

The Benin Formation is underlain by the Agbada Formation which is the hydrocarbon reservoir region of the zone. The Formation consists mainly of alterations of sands (30% to 70%) sandy shales, shales and clay. This formation has thickness of about 3,000 m in some regions and the shaliness of the formation increases downwards to depths of about 5,000 m below the earth surface to join the third formation, the Akata Formation. The Akata Formation is the petroleum source bed of the region and is composed of shales, clay and silts with estimated thickness of 7,000 m. The major structural features in the region are growth faults, diapers, and anticline and syncline structures.

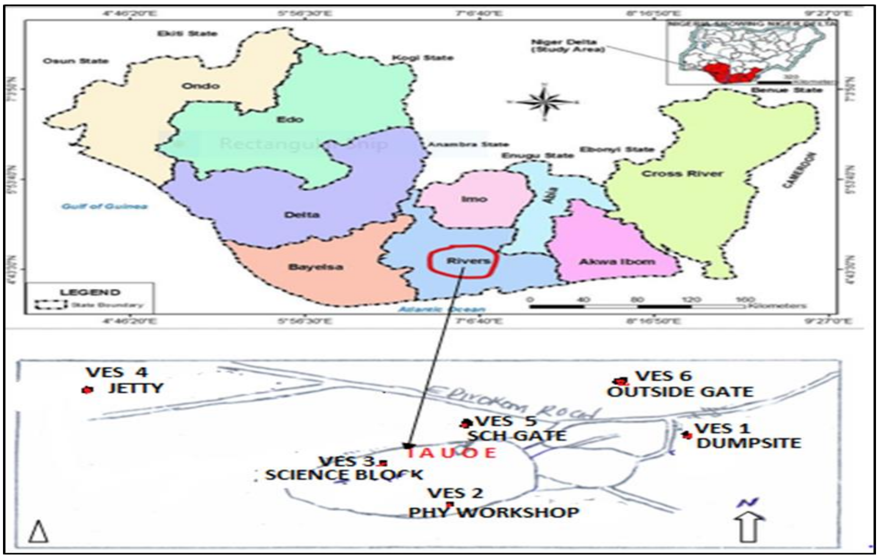

Fig.1: The Study Area [Modified from 10]

3. MATERIALS AND METHODS

The field work was carried out with ABEM SAS 300B Terrameter and SAS log 200 Resistivity Meter. The survey utilized the Schlumberger Vertical Electrical Sounding (VES) array method with maximum electrode spread of 200 m and maximum potential electrode spread of 30 m. Five VES profiles were taken within the environment. From [11] it shows that for a Schlumberger array with current electrode spread $AB = 2a$ and potential electrode spread $MN = b$, the apparent resistivity is derived by the equation

$$\rho_a = \pi R \frac{a^2}{b}[1 - \frac{b^2}{4a^2}] \quad (1)$$

Where, a is the distance between the current electrodes and the center of the distance between the potential electrodes, while b is the distance between the potential electrodes.

According to [12] the apparent resistivity generally does not represent the true resistivity of any part of the ground. Its value may be larger or smaller than the actual resistivity, or in rare cases, it may be identical with one of the true resistivity values in a heterogeneous earth. The reason is because the apparent resistivity in equation one is derived on the assumption of a homogeneous earth. However, it can be used to obtain resistivity values that are close to formation resistivities.

The borehole log was done by Hand Auger drilling down to a depth of 20 m and the resistivity of the formations logged using the SAS log 200 Resistivity Meter. Sample sands from various depths were collected as the drilling continued and examined to identify the type of soil.

4. RESULTS AND DISCUSSION

Tables 1 show the apparent resistivity values obtained from the VES readings for the five locations (L_1, L_2, L_3, L_4 *and* L_5) while Table 2 is the borehole log result from the control site.

Table 1: Apparent Resistivity values of the five locations

$\rho_{a_{L1}} / \Omega m$	$\rho_{a_{L2}} / \Omega m$	$\rho_{a_{L3}} / \Omega m$	$\rho_{a_{L4}} / \Omega m$	$\rho_{a_{L5}} / \Omega m$
6.2361	41.3644	97.1924	6.2989	23.6667
5.6313	1585.00200	73.7229	5.7726	477.7155
5.1732	879.2291	54.5668	5.4245	414.2723
45.8108	405.1270	60.8213	46.1914	220.4881
9.7968	435.2992	65.18803	10.4000	237.2532
10.6186	699.7896	76.1993	11.5612	450.8185
7.1812	404.0873	111.5894	8.1048	287.0944
16.7183	212.1204	256.0400	17.9247	179.9505

8.9378	387.9866	149.28850	10.8228	397.4114
6.7180	160.5982	73.0420	9.4323	38.4531
5.7723	75.3982	894.7255	8.6001	91.8915
3.0159	550.4070	2583.6008	6.0319	15147.5000
7.9718	2548.6170	1118.3269	12.6842	3239.7680
39.7254	1386.0800	3493.4509	46.5110	1990.5130
10.3547	5142.1590	3707.0795	16.3866	864.5663
16.8075	5772.6770	4418.0218	26.2323	950.3318
22.0131	5657.2230	3749.8048	31.2494	638.8429
23.8258	3920.7070	2847.5254	35.8896	995.2565
28.4753	1813.5080	3815.1502	47.5648	1765.7840
40.4135	2246.8670	400.55307	58.5090	2457.9820
61.7323	1884.9560	1633.6282	90.0066	1555.0880
55.7109	1549.8520	1664.2322	105.9764	1298.5250

Table 2: Borehole Data of Study Area

Depth/m	**SN 16 /mΩ**	**LN 64" /mΩ**	**SP /mV**	**Formation Description**	**Formation Colour**
2	2000	938	-2720	Silty sands	Brownish
4	3700	1800	-2990	Laterite	Brownish
6	4000	709	-1510	Laterite	Brownish
8	3650	721	-152	Grain sand	Light brown
10	3350	721	-1832	Grain sand	Light brown
12	2780	801	81.2	Grain sand	Light brown
14	2370	759	-1164	Grain sand	Light brown
16	2150	670	-897	Medium coarse	Grey
18	2030	687	-1190	Medium coarse	Grey
20	1852	579	-288	Medium coarse	Grey

Figure 2 is the sounding curves for locations 1 to 5 using IP2WIN software which plotted the apparent resistivity values against the corresponding half current electrode separation (AB/2) from which the parameters of the geoelectric section; the layer resistivity, thickness and depth that are shown in Table 3 were obtained.

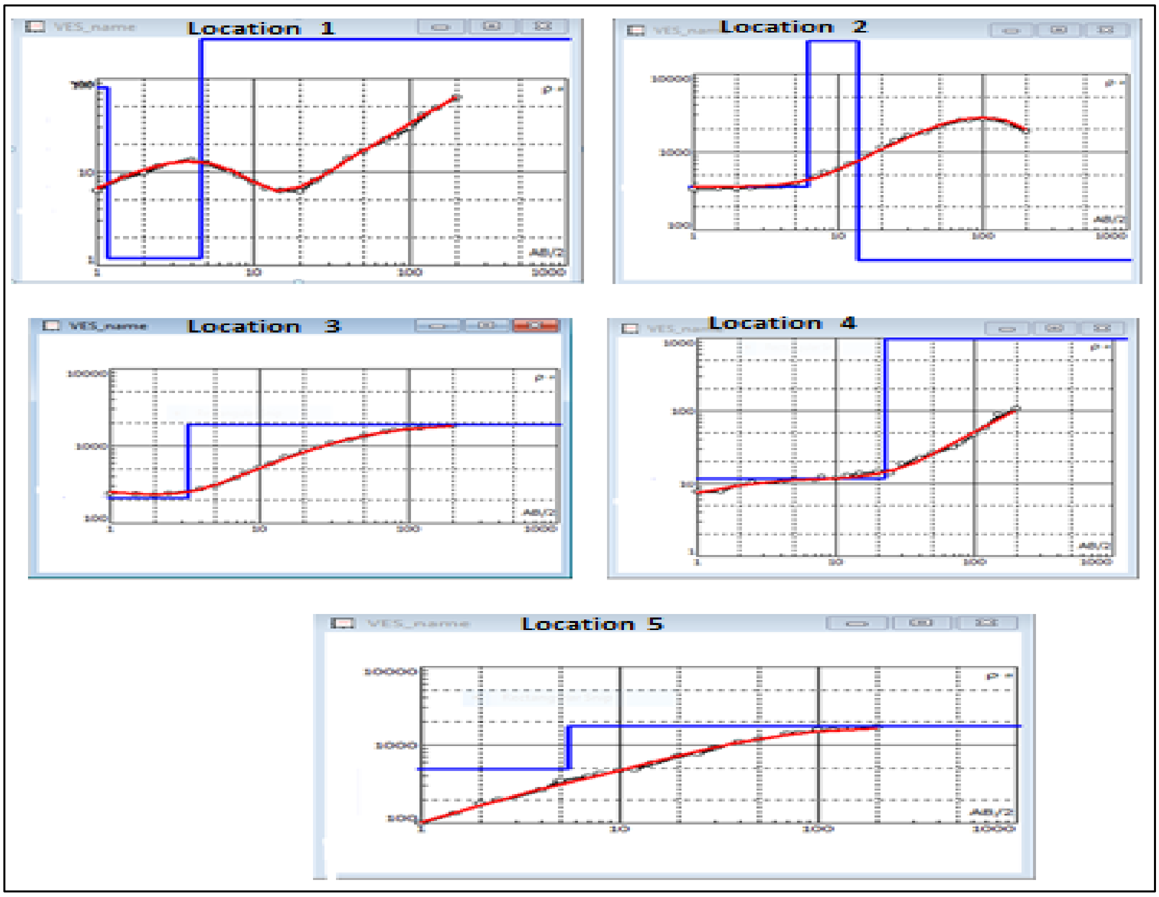

Fig.2: Sounding Curves for the five Locations

The summary of the sounding curve and borehole log results as presented in Table 3 show that the sounding curves reveal three to four geoelectric sections while the borehole log reveals the type of soils at various depths. Location one which is close to a solid waste dumpsite is a type KH-curve has four geoelectric sections with the first layer, topsoil, having a resistivity value of 3.71 Ωm to a depth of 0.5 m. The total depth penetrated by the VES in this location is 4.54 m and this covers the top three geoelectric sections. The fourth layer whose depth could not be reached because of the electrode spread has a high resistivity of 2607 Ωm. The inferred lithology of this location includes silty sands, sandy-clay, and laterite and grain sands.

Table 3: Summary of VES and Log Data Interpretation

S/N	Layers	Resistivity/ Ωm	Thickness/m	Depth/m	Curve Type	Lithology/ Soil type
VES 1	I	3.71	0.50	0.50	KH	Silty sands
	II	8I.4	0.652	1.15		sandy clay

	III	1.2	3.39	4.54		laterite
	IV	2607				grain sand
VES 2	I	359	6.11	6.11	K	Lateritic/grain sands
	II	4335	7.60	13.70		coarse sand
	III	41.4				Coarse sand
VES 3	I	275	0.50	0.50	H	Laterite
	II	210	2.79	3.29		Laterite
	III	1918				Grain sand
VES 4	I	7.21	0.50	0.50	A	Laterite
	II	10.3	19.3	19.8		Laterite/grain sands
	III	1138				Grain/coarse sand
VES 5	I	59.4	0.50	0.50	A	Laterite
	II	492	4.96	5.46		Laterite
	III	1745				grain sand

Location 2 is a type H-curve and has three geoelectric sections with the first layer having a high resistivity value of 359 Ωm to a depth of 6.11m. The topsoil is composed of laterite and grain sands. The second layer has a resistivity of 4335 Ωm to a depth of 13.7 m while the third layer has a very low resistivity value of 41.4 Ωm both are composed of grain and coarse sands.

Location 3 has three geoelectric sections with resistivity of 275 Ωm, 210 Ωm and at a depth of 3.79 m and a third layer whose depth could not be reached with resistivity of 1918 Ωm. The lithology is inferred as laterite and grain sands.

Location 4 has three geoelectric sections with resistivity values of 7.21 Ωm, 10.3 Ωm, and 1138 Ωm respectively. The maximum depth is 19.8 m with lithology of laterite, grain/coarse sands.

Location 5 also has three geoelectric sections with resistivity values of 59.4 Ωm, 492 Ωm and 1745Ωm with lithology of laterite and grain sands.

From the results it shows that the general lithology of the area down to a depth of 20 m is composed of silty sands, laterite, grain sands and coarse sands. These soils are unlike clay soils, which can retain moisture that will swell and shrink seasonally causing cracks and shifts that will affect the foundations of structures and the eventual collapse of the buildings. From [13] it has been shown that, laterites and sands are good for building foundations. Laterite soils are rich in iron and aluminum and do not retain moisture just like sandy soils which have gritty texture and because of their irregular shapes, the fragments catch against each other and lock in place to provide additional stability to buildings and readily drain away water from buildings. Thus, foundations that fall within the laterite or sand zones in this area are safe for building structures. The depth of foundation will depend on the type of structure and of course additional geotechnical soil test must be carried out.

5. CONCLUSION

Electrical resistivity methods of VES and borehole logging of Ignatius Ajuru University of Education, Port Harcourt, Nigeria has revealed that the upper subsurface lithostratigraphy of the area and its environs is composed of silty sands, laterite, grain and coarse sands down to a depth of 20 m. This shows that building foundations can be laid from depths where laterite and sands are found which in some locations are 0.5 m to the earth surface. However, the depth will depend on the type of structure to be built as heavier structures will require deeper foundations.

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