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RESISTIVITY SURVEY OF LIMESTONE DEPOSIT AT NKALAGU IN EBONYI STATE, EASTERN NIGERIA

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ABSRACT

A geophysical survey for limestone deposits was carried out at Nkalagu of Ebonyi State in eastern Nigeria covering Block B zone at Nigercem- Ezeaku shale and Nkalagu cement factory. This was successfully done by employing the electrical resistivity method to investigate the thickness and depth of limestone variation in the covered areas with the application of Schlumberger array. The data obtained from the field were analyzed by computation of the apparent resistivity and plotting the graph of half electrode spacing and the apparent resistivity. Interpretation was by employing computer assisted evaluation procedure in which depths of limestone deposits were estimated. In VES 1, the depth of limestone is about 6.4m and the thickness is about 36.8m. In VES 2, the depth of limestone is about 38.8m and the thickness is about 19.1m.
Keywords: Schlumberger array, apparent resistivity, VES.

INTRODUCTION

Limestone is a type of sedimentary rock which is very useful in our every day experience. Sedimentary rocks are in stratified layers; hence sediments and the different aspects of sedimentation are weathering, erosion, deposition and digenesis. Limestone is composed mainly of calcium carbonate ($CaCo_3$). Due to its calcium content, it is used in liming. It is also an excellent building stone because it can be carved easily and is often free stone because of its characteristics. Limestone is quarried and is used in the construction of roads, houses, e.t.c. It is the primary raw material in the manufacture of cement and this explains why most cement factories are cited where near areas with limestone deposits; NIGERCEM cement factory at Nkalagu, Okpella cement factory at Okpella. Limestone is good especially for foundations and walls where a high polish is not needed. Some factories however, use limestone to clean waste gases and water before releasing them into the environment. The Nkalagu limestone is a quaternary deposit (the youngest of the rocks of the basins). They form the bed on which the other structure of the earth lies. The resistivity of the rocks depends on its porosity, that is, more porous less resistivity and less porous more resistivity. The resistivity of rocks or minerals is defined as the resistance in Ohms between the opposite faces of a unit cube of the mineral. There are different electrical methods of geophysical survey but the one employed in this work is the introduction of artificially generated currents into the ground, which includes resistivity method using any of the configurations. The instrument used for the survey is the ABEM-TERRAMETER with the Schlumberger electrode arrangement

THEORY

Consider a completely homogeneous Iso-tropic earth layer of a uniform resistivity. From the aspect of quantitative treatment, let us consider a homogeneous layer of length L and resistance R through which a current I, is flowing. The potential difference across the ends of the resistance will be given by Ohm's law and

$\Delta V = IR$ -----------------------------1.1

The cross – sectional area A, resistivity L, resistance ℓ and the layer is specified by its length L from resistivity equation, ℓ = RA/L. Therefore, it follows that R = ℓL/A and equation 1.1 can be rewritten as

$\frac{\Delta V}{I} = \frac{\ell L}{A}$ ---1.2

Or $gradV = \ell j$ ------------------------------1.3

Where j is the current density per unit of cross-sectional area and grad V is the potential gradient.

Consider a semi-infinite conducting layer of uniform resistivity bounded by the ground surface and assume a current of strength + 1 entering at point C_1 on the ground surface (fig 1.0). This current will flow away radially from the point of entry and at any instant its distribution will be uniform over a hemispherical surface of the underground resistivity.

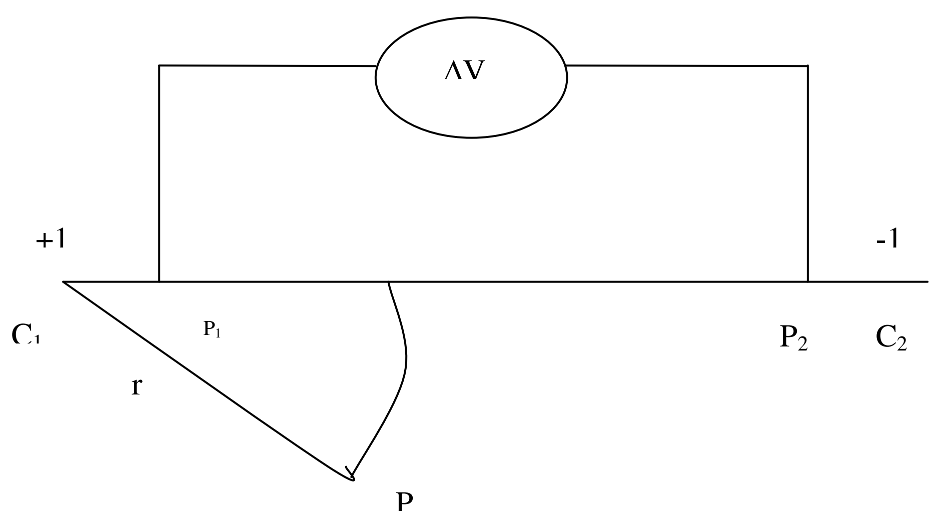

Fig. 1.0: Shows a method of calculating potential distribution due to a current source in a homogeneous medium. The current density **j**, at a distance **r**, away from the current source, would be:

$$j = \frac{I}{2\pi r^2} ------a$$
$$-\frac{dv}{dr} = \ell j -----b \quad ....1.4$$

The potential gradient associated with the Current is given in equation (1.3). Now let's substitute j in equation 1.4a into equation 1.4b. We then have that

$$\frac{-dv}{dr} = \frac{\ell I}{2\pi r^2} \text{———————————} 1.5$$

The potential at distance r in fig. 2.0 can be obtained by integrating equation (1.5)

$$-\int dv = \frac{\ell I}{2\pi}\int r^{-2} dr$$
$$-v = -\frac{\ell I}{2\pi} r^{-1}$$
$$\therefore v = \frac{\ell I}{2\pi r} ------------1.6$$

The above equation 1.6 can be said to be the basic equation, which enables the calculation of the potential distribution in a homogeneous conducting semi-infinite medium.

It is also easy to see from equation (1.6) that the potential difference between points P_1 and P_2 (fig 2.0 coursed by current + 1 at the "source" entry point C_1) is given as:

$$v = \frac{I\ell}{2\pi}\left[\frac{1}{C_1P_1}\right] - \frac{I\ell}{2\pi}\left[\frac{1}{C_1P_2}\right]$$

$$v = \frac{I\ell}{2\pi}\left[\frac{1}{C_1P_1} - \frac{1}{C_1P_2}\right] ------1.7$$

In the same manner, the potential difference between P_1 and P_2 is

$$v = \frac{I\ell}{2\pi}\left[\frac{1}{C_2P_1} - \frac{1}{C_2P_2}\right] -------1.8$$

The total potential difference between P_1 and P_2 is therefore, given by the sum of the right hand sides of equation (1.7) and (1.8) which is:

$$v = \frac{I\ell}{2\pi}\left[\frac{1}{C_1P_1} - \frac{1}{C_1P_2}\right] - \frac{I\ell}{2\pi}\left[\frac{1}{C_2P_1} - \frac{1}{C_2P_2}\right]$$

$$v = \frac{I\ell}{2\pi C_1P_1} - \frac{I\ell}{2\pi C_1P_2} - \frac{I\ell}{2\pi C_2P_1} + \frac{I\ell}{2\pi C_2P_2}$$

Collecting like terms

$$v = \frac{I\ell}{2\pi}\left[\frac{1}{C_1P_1} - \frac{1}{C1P_2} - \frac{1}{C_2P_1} + \frac{1}{C_2P_2}\right] - - - - - - - - 1.9$$

or

$$\ell = G\frac{\Delta v}{I}(Sharma\ , P.V.1976\ ) - - - - - - - - - - - 1.10$$

Where:

$$G = 2\pi\left[\frac{1}{C_1P_1} - \frac{1}{C_1P_2} - \frac{1}{C_2P_1} + \frac{1}{C_2P_2}\right]^{-1}$$

G denotes the geometric factor of an electrode configuration.
Here, the value of ℓ for a homogeneous conducting medium is independent of the positions of electrodes and is not affected when the positions of the current and potential electrodes are interchanged.

METHODOLOGY

The method applied for this research work is the vertical electrical sounding (VES) method; which is also known as electrical drilling or expanding probe. It is the use of electrical methods with depth control in which electrode spacing is increased to obtain information from greater depths at a given surface location. It is used for detecting changes in the resistivity of the earth with depth beneath the given location. The principles of VES are based on the fact that the wider the current electrode separation the deeper the current penetration. As the current reaches greater depths subsequent readings are progressively taken. ABEM-TERRAMETER was used. Current electrode spacing was between 4.0 and 400 meters. The resistivity field curves, showing the variation of apparent resistivity with half the current electrode spacing on a log. Log scale graphs were plotted for each VES measurement. The interpretation was by a computer based analysis. The Schlumberger array method is as shown below.

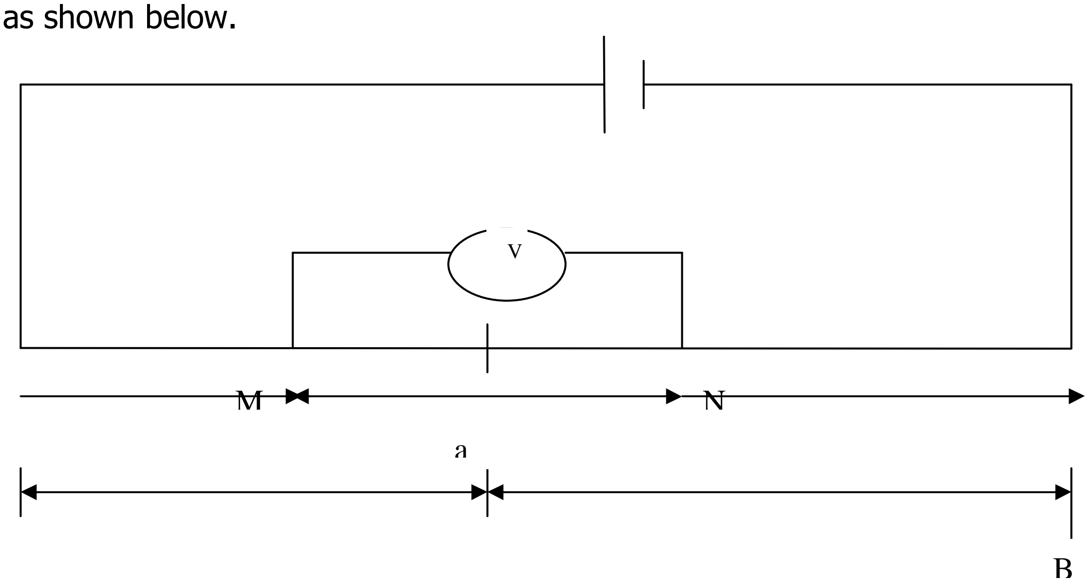

Fig 2.0 The Schlumberger array method

$\rho_a = \pi\,[r^2]\,R$

a
r = AM=NB
ρ_a = apparent resistivity
AB = current electrode spacing
MN = potential electrode spacing

RESULTS

A field survey was conducted through the vertical electrical sounding (VES). The data obtained from the measurement are represented in table 1.0 and 2.0 for VES 1 and VES 2 respectively.

TABLE 1.0. VES 1 data

AB/2 (m)	MN/2 (m)	Resistance (R) (Ω)	Apparent Resistivity(ℓ_a)(Ωm)
2	1	17.750	225.610
3	1	6.750	191.050
4	1	3.218	161.800
6	1	0.750	85.580
9	1	0.618	157.280
9	4	5.228	332.620
15	4	3.890	687.350
25	4	2.665	1308.120
40	4	1.825	2293.900
50	4	3.957	7769.910
75	20	4.787	4230.230
75	20	3.0009	2659.230
100	20	4.058	6375.110
150	20	2.039	7207.600
200	20	1.150	7226.600

TABLE 2.0. VES 2 data

AB/2 (m)	MN/2 (m)	Resistance (R) (Ω)	Apparent Resistivity(ℓ_a)(Ωm)
2	1	656.165	8246.680
3	1	241.080	6817.260
4	1	121.653	6115.740
6	1	59.433	6722.620
9	1	26.400	6718.850
9	4	115.942	7376.850
15	4	20.368	3599.850
25	4	7.332	3599.460
40	4	1.177	1479.120
50	4	0.505	991.940
75	20	0.125	551.840
75	20	0.484	427.860
100	20	0.831	1306.270
150	20	1.005	3553.770
200	20	1.117	7019.590

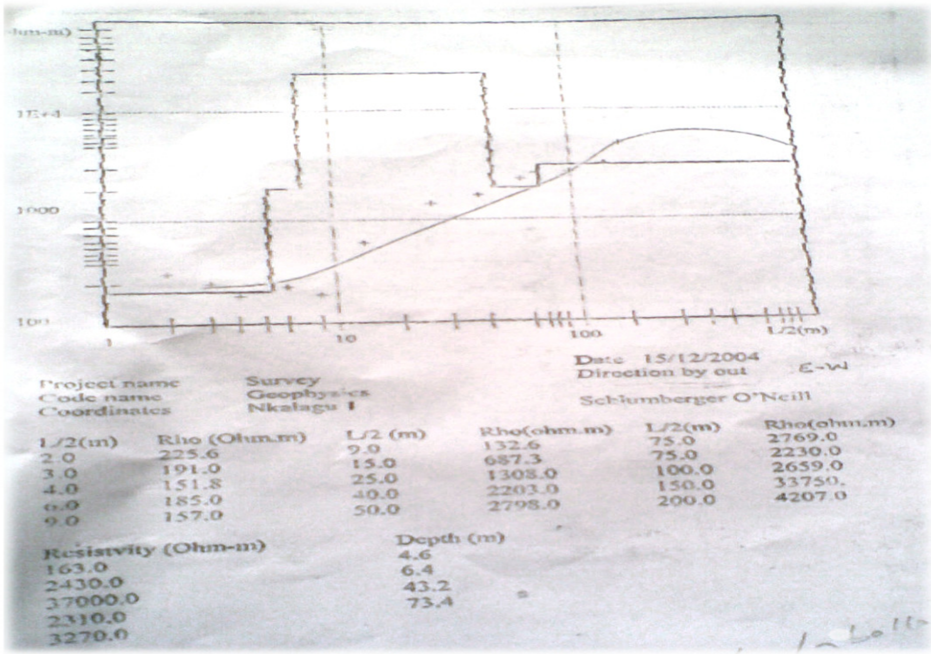

Figure 3.0: Graph of VES 1

Geoelectric Sections of VES 1

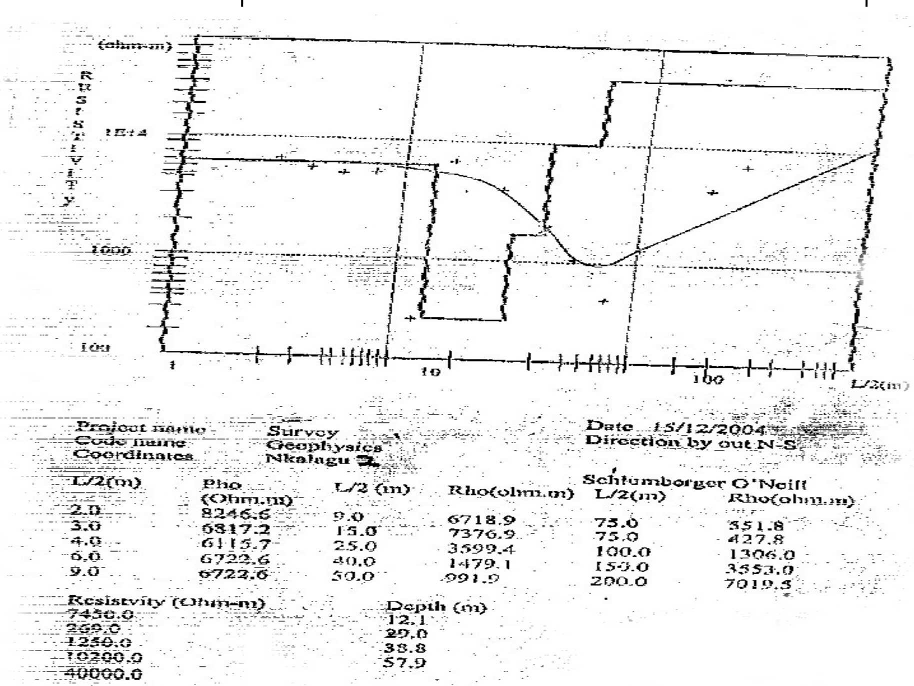

Figure 4.0: Graph of VES 2

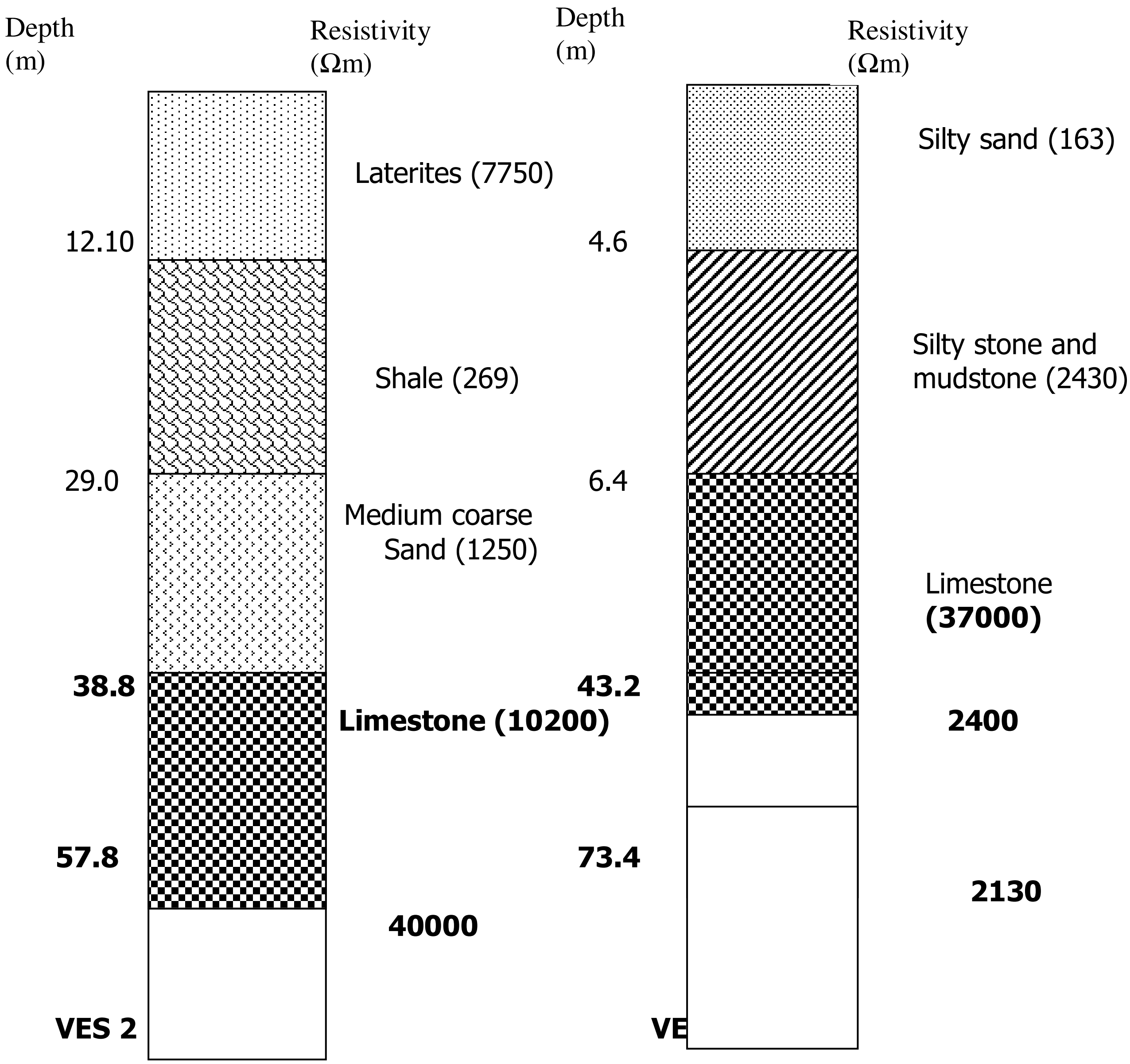

Figure 5.0: Geoelectric Section of VES 1 and 2

RESULT ANALYSIS

The current electrode spread for both VES 1 and VES 2 was 400m by 200m on either side of the measuring instrument. From the computer analysis, the survey also interpreted five stratigraphic units. From VES 1, the first layer is about 4.6m thick consisting of silty sand with apparent resistivity of 163.0Ωm. the second layer has a depth of about 4.6m – 6.4m consisting mainly of silt stone and a mudstone with apparent resistivity of 2430 Ωm. the third layer has a depth of 36.8m with a resistivity of 3700 Ωm. this is the zone of interest containing limestone. Beyond this range downwards is characterized by a mixture of relatively low and high resistivity which could be a layer of rock, siltstone or other parent material. From VES 2, the first layer is about 12.1m thick containing laterite and has apparent resistivity of about 7450 Ωm. the second layer has a depth of about 16.9m, contains shale and has a low resistivity of about 269.0 Ωm. the third layer has a thickness of about 9.8m and is made up of medium coarse sand of relative high resistivity of 1250Ωm. The fourth layer lies between 38.8-57.9m and is made up of limestone with a higher resistivity of 10,200Ωm. The underlying fifth layer has a depth of 57.9m, a very high resistivity of about 40,000Ωm and downward is the area of basement rock. The thickness of limestone is about 19.1m. Large resistivity represents limestone zone.

CONCLUSION

From the field work, two profiles were made; analyzed, interpreted and apparent resistivities were also obtained. From the two profiles, VES 1 and VES 2, analyses shows that there is no clear distinction in the resistivity ranges corresponding to the different formations, but if a layer exhibits a high resistivity one can deduce that the conductivity of the layer is low. That is;

$$C = \frac{1}{\ell_a}$$

Where, C = Conductivity and
ℓ_a = apparent resistivity

Hence we concluded that the composition is that of dry stone, igneous rock and sedimentary or metamorphic rocks. A medium range resistivity suggests that the layer is composed of porous sand and water bearing layers. Low resistivity on the other hand suggests the presence of clay and shale and then fine grained formations. For the two profiles, the depth, thickness and their corresponding apparent resistivity, are summarized below;

Table3.0. Summary of VES results

Profile	Depth of limestone(m)	Thickness(m)	Resistivity(Ωm)
VES 1	6.4	36.8	37,000
VES 2	38.8	19.0	10,200

The site for VES 1 with a depth of 6.4, thickness of 36.8m and with a high apparent resistivity of 37000 Ωm has more limestone, than the site for VES 2 with a depth of 38.8m, 19.10m thick and with a low resistivity of 10,200 Ωm. Therefore, there is abundance of limestone at Nkalagu and the depth, thickness and resistivity of limestone deposit in the zone varies from station to station, hence, the location of a cement factory at Nkalagu.

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