GEOTECHNICAL INVESTIGATION OF THE SUBSURFACE FORMATIONS, USING ELECTRICAL RESISTIVITY METHOD IN NORTHERN PART OF PAIKO TOWN, NIGER STATE, NIGERIA

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Abstract: Vertical electrical sounding (VES) was carried out in northern part of Paiko town, using Abem Terrameter model SAS 4000. The study was carried out with a view to determine the subsurface layer parameters (resistivity, depth, thickness and lithologies) which were employed in delineating the sites for building construction. Six transverses with ten VES stations along each traverse, having separation of 50 m apart were investigated. It has a maximum current electrode separation (AB/2) of 100 m. Three to four distinct geoelectric layers were observed namely; Top layer which consist of gravel, sand, laterite and alluvial; weathered/fractured layer consist of clay and laterite, and fresh basement layer that consist of granite, gneiss and igneous rock. The observed frequencies in curve types include 21.6% of H, 0.6% of HA, 2.4% of K, 0.6% of A, 3.6% of KH, 6% of QA and 1.2% of HK. Sixteen VES stations were delineated for building construction, having depths to fresh basement varying between 2.18 m and 3.93 m with fresh basement resistivity ranged between 1038 Ωm and 194453 Ωm.

Keywords: Building construction, resistivity, depth, geoelectric layer, bedrock, Abem Terrameter

Introduction

Vertical electrical sounding was carried out to examine the competence of the formation for high rise buildings. Geophysical site investigation minimizes the cost of direct boring/drilling into the subsurface and it has a wide coverage of various materials occurring at a particular site (Bell, 2007). In the recent time, building collapse has become a familiar occurrence on the street in Nigeria with higher reported cases between 1980 and 2014 (Alamu & Gana, 2014). Most problems of structural failure are often associated with improper founding of foundations and poor quality of building materials (Akintorinwa & Abiola, 2011; Ofomola *et al.,* 2009). The choice of location, foundation/soil investigation, design of structural type, building construction expertise among others, is highly essential in building constructions. Buildings are affected not only by design errors but also by foundation inadequacies such as sitting them on incompetent earth layers. A good foundation should safely sustain the super structure to be erected on it in such a way as not to cause any settlement or other movement which would impair stability or cause damage to the whole or any part of the buildings.

In recent time resistivity method is widely used in preliminary site investigation to show the materials existing in the subsurface (Omowumi, 2014). The study area is located in the north central part of Nigeria. The population of Paiko is increasing rapidly as a result of people migrating from rural areas to urban towns to earn a living. As such, there is need for more estate development to accommodate the growing population of the area. However, presently in Nigeria there are several cases of building collapse and cracking of walls as a result of poor foundation and lack of site investigation (Alhassan *et al.*, 2015). There is need to search for the areas where the consolidated basement is shallow and have high resistivity values which can provide strong base for building construction. Therefore, the aim of this work is to employ geoelectrical method to determine sites where the fresh basement is intruded close to the surface that can support foundations to buildings.

Among several geophysical methods employed in determining depth to bedrock (electrical resistivity, gravity, seismic, magnetic, remote sensing, and electromagnetic), the electrical resistivity method is the most effective (Kearey *et al.*, 2002; Alhassan *et al.*, 2017). It is an effective and a reliable tool in slicing the earth into geoelectric layers. It has the advantage of non-destructive effect on the environment, cost effective, rapid and quick survey time and less ambiguity in interpretations of results when compared to other geophysical survey methods (Todd, 1980). The vertical electrical sounding (VES) technique provides information on the vertical variations in the resistivity of the ground with depth (Ariyo, 2005; Alhassan *et al.*, 2015; Obiora *et al.*, 2016). It is used to solve a wide variety of problems, such as; determination of depth, thickness and boundary of aquifer (Asfahani, 2006; Bello and Makinde, 2007).

Materials and Methods

Geology of the study area

The study area is located within the north central Nigerian basement complex. It has an elevation of 304 m above sea level with population of about 736,133 people as at 2006 census. It is bounded by latitudes 9º 25^{1}N and 9º 27^{1}N and longitudes 6 º 37^{1}E and 6 º 39^{1}E. Generally, the area mapped forms part of the Minna- granitic formation that consists of Metasediment `and metavolcanics. The Metasediment include quartzites, gneisses and the metavolcanics are mainly granites. Among the main rock groups are granites which occur at the central and northern parts of the area, while on the south and east, cobbles of quartzite are found especially along the channels and valley. However, the other bodies like pegmatites and quartz veins also occur within the major rock types (Fig. 1). The rocks are mainly biotite –granites with medium to coarse grained, light colored rocks with some variation in biotite content. The mineral constituents are leucocratic to mesocratic. However, the biotite minerals are thread like and are arranged rough parallel streak, although some are disoriented in the groundmass. The feldspar minerals occur as fine to medium grained, though grains are cloudy as a result of alteration mostly along the twin planes, while the quartz minerals are constituents of the granitic rocks which show strong fracturing in the granitic rocks of the area (Ajibade, 1980).

The area is therefore, underlain by four lithological formations as it is evident from the rocks in the area. The rock types in this region include granites, gneisses quartzite as well as laterites while most of the granites are older granites and this distinguishes them from the younger granites found in Jos area. From field observation, granitic rocks are the most

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abundant and they are widely distributed in the study area, as well characterized by hills with relative low lands and slightly drained by streams of intermittent and ephemeral types and also some tributaries. The area mapped is underlain by coarse to medium grained granite. These rocks are well exposed at the southern and eastern parts of the area. In hand specimen

they have a coarse texture. The outcrops are all light in colour and the major minerals contained are quartz, feldspar and biotite as revealed under the thin section studies by the use of a petrological microscope (Fig. 1).
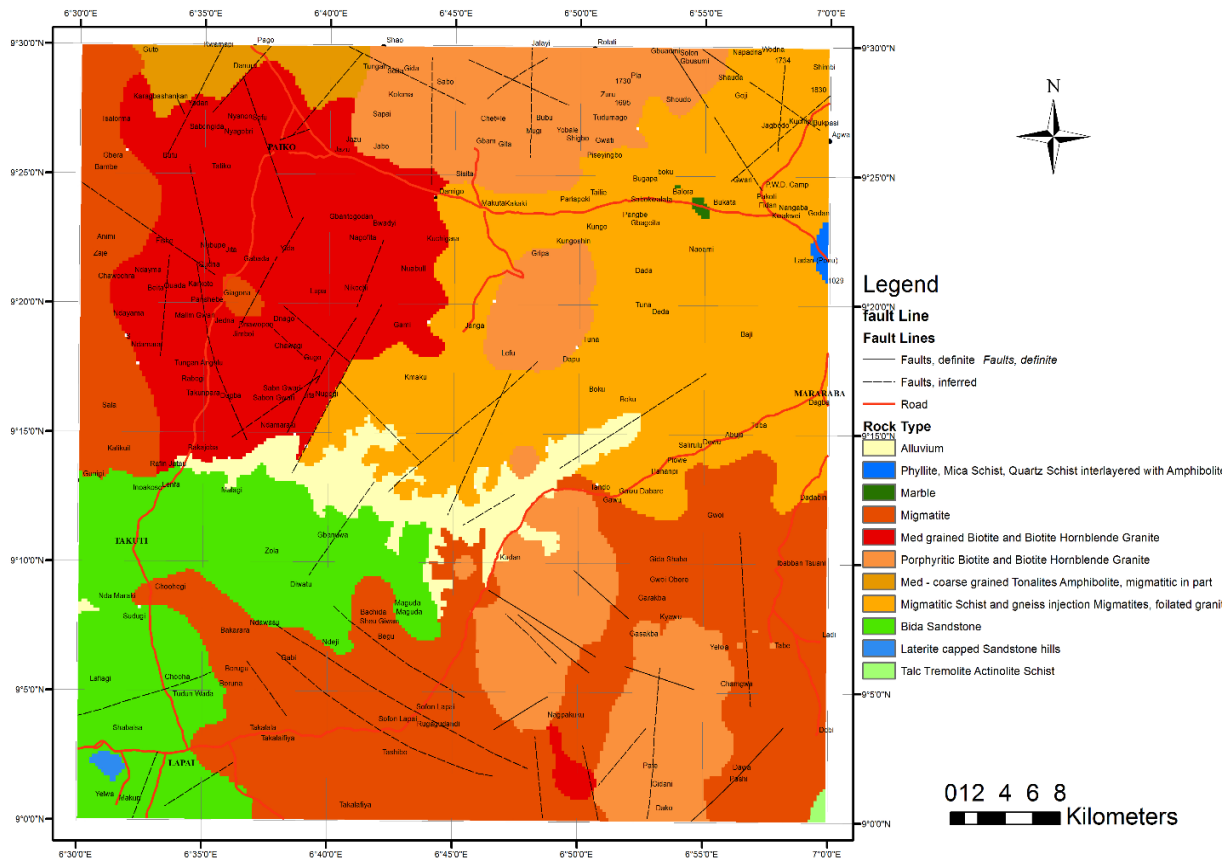

Fig. 1: Geological map of Paiko Area (Modified after NGSA, 2010)

Methodology

This research has utilized the electrical resistivity method in delineating the shallow consolidated basement of the study area. Sixty vertical electrical soundings were carried out using SAS 4000 model Terrameter and its accessories. The conventional Schlumberger array pattern with half electrode spacing (AB/2) varying from 1 m to a maximum of 100 m was adopted. The apparent resistivity was computed using equation 1

$$\rho_a = KR \qquad (1)$$

Where ρ_a is an apparent resistivity and the earth resistance (R) is given as

$$R = \frac{\Delta V}{I} \qquad (2)$$

The geometric factor, K, is expressed as

$$K = \pi \left(\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \right) \qquad (3)$$

The apparent resistivity values obtained from equation (1) were plotted against the half current electrode separation spacing using IPI2WIN software. From these plots, vertical electrical sounding curves were obtained (Fig. 2) and qualitative deductions such as resistivity of the layers, the depth of each layer, the thickness of each layer, number of layers, curve types and geologic cross section of the area were made.

Results and Discussion

The summary of the interpreted electrical resistivity survey is presented in Tables 1, 2, 3 and 4. Table 1 consists of VES stations G_1 to I_{10} while Table 2 comprised of VES stations J_1 to L_{10}. The tables 3 and 4 show the depth to consolidated basement. From the plot of apparent resistivity versus half current electrode spacing, geoelectric sections were produced (Fig. 2), where resistivity of the layers, the depth of each layer, the thickness of each layer, and number of layers, were obtained.

The geologic cross section (Fig. 3a-f) reveals that the area is characterized by 3 to 4 geologic subsurface layers. Six profiles with sixty VES stations were covered and their subsurface geologic cross sections were presented in Fig. 3. The geologic cross section shows the layers in vertical sequence with colorations differentiate one layer from another layer (Fig. 3a-f). From the Fig., 3- layer type occurring more and are characterized by H curve type. Some are characterized by A and K curve types. The 3- layer geologic sections are generally made up of topsoil, weathered/fractured layer and fresh basement rock from top to the bottom with variable depths, thicknesses and resistivities. The 4- layer geoelectric sections are characterized by HA, KH and HK curve types. The observed frequencies in curve types include 21.6 % of H, 3.0 % of HK, 4.2 % of HA, 3.6 % of A, 2.4 % of K, and 1.2 % of KH

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Table 1: Layers resistivity, depth, thickness and curve types

VES Station	No of Layer	Layer resistivity (Ωm)				Layer depth (m)				Layer Thickness (m)				Curve type
		ρ_1	ρ_2	ρ_3	ρ_4	d_1	d_2	d_3	d_4	h_1	h_2	h_3	h_4	
G_1	3	1248	184	60671		1.40	6.00	∞		1.40	4.60	∞		H
G_2	3	1720	526	11221		1.38	7.27	∞		1.38	5.89	∞		H
G_3	3	667	126	12178		1.14	4.07	∞		1.15	2.92	∞		H
G_4	3	947	70.80	78315		1.63	5.11	∞		1.63	3.47	∞		H
G_5	4	820	247	1021	308865	1.04	1.88	26.30	∞	1.04	0.85	24.40	∞	HA
G_6	3	380	8244	1522		2.87	4.91	∞		2.07	2.04	∞		K
G_7	3	1120	132	4920		2.07	3.93	∞		2.07	1.06	∞		H
G_8	3	419	968	15552		3.91	23.30	∞		3.91	19.40	∞		A
G_9	3	229	11184	1303		2.11	6.87	∞		2.11	4.75	∞		K
G_{10}	3	117	351	13298		1.18	9.07	∞		1.19	7.88	∞		A
H_1	4	1490	152	750	117922	1.18	3.21	25.40	∞	1.18	2.03	22.10	∞	HA
H_2	3	415	124	3204		1.69	3.93	∞		1.69	2.24	∞		H
H_3	3	308	130	13859		1.42	3.28	∞		1.42	1.86	∞		H
H_4	3	1114	136	41263		1.93	7.16	∞		1.93	5.23	∞		H
H_5	3	39.90	60825	5239		3.07	75.10	∞		3.07	72.00	∞		K
H_6	3	1070	80368	224		1.38	4.81	∞		1.38	3.43	∞		K
H_7	3	243	941	92291		1.85	26.10	∞		1.05	24.30	∞		A
H_8	3	457	700	215028		1.45	12.40	∞		1.45	10.90	∞		A
H_9	3	550	28	4233		1.12	3.30	∞		1.12	2.17	∞		H
H_{10}	4	191	106	263	278439	1.43	3.03	17.60	∞	1.43	1.60	14.60	∞	HA
I_1	3	595	46.40	194453		1.37	3.34	∞		1.37	1.96	∞		H
I_2	3	761	110	3542		1.25	4.10	∞		1.25	2.86	∞		H
I_3	3	536	153	7580		1.52	4.75	∞		1.52	3.23	∞		H
I_4	3	527	32	103681		1.16	5.47	∞		1.16	4.31	∞		H
I_5	3	180	27.70	55673		1.22	5.23	∞		1.22	4.02	∞		H
I_6	3	1606	154	1796		1.12	3.72	∞		1.12	2.60	∞		H
I_7	3	764	34.10	2027		1.06	2.18	∞		1.06	1.12	∞		H
I_8	3	3082	131	43827		2.15	8.22	∞		2.15	6.06	∞		H
I_9	3	474	27	38527		1.61	3.97	∞		1.61	2.36	∞		H
I_{10}	3	1463	10.90	19302		1.11	2.78	∞		1.11	1.67	∞		H

VES-vertical electrical sounding; ρ-layer resistivity; d- layer depth; h – layer thickness; m-metre

Table 2: Layers resistivity, depth, thickness and curve types

VES station	No of Layer	Layer resistivity (Ωm)				Layer depth (m)				Layer Thickness (m)				Curve type
		ρ_1	ρ_2	ρ_3	ρ_4	d_1	d_2	d_3	d_4	h_1	h_2	h_3	h_4	
J_1	3	841	223	2867		1.36	3.61	∞		1.36	2.25	∞		H
J_2	4	439	85.20	236672	696	1.35	3.53	8.57	∞	1.35	2.18	5.04	∞	HK
J_3	3	1423	978	9225		8.53	15.70	∞		8.53	7.20	∞		H
J_4	4	985	189	94441	288	1.05	3.27	11.20	∞	1.05	2.22	7.93	∞	HK
J_5	3	83.80	29.40	131987		1.86	5.86	∞		1.86	3.99	∞		H
J_6	2	62.20	1623			1.56	∞			1.56	∞			A
J_7	3	982	199	2950		0.95	3.54	∞		0.95	2.59	∞		H
J_8	4	387	140	398	118946	1.86	6.09	36.60	∞	1.86	4.22	30.50	∞	HA
J_9	3	620	11.20	58241		1.00	3.00	∞		1.00	2.00	∞		H
J_{10}	4	571	124	354	213414	1.30	2.73	17.80	∞	1.30	1.43	15.10	∞	HA
K_1	4	554	4846	296	196873	3.57	7.19	16.40	∞	3.57	3.61	9.22	∞	KH
K_2	3	636	978	5752		4.06	26.20	∞		4.06	22.10	∞		A
K_3	3	517	78	5437		1.17	3.22	∞		1.17	2.05	∞		H
K_4	3	178	111	6005		1.42	4.47	∞		1.42	3.05	∞		H
K_5	4	469	117	191	134745	1.07	3.00	15.70	∞	1.07	1.93	12.70	∞	HA
K_6	3	198	331	95088		1.30	15.20	∞		1.30	13.90	∞		A
K_7	4	776	61.30	1478	59411	1.21	2.76	40.30	∞	1.21	1.54	37.50	∞	HA
K_8	3	712	61.20	108026		1.06	7.45	∞		1.06	6.39	∞		H
K_9	3	786	114	29362		2.02	16.10	∞		2.02	14.10	∞		H
K_{10}	3	433	113	1038		2.02	3.62	∞		2.02	1.60	∞		H
L_1	4	300	196	27962	79.90	2.69	7.93	15.30	∞	2.69	5.23	7.41	∞	HK
L_2	4	620	154	38600	130	1.18	3.24	8.02	∞	1.18	2.06	4.78	∞	HK
L_3	4	625	132	113317	303	1.28	3.03	6.78	∞	1.28	1.75	3.75	∞	HK
L_4	3	1052	232	172184		1.24	12.70	∞		1.24	11.40	∞		H
L_5	3	656	289	4230		1.49	13.60	∞		1.49	12.10	∞		H
L_6	3	85	15.20	78682		1.13	5.26	∞		1.13	4.13	∞		H
L_7	3	584	156	2853		1.18	3.73	∞		1.18	2.55	∞		H
L_8	3	1003	59.80	31877		2.54	7.28	∞		2.54	4.75	∞		H
L_9	3	546	43.20	107599		1.42	7.54	∞		1.42	6.12	∞		H
L_{10}	3	420	170	110943		2.31	14.40	∞		2.31	12.10	∞		H

VES-vertical electrical sounding; ρ-layer resistivity; d- layer depth; h – layer thickness; m-metre
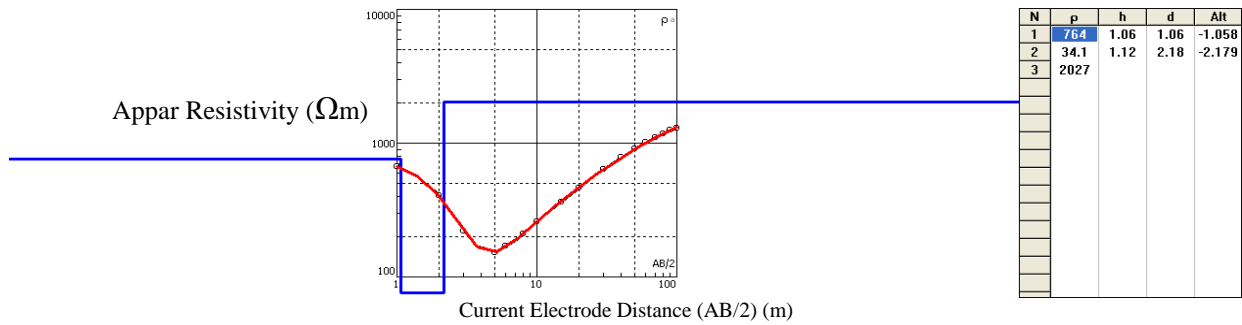
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Fig. 2a: VES Curve I₇

Appar Resistivity (Ωm)

Current Electrode Distance (AB/2) (m)

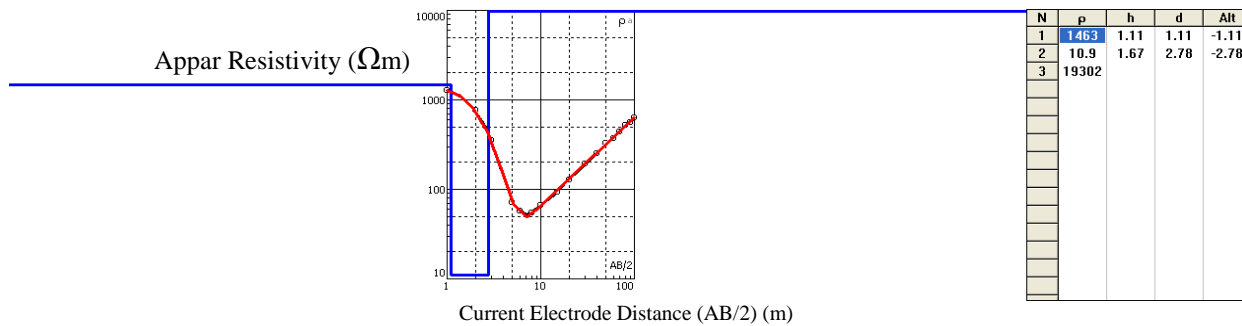**Fig. 2b: VES Curve I₁₀**

Appar Resistivity (Ωm)

Current Electrode Distance (AB/2) (m)

The 4- layer geoelectric section is made up of topsoil, weathered layer, fractured layer and fresh basement rock. Generally, the topsoil of the area is made up of loose sand, gravels, sandy clay, laterite and clay. In a basement complex terrain, areas with fresh basement layer depth less or equal to 4 m are favorable and good for building construction (Alhassan *et al*., 2015).
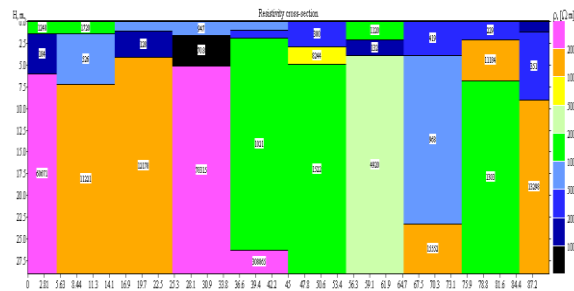
Fig. 3a: Geologic cross-section of profile G
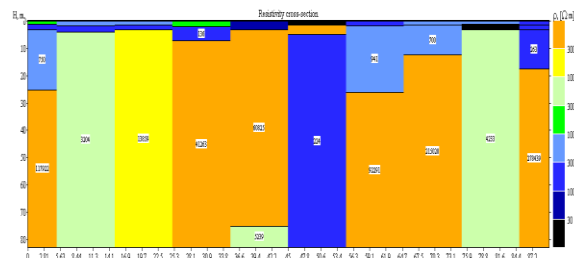
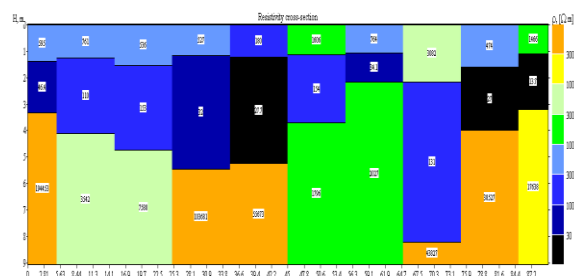**Fig. 3b: Geologic cross-section of profile H**

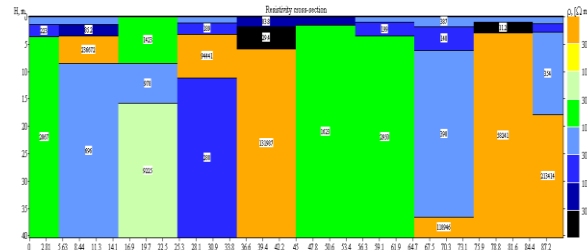**Fig. 3c: Geologic cross-section of profile I**

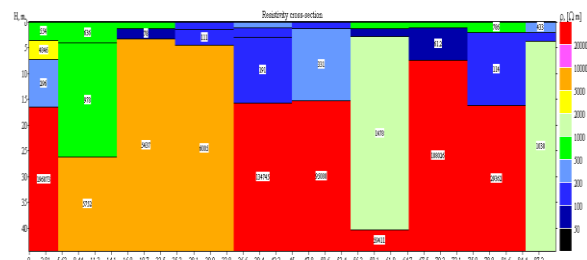**Fig. 3d: Geologic cross-section of profile J**
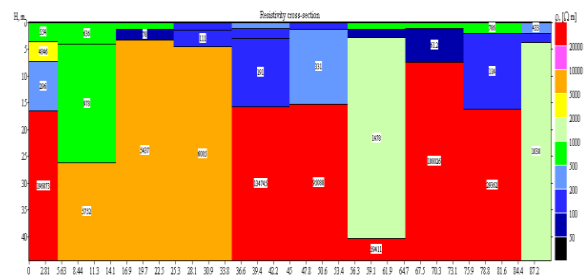

Fig. 3e: Geologic cross-section of profile K

Fig. 3f: Geologic cross-section of profile L

In order to investigating the continuous variation of resistivity with depth, iso-resistivity maps using Golden software (Surfer 11.0) version were obtained for the layers (Fig. 4). It shows the color range corresponding to resistivity range of the earth materials. The iso-resistivity map of the first layer reveal that blue represent gravels, sky blue represent sand, green correspond to laterite and yellow represent alluvial deposits (Fig. 4a).

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Table 3: Depths to fresh basement of the area

VES Station	Latitude (degrees)	Longitude (degrees)	Elevation (m)	Depth to Basement (m)
G_1	09.46521	006.63871	320	6.00
G_2	09.46500	006.63832	312	7.27
G_3	09.46463	006.63797	307	4.07
G_4	09.46435	006.63756	311	5.11
G_5	09.46410	006.63720	310	26.30
G_6	09.46379	006.63683	313	4.91
G_7	09.46360	006.63642	307	3.93
G_8	09.46330	006.63602	306	23.30
G_9	09.46294	006.63575	308	6.87
G_{10}	09.46264	006.63533	312	9.07
H_1	09.46567	006.63856	313	25.40
H_2	09.46538	006.63799	305	3.93
H_3	09.46502	006.63739	299	3.28
H_4	09.46469	006.63698	304	7.16
H_5	09.46443	006.63658	307	75.10
H_6	09.46413	006.63629	307	4.81
H_7	09.46382	006.63595	310	26.10
H_8	09.46353	006.63560	305	12.40
H_9	09.46279	006.63505	303	3.30
H_{10}	09.46278	006.63501	305	17.60
I_1	09.46609	006.63838	309	3.34
I_2	09.46596	006.63795	313	4.10
I_3	09.46572	006.63758	310	4.75
I_4	09.46551	006.63718	305	5.47
I_5	09.46535	006.63672	305	5.23
I_6	09.46510	006.63634	306	3.72
I_7	09.46483	006.63597	306	2.18
I_8	09.46458	006.63562	305	8.22
I_9	09.46424	006.63528	308	3.97
I_{10}	09.46383	006.63491	296	2.78

Table 4: Depths to fresh basement of the area

VES Station	Latitude (degrees)	Longitude (degrees)	Elevation (m)	Depth to Basement (m)
J_1	09.46655	006.63817	312	3.61
J_2	09.4663	006.63778	311	8.57
J_3	09.46610	006.63736	310	15.70
J_4	09.46587	006.63693	303	11.20
J_5	09.46569	006.63650	291	5.86
J_6	09.46538	006.63613	301	3.00
J_7	09.46520	006.63573	305	3.54
J_8	09.46494	006.63538	304	36.60
J_9	09.46465	006.63501	303	3.00
J_{10}	09.46429	006.63460	303	17.80
K_1	09.46704	006.63790	316	16.40
K_2	09.46672	006.63721	311	26.20
K_3	09.46640	006.63688	301	3.22
K_4	09.46617	006.63649	302	4.47
K_5	09.46588	006.63613	300	15.70
K_6	09.46560	006.63574	301	15.20
K_7	09.46533	006.63533	302	40.30
K_8	09.46504	006.63494	303	7.45
K_9	09.46473	006.63451	298	16.10
K_{10}	09.46443	006.63412	305	3.62
L_1	09.46746	006.63768	314	15.30
L_2	09.46734	006.63724	310	8.02
L_3	09.46703	006.63681	314	6.78
L_4	09.46677	006.63638	312	12.70
L_5	09.46650	006.63600	313	13.60
L_6	09.46621	006.63557	306	5.26
L_7	09.46585	006.63514	299	3.73
L_8	09.46552	006.63486	296	7.28
L_9	09.46529	006.63436	304	7.54
L_{10}	09.46497	006.63390	314	14.40

The iso-resistivity map of the second layer shows that blue color corresponds to clay and sky blue represent laterite (Fig. 4b). Third layer iso-resistivity maps reveal that blue represent granite, sky blue represent gneiss, green correspond to igneous rock, and yellow represent gabbro rock (Fig. 4c).

The depth to consolidated basement map shows the depth distribution within the area (Fig. 4d). From the map, the area with blue coloration corresponds to the shallow depth to fresh basement with high resistivity values and therefore be the suitable areas delineated for building construction.
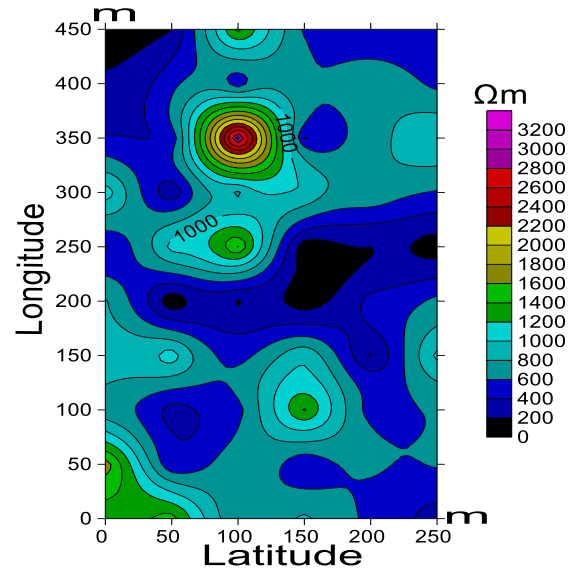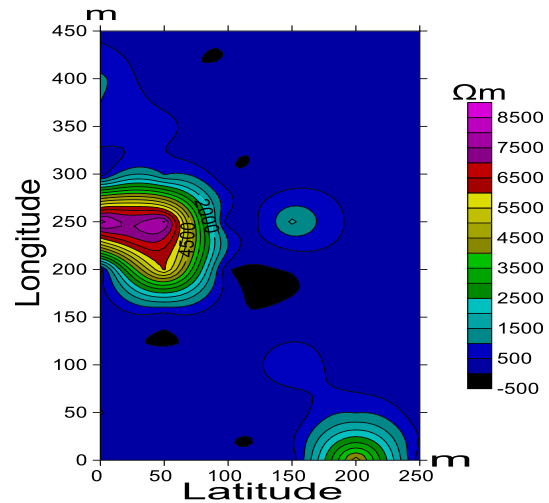

Fig. 4a: Iso resistivity map of the first layer

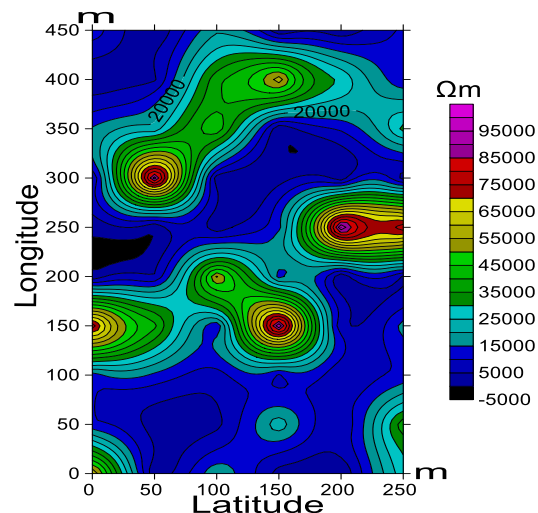**Fig. 4b: Iso resistivity map of the second layer**

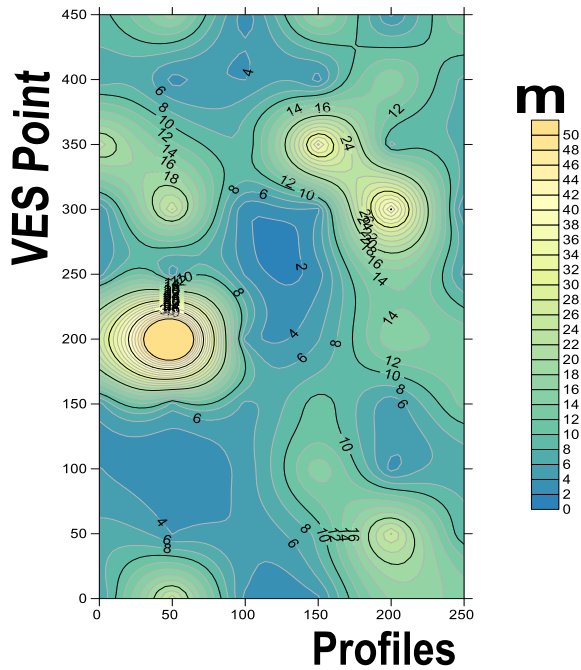**Fig. 4c: Iso resistivity map of the third layer**

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Fig. 4d: Depths to fresh basement contour map

Table 5: Areas delineated for building construction

VES Station	Latitude (degrees)	Longitude (degrees)	Elevation (m)	Depth to Basement (m)
G_7	09.46360	006.63642	307	3.93
H_2	09.46538	006.63799	305	3.93
H_3	09.46502	006.63739	299	3.28
H_9	09.46279	006.63505	303	3.30
I_1	09.46609	006.63838	309	3.34
I_6	09.46510	006.63634	306	3.72
I_7	09.46483	006.63597	306	2.18
I_9	09.46424	006.63528	308	3.97
I_{10}	09.46383	006.63491	296	2.78
J_1	09.46655	006.63817	312	3.61
J_6	09.46538	006.63613	301	3.00
J_7	09.46520	006.63573	305	3.54
J_9	09.46465	006.63501	303	3.00
K_3	09.46640	006.63688	301	3.22
K_{10}	09.46443	006.63412	305	3.62
L_7	09.46585	006.63514	299	3.73

Sixteen VES stations were delineated for building construction having depths to fresh basement varying between 2.18 and 3.93 m and resistivity values ranged between 1038 and 194453 Ωm, where consolidated basement is shallow as indicated in Table 5.

Conclusion

The use of various electrical resistivity parameters (resistivity of the layer, depth of the layer, thickness of the layer) were employed to determine the suitable site for building construction. Three to four distinct geoelectric layers were observed namely; Top layer, weathered layer, fractured layer, and fresh basement layer. The observed frequencies in curve types include 21.6% of H, 4.2% of HA, 2.4% of K, 3.6% of A, 1.2% of KH, and 3% of HK. Sixteen VES stations were delineated for building construction, having depths to fresh basement varying between 2.18 and 3.97 m and fresh basement resistivities ranged from 1038 to 194453 Ωm. Government and estate developers in the area are encouraged to make use of the results of this study for building construction site selection to reduce the problem of building collapse and cracking of walls. More research work in this area would contribute to solving the problem of collapse of building completely.

References

Ajibade AC 1980. The Geology of the Country around Zungeru, Northwestern state of Nigeria. M.Sc. thesis, University of Ibadan, Ibadan, Nigeria.

Alhassan DU, Obiora AN & Okeke FN 2015. The assessment of aquifer potentials and aquifer vulnerability of southern Paiko, north central Nigeria, using geoelectric method. *Global J. Pure & Appl. Sci.*, 21: 51- 70.

Alhassan DU, Mamodu A, Jimoh MO & Mohammed A 2015. Geotechnical investigation of the earth subsurface formation for its suitability for high-rise buildings in southern part of Paiko, Niger State, North Central Nigeria. *Journal of Science, Technology and Mathematics Education (JOSTMED)*, 11 (3):10-22

Alhassan DU, Obiora DN & Okeke FN 2017. Geoelectrical investigation of groundwater potentials of northern Paiko, Niger State, north central Nigeria. *Journal of Earth Science*, 28(1): 103-112

Alamu FB & Gana MS 2014. An investigation on the causes of building collapse in Nigeria. *J. Envtl. Sci. & Resources Mgt.*, 1.

Akintorinwa OJ & Abiola O 2011. Subsoil evaluation for pre-foundation study, using geophysical and geotechnical approach. *J. Engr. Trends in Engr. & Appl. Sci.*, 858 – 863.

Ariyo SO 2005. Geoelectrical Characterization of Aquifers and Geochemical study of Groundwater in the Basement Complex/Sedimentary Transition Zone around Isharsa, Southwest Nigeria. M.Sc. thesis, University of Ibadan, Ibadan, Nigeria.

Asfahani J 2006. Geoelectrical investigation for characterizing the hydrogeological conditions in semi-arid region in Khanasser valley, Syria. *J. Arid Environ.* 68: 31 – 52.

Bell, F.G (2007): Engineering Geology, Oxford United Kingdom: Elsevier Ltd.

Bello AA & Makinde V 2007. Delineation of the aquifer in the Sout-Western part of the Nupe Basin, Kwara State, Nigeria. *J. Am. Sci.*, 3: 36 – 44.

Dangana LM 2007. Geoelectric survey for subsurface water in Paiko town, Niger State, Nigeria, Ph.D thesis, University of Abuja, Nigeria

Obiora DN, Alhassan UD, Johnson CI & Okeke FN 2016. Geoelectric evaluation of aquifer potential and vulnerability of Northern Paiko, Niger State, Nigeria. *Water Environment Res.*, 88(7): 644 – 651.

Ofomola MO, Adiat KN, Olayanju GM & Ako BD 2009. Integrated geophysical methods for post foundation studies, Obanla Staff Quarters of the Federal University of Technology, Akure, Nigeria. *Pacific J. Sci. & Techn.*, 10(2): 93 – 111.

Omowumi FP 2014. Application of electrical resistivity in building foundation investigation in Ibese Southwestern Nigeria. *Asia Pacific J. Energy and Envt.*, 1(2).

Niger State Water and Sanitation Board 2001.

Todd KD 1980. Groundwater Hydrology. 2nd edition; John Wiley and Sons, New York.

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