Journal of the Nigerian Association of Mathematical Physics
***Volume* 25 (November, 2013), pp 183 – 186**
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Lithologic Deduction from Resistivity Studies in Nkwegu, Nigeria

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Abstract

Direct current (D.C) resistivity method was used to study the sub-surface lithology of Nkwegu. Data obtained through depth sounding from four locations within the study area were used in the analysis. The ABEM terrameter signal averaging system (SAS 300C) was the equipment used and schlumberger electrode configuration was employed. The maximum current electrode spread was 300meters. Computer modelling was used for the interpretation of the field data. The depth sounding in two of the locations revealed four geoelectric layers while the sounding in the other two locations revealed five geoelectric layers. The result shows that the average resistivity and thickness of earth layers in the study area from the surface are 917.64Ωm and 1.3m for the first layer; 138.89Ωm and 8.8m for the second layer; 480.82Ωm and 17.9m for the third layer and 65.96Ωm and 21.5m for the fourth layer respectively. The result indicates that the first four layers of Nkwegu are made up of lateritic over burden, wet feruginised clay, fissile dry shale and consolidated wet shale accordingly.

***Keywords*:** Resistivity, Geoelectric, Schlumberger, Overburden.

1.0 Introduction

The solid earth is divided into layers due to the inhomogenous nature of its sub-surface. It is possible, however to image the sub-surface quickly through the application of various geoplysical methods including gravity, magnetic, seismic and electrical methods [1].

To determine the lithologic units that characterize the sub-surface in Nkwegu, the electrical resistivity method has been chosen. This method was selected because the geophysical instrument that can easily be accessed in the neighbourhood was the terrameter - a device used in electrical resistivity surveys for measurement of earth's resistance.

Surface electrical resistivity survey is based on the principle that the distribution of electrical potential in the ground around a current-carrying electrode depends on the electrical resistivities and distribution of the surrounding soils and rocks [2]. The usual practice in the field is to apply an electrical direct current (d.c) between two electrodes implanted in the ground and to measure the difference of potential between the two additional electrodes that do not carry current. An empirical relationship between the curent flowing through a conducting material and the voltage (potential) required to drive the current is mathematically given by V=IR where I is amount of current or charge per unit time in (amperes), V is electrical potential energy per unit charge (volts) and R is resistivity (proportionality constant in ohms) [3].

In principle, this is simply to measure the resistance of a material in this case, the earth. But resistance, R depends not only on the material of the conductor but also on the geometry of the conductor. This geometrical factor denoted by the symbol K is related to the resistivity, ρ of the material by: ρ=KxR [4].

Nkwegu is a sedimentary area, hence it is expected that its sub-surface layers will be made up of sedimentary structures. Common examples of these structures are sand, silt, clay, sandstone, limestone, shales, etc [5]. This work aims at deducing the structures or units (lithologic units) that make up the earth's interior in Nkwegu using electrical resistivity surveying. There is apparently no record of any survey done in Nkwegu with respect to sub-surface geophysical investigations. However geophysical surveys have been conducted at neighboring towns such as Afikpo (South of Nkwegu). Agha et al [6] carried out

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a seismic refraction survey at Afikpo, Nigeria with the aim of determining the elastic constants of sub-surface rocks in the area. The instrument he used was the S79 digital enhancement seismograph. From his findings, the first two layers in Afikpo had average seismic velocities of 370m/s and 1060m/s respectively. These layers were interpreted to be probably sandy clay (3.6m thick) and sand with gravel (11.8m thick). Nkwegu is located within longitdudes
7^o 29′ – 7^o 31′E and latitudes 6^o 20′ - 6^o 22′N. It has an area of about 30km^2 and is situated on the sedimentary coastal land of Nigeria at about 20km south of Abakaliki.

2.0 Materials and Method

MATERIALS: In this research work the principal instrument used is the ABEM terrameter. The instrument comprises an automatic signal averaging system (SAS 300C) in which measurements are automatically made and averaged depending on the cycle setting. It is one of the modern field instruments needed for reliable results.
The ABEM system include four steel electrodes, two plastic reels of current cables/cables for potential electrodes, four crocodile heads, two reels of already marked twines each extending up to 300m which facilitate easy
location of points for the current and potential electrodes. The global positioning system (GPS) was also used. This instrument served in measuring the longitudes and latitudes of the area of study.

METHOD: Since this work is aimed at deducing lithology, the vertical electrical sounding (VES) approach of resitivity surveying was adopted [7]. Moreover, in consideration of the topography of the study area, the Schlumberger configuration was employed with appropriate scheme of expanding the electrodes to ensure effective current peretration into the ground (Fig. 1).
While the current electrodes separations were varied, the potential electrodes spacings were relatively fixed excepting at very few occasions. The resistance R of the earth at each spread was read-off through the digital display of the terrameter and a geometric factor, K was calculated. A combination of the resistance and the geometric factor was used to calculate the bulk apparent resistivity of the measured sequence for every spread. The apparent resistivity was obtained by multiplying the geometric factor, K by the resistance, R. That is:
ρ_a = K x R
where the geometric factor, K is given by:

$$k = \frac{\pi}{4}\frac{(AB^2 - MN^2)}{MN}$$

$$\therefore \rho_a = \frac{\pi}{4}\frac{V}{I}\frac{(AB^2 - MN^2)}{MN}$$

where AB is correct electrode spacing, MN is potential electrode spacing, V/I represents the resistance, R of the earth [8](see Fig. 1).

3.0 Results and Discussions

Resistitivity data were obtained for four locations chosen within the study area. Sample data (truncated at 140m) from one of the locations and the corresponding Vertical Electrical Sounding (VES) curve generated are shown in Table 1 and Fig. 2 respectively. The data obtained include the resistance reading of the terrameter and the corresponding current electrode spacing and potential electrode spacing in addition to a computed apparent resistivity, ρa in Ωm.
The VES curve (Fig. 2) reveals five geoelectrical layers with the fifth layer having an undetermined depth. The resistivity, thickness depth and altitude of each of the layers are designated with ρ, h, d and A respectively. Average values of ρ, h, d and A were computed and shown in Table 2. The lithology of each layer was equally deduced.

Table 1: Sample resistivity field data from one of the locations in Nkwegu

Survey point	Current Electrode Spacing (m)	Potential Electrode Spacing (m)	Geometric factor, K	Resistance, R (Ω)	Apparent Resistivity (Ωm)
1	2.5	0.5	18.84	28.300	533.172
2	3.5	0.5	37.68	10.200	384.336
3	5	0.5	77.72	2.860	222.265
4	7	0.5	153.08	0.690	105.622
5	10	0.5	313.22	0.170	53.247
6	15	0.5	705.72	0.067	47.283
7	15	3.5	95.43	0.255	24.336
8	20	0.5	1255.22	0.018	22.594
9	20	3.5	173.93	0.178	30.960
10	30	3.5	398.22	0.186	74.069
11	40	3.5	712.22	0.213	151.703
12	50	3.5	1115.93	0.210	234.346
13	60	3.5	1609.36	0.079	127.140
14	60	3.5	549.50	0.410	225.295
15	70	10.0	2192.51	0.020	43.850
16	70	3.5	753.60	0.030	22.608
17	80	10.0	989.10	0.016	15.826
18	100	10.0	1554.30	0.080	124.344
19	120	10.0	2245.10	0.057	127.971
20	140	10.0	3061.50	0.036	110.214

Table 2: Mean values of apparent resistivity, thickness, depth and deduced lithology

Layer, N	Resistivity ρ_a (Ωm)	Thickness h (m)	Depth, d (m)	Lithology
1	917.64	1.3	1.3	Lateritic overburden
2	138.89	8.8	10.1	Wet clay
3	480.82	17.9	28.0	Dry shale
4	65.96	21.5	49.5	Consolidated wet shale

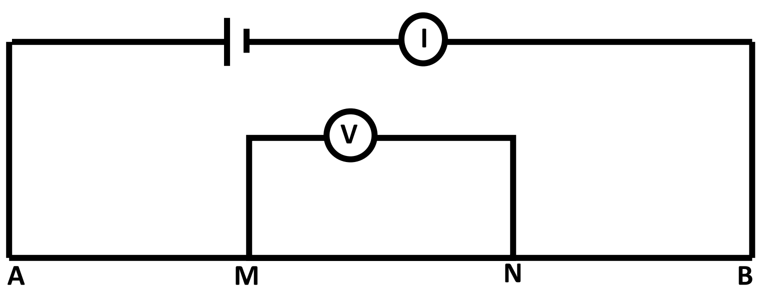

Fig 1: Schematic diagram of schlumberger array with potential (V) electrodes, M, N, inner and current (I) electrodes, A, B, outer.

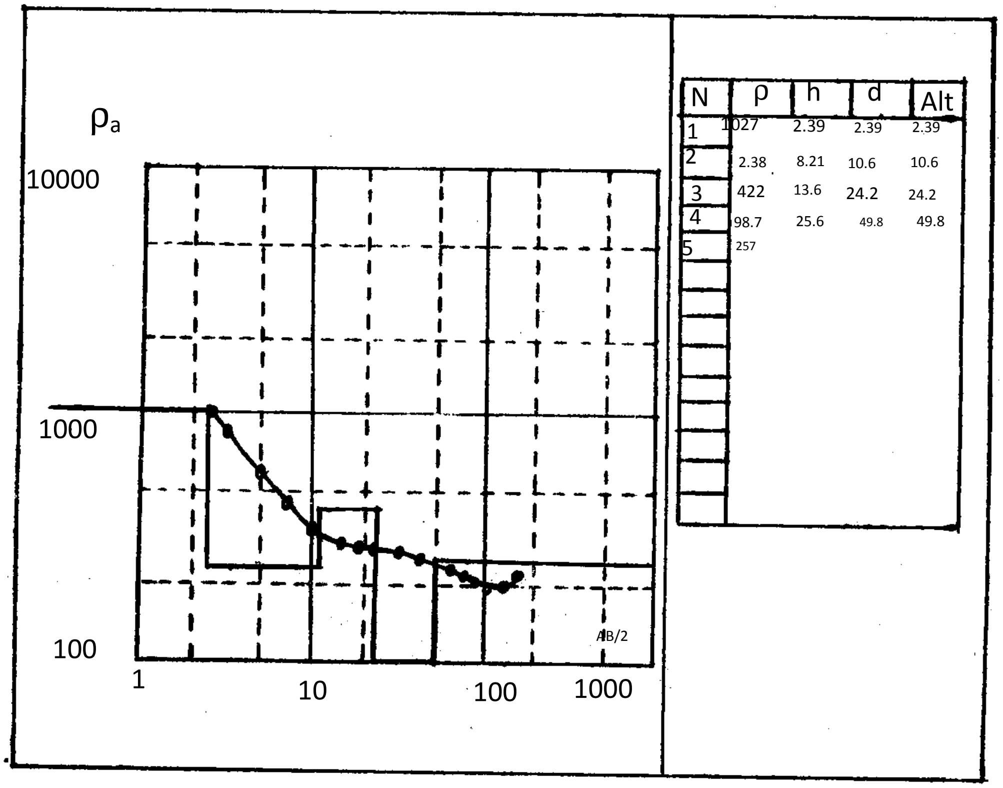

Fig. 2: Corresponding VES curve for resistivity data shown in Table 1 (truncated at 140m)

4.0 Conclusion:

In the light of the above result, we conclude that the topmost layer of Nkwegu, probably lateritic earth with thickness 1.3m is underlain by clay soil of thickness 8.8m which in turn overlies two shale beds – the upper of which is dry and the lower wet and consolidated. The mean thicknesses of the shale substrata (top and bottom) are respectively 17.9m and 27.5m.

ACKNOWLEDGMENT

The authors are grateful to Miss. Nwafor Veronica U. for typesetting the manuscript.

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