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Lithological Delineation in Parts of Asa Local Government Area, Southwestern, Nigeria Using Geophysical Approach

O. Ologe[1] and J. A. Sunday[2]

[1]Department of Chemical and Geological Sciences, Al-Hikmah University, Ilorin, Nigeria
[2]Department of Science Laboratory Technology, Kwara State Polytechnic, Ilorin, Nigeria

Abstract

Lithological delineation from geophysical survey in Part of Asa Local Government area, Southwestern Nigeria was carried out as part of efforts aimed at providing background information on the subsurface lithologies underlain the area. Eleven Vertical Electrical soundings (VES) were carried out across the area using the Schlumberger electrode array configuration, with half-current electrode separation (AB/2) varying from 1m to 40m. The resistivity data acquired was processed using computer iteration software IP2WIN. The geoelectric sections obtained from the sounding curves revealed 2-layer, 3-layer and 4-layer earth models respectively. The 3-layer and 4-layer models show the subsurface layers are categorized into the top soil/laterites, sandy clay, the weathered basement and the fresh basements. The topsoil apparent resistivity and thickness ranges from 559-2070 Ωm and from 0.5–2.49 m respectively. The second layer is the sandy clay which has a resistivity and thickness ranging from 6.59–3257 Ωm and 0.164–12.4 m while the weathered basement which has a resistivity and thickness ranges from 20.1-1083 Ωm and 7.53–12.8 m. The fourth layer is the fresh basement of varying resistivity of 1036- 4894Ωm. The depth to basement in the study area varies from 7.95-14.67m. On the basis of the geoelectric parameters, it will guide efficiently subsequent groundwater drilling program and geotechnical study in the area.

Keywords: Geoelectric parameters, weathered basement, sounding curves, current electrodes, lithology

1.0 Introduction

Lithological delineation is an important tool in providing background information in groundwater exploration and geotechnical studies. The importance of water is well established and according to [1], water is one of the most valuable natural resource vital to the existence of any form of life. Water is used by man for his various activities which includes domestics, industrial and agriculture etc. For these activities, man requires fresh water. Ground water is the water located beneath the ground surface in the soil pore spaces and in the fractures, it accounts for the greatest percentage of domestic and industrial water and respectively especially in developed countries [2].

Geophysical survey are efficient and cost effective in providing subsurface information since it combines high speed and appreciable accuracy in providing subsurface information over large areas [3]. In groundwater exploration, a lithological assessment is carried out to locate a suitable point or aquifer where viable borehole should be drilled for groundwater abstraction [4]. In geotechnical studies, subsurface lithologies is relevant in foundation studies as this is used in building construction to determine depth to competent layer and to detect the presence of clay. More so, in road construction, the presence of clay (swelling clay) may be undesirable as it causes differential settlement and is often associated with persistent failure.

According to [5], the geological factor influencing road failures includes the nature of the soil (laterite) and the near surface geologic sequence, hence there is therefore the need to provide information on the number of layer and litholgical units of the study area such information will be used in both groundwater and geotechnical studies.

Corresponding author: O. Ologe, E-mail: toyin.ologe@gmail.com , Tel.: +2348168101379, 8053376808(J.A.S)

2.0 The Study Area

The study area lies within latitude 8º15'N and 8º45'N and longitude 4º15E and 4º45 E and is accessible by road from the north through (Figure 1). This area fall within the transitional climate zone of Nigeria average daily temperature ranges between 26.28 ºand 31.95ºC. There are two distinctive season namely the Rainy season (March to October) and the dry season October to February [6]. The raining season is characterized by high rain fall with an annual rain fall of high 1237 millimeter [7]. The vegetation is characterized by shrubs and scattered little grasses and drained by several river namely River Asa, River ogun, River oyun, River Busamu and River imotu. The drainage pattern is generally dendrites and the drainage is structural controlled.

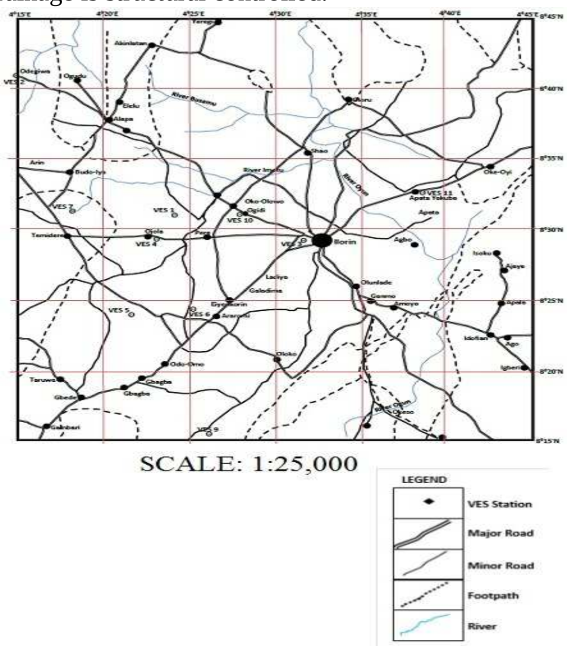

Figure 1: Digitized Map of the Study Area with VES Locations (Modified after [8])

3.0 Geology of Nigeria

The Geology of Nigeria according to [9] is made up of three major geological components: 1) Basement Complex which is Precambrian in age (>+600 million years), 2) Younger Granites i.e. Jurassic (200 -145 million years) and 3) Sedimentary Basins i.e. Cretaceous to Recent (<145 million years). Nearly one half of the country is underlain by basement complex including the younger granite while the other half comprises of the sedimentary terrain **[**10**].** The basement complex of Nigeria forms a part of the Pan-African mobile belt and lies between the West African and Congo cratons and south of the Tuareg shield [11]. It is intruded by the Mesozoic calc-alkaline ring complexes (younger granites) of the Jos plateau and is unconformably overlain by Cretaceous and younger sediments. The Nigeria basement complex according to [12,13 and 14] consists of the following main groups of rocks: 1) Migmatite-Gneiss Complex (migmatites, gneisses, granite-gneisses), 2) Metasedimentary and Metavolcanic rocks (phylites, schists, pelites, quartzites, marbles, amphibolites), 3) Older Granites (granites, granodiorites, syenites, monzonites, gabbro, charnockites) and 4) Undeformed Acid and Basic Dykes (muscovite-, tourmaline- and beryl-bearing pegmatites, applites and syenite dykes; basaltic, doleritic and lampropyricdykes).

4.0 Geology of the Study Area

The study area (Asa, South-western, Nigeria) consists mainly of basement complex rocks of the older granite type and also the undifferentiated types [15]. These rocks in this region have been greatly weathered. This weathered basement formed good aquifer for underground water. The study area is dominantly underlained by migmatite, other rock types include medium-coarse grained granite gneiss which is located North-east of the study area (Figure 2). The migmatite gneisses were trending south-west of the mapped area. Most of the mapped migmatite gneiss occurs as low-lying outcrop ranging in textural characteristics from medium to coarse-grained with mafic and mostly felsic bands.

Field observations at the time of mapping revealed that the lithology is the Granite gneiss and migmatite rocks types. The bedrock occurs as outcrops and boulders within the study locations. The outcrops presents are mainly low-lied from the ground surface. A characteristic feature of the Basement Complex tectonics is the widespread occurrence of fractures [16]. Thus, varieties of structural features such as foliations, folds, faults, joints, fractures and fissures exist in the Basement Complex environment [17].

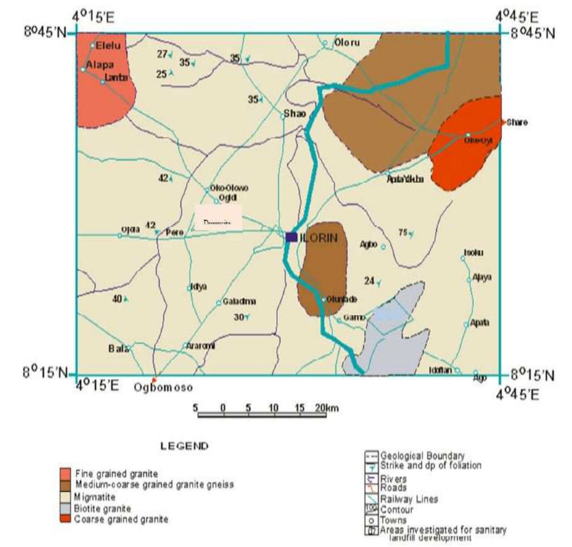

Figure 2: Geological map of the study area (Modified after [8])

5.0 Data Acquisition and Analysis

The Vertical Electrical Sounding (VES) was conducted using the Schlumberger electrode array [18]. The Terrameter SAS 1000 was used for resistance measurements. In all, eleven (11) soundings were conducted, with maximum half-current electrode spacing (AB/2) of 40m. The field curves were interpreted through partial curve matching with the help of master curves and auxiliary point charts. From the preliminary interpretation, initial estimates of the resistivity and thickness of the various geoelectric layers at each VES location were obtained. These geoelectric parameters (see appendix) were later used as a starting model for a fast computer-assisted interpretation [19]. The algorithm takes the manually derived parameters as the starting geoelectric model, successively improved on it until the error is minimized to an acceptable level.

6.0 Discussion of Results

A total of eleven (11) vertical electrical sounding (VES) stations were occupied as part of the geophysical survey to assess the lithology of the study area. The Table in the appendix shows the summary of resistivity data obtained from the study area. The VES data were inverted using software IP2Win.1D curves generated from the inversion of the field data are presented in Figures 3.1 and 3.2. The geoelectric parameters obtained from the resistivity data were contoured to generate 2D iso-resistivity map for each of the layers delineated (Figures 3.4 and 3.6). Also, the depth to basement obtained from the 1D inversion was also contoured to obtain a basement relief map presented in Figure 3.7.

7.0 Resistivity Sounding Curves and Geoelectric Sections

The resistivity sounding curves obtained from the surveyed area vary from 3-layer (A type) to 4-layer (HQ and AH types) as shown in Figure 3.1 and 3.2. The 2-D view of the geoelectric parameters (resistivity and depth) obtained from the inversion of the electrical resistivity sounding data is presented as geo-electric sections.

Figure 3.3 is a geoelectric section drawn through VES locations 1-11 in the West to East direction shows these geoelectric layers. The top soil, which is relatively thin, is characterized by resistivity values between 43 Ohm-m and 670 Ohm-m and thickness values between 0.4m and 1m. Based on the resistivity values, the top soil can be attributed to be lateritic unit at shallow depth. Beneath the top soil layer, the profile reflects a layer identified as sandy clay characterized by resistivity values between 58 Ohm-m and 326 Ohm-m and thickness ranging from 9.9m and 12.7m respectively. The underlying bedrock with resistivity values of 559 Ohm-m at VES 5 is diagnostic of fractured basement. This indicates that the location is suitable for sitting bore hole in the area. The basal unit with resistivty values ranging from 2036 Ohm-m to 2726 Ohm-m is identified as the fresh bedrock along the section.

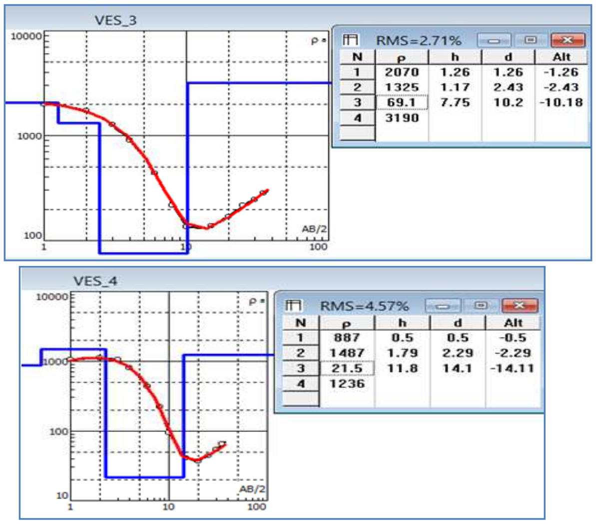

Figure 3.1: Sounding curves for VES1 and VES2

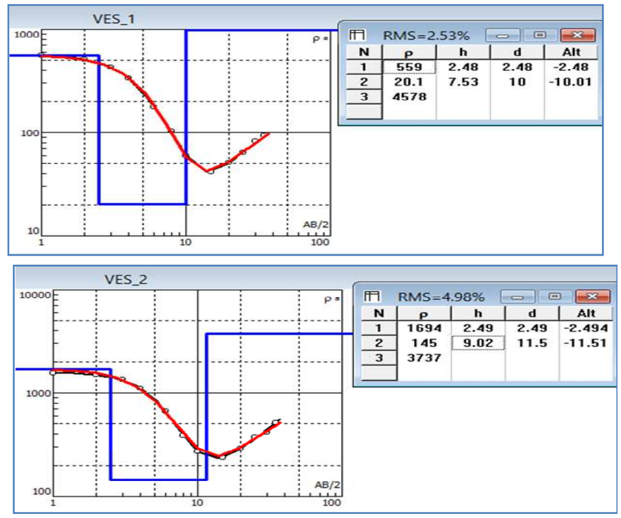

Figure 3.2: Sounding curves for VES3 and VES4

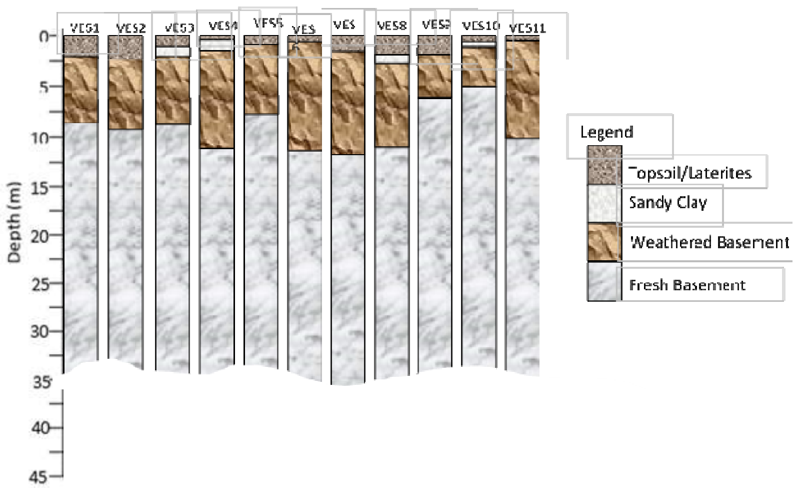

Figure 3.3: Lithological Section for VES1-VES11

8.0 Contoured Map (2D Model)

The 2D Iso resistivity map of the first layer shows that resistivity is higher in the northwest and southeast part of the study area while a relatively lower resistivity is obtained in the northeast and southwest of the study area (Figure 3.4). From this resistivity distribution in the first layer, the northwest and southeast part of the study area are covered by laterite at the surface while the northeast and southwest of the study area covered by topsoil composed of loose sediment mixed with organic matter. Isoresistivity map of the weathered basement is presented in Figure 3.5.The resistivity in this layer is intermediate which is presumed to be a saturated zone. Hence, this layer is considered suitable for groundwater exploitation. The Iso-resistivity map of the fresh basement (fourth layer) shows that basement is highly resistive except at the southwestern part of the study area (Figure. 3.6). This is probably due to absence of fractures which is having the capacity of storing water and consequently reducing resistivity. Also, the basement relief map shows that the depth to basement is lower in the northeast and southwest while the depth to basement is higher in the northwest through the central portion to southeast part of the study area (Figure. 3.7).

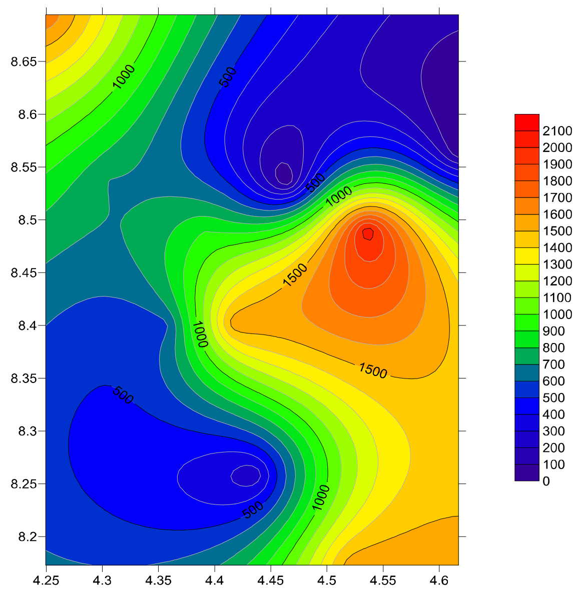

Figure 3.4: Iso resistivity Map of the Top Layer

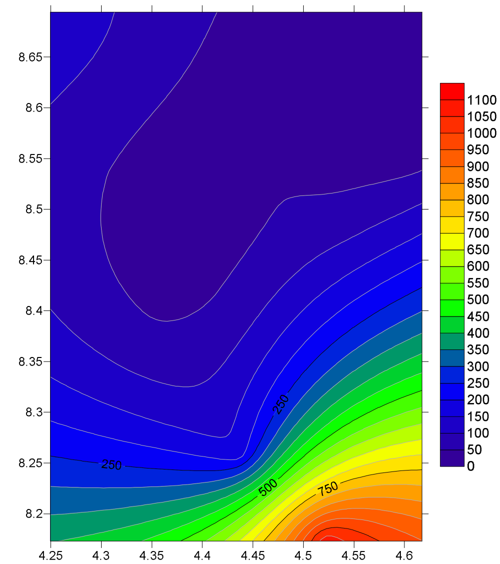

Figure 3.5: Iso resistivity Map of the Weathered Basement

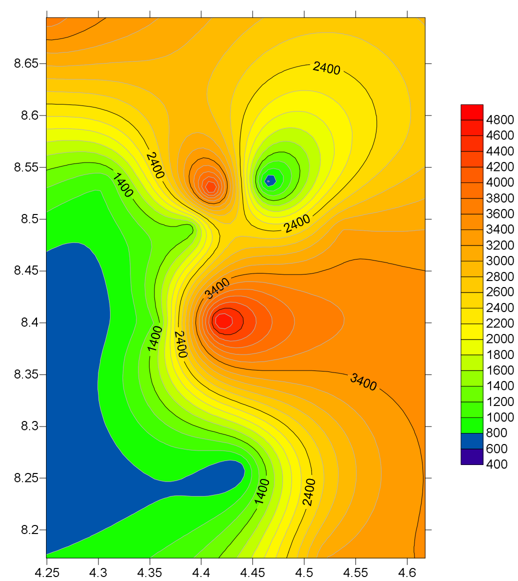

Figure 3.6: Iso resistivity Map of the Fresh Basement

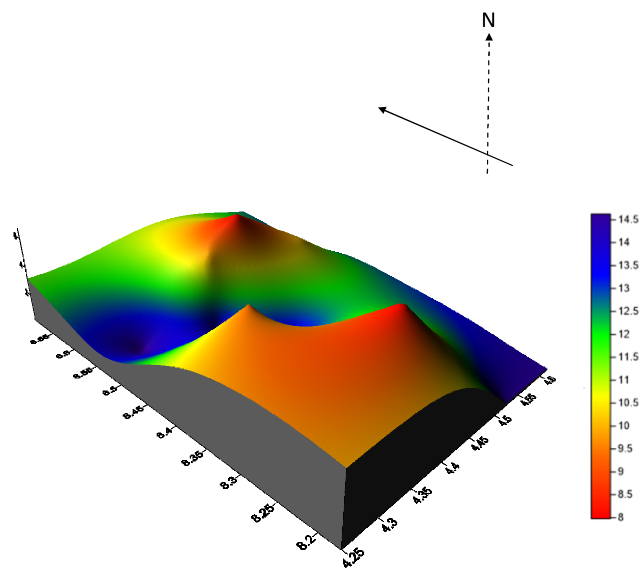

Figure 3.7: 3D Basement Relief Map

9.0 Conclusion

The critical idea of deploying electrical resistivity method of vertical electric sounding (VES) in this study was to characterize subsurface layers and being able to delineate subsurface structures i.e. faults/fracture zones. Noting that the weathered layer and weathered/fractured bedrock constitute the aquifer units in the study area, eleven VES data with Schlumberger electrode configuration acquired from the study area were interpreted and their sounding curves show three layer and four layer earth models. The interpreted subsurface layers include the top soil, weathered layer (which are clayey in some locations), weathered/fractured basement and fresh basement. Considering the result of the VES interpretation, the groundwater potential zonation presented here can be applied only for local studies for the purpose of groundwater development, providing quick prospective guides for groundwater exploration and exploitation in such crystalline basement settings, while individual site selection for groundwater development should take into consideration other site-specific conventional ground-truthing methods.

10.0 Reference

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11.0 Appendix:

Summary of Resistivity Data obtained in the Study Area

AB/2 (m)	MN/2 (m)	VES1	VES2	VES3	VES4	VES5	VES6
		8^{0}31'46.17"N4º 24'35.23"E	8^{0}41'39.81"N4^0 14'58.51"E	8^{0}29'29"N, 4^{0}32'09"E	8^{0}29'32.53"N4^0 23'23.39"E	8^{0}23'59.59"N 4^{0}21'23.23"E	8^{0}24'6.84"N, 4^{0}25'2.58"E
		ρ (Ωm)	ρ (Ωm)	ρ (Ωm)	ρ (Ωm)	ρ (Ωm)	ρ (Ωm)
1	0.5	736.9	1538.8	2000.6	970	488.80	1734.90
2	0.5	514.76	1495.65	1858.14	1260.98	512.74	1621.36
3	0.5	355.7	1431.31	1455.08	1112.91	399.03	1499.52
4	0.5	267.07	1200.63	806.27	612.26	177.66	1216.67
6	1.0	176.15	667.6	373.3	475.91	101.10	606.92
8	1.0	110.24	349.35	209.58	227.99	70.04	214.79
10	1.0	68.8	270.8	172	81	50.80	95.60
15	2.5	39.97	235.62	129.17	45.54	62.76	67.28
20	2.5	36.55	257.06	153.52	34.83	94.31	87.85
25	2.5	50.25	342.25	203.3	43.94	131.00	115.99
30	2.5	97.68	407.48	265.43	50.81	211.11	
35	2.5	121.15	564.52	338.64	65.5	317.45	
40	2.5				95	440.00	

AB/2 (m)	MN/2 (m)	VES7	VES8	VES9	VES10	VES11
		$8^0$32'12.99"N4^{0}18'21.99"E	**$8^0$10'23.17"N 4^{0}31'18.21"E**	**$8^0$15'31.18"N 4^{0}26'8.12"E**	**$8^0$32'10.18"N 4^{0}27'51.12"E**	**$8^0$33'51.18"N4^{0}37'2.12"E**
		ρ (Ωm)	**ρ (Ωm)**	**ρ (Ωm)**	**ρ (Ωm)**	**ρ (Ωm)**
1	0.5	740.00	1394.00	353.00	29.22	33.35
2	0.5	592.58	1359.99	309.30	120.01	53.45
3	0.5	435.43	1171.33	261.68	110.37	50.32
4	0.5	293.24	759.36	207.02	94.92	43.18
6	1.0	215.85	316.10	142.86	91.73	35.73
6	1.0			87.52	23.60	34.32
8	1.0	136.33	106.88	63.80	17.33	27.23
10	1.0	68.50	77.00	52.51	26.83	26.36
10	2.5			58.72	82.46	29.10
15	2.5	56.27	78.67	77.37	108.78	30.87
20	2.5	79.56	88.59	119.07	142.84	30.87
25	2.5	108.01	121.55	179.17	200.07	34.84
30	2.5	130.60		173.43	252.25	30.03
35	2.5	142.78	171.63		244.57	27.13
40	2.5		227.15			37.89