Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.7, No.6, 2017

Preliminary Geophysical Investigation of Orin Clay Deposit, Southwestern Nigeria: Deductions, Implications and Possible Applications

Oluwakunle Moyofoluwa Ogunsakin
Department of Geology, Wesley University, P.M.B 507, Ondo, Nigeria

Abstract

Clay resources exploration and exploitation has been on a steady increase in a bid to satisfy a growing mineral resource utilization industry. This necessitated a preliminary geophysical investigation of Orin - Ekiti clay deposit aimed at investigating the subsurface lithology, make deductions on the depth and thickness of any clay deposit encountered in the region as well as implications on possible industrial and engineering uses respectively and finally suggest possible areas for groundwater prospecting as a solution to the prevailing need for water in the area. Prospecting for clay deposits in the study area employed the vertical electrical sounding (VES) technique of the electrical resistivity geophysical survey method utilizing Schlumberger array. Six (6) VES at six (6) stations in the study area were carried out with maximum electrode spacing of 55.0m. Preliminary VES results revealed three main sounding curves namely HK (VES 1), KH (VES 2, VES 3 and VES 4) and K (VES 5 and VES 6). Indication of three to four geoelectric layers representing subsurface lithological formations was observed namely the top soil (0.5 – 1.9m), sandy clay (2.2m), compacted lateritic clay/hardpan (2.2 - 10.8m), weathered basement {clayey – 7.1 m and above, clayey sand (4.2 – 7.4m)}, fractured basement (9.2 m and above) and fresh basement (9.9m and above). Preliminary assessment from 2D maps and 3D models indicates layer 2 of the geoelectric sections corresponding to the lateritic hardpan formation have moderate to high potential while the weathered clayey zone (layer 3) have low to moderate potential for future mining purposes. Groundwater potential in the area is rated low to medium based on overburden thickness {VES 5 (>12.4m) and VES 6 (>8.4m)} and clayey sand formation composition {VES 3 (>9.2m) and VES 4(>11.4m)} although the presence of fractured basement of undetermined thickness in VES 3 and VES 4 could significantly increase the odds. Any engineering construction project in the area would have to take into consideration the considerable thickness of the clay layers (≥ 10.8m) during planning and execution.

Keywords: Clay, vertical electrical sounding, Geo-electric section, lateritic hardpan, overburden.

1.0 INTRODUCTION

Clay deposits are highly sought after natural resources in many parts of the world due to the many potential domestic (earth and cookwares), residential (brick building), engineering (in form of stabilized laterite), agricultural (good for tree crops like cashew and coffee),industrial applications (as raw materials for clay firing industries, oil drilling lubricants), indirect control on ground water potential and filtration (it overlies weathered basement which is an important aquifer and in form of laterite hardpan acts as a seal which prevents aquifer contamination) and in form of lateritic clay could be an important source of bauxite (Babatunde and Dayo,2015). Clay deposits have been reported from various parts of Southwestern Nigeria - an area within the tropical region of alternating wet and dry climates - as residual products of tropical weathering of parent rocks (Elueze and Bolarinwa, 2001) (Ajayi and Agagu,1981). Geological evaluation, geotechnical parameters and industrial properties of clay deposits of Southwestern Nigeria have identified their potential industrial applications in ceramics, oil industries and as principal raw materials in Burnt brick industries (Olorunfemi and Oloruniwo, 1990; Elueze and Bolarinwa, 1994).

Orin is located in Southwestern Nigeria on latitude 7° 49′48.00″N and longitude 5° 14 ′ 24.00″E with an average elevation of 557m (Figure 1). The study area which is a farm settlement has long been plagued with bad roads especially during the rainy season with dry wells during the dry season due to the extensive clay deposits identified in several areas (Adekoya, 1989; Jones, 1990) with several housing units also susceptible to premature collapse. Lateritic clay has been reported from this region and recent studies showed this could be an important ore contributor of Bauxite (Talabi et al, 2013) (Babatunde and Dayo, 2015). Thus, this study aims at using the geophysical exploration approach in investigating the subsurface lithology, identify the depth and thickness of any clay deposit encountered, identify any laterite deposit in the region, build overburden maps and 3D laterite thickness models, make deductions on possible engineering/residential construction scenarios and industrial uses respectively and finally suggest possible areas for groundwater prospecting. The study utilized the Electrical Resistivity method involving the Vertical Electrical Sounding (VES) field technique with the use of the Schlumberger array preferred due to ease of field instrument operation and less unwieldy and more economical data analysis (Ezeh and Ugwu, 2010; Anomohanran, 2011a, b; Atakpo and Ofomola, 2012).

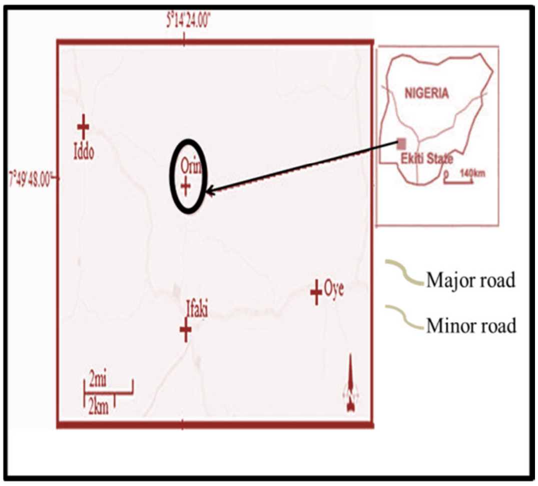


Figure 1: Location Map of Study Area Map data@ Google, 2013)

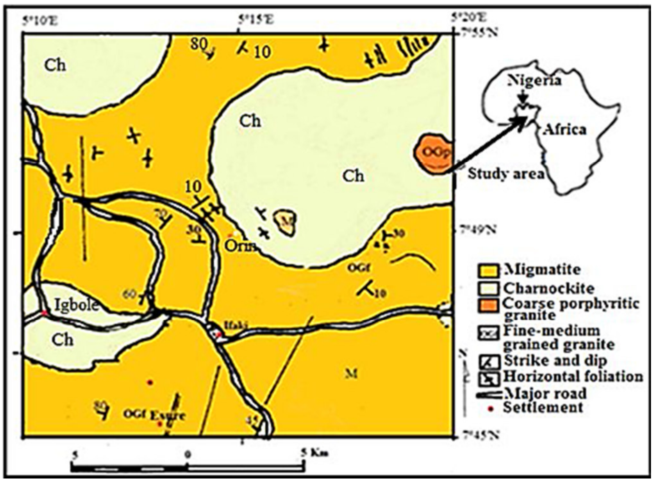


Figure 2: Geology Map of Study Area (Adapted (Modified from from Geological Survey of Nigeria, Akure Sheet 61)

1.1 GEOLOGIC SETTING

The area of study, Orin-Ekiti lies within the Southwestern sector of the Nigeria Basement Complex forming the southern part of the Trans-Saharan mobile belt of Neo-proterozoic (750 - 500Ma) age (Caby, 1989) (Figure 1). The regional geology of Nigeria is characterized by a nearly equal proportion of both sedimentary and crytsalline rocks occurring all over the country (Rahaman and Malomo, 1983; Shitta 2007) with the sediments ranging from Upper Cretaceous to Recent in age while the Basement Complex rocks are of Precambrian age. Basement Complex rocks range from the Migmatite-gneiss complex, Schist belt and younger metasediments and Older granites. In terms of local geology, Orin-Ekiti is underlain by two major lithlogic units namely Migmatites and Charnockites (coarse grained type) with isolated Granites pinpointed in some places. Charnockites covered a greater portion of the area and intruded into the migmatites (Figure 2).

2.0 MATERIALS AND METHODS

This involved two parts namely the field work and laboratory analysis/Interpretation. The Field aspect entailed carrying out measurements in the field using geophysical technique and this was done in January 2017 (Figure 3a).The geophysical technique employed was the Electrical resistivity method which involved the Vertical Electrical sounding (VES) field technique with the use of the Schlumberger array carried out at Orin farm settlement in Orin Ekiti, Southwestern Nigeria. The operational principle involves electrical sounding in which the potential electrodes are fixed and the current electrodes are expanded simultaneously about the center of the spread. Distance between potential electrodes may be increased if electrode distance becomes too large so as to have definite measurable potential difference.

Electrical resistivity methods primarily reflect variation in ground resistivity. Geoelectric layers and lithology contrasts in electric resistivity give adequate information on each geoelectric layer (Dodds and Ivic, 1998; Lashkaripour, 2003). Thus, delineation and identification of various formations (aquaferous, nonaquaferous and lateritic) with reliable geological deductions are made possible.

In principle, the technique involves introducing a current (I) into the ground via a pair of electrodes (A and B) as shown in Figure 3b. This current in turn produces an electrical potential difference between another pair of electrodes (M and N) measured as V with the apparent resistivity (ρ_a) of the subsurface is given by the relation:

$$\rho_a = \frac{AB^2}{MN} \times \frac{V}{R} \qquad (1)$$

Where, V is the potential difference between the pair of electrodes (M and N), R is the transverse resistance, AB is the current electrode separation and MN is the potential electrode separation (Figure 3b).

VES can be greatly increased by making use of a multicore cable to which a number of electrodes are permanently affected at standard separation helping sounding to be rapidly enhanced by switching between different sets of four electrodes. In this technique, the electrodes were normally arranged along a straight line with the potential electrodes placed in between the current electrodes and variations of apparent resistivity with depth are measured. The soundings (six in all) were carried out at locations where there are convenient spaces for maximum spreading of current electrodes. The electrodes were expanded from a minimum current electrode spacing (AB/2) of 1.0 m to a maximum of 55 m. In terms of Instrumentation for this study, the equipment used for apparent resistivity measurement is the ABEM TERRAMETER SAS 300B.Other instruments include metal electrodes, hammers, connecting cables, measuring tapes, cutlass, rope, compass clinometers and a Garmin e-trex Geographic Positioning System (GPS) meter was used in locating the coordinates of the sounding stations. Six different points were located and fully occupied in a systematic manner to cover the area of interest (Figure 3a) with the following GPS coordinates:

VES 1: (Latitude 7° 50′ 491″N Longitude 005° 14 ′ 500″E)
VES 2: (Latitude 7° 50′ 515″N Longitude 005° 14 ′ 515″E)
VES 3: (Latitude 7° 50′ 525″N Longitude 005° 14 ′ 550″E)
VES 4: (Latitude 7° 50′ 540″N Longitude 005° 14 ′ 570″E)
VES 5: (Latitude 7° 50′ 590″N Longitude 005° 14 ′ 595″E)
VES 6: (Latitude 7° 50′ 605″N Longitude 005° 14 ′ 600″E)

Good quality data were obtained with the errors due to observation less than 1%. Preliminary interpretation of field data was done using partial curve matching involving two-layer master curves and the appropriate auxiliary charts to obtain initial model parameters. The final interpretation was carried out by inputting the initial model parameters for iteration. Computer modeling using **WinResist version 1.0** program was used for the iteration to obtain the geoelectrical parameters. Interpretations of VES data were used to generate lateritic layer resistivity and thickness map, and overburden/aquifer unit thickness map using computer software.

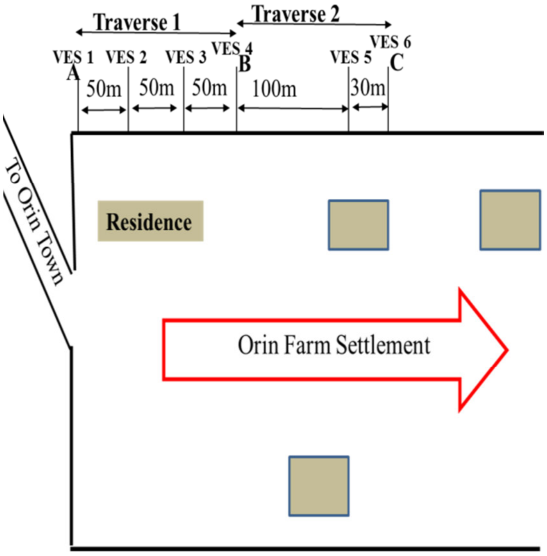


Figure 3a: Location layout of Vertical Electrical Sounding (VES) points

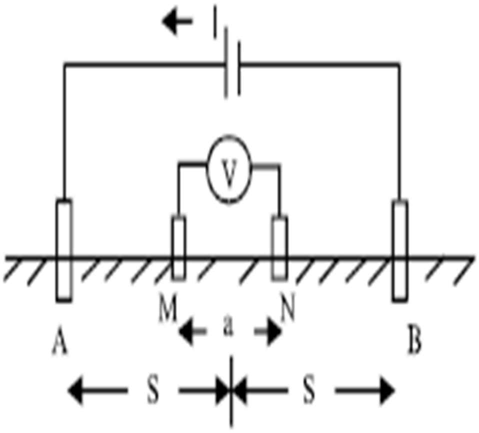


Figure 3b: Sketch diagram of Schlumberger Array configuration

3.0 RESULTS AND DISCUSSION

The field data were interpreted both quantitatively and qualitatively.

3.1 QUANTITATIVE INTERPRETATION

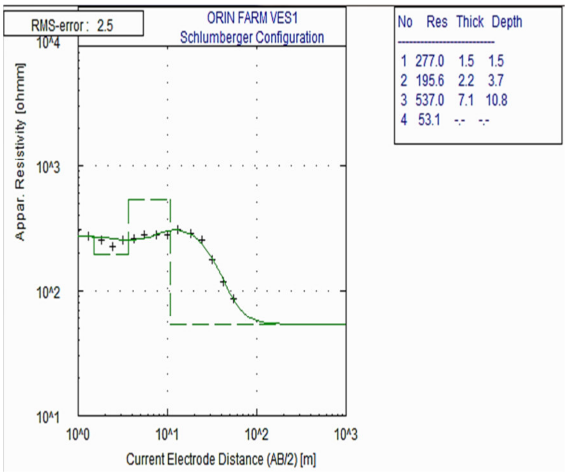
This involved the use of initial model parameters derived using partial curve matching and computer iteration using **WinResist version 1.0** to generate VES curves of apparent resistivity (Ωm) against current electrode spacing (m). Presentation of raw field data is shown in Table 1 with final model parameters derived from quantitative interpretation of the raw field data shown in Table 2.Graphical presentation of the interpretation of field data collected are shown as VES curves in Figures 4 to 9.The VES curves are classified into different types based on layer resistivity observations indicating a typical environment. The interpretation of the sounding curves shows that three curve types exist in the study area namely HK (VES 1), KH (VES 2, VES 3, VES 4) and K (VES 5, VES 6) types. These curves are typical of what is obtainable in basement complex terrains. The KH VES curves is the predominant curve type as it account for 50%, and it is followed by K and HK VES curve types which account for 33 and 17% each. The results of the interpretation reveal two (VES 5 and 6) or three (1, 2, 3 and 4) distinct geoelectrical layers overlying a resistive bedrock.

Table 1: Raw Field data from the Study Area (Orin Farm Settlement)

Current electrode spacing (AB/2)m	APPARENT RESISTIVITY(Ωm)					
	VES 1	VES 2	VES 3	VES 4	VES 5	VES 6
1.0	240.3	94.4	1729.9	1944.6	30.7	212.6
1.3	256.3	110.7	2377.5	2481.5	38.8	259.9
1.8	204.7	139.3	2873.3	3089.3	47.7	276.1
2.4	222.9	166.5	3422.2	3669.7	54.0	263.6
3.2	231.0	198.6	3608.7	3922.2	62.1	306.6
3.2	285.4	218.7	2452.2	3496.9	58.3	244.1
4.2	290.2	258.8	2018.0	3215.2	66.7	273.2
5.5	278.9	314.8	1810.4	3239.5	78.0	313.4
7.5	260.4	384.5	1649.0	2326.0	91.4	315.0
10.0	282.4	433.9	1217.6	1810.1	107.6	308.1
13.0	297.4	410.1	1042.4	1546.4	121.1	296.1
13.0	317.5	373.2	899.4	1491.6	125.2	264.4
18.0	284.5	409.4	633.5	1120.9	132.5	245.5
24.0	255.2	491.9	581.3	846.8	1379.4	221.5
32.0	178.7	660.7	625.7	830.6	156.5	165.8
42.0	117.9	836.3	627.6	862.6	168.2	128.6
55.0	86.8	994.2	650.1	1070.1	154.0	103.4

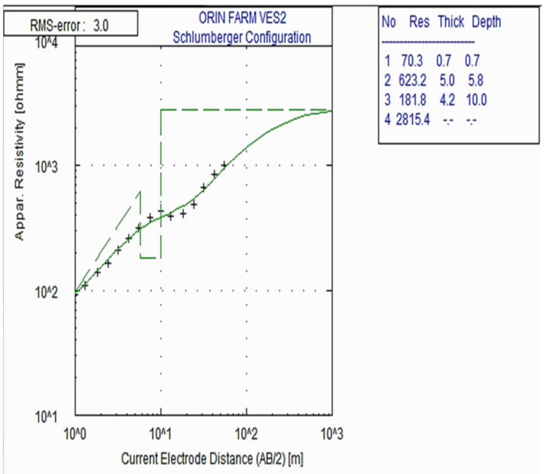
Table 2: Quantitative Interpretation Results (Orin Farm Settlement)

VES NO	Apparent Resistivity (Ωm)(p_1) (p_2)….(p_n)	Depth (m)(d_1) (d_2) …..(d_{n-1})
1	(277); (196); (537); (53)	(1.5); (3.7); (7.1)
2	(70); (623); (182); (2815)	(0.7); (5.7); (9.9)
3	(2127); (4159); (373); (708)	(0.9); (3.1); (9.2)
4	(1586); (4847); (507); (1140)	(0.5); (3.6); (11.0)
5	(35); (199); (108)	(1.6); (12.4)
6	(226); (438); (97)	(1.9); (8.4)



No	Res	Thick	Depth
1	277.0	1.5	1.5
2	195.6	2.2	3.7
3	537.0	7.1	10.8
4	53.1	-.-	-.-

Figure 4: Orin Farm VES curve for location 1



No	Res	Thick	Depth
1	70.3	0.7	0.7
2	623.2	5.0	5.8
3	181.8	4.2	10.0
4	2815.4	-.-	-.-

Figure 5: Orin Farm VES curve for location 2

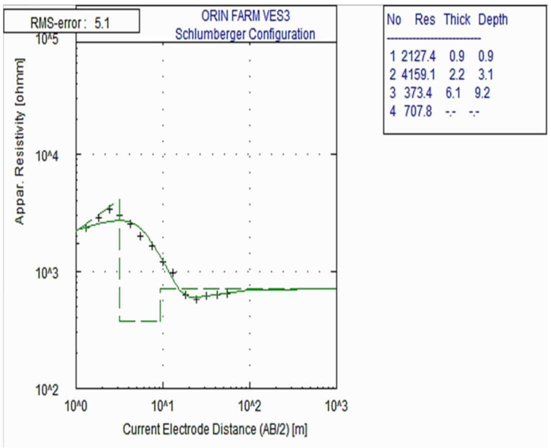


Figure 6: Orin Farm VES curve for location 3

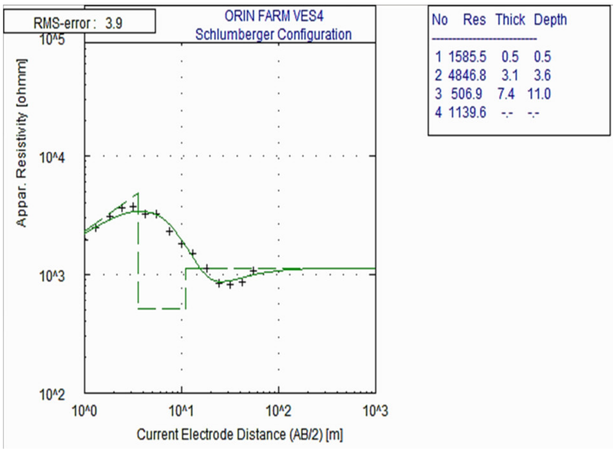


Figure 7: Orin Farm VES curve for location 4

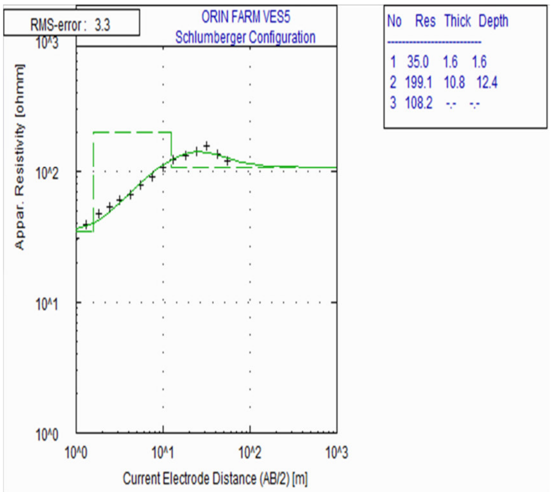


Figure 8: Orin Farm VES curve for location 5

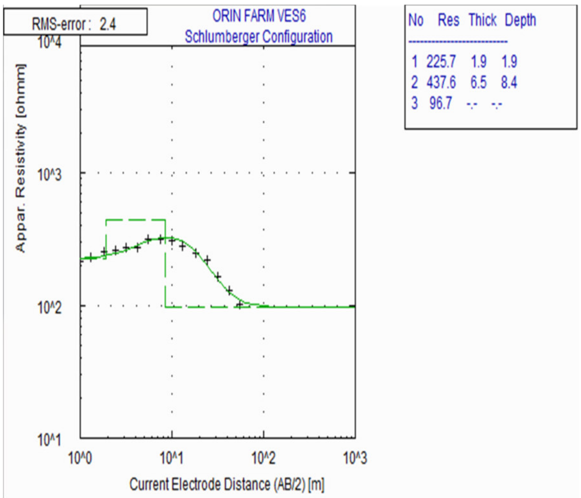


Figure 9: Orin Farm VES curve for location 6

3.2 QUALITATIVE INTERPRETATION (DEDUCTIONS)

This entails the geological interpretation of obtained quantitative data in form of geo-electric sections, 2D Maps, 3D overburden and thickness Models of target lithologies.

3.2.1 GEO-ELECTRIC SECTION

The geo-electric sections were generated using the result of the iterated curves with the apparent resistivity, the thickness of each lithology and the depth of each layer. The disposition of each section/layer mirrored the lithology in subsurface. The geoelectric section revealed the number of layers along each profile line and also their depths and thicknesses. The resisitivity values of each layer are shown on the section. It also help to correlates geoelectric layers and give the two dimensional view of the subsurface thereby given a better image of the subsurface (Figure 10).

The VES curve type is predominantly the HK, KH and K – types. The HK (Figure 4) and KH (Figures 5 to 7) - types show a system of four geo-electric layers of the topsoil, sandy clay, compacted lateritic clay, weathered basement and fractured basement while the K (Figures 8 and 9) - type showed three geo-electric layers of the topsoil, compacted lateritic clay and weathered basement. A summary of distinct geoelectric layers, accompanying resistivities, thicknesses, depths, curve types and probable lithology is given in Table 3.

Descriptionally, the geoelectric section along the traverse line AB (Figure 10) which comprise of VES 1, 2, 3 and 4 revealed that the line is made up of four layers at all VES points while the section along traverse line BC revealed three layers at VES 5 and VES 6. The first layer is a topsoil layer which is well compacted in some areas due to high resistivity values obtained at such points except for VES 2 where the resistivity value decreases significantly compare to other while at VES 3, there is also a significant increase in the resistivity value of the topsoil. The resistivity value of the top layer ranges from 35 to 2127 Ωm with average resistivity of 1015 Ωm, average thickness of about 0.9 m along traverse AB (Figure 10) while resistivity ranges from 36 Ωm to 1586 Ωm averaging 629 Ωm with average thickness of 1.3m along traverse BC (Figure 11). The high resistivity value obtained for the topsoil here may be due to compaction and dryness of the topsoil as a result of high evaporation rate. In VES 1, the topsoil is underlain by a layer that has a resistivity value different from others which may be as a result of degree of weathering around the area. This layer is interpreted as sandy clay due to its resistivity value, absent in other VES points and has a thickness of about 2.2 m with a resistivity value of 196 Ωm. Underlying the topsoil in other VES points; a geoelectrical equivalent of the third layer in VES 1 is the compacted lateritic layer or lateritic hardpan. This layer is interpreted as a compacted lateritic layer/lateritic hardpan because of the increased resistivity values observed here. The resistivity value of this layer ranges from 537 Ωm (VES 1) to 4847 Ωm (VES 4) with an average resistivity of 1800/2541 Ωm, average thickness of about 4.35m along traverse AB while a resistivity range of 199 Ωm to 4847 Ωm, average resistivity of 1828 Ωm and average thickness of 6.8m is obtained along traverse BC. This is part of weathered layer but the level of weathering here is high and the layer has been oxidized to give it the lateritic characteristic and has also gone through some level of compaction which gave it the elevated resistivity value. ,

Underlying the compacted lateritic layer is a layer with average thickness and resistivity of about 5.9m and 279Ωm along traverse AB (Figure 10) while along traverse BC (Figure 11), no determinable thickness is observed which is as a result of the electrode spread length on those points and is interpreted as weathered basement which ranged from clayey to clayey sand depending on the degree of weathering that the parent rock must have undergone with varying resistivity values ranging from 53 Ωm (VES 1) to 507 Ωm (VES 4) along traverse AB, 96Ωm (VES 6) to 507Ωm (VES 4) along traverse BC, observed. This weathered basement is the last layer of the geophysical-spread length-covered area in VES 1, VES 5 and VES 6 (Figure 11). The last layer on the geosection (traverse AB) is the fresh basement (VES 2) with a resistivity value of 2815 Ωm and fractured basement (VES 3 and VES 4) (Figure 10) with an average resistivity value of 1550 Ωm because of its resistivity value, although Olayinka and Olorunfemi (1992), has argued that the basement resistivity values that exceed 1000Ωm is of fresh bedrock but where the resistivity values are less than 1000Ωm, the bedrock is fractured and saturated with freshwater but experience in drilling which is a confirmatory tool has shown that the elevated resistivity sometimes does not mean the basement is completely fresh.

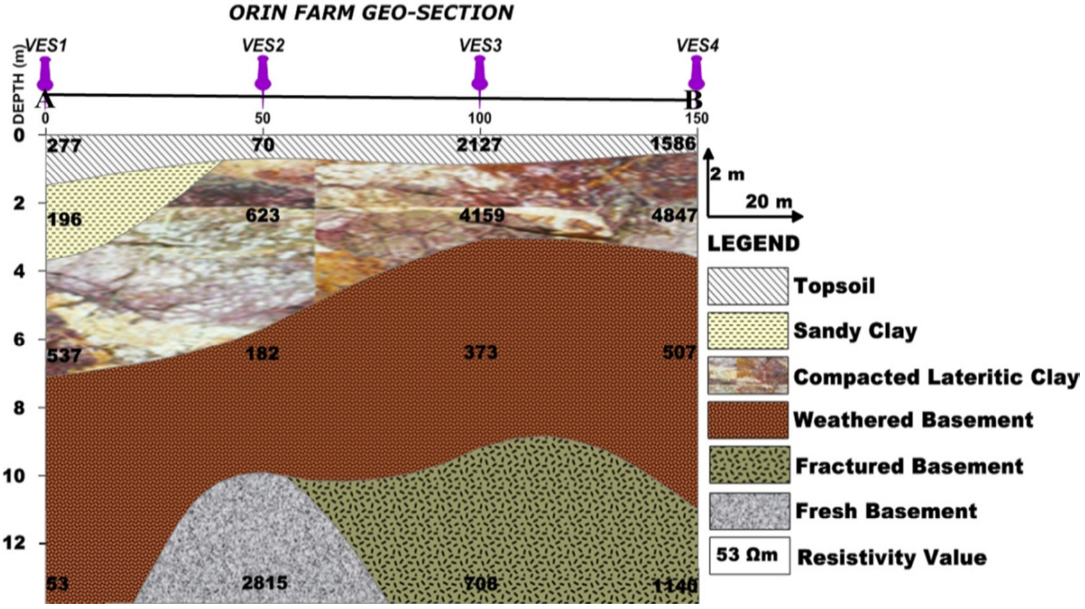


Figure 10: Orin Farm Geo-electric section through VES 1 to VES 4 equidistant at 50metres

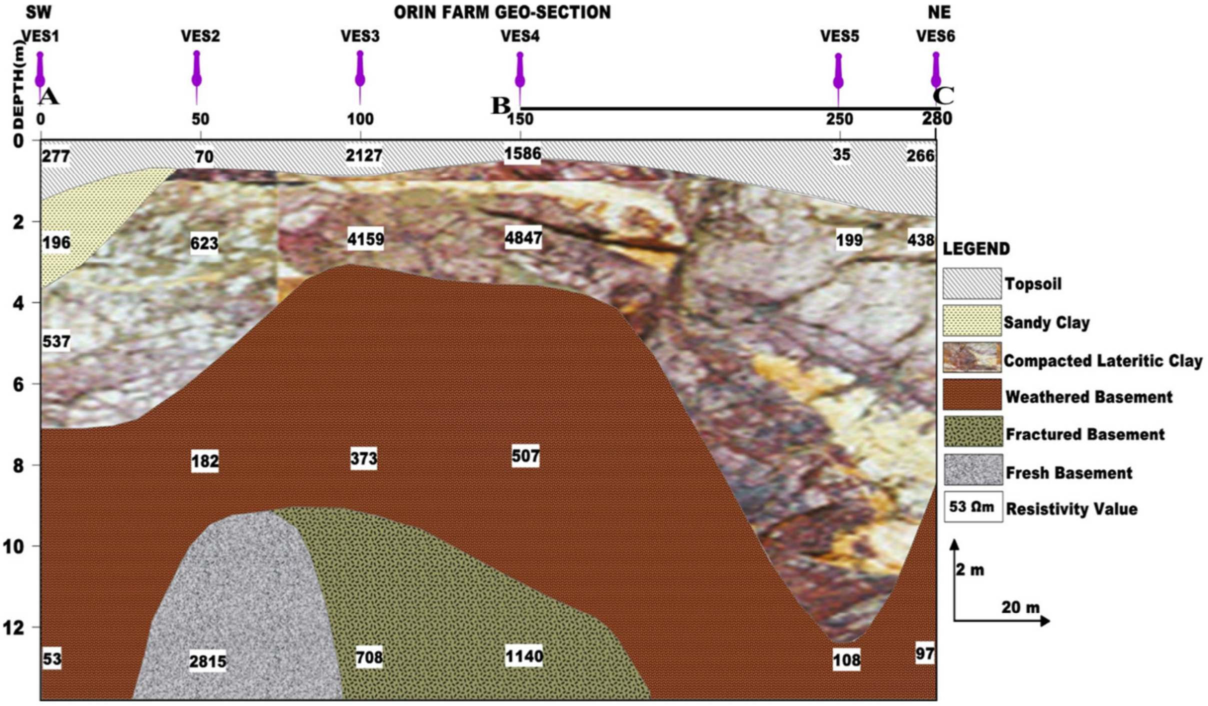


Figure 11: Orin Farm Geo-electric section through VES 1 to VES 6

TABLE 3: Orin Farm Interpreted Resistivity Result for Vertical Electrical Sounding VES

VES NO	*LAYER*	*RESISTIVITY (ohms-m)*	*LAYER THICKNESS (m)*	*DEPTH (m)*	*CURVE TYPES*	*PROBABLE LITHOLOGY*
VES 1	1	277	1.5	1.5	HK	Topsoil
	2	196	2.2	3.7		Sandy Clay
	3	537	7.1	7.1		Compacted Lateritic Clay/Hardpan
	4	53	-	-		Weathered Basement (Clayey)
VES 2	1	70	0.7	0.7	KH	Topsoil
	2	623	5.0	5.7		Compacted Lateritic Clay/Hardpan
	3	182	4.2	9.9		Weathered Basement (Clayey sand)
	4	2815	-	-		Fresh Basement
VES 3	1	2127	0.9	0.9	KH	Topsoil
	2	4159	2.2	3.1		Compacted Lateritic Clay/Hardpan
	3	373	6.1	9.2		Weathered Basement (Clayey sand)
	4	708	-	-		Fractured Basement
VES 4	1	1586	0.5	0.5	KH	Topsoil
	2	4847	3.1	3.6		Compacted Lateritic Clay/Hardpan
	3	507	7.4	11.0		Weathered Basement (Clayey sand)
	4	1140	-	-		Fractured Basement
VES 5	1	35	1.6	1.6	K	Topsoil
	2	199	10.8	12.4		Compacted Lateritic Clay/Hardpan
	3	108	-	-		Weathered Basement (Clayey)
VES 6	1	226	1.9	1.9	K	Topsoil
	2	438	6.5	8.4		Compacted Lateritic Clay/Hardpan
	3	97	-	-		Weathered Basement (Clayey)

3.3 IMPLICATIONS AND POSSIBLE APPLICATIONS

3.3.1 LATERITE POTENTIAL

Figures 12 and 14 show the contour maps of the laterite resistivity and thickness across the area investigated respectively. The resistivity values of the lateritic hardpan vary between 199 Ωm – 4847 Ωm. According to Reynolds (1997), the resistivity value of laterite and unaltered lateritic soil is given to be between 120 and 1500 Ωm, but when laterite is compacted and with some clay infillings (lateritic hardpan), the resistivity value can be very high as seen in VES 3 and 4. In VES 1, 2, 5 and 6, the resistivity value of the laterite falls within the range given by Reynold.

The thickness of the lateritic hardpan ranges from 2.2 m in VES 3 to 10.8m in VES 5 which is clearly shown on the 3D model (Figure 15) produced to showcase this. Topographic depressions and ridges are identified on the thickness map (Figure 14). The depressions are characterized by the thin lateritic hardpan as seen in the southeastern part of the 2Dmap/3Dmodel while ridges are noted for thick lateritic hardpan as seen in the extreme northeastern (VES 5 and 6) and the southwestern part (VES 1) of the 3D model (Figures 14 and 15).

Comparing Figures 12 and 14, it can be deduced that most of the areas with thin lateritic hardpan layer correspond with high resistivity values while areas with low lateritic resistivities are areas of that correspond with thick lateritic hardpan layers as shown in Figures 13 and 15.

Consequently, VES 1 (7.1m), VES 5 (10.8m) and VES 6 (6.1m) are good points to start exploring for lateritic soil if the need arises because of the appreciable thickness. Increased electrode spread length would have offered more information on how far deeper the lateritic hardpan extends but appreciable thicknesses noticed in VES 5 and VES 6 offer encouraging proof for the development of brick making industries in that area.

The appreciable thickness could also be of interest for further investigations into bauxite mining. Bauxite bearing lateritic soils has been reported by Talabi et.al (2013) and Babatunde and Dayo, (2015) in Orin – Ekiti. If sufficiently developed, this would further add not only direct employment to the youths of the community but also serve as revenue earner for the state in particular and Nigeria as a whole.

The lateritic hardpan thickness is also appreciable enough in VES 1 (7.1m), VES 5 (10.8m) and VES 6 (6.1m) to help to prevent the groundwater from surface contamination as it can act as a good seal for groundwater whereby it filters all the contaminant from seeping into the aquifer.

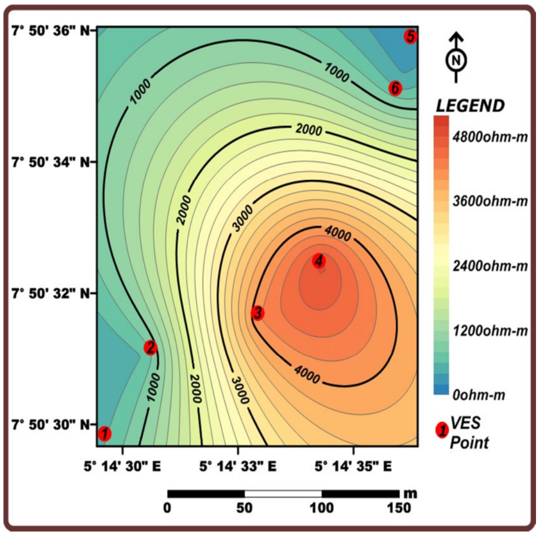


Figure 12: Orin Farm 2D Laterite resistivity Map

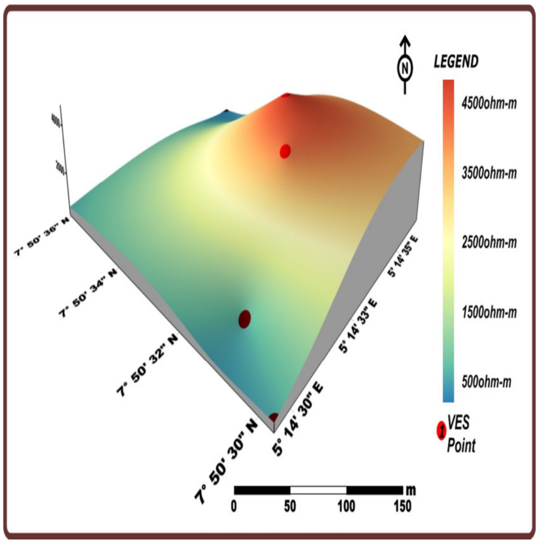


Figure 13: Orin Farm 3D Laterite resistivity Model

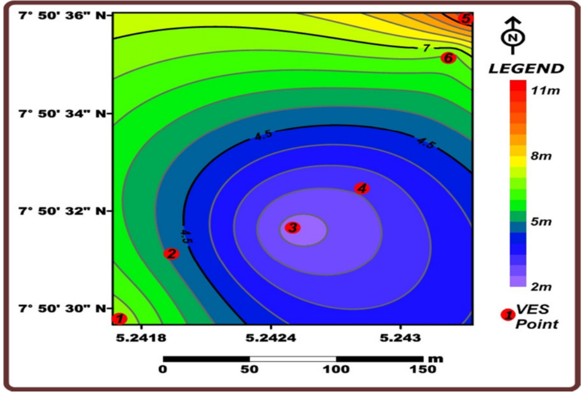


Figure 14: Orin Farm 2D Laterite thickness Map

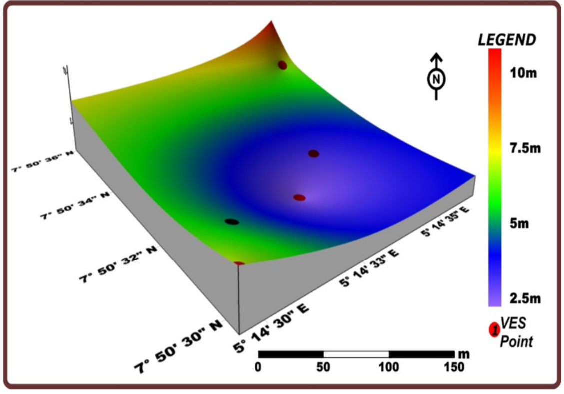


Figure 15: Orin Farm 3D Laterite thickness Model

3.3.2 ENGINEERING CONSTRUCTION PROJECTS

Preliminary geophysical investigation of Orin Clay deposit revealed that apart from the topsoil (maximum thickness of 2m), the second and third layers are lateritic clay and weathered basement (clayey - VES 1, VES 5 and VES 6 and Clayey sand – VES 3 and VES 4) respectively, cutting across the whole area under investigation with a maximum overburden thickness of 12.4m (Tables 2 and 3) for lateritic clay while the clayey weathered basement in VES 5 and VES 6 has undetermined thickness above 12.4m. This deep depth could pose a problem for both building and road construction works especially if the stability and load bearing strength of these subsurface layers cannot be accurately determined. Construction projects in the study area will be better served if adequate knowledge of the geotechnical parameters of samples from the lateritic hardpan layer is obtained because according to Gidigasu, 1976, not all lateritic soils are problem soils as these soils range in performance from excellent to poor for engineering construction purposes. From the obtained geoelectric results, drastic consideration of foundation types that enable the structural load to be transferred to the next strongest load bearing basement (fractured – VES 3 and VES 4 or Fresh – VES 2) like Pile foundation seemed feasible especially if heavy structures/buildings are being considered while road projects will require some sort of soil stabilization of these subsurface layers to improve their strength and durability.

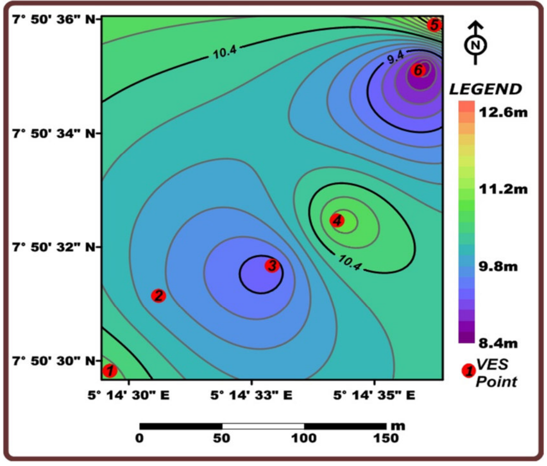


Figure 16: Orin Farm 2D Overburden thickness Map

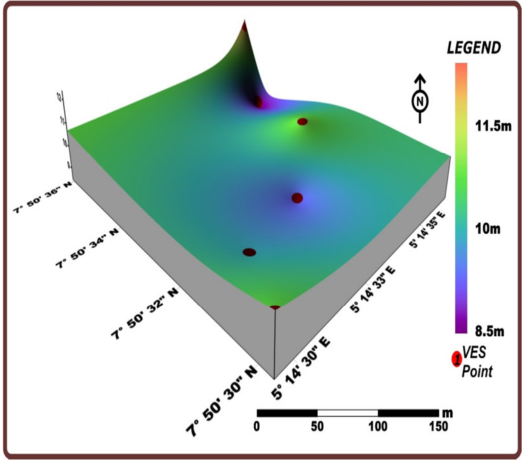


Figure 17: Orin Farm 3D Overburden Model

3.3.3 GROUNDWATER POTENTIAL

Groundwater availability depends on the thickness and lateral extent of the overburden serving as conduits for water to pass through to the saturated zone while groundwater storage is primarily dependent on how porous or permeable the subsurface strata are, which is also a function of the lithology, extent of weathering and fracturing observed in these strata.

In terms of overburden thickness, Figures 16 and 17 showed that VES 1 (7.1m) and VES 6 (12.4m) have the lowest and highest overburden thickness respectively for the study area. The overburden as used in this work includes all material above the presumably fractured/fresh bedrock.

Generally, the overburden is relatively moderate within the study area with average overburden thickness of 10 m. The overburden at the eastern part of the study area is a little thick with average overburden thickness of about 12 m and the southern part of the area has a very shallow overburden thickness compare to other areas (Figures 16 and 17).

The nature and thickness of the weathered layer are important groundwater potential evaluation parameters especially in a basement complex terrain (Clerk, 1985; Bala and Ike, 2001). In terms of groundwater storage capability, most of the VES stations terminated at the weathered basement layer (VES 1,VES 5 and VES 6) with infinity thicknesses while the highest overburden thickness for the preceding layer is 12.6 (VES 6). Here, if saturated can contribute to the yield of groundwater because of its relative thickness. The weathered basement is basically clayey at all three VES stations but extension of electrode spacing length from 55m to above 100m could give better clues on the extent of the weathered basement and may also help pinpoint deeper lithologies (Fractured basement). VES stations with weathered basement of clayey sand composition (VES 3 and VES 4) have layer thicknesses of 6.1m and 7.4 m, overall overburden thickness of 9.2m and 11.0m respectively look encouraging (Table 3). That this layer is underlain by fractured basement of infinity thickness lends strong support to the possibility of good groundwater storage especially if interconnected and permeable. The presence of weathered basement of 4.2 m thickness and fresh basement in VES 2 starting from a depth of 9.9m till infinity reduce the groundwater storage potential at that location (Table 3).

Conclusively, the overburden of the study area is shallow compared to the range given by Olorunfemi and Okhue (1991), Dan-Hassan and Olorunfemi (1999) and Omosuyi et.al, (2003). The groundwater abstraction from the weathered (clayey sand) and the fractured zone may be feasible in the investigated area but better yield may be encountered around the portion where the overburden is relatively thick which is the eastern/extreme northeastern part of the area.

4.0 CONCLUSION AND RECOMMENDATION

Preliminary geophysical investigation of Orin Clay deposit was carried out using the Vertical Electrical Sounding (VES) technique of the Electrical Resistivity method in Orin Farm Settlement, Orin – Ekiti, Southwestern Nigeria with the aim of investigating the subsurface lithology, identify the depth and thickness of any clay deposit encountered, identify any laterite deposit in the region, build overburden maps and 3D laterite thickness models, make deductions on possible engineering/residential construction scenarios and industrial uses respectively and finally suggest possible areas for groundwater prospecting. A total of six VES points were sounded with computer iteration results interpreted both quantitatively and quantitatively. Quantitative interpretation of VES curves revealed three curve types namely the HK, KH and K - types which typify basement terrain of southwestern Nigeria and three to four geoelectric layers. Qualitative interpretation using the geoelectric section, 2D maps and 3D models revealed the subsurface lithology of the study area to be relatively homogenous across all VES points with topsoil (VES 1 – VES 6), sandy clay (VES 1) or lateritic clay/hardpan (VES 2 – VES 6), weathered basement (VES 1 - VES 6), Fractured basement (VES 2 - VES 4) and Fresh basement (VES 2) delineating the probable lithologies in the study area. The lateritic clay/hardpan layer showed variable thickness along traverse AB (7.1m, 5.0m, 2.2m, 7.4m) and decreasing thickness along traverse BC (10.4, 6.1m) indicating a potential not only as a raw material for clay firing industries but also as a potential ore source for bauxite which has been reported by some authors who worked in Orin (Talabi et al, 2013). The weathered basement layer has both clayey (K and HK curves) and clayey sand (KH curve) portions with undetermined/infinity thicknesses in several VES stations (VES 1,VES 5 and VES 6) and the clayey portions having the thickest overburden (VES 6). Fractured basement exist in VES 3 and VES 4 with undetermined/infinity thickness. In terms of groundwater potential, VES 6 (minimum thickest overburden), VES 3 (clayey sand composition and existence of fractured basement) and VES 4 (overburden thickness, clayey sand composition and existence of fractured basement) offer preliminary promising results. The existence of a lateritic hardpan above the weathered and fractured basement layers could provide natural seals to prevent groundwater contamination. However, the depths of the lateritic hardpan (maximum thickness of 12m) could affect construction projects in the area if the geotechnical parameters indicate a low load bearing strength and stability.

This is a preliminary study and i would recommend a comprehensive geotechnical study of the lateritic clay deposits in Orin Farm Settlement to enable determine their suitability for engineering projects. I would also recommend that other studies using increased electrode spread lengths greater than 55m be carried out to determine the full extent of the weathered and fractured basement layers with a view to obtaining a more detailed picture of the groundwater potential especially around VES 3 – VES 6.

REFERENCES

Adekoya, J.A. (1989). Geological Study of Orin Clay Deposit. Unpublished Technical report of the Federal University of Technology, Akure

Ajayi J.O & Agagu O.K. (1981). Mineralogy of primary clay deposits in the basement complex areas of Nigeria. J. Min. Geol. 18(1): 27-30.

Anomohanran, O. (2011). Underground water exploration of Oleh, Nigeria using the electrical resistivity method. Scientific Res. Essays, 6: 4295-4300.

Anomohanran, O. (2011). Determination of groundwater potential in Asaba, Nigeria using surface geoelectric sounding. Int. J. Physical Sci., 6: 7651-7656

Atakpo, E. & Ofomola, M.O. (2012). Hydrogeological investigation using vertical electrical sounding method in Agbarha Otor, Delta State Nigeria. Nig. J. Sci. Environ., 11: 95-103.

Bala A.E & Ike E.C. (2001). The aquifer of the crystalline basement rocks In Gusau area, Northwestern Nigeria. J. Min. Geol. 37 (2): 177-184.

Jones, B. (1990). Geological Study of Orin Area. An unpublished Technical Report by Geological Consultancy Firm, Ibadan. Southwestern Nigeria

Caby, R. (1989). Precambrian terranes of the Benin-Nigeria and Northeast Brazil and the late Proterozoic South Atlantic fit. Geological Society of America Special Paper, 230, 145-158.

Clerk, L. (1985). Groundwater Abstraction from Basement Complex Areas of Africa. J. Eng. Geol., London 18: 25-34

Dan-Hassan,M.A & Olorunfemi M.O. (1999). Hydro-geophysical investigation of a basement terrain in the north central part of the Kaduna state, Nigeria. J. Min. G.ol., 35(2): 189-206.

Dodds, A.R & Ivic D. (1988). Integrated Geophysical Methods Used for Groundwater Studies in the Murray Basin, South Australia. In: Geotechnical and Environmental Studies. Geophysics, Vol. II. Soc. Explor Geophys. Tulsa, OK. pp. 303-310

Elueze, A.A & Bolarinwa, A.T. (1994). Assessment of functional applications of lateritic clay bodies in Ekiti Evirons,Southwestern Nigeria.Journal of Mining and Geology Vol.31(1), pp 79-87

Elueze, A.A & Bolarinwa, A.T. (2001). Appraisal of the residual and sedimentary clays in parts of Abeokuta area, Southwestern Nigeria.J. Min. Geol. 37(1): 7-14.

Ezeh, C.C. and Ugwu, G.Z. (2010). Geoelectrical sounding for estimating groundwater potential in Nsukka L.G.A. Enugu State, Nigeria. Int. J. Phys. Sci., 5: 415-420.

Gidigasu, M. D. (1976). Laterite Soil Engineering Pedo-Genesis and Engineering Principles," Amsterdam Elsevier Scientific, New York, 1976, p. 554.

Lashkarripour, G.R. (2003). An investigation of Groundwater Condition by Geoelectrical resistivity Method: A

Case study in Korin Aquifer, Southeast, Iran. Journal of Spacial Hydrology. 3(1): 1-5

Olayinka A.I & Olorunfemi M.O. (1992). Determination of geoelectrical Characteristic in Okene Area and implication for boreholes setting. J. Min. Geol., 28: 403-412

Olorunfemi M.O & Okhue E.J. (1992). Hyrogeologic and Geologic significance of a Geoelectric Survey at Ile–Ife, Nig. J. Min Geol. 28:242-350

Omosuyi, G.O, Ojo, J.S & Enikanselu, P.A. (2003). Geophysical Investigation for Groundwater around Obanla – Obakekere in Akure Area within the Basement complex of South-Western Nigeria. J. Min Geol. 39(2):109 – 116

Olorunfemi, M.O & Olorunniwo, M.A. (1990). The determination of the geoelectric parameters of some Nigerian residual and detrital clays. Journal of Mining and Geology, Vol.26, No.1, pp 81-84.

Rahaman, M. A & Malomo, S. (1983). “Sedimentary and Crystalline Rocks of Nigeria”, in “Tropical soils of Nigeria in engineering practice”, edited by S. A. Ola, A.A. Balkema/Rotterdam, Pp. 17-38.

Reynolds, J.M. (1997). *An Introduction to Applied and Environmental Geophysics*, John Wiley and Sons Ltd, Chichester, 796 pp, first edition.

Shitta, K. A. (2007). “Lithostratigraphy of Nigeria–an overview”, Proceedings of 32nd workshop on Geothermal Reservoir Engineering, Stanford University - Stanford, California, Pp.1–9.