International Journal of Engineering Research and Development
e-ISSN: 2278-067X, **p**-ISSN : 2278-800X, www.ijerd.com
Volume 5, Issue 10 (January 2013), PP. 19-26

Subsurface Electrical Resistivity Investigation At The Centre for Energy Research and Training, Ahmadu Bello University, Zaria, Kaduna State,Nigeria.

[1]Fadele, S.I, [2]Jatau, B.S and [3]Baba, A. and [4]Adegoke, I.
[1,2,.3,4] Nasarawa State University, Keffi, Nigeria.

Abstract:- Electrical resistivity method was used in carrying out geophysical investigations at the Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria, with a view of determining the depth to the bedrock, thickness of the top soil and weathered basement.Vertical Electrical Sounding (VES) using Schlumberger array was carried out at forty (40) VES stations. ABEM terrameter (SAS 300) was used for the data acquisition. The field data obtained have been analysed using computer software (*IPI2win*) which gives an automatic interpretation of the apparent resistivity. Results from the interpretation suggest three layers in most parts of the study area. However, there is a case of two layers at a station. The resistivity value for the topsoil layer varies from 2 to 738**Ω**m with thickness ranging from 1 to 3.9 metres. The weathered basement has resistivity values ranging from 32 to 1735**Ω**m and thickness of between 0.52 and 23 metres. The fresh basement (bedrock) has resistivity values ranging from 100 to 6,036**Ω**m.

Keywords: Electrical Resistivity, CERT (CT), Vertical Electrical Sounding (VES), Top Soil (TP), Weathered basement (WB), fresh basement (FB).

INTRODUCTION

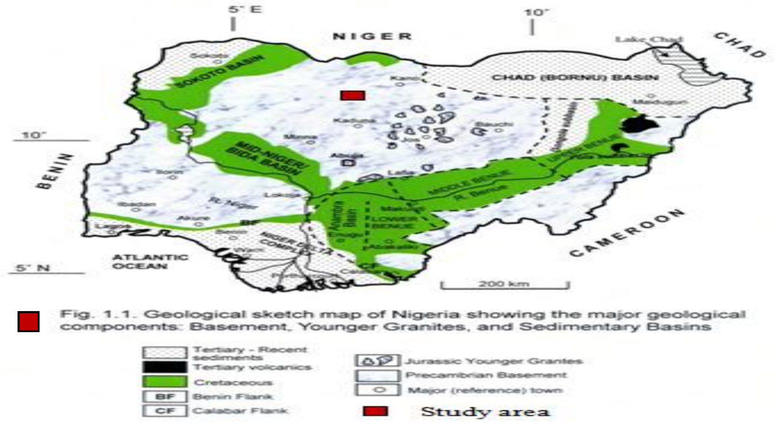
Geophysics is a branch of science that applies physical principles to the study of the earth. Many geophysical surveying methods exist, and each has an operative physical property to which each method is sensitive. Electrical methods are generally classified according to the energy source involved, i.e., 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. Klinkenbera (1970) has classified the soils in Zaria under leached ferruginous tropical soils. According to him, the soil is weakly developed near the inselbergs and formed fadama soils and that the soils contain about 40% clay deposit. 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 the present study, electrical resistivity investigations at the Centre for Energy Research and Training, Ahmadu Bello University, Zaria, Kaduna State, Nigeria, have been carried out. Forty soundings have been carried out and interpreted fully.

GEOLOGY OF THE STUDY AREA

The study area is a Basement Complex terrain and is p the Zaria Batholiths. A thick overburden covers the area with varying thicknesses. Underlying the overburden are crystalline rocks consisting of biotite-hornblende granite. The granites belong to the Older Granite suite of the North-Western Nigeria, emplaced during the Pan-Africa Orogeny

That took place about 600 million years ago (McCurry,1970).



SITE DESCRIPTION

The Centre for Energy Research and Training, Ahmadu Bello University, Zaria, has an area extent of about 1 square-km, bounded approximately by longitudes $7^0 39'58''$E and $7^0 40'15''$E, latitudes $11^0 08'35''$N and $11^0 08'58''$N within the Zaria sheet 102 SW map (Fig 2). 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 generally less than 3 metres high.

METHODOLOGY

Vertical Electrical Soundings (VES) using Schlumberger array were carried out at forty (40) stations. A regular direction of N-S azimuth was maintained in the orientation of the profiles.

In order to achieve the aim and objective of this work, the Schlumberger array was chosen as a result of the following reasons:

1. In depth probing, the potential electrodes are fixed while only the current electrodes are moved symmetrically about the centre of spread. For large values of electrode spacing L, it may be necessary to increase b in order to obtain a measurable potential difference. Thus, it is more convenient than Wenner array for sounding since only the two current electrodes are essentially moved.
2. The effect of shallow resistivity variation is constant with the fixed potential electrodes.
3. The electrode effect on the resistivity curve is greatly minimised. This effect comes about because of the perturbations caused by the passage of the potential electrodes over a superficial inhomogeneity which are much greater than those due to the current electrodes (Kunetz, 1966: Parasnis, 1962). Since the movements of the potential electrodes are minimised, this electrodes effect is also minimised.

Previous geophysical works, carried out within the northern part of Nigeria, has shown that the 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 potential electrode separation, MN, was also increased intermittently in order to maintain a measurable potential difference, but it did exceed

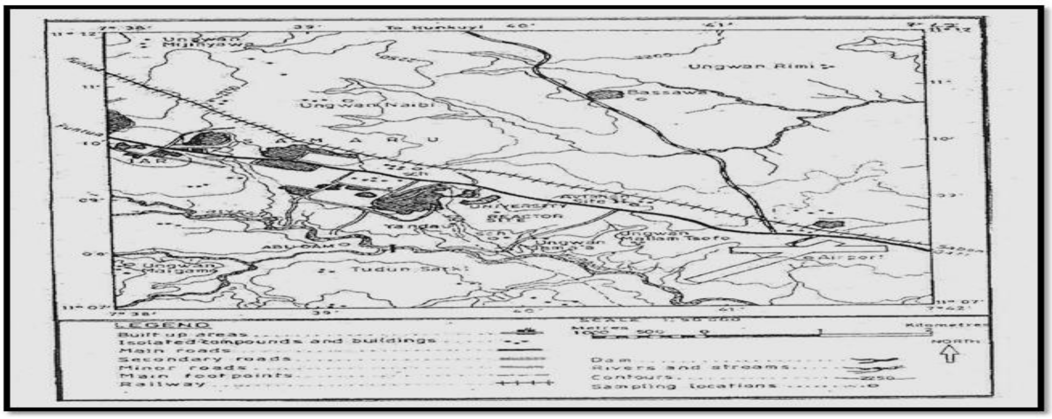


FIG 2: Part of Zaria Sheet 102 Map Showing the Study Area (Drawn from Northern Nigerian Survey Map).

One-fifth of the half-current electrode separation, 1/2AB, as suggested by Dobrin and Savit (1988).
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* in the present study. Some sounding curves and their models are shown in Fig 3. Similarly, geoelectric sections are shown in Figs. 4 and 5.

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. The results of the interpreted VES curves are shown in Table 1.

The modeling of the VES measurements carried out at forty (40) stations has been used to derive the geoelectric sections for the various profiles. These have revealed that there are mostly three geologic layers beneath each VES station, and a two layer geologic section at a VES point. The predominant layers are: the top soil (TP) consisting of clay, silt, and sandy soil. The resistivity of the layer is as low as 2**Ω**m and as high as 738**Ω**m on some profiles while the thickness range is from 1 to 3.9 m. The weathered basement (WB) formed the second layer in most of the profiles with the resistivity value as low as 32**Ω**m and as high as 1735**Ω**m on some profiles. The thickness ranges from 0.52 to 23 m. The shallowest depth to bedrock is 1.75 m and deepest is 26.91 m. The resistivity values of this layer suggest a high degree of saturation which suggests that the layer corresponds to the aquiferrous zone in the area. The third layer is the fresh basement (FB) whose resistivity is as high as 6,030**Ω**m and as low as 100**Ω**m and it is of infinite depth. The parameters of investigation have helped in identifying strategic areas for siting high-rise buildings which include VES CT38, 37, 30, 28, 26, 25, 11, 10, 2 and 1 along profiles AB, CD GH, KL and MN. These are areas with shallow depths to the bedrock with thickness from 5 to 10 m. The bedrock can serve as pillar supports to the buildings and also thin topsoil with thickness (<2 m) because of the clayey nature of the topsoil. 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 25m are fairly competent and can support large civil engineering structures. For identifying potential positions for the location of boreholes, VES points along the profiles with thickness of weathered basement >10 m which include VES CT3, 5, 23, 29, 36, 39 and 40 are good aquifer for boreholes. This is because the weathered basement is referred to as the fractured zone characterized by structural elements like fissures, faults e.t.c. that enhance groundwater permeability and storage. The depth of sewage system in this area generally, should be <5 m to the weathered basement (aquiferrous zone) in order to avoid groundwater contamination since the area is generally has shallow fresh basement.

CONCLUSION

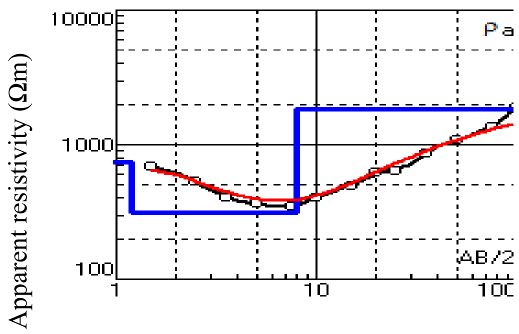
The electrical d.c. resistivity was used to investigate the Centre for Energy Research and Training (CERT), Ahmad

Table 1: The results of the interpreted VES curves

Stations	Thickness (m)	Layer resistivity (Ωm)	Remarks	Curve types	Numb of layers
CT1	1.35 6.81 -	738 282 1931	TP WB FB	H	3
CT2	1.19 6.77 -	738 312 1835	TP WB FB	H	3
CT3	2.11 12.30 -	87 1179 1585	TP WB FB	A	3
CT4	2.89 2.24 -	64 150 960	TP WB FB	A	3
CT5	1.37 11.40 -	57 326 1630	TP WB FB	A	3
	3.90	361	TB		

CT6	6.20 -	107 767	WB FB	H	3
CT7	1.26 3.20 -	19 757 927	TP WB FB	A	3
CT8	1.36 0.78 -	97 289 3162	TP WB FB	A	3
CT9	1.23 0.52 -	93 287 305	TP WB FB	H	3
CT10	1.28 4.65 -	8 305 901	TP WB FB	A	3
CT11	1.26 4.06 -	8 6 100	TB WB FB	H	3
CT13	2.48 -	10 534	WB FB		2
CT12	1.18 4.08 -	91 321 1134	TP WB FB	A	3
CT14	2.42 2.76 -	135 618 2364	TP WB FB	A	3
CT15	2.85 6.86 -	87 197 1230	TP WB FB	A	3
CT16	1.21 9.42 -	108 546 2859	TP WB FB	A	3
CT17	1.23 9.49 -	107 404 2783	TP WB FB	A	3
	1.95	118	TP		
CT18	7.94 -	501 1540	WB FB	A	3
CT19	1.94 4.34 -	125 735 3574	TP WB FB	A	3
CT20	1.36 8.65 -	55 113 1072	TB WB FB	A	3
CT21	1.96 2.68 -	132 313 2257	TP WB FB	A	3
CT22	2.40 4.61 -	112 442 1610	TP WB FB	A	3
CT23	3.35 10.10 -	33 15 110	TP WB FB	H	3
CT24	2.08 5.23 -	13 6 107	TP WB FB	H	3
CT25	1.63 8.08 -	2.85 17.3 1128	TP WB FB	A	3
CT26	1.97 6.12 -	28 32 83	TB WB FB	A	3
CT27	1.69 0.60 -	104 229 6036	TP WB FB	A	3
CT28	1.69 7.32 -	33 933 1322	TP WB FB	A	3
CT29	1.30 19.50 -	17 588 1277	TP WB FB	A	3
CT30	1.94 4.34 -	123 987 2584	TP WB FB	A	3
CT31	1.36 8.64 -	56 116 1072	TB WB FB	A	3
CT32	1.37 2.67 -	7 336 635	TP WB FB	A	3
CT33	1.57 9.04 -	14 275 1369	TP WB FB	A	3
CT34	1.21 9.42 -	108 546 2857	TP WB FB	A	3
CT35	3.91 23.00 -	336 159 767	TP WB FB	H	3
	2.01	62	TB		

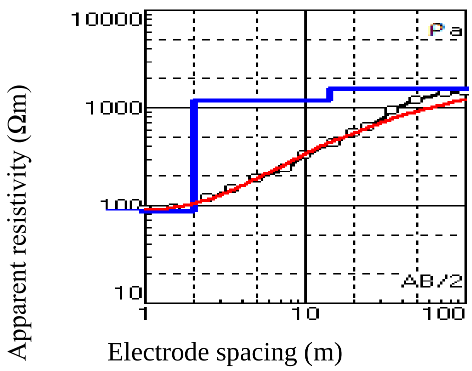
Stations	Thickness (m)	Layer resistivity (Ωm)	Remarks	Curve types	Numb of layers
CT36	20.50 -	613 1026	WB FB	A	3
CT37	2.08 8.83 -	50 966 3162	TP WB FB	A	3
CT38	1.72 3.43 -	43 248 1150	TP WB FB	A	3
CT39	1.21 10.80 -	13 159 521	TB WB FB	A	3
CT40	2.24 10.60 -	25 681 1150	TP WB FB	A	3



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)
Electrode spacing (m)

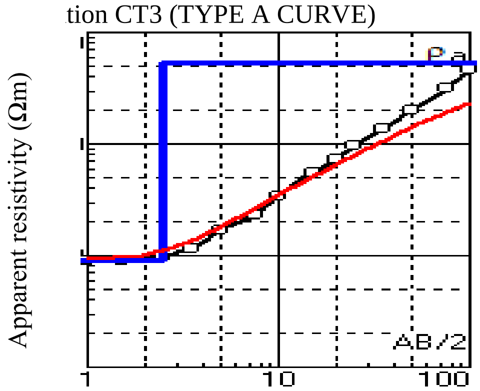


N	ρ	h	d
1	87	2.11	2.11
2	1179	12.30	14.4
3	1585		

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.

Electrode spacing (m)

(b) tion CT3 (TYPE A CURVE)

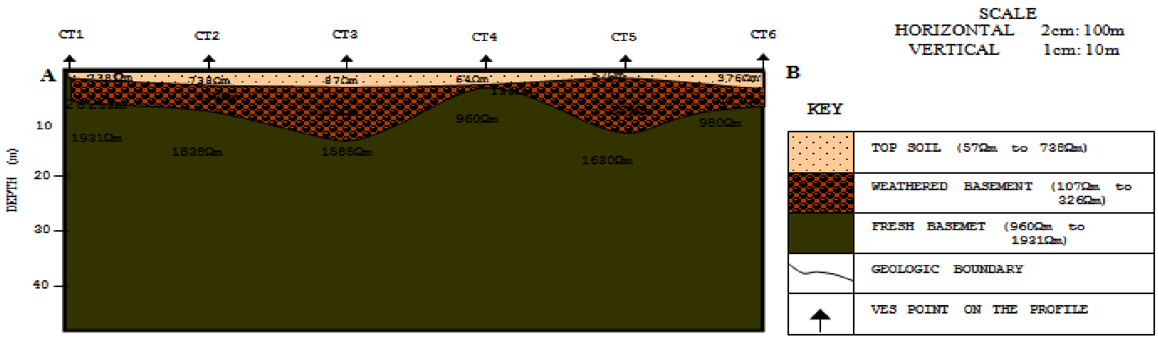


N	ρ	h	d
1	9	2.48	2.48
2	534		

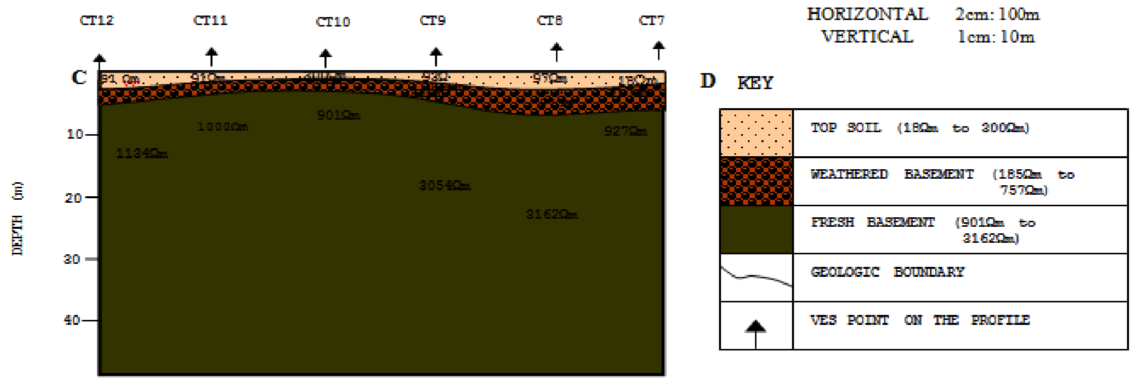
Where,
N is the layer number,
ρ is the apperent resistivity
in ohm-metre,
h is the layer thickness and
d is the depth to interface of
each layer

Electrode spacing (m)
(c) Station CT13 (2 LAYER CASE)

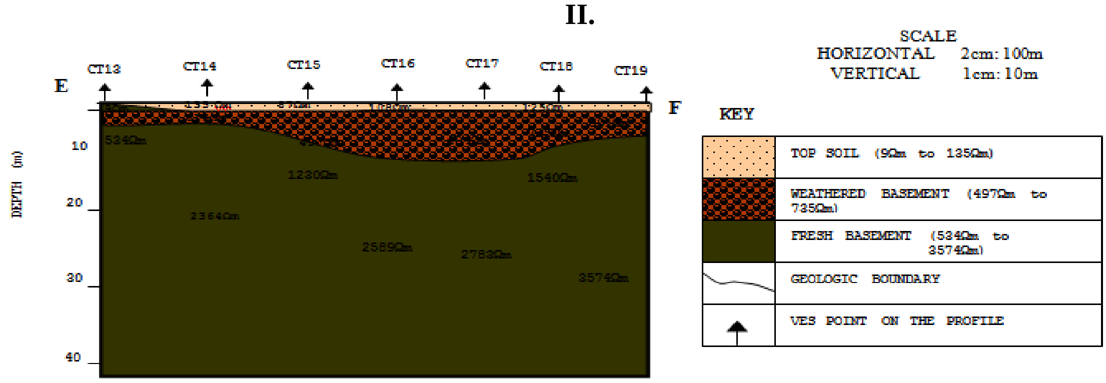
FIG. 3: Examples of curve types and models obtained from the study area.



I.

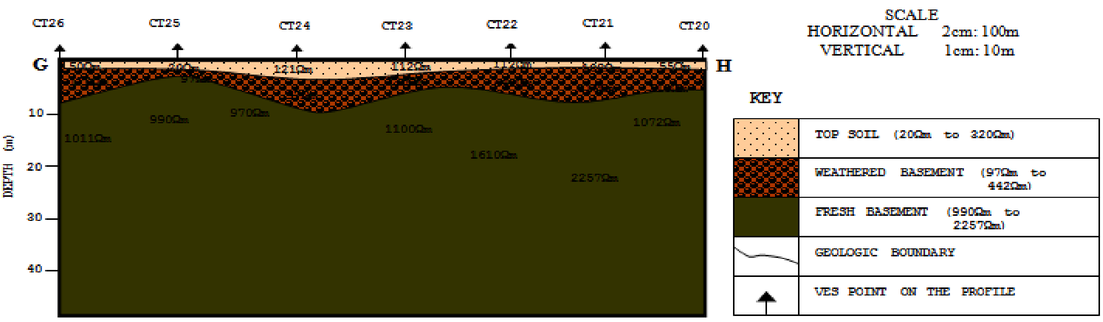


II.



III

FIG. 4: Geoelectric sections along profiles AB, CD AND EF.



IV

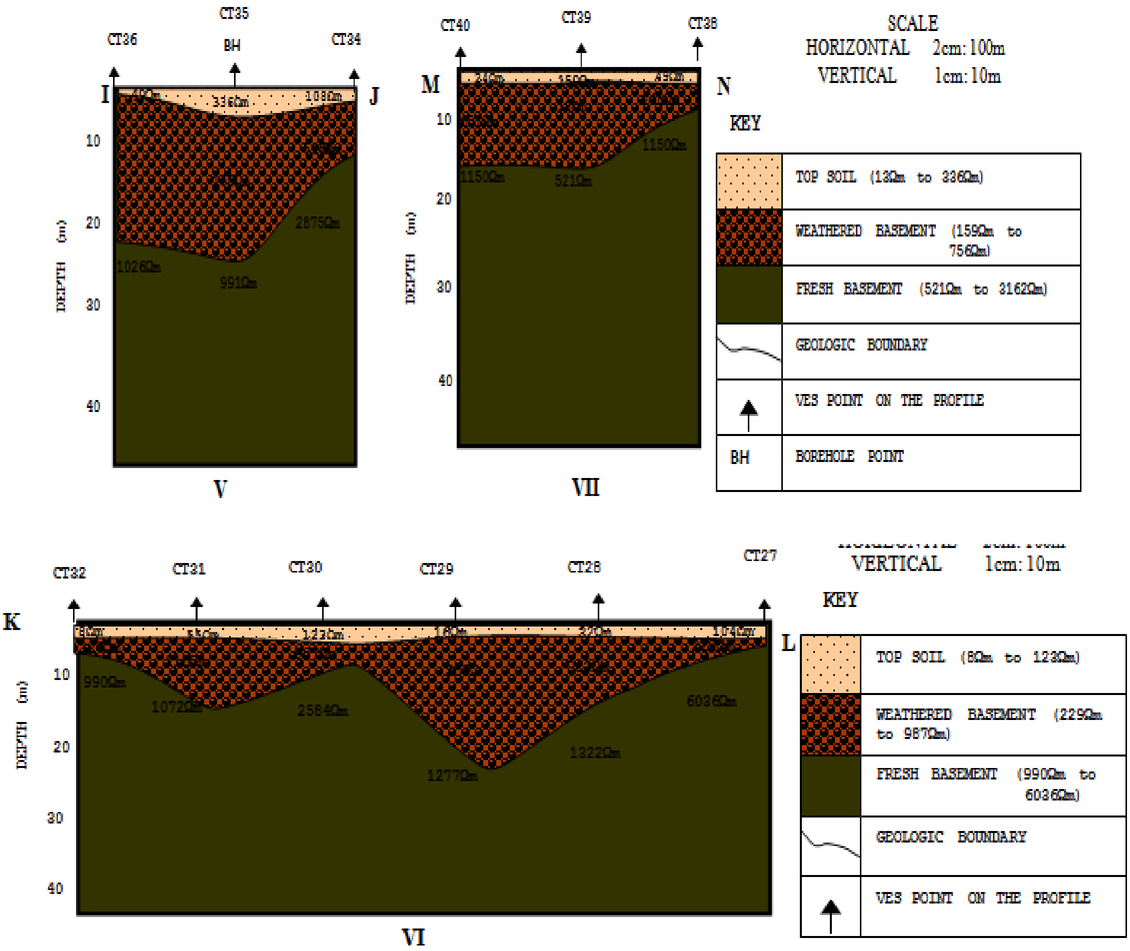


FIG. 5: Geoelectric sections along profiles GH, MN, IJ AND KL.

Bello University, Zaria, with a view to determining the depth to bedrock, thickness of the top soil and weathered basement. The following conclusions are drawn from the results of this work; the study area is mostly three (3) layered which include the top soil, weathered basement and fresh basement. The topsoil has resistivity values ranging from 2 to 738**Ω**m, and thickness ranging from 1 to 3.9 m. The weathered basement has resistivity value ranging from 32 to 1735**Ω**m with thickness ranging from 0.5 to 23m. The sounding point is deepest at VES CT35 with a depth of 26.9 m and shallowest at VES CT9 and CT27 with depth of 1.75 m to bedrock. The fresh basement therefore has its deepest part around VES CT35. The parameters of investigation have helped as follows.

* Identifying strategic areas for siting high-rise buildings: these are areas with shallow depths to the bedrock with thickness from 5 to 10m. The bedrock can serve as pillar supports to the buildings and also thin topsoil with thickness (<2 m) because of the clayey nature of the topsoil. 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 m are fairly competent and can support large civil engineering structures.
* Identifying potential positions for the location of boreholes: points along the profiles with thickness of weathered basement >10 m are good aquifer for boreholes. This is because the weathered basement is referred to as the fractured zone characterized by structural elements like fissures, faults e.t.c. that enhance groundwater permeability and storage.
* Possible depth of sewage system: the depth of sewage system should be <5 m to the weathered basement (aquiferrous zone) in order to avoid groundwater contamination. On the other hand, since the area is generally shallow to the fresh basement and groundwater in this area is vulnerable to pollution if there is leakage of buried underground septic tank, sewage channels or infiltration of leachate from decomposing refuse dumps, it is recommended that potential sources of contamination site should be sited far away from viable aquifer units to ensure safety consumption of groundwater within the area.

REFERENCES

[1]. DANLADI, G.G. 1985. "Appraisal of Hydrological Investigation in Shallow Basement Area of Zaria". Unpublished M.Sc. Thesis, Department of Geology, Ahmadu Bello University, Zaria.
[2]. DOBRIN, M. B. and SAVIT, C. H. 1988. "Introduction to Geophysical Prospecting". Fourth Edition, McGraw-Hill Book Co.
[3]. FAROUQ, A.U. 2001. "Geoelectric Investigation of the groundwater potential in the Institute for Agricultural Research farm". Unpublished M.Sc., Thesis, Department of Physics, Ahmadu Bello University, Zaria.
[4]. HAROLD, E.D. 1970. "Arid Lands in Transition". The Hornshafer Company Division of G.D.W. King Printing Co., U.S.A.
[5]. KLINKENBERA, K. 1970. "Soil of Zaria Area, In Zaria and its Region" (ed. M. J. Mortimore), Department of Geography, Occasional Paper No. 4, Ahmadu Bello University, Zaria, P. 223 – 238.
[6]. KUNETZ, G. 1966. "Principles of D.C. Resistivity Prospecting". Geoexploration Monograph, Series No. 1, Gebruder Borntraeger, Berlin.
[7]. McCURRY, P. 1970. "The Geology of Zaria Sheet 21". Unpublished M.Sc. Thesis, Department of Geology, Ahmadu Bello University, Zaria.
[8]. PARASNIS, D.S. 1962. "Principles of Applied Geophysics". Chapman and Hall Ltd., London.
[9]. SAMINU, O. 1999. "Geophysical Investigation of Federal College of Education, Zaria". Unpublished M.Sc. Thesis, Department of Physics, Ahmadu Bello University, Zaria.