Subsurface Stratigraphic Mapping using the D.C. Electrical Resistivity around Shika, Kaduna State, Nigeria.

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ABSTRACT

Geophysical investigation for foundation studies was carried out around Bajimi, which falls within the Basement Complex of North-Western Nigeria. The study is aimed at evaluating the competence of the near surface formation as foundation materials, and to unravel the subsurface profile which in turn determines if there would be any subsurface lithological variation(s) that might lead to structural failure at a new site.

Vertical Electrical Sounding (VES) using Schlumberger Array was carried out at nineteen (19) VES stations. ABEM terrameter (SAS 300) was used for the data acquisition. The field data obtained was analyzed using computer software (*IPI2win*) which gives an automatic interpretation of the apparent resistivity. The VES results revealed heterogeneous nature of the subsurface geological sequence. The geologic sequence beneath the study area is composed of hard pan top soil (clayey and sandy-lateritic), weathered layer, partly weathered or fractured basement and fresh basement. The resistivity value for the topsoil layer varies from 7Ωm to 361Ωm with thickness ranging from 1.19 to 3.90 m.

The weathered basement has resistivity values ranging from 60Ωm to 336Ωm and thickness of between 0.6 to 11.4 m. The fractured or partly weathered basement has resistivity values ranging from 442Ωm to 987Ωm and thickness of between 4.61 to 19.5 m. The fresh basement has relatively high resistivity values ranging from 967Ωm to 6036Ωm with infinite depth. However, the depth from the earth's surface to the bedrock surface varies between 2.29 to 20.8 m.

Based on the resistivity values, it is concluded that the subsurface material up to the depth greater than 15m is competent and has high load-bearing capacity. However, resistivity values less than 50Ωm at depths of 5m-10m indicate high porosity, high clayey sand content and high degree of saturation which are indications of soil conditions requiring serious consideration in the design of massive engineering structures. around Shika, Kaduna state, Nigeria in order to delineate the subsurface geologic strata with a view of determining the depth to the bedrock and thickness of the geologic strata.

VES using Schlumberger Array was carried out at eighteen (18) VES stations. ABEM terrameter (SAS 300) was used for the data acquisition. The field data obtained have been analyzed using computer software (*IPI2win*) which gives an automatic interpretation of the apparent resistivity. The VES results revealed heterogeneous nature of the subsurface geological sequence. The geologic sequence beneath the study area is composed of hard pan top soil (clayey and sandy-lateritic), weathered layer, partly weathered or fractured basement and fresh basement. The resistivity value for the topsoil layer varies from 60Ωm to 373Ωm with thickness ranging from 1.06 to 4.14 m. The weathered basement has resistivity values ranging from 70Ωm to 708Ωm and thickness of between 1.77 to 33.04 m. The fractured or partly weathered basement has resistivity values ranging from 318Ωm to 834Ωm and thickness of between 12.9 to 26.3 m. The fresh basement (bedrock) has relatively high resistivity values ranging from 1161Ωm to 3115Ωm with infinite depth. However, the depth from the earth's surface to the bedrock surface varies between 3.32 to 36 m. The study further stressed the importance of the findings in engineering, groundwater exploration and waste disposal problem.

(Keywords: VES, top soil, weathered basement, partly weathered, fractured basement, fresh basement)

INTRODUCTION

The use of geophysics for engineering studies and water groundwater exploration has increased over the last few years due to the rapid advances in computer software and associated numerical modeling solutions. The Vertical Electrical Sounding (VES) has proved very popular with groundwater prospecting and engineering investigations due to simplicity of the techniques.

The electrical geophysical survey method is the detection of the surface effects produced by the flow of electric current inside the earth. The electrical techniques have been used in a wide range of geophysical investigations such as mineral exploration, engineering studies, geothermal exploration, archeological investigations, permafrost mapping and geological mapping. Electrical methods are generally classified according to the energy source involved, i.e., natural or artificial. Thus, self potential (SP), telluric current come under natural source methods, while resistivity, electromagnetic (EM) and induced polarization (IP) methods are artificial source methods. The electrical D.C. resistivity method used in carrying out the present survey is of artificial source using the ABEM terrameter (SAS 300).

Appraising the hydrogeology in Zaria, Danladi (1985) has confirmed the presence of water bearing fractures, which aquifers are located at a shallow basement area of Zaria. McCurry (1970), who studied the geology of Zaria, has established that the Basement Complex rock is made up of the older granite, Biotite granite-gneiss.

Farouq (2001), carried out geoelectric investigation of the groundwater potential in the Institute for Agricultural Research Farm, Samaru, Zaria, showed that the thickness of the weathered basement around the area varies from 3.4 to 30.4 m and depth to fresh basement was 40 m.

Similarly, Saminu (1999), carried out a comprehensive geophysical survey over the premises of Federal College of Education, Zaria, showed that the thickness of the top soil of the area ranges between 3.5 and 14 m while the thickness of the weathered basement ranges between 9 and 36.5 m. The depth to bedrock varies from 5 to 14 m. In this study, electrical resistivity investigation covering eighteen stations have been carried out and interpreted fully around Shika**,** Kaduna State, Nigeria, in order to map or delineate the subsurface geologic strata with a view of determining the depth to the bedrock and thickness of the geologic strata. The study further stressed the importance of the findings in engineering, groundwater exploration and waste disposal problem.

GEOLOGY OF THE STUDY AREA

The study area is part of the NW basement terrain underlain by basement rocks of Precambrian age. They are mainly granites, gneisses, and schists. Oyawoye (1964) showed that there is structural relationship between this Basement Complex and the rest of the West African basement. This is partly due to the fact that the whole region was involved in a single set of orogenic episode, the Pan African orogeny, which left an imprint of structural similarity upon the rock units. The gneisses are found as small belts within the granite intrusions, and are also found east and west of the batholiths (McCurry, 1970). The biotite gneiss extends westwards to form a gradational boundary with the schist belt. The gneiss continues eastwards to some extent and is occasionally broken up by the Older Granite (Wright and McCurry, 1970).

SITE DESCRIPTION

The study area is bounded approximately by longitudes $7^0$31'50''E and $7^0$34'40''E, latitudes $11^0$10'07''N and $11^0$12'10''N as shown in location map (Figure 1) with an average elevation of 685m above sea level. The area falls within the semi-arid zone of Nigeria (Harold, 1970). It lies in the guinea savannah; the woodland vegetation is characterized by bushes less than 3m high.

METHODOLOGY

Vertical Electrical Soundings (VES) using Schlumberger array were carried out at eighteen (18) stations. A regular direction of N-S azimuth was maintained in the orientation of the profiles. Overburden in the basement area is not as thick as to warrant large current electrode spacing for deeper penetration, therefore the largest Current electrode spacing AB used was 200m, that is, 1/2AB=100m. The principal instrument used for this survey is the ABEM (Signal Averaging System, (SAS 300) Terrameter.

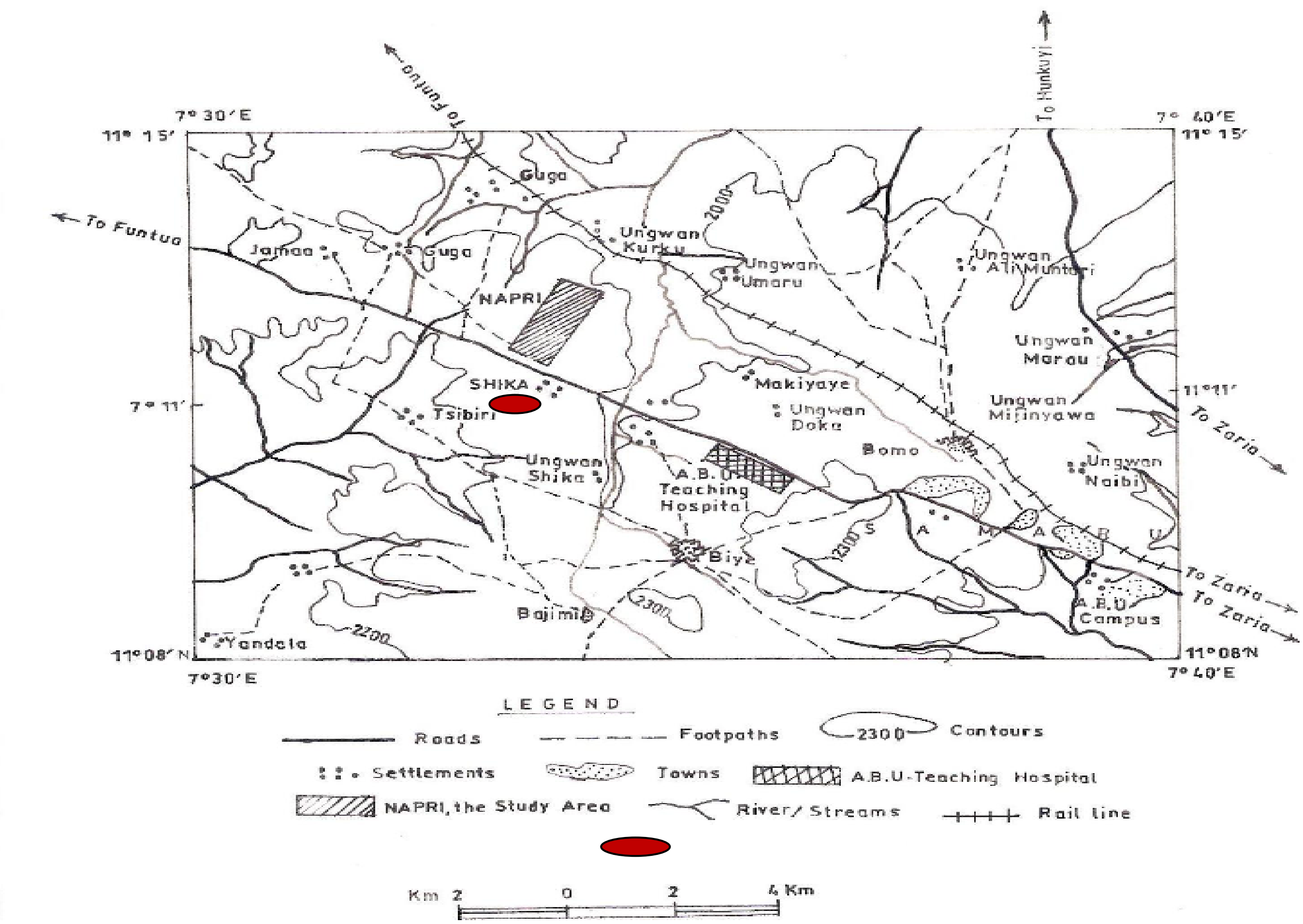


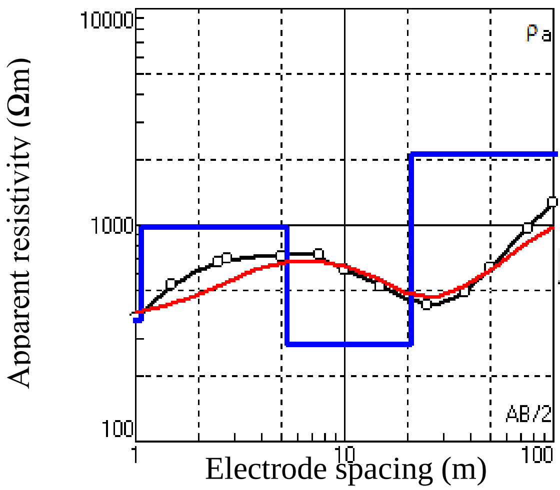
Figure 1: Location Map Showing the Study Area (From Northern Nigerian Survey Map).

The resistance readings at every VES point were automatically displayed on the digital readout screen and then written down on paper.

RESULTS AND DISCUSSION

The geometric factor, K, was first calculated for all the electrode spacings using the formula; $K = \pi (L^2/2b - b/2)$, for Schlumberger array with MN=2b and 1/2AB=L. The values obtained, were then multiplied with the resistance values to obtain the apparent resistivity, ρ_a, values. Then the apparent resistivity, ρ_a, values were plotted against the electrode spacings (1/2AB) on a log-log scale to obtain the VES sounding curves using an appropriate computer software *IPI2win* in the present study. Some sounding curves and their models are shown in Figure 2. Similarly, geoelectric sections are shown in Figures 3 and 4. Three resistivity sounding curve types were obtained from the studied area and these are the H ($\rho_1 > \rho_2 < \rho_3$), A ($\rho_1 < \rho_2 < \rho_3$) and KH ($\rho_1 > \rho_2 < \rho_3 > \rho_4$) type curves. The results of the interpreted VES curves are shown in Table 1.

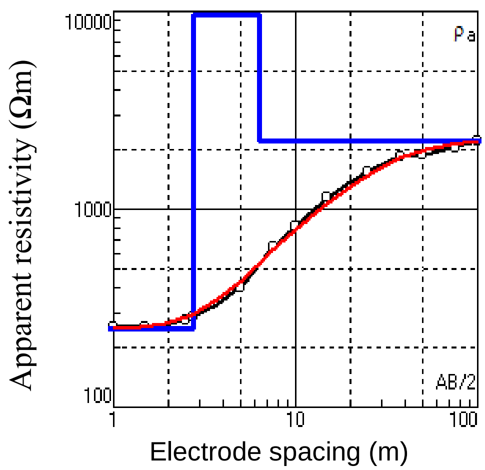
The modeling of the VES measurements carried out at eighteen (18) stations has been used to derive the geoelectric sections for the various profiles. These have revealed that there are mostly four and three geologic layers beneath each VES station. The geologic sequence beneath the study area is composed of top soil, weathered basement, partly weathered/fractured basement, and fresh basement. The topsoil is composed of clayey and sandy-lateritic hard pan with resistivity values ranging from 60Ωm to 373Ωm and thickness varying from 1.06 to 4.4 m, the strata is thinnest at VES 12 and thickest at VES 17.



N	ρ	h	d
1	370	1.65	1.65
2	410	15.7	17.4
3	503	20.4	37.8
4	1161		

Where,
N is the number of layers,
ρ is the apparent resistivity,
h is the thickness and
d is the depth to interface of each layer.

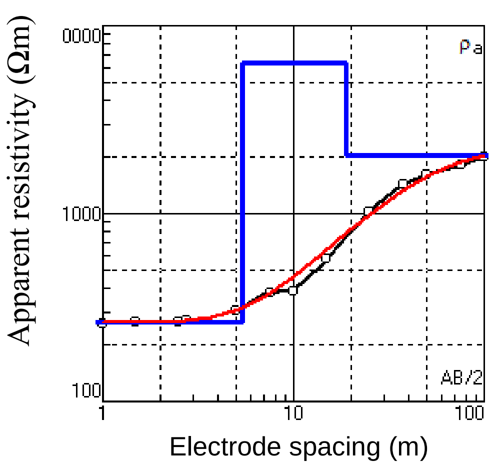
(a) VES Station 11 (TYPE KH CURVE)



N	ρ	h	d
1	135	2.57	2.57
2	523	7.6	10.2
3	1520		

Where,
N is the number of layers,
ρ is the apparent resistivity,
h is the thickness and
d is the depth to interface of each layer.

(b) VES Station 6 (TYPE A CURVE)



N	ρ	h	d
1	256	1.29	1.29
2	391	12.7	14
3	1450		

Where,
N is the layer number,
ρ is the apparent resistivity in ohm-metre,
h is the layer thickness and
d is the depth to interface of each layer

(c) VES Station 9 (TYPE A CURVE)

Figure 2: Typical Curve Types and Models Obtained from the Study Area.

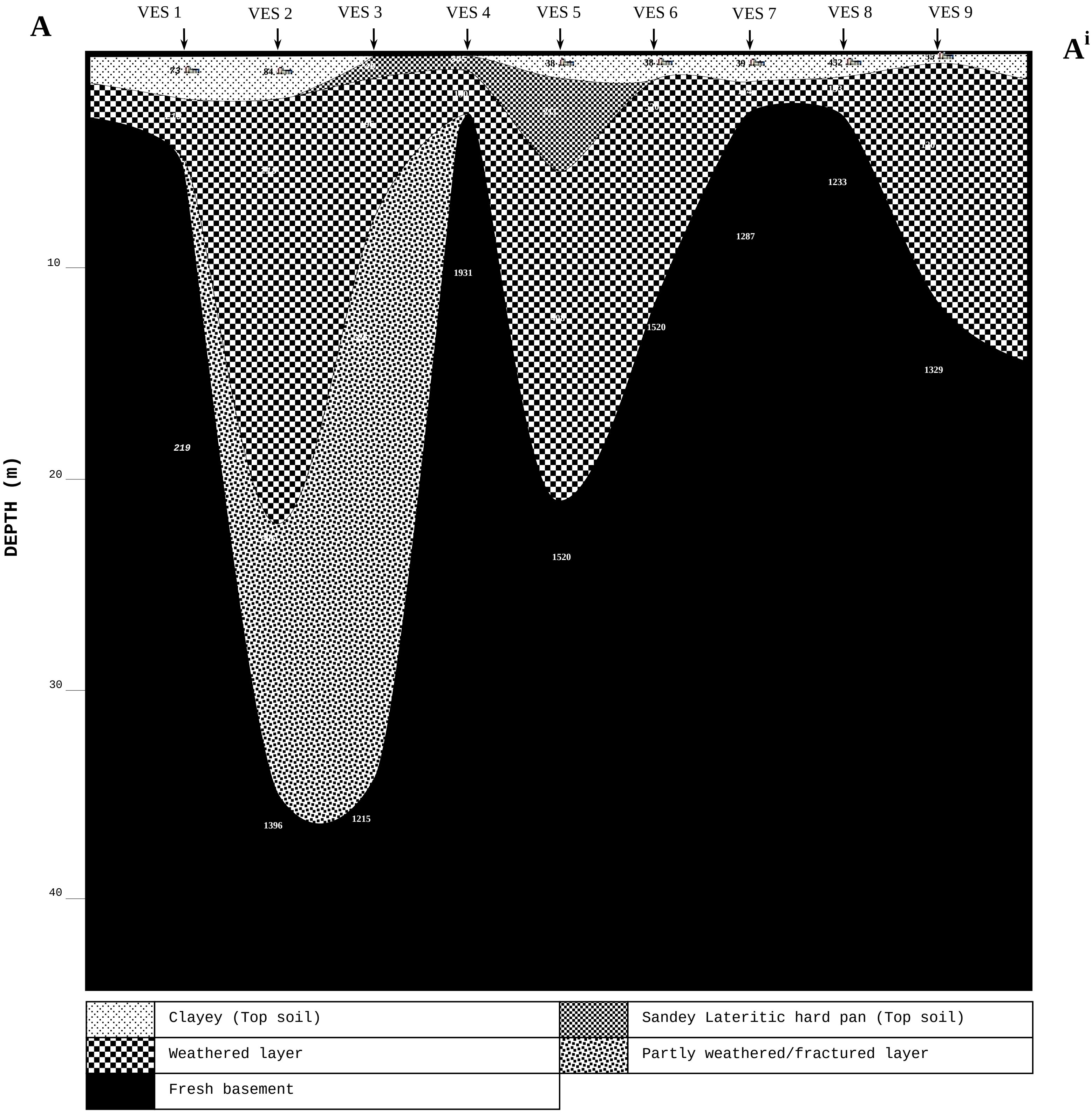


Figure 3: Geoelectric Section along Profiles A-A[i]

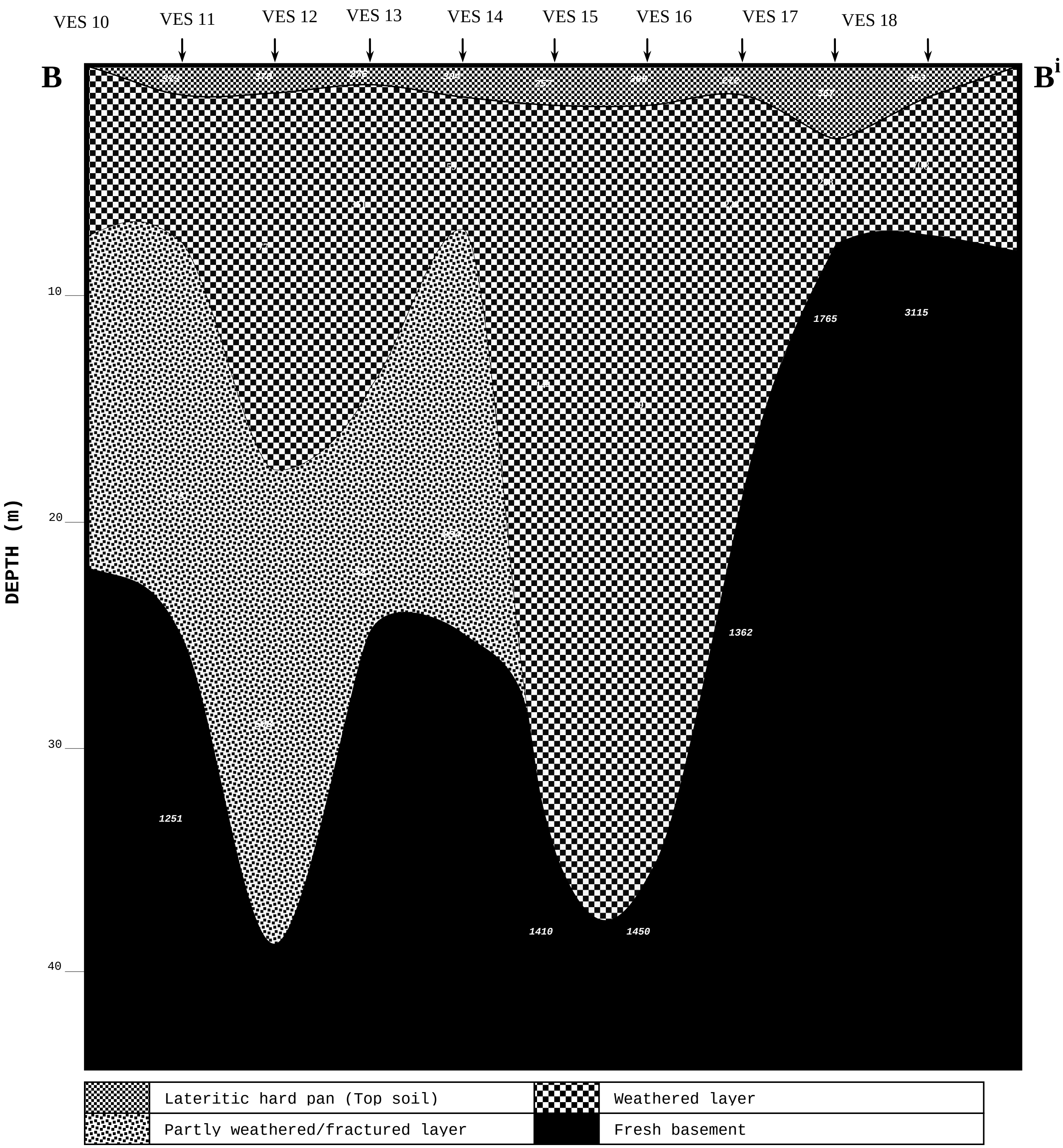


Figure 4: Geoelectric Section along Profiles B-B[i]

Table 1: The Results of the Interpreted VES Curves.

VES Stations	Thickness (m)	Layer Resistivity (Ωm)	Remarks	Curve Types	Number of Layers
1	1.77 3.33 -	85 319 2115	TP WB FB	A	3
2	2.01 20.1 12.9 -	80 418 318 1396	TP WB PWB FB	KH	4
3	1.35 5.05 26.3 -	245 290 510 1215	TP WB PWB FB	KH	4
4	1.24 2.04 -	145 100 1930	TP WB FB	H	3
5	2.22 4.95 18.04 -	214 493 408 2020	TB WB PWB FB	KH	4
6	2.57 7.6 -	135 523 1520	TP PWB FB	A	3
7	1.55 1.77 -	60 234 1230	TP WB FB	A	3
8	1.51 1.97 -	150 224 1280	TP WB FB	A	3
9	1.29 12.7 -	256 391 1450	TP WB FB	A	3
10	1.43 6.8 17 -	373 221 473 1251	TP WB PWB FB	KH	4
11	1.65 15.7 20.4 -	370 70 503 1161	TB WB PWB FB	KH	4
12	1.06 12.84 11 -	276 351 522 1197	TP WB PWB FB	KH	4
13	2.02 5.51 17.4 -	304 593 834 2019	TP WB PWB FB	KH	4
14	2.64 32.36 -	257 144 1410	TB WB FB	H	3
15	2.96 33.04 -	256 391 1450	TB WB FB	A	3
16	1.87 17.13 -	272 228 1362	TP WB FB	H	3
17	4.14 3.85 -	367 298 1765	TP WB FB	H	3
18	1.54 6.58 -	353 708 3115	TP WB FB	A	3

It is however, observed from the geoelectric sections that VES 1, 2 and 7 are characterized with low resistivity values varying between 60Ωm to 85Ωm suggesting the clayey nature of the strata in these areas are possibly high moisture content.

The second layer is the weathered basement with resistivity and thickness values varying between 70Ωm and 708Ωm and 1.77 to 33.04 m, respectively. This stratum is thickest at VES 15, suggesting this point for siting borehole but thinnest at VES 7. Other points with probable high water potentials viable for siting borehole include: VES 2, 3, 5, 9, 10, 11, 13, 14, 15, and 17 respectively with aquifferous zone.

The third strata are the partly weathered or fractured basement with resistivity and thickness values varying between 318Ωm to 834Ωm and 12.9 to 26.3 m respectively. The strata are extensive and thickest at VES 3 and thinnest at VES 11. The fourth layer is presumably fresh basement whose resistivity values vary from 1161Ωm to 3115Ωm with an infinite depth. However, the depth from the earth's surface to the bedrock surface varies between 3.32 to 36 m, deepest at VES 15 and shallowest at VES 7.

CONCLUSION

Subsurface Stratigraphic Mapping using the D.C. electrical resistivity method was carried out around Shika, Kaduna State, Nigeria, three to four geologic strata are delineated at the subsurface composed of top soil, weathered basement, partly weathered or fractured basement and fresh basement. Based on the qualitative interpretation of the VES data, it is deduced that VES Stations 2, 3, 5, 9, 10, 11, 13, 14, 15 and 17 are viable positions for siting boreholes with appreciable thickness of weathered and fractured basement (aquifferrous zone) ranging from 12.7 to 33.04 m. These geologic strata are characterized by structural features like fractures, fissures or pore spaces that enhance groundwater permeability and storage hence suggesting these points for siting borehole.

To ensure safety consumption of groundwater in the area, potential sources of contamination site should be sited far away from viable aquifer units because the area is vulnerable to pollution if there is leakage of buried tank, sewage channels or infiltration of leachate from decomposing waste disposal in the area as a result of their shallow depth to the aquifferrous zone ranging from 1.06 to 4.14 m. It is also deduced that the area can support low to massive engineering structures as a result of the thin clayey nature in the study area underlain by basement rocks at shallow depth. This underlying rock serve as pillar supports to the building, hence, the structural foundation requires little or no pilling. Based on the resistivity values of the different geoelectric layers, it has been concluded that the various geologic units, up to a depth of about 25 - 30m are fairly competent and can support large civil engineering structure.

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