Relevance of Geophysics in Foundation Evaluation in a Typical Basement Complex of North-Western 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.

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

INTRODUCTION

The statistics of failures of structures such as buildings, tarred roads, and bridges throughout the nation is increasing geometrically. A case in point that readily comes to mind is the subsidence or collapse of massive structures in the federal capital of Nigeria, Abuja which is part of Nigeria Basement Complex.

Property worth millions of dollars has been lost in many countries due to structural disasters. Some common structural failures in the world today include the failures of roads, bridges, dams, and the failure of low and high rise buildings. Most of these failures were caused by swelling clays (Blyth and Freitas, 1988).

The need for pre-foundation studies has therefore become very imperative so as to prevent loss of valuable properties and lives that always accompany such a failure. Foundation study usually provides subsurface information that assists civil engineers in the design of civil engineering structures. (Akintorinwa and Adeusi, 2009). Foundation study of a new site is necessary so as to provide subsurface and aerial information that normally assist civil engineers, builders and town planners in the design and siting of foundations of civil engineering structures (Omoyoloye, et al., 2008).

Geophysical methods such as the Electrical Resistivity (ER), Seismic refraction, Electromagnetic (EM), Magnetic and Ground

Penetrating Radar (GPR) are used singly or in combinations for engineering site investigations. The applications of such geophysical investigation are used for the determination of depth to bedrock, structural mapping and evaluation of subsoil competence (Burland and Burbidge, 1981**).** This present study is aimed at determining the depth to the competent stratum in the subsurface and delineation of areas that are prone to subsidence or some form of instability at a new site sitting on the Basement Complex rock of the north-western part of Nigeria.

LOCATION AND TOPOGRAPHY OF THE STUDY AREA

The study area lies between Latitudes $11^0$08**'** 05"N and $11^0$09**'**10**"** N and Longitudes 7^0 30'35"E and 7^0 30**'**40**"** E. The site is situated off the Funtua road some few kilometers away from the Ahmadu Bello University Teaching Hospital (ABUTH), North West of Zaria (Figure 1).

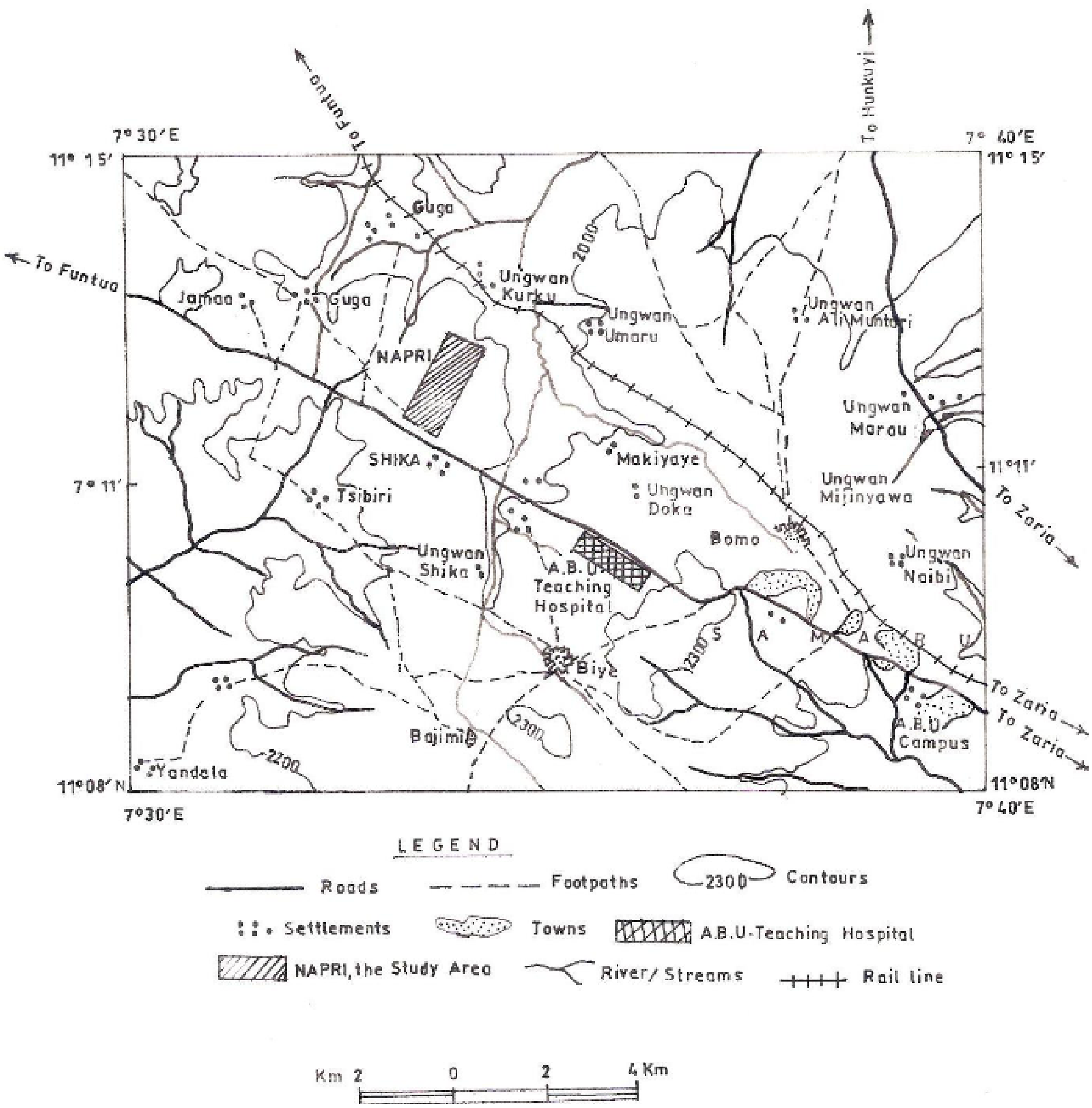


Figure 1: Location Map Showing the Study Area (From Northern Nigerian Survey Map).

The topography is that of high plain (flat terrain). The site is located within the tropical climatic belt with Sudan Savannah vegetation. The environment is Savannah type with distinct wet and dry season. The rainfall regime is simple but with slight variation which consists of wet season lasting from May to September and characterized by heavy down pour at the start and end of the rainy season. The annual rainfall varies between 800 mm to 1090 mm while the mean annual temperature ranges between 24^0C to 31^0C reaching a maximum of about 36^0C around April (Hore,1970; Goh Cheng Leong and Adeleke, 1978).

GEOLOGY OF STUDY AREA

The study area is part of the NW basement terrain underlain by basement rocks of Precambrian age (Figure 2). They are mainly granites, gneisses, and schist. 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).

METHODOLOGY

Vertical Electrical Soundings (VES) using Schlumberger Array were carried out at nineteen (19) stations. A regular direction of N-S azimuth was maintained in the orientation of the profiles.

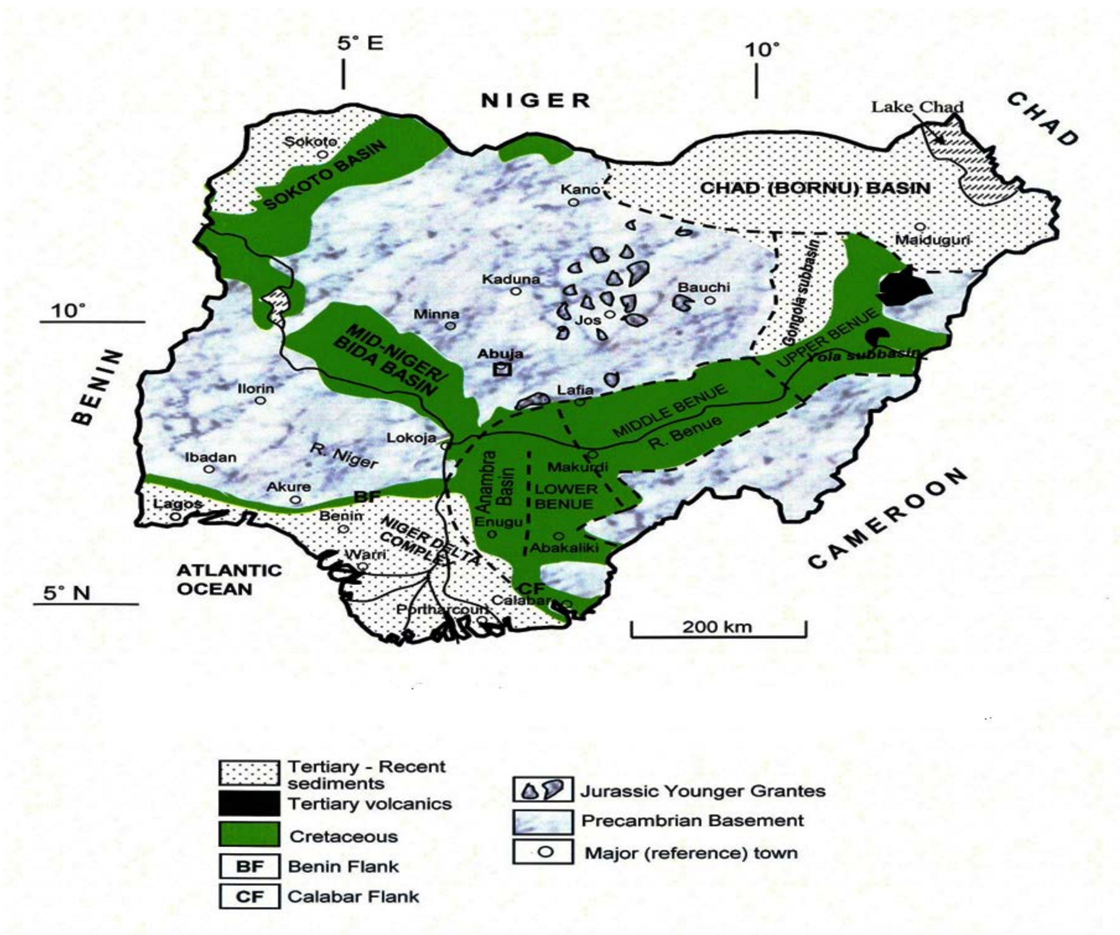
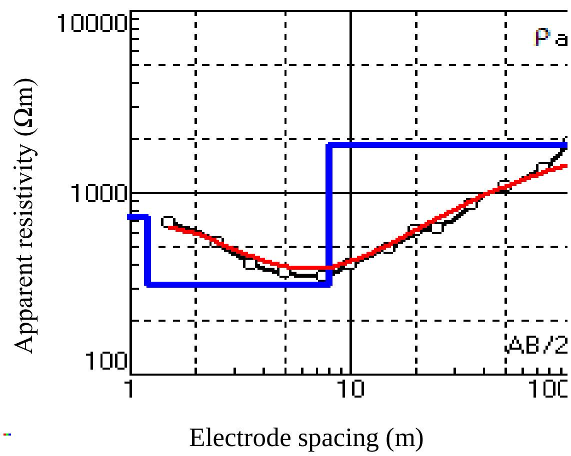


Figure 2: Geological Map of Nigeria showing the Study Area.

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

RESULTS AND DISCUSSION

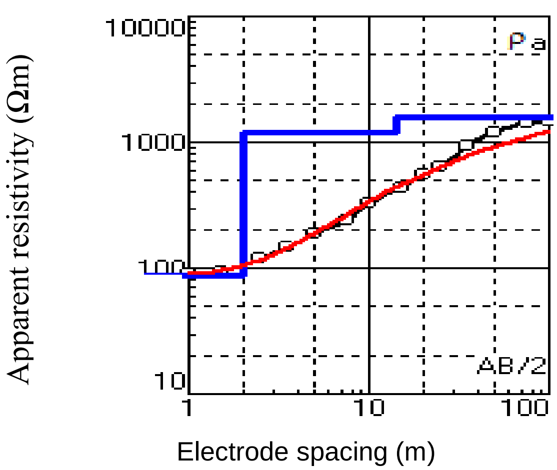
The geometric factor, K, was first calculated for all the electrode spacings using the formula; $K= \pi (L^2/2b – b/2)$, for Schlumberger array with MN=2b and 1/2AB=L. The values obtained, were then multiplied with the resistance values to obtain the apparent resistivity, ρ_a, values. Then the apparent 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*. Some sounding curves and their models are shown in Figure 3. Similarly, geoelectric sections are shown in figures 4. Two resistivity sounding curve types were obtained from the studied area and these are the H ($\rho_1>\rho_2<\rho_3$) and A ($\rho_1< \rho_2<\rho_3$) type curves (Figure 3). The results of the interpreted VES curves are shown in Table 1.



N	ρ	h	d
1	738	1.19	1.19
2	312	6.77	7.96
3	1835		

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

(a) Station CT1 (TYPE H CURVE)



N	ρ	h	d
1	87	2.11	2.11
2	1179	12.30	14.4
3	1585		

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

(b) Station CT3 (TYPE A CURVE)

Figure 3: Typical of Curve Types and Models Obtained from the Study Area.

Table 1: The Results of the Interpreted VES Curves.

VES Stations	Thickness (m)	Layer Resistivity (Ωm)	Remarks	Curve Types	Number of Layers
CT1	1.97 6.12 -	28 132 1011	TP WB FB	A	3
CT2	1.63 8.08 -	285 173 1128	TP WB FB	H	3
CT3	2.08 5.23 -	13 60 1107	TP WB FB	H	3
CT4	3.35 10.10 -	33 150 1010	TP WB FB	A	3
CT5	2.40 4.61 -	112 442 1610	TB PWB FB	A	3
CT6	1.96 2.68 -	132 313 2257	TP WB FB	A	3
CT7	1.36 8.65 -	55 113 1072	TP WB FB	A	3
CT8	1.35 6.81 -	78 282 1931	TP WB FB	H	3
CT9	1.19 6.77 -	78 312 1835	TP WB FB	H	3
CT10	2.11 12.30 -	87 779 1585	TP PWB FB	A	3
CT11	2.89 2.24 -	64 150 980	TB WB FB	A	3
CT12	1.37 11.40 -	57 326 1630	TP WB FB	A	3
CT13	3.90 6.20 -	361 107 967	TP WB FB	H	3
CT14	1.37 2.67 -	7 336 990	TB WB FB	A	3
CT15	1.36 8.64 -	56 116 1072	TB WB FB	A	3
CT16	1.94 4.34 -	123 987 2584	TP PWB FB	A	3
CT17	1.30 19.50 -	17 588 1277	TP PWB FB	A	3
CT18	1.69 7.32 -	33 933 1322	TP PWB FB	A	3
CT19	1.69 0.60 -	104 229 6036	TP WB FB	A	3

The modeling of the VES measurements carried out at nineteen (19) stations has been used to derive the geoelectric sections for profiles A-A’, B-B’ and C-C’ respectively (Figure 4). These have revealed that there are mostly three geologic layers beneath each VES station. The geologic sequence beneath the study area is composed of top soil, weathered basement or fractured basement and fresh basement.

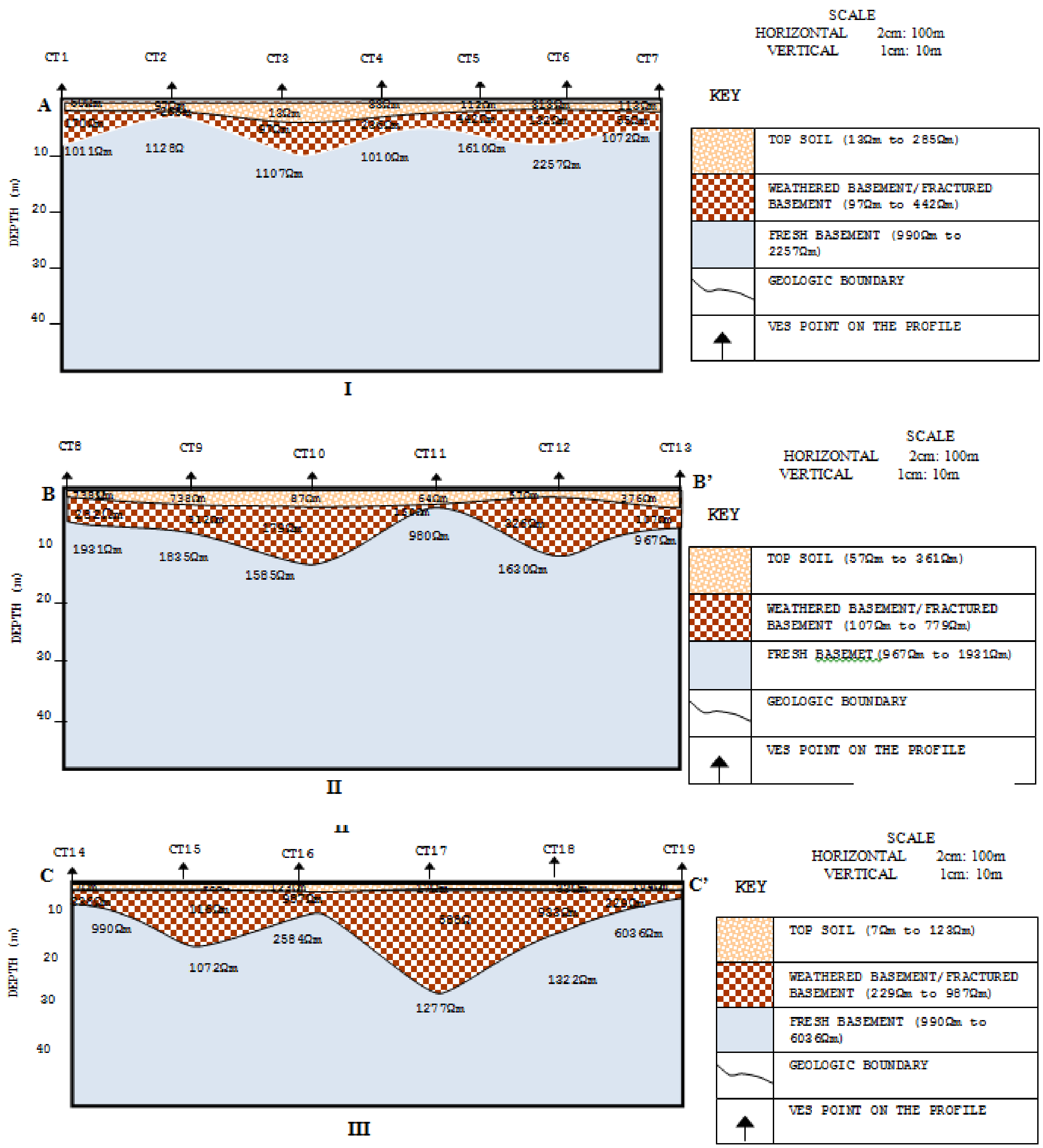


Figure 4: Geoelectric sections along profiles A-A’, B-B’ AND C-C’.

The topsoil is composed of clayey-sandy and sandy-lateritic hard crust with resistivity values ranging from 7Ωm to 361Ωm and thickness varying from 1.19m to 3.90m, thinnest at VES CT9 and thickest at VES CT13. It is however, observed from the geoelectric sections that VES CT 1, 3, 4, 7, 14, and 17 are characterized with low resistivity values varying between 7Ωm to 33Ωm suggesting the clayey nature of the topsoil in these areas and possibly high moisture content.

The second layer is the weathered basement with resistivity values varying from 60Ωm to 336Ωm and thickness ranges between 0.6m to 11.4m, thinnest at VES CT19 and thickest at VES CT12, some areas around this layer are partly weathered or fractured with resistivity and thickness values varying between 442Ωm to 987Ωm and 4.61m to 19.5m, respectively. The layer is extensive and thickest at VES CT17 and thinnest at VES CT5.

The third layer is presumably fresh basement whose resistivity values vary from 967Ωm to 6036Ωm with an infinite depth. Though the thickness of the bedrock is assumed to be infinite but the depth from the earth's surface to the bedrock surface varies between 2.29m to 20.8m. Quite a few of the profiles is dipping and a large number of them show synclinal structure. These formations have some geological, physical and near-surface engineering significance.

PROFILE A-A'

Profile A-A' geoelectric section suggests that the site is characterized by lateritic hard pan at different consolidation levels within shallow depths, while gneiss and granites mainly, characterize the basements (Figure 4(I)). The fresh basements have synclinal structure which cut across the profile (CT 1, 3, 5, and 6). The weathered/fractured basement has shallow, gentle dipping layers.

The probable feature that may cause building failure could be geologic feature like dipping bedrock or synclinal structure. This is because while overburden materials fill the synclinal structure, their columns undergo ground movement by subsidence and thereby could amount to uneven settlement at the foundation depths of buildings. In other words, uneven stress distribution may occur at the foundation depths of subsurface, that is one side of building structure may have a stronger support than the other adjacent of it.

Another factor that could contribute to structural defect of building is the seasonal variation in the saturation of clay which causes ground movement and is caused by clay swells and shrinkages which are occasioned by alternate wet and dry seasons. The area is characterized by clay soils with lateritic patches at shallow depths with their thickness ranging between 1.36m and 3.35m and A-curve type which shows a continuous and uniform increase in resistivity predominates. This curve typifies an area showing characteristics of high load-bearing strength. This area forms a good site for the erection of small civil engineering structures.

PROFILE B-B'

The geoelectric section revealed clayey sandy topsoil having some lateritic hard crust patches (Figure 4(II)). The synclinal structure at VES CT10 and CT12 is well pronounced and may pose serious danger to building foundation. However, there is a thick weathered rock beneath these VES points which may serve as pillar supports to building. The area is characterized by clay soils with lateritic patches at shallow depths with their thickness ranging between 1.19m and 3.90m reduces the danger posed by clay formation to large buildings. This area forms a good site for the erection of small civil engineering structures. Similarly, there are appreciable numbers of the H-curve type which has a minimum resistivity intermediate layer underlain and overlain by more resistant materials making these points promising for groundwater development.

PROFILE C-C'

Profile C-C' geoelectric section suggests that the site is characterized by clayey topsoil at different consolidation levels (Figure 4(III)). The fresh basements have synclinal structure which cut across the profile which is not pronounced around VES CT15 but obvious around CT 17, 18 and CT19, with steeply dipping weathered layer and may pose serious danger to building foundation. However, the weathered basement around this area is thick and cut across the profile. The area is characterized by clay soils at shallow depths with their thickness ranging between 1.30m and 1.94m. A-curve type which shows a continuous and uniform increase in resistivity predominates. This curve typifies an area showing characteristics of high load-bearing strength. This area forms a good site for the erection of high-rise buildings.

CONCLUSION

The VES results revealed heterogeneous nature of the subsurface geological sequence. Though the geoelectric section showed complexity in the subsurface lithology, there is however, no indication of any major fracture or fault that could aid subsidence. The geologic sequence beneath the study area is composed of topsoil, weathered layer, partly weathered/fractured basement, and fresh basement.

The A-curve type which shows a continuous and uniform increase in resistivity predominates. This curve typifies an area showing characteristics of high load-bearing strength. The H-type curve which has a minimum resistivity intermediate layer underlain and overlain by more resistant materials reminiscent of areas promising for groundwater development.

Based on the resistivity values of the different geoelectric layers, the various geologic units greater than 20m, thin clayey layers and thick weathered bedrock are competent and can support massive civil engineering structures while units between 5m – 10m can support small civil engineering structures which requires little or no pilling because of its shallow depth to the bedrock which can serve as pillar support to the structures. Other probable causes of foundation defects are the growth of tree roots, organic deposits, sink holes, cavities or ground surface saturation due to seepages and this should be taken care of during building project implementation to ensure that buildings erected at the site stands the test of time.

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