Journal of the Nigerian Association of Mathematical Physics
Volume **17 (November, 2010), pp 409 - 414**

Vertical Electrical Sounding as a Viable Tool for Investigating Subsurface Lithology at Auchi, Edo State of Nigeria

F.O. Ezomo
Department of Physics,
Faculty of Physical Sciences,
University of Benin, P.M.B 1154,
Ugbowo, Benin City, Nigeria

Abstract

Vertical electrical sounding (VES) utilizing schlumberger electrode array was used to investigate subsurface lithology in Auchi, Edo State of Nigeria. Ten (10) VES (uniformly distributed) were conducted at four(4) different stations. The need to carry out this research became inevitable in view of the fact that subsurface lithologies are of economy importance to mankind for development for example clay which is one of the subsurface lithologies if discover can solve the problem of youth resistiveness by way of mining industries that rely solely on clay. The software, IPI2WIN which utilizes computer iteration was used to plot graph of apparent resistivity versus semi current electrodes spacing. From the results, the number of subsurface layers, their corresponding resistivities and thicknesses of each layer were obtained.

The result of the VES showed the existence of the following subsurface lithologies or rock types: top soil, wetsand, clay, sandstone, and sands having resistivities from 100.0 ohm-m to 32000 ohm-m, depths in the range 0.50m-180.0m and thicknesses in the range 0.50m-75.0m.

Area of probable subsurface lithological formations and their thicknesses have been identified for economical purposes, environmental purposes, engineering purposes, especially for future, mining of industries foundation operations and drilling.

1.0 Introduction

Nigeria whose economy is slowly growing in a developing nation blessed with abundant natural resources e.g oil, gas, rubber, coal, tin, clay e.t.c but currently depends heavily on finished products imported into the country. These include refined oil, ceramics floor tiles, fabrics, shoes, pharmaceutical products, the list of which is endless [1]. This dependence on importation of foreign products whose raw materials abound the country is a major draw back in the economy [2]. With technological advancement, there is a current drive towards the attainment of self reliance in the local sourcing of industrial raw materials for the establishment of the industries for example, the use of clay products for constructions and building purposes has greatly aided many developed and developing nations of the world e.g china, Spain and Brazil [3].

The study area is currently being known for its youth restivesness [4]. This is a consequence of the growing number of unemployment in the region, with the youth feeling denied of the benefit accruing from subsurface lithologies which is the deposit of mineral resources. This research is further stimulated by the need and demand for industrial raw materials usually obtained from subsurface lithologies to support fast growing industrial project in the area [5] vertical electrical sounding (VES) has gradually and continually made its way to the top in the successful search and exploitation of these subsurface lithologies [6].

2.0 Brief Local Geology of the Study Area

The study area was Auchi in Edo State of Nigeria. The area is located in the northern part of Edo State and lies approximately on latitude $7^0 10^1$ and longitude 6^0.48’ E’ with an elevation of approximately 30 m [7]. It is

Corresponding author: E-mail; ezomofriday@yahoo.com Tel. +2348054470436

underlain by the Ameki formation. The Ameki formation consist mainly of a series of cross-bedded sandstone, clays pebbly grit and grey silt stone [8].

3.0 Experimental Work

Geophysical survey based on vertical electrical sounding (VES) was carried out in Auchi area of Edo State, Nigeria with the aid of SAS (signal averaging system) ABEM 300 digital terrameter and its SAS 2000 booster [9]. VES was carried

out using he schlumberger array in the survey area with the current electrode (AB/2) spacing ranging from 2m-1000m. This
spacing depends on the number of points per decade which is usually n=6 in accordance with the formula $10^{1/n}$. This resulted to spread of 1.0m, 1.47m, 2.15m, 3.16m, 4.64m, 6.81m, 10.0m, 14.7m, 21.5m e.t.c [10].

Measurements were taken at increasing current electrode distances so that the electric current introduced into the ground penetrated greater depths. In places, where the ground was dry, small amount of water was applied to the ground for easy penetration of current electrode into the ground which made good contact with it [11].

The current electrodes were expanded at six points per decade while the potential electrode remained fixed. A decrease in the potential difference across the potential electrodes necessitated a new potential electrode spacing in accordance with schlumberger field condition of AB≥5MN where A and B are current electrodes, M and N are potential electrodes [11].

For easy reference, a table of semi current electrode spacing (AB/2) and respective apparent, resistivities for the four covered stations is shown below in table 5.1.

4.0 Theoretical analysis

In vertical electrical sounding (VES) employing schlumberger array, the earth is approximated to be composed of horizontally stratified, isotropic and homogeneous media such that the change of resistivity is a function of depth. The theoretical analysis of the method employed have been documented in the previous research work of the author, [1], [2],[5],[6].

In VES, four electrodes are earthed along a straight line in the order AMNB, with AB as current electrodes and MN as potential electrodes the calculated apparent resistivity (ℓ_a) according to schlumberger array condition of AB ≥ 5MN is

$$\ell_a = \pi \left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \right] \frac{\Delta V}{I} \quad [9] \qquad (4.1)$$

The determination of the subsurface resistivity distribution from surface measurements can be obtained by using kernel function. This function represents the ideal solution to the inverse problem interms of lithology variation with depths. The function does not depend on electrode geometry and can be obtained from transformation of measured apparent resistivities. The kernel function used in this work is obtained from [12] and [14], if the observed apparent resistivity is

$$\ell_a = r^2 \int_o^\infty \lambda\, T(\lambda) J_1(\lambda r)\, d\lambda \quad [10] \qquad (4.2)$$

Where kernel function = $T(\lambda) = \int_o^\infty \frac{1}{r} \ell_a\ (r) J_1 (\lambda r)\, dr$ (4.3). J_1 is the Bessel function of the first order, first kind and $T(\lambda)$ is the transformed resistivity data arising from kernel function. [11]

RESULTS AND DISCUSSION

The apparent resistivity values obtained from the measurement were plotted against half the current electrode spacing. The vertical electrical sounding (VES) curves are shown in figures 5.1-5.4 while the apparent resistivities table is shown in table 5.1-5.5. The resulting curves shown in figures 5.1-5.4 indicate the geoelectric layers or subsurface lithologies thicknesses cummulative thicknesses and layers resistivities of the studied area.

The results of plotting apparent resistivity against semi current electrode spacing AB/2 produced sounding curves shown in figures 5.1-5.4. The sounding curve were interpreted using computer software IPI2WIN to provide a model showing the subsurface layer thicknesses and resistivities [13]. The interpreter inputs a preliminary model into the software programme that calculates the sounding curve model: it then adjust the model and calculates a new sounding curve that better fits the field data.

This process was repeated until a satisfactory (match) fit was obtained between the model and the field data. This computer model process is called inversion. The inversion process also produced the subsurface lithological layer thicknesses and resistivities as shown in tables 5.2-5.5 below [12]. The analysis of the resistivities of various lithological formations is usually ambiguous because different lithological unit or rock types do have the same resistivity. This usually leads to overlapping of resistivity values as already documented [6]. The establishment of various subsurface lithological units is usually achieved by integrating the results of the VES curves with the

Corresponding author: E-mail; ezomofriday@yahoo.com Tel. +2348054470436

desired borehole/lithological log/drillers log [13]. From the synthesis of the borehole/lithological/driller's log and the inversion process of the VES, the subsurface lithological unit [14] encountered are shown in the table 5.6

Table 5.1: Apparent resistivities values for typical stations.

S/N	AB/2 (m)	App. Resist for	App. Resist for	App. Resist for	App. Resist for
1	1.00	210.59	780.74	627.80	827.86
2	1.47	278.64	350.11	992.84	992.94
3	2.15	384.79	473.81	1205.51	1205.51
4	3.16	538.03	659.99	1475.49	1475.49
5	4.64	747.30	900.27	1809.06	1809.06
6	6.81	1017.28	1179.39	2194.82	2194.82
7	10.00	1356.62	1467.74	2615.19	2615.19
8	14.70	1770.51	1713.01	3092.43	3092.42
9	21.50	2445.45	1862.71	3827.15	3627.15
10	31.60	2788.56	1955.39	4062.85	4062.85
11	46.40	3412.47	2149.02	3095.22	3996.27
12	68.10	4108.69	2588.94	3044.84	3144.84
13	100.0	4713.84	3750.78	1831.90	1831.90
14	147.00	4903.89	3957.56	804.32	804.32
15	215.00	4487.06	4423.16	417.68	417.02
16	316.00	3713.42	4331.28	417.89	417.99
17	464.00	3115.70	3560.93		
			2489.53		

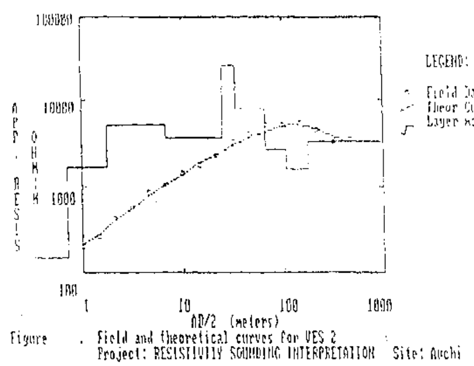


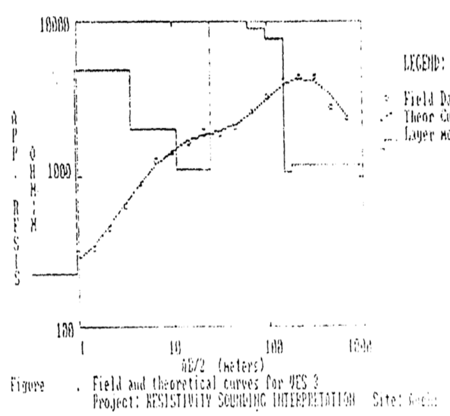
Fig 5.1 Iterated Sounding Curve for Station 1

LAYER PARAMETERS OF MODEL

LAYER	RESISTIVITY	THICKNESS	CUM THICK
1.00	145.00	0.71	0.71
2.00	1606.50	1.09	1.80
3.00	5060.00	5.09	6.89
4.00	3456.00	18.48	25.37
5.00	26040.08	8.32	33.69
6.00	7767.56	32.73	66.42
7.00	2571.43	39.79	106.21
8.00	1532.52	70.28	176.49
9.00	3122.38	infinity	infinity
9.00	3122.30	infinity	infinity

Field data & computer interpretation by
Nwadiei O. Lucky

Table 5.2: Lithology for Station 1



LAYER PARAMETERS OF MODEL

LAYER	RESISTIVITY	THICKNESS	CUM THICK
1.00	227.09	0.95	0.95
2.00	5023.31	2.70	3.65
3.00	2028.03	7.42	11.07
4.00	1050.96	13.50	24.97
5.00	9995.26	37.03	62.00
6.00	8964.05	34.33	96.33
7.00	7857.60	51.09	147.51
8.00	1075.63	29.08	177.41
9.00	1167.00		

Field data & computer interpretation by
Nwadiei O. Lucky

Fig 5.2 Iterated Sounding Curve for Station 2

Table 5.3 Lithology of Station 2

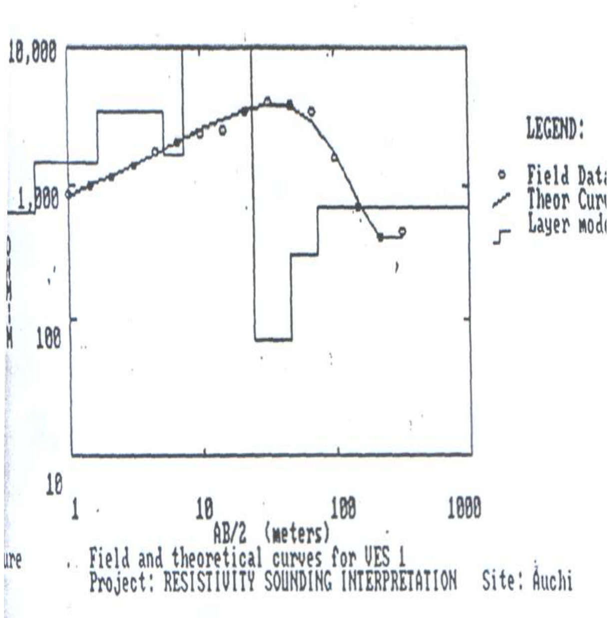


Fig 5.3 Iterated Sounding Curve for Station 3

LAYER PARAMETERS OF MODEL

LAYER	RESISTIVITY	THICKNESS	CUM THICK
1.00	628.14	0.56	0.56
2.00	1549.59	1.14	1.70
3.00	3605.25	3.63	5.33
4.00	1764.00	2.26	7.59
5.00	9840.00	16.91	24.50
6.00	68.00	21.17	45.67
7.00	321.00	27.81	73.48
8.00	703.50	infinity	infinity
8.00	703.50	infinity	infinity

Field data & computer interpretation by:
ESIEKPE Ese Lawrence

Table 5.4 Lithology for Station 3

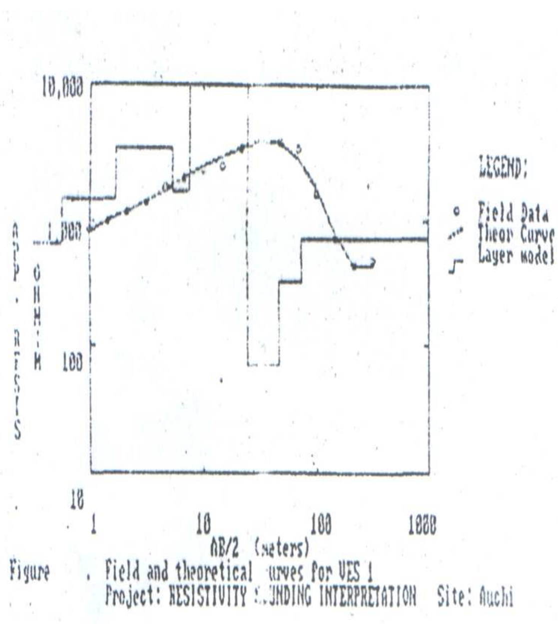


Fig 5.4 Iterated Sounding Curve for Station 4

LAYER PARAMETERS OF MODEL

LAYER	RESISTIVITY	THICKNESS	CUM THICK
1.00	628.14	0.56	0.56
2.00	1549.59	1.14	1.70
3.00	3605.25	3.63	5.33
4.00	1764.00	2.26	7.59
5.00	9840.00	16.91	24.50
6.00	68.00	21.17	45.67
7.00	321.00	27.81	73.48
8.00	703.50	infinity	infinity
8.00	703.50	infinity	infinity

Field data & computer interpretation by
MARERE [illegible]

Table 5.5 Lithology for Station 4

Corresponding author: E-mail; ezomofriday@yahoo.com Tel. +2348054470436

Journal of the Nigerian Association of Mathematical Physics Volume 17 (November, 2010), 409 - 414

Stations	Layers Resistivity (ohm-m)	Layer thickness (m)	Depth (m)	Subsurface lithology
1	145.0	0.71	0.71	Clay/Wet top soil
	1606.50	1.09	1.80	Sandstones
	5060.00	5.09	6.89	Sandstones
	3456.00	18.48	25.37	Sand
	2540.09	8.32	33.69	Sand
	7767.56	32.73	66.42	Sandstone
	2671.43	39.79	106.21	River sand
	1532.00	70.28	176.49	River sand
	3122.26	Infinity	Infinity	Dry sand
2	227.09	0.95	0.95	River sand and gravel/topsoil
	5623.31	2.70	3.65	Sand stones
	2028.03	7.42	11.07	Sand stones
	1090.96	13.90	24.97	Loose sands
	9995.26	37.03	62.00	Loose sands
	8964.00	34.33	96.33	Sands
	7857.00	51.00	147.33	Sands
	1075.00	30.00	177.41	Sands
	1167.00	Infinity	Infinity	Wet clay
3	628.14	0.56	0.56	Topsoil/River Sand
	1549.59	1.14	1.70	Loose sands
	3606.25	3.63	5.31	Loose sands
	1764.00	2.28	7.59	Sand stones
	9840.00	16.91	24.50	Sandstones
	60.00	21.42	45.92	Clay
	321.00	27.81	73.73	Clay soils
	402.50	Infinity	Infinity	Sands
	703.60	Infinity	Infinity	Sands
4	75.46	1.00	1.00	Top soil/clay
	125.00	0.81	1.81	Clay soils
	15.50	2.36	4.17	Clay
	12.50	3.99	8.16	Clay
	10.00	8.98	17.14	Wet clay
	11.50	7.48	24.62	Wet clay
	18.66	27.06	51.68	Sands
	10.38	24.98	76.66	Sands
	27.80	89.82	168.48	Sands
	247.00	Infinity	Infinity	Sandstones

Table 5.6: various subsurface lithologies encountered for typical stations

Corresponding author: E-mail; ezomofriday@yahoo.com Tel. +2348054470436

Vertical Electrical Sounding as a Viable Tool for Investigating... ***F.O. Ezomo*** ***J of NAMP***

6.0 Conclusion

Vertical electrical sounding (VES) of electrical resistivity method employing schlumberger electrode array used for investigating subsurface lithologies is very reliable and successful. The studies demonstrated the usefulness of VES for the delineation of subsurface lithologies. The various subsurface lithologies intercepted were Topsoil, wet sand, clay, sandstones and sand having resistivities in the range 100.0 ohm-m to 32,000 ohm-m, depths in the range 0.50m to 180.0m, and thicknesses in the range 0.50m to 75.om.

These results agreed very well with available bore-hole/lithologically/log/driller's log. These subsurface lithologies are of economy importance to mankind for development for example clay which is one of the subsurface lithologics intercepted falls into one of the industrial minerals that are needed for the manufacture of industrial products. Also sand deposit geophysically means aquifer or water bearing formations which can serve as a guide to competent bore-hole driller for pure water production etc.

References

[1] Ezomo, F.O. and Ifedili, S.O.; (2006) Determination of water bearing formations at Osasogie quarters by electrical resistivity method published M.Sc thesis, physics Dept, University of Benin, Benin City, Nigeria

[2] Ezomo, F.O. and Ifedili, S.O.; (2004).Groundwater exploration in Ekpoma and its environs by electrical resistivity method. Published Ph.D thesis university of Benin, Benin City, Nigeria

[3] Adelola, Olorunfemi Fasuyi.; (1999) Groundwater investigation in Kaduna Basin, Nigeria Association of petroleum explorationist, 46 1364-1393.

[4] Okwueze, E.E.; (1996) Global journal of pure and applied sciences vol. 12 210-211.

[5] Ezomo, F.O. and Ifedili, S.O.; (2005) journal of Applied Science vol 9 --- 6579-6588

[6] Ezomo, F.O. and Ifedili, S.O.; (2006) African journal of Sciences vol, 9, No. 1 pp 2195-2203.

[7] Omorogbe, O.; (2005)federal information enter Akpakpava Road, Benin City, Nigeria

[8] Kogbe, C.A.; (1976) Geology of Nigeria, Elizabeth press, first published 1145p.

[9] Ezomo, F.O. and Akujieze, C.N.; (2009) Geophysical determination of Buried structural features at Ovbiogie village, Edo State, Nigeria journal of the Nig Associa. Of math. Phy. 14 177-180.

[10] Ezomo, F.O. and Ifedili, S.O.; (2007) vertical electrical sounding investigation of Aquifers in the Ekpoma area of Nigeria. Journal of the Nig. Associa. Of math. Phy. 11 597-604.

[11] Ezomo, F.O and Ifedili, S.O.; (2004) Application of schlumberger array of vertical electrical sounding to detection of water bearing formations. Journ. Of the Nig. Associa. Of Math Phy. 8 247-252

[12] Information from w.w.w.cflud.gov/agm/engapplications/subsurfaccharacter/613a

[13] Profile of Bore-hole lithology/driller's log for Auchi, Edo State, Nigeria.

[14] Okwueze, and Akpotu.; (1979)Approximate ranges for electrical resistivity of rocks and soils. Journal of African Earth Sciences 5 20-22.

Corresponding author: E-mail; ezomofriday@yahoo.com Tel. +2348054470436