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USE OF ELECTRICAL RESISTIVITY TECHNIQUE FOR ENGINEERING SITE INVESTIGATION: A CASE STUDY FROM ADO-EKITI, SOUTH-WESTERN NIGERIA.

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ABSTRACT

A geophysical investigation of part of the Federal Polytechnic Ado-Ekiti campus involved use of the electrical resistivity method for foundation studies. A combined geophysical technique of vertical electrical sounding and horizontal profiling was employed. The quantitative interpretation of the geophysical results allowed the layer parameters to be established, while the isoresistivity maps at varying electrode spacing provided information on the nature, type and competence of the underlying material. The qualitative interpretation of the horizontal profiling delineated the contact zone. Also analysis of transverse unit resistance showed the relevance of this parameter as an index in predicting engineering properties of the rock.

The presence of moderately thick (1.5 – 16.5m) clay has been established in this area; therefore the use of raft foundation and/or any other foundation that is commensurate with civil engineering standard is suggested for high rise structures.

KEY WORDS: Bedrock integrity, Transverse unit Resistance, Foundation.

INTRODUCTION

The application of geophysics to engineering site investigation is relatively new in Nigeria. Usually most of our civil and building engineers prefer using drilling, cone penetrometer test and some other geotechnical methods in assessing the strength of materials for the support of infrastructures such as roads, buildings and dams. As good as these methods are however, not only are thy very expensive in terms of cost but also might not give adequate information about the entire area and good depth of investigation could not b- achieved. Therefore the use of geophysical investigation should be encouraged which is cost effective compared to the traditional techniques.

Also, there have been recent occurrences of differential settlement leading to the collapse of buildings, which probably had poor foundations. It is therefore imperative to use some cost effective methods of geophysics (Dobecki and Romig, 1985, Olorunfemi and Mesida, 1987) as tools in geotechnical investigation.

Electrical resistivity and magnetic methods are very cheap and affordable by both individuals and corporations for the survey of sites for building construction purposes.

This paper describes how the electrical resistivity method was employed in a basement complex terrain for engineering site investigation.

GEOLOGY AND GEOMORPHOLOGY

The area around the campus of the Federal Polytechnic Ado-Ekiti (Fig. 1) is underlain by rocks of the Precambrain crystalline basement complex (Rahaman, 1988 and Olarewaju 1988). The main lithological units are gneisses and charnockite. Although this rock units have been concealed in most parts of the site, few isolated outcrops exist around the school premises. The terrain around the site is low-lying.

MATERIALS AND METHODS

The equipment used for the execution of this survey was the ABEM Terrameter Model 300B. It is portable, easy to operate and of high precision. Three geophysical traverses trending along east-west direction were established with inter-traverse spacing ranging from 60m to 80m (Fig. 2). Twelve vertical electrical sounding points were established along all the traverses and an inter VES station distance of 61m was maintained. The Schlumberger array with electrode spacing AB/2 varying from 1 to 100m was utilized. Horizontal profiling measurement along the three traverses each 232m was made using Wenner array with varying electrode spread "a" of 5m, 10m and 20m respectively in understanding the lateral variation of subsurface resisitivity at specific electrode spacing.

PROCESSING AND INTERPREATION OF DATA

The VES data obtained on the field was transformed into apparent resistivity using appropriate geometric factor, which was subsequently plotted on a log-log graph paper against half the current electrode separation (AB/2). The VES data were later subjected to manual interpretation process using partial curve matching, which entails the use of two-layer model master and auxiliary curves. The results of the interpretation were used as input model for computer aided interpretation (Ghosh, 1971, Verma and Pantulu, 1990). Figure 3 depicts typical curve types encountered in the study location while the result of the layer model interpretation of the study area is shown in (Table 1). Horizontal profiling data was presented as curves (Fig. 5). Geophysical structural maps and geoelectric sections (Figs. 4, 7, 6, 8 and 9) were also constructed in order to understand its engineering implications on the subsurface lithologic units.

DISCUSSION OF RESULTS

(a) Curve Types

The results of the interpretation indicate that the curve types associated with the area of investigation are H($\rho_1 > \rho_2 < \rho_3$), KH ($\rho_1 < \rho_2 > \rho_3 < \rho_4$) and HA ($\rho_1 > \rho_2 < \rho_3 < \rho_4$). Figure 3 shows typical sounding curves of the study location. Computer interpretation gave three or four geoelectric layers. The first layer constitutes the topsoil (clay/sandy clay/sand). Layer two is essentially clay, which has additional units of sand/weathered materials in VES 4, 7 and 9. The third layer in all the curves is sand/ weathered / crystalline bedrock.

(b) Geoelectric Sections

Figure 4 presents geoelectric sections along the respective traverses.

Geoelectric section along traverse 1

The geologic layers comprising this section are as shown below:

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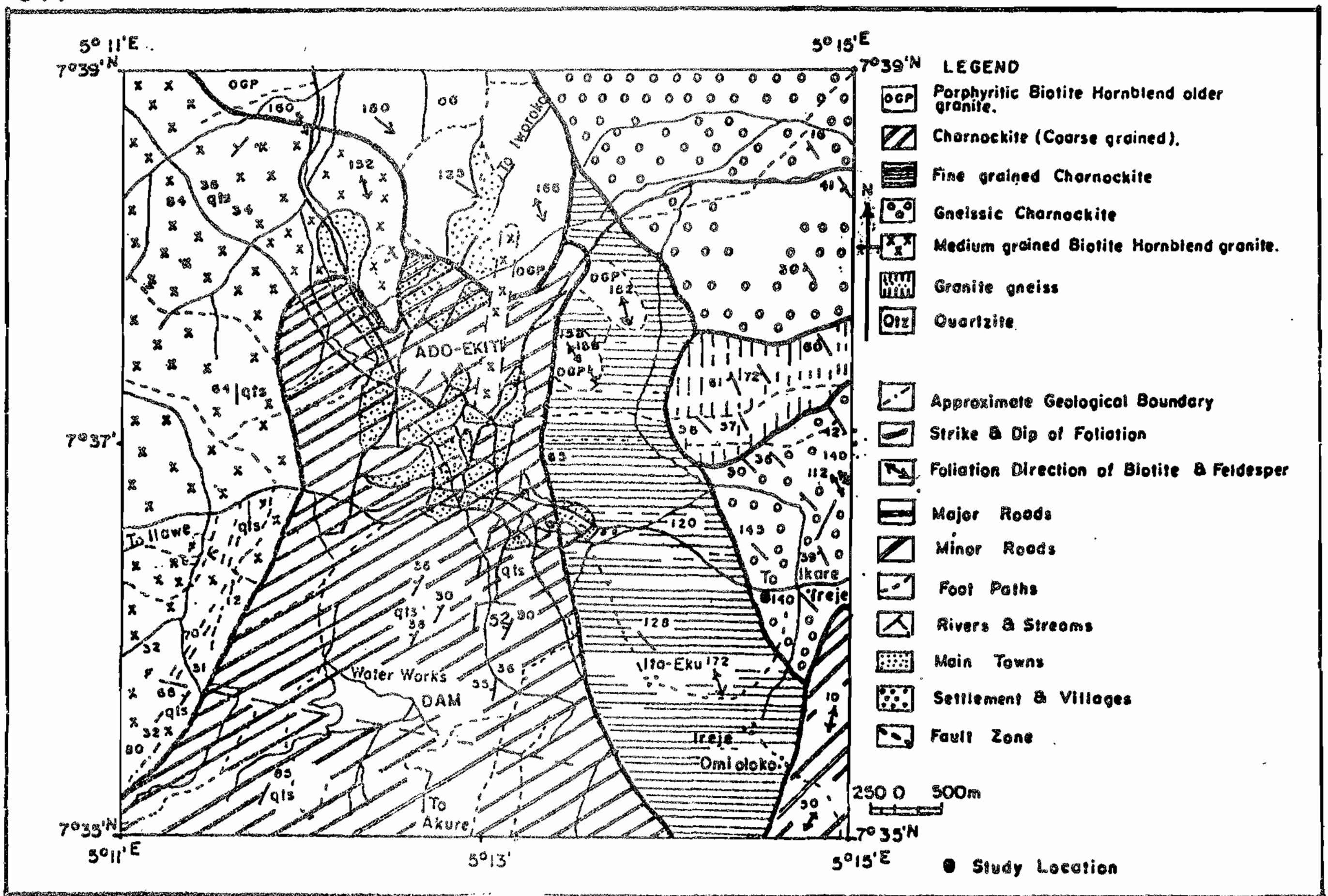

Fig. 1: Geological map of Ado-Ekiti area with study location (after Fadipe and Adeduro, 1990.

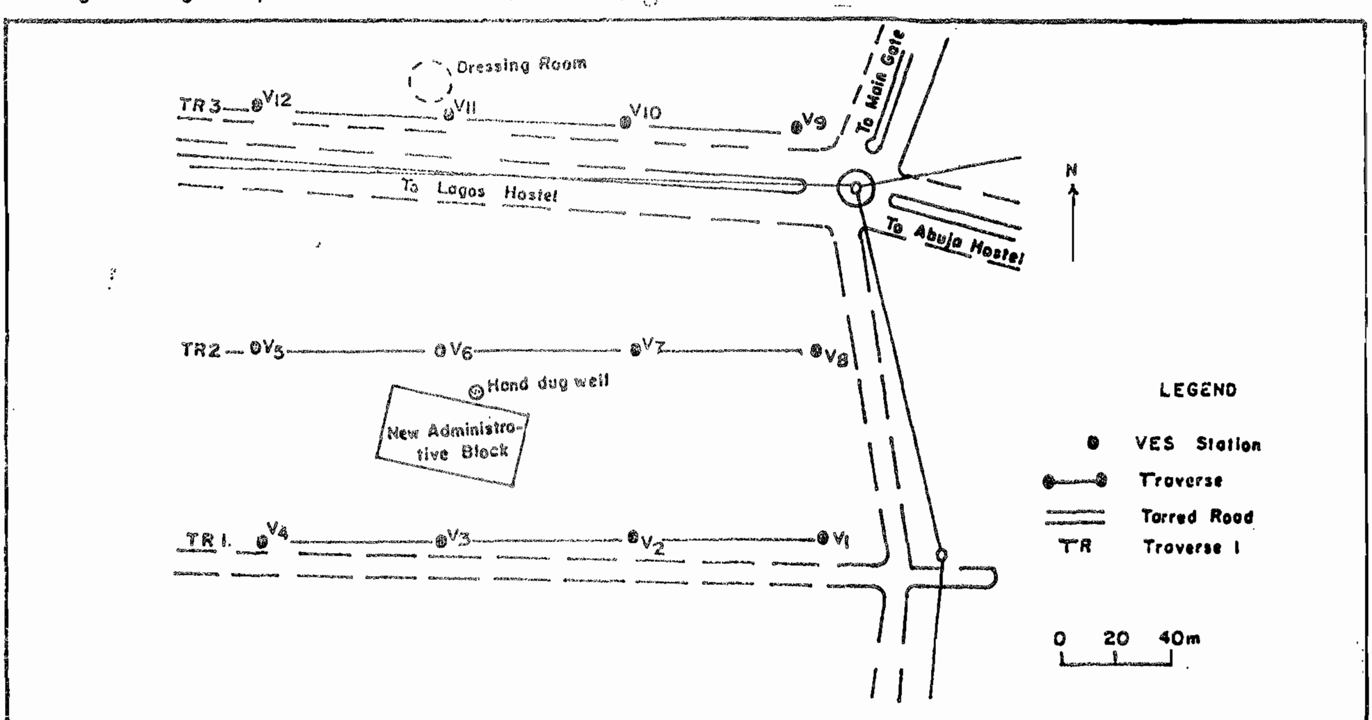

Fig. 2: Base map of study location ation.

Layer one: Topsoil of clay, sandy clay and sand.

Resistivity: 57 – 184 ohm-m; and thickness of 0.4 – 2.4m.

This layer is continuous across all the VES points.

Layer two: Thick clay and sandy underneath VES 4.

Resistivity: 21 – 150 ohm-m, and thickness of 1.5 – 14.1.m.

This layer exhibits variable thickness underneath the stations and is thickest around VES 2. Underlying this layer at VES 4 is

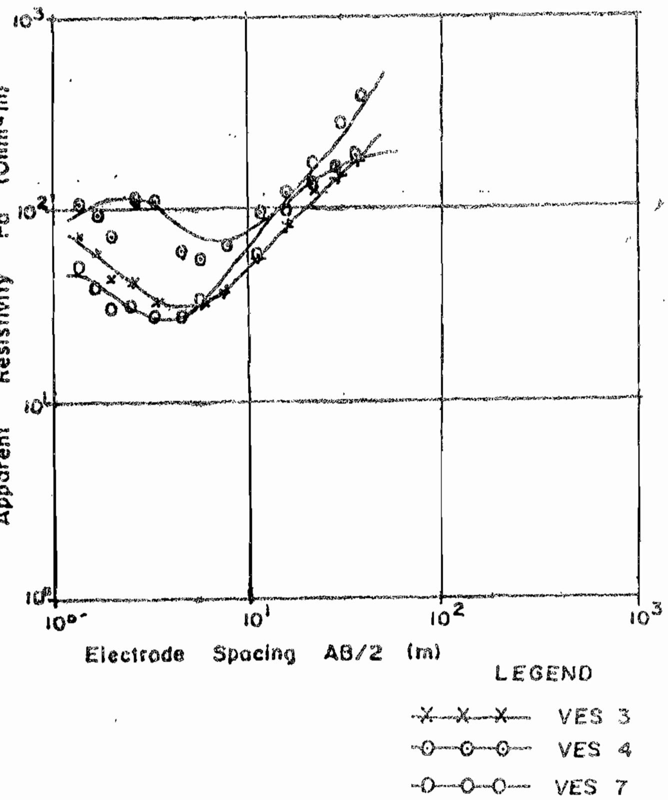

Fig. 3: Typical Schlumberger Sounding Curves

a clay unit having thickness of 4.3m and resistivity of 21 ohm-m.

Layer three: weathered bedrock.

Resistivitiy: 180 – 1624 ohm-m; and infinite thickness.

Depths to the top of the bedrock varies from 6.5m – 6.5m

The bedrock topography is highly undulating.

Geoelectric section along traverse 2

It is composed of the following lithologic units:

Layer one: Topsoil of clay, sandy clay and sand.

Resistivity: 38 – 622 ohm-m; and thickness 0.8 –2m.

This layer cuts across all the VES stations.

Layer two: Thick clay

Resistivity: 9 – 25 ohm-m; and thickness 5.1 – 9.6m.

This layer is of variable thickness and continuous underneath all the VES points. Underlying this layer at VES 7 is a sand/weathered bedrock lithologic unit. It has a resisitivty of 360ohm-m and 4.6m thick.

Layer three: Bedrock which is weathered at VES points 5 and 6 and crystalline at VES 7and 8 respectively.

Resistivity: 517 – 4995 ohm-m. Depths to the top of the bedrock vary from 7.1 – 15m. The bedrock topography is undulating.

Geoelectric section along traverse 3

The lithologic constituents of the section are as outlined below:

Layer one: Topsoil of clay and sand.

Resistivity: 91 – 445 ohm-m; and thickness 1.0 – 1.9M.

This layer is found underneath all the VES stations.

Layer Two: Thick clay.

Resistivity: 12 – 21 ohm-m, and thickness 5.7 – 16.4m.

This layer is prominent underneath all the sounding points. Underlying this layer at VES 9 is a sand/weathered bedrock lithologic unit. It has a resistivity of 207 ohm-m and is 4.5m thick.

Layer three: Bedrock which exhibits variable degree of weathering. It is weathered/fractured at VES points 12 and 10 and probably fresh at VES 11 and 9.

Resistivity: 940 – 3121ohm-m.

Depths to the top of the bedrock vary from 9.7 – 18.1m. The bedrock topography is undulating. In all the three sections the bedrock topography though undulating, has no significant displacement diagnostic of normal faulting (*Olorunfemi et al., 2000*).

(c) **Horizontal Resistivity Profiles**

Figure 5 presents horizontal resistivity profiles along traverses 1, 2 and 3.

Table 1: **Interpreted Vertical Electrical Sounding Results of the study area.**

VES NO	Layer Number	Resistivity (Ωm)	Thickness (m)	Depth (m)	Curve Type
1	1	117	1.9	1.9	
	2	31	10.0	11.9	H
	3	280	-	-	
2	1	184	2.4	2.4	
	2	42	14.1	16.5	H
	3	1624	-	-	
3	1	63	1.4	1.4	
	2	21	9.2	10.6	H
	3	354	-	-	
4	1	57	0.7	0.7	
	2	150	1.5	2.2	KH
	3	21	4.3	6.5	
	4	180	-	-	
5	1	622	1.5	1.5	
	2	25	9.4	10.9	H
	3	517	-	-	
6	1	182	1.0	1.0	
	2	9	6.5	7.5	H
	3	1261	-	-	
7	1	47	0.8	0.8	
	2	25	9.6	10.4	HA
	3	360	4.6	15.0	
	4	4106	-	-	
8	1	38	2.0	2.0	
	2	10	5.1	7.1	H
	3	4995	-	-	
9	1	96	1.9	1.9	
	2	12	5.7	7.6	
	3	207	4.5	12.1	HA
	4	3121	-	-	
10	1	257	1.1	1.1	
	2	15	8.6	9.7	H
	3	1565	-	-	
11	1	445	1.0	1.0	
	2	17	10.7	11.7	H
	3	2650	-	-	
12	1	91	1.7	1.7	
	2	21	16.4	18.1	H
	3	940	-	-	

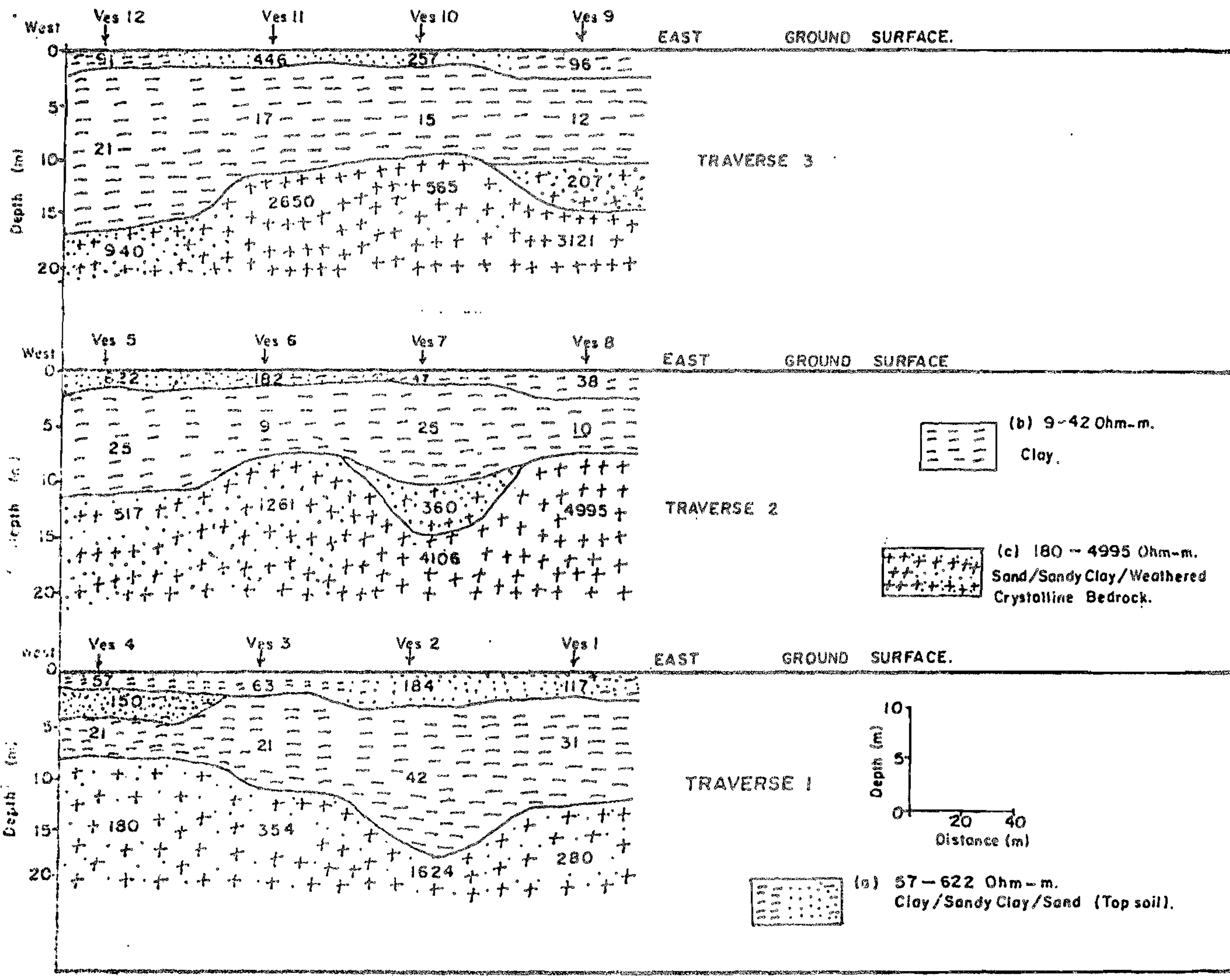

Fig. 4: Geo-electric Sections along traverses 1 - 3

Resistivity profile along traverse 1

Figure 5 shows resistivity profile along traverse 1. This diagram depicts lateral resistivity variation at electrodes spread "a" of 5m, 10m and 20m respectively. For all the spread there is a region of low resistivity from origin to a distance of 114m. Beyond this distance resistivity rises, although irregular until towards the end of the traverse then it drops again. The point characterized by anomalous low resistivity is probably a rock contact (Ojo and Olorunfemi 1994). This contact although occurring in the same rock unit, it is clay in the west and beyond the contact zone toward the east it is sandy clay.

Resistivity profile along traverse 2

Figure 5 shows the resistivity profile along traverse 2. the same trend of low resistivity is observed, although it is irregular throughout the traverse. The zone of anomalous resistivity occurs at a distance of 114m from the origin; however it is not as wide as the one in traverse 1. The same lithologic units of clay and sandy clay separated by a contact exist.

Resistivity profile along traverse 3

Figure 5 presents resistivity profile along traverse 3. The same trend of low resistivity is observable. The resistivity is irregular and the contact which is not as wide as the ones previously discussed is located at a distance of 114m from the origin. The lithologic units are similar to those along traverse 1 and 2.

(d) Lateral Resistivity Maps

Figures 6a, b and c present lateral resistivity maps at electrode spread "a" 5m, 10m and 20m. The maps convey information about lateral resistivity variation in the study location.

Lateral resistivity map at "a" equal 5m

Figure 6a depicts lateral resistivity variation map. A resistivity range of 15 – 70 ohm-m is observed. At the western flank resistivity is low (30 - 40 ohm-m), high at the center (35 – 75 ohm-m), typified by the closure which is a resistivity high, and decreased systematically towards the eastern part. At the centre in between VES 11 and 10, where there is an abrupt change in resistivity from low to high closure connotes a contact. The resistivity range is typical of clay material.

Lateral Resistivity map at "a" equal 10m.

Figure 6b shows the map. A resistivity range of 15 – 70 ohm-m is also observed. The same trend of low resistivity to the west, high at the center and low towards the east is also maintained. The same rock contact trend extends to this depth. Resistivity range is that of clay material.

Lateral Resistivity map at "a" equal 20m

Figure 6c depicts the map. It has a resistivity of 30 –

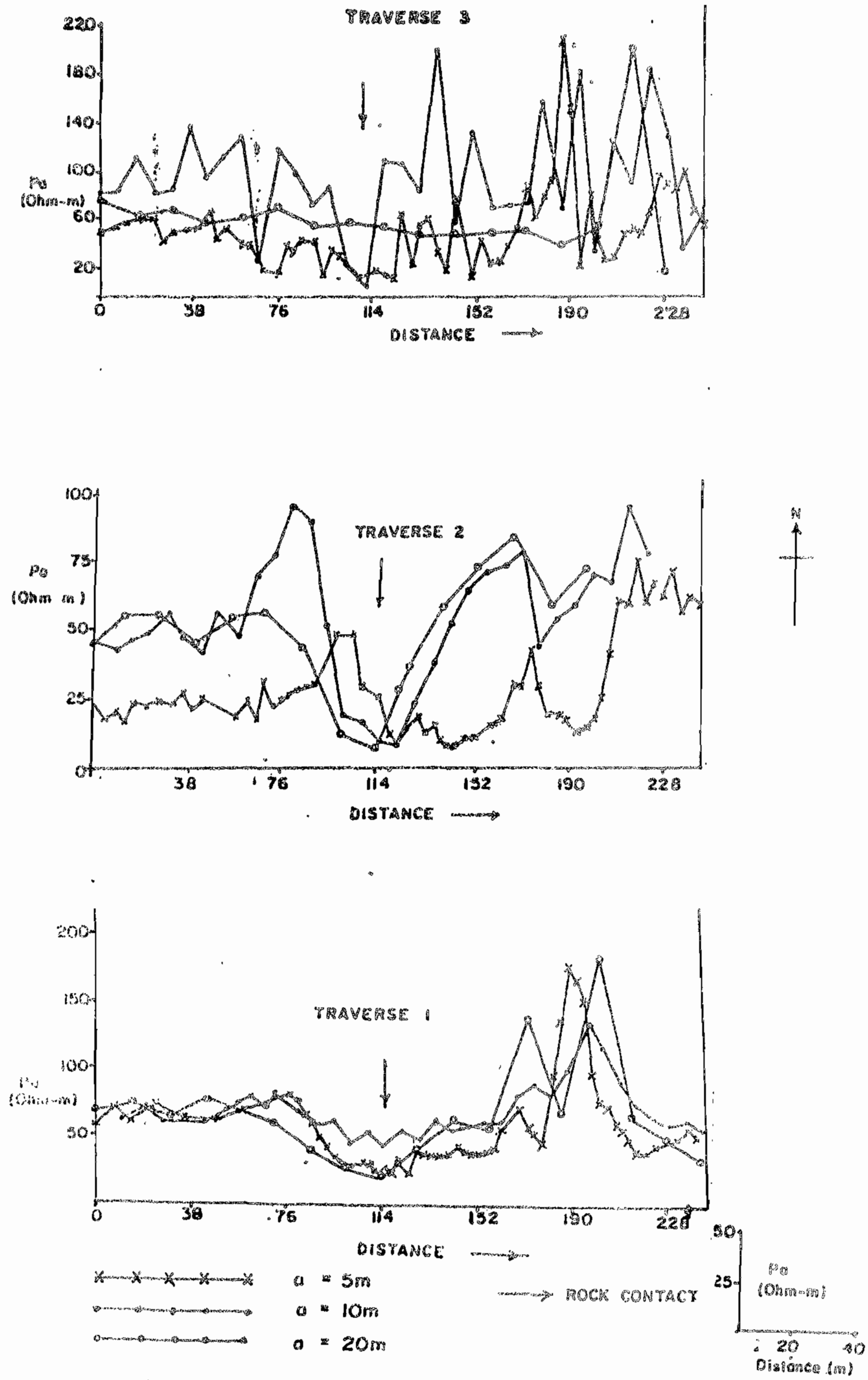

Fig. 5: Horizontal profiling curves for traverses 1 - 3

130 ohm-m. Resistivity range in the west is between 50 – 70 ohm-m, at the center it is 45 – 60 ohm-m and in the east it is 70 – 130 ohm-m. The rock contact is not prominent at this depth. Resisitivty range is typical of clay/sandy clay lithologic units.

(e) Isoresistivity Maps

Figures 7a – e present Isoresistivity maps at AB/2 equal 2m, 5m, 7.5m and 10m. The maps give us an insight into vertical resistivity distribution with depth.

Isoresistivity mapat AB/2 equal 2m

Figure 7a shows the isoresistivity map. It has a resistivity of 100 – 460 ohm-m. Resistivity decreases generally from east to west and has a range of 80 – 460 ohm-m. The resistivity values are typical of clay, sandy clay and sand.

Isoresistivity map at AB/2 equal 3.5m

Figure 7b shows the resistivity map. The range of resistivity is from 100 – 460 ohm-m. The same trend of resistivity increase from east to west is prominent with a range of 180 – 460 ohm-m. This resistivity range depicts that of sandy clay and sand.

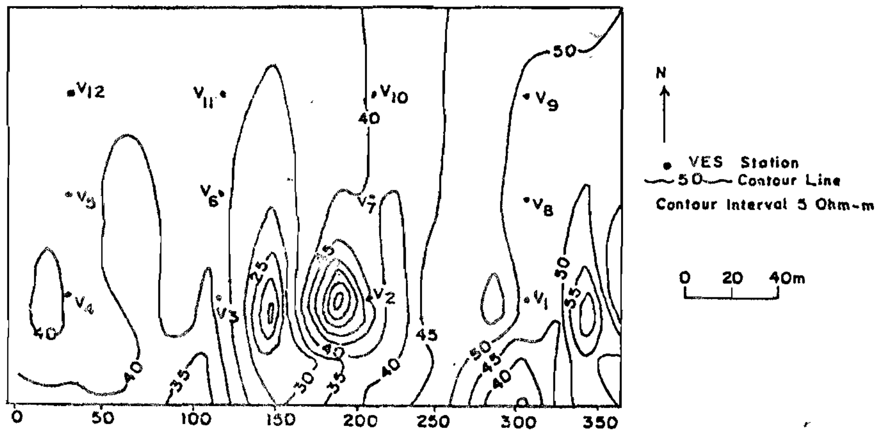

Fig. 6a: Lateral resistivity variation map at a = 5m

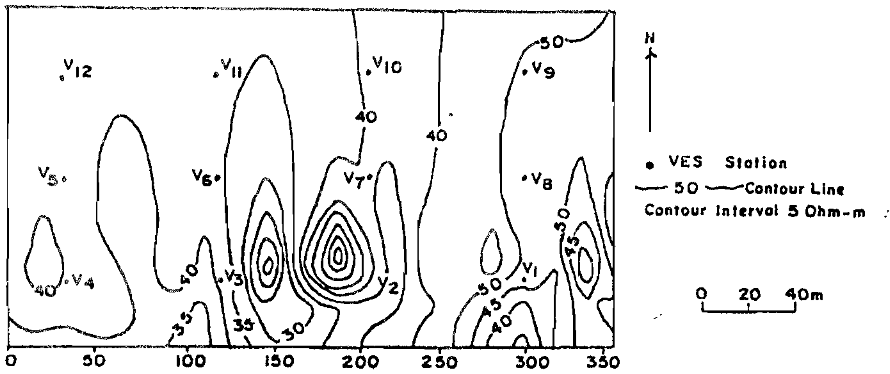

Fig. 6b: Lateral resistivity variation map at a = 10m

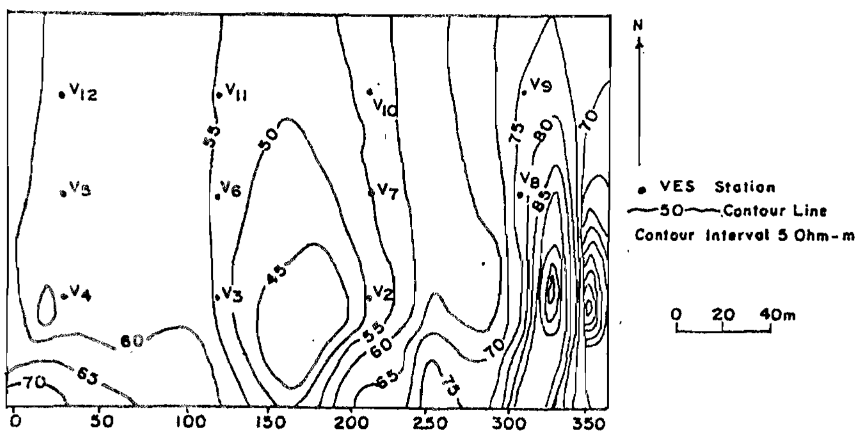

Fig. 6c: Lateral resistivity variation map at a = 20m

Isoresistivity map at AB/2 equal 5m

The map showing resistivity distribution is shown in Figure 7c. The range of resistivity is from 20 – 95 ohm-m. Resistivity increases from east to west with a range of 15 - 95 ohm-m. It is also high in the southeastern part with a range of 45 – 95 ohm-m. The range of resistivity connotes clay material.

Isoresistivity map at AB/2 equal 7.5m

Figure 7d is the isoresistivity map. The map has a resistivity of between 18 – 48 ohm-m. The same trend of increase in resistivity from east to west is maintained. Resistivity is also high at the southeastern part. The subsurface material with this resistivity distribution is clay.

Isoresistivity Map at AB/2 equal 10m

Figure 7e is the isoresistivity map. It has a resistivity ranging from 16 – 54 ohm-m. Resistivity distribution showed that it is high toward southeastern corner, with a magnitude of 32 – 54 ohm-m. It is also high at the middle portion of the map and around southwestern corner. The magnitude of resistivity is typical of clay material.

(f) Transverse Unit Resistance Map

Figure 8 shows the transverse unit resistance map of the study area. The map is relevant in understanding the integrity of the bedrock. In general the unit resistance varies from 200 – 1900 ohm-m^2,. Southeast, southwest and northeast have very high values in the range of 200 – 1900 ohm-m^2. The new administrative block is also located in a zone with fairly high values of transverse unit resistance 300 – 1300-ohm-m^2. Areas of high transverse unit resistance imply that subsurface materials are thick in such regions (Zohdy et al., 1980).

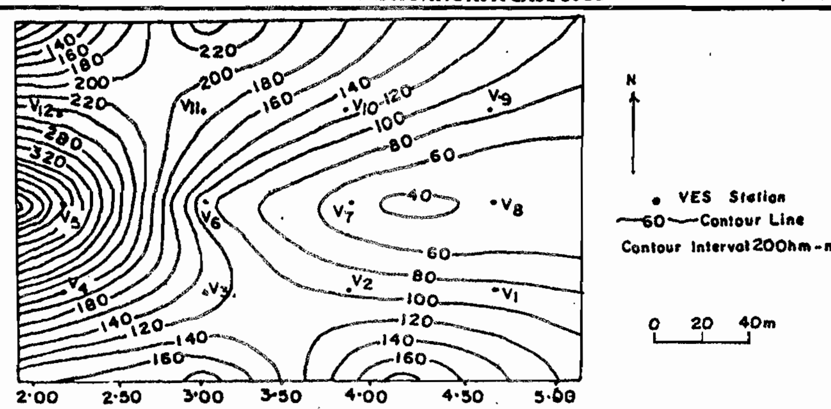

Fig. 7a: Isoresistivity map at AB/2 = 2m

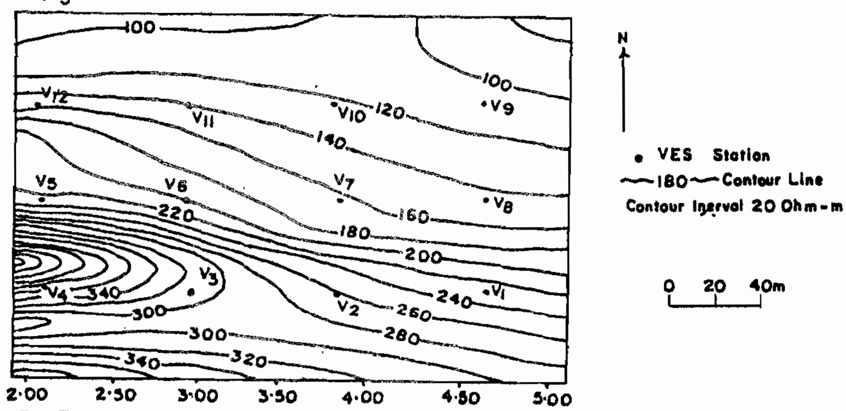

Fig. 7b: Isoresistivity map at AB/2 = 3.5

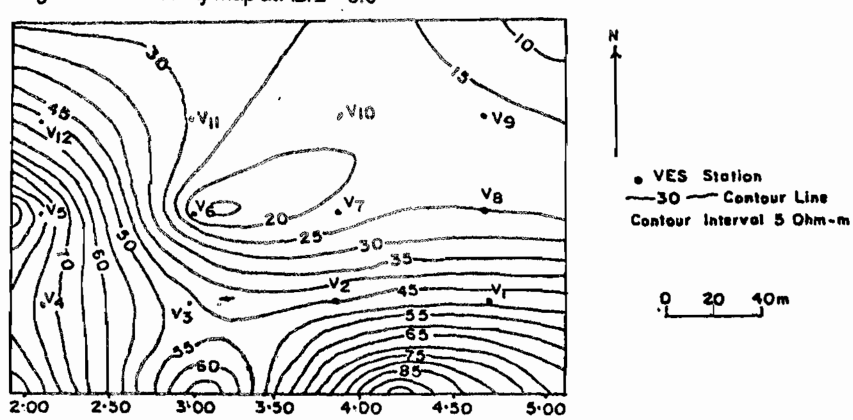

Fig. 7c: Isoresistivity map at AB/2 = 5m

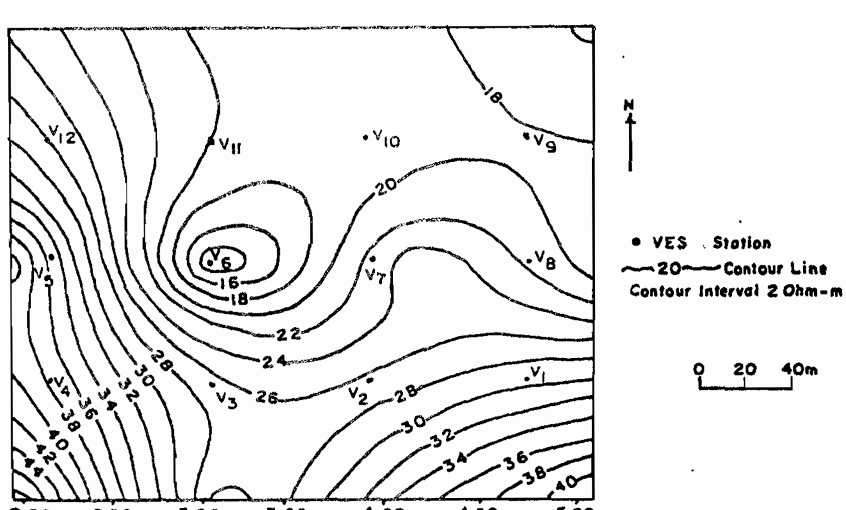

Fig. 7d: Isoresistivity map at AB/2 = 7.5m

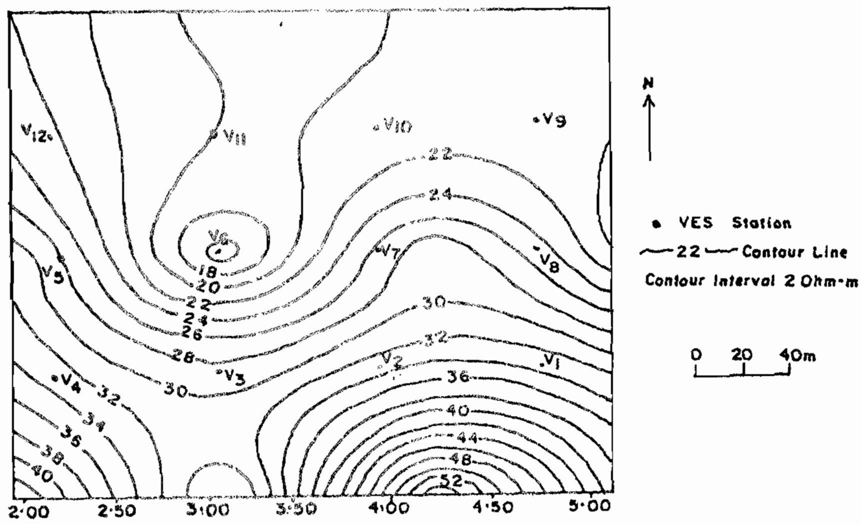

Fig. 7e: Isoresistivity map at AB/2 = 10m

(g) Isopach Map

Figure 9 presents the isopach map. The map displays variation in overburden thickness distribution. The thickness range is from 7 – 18m. In the northwest, northeast, southwest and southeast thicknesses are very high with a range of 7 – 18m. The southwestern part of the map where the administrative block is located has a thickness of between 8 – 14m.

GEOTECHNICAL CONSIDERATIONS

The area of investigation (new administrative block premises) is underlain by incompetent geologic materials comprising clay, sandy clay, sand, weathered and crystalline bedrock. A regrouping of these petrologic units for geotechnical engineering purposes is as given below:

Topsoil: (Clay/sand clay/ sand).

Resistivity: 38 – 622 ohm-m and thickness: 0.4 – 2.4m

Clay: Resistivity: 9 - 25 ohm-m and thickness: 4.3 -16.4m

Bedrock: Resistivity: 180 – 4995 ohm-m and thickness: infinity.

Clay and sandy clay materials in this environment are non swelling because they are rich in kaolinite (Akinola et al, 1993), and consequently have low shrinkage efficiency. Horizontal resistivity profiles (Fig. 5) are characterized by alternate peak – trough outline which is diagnostic of fractures/joints/lineaments. Lateral resistivity maps (Figs 6a-c) show distinct changes in resistivity across the area thus corroborating the horizontal resistivity profiles. Isoresistivity maps (Figs 7a – e) of the various electrode spread indicate a decrease in resistivity with depth, which is probably due to the difference in water saturation of the different lithologic units. The bedrock topography as observed from the geoelectric sections (Fig. 4) is undulating and there is no vertical displacement to depict any faulting. Transverse unit resistance map (Fig. 8) and Isopach map (Fig. 9) all point to the fact that the subsurface materials (Clay/sandy clay) thicken in the southwest, southeast, northeast and northwest respectively.

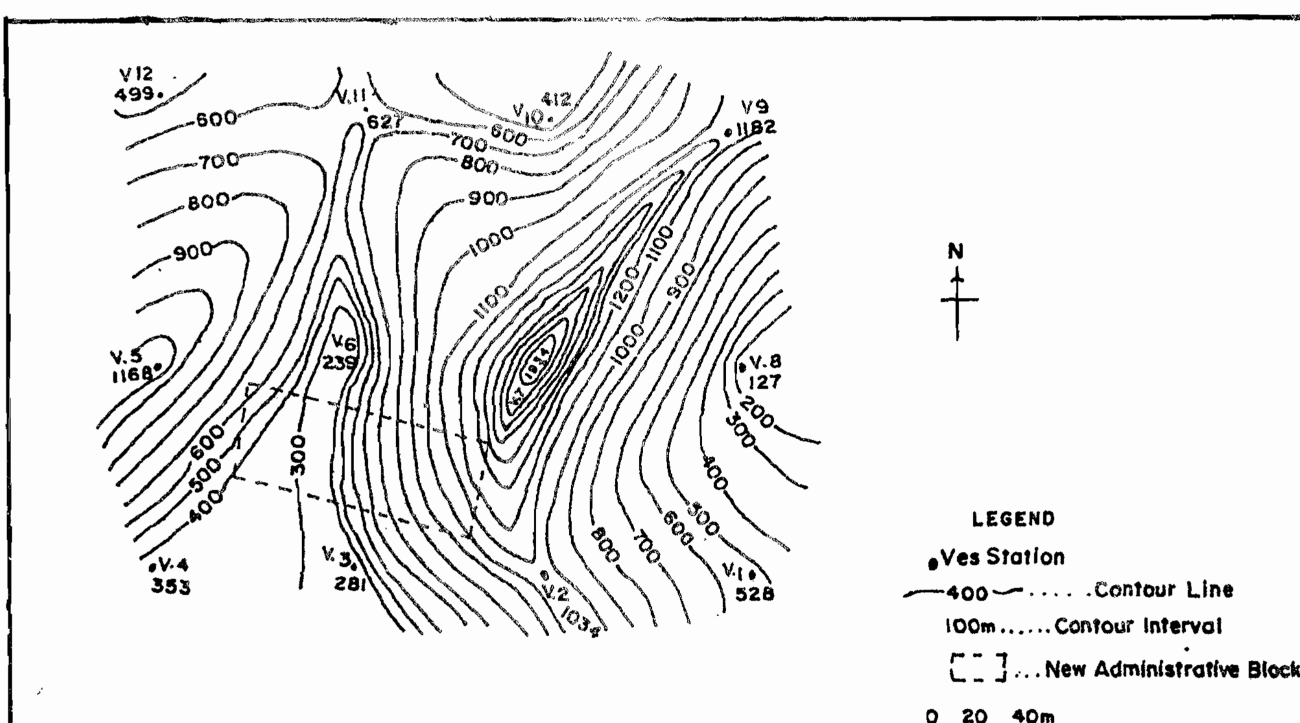

Fig. 8: Transverse unit resistance map

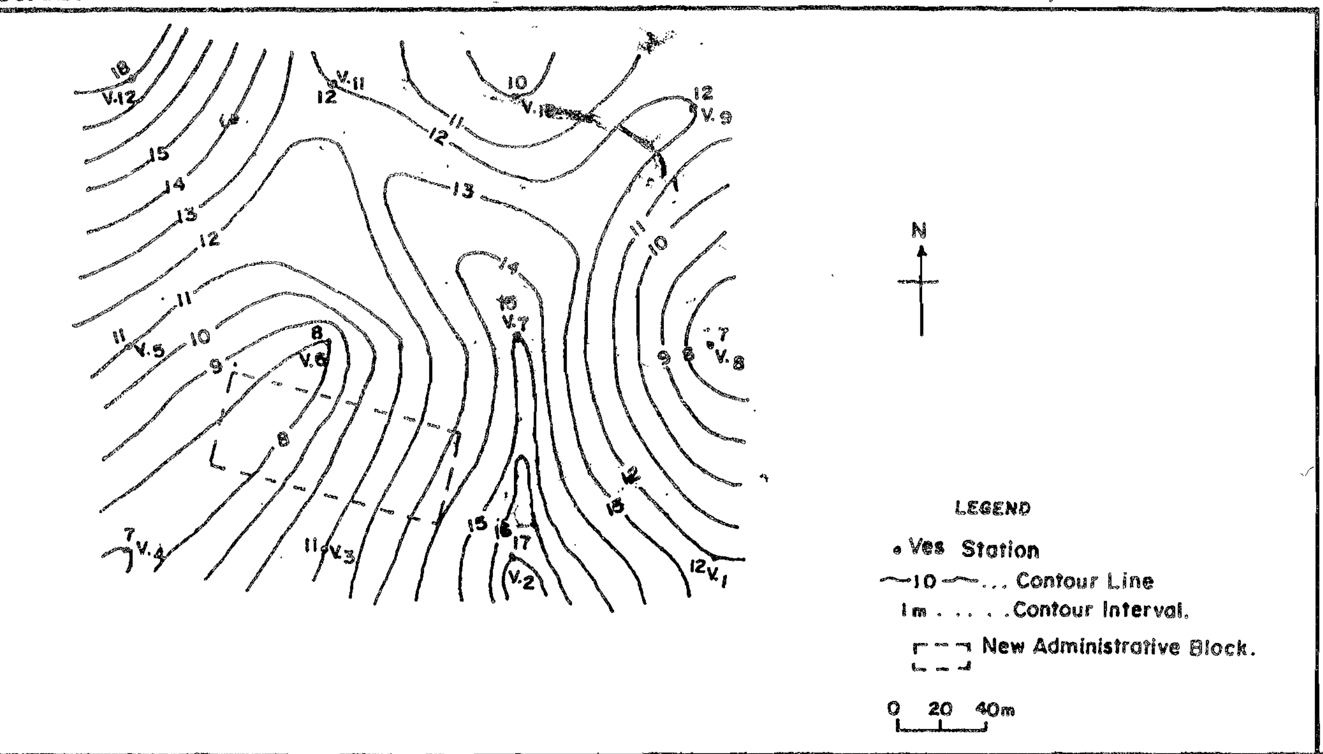

Fig. 9: Isopach map of overburden materials in the study area

From the afore discussion of the physical properties subsurface lithologic units within the area of investigation: excavation is needed and a deep foundation (that which is signed to transmit loads/stresses to deeper layers of soil) is commended. This is probably consistent with the structure in ace, which is characterized by pillars of different sizes and ultiple storey/floors.

ONCLUSIONS

A geophysical investigation targeted at delineating e engineering characteristics of subsurface lithologic units s been conducted at a locality within the Federal Polytechnic o-Ekiti Campus. The curve types exhibited by rocks within s area are H($\rho_1 > \rho_2 < \rho_3$), KH($\rho_1 < \rho_2 > \rho_3 < \rho_4$) and HA ($\rho_1$ $\rho_2 < \rho_3 < \rho_4$) (Figs 3). The area is underlain principally by ee to four geologic units (Fig. 4): topsoil (Clay/sandy y/sand), clay/sandy clay/sand, clay and athered/crystallinbedrock. Resistivity range for the first three ers is between 9 – 622 ohm-m while that for the bedrock is 0 – *4995 ohm-m.*

Horizontal profiling curves (Fig. 5) and lateral istivity maps (Figs 6a – c) indicate that materials within the osurface is *jointed/fissured and separates the rock units into* ly low resistivity zone to the west and a high resistivity zone the east. Isoresistivity maps (Figs. 7a – e) portray a stematic decrease *in resistivity with depth; implying* stence of weak materials with depth. The resistivity range is m 15 – 540 ohm-m. Transverse unit resistance map (Fig. 8) icates that zones of thick clay/sandy clay exist around uthwest, southeast and northeast. The range of values of nsverse unit resistance is from 200 – 1900 ohm-m^2. This servation is corroborated by the isopach map (Fig. 9) picting high thicknesses of subsurface rock units in these gions. The thickness range is from 7 – 18m.

This study has been able to outline the stratigraphy d structural disposition of petrologic units underlying the ea. Physical properties of these units such as resistivities d thicknesses have also been delineated. The subsurface properties of the rock units as well as appropriate deep foundation design are capable of supporting a multi-storey building as the one already in place.

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