CORRELATION OF VERTICAL ELECRIC SOUNDING AND MAGNETIC SURVEY RESULTS IN GROUNDWATER DELINEATION OF A PART OF SOUTHWESTERN NIGERIA

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Abstract

The location of aquifer structures was investigated at Owode, in Akure, Ondo State, Southwestern Nigeria, using Vertical Electric Sounding (VES) and the most uncommon Magnetic Survey. The results were correlated to locate physical features that are potential aquifers in the area. The Magnetic Surveys were carried out along 8 traverses: the South-North, North-South, and East-West directions across the study area. Both high and low magnetic values were obtained. The half-with method was used to calculate the depth to the basement. The high amplitude magnetic lows were analysed. Using the Schlumberger configuration, VES were carried out at selected sites, along 8 traverses, based on the magnetic data interpretation. The data were analysed using both the partial curve matching and microprocessor iterated techniques. The presence of 3&4 geoelectric layers of clay, sand, partly or completely weathered bedrock and fresh basement in various arrangements were identified. The aquifers in the area are the sandy and weathered basement zones.

The curve types identified were the QH, H, HA and HK, with the various resistivities and layer thickness. VES locations, 4, 8, 9 and 10 are areas delineated as having good groundwater potentials, with VES position 10 having the best groundwater potential

***Keywords** : Groundwater, magnetic, aquifer, resistivity and vertical electric sounding*

1.0 Introduction

The Precambrian, crystalline rocks of the basement complex and the cretaceous sedimentary formations (which occur in nearly equal proportions), are the two broad groups of Nigerian rocks. The basement complex rocks of Nigerian are mainly granitic in composition and are in different stages of metamorphism, while the Cretaceous sediments are mainly sandstones, shale, clay and limestone, mudstones and siltstones.
Owode lies within the basement complex region of Ondo state. The basement rock there is composed of granite gneiss, migmatite and charnockite rocks with the granite gneiss covering almost the entire south of Owode (Fig. 1a). Owode itself is located in the northern part of Ondo state which is in South-Western part of Nigeria. A rural community with a reasonably average population density, It is accessible through the state government road that runs from Oba-Ile to Owode (Fig 1b).

The area is composed of low lands and rugged hills with granitic outcrops. The major characteristic of the drainage system is the proliferation of small river channels. The channels

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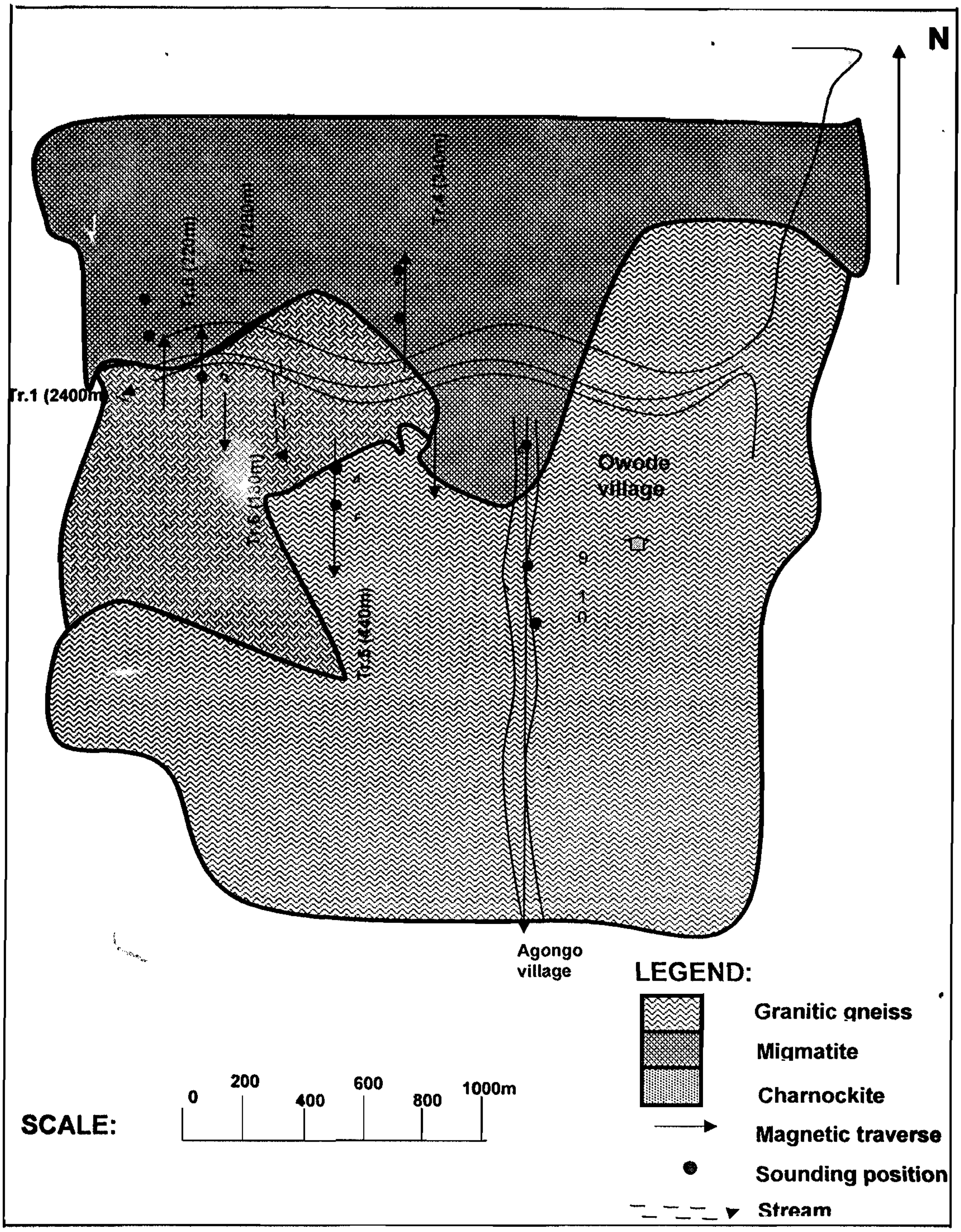


Fig.1a: Geological map of Owode area, Akure - Ondo state.

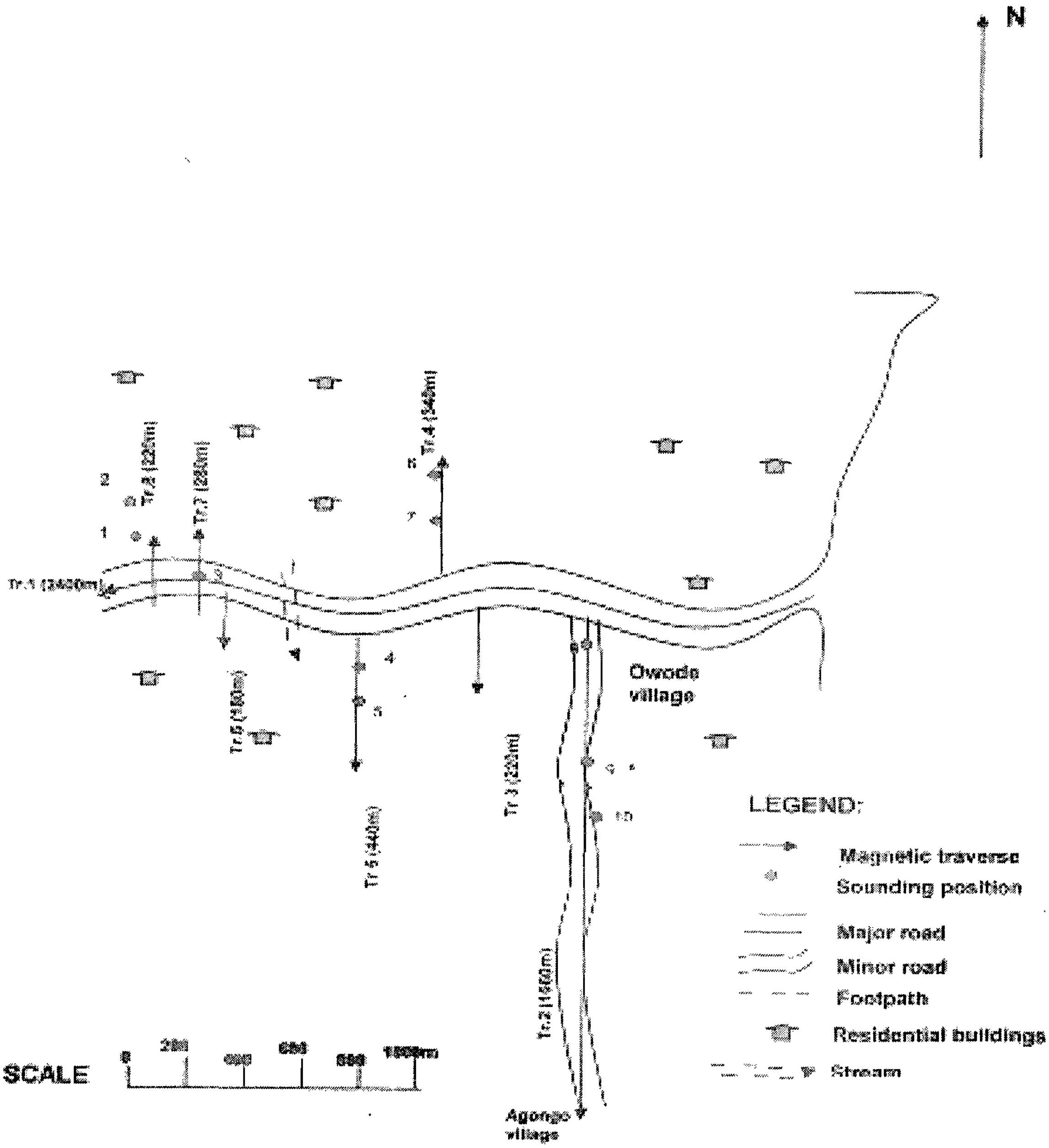


Fig. 1b: Base map of Owode area, Akure-Ondo State.

of the smaller streams are dry for many months especially from November to May of each year. The climate of Owode is of the lowland tropical rainforest type, with distinct wet and dry seasons. The mean monthly temperature is 30°C with a mean monthly range of 6°C.The mean monthly relative humidity is less than 70%. There is marked dry season from November to March when little or no rain falls and the total annual rainfall is about 1800 millimeters (Iloeje, 1980).

Basement complex rocks in their unaltered forms are aquifuge that is, they can neither store nor transmit water, due to low porosity and permeability (Rahaman, 1976). In order for such rocks to become good aquifers, they must be fractured / and or weathered. As a result, the occurrence of groundwater in this basement complex is usually localized.

The objective of this study therefore is to utilize the vertical electric sounding (VES) and magnetic surveys to locate the aquifers in this area and to also characterize them as far as possible.

2.0 Survey Methodology

Two geophysical methods were employed in this work: the magnetic survey, was first delineate areas with magnetic lows and then the vertical electric soundings were used to further investigate the selected site. The magnetic survey proceeded along eight traverses (Fig.1b), each separated by a space of 20m, using a proton precession magnetometer, model G- 856. A base station was first established to which every other magnetic reading was referenced. This was to monitor the diurnal variation caused by magnetic effects of external origin and also for the purpose of determining the time corrections. The relative magnetic values were plotted as a function of the station positions, producing geomagnetic profiles, geomagnetic contour maps and sections from which the subsurface characteristics of the study area were deducted.

The vertical electric sounding (VES) locations were sited in regions considered from the high amplitude magnetic lows as having thick overburdens. The sounding was done with the aid of the R-50 DC resistivity meters, using the Schlumberger electrodes configuration.

The data obtained from the field survey were processed to obtain the apparent resistivity using the geometrical factor of the Schlumberger array and the resistance obtained for each current electrode spacing (AB/2). The apparent resistivities obtained were first plotted on a transparent paper using a log-log sheet. The best smooth curves through the set of data points were interpreted quantitatively by a method of partial curve matching using a 2-layer master curves and auxiliary curves (Orellana and Mooney, 1966). The results were then fed into the computer as initial models and subjected to repeated iterations until a satisfactory fit to the field data was obtained.

3.0 Results and Discussions

3.1 Magnetic data

The aim of this magnetic survey was to determine the depth to basement. Magnetic basement refers to the zone beneath the earth's surface where sources of magnetic anomalies are situated, (Edwin and Cahit, 1988). It is also used to estimate the thickness of the overlying layers (overburden) which may have ground water reservoirs.

The magnetic data were interpreted using the half-width method and considering only magnetic lows (area dominated by the field of the negative pole) to select possible groundwater reservoir sites.

The analyzed data were presented as profiles, geomagnetic sections, magnetic contour map and 3-D orthographic view of the study area.

Figure 3 shows the various profiles and their corresponding geomagnetic section, while fig. 4 shows the contour map and 3-Dimensional orthographic view of the study area.

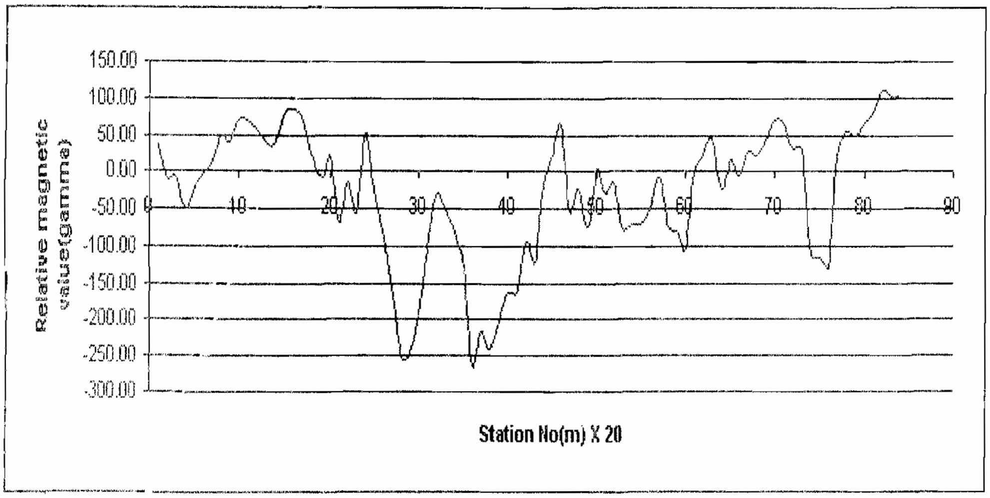


Fig. 3a: Magnetic profile 2 along (N - S) direction

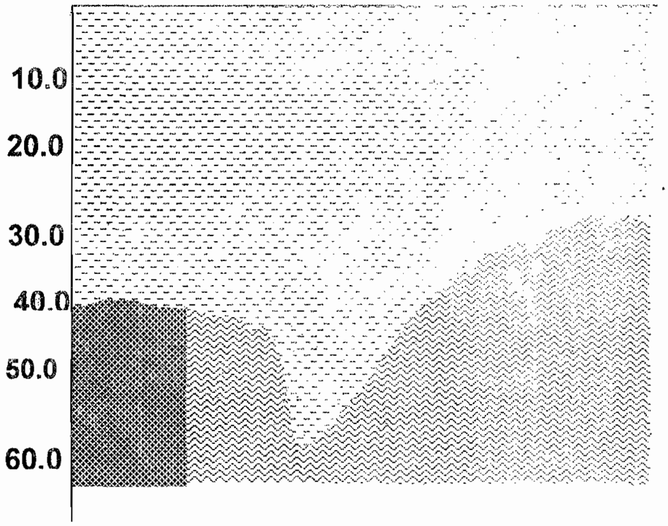


Figure 3b) Interpreted subsurface structure of magnetic profile 2 along (S-N) direction

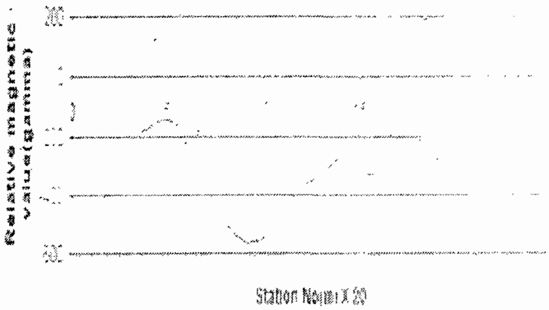


Fig. 3c: Magnetic profile 5 along (N - S) direction

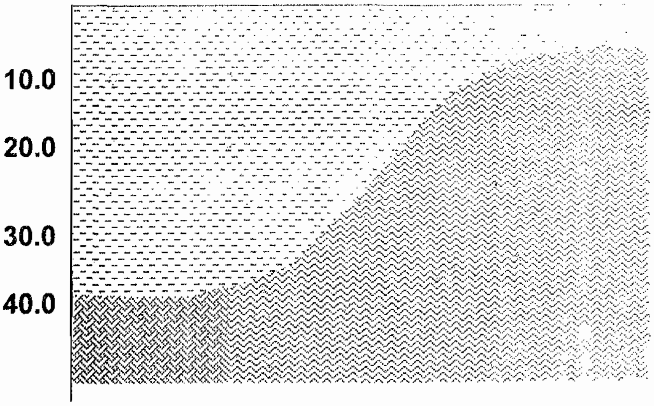


Figure 3d) Interpreted subsurface structure of magnetic profile 5 along (N - S) direction

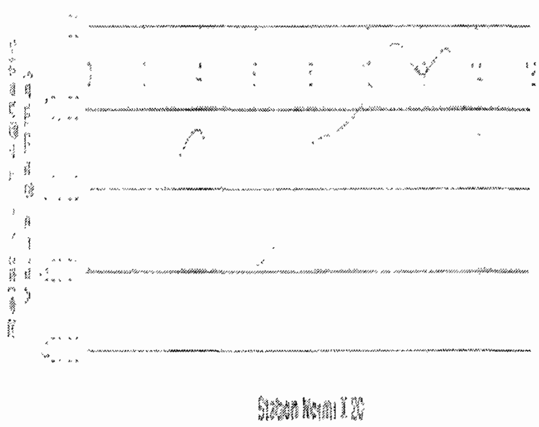


Fig. 3e Magnetic profile 7 along (S - N) direction

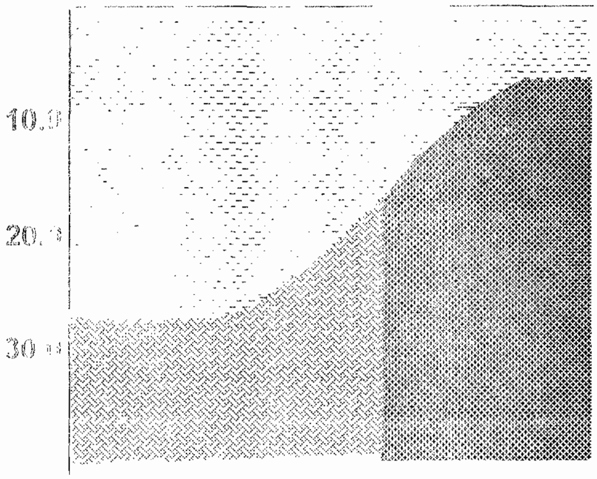


Figure 3f: Interpreted subsurface structure of magnetic profile 7 along (S - N) direction

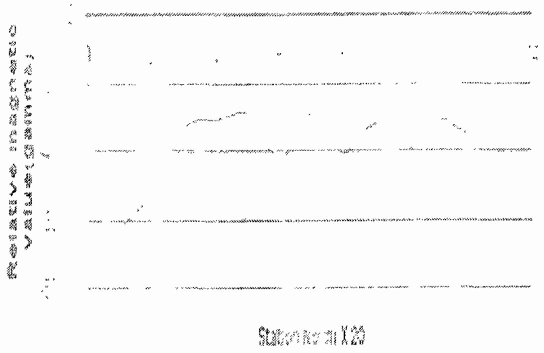


Fig. 3[illegible] Magnetic profile 8 along (S - N) direction

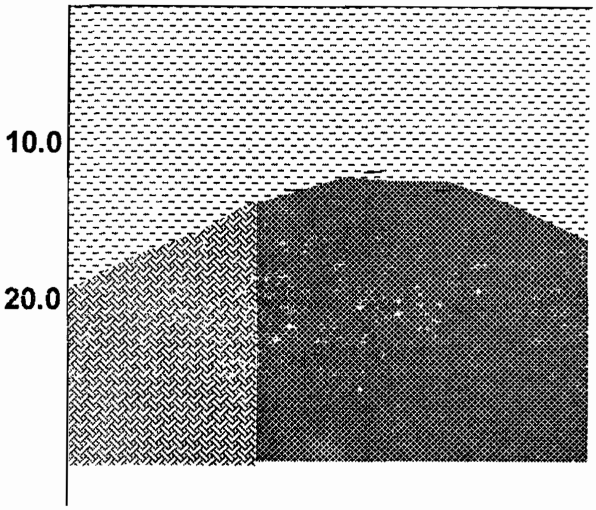


Fig. 3h: Interpreted subsurface structure of magnetic profile 8 along (S-N) direction

Generally, all the profiles exhibit magnetic lows, implying that the study area has relatively low magnetic susceptibilities. The magnetic lows show various anomalies with varying frequencies and amplitudes. Four of the anomalies with the highest amplitude are analysed using the half-width method to obtain the depth to basement.

Profile 2: This profile (Fig. 3a) which has a length of 1600m in the N-S direction is complex and irregular but not as long as profile 1(not shown). They share almost similar characteristics except that the major high amplitude magnetic lows for this profile are distinct, with one of the magnetic lows having a width of 120m. The geomagnetic section (fig. 3b) shows only two rock formations (granitic gneiss and migmatite) with a dip in the overburden occurring at 620m-880m, giving rise to a thick overburden.

Profile 5: The profile runs for 440m in the N-S direction. It shows a negative relative magnetic susceptibility with distinguished high amplitude magnetic lows (Fig 3c). The geomagnetic section (Fig 3d) shows a decrease in the overburden thickness from north-south direction, with a thick overburden from the beginning of the traverse to about 240m. It also shows the presence of two rock types.

Profile 7: The profile (fig. 3e) runs for 290m in the S-N direction. It depicts a high amplitude anomaly low with a width of about 48m, giving rise to a thick overburden as shown on the geomagnetic section (Fig 3f). The basement rises from north to south, with 2 rock types.

Profile 8: The profile runs for 220m in the S-N direction. The magnetic anomaly lows on this profile do not have high amplitudes (Fig 3g). The overburden is relatively thin and shows two rock types.

Contour Map: The map shows a 3-D orthographic view of the study area, (fig. 4.2). From the contour map, there is an increase in the magnetic susceptibility to the south, while there exists a decrease to the north. The east and the west both have high susceptibilities, while there exist some isolated areas of high susceptibilities in the north.

These areas can be seen on the orthographic map as having a rugged topography while the south has a gentle slope.

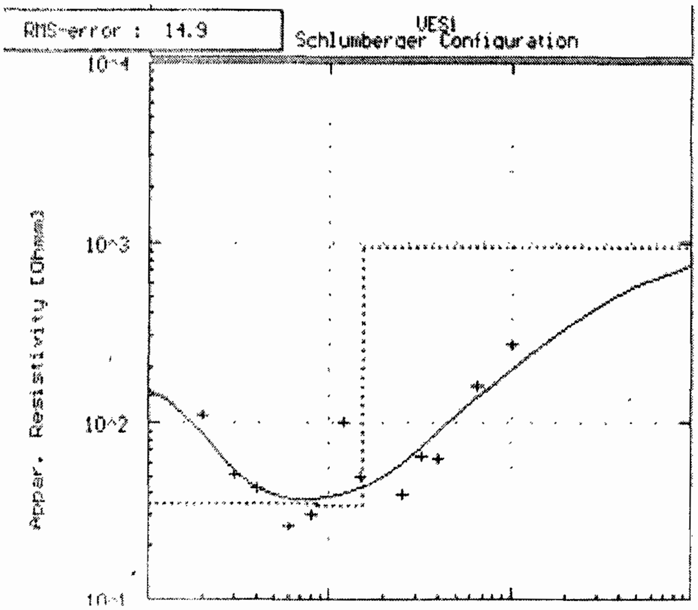
Table 1: Summary of the anomaly and depth estimates of observed profiles

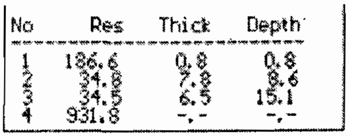
Profile	Direction	Anomaly Number (m)				Depth to Basement (m)			
		1	2	3	4	1	2	3	4
1	E-W	880	1040	1700	-	32	48	22	-
2	N-S	548	1080	1480	620-880	44	40	30	60
3	N-S	100	-	-	-	9	-	-	-
4	S-N	160	280	-	-	34	22	-	-
5	N-S	130	320	-	-	35	8	-	-
6	N-S	180	-	-	--	8	-	-	-

7	S-N	100	220	-	-	24	8	-	-
8	S-N	100	140	180	-	12	11	12	-

4.0 Resistivity

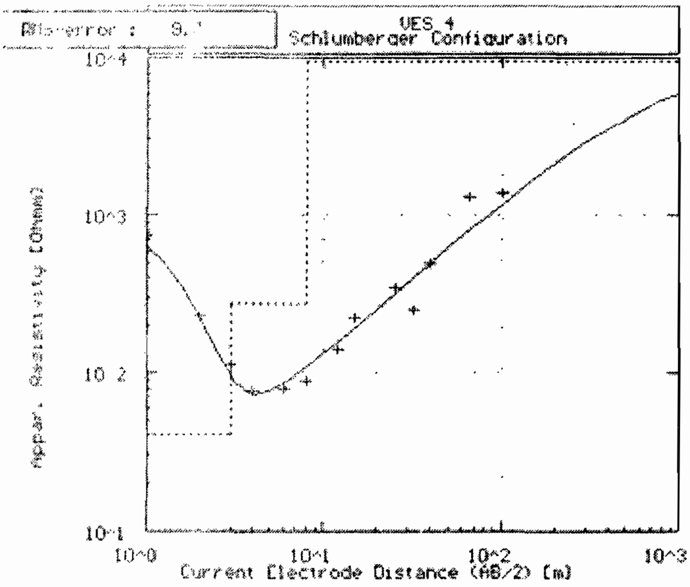
The processed data were used in obtaining the resistivity curves, maps and geoelectric section. Five (out of the ten) of the curves obtained from the iteration are given in figure 4.1 with VES numbers as indicated.





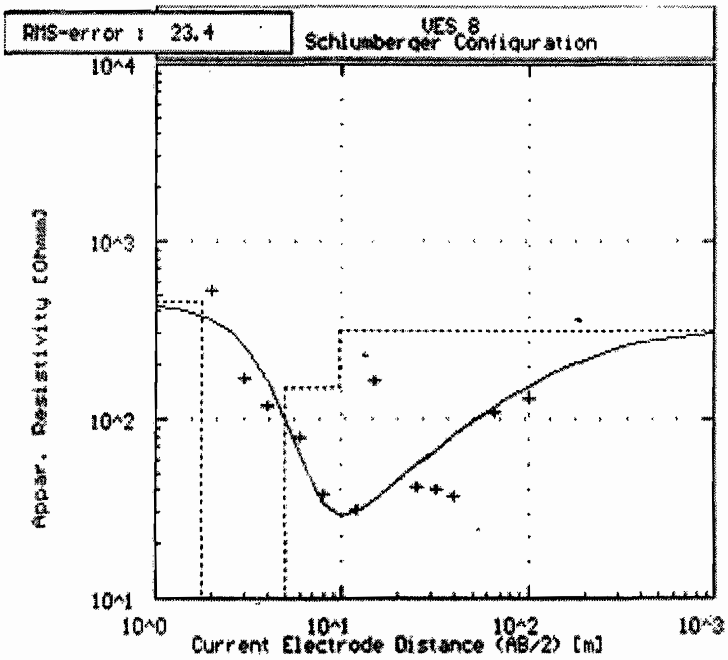
No	Res	Thick	Depth
1	186.6	0.8	0.8
2	34.8	7.8	8.6
3	34.5	6.5	15.1
4	931.8	-.-	-.-

(a)



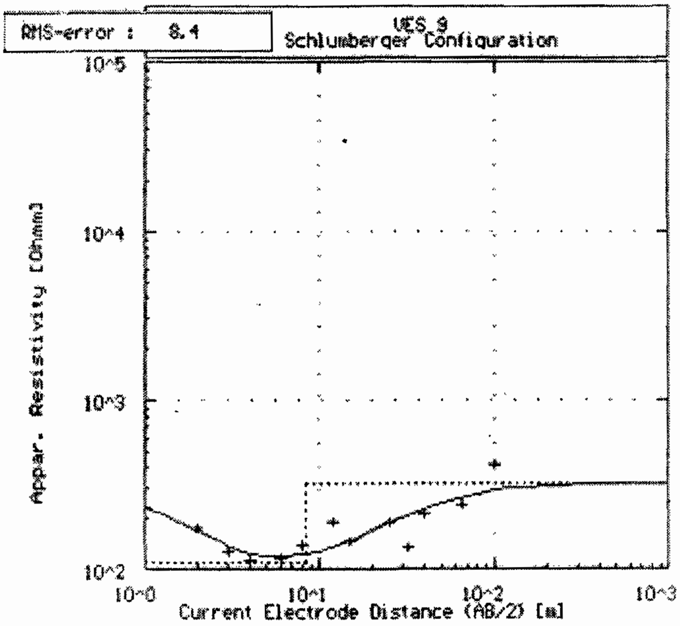
No	Res	Thick	Depth
1	928.4	0.7	0.7
2	40.5	2.3	3.0
3	273.6	5.0	8.0
4	9329.9	-.-	-.-

(b)



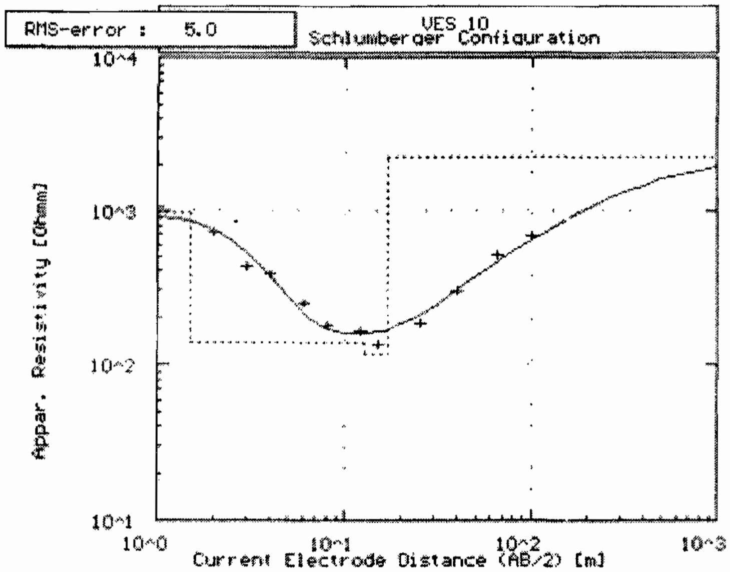
No	Res	Thick	Depth
1	448.7	1.8	1.8
2	9.1	3.2	5.0
3	149.8	4.7	9.7
4	311.7	-.-	-.-

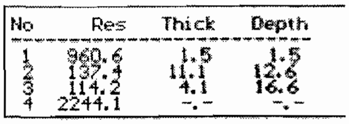
(c)



No	Res	Thick	Depth
1	264.5	0.8	0.8
2	107.7	7.6	8.4
3	321.3	-.-	-.-

(d)





No	Res	Thick	Depth
1	960.6	1.5	1.5
2	137.4	11.1	12.6
3	114.2	4.1	16.6
4	2244.1	-.-	-.-

(e)

Fig. 4.1: Resistivity curves for some of the VES location points.

Visual inspection of the curves based on their distinct geoelectric characteristics was used to classify the curves in the following order:

Group A	:	H type
Group B	:	HA type
Group C	:	QH type
Group D	:	HK type

Group A: The group consists of curves with 3 layers $\rho_1 > \rho_2 < \rho_3$ and is typical of VES 1, 4, 9, and 10. VES 3 seem hydrogeologically insignificant due to the lack of weathered layer, while VES 9 and 10 have marked characteristic of a water bearing formation because it has a weathered layer that is significantly thick. The layer resistivities are shown in table 1.

Group B: The group is made up of curves having four layers with $\rho_1 > \rho_2 < \rho_3 < \rho_4$ and is typical of VES locations 4 and 8. These locations all have either weathered or partly weathered 3rd layer, this formation is also a potential aquifer, but is not thick enough compared to VES 9 and 10.

Group C: This consists of a 4-layer curve where the second layers are made up of clay with low porosity and permeability and thus cannot be delineated as an aquifer.

Group D: This curve type is exhibited by VES 6 (not shown), with $\rho_1 > \rho_2 < \rho_3 > \rho_4$. It has two partly weathered layers (3 and 4) and is also a potential aquifer, though it might not give a high yield.

MAPS: The maps presented in this study include:

Iso-Resistivity Map: An iso-resistivity map depicts the resistivity distribution within an area of study. Fig. 4.3 is an iso-resistivity map of the first layer and shows a high resistivity value towards the north especially the North-West ends, indicating that the region is not conductive. The 3-D orthographic view also collaborates thé same thing, showing a region of high resistivity also in the middle and relatively similar resistivity trend to the south.

Isopach Map: This map shows over burden thickness contour of depth to the bottom layer. From the map, it can be seen that the depth of the bottom layer increases to the North-West end and South-East end of the contour map showing that the overburden in these areas is thick. The 3-D orthographic view gives a clearer picture, with the central part of the map having between 6-8m depth to basement and the ends having thick overburden from the protrusion seen from the orthographic view. (Fig. 4.4).

Bedrock Relief Contour Map: This contour map shows the distribution of the resistivity of the bottom layer within the study area. A 3-D orthographic view obtained from the contour is also given. The map is marked by high resistivity values in the central part of the map and reducing resistivity values to the ends. The 3-D view gives protruding shape in the centre also indicating high resistivity. These values agree with that obtained from the Isopach map on which the central part had a low depth to basement, indicating an increase in resistivity, preventing the flow of current to deeper parts. The thick overburden observed on the Isopach map at the North-West and South-West ends of the map corresponds to the low resistivity observed at the same part on the Bedrock relief contour map (Fig. 4.5).

Geo-Electric Sections: The heterogeneity of the sounding curves shows the variable nature of the weathered basement complex. Prediction of aquifer parameters in basement terrain is not always successful. Thus, the analysis of the geo-electricity of the bedrock is carried out to observe variations in the character and behaviour of the basement aquifer, (Omisore, 2001).

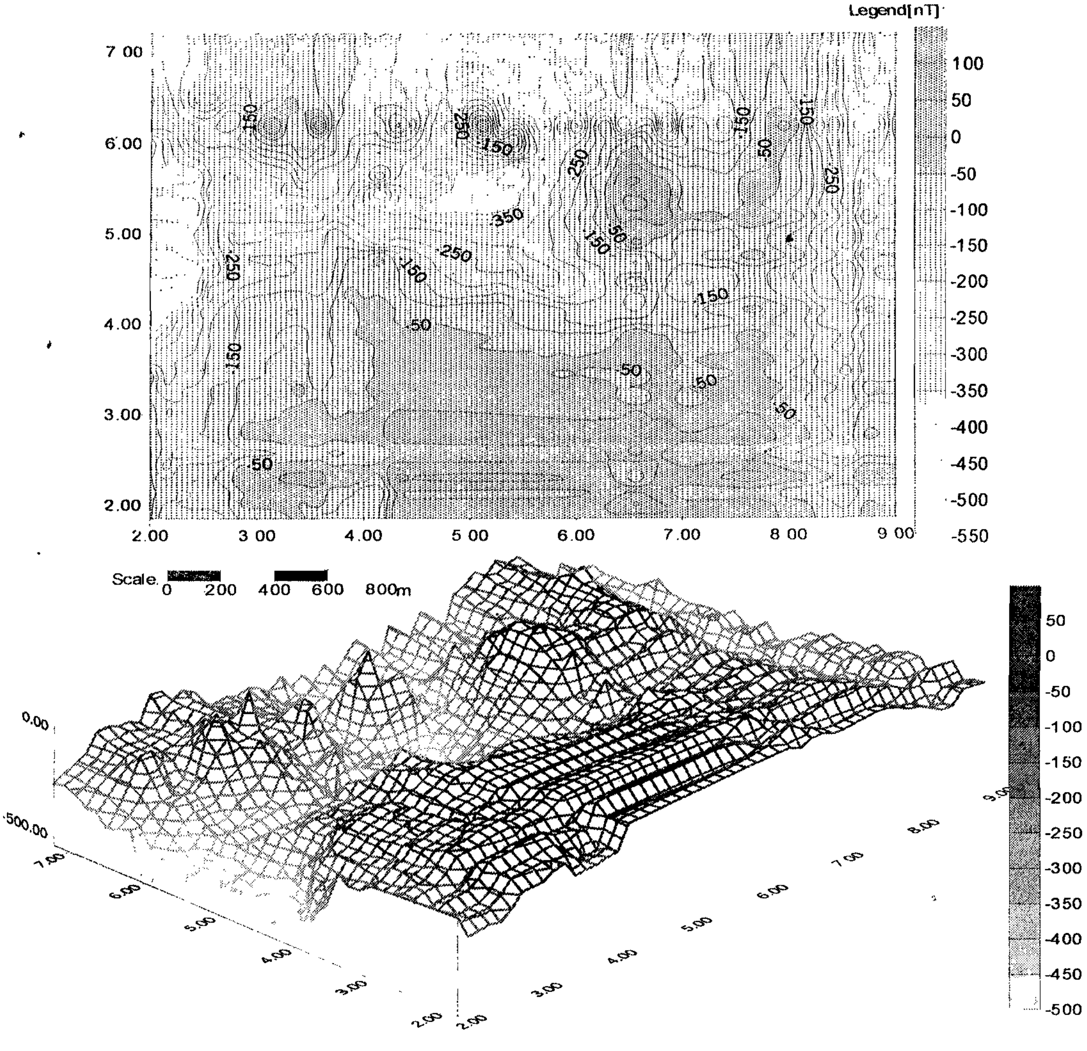


Fig.4.2: Groundmagnetic contour map and its Orthographic view of the study area.

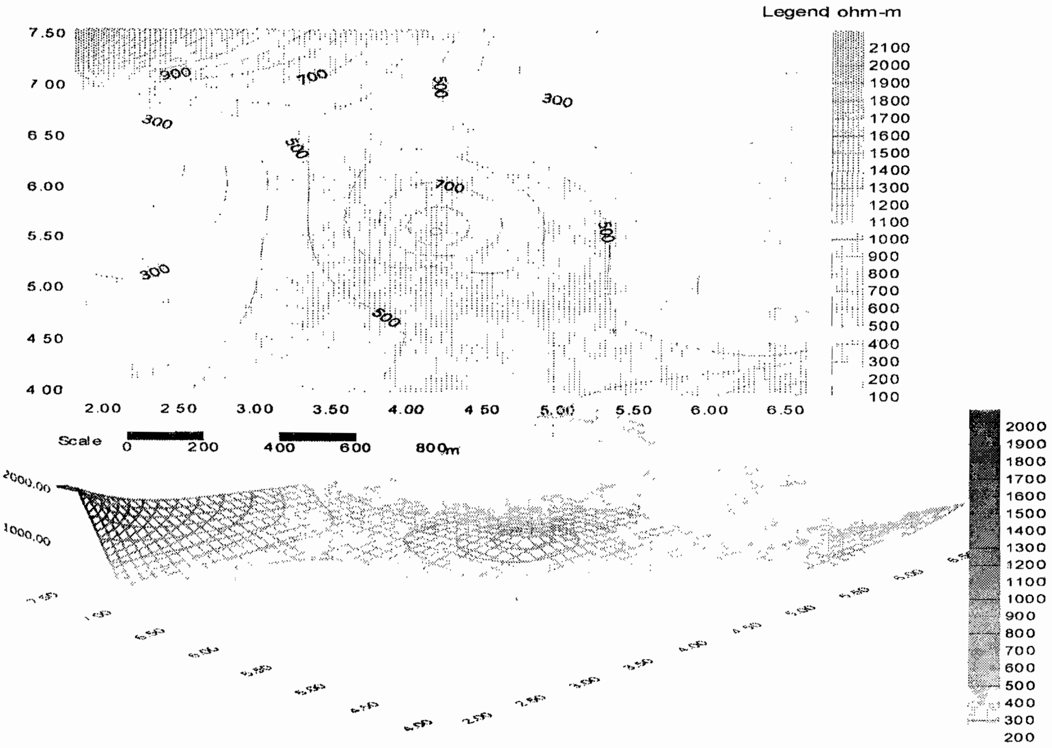


Fig.4.3: First layer contour map and its 3-D orthographic view of the study area.

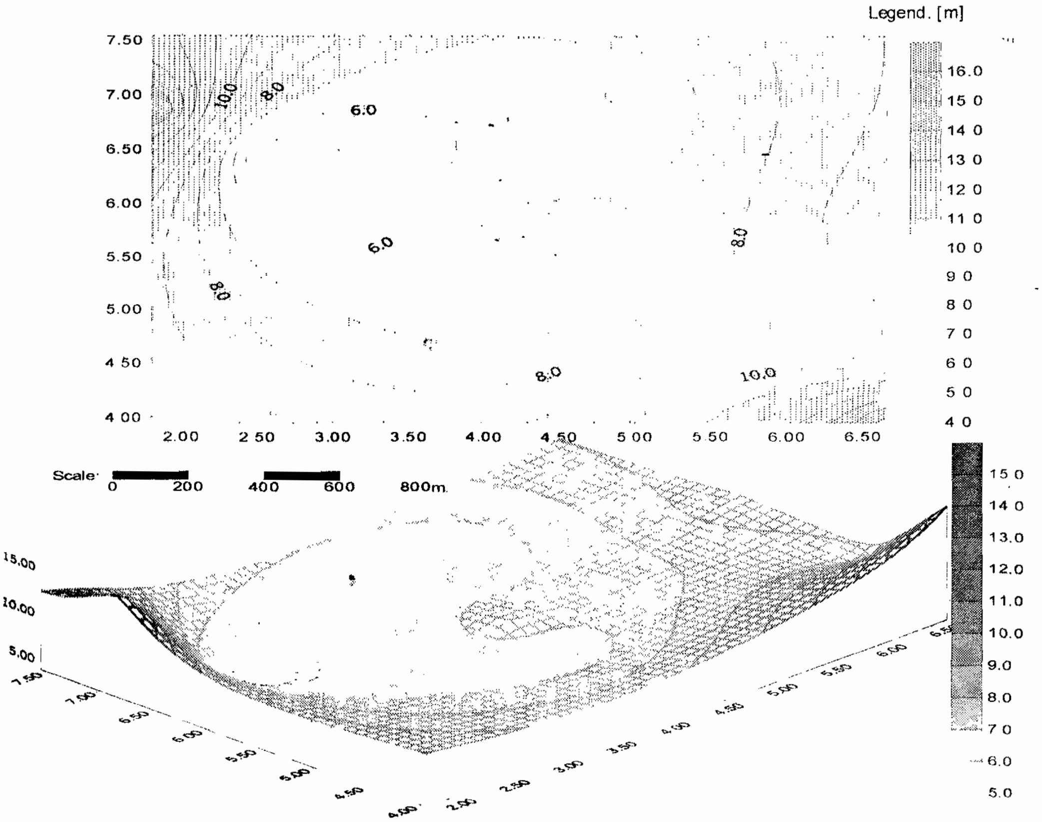


Fig. 4.4: Isopach contour map and its 3 D Orthographic view of the study area.

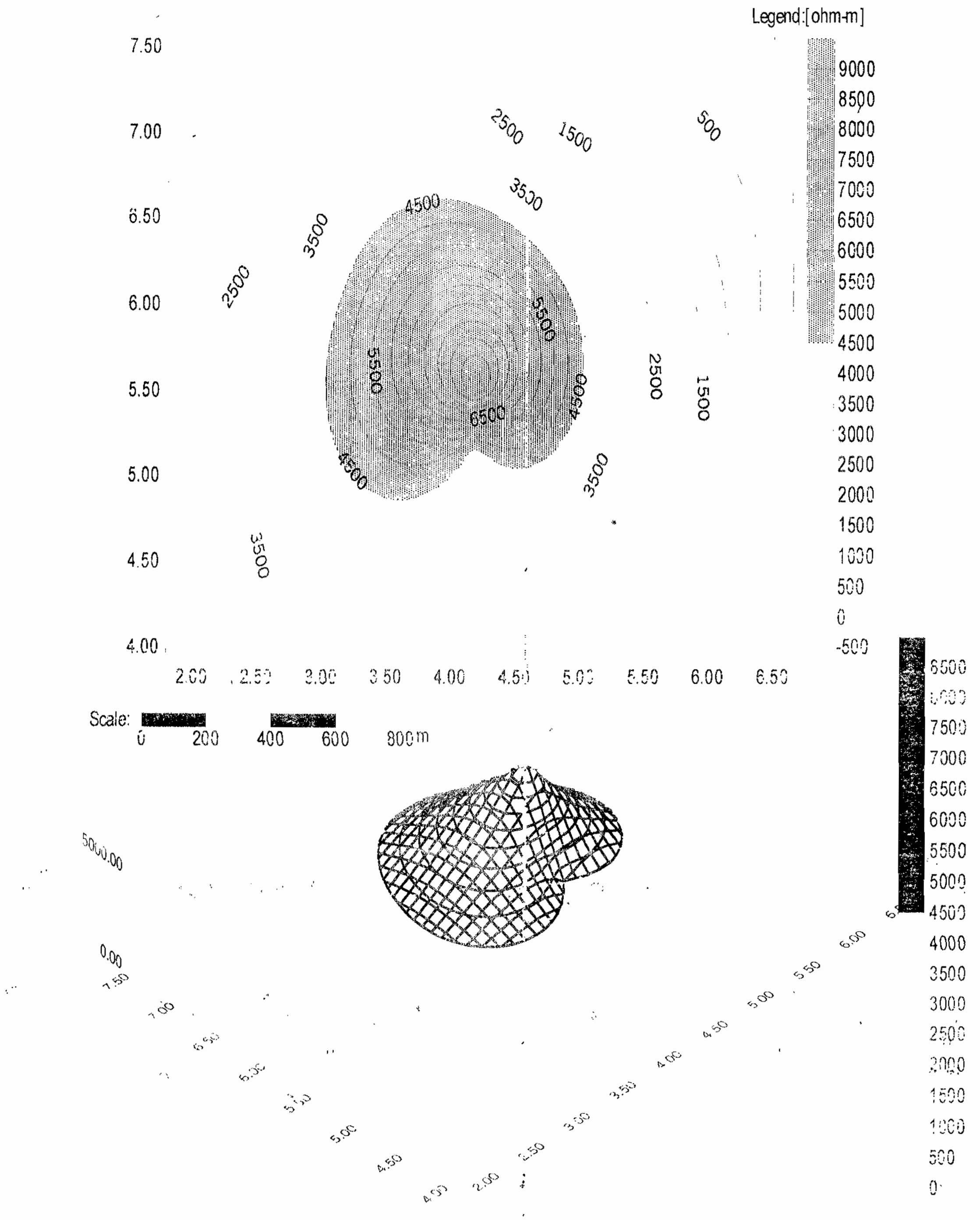


Fig.4.5 : Bedrock relief contour map and its 3 D Orthographic view of the study area.

For the study area, 4 geo-electric sections will be considered (fig. 4.6).

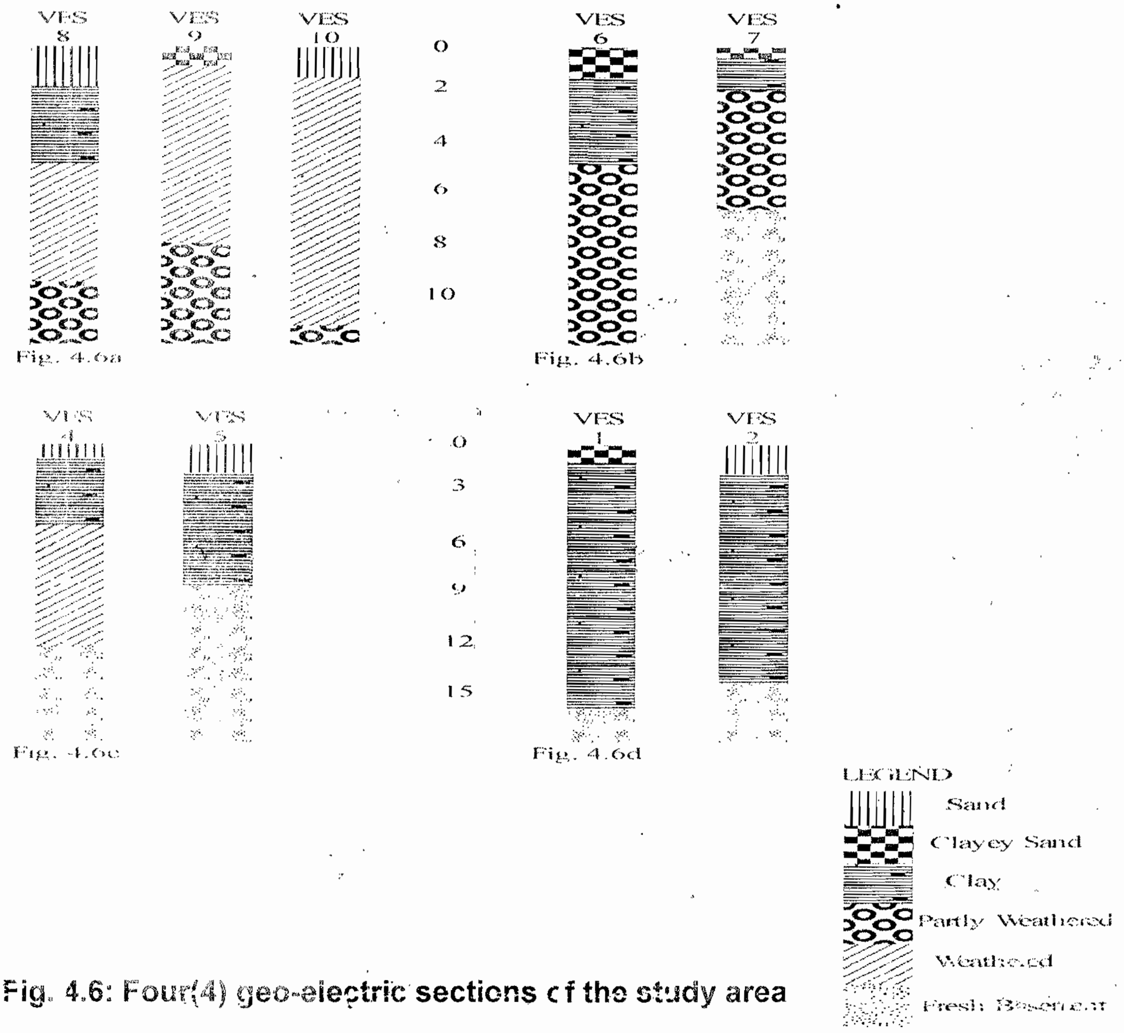


Fig. 4.6a

Fig. 4.6b

Fig. 4.6c

Fig. 4.6d

Fig. 4.6: Four(4) geo-electric sections of the study area

(a) Geoelectric Section Along Traverse 2: This runs in the North-South direction and it has VES 8, 9 and 4.6a). From the section, it can be seen that the weathered layer increases in thickness from VES 8 to 10, while the 2nd layer in VES 8 that was clay weathered to clayey sand in VES 9 and to Sand in VES 10. This indicates that a bore-hole sited on VES location 10 will be most productive.

(b) Geoelectric Section Along Traverse 4: This section runs from the South to North and includes VES 6 and 7 (fig. 4.6b). Both VES locations gives partly weathered third layer, with an increase in the general weathering from VES 6 to VES 7. Since these layers are partly weathered, they do not have good ground water potential.

(c) Geoelectric Section Along Traverse 5: This runs from the North to the South. In VES 5, the section shows a 2nd layer of clay and a low depth to basement, while VES 4 give a considerable thick weathered layer which is an aquifer, confined by a top-layer of clay. VES 4 shows good potential for ground water source.

(d) Geoelectric Section Along Traverse 8: This section has VES 1 and 2 on it and is hydro-geologically irrelevant because there is no weathered layer. There is a general increment in weathering from VES 2 to 1.

5.0 Conclusions

The magnetic survey which acted as a preliminary survey technique was used to obtain sites for Vertical Electrical Soundings. The sites chosen corresponded to the points where high amplitude magnetic lows were observed. Although, not all observed sites proved to be of good ground water potential, most of the sites chosen showed geoelectric terrains that had good aquifer potential.

One can therefore conclude that, high amplitude magnetic lows are good sites for ground water reservoir.

In a basement complex terrain, ground water is confined within weathered layer fractured/jointed or sheared basement columns (Afolayan et al 2004). Thus, in the VES results obtained, we will be interested only in weathered layers which can be identified by this study. The yield in such a geological environment is a complex function of the weathered layer thickness, its clay content and the density of the fracture (Afolayan et al 2004). This also implies that apart from being interested in a weathered layer, the thickness of the layer has to be put into consideration for high yield to be obtained. From the data analysis, the potential ground water sites delineated and their aquifer thicknesses are presented in VES 8 (4.7m thick), VES 4 (5.0m thick), and VES 9 (7.6m thick and VES 10 (11.1m thick).

Acknowledgement

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