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Some Results of Geoelectrical Sounding for Aquifer Determination In Northern Parts of Delta State – Nigeria

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Abstract

A geoelectrical resistivity exploration approach within the poorly exposed basement complex terrain of Northern parts of Delta State has been carried out. The aim of the survey was to explore the ground water potential of the areas and ascertain the structures that are needed for the occurrence of ground water. Three (3) vertical electrical sounding located at Agbor, Issele-Mkpitime and Ogwashi-Uku were conducted using the Schlumberger electrode configuration while the true depths and resistivity values were also determined by curve matching and iterative processing techniques. Five geoelectrical layers charactrerized Agbor VES 2 sounding and it comprises topsoil/laterite, sand, sandy clay, sandstone coarse and sand. Similarly, five layers also characterized Issele-Mkipitime VES 3 and the probable rock formation ranges from topsoil/laterite to sand (aquiferous) while four geoelectric layers characterized the Ugwashi-Uku VES 5 sounding comprising topsoil/laterite, wet clay, shale and coarse sand with water.

1.0 Introduction

This paper describes the geo-electric investigations undertaken in the northern parts of delta state with the aim of exploring ground water potential of the areas. Ground water is very important resource and it also widely used as a source for drinking supply and irrigation in food production [12]. Naturally, about 53% of all population relies on ground water as a source of drinking water. It is known to occur more widely than surface water. But, unfortunately, ground water availability is limited by so many factors hence the urgent need for a thorough geophysical survey to determine amongst others the suitable ground point for borehole construction and determination of the hydrostratigraphic characteristics of the subsurface layers.

Geophysical prospecting methods generally involve either direct or indirect use of physical parameters to study the part of the earth that is hidden from our direct views by measuring their physical quantity at the surface. The choice of any method therefore depends on the known and or anticipated physical properties of the target, details of instruments required, logistics, equipment and the purpose for which the survey is intended [7]. While some geophysical methods are ideal for large anomalies only, others are most appropriate for small anomalies.

The superiority of the geoelectric method over others in the groundwater research is based on its ability to furnish information on the subsurface geology which is unobtainable by other methods in the groundwater studies. The resistivity techniques with Schlumberger array has been successfully utilized in assessing water supply potential in boundaries and in the assessment of the ground water resources potentials. It has greater penetration than the Wenner because Wenner configuration discriminates between resistivities of different geoelectric lataral layers while the Schlumberger configuration is used for the depth sounding [2, 4, 5, 6, and 11]. There is therefore urgent need to have a reliable water supply to the growing northern parts of the state due to the erratic nature of the public water supplies in the country.

2.0 LOCAL GEOLOGY AND HYDROGEOLOGY 0F THE STUDY AREAS

Agbor, Issele-Mkpitime and Ogwashi-Uku are towns located in Northern parts of Delta State. They are located within the Asaba-Ogwashi-Uku formations and Osse-Owena Basin resectively which is highly characterized by thick lateritic overburden, clay/silts, sand stones and lignite. The towns are highly consolidated because of the undulating nature in surface plane within latitude $06^0 15.245^1$ and longitude $007^0 123.123^1$ (Agbor), and latitude $N06^0 20.625$ and longitude $E006^0 23.0740$. The rocks are essentially pegmatite and migmatites and are found in association with gneisses and older granites.

3.0 Theory and Method of Study

When electrical current is passed into the ground by pair of electrodes called the current electrodes, their potential drop is measured through another pair of electrodes called the potential electrodes. The principle of operation depends on the fact

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that any subsurface variation in conductivity utters the form of current flow within the earth and thus in turn affect the distribution of electric potential. Thus it is possible to have information about the subsurface formations from the potential measurement made at the surface.

The resistivity of the earth is strongly influenced by both the physical and chemical properties of the earth materials. These properties include composition, porosity, moisture content, degree of compaction, recrystalization etc. the simplest approach in geophysical theoretical formulation is to assume a completely homogeneous isotopic earth. Consider a continuous current (I) flowing in an isotropic homogeneous medium from a single source point in the earth's surface [10]. Let the cross sectional area be δA. Then the current (I) passing through δA is given by the equation:

$$I = j.\ \delta A \tag{3.1}$$

Where j current density in ampers/square metre. Recall from Ohm's law,

$$J = \frac{E}{\rho} \tag{3.2}$$

Where

E = electric field and

ρ = resistivity of the medium

But E = $-\nabla V$

Therefore

$$j = -\frac{I}{\rho}\nabla V \tag{3.3}$$

If the charge is conserved within the volume enclosed by a surface A, then

$$\int_A J.dA = 0 \tag{3.4}$$

Applying Gauss's law on equation 3.4 in terms of volume we have that

$$\int_V \nabla.J.dV = 0 \tag{3.5}$$

Now if V is very small, then

$$\nabla.J = 0 \tag{3.6}$$

Taking the divergence of equation (3.4) we have

$$\nabla.J = -\nabla\nabla\left(\frac{I}{\rho}\right)V = 0 \tag{3.7}$$

Hence

$$\nabla\left(\frac{I}{\rho}\right).\nabla V + \frac{I}{\rho}\nabla^2 V = 0 \tag{3.8}$$

Assuming ρ is constant throughout, then the term

$\nabla\left(\frac{I}{\rho}\right).\nabla.V$ will vanish so that equation (3.8) reduces to

$$\nabla^2 V = 0 \tag{3.9}$$

In spherical coordinates, the laplace's equation above is expressed as

$$\nabla^2 V = \frac{\delta^2 V}{\delta r^2} + \frac{2\delta V}{r\delta r} \tag{3.10}$$

Now the potential at P_1 due to a point source C_1 is a function of r where r is the distance. Multiplying equation (3.10) by r^2 we have

$$r^2\nabla^2 V = \frac{r^2\delta^2 V}{\delta r^2} + \frac{2r\delta V}{\delta r} \tag{3.11}$$

Integrating equation (3.11)we have

$$\frac{\delta V}{\delta r} = \frac{A}{r^2} \tag{3.12}$$

Integrating equation (3.12) further we have

$$V = \frac{A}{r} + B \qquad (3.13)$$

Where A and B are constant. At a greater distance from the current source ($r \to \infty$) where the potential (V) is zero, B becomes zero. Since the current flows radially outward, then the current passing a spherical surface of a buried point source of current in homogenous ground is given by

$$I = 4\pi r^2 j \qquad (3.14)$$

However, the current crossing a hemispherical surface is given as

$$I = 2\pi r^2 j \qquad (3.15)$$

Substituting for J in equation (3.15) using equation (3.3) we have

$$I = \frac{2\pi r^2 \nabla V}{\rho} \qquad (3.16)$$

Recall from equation (3.12) that

$$\frac{\delta V}{\delta r} = \frac{A}{r^2}$$

Therefore

$$I = \frac{2\pi A}{\rho} \qquad (3.17)$$

Cross multiplying we have

$$I\rho = 2\pi A$$

$$A = \frac{I\rho}{2\pi} \qquad (3.18)$$

Substituting equation (3.18) into equation (3.13) and setting B to zero we have

$$V = \frac{I\rho}{2\pi r} \qquad (3.19)$$

This is the potential equation for a two electrode array (one current and one potential). In practice, four electrodes (2 current and 2 potential electrodes) are used in most electrical survey.

If we consider a typical electrode configuration the potential difference between M and N for example can be obtained by considering the effect of C_1 and C_2 at the potential points. The potential at point c is given by

$$V_c = \frac{I\rho}{2\pi}\left[\frac{1}{r_1} - \frac{1}{r_2}\right] \qquad (3.20)$$

Similarly the potential at point d is given by

$$V_d = \frac{I\rho}{2\pi}\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \qquad (3.21)$$

The potential difference between c and d is given

$$\Delta V = \frac{I\rho}{2\pi}\left[\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{R_1} \div \frac{1}{R_2}\right] \qquad (3.22)$$

From equation (3.22), the resistivity can be computed as

$$\rho = 2\pi \frac{\Delta V}{I}\left[\frac{1}{\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{R_1} \div \frac{1}{R_2}}\right] \qquad (3.23)$$

or ρ = G.R

where R = $\frac{\Delta V}{I}$ and

$$G = \left[\frac{2\pi}{\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{R_1} \div \frac{1}{R_2}} \right] \qquad (3.24)$$

G in equation (3.24) is refered to as the geometric factor whose value depends on the electrode configurations being considered during field/laboratory measurements. Based on the geology and the general knowledge of the study area, the schlumberger electrode configuration was employed for the vertical electrical sounding profile. Schlumberger array was so chosen because of the fact for a given electrode separation, current penetrates deeper so that it is more economical. In terms of manpower, one person can also operate the potential electrode and above all, it is less sensitive to lateral inhomogenities as well as stray current [1].
Various measurements were taken conveniently at three different stations Agbor VES 2, Issele-Mkpitime VES 3 and while the other in Ogwashi-Uku VES 5. The Schlumberger electrode configuration was used to determine the static water levels and the effect of weathering bedrock topography. On the whole, sixty five (65) vertical soundings were carried out in both locations (Agbor 18, Issele-Mkpitime 24 and Ogwashi-Uku 23) while the ABEM Terrameter SAS 1000 was utilized in data gathering. The maximum current electrodes distance was 1000m for the 3 locations while resistivity meter reading in the form of resistance values were reduced to apparent resistivity.
Interpretation of resistivity results was done by curve matching which involves the comparison of curve obtained from the field data with the standard characteristic curve called **MASTER CURVE.** Theoretically, calculated types of curve have been prepared by various workers showing apparent resistivity against half the current electrode spacing for a variety of 2,3 or 4 layered models with different resistivity value for each layer. To match a field curve obtained from the field, it is only necessary to slide the field curve around on the master curve until the field curve coincides more or less with one of the master curves. This gives information about the thickness and apparent resistivity of the various layers.

4.0 Results

The measurement analysis for quantitative interpretation of resistivity results is most highly developed for the depth probing techniques (VES). The readings which were obtained from the resistivity sounding survey represents a data set which can be used after all necessary evaluation to obtain some knowledge about the geoelectric stratification of the subsurface and contribute information about the hydrogeology of the areas under study.

Table 1: Summary of VES 2 results

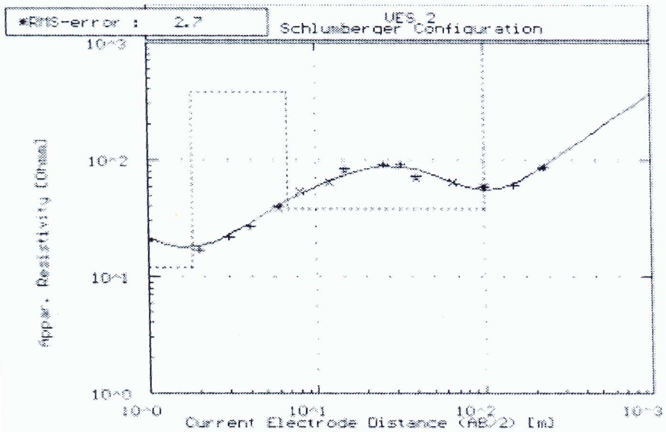
Layers	Resistivity. (m)	Thickness (m)	Cum. Thickness (m)	Lithology
1	36.0	0.4	0.4	Wet top soil/laterite
2	12.0	1.4	1.8	Dry sand
3	384	4.9	6.7	Sandy clay
4	38	93.	99.7	Sand stone
5	10000	Infinity	Infinity	Sand

Table 2: Summary of VES 3 results

Layers	Resistivity. (m)	Thickness (m)	Cum. Thickness (m)	Lithology
1	102.0	0.8	0.8	Top soil/laterite
2	88.0	2.6	3.4	Laterite sand
3	170.0	14.7	18.1	Dry sand zone
4	34.0	62.5	80.6	Sand stone
5	10000	infinity39	infinity	Sand

Table 3: Summary of VES 5 results

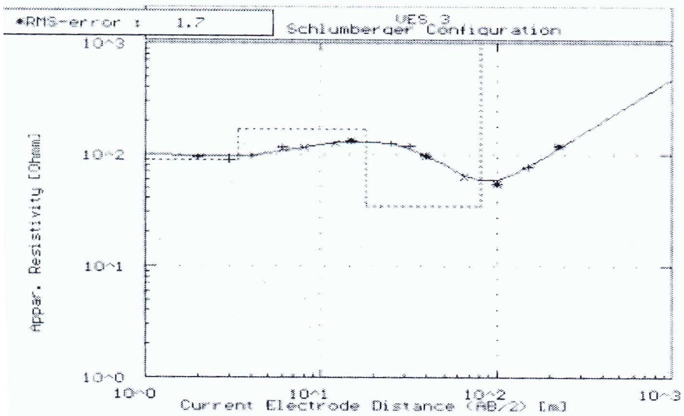
Layers	Resistivity. (m)	Thickness (m)	Cum. Thickness (m)	Lithology
1	82.0	1.8	1.8	Top soil/laterite
2	286	9.6	11.4	Laterite
3	34	59.6	71.0	Sand stone
4	10,000	Infinity	Infinity	Sand



No	Res	Thick	Depth
1	36.0	0.4	0.4
2	12.0	1.4	1.8
3	384.0	4.9	6.7
4	38.0	93.0	99.7
5	10000.0	-.-	-.-

* RMS on smoothed data

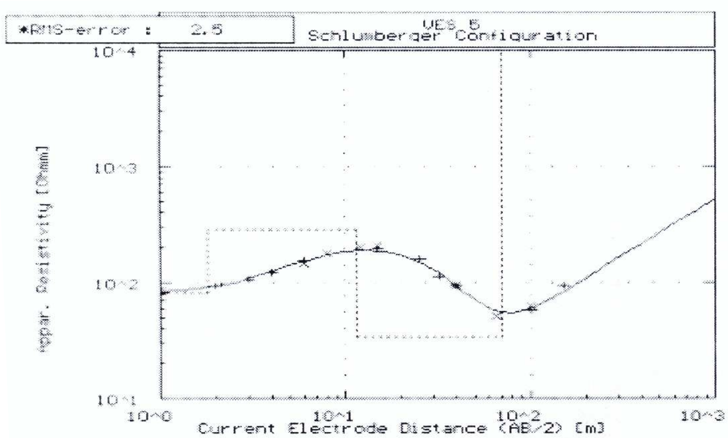
Fig. 1: Field and theoretical curve for VES 2
Location: Agbor



No	Res	Thick	Depth
1	102.0	0.8	0.8
2	88.0	2.6	3.4
3	170.0	14.7	18.1
4	34.0	62.5	80.6
5	10000.0	-.-	-.-

* RMS on smoothed data

Fig. 2: Field and theoretical curve for VES 3
Location: Issele-Mkpitime



No	Res	Thick	Depth
1	82.0	1.8	1.8
2	286.0	9.6	11.4
3	34.0	59.6	71.0
4	10000.0	-.-	-.-

* RMS on smoothed data

Fig. 3: Field and theoretical curve for VES 5
Location: Ugwashi-Uku

5.0 Discussion of Results

For the three locations, the curve shape is is approximately HA type ie Bowl and Ascending type. 65 vertical electrical soundings were conducted in all. Curve matching was used to determine both the true resistivity and depth values. The curve matching was done by comparing the standard curve called the master curves with the field curve obtained from the field by sliding the field curve around on the master curve until the field curve coincides more or less with the master curves. This gives information about the thickness and apparent resistivity of the various layers. Similarly the interpretation was done in the form of geoeletric layers which involves the merging of layers into geological layers for the purpose of geological interpretation [3, 8, 9, and 13].

Five geoelectrical layers charactrerized Agbor VES 2 sounding and it comprises topsoil/laterite, sand, sandy clay, sandstone coarse and sand stone, another five layers for Issele-Mkipitime and the probable rock formation ranges from topsoil/laterite to sand (aquiferous) while four geoelectric layers characterized the Ugwashi-Uku VES 5 sounding comprising topsoil/laterite, wet clay, shale and coarse sand with water.

6.0 Conclusion

Vertical electrical sounding with schlumberger electrode configuration was used to investigate the northern sections of Agbor, Issele-Mkpitime and Ogwashi-Uku. The results obtained shows that geological and geoelectrical sections correlate well and that at a depth of 99.7 m probed in Agbor VES 2, 80.6 m probed in Issele-Mkpitime VES 3 and 71.0 m probed in Ogwashi-Uku VES 5, rich aquifer can be found.

7.0 Recommendation for Further Study

Although appreciable quantity of groundwater may be encountered through boreholes, other alternative sources are still desirable to augment the available groundwater especially in view of the continued increase in the population. This is because if there is a lack of readily recharge source for groundwater aquifer in the immediate vicinity, the yield of the borehole could diminish with time.

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