Identification of depth to top of limestone body within a concession at Ibese, Southwestern Nigeria, using vertical electric sounding.

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Identification of Depth to Top of Limestone Body Within a Concession at Ibese, Southwestern Nigeria, Using Vertical Electric Sounding

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Abstract: The depth to top of limestone body within a concession at Ibese, in Ogun state, Southwestern Nigeria was evaluated using the Vertical Electric Sounding (VES). The electrical resistivity method employing the VES technique was used to carry out the geophysical investigation and a total 10 VES data was acquired. Three curve types were identified from the acquired data which are the H, A and HK-type curves. Also a geo-electric section was obtained from the result of the field sounding areas, where all the materials above the limestone is regarded as an overburden. The study area (line) spans 5 km of which the trend (direction) of the limestone was found to be NW-SE. VES locations 2, 5, 6, 7, 8 were found to have a shallow depth which is less than 6 m and can be said to be of economic importance.

Key words: Limestone, vertical electric sounding, resistivity, overburden, concession

INTRODUCTION

Limestones are polygenetic. While, some are fragmental or detritus and are mechanically transported and deposited; others are chemical or biological precipitation and are formed in place; that is, *in situ*. The detritus limestone displays current bedding while those formed *in situ* show growth bedding. Both types may be profoundly modified by various post-depositional changes, both mechanically and chemically, such that the original characters are obscured or erased (Nton, 2001).

Ibese town is located in South Western Nigeria and lies entirely in the Dahomey Basin which is a sedimentary basin. Ibese lies at the southern edge of the Ewekoro depression and is overlooked by the escarpment capped by the Ilaro Formation, which forms a prominent feature in the area. There is however, no surface expression of the strike fault down throwing to the North, which is presumed to lie between Ilaro and Ibese.

Occurrence of limestone in the area is associated with the Abeokuta and Ilaro formations where thin layers of limestone have been delineated. The deposit of economic importance however is the thick limestone body near the base of the Ewekoro formation (Jones and Hockey, 1964). The known extent of the Ewekoro limestone has been observed at Shagamu, Ewekoro and the North of Ibese at varying depths of burial.

Generally, the Ewekoro formation is believed to be entirely of Palaeocene age (Adegoke, 1977). The formation consists of algae limestone of varying thickness, overlain by finely laminated black and grey shale with interbreed marl layers. The gray shale at the top of the sequence, grades into thick reddish clay and sand. These have been tentatively referred to as Akinbo and Oshosun Formations, respectively.

Figure 1 presents the geological map of Ogun State showing Ibese the study area and environ with the major geologic formations indicated.

Ibese town, which is about 14 km North of Ilaro town is in Yewa North Local Government Area of Ogun State and lies along the Ilaro-Igbogila road.

The concession, 44 km from Ewekoro, is approximately bounded in the North by Longitude 7^0 0' 0''-6^0 57' 34'' and in Latitude 3^0 00' 00''-3^0 05' 00'' but Line 3 (Fig. 2) where the survey was carried out is in the North by Longitude 0.06^0 59' 34'' and in the East by latitude 3^0 02' 052''.

Generally, the relief of the area is of gently rolling highs with intervening depressions. In the northern part of the concession lie river Iju and its tributaries, river Imina and river Imiya. While, river Igbin lies in the eastern part. The streams in the area are generally turbid during the rainy season as a result of surface erosion. The flow is considerably reduced in the dry season with the smallest stream turning into puddles and connecting trickles.

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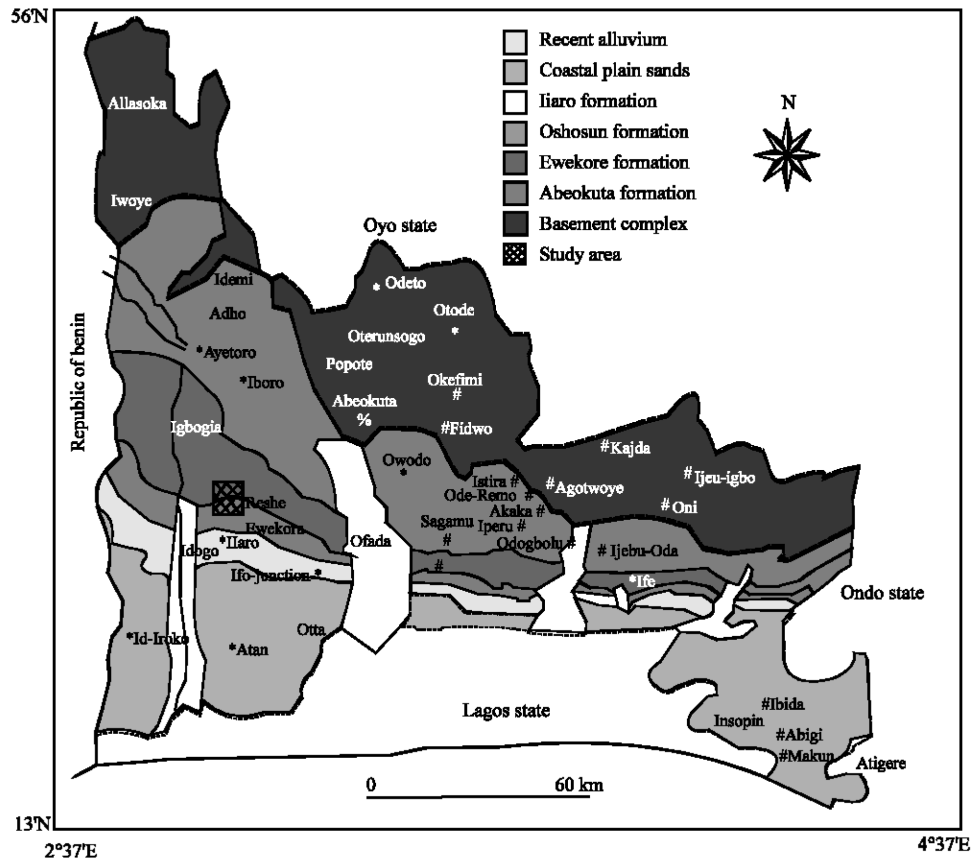


Fig. 1: Shows Geologic Map of Ogun State showing the major geologic formations around Ibeshe, the Study Area

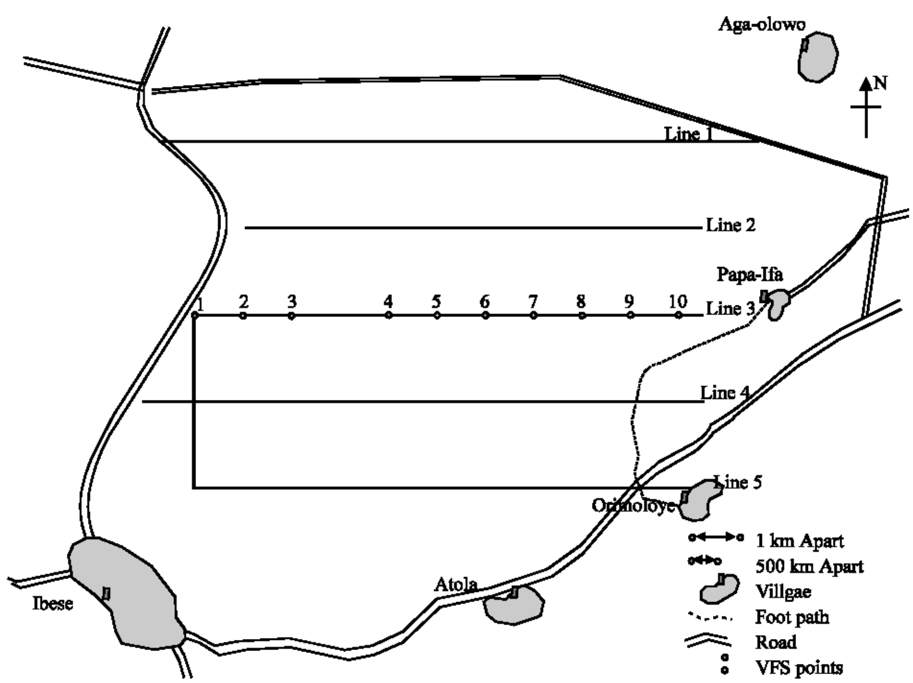


Fig. 2: Base Map of the study area (Ibese)

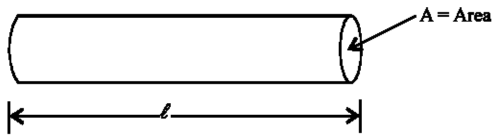


Fig. 3: A conducting material

The area being studied lies within the rainforest belt characterized by a relatively hot climate and two distinct seasons. It is characterized by a high precipitation, low pressure, high evapo-transpiration and relative humidity, which is about 75%. The raining season starts from late April and last till October with a short break in August. The mean monthly rainfall varies from 50 mm in January to more than 200 mm in June and July with a seasonal temperature averaging between 21.3 and 31.2°C. The dry season is between November and March. The temperature ranges from a mean maximum of 36.6°C in December to a minimum of 19.4°C in January.

The objective of the study therefore is to make an assessment of the depth to the top of the lime stone using the Resistivity method, locate its trend or direction and deduce the economic importance from the evaluated volume of the limestone.

Theoretical analysis: The Resistivity method employs an artificial source of current, which is introduced into the ground through point electrodes. The potential difference due to the applied current is measured in the vicinity of the current flow. Since, the current applied is also measured, it is possible to determine an effective or apparent Resistivity, ρ_a of the subsurface. This provides information on the form and electrical properties of subsurface inhomogeneities. For a conducting material of resistance R, having a length ℓ and a cross-sectional area A as shown in Fig. 3.

$$R \alpha \frac{\ell}{A} \quad (1)$$

$$\therefore R = \frac{\rho \ell}{A} \quad (2)$$

Now, from Ohm's law;

$$R = \frac{\Delta V}{I} = \frac{\rho \ell}{A}$$

$$\therefore \rho = \frac{\Delta V . A}{I . \ell} \quad (3)$$

Where,

ρ = Resistivity.
R = Resistance.
I = Current.
V = Potential.

Equation (3) can be used to determine the resistivity of any homogeneous or isotropic medium provided the geometry is simple. For a semi-infinite medium, the resistivity at every point must be defined. If we allow parameters A and ℓ to shrink to infinitesimal size, then

$$\rho = \frac{\lim_{\ell \to 0} \frac{\Delta V}{\ell}}{\lim_{A \to 0} \frac{I}{A}}$$

$$\therefore \rho = \frac{E}{J} \quad (4)$$

Hence, $J = \sigma E$

Where,

E = Electric field.
J = Current density.
σ = Conductivity.

If the current source is located at the centre of a spherical body of radius r, the current density at the spherical surface is:

$$J = \frac{I}{4\pi r^2} \text{ and } E = \frac{\rho I}{4\pi r^2}$$

$$\text{But, } E = -\nabla V \quad (5)$$

And,

$$\therefore \frac{dv}{dr} = -\frac{\rho I}{4\pi r^2}$$

Therefore,

$$V = \frac{\rho I}{4\pi r} \quad (6)$$

In practice, the earth structure is an approximate of hemi-sphere, hence

$$J = \frac{I}{2\pi r^2} \text{ and } E = \frac{\rho I}{2\pi r^2}$$

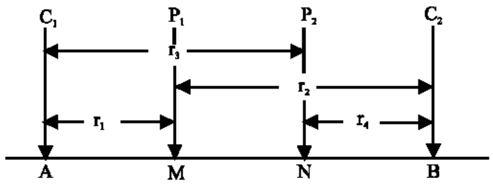


Fig. 4: General electrode configuration for electrical resistivity potential at p_1 due to current at C_1

$$\therefore \frac{dv}{dr} = -\frac{\rho I}{2\pi r^2}$$

$$\therefore V = \int -\frac{\rho I}{2\pi r^2} dr = \frac{\rho I}{2\pi r} \qquad (7)$$

Equation 7 is the potential at a point P due to current at another point C at the surface of the earth. For a 4 electrode on the surface of the earth:

- Potential at P_1 due to current at C_2

$$V_{c_1}^{P_1} = \frac{\rho I}{2\pi r_1}$$

- Potential at P_1 due to current at C_2

$$V_{c_2}^{P_1} = \frac{\rho I}{2\pi r_2}$$

- Potential at P_1 due to current at C_1 and C_2

$$\Delta V_{c_1 c_2}^{P_1} = \frac{\rho I}{2\pi}\left\{\frac{1}{r_1} - \frac{1}{r_2}\right\} \qquad (8)$$

- Also, Potential at P_2 due to current at C_1 and C_2

$$\Delta V_{c_1 c_2}^{P_2} = \frac{\rho I}{2\pi}\left\{\frac{1}{r_3} - \frac{1}{r_4}\right\} \qquad (9)$$

- The Potential difference between P_1 and P_2 due to current at C_1 and C_2

$$\Delta V_{c_1 c_2}^{P_1 P_2} = \frac{\rho I}{2\pi}\left\{\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}\right\}$$

Hence, resistivity ρ is given by the equation

$$\rho = \frac{2\pi \Delta V}{I}\left\{\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}\right\}^{-1} \qquad (10)$$

Where:

$$2\pi\left\{\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}\right\}^{-1} = K$$

the geometric factor of the electrode configuration.

In Schlumberger configuration, used in this study, let the distance between current electrode pair be L and the distances between potential electrodes be r, so that, using Fig. 4:

$$r_1 = \frac{(L - r)}{2} - r_4 \text{ and } r_2 = \frac{(L + r)}{2} = r_3$$

hence for Schlumberger, configuration (Lowrie, 1997),

$$\rho_a = \frac{\pi}{4}\frac{\Delta V}{I}\frac{(L^2 - r^2)}{r} \qquad (11)$$

MATERIALS AND METHODS

The vertical electric sounding was done using the ABEM SAS 300C Terrameter with ABEM 2000 booster. The Garmin II Plus GPS (Global Positioning System) was used to establish co-ordinate references and altitude at the VES stations.

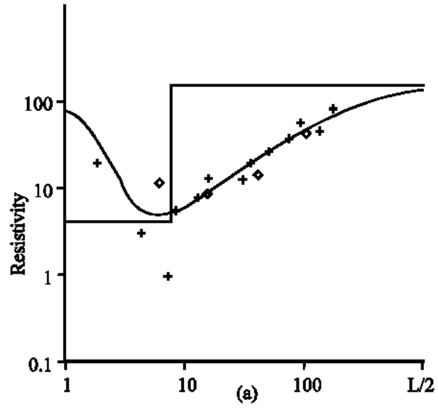
A total of 10 VES data were acquired in the study using a Schlumberger array with a maximum current electrode separation of 300 m and a maximum potential electrode spacing of 10 m.

The field data for the VES are represented in graph in which half of the current electrode separation, AB/2 i.e. L/2 was plotted in abscissa (x-axis) while the corresponding apparent resistivity was plotted in the ordinate (y-axis). The scales of both axes are logarithmic.

The data obtained were interpreted quantitatively and qualitatively. The plotted curve is partially curve-matched with a set of two layer Schlumberger master curves in conjunction with auxiliary curve (Orellana and Mooney, 1972). The output was now passed through computerized program based on iterative method of Gauss to reduce the percentage error to the barest minimum.

RESULTS AND DISCUSSION

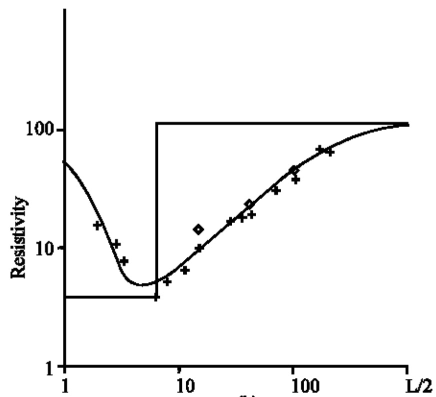
The processed data were used in obtaining the Resistivity curves and the geoelectric section. Figure 5 (a-j) shows the curves obtained from the iteration with VES numbers as indicated.



(a)

VES 1

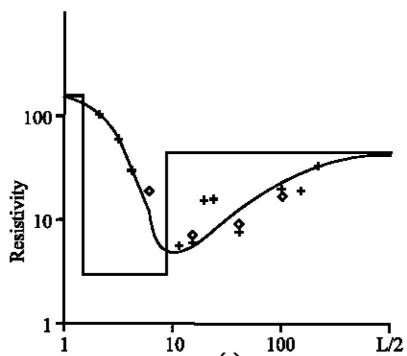
Resistivity (Ω m)	Thickness (m)	Depth (m)
89.5	0.75	0.75
3.53	6.70	7.45
125		



(b)

VES 2

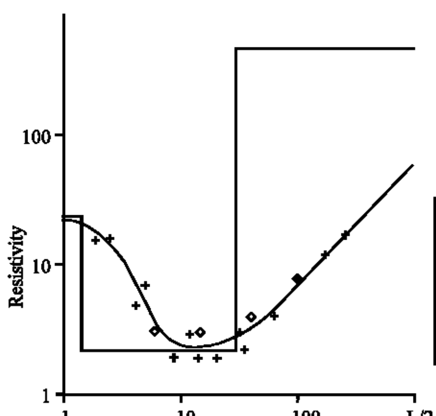
Resistivity (Ω m)	Thickness (m)	Depth (m)
80	0.67	0.67
3.85	5.53	6.20
113.45		



(c)

VES 3

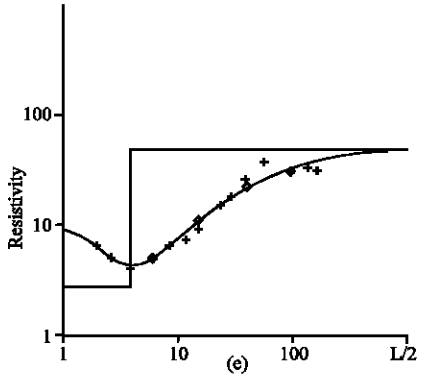
Resistivity (Ω m)	Thickness (m)	Depth (m)
159.94	1.44	1.44
3.05	7.36	8.80
45		



(d)

VES 4

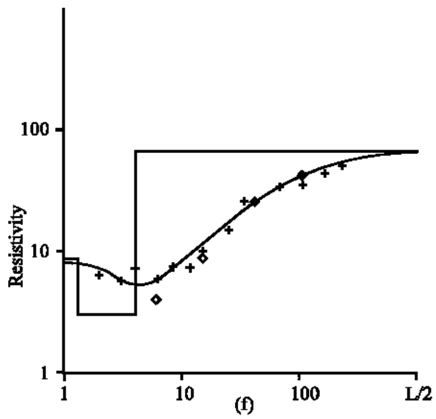
Resistivity (Ω m)	Thickness (m)	Depth (m)
25.42	1.45	1.45
2.18	29.36	30.81
537.8		



(e)

VES 5

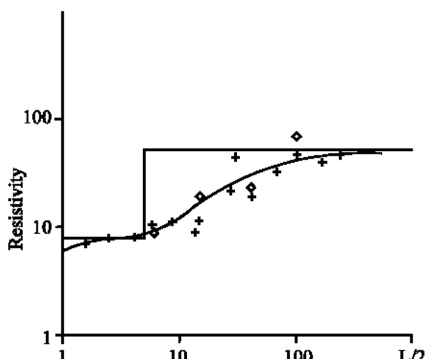
Resistivity (Ω m)	Thickness (m)	Depth (m)
10.07	0.92	0.92
2.75	3.03	3.95
48.08		



(f)

VES 6

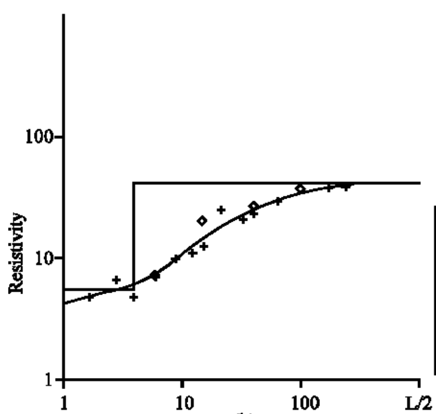
Resistivity (Ω m)	Thickness (m)	Depth (m)
8.50	1.31	1.31
3.02	2.80	4.11
64.45		



(g)

VES 7

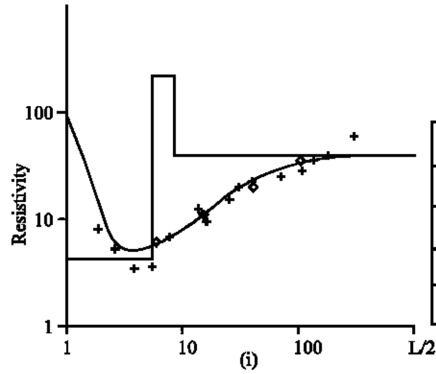
Resistivity (Ω m)	Thickness (m)	Depth (m)
4.75	0.31	0.31
7.88	4.70	5.01
49.6		



(h)

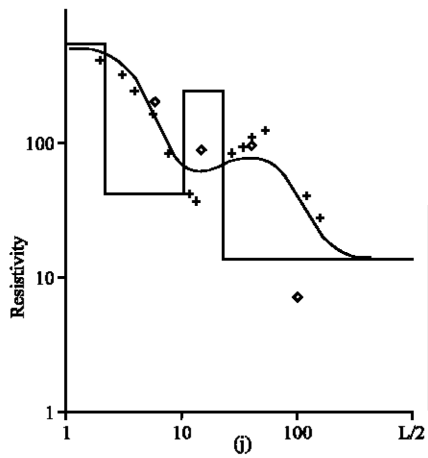
VES 8

Resistivity (Ω m)	Thickness (m)	Depth (m)
3.02	0.35	0.35
5.49	3.50	3.85
41.68		



VES 9

Resistivity (Ω m)	Thickness (m)	Depth (m)
294.32	0.43	0.43
4.3	5.07	5.50
274.9	2.90	8.40
40		



VES 10

Resistivity (Ω m)	Thickness (m)	Depth (m)
543.43	2.2	2.20
41.44	8.36	10.56
238.55	12.27	22.83
13.36		

Fig. 5(a-j): Resistivity curves for the 10 VES location points

Table 1: Common rocks and their ranges of resistivity values (Telford *et al.*, 1990)

Rock type	Resistivity (Ωm)
Clay/Shale	1-90
Sandstone	1-1000
Brackish water sand	4-20
Fresh water sand	50-1000
Limestone	10-10000
Dry sand	2000-100,000

Visually, inspecting the curves, we thus classify them into 3 groups in the following order:

Group I : H type
Group II : A type
Group III : HK type

Group I: This is commonest type of VES curves characteristic in the study. There are 6 curves in this group. These are VES locations 1, 2, 3, 4, 5 and 6. The H curve type is characterized by $\rho1 > \rho2 < \rho3$, i.e. the resistivity of the first layer is greater than the second layer while the third layer has resistivity greater than the overlying layer. They are of 3 geo-electric layers.

The first layer of VES location 1 is found at a depth of 0.75 m with the resistivity value of 89.5 Ω m which is regarded as the topsoil. The second layer has a low resistivity value of 3.53 Ωm and it is being classified as clay and at the depth of 7.45 m we have a resistivity of 125 Ωm which is classified as limestone (Telford *et al.*, 1990).

In VES location 2, the first layer is found at a depth of 0.67 m (Table 1) with the resistivity value of 80.0 Ωm which is regarded as the topsoil. The second layer has a low resistivity value of 3.85 Ωm which is being classified as clay and at the depth of 6.20 m we have a resistivity of 113.45 Ωm which is classified as limestone.

VES locations 3, 4, 5 and 6, also have the same curve characteristics as that of 1 and 2, as they belonged to the same group Table 2.

Group II: This group is characterized by $\rho1 < \rho2 < \rho3$, i.e. the resistivity of the first layer is less than that of the second layer, while the third layer has resistivity greater than the overlying layer. They are also of 3 geo-electric layers. There are two-curves in this group which are VES location 7 and 8. Also, refer to Table 2 for geoelectric characteristics.

Table 2: Quantitative interpretation showing their geo-electric parameters

VES PTS.	Curve type	No of layers	Resistivity (Ωm)	Thickness (m)	Depth to bottom (m)	Lithological units
1	H	3	89.5	0.75	0.75	Top soil
			3.53	6.70	7.45	Clay
			125			Limestone
2	H	3	80	0.67	0.67	Top soil
			3.85	5.53	6.20	Clay
			113.45			Limestone
3	H	3	159.94	1.44	1.44	Top soil
			3.05	7.36	8.80	Clay
			45			Limestone
4	H	3	25.42	1.45	1.45	Top soil
			2.18	29.36	30.81	Shale/Clay
			537.8			Limestone
5	H	3	10.07	0.92	0.92	Top soil
			2.75	3.03	3.95	Clay/Shale
			48.08			Limestone
6	H	3	8.50	1.31	1.31	Top soil
			3.02	2.80	4.11	Shale
			64.45			Limestone
7	A	3	4.75	0.31	0.31	Top soil
			7.88	4.70	5.01	Shale/Clay
			49.60			Limestone
8	A	3	3.02	0.35	0.35	Top soil
			5.49	3.50	3.50	Shale/Clay
			41.68			Limestone
9	HK	4	294.32	0.43	0.43	Top soil
			4.3	5.07	5.50	Clay/Shale
			274.9	2.90	8.40	Limestone
			40			Limestone
10	HK	4	543.43	2.2	2.20	Top soil
			41.44	8.36	10.56	Limestone
			238.55	12.27	22.83	Limestone
			13.36			Limestone

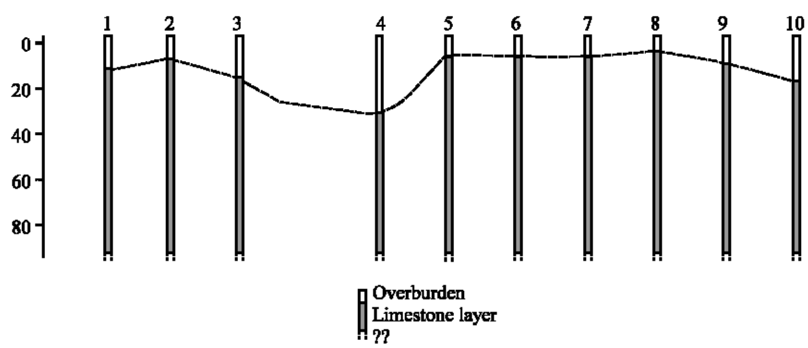


Fig. 6: Depth to top of limestone on line 3

Group III: This group is characterized by ρ1> ρ2< ρ3> ρ4. Two curve types; VES locations 9 and 10 fall into this group. Here we have four geo-electric layers. Table 2.

A geo-electric section was drawn from the result of the field sounding curves, the section represents the bedrock topography-geo-electric unit and across the line which is the study area. The section maintains a NW-SE trend and comprises of VES 1-10. The geo-electric section is essentially that of the depth to the geo-electric bedrock corresponding to the top of the limestone with the overburden layer stripped off (Fig. 6).

The geo-electric section has been classified mainly in 2 parts i.e. the overburden and the limestone where the other materials such as top soil, clay, shale, has been classified as the overburden. The areas of interest where shallow depth to the top of limestone are less than 6m are VES locations 2, 5 ,6, 7 and 8 and they can be said to be economic importance. This can be seen in Fig. 7.

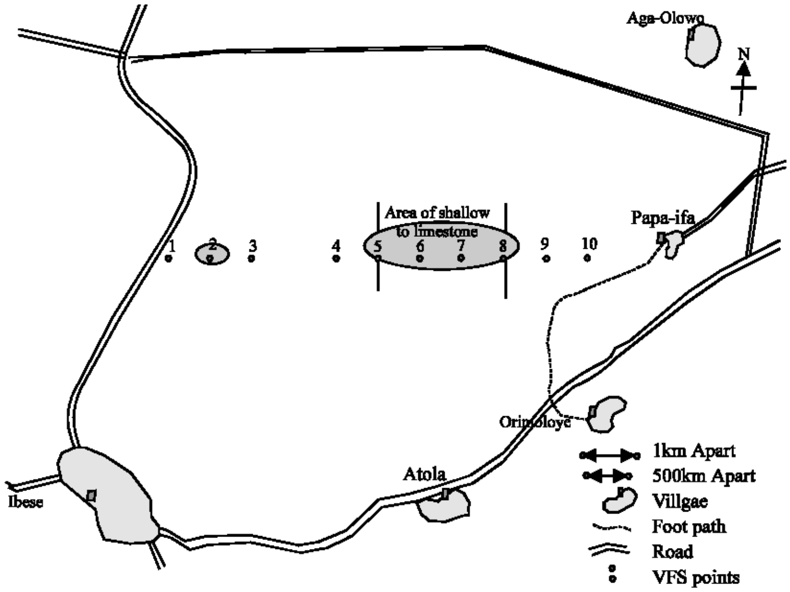


Fig. 7: Area of shallow depth to top of limestone

CONCLUSION

The Vertical Electric Sounding of the resistivity method was used to delineate locations within the study area where the top of the limestone occurs at shallow depths. The trend of the limestone body from locations of thick overburden to thin overburden is clearly indicated from the results of the study such that area of interest or of economic importance can easily be picked from a cursory look. These areas where depths to the top of the limestone are less than 6 m are VES locations 2, 5, 6, 7 and 8. The results also showed that the shallow occurrence of the limestone deposit with overburden thickness ranging from 2-12 m is concentrated in the study area, with the general trend identified to be NW-SE.

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