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A GEOELECTRIC INVESTIGATION FOR GROUNDWATER DEVELOPMENT OF ORITA-OBELE AREA, NEAR AKURE SW NIGERIA

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ABSTRACT

A geophysical investigation of the study area has been carried out, which involved the use of vertical electrical sounding (VES) Wenner array using R-50 DC Resistivity meter. The geoelectric sequence identified in the area showed six geoelectric units; corresponding to four lithological units which are the loose sands/sandy clay/laterite/clayey sand top soil, the clay zone, the weathered basement and the bedrock with layer resistivities of 16-380 ohm meters, 14-130 ohm-meters, 145-247 ohm metres and 340 – 842 ohm-metres respectively. The layer thickness also range form 0.3 – 5.0m, 1.1 – 16.0m, 15.5-25. 1m respectively and an infinite thickness for the bedrock. The varying thickness (1.1-61.0m) of the clay zone constitute a major problem in this area in siting hand dug wells; therefore the use of deep wells and/or boreholes seems relevant even for domestic use to ameliorate the seasonal nature of the hand dug wells only when they are established within the aquifer units.

The aquifer units in this area is mainly of the weathered basement and the fracture unconfined/fracture confined aquifer types; thus revealing the hydrogeophysical characteristics of the area.

KEY WORDS: Hydrogeophysical characteristics, Bedrock structures.

INTRODUCTION

The area under investigation is about 2.5km. NE of the Ilesa – Owo road (Fig. 1); close to the junction leading to Akure township on longitudes 5^0 $10^{\prime}$E to 5^0 $11^{\prime}$ $30^{\prime\prime}$ E and latitudes 7^0 $19^{\prime}$N to 7^0 $21^{\prime}$N which is believed to have been affected by various geological events (Rahaman. 1976: Olarewaju, 1987). These events resulted in the development of structures such as faults, folds and fractures.

The nature of the rock types and the characteristic environmental factors could have subjected the rocks to weathering that may eventually in most cases lead to the formation of clays. The acute shortage of water been experienced in the area arise mainly from the seasonal nature of the hand dug wells which are located within the clay zone, also some of the boreholes drilled prove abortive.

The present study is aimed in determining the geoelectric sequence of the area, the thickness of the subsurface clay units, aquifer characteristics, types and the geophysical characteristics of the bedrock in terms of is nature and subsurface condition.

GEOLOGY OF THE AREA

The Orita-Obele area is underlain by Precambrian rocks typical of the basement complex of Nigeria (Fig. 1). The essential features of the basement complex have been reviewed by various workers (Annor, 1986; Rahaman, 1988; Folami, 1998; Odeyemi et al. 1999; Oluyide 1988). The main rock types in the area are granites and charnockites which are extensively developed, occurring largely as smooth, widely distributedboulders but form residual hills in some places. Three types of charnockites can be distinguished based on their petrography and structural characteristics: these are the coarse grained charnockites (quartz hapersthene syenite), granodiorite and quartz monzonite (Cooray, 1972; Tubosun et al. 1984; Olarewaju 1987).

There is association between the charnockites and non-charnockitic granite rocks due to their field relations (Rahaman, 1976; Olarewaju, 1987; Cooray 1972, 1974). There are also, three textural types of granites that can be recognised in this area, they are fine to medium grained granite biotite, medium to coarse grained non porphyritic biotite-hornblende and the porphyritic biotite hornblende granite.

CLASSIFICATION OF CLAYS

On the basis of their origin clays can be divided into two groups, namely primary and secondary deposits. The primary clay deposit are clays that are formed as a result of endothermic processes taking place under high temperature and pressure. Also, known as hydrothermal and volcanic clays, they are formed insitu and are products of metasomatic (hyrothermal) alteration of pre-existing igneous rocks. Secondary clay deposits are formed from exothemic processes. These include residual, sedimentary and alluvial clays which are formed from solutions of orgillaceous limestones or dolomites leaving behind clay as a residual or from the decomposition of feldspars rich rocks such as granites, charnockites, pegmatites and migmatites. Therefore, clays in Orita-Obele area are examples of residual clay formed from the decomposition of granite and charnockites rocks which are the major rock units in the area.

GEOPHYSICAL INVESTIGATION

The geophysical investigation involves the use of

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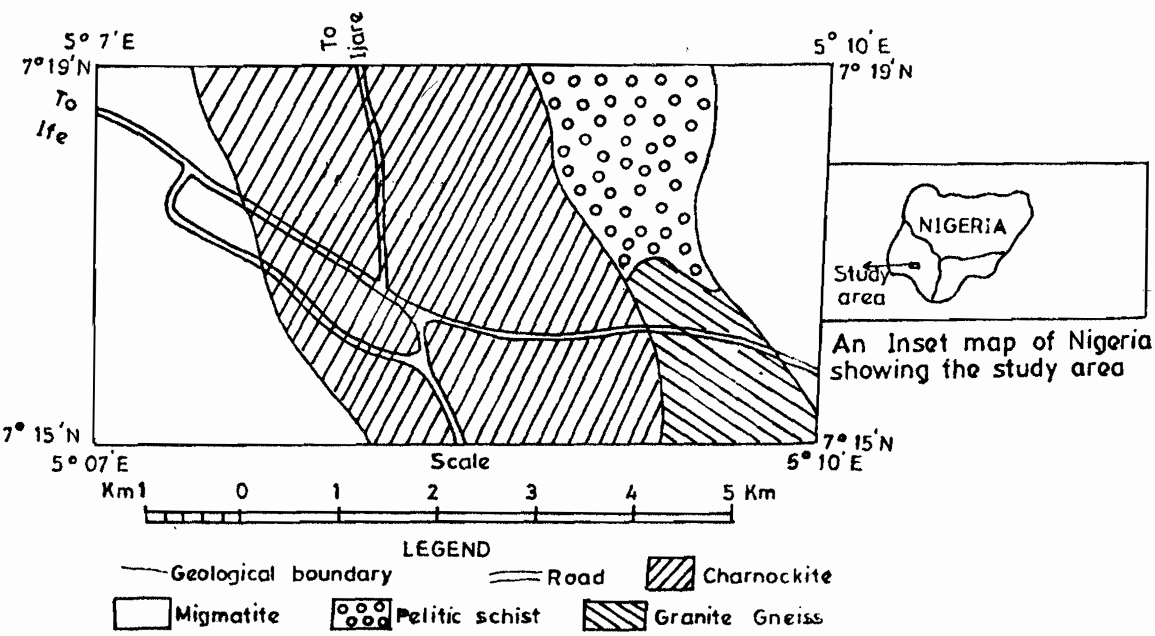


Fig 1: Geological map of Orita - Obele area, Akure

electrical resistivity employing the vertical electrical sounding (VES) technique. The wenner configuration was employed, the arrangement is such that the four electrodes are equidistant from each other. (Olayinka, 1999; Olasehinde, 1999).

The electrode spread begins from AB/3 or a = 1m increasing gradually in most cases to a maximum spread length of 128m (max. AB/3 = 128m or AB = 384m). The orientation of the spread, is approximately N-S to minimise the induced effect due to current distortion. A total of thirty (30) sounding stations were occupied (Fig. 2) to cover the entire area of study.

DATA INTERPRETATION

The vertical electrical sounding (VES) was interpreted qualitatively, semi quantitatively and quantitatively. The qualitative interpretation of the resulting depth sounding curves involve its visual inspection for its characterization while the semi-quantitative interpretation of the sounding field curves involve the determination of the number of geoelectric layers. The quantitative interpretation of the sounding curves involved partial curve matching technique using 2-layer master curve which will be refined by a computer iteration technique (Verma and Pantulu 1990).Thus, where a good match of above 90% is obtained, the results are assumed to be good.

DISCUSSION OF RESULT

(a) Observed sounding Curves

Nine curve types were identified in the study area, ranging from 4 to 6 geoelectric layers (Fig. 3a). The observed curve types (KH, KHA, KHKH, KQHA, HK, HKH, HAA, AA, AAA) and its characteristic nature (Table 1) has been used in classifying them into three groups. Also typical curve types obtained in this area is observed in figure 3b.

GROUP A (KH, KHA, KQHA, KHKH)

In this group, the third geoelectric layer (KH, KHA) corresponds to the clay horizon with resistivity value ranging from 31 – 78 ohm metres while in KQHA curve type; it corresponds to the third and fourth geoelectric layers with resistivity of 51 – 108 ohm metres. Also in KHKH, it is observed on the third and fifth geoelectric layers, having resistivity range of 55 – 111 ohm-metres.

GROUP B (HK, HKH)

The second and fourth geoelectric layers correspond to the clay zone with resistivity of 14 – 42 ohm-metres.

GROUP C (HAA, AA, AAA)

The second and third geoelectric layers in HAA and AAA curve types correspond to the clay units with resistivity of 22 – 92 ohm-metres; also in AA curve type it falls within the corresponding geoelectric layer. In general, mostly the descending arm of the second, third and fourth segments of the sounding curves correspond to the clay zone (Fig. 3a).

(b) Geoelectric Sections

From the geoelectric sections, the characteristic behaviour of the subsurface units can be observed. In figure 4a, the resistivity for the uppermost layer is 22-214 ohm-metres constituting the loose sandy/clayey topsoil with a thickness of about 0.5-1.1m. The clayey topsoil thins out towards the eastern portion resulting in a loose sandy

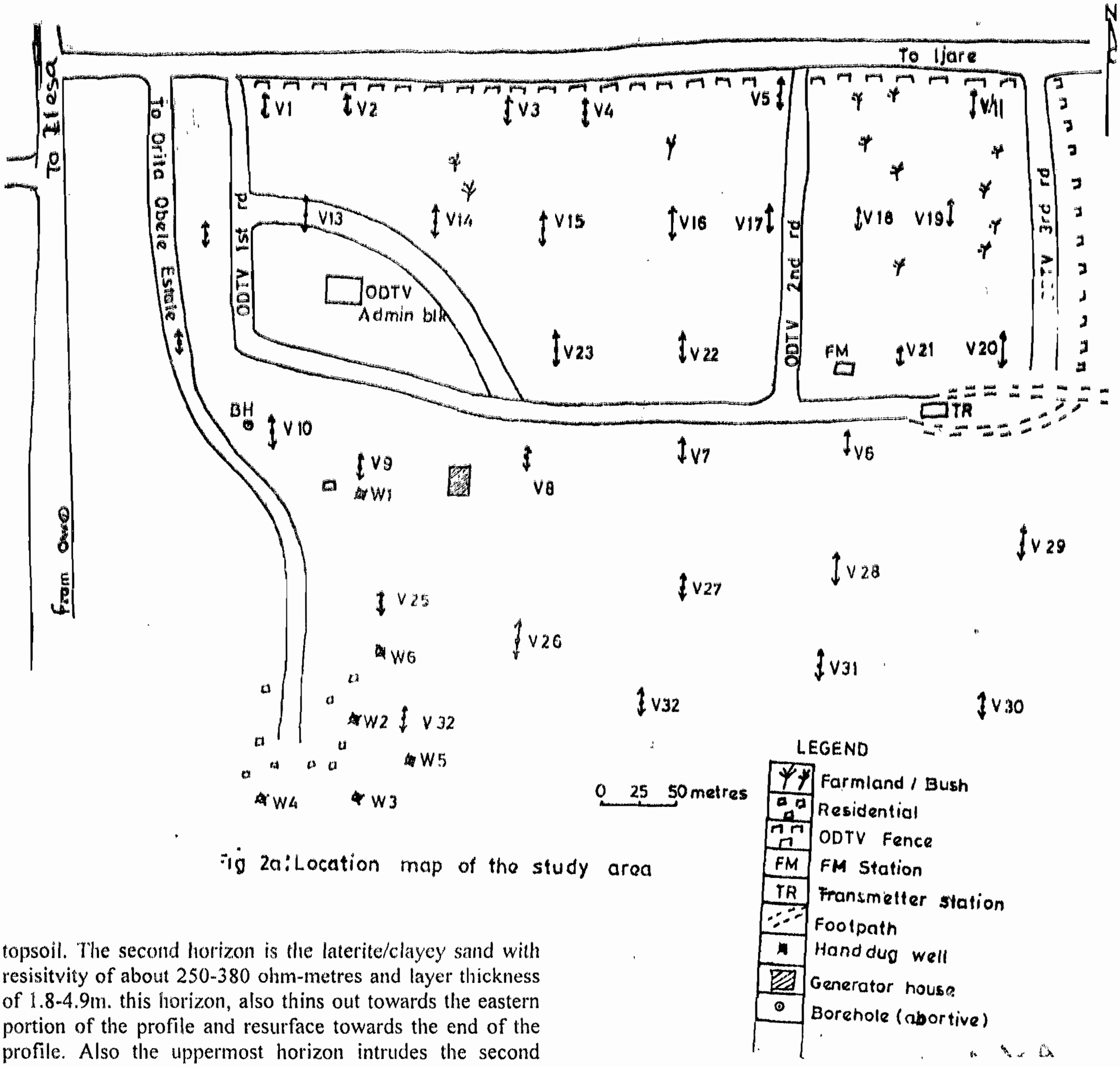


Fig 2a: Location map of the study area

topsoil. The second horizon is the laterite/clayey sand with resisitvity of about 250-380 ohm-metres and layer thickness of 1.8-4.9m. this horizon, also thins out towards the eastern portion of the profile and resurface towards the end of the profile. Also the uppermost horizon intrudes the second horizon along the profile particularly sounding positions V_4 and V_5.

Therefore, the uppermost layer and the second layer could be regarded as a single unit with resistivity of 22 – 380 ohm-metres and a thickness of about 0.5-5.0m; thus, there is a thick sandy clay/laterite/clayey sand in this area. The intermediate zone is the clay zone with resistivity of about 55-130 ohm-metres and thickness of 1.1-21.1m. The presence of thick clay layer overlying the bedrock constitute a problem in groundwater development of the area because most of the hand dug wells are situated within this zone and clay is aquiclude in nature. The third unit is the weathered basement with resistivity of about 180 – 247 ohm-metres with a varying thickness of 15.5 – 25.1m. In areas where the thick layer overlies the fractured bedrock, the conditions are favourable for groundwater resource.

From figure 4b, the area has been divided into six geoelectric layers arising from their distinct layer resistivities and thicknesses. These include clayey topsoil (16-110 ohm-metres) with a thickness of 0.3 – 0.8m; the loose sandy topsoil (130-289 ohm-metres) and a thickness of 0.3-5.1m; the laterite/clayey sand (230-508 ohm-metres) and thickness of 2.5 – 8.0m; the intermediate zone usually clay with resistivity of 14-108 ohm-metres and thickness of 10.0-61.0m; where it forms the last geoelectric layer, thickness may be greater. The weathered bedrock with resistivity of about 145 ohm-metres and thickness of 18.1-22.0m; the bedrock resistivity is 455-801 metres. The geoelectric layers have been classified into four geologic units which are the clayey sand/laterite/sandy clay topsoil the clayey intermediate layer with resistivity of 14 – 108 ohm-metres and thickness of 10.5-61.0m indicating a thick clay horizon which has made groundwater development difficult in the area because of the peculiar characteristics of clay to groundwater transmissivity, hence localized aquifer with minimal clay horizon is suitable for the area. The third unit is the weathered bedrock with resistivity of about 145 ohm-metres and thickness of 18.1-22m. The fourth unit is the bedrock with resistivity of 451-801 ohm-metres which is infinitely thick.

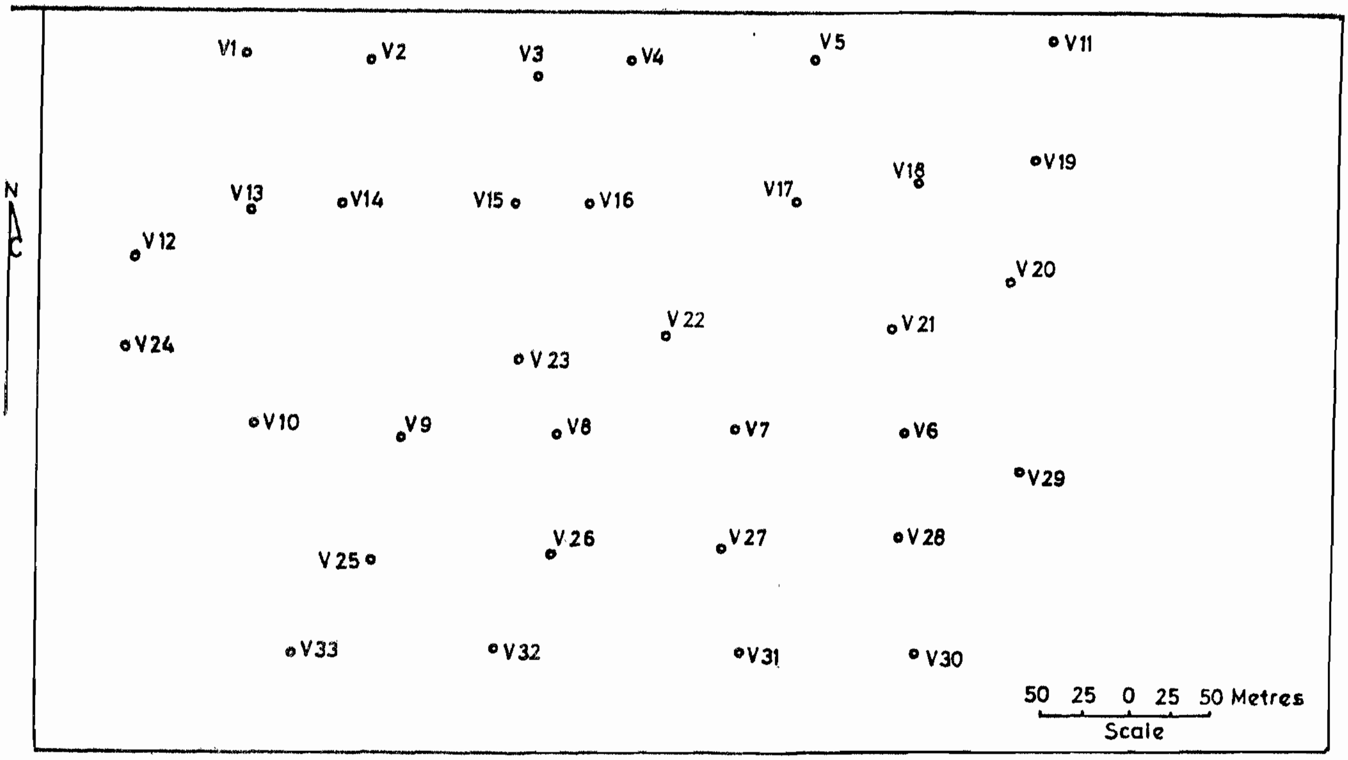


Fig 2b :Sounding positions of the study area

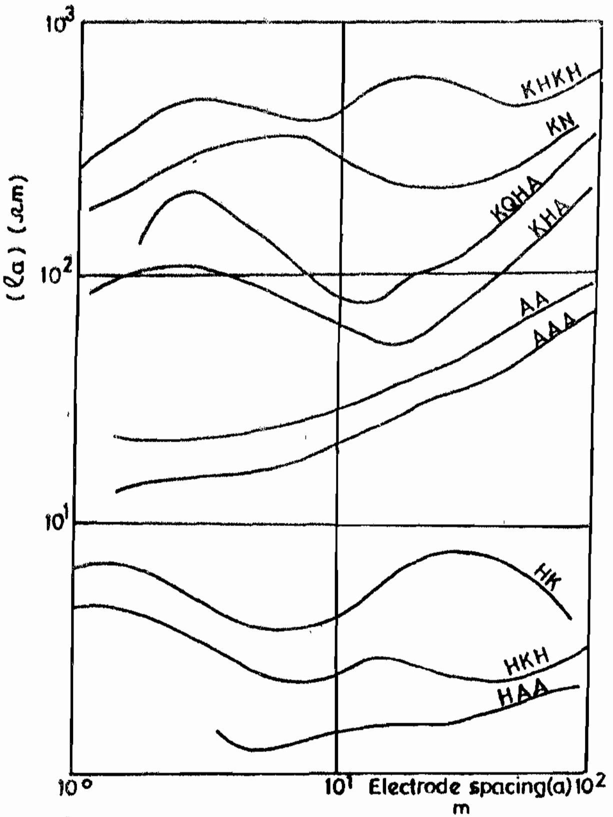
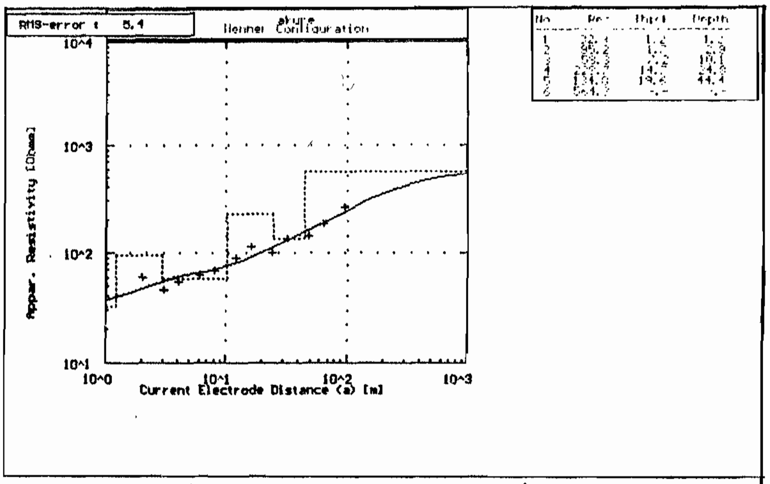
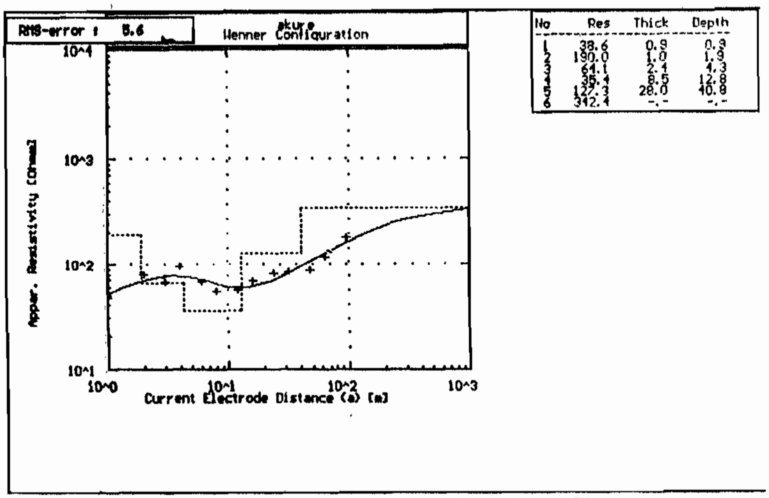


Fig 3a :Typical observed sounding curves from Orita Obele area (KH, HK, AA, KHA, HKH HAA, AAA, KHKH, KQHA)



No	Res	Thick	Depth
1	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	10.1
4	[illegible]	[illegible]	[illegible]
5	[illegible]	19.6	44.4
6	[illegible]	-.-	-.-

Fig 3b (i) : Typical model curve of Orita -Obele area



No	Res	Thick	Depth
1	38.6	0.9	0.9
2	190.0	1.0	1.9
3	64.1	2.4	4.3
4	35.4	8.5	12.8
5	127.3	28.0	40.8
6	342.4	-.-	-.-

Fig 3b (ii) :Typical model curve of Orita-Obele area

Figure 4c showed a thin layer forming the topsoil while the intermediate layer correspond to clay with resistivity of55-90 ohm-metres and thickness of about 10-15m. The weathered basement has a thickness of 180 – 230 ohm-metres with thickness of 10-20m. The bedrock has a resistivity of 900-1500 ohm-metres. In figure 4d. the six geoelectric units identified exhibit varying resistivities and thicknesses. The uppermost layer has resistivity of 20-120 ohm-metres with thickness of 0.5 – 1.2m. The next layer is the laterite/clayey sand with resistivity of 150-398 ohm-metres and thickness of 1.5 – 5.0m. The intermediate layer is the clay zone with thickness ranging from 10-55m and resistivity of about 15-105 ohm-metres. The weathered bedrock is localized with resistivity of about 200 ohm-metres. The bedrock has resistivity of 980 – 2050 ohm-metres. The varying thickness of the clay unit underlain by fresh bedrock show that geophysical study is necessary for meaningful groundwater development of the area.

(c) Isoresistivity Map:

The isoresistivity maps of the area have been produced at electrode spacing a = 12m. 24m. 48m and 96m respectively. These maps showed the resistivity pattern of the area which is indicative of the type of geoelectric unit/geologic unit at a particular depth. In figure 5a, the isoresistivity map is produced at electrode spacing a = 12m, thus showing the behaviour of the subsurface units progressively as electrode spacing is increased. The values range from 60-260 ohm-metres. In SE-NW direction, there is a gradual decrease in the resistivity values; also in the SE-SW direction it also decreases, thus generally in this area it showed no definite resistivity pattern hence the clay horizon still extends beyond this depth.

In figure 5b, there is a striking similarity in the contour behaviour to that of figure 5a which showed that the clay still extends to a = 24m except in northwestern portion where the contour line of 100 ohm-metres mark the baseline and towards the central portion a small extent shows the clay zone thinning out, later it resurface towards the end of the profile. In figure 6a which is the isoresistivity map at a =48m, the northcentral portion to the northwestern side exhibit closely packed resistivity contour line which is diagnostic of the bedrock. Therefore at this horizon bedrock may be encountered at the northern side of the area.

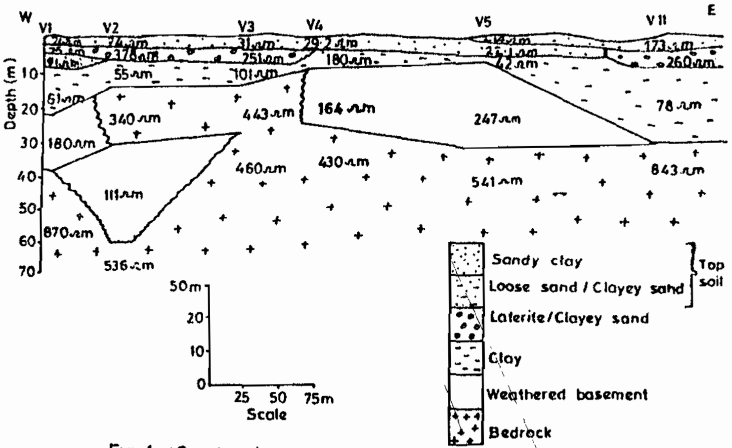


Fig 4a: Geoelectric section of Orita-Obele area W-E direction

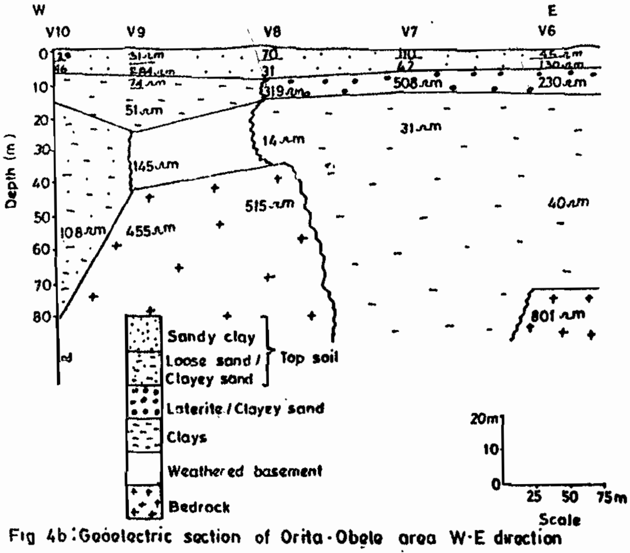


Fig 4b: Geoelectric section of Orita-Obele area W-E direction

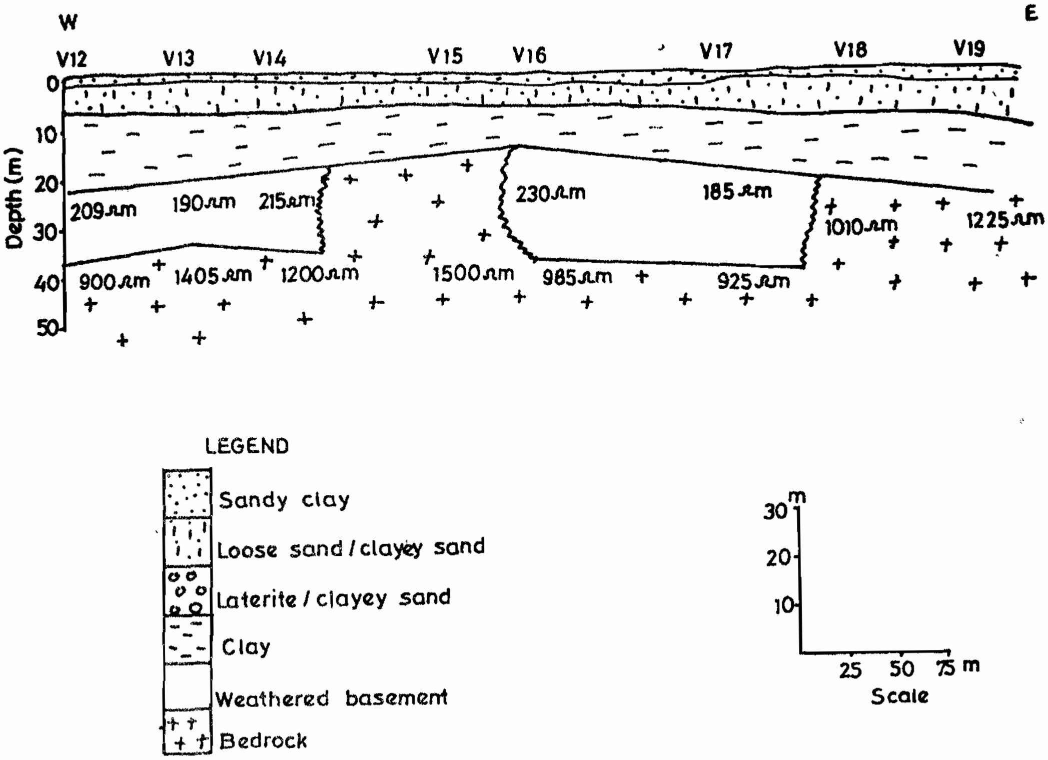


Fig 4c : Geoelectric section of Orita - Obele, area in W-E direction

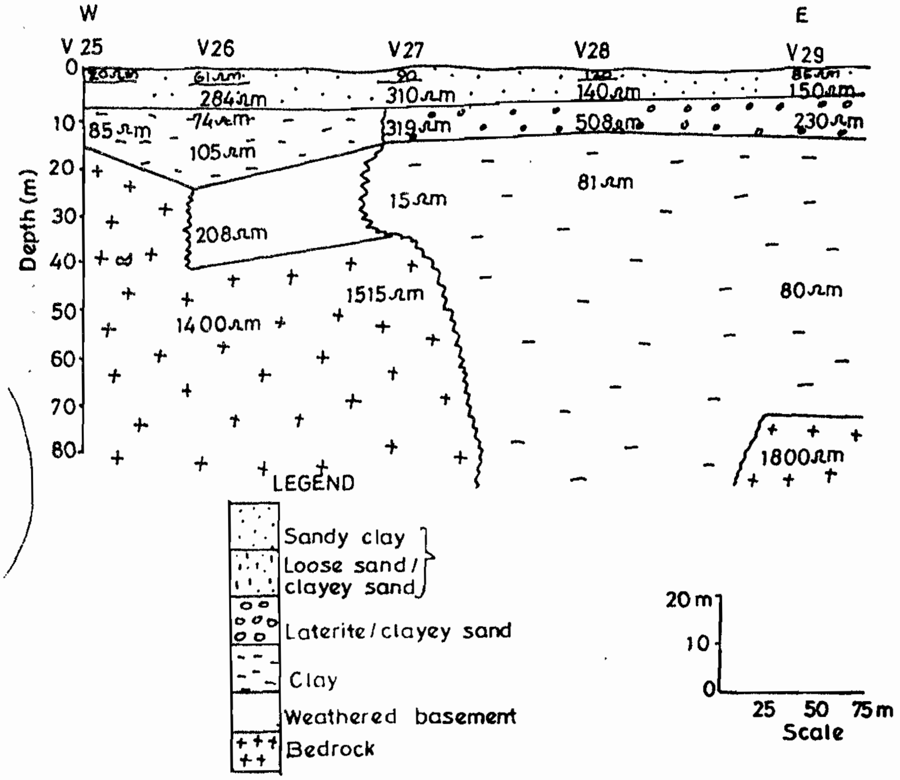


Fig 4d ; Geoelectric section of Orita-Obele area in W-E direction

In the southern side (SE-SW) of this area the elongated contours of low resistivity values which are fairly spaced still showed that the low resistivity zone still extends to this depth, hence the characteristic resistivity trend shown by figures 5a and 5b can be traced to figure 6a at the SE-SW direction of the map which is still indicative of clay. Also, the bedrock at the northwestern to northcentral portion intrudes into the clay zone resulting in weathered basement/fracture unconfined/fracture confined aquifer type. Figure 6b, is the isoresistivity map of the area at electrode spacing a = 96m; the bedrock is encountered at the NW-NE direction which is similar to figure 6a. Also, the bedrock is dipping towards the clay, the SW-SE trend is significantly clay horizon thus the bedrock is deeper with a thick clay

Table 1: Curve Types and its characteristics.

Curve Types	Curve Characteristics	No of geoelectric layers
KH	$\rho_1<\rho_2>\rho_3<\rho_4$	4
KHA	$\rho_1<\rho_2>\rho_3<\rho_4<\rho_5$	5
KHKH	$\rho_1<\rho_2>\rho_3<\rho_4>\rho_5<\rho_6$	6
KQHA	$\rho_1<\rho_2>\rho_3>\rho_4<\rho_5<\rho_6$	6
HK	$\rho_1>\rho_2<\rho_3>\rho_4$	4
HKH	$\rho_1>\rho_2<\rho_3>\rho_4<\rho_5$	5
HAA	$\rho_1>\rho_2<\rho_3<\rho_4<\rho_5$	5
AA	$\rho_1<\rho_2<\rho_3<\rho_4$	4
AAA	$\rho_1<\rho_2<\rho_3<\rho_4<\rho_5$	5

horizon overlying the bedrock. The resisitvity trend observed, showed that the groundwater development is to be concentrated mainly along the NW-NE portion of the area. The unpredictable clay thickness in the area has made groundwater resource a major task because most of the wells are terminated within the horizon, while some boreholes drilled beyond the clay horizon is underlain by crystalline bedrock. Therefore locations with minimal or no clay horizon is a possible site, this may be encountered along the NW-NE side of the area; where localised aquifer of weathered basement/fractured bedrock is desirable.

(d) Isopach map of the horizon

The isopach map of the clay horizon (Fig.7) is relevant in groundwater, engineering, foundation and geotechnical studies because it will guide further sinking of wells in the area such that areas with minimal clay thickness is desired. The map is useful in the subsurface delineation of the clay thickness.

Therefore, from the map there is an appreciable significant clay thickness in SE SW portion of the are; while

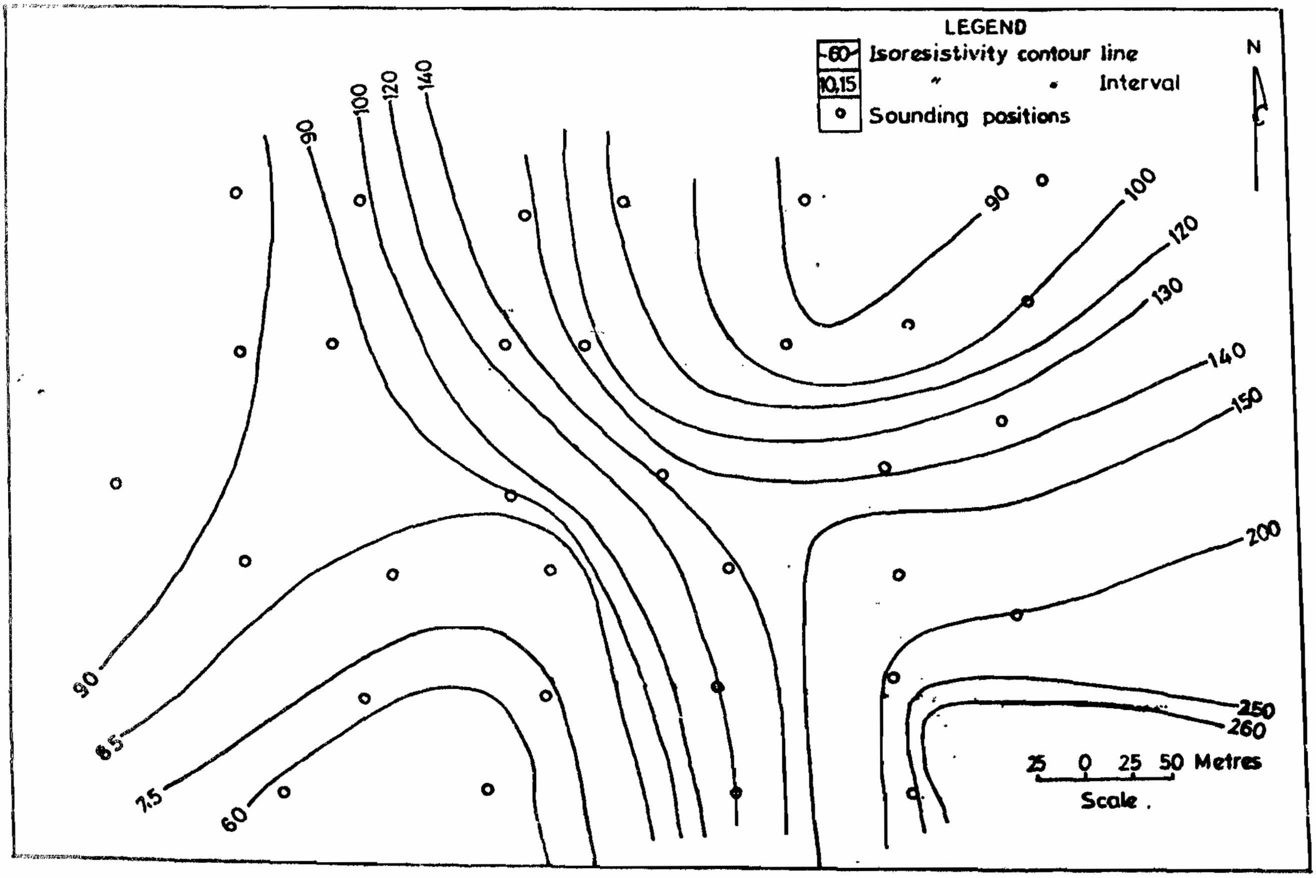


Fig 5a : Isoresistivity map of Orita-Obele area (a = 12 m)

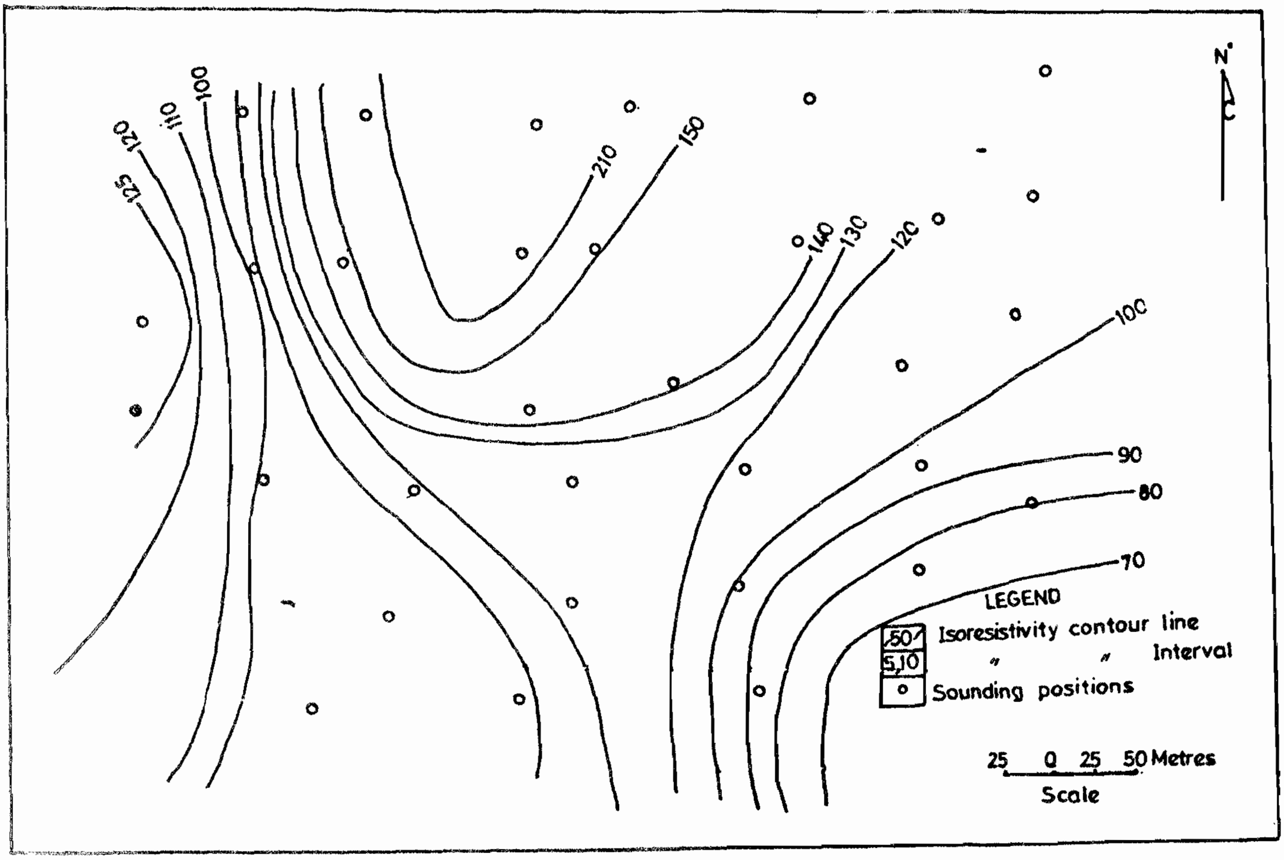


Fig 5b : Isoresistivity map of Orita Obele area (a =24m)

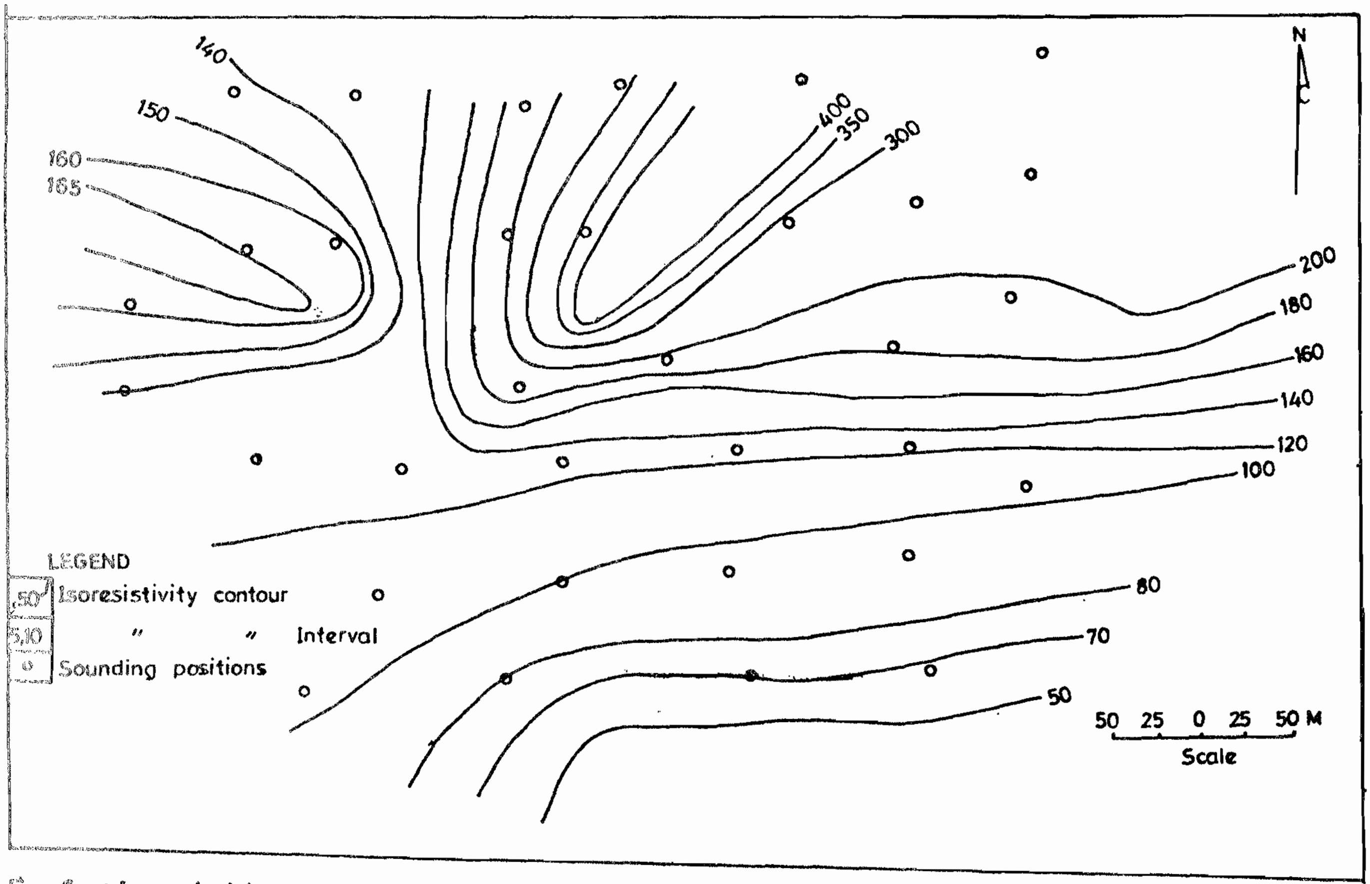


Fig 6a : Isoresistivity map of Orita Obele area (a=48m)

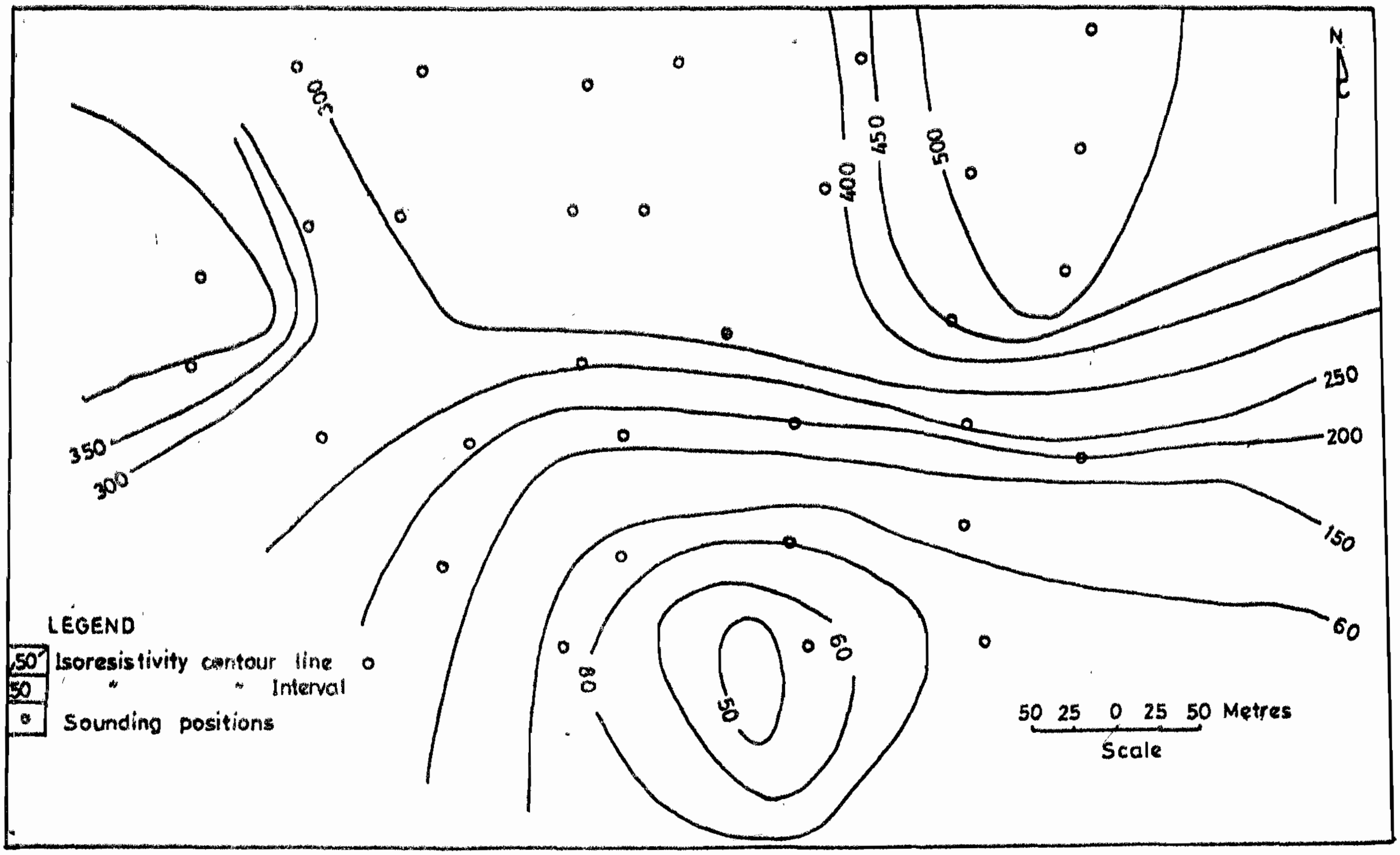


Fig 6b : Isoresistivity map of Orita-Obele area (a =96m)

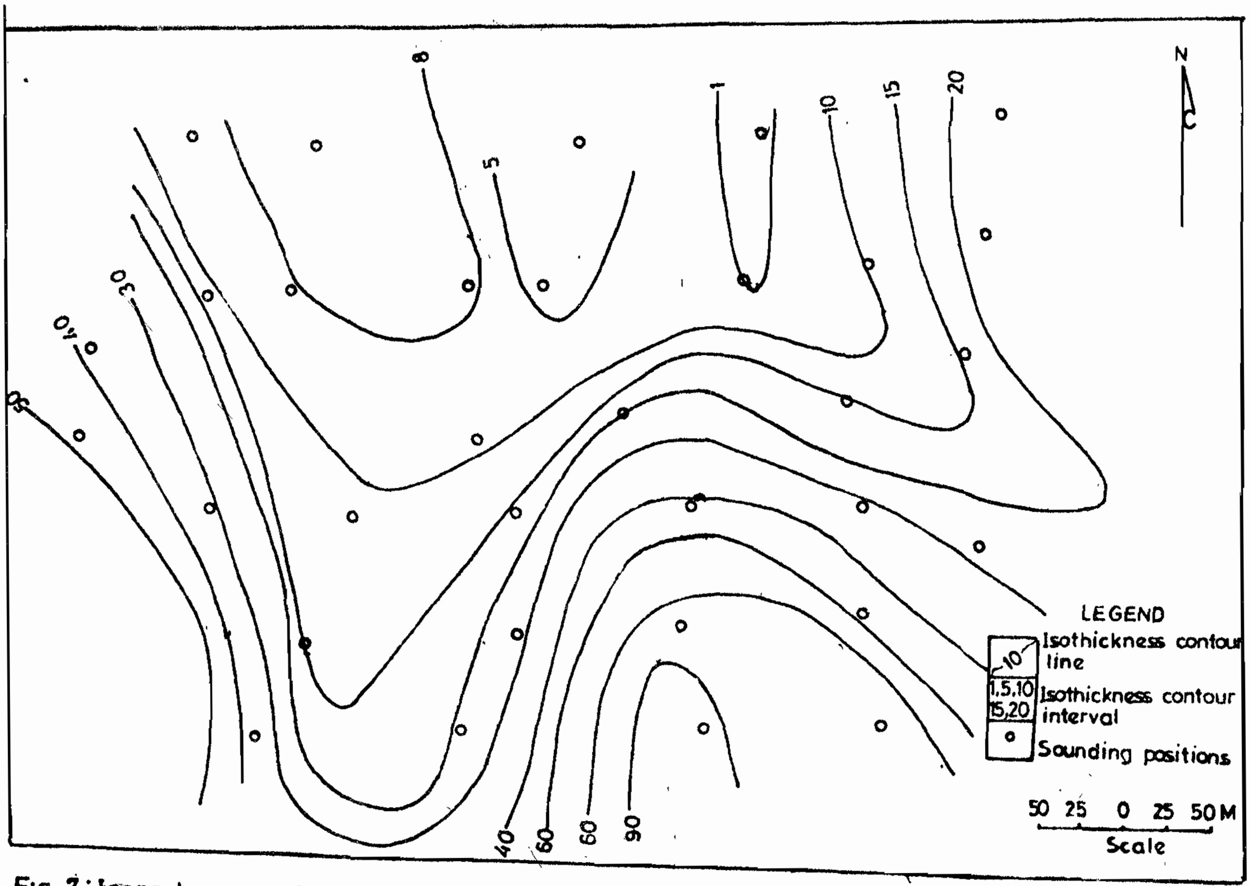


Fig 7: Isopach map of the clay horizon at Orita Obele area, Akure

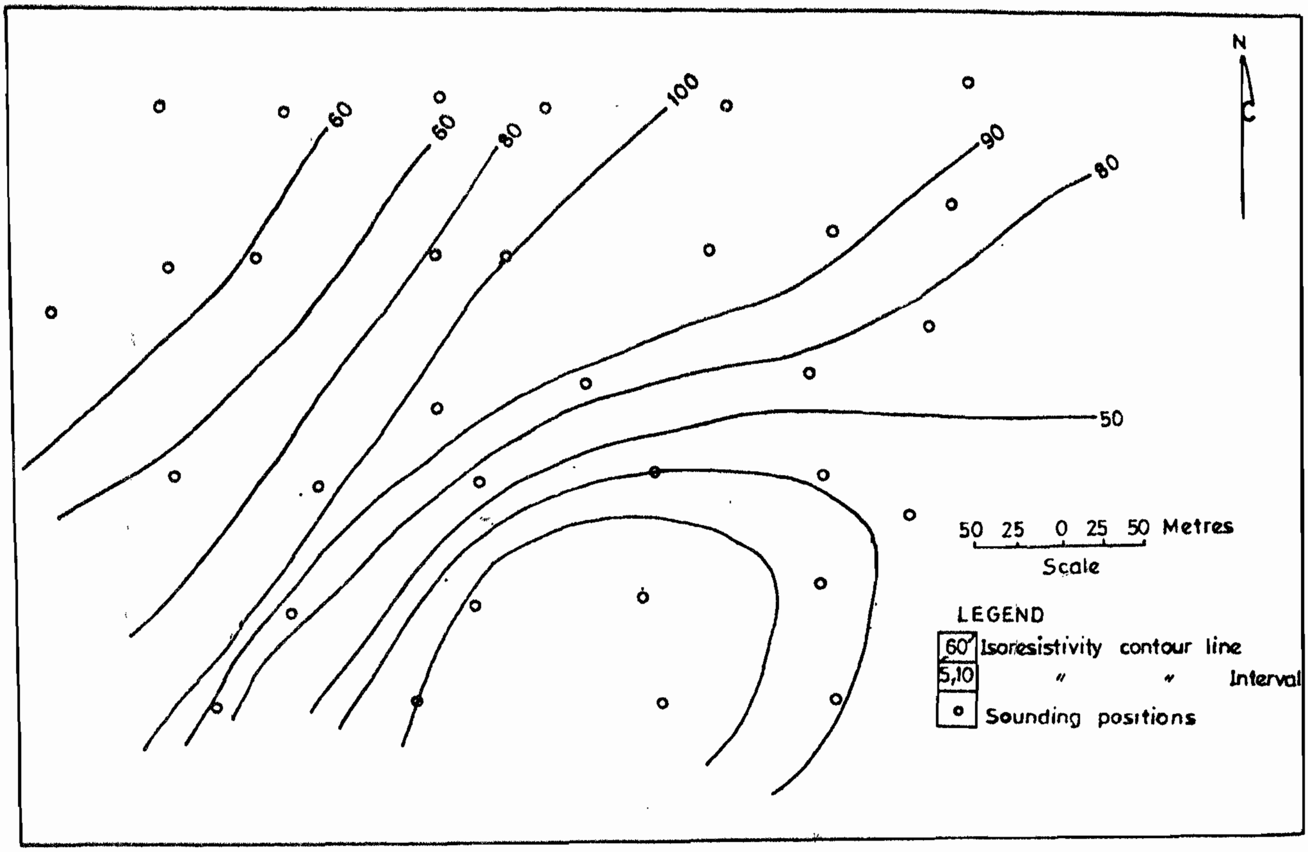


Fig 8: Layer resistivity map of Orita-Obele area

there is a minimal clay thickness along the NW-NE part of the Orita-Obele area. Also, a zone of relatively thin clay has been delineated along the central portion of the area. The clay thickness in this area is so erratic, that geophysical study is necessary in delineating this unit. Therefore, a thick regolith with minimal clay unit overlying weathered bedrock plus a fractured bedrock are necessary requirements for groundwater development in this area.

(e) Layer Resistivity map:

The layer resistivity obtained from the interpreted sounding curves have been used in producing this map (Fig. 8) which uses the resistivity of the third, fourth and fifth geoelectric layer in this area. It is relevant in delineating clay layer laterally and vertically such that a thin clay layer encountered at the near surface is better than encountering it at a greater depth with a significant thickness. This map is relevant only when combined with the geoelectric section of the area. Therefore clay horizon is found mainly at the SE-SW and NW-NE portions of the area with differing depth of occurrence and thickness.

CONCLUSION

The hydrogeophysical characteristics of this area have been defined in terms of the thickness of clay, weathered basement, the presence of fractured bedrock and aquifer types. The following cases were established within the area as evidently observed in figures 3.4.5.6 and 7. Case 1: the presence of thick clay to a maximum of 80m overlying the fresh bedrock: case 2: the presence of thick clay to a maximum of 30-40m with a minimal weathered basement/fresh bedrock; Case 3: is that of a moderately thick clay (15-30m) with a thin weathered basement/fractured bedrock; Case 4: the presence of fairly thick clay (5-15m) with a thin weathered basement/fresh bedrock; case 5: a thin clay (1-5m) plus a thin weathered bedrock/fresh bedrock; case 6: a thin clay (1-5m) with moderately thick/thick weathered basement/fresh bedrock and case 7: a thin clay (1-5m) with thick weathered basement underlain by a fractured bedrock.

In all, about five cases have been established as potential problems arising mostly from unpredictable clay thicknesses plus other associated problems therefore groundwater abstraction in this area need thorough investigation such that the remaining two cases that are relevant in groundwater development need to be searched for in order to delineate these zones.

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