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Ground water exploration and exploitation in parts of Abakaliki, Nigeria, using direct current resistivity method

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Abstract

A geophysical exploration has been carried out with the objective of determining the depth to which ground water can be located and exploited in different parts of Abakaliki, Nigeria. Abakaliki is situated within latitudes 6^0 17′ - $6^0$21′N and longitudes 8^0 05′ - 8^0 10′E. It has an area of about 71km ^{2}. The geophysical method used was the direct current resistivity method. The equipment utilized for data collection include ABEM terrameter (SAS 300C), four electrodes, hammer, four reels of wires, connecting cords, measuring tapes and global positioning system. The field layout used was schlumberger electrode array. The survey was carried out in three selected parts of Abakaliki which include the Metropolis, Kpiri Kpiri area and Nkaliki area. Vertical electrode sounding (VES) was also adopted to delineate the thickness of the underlying layers of the soil and the embodied rocks. From the result of the study, five geoelectrical layers were delineated in the Metropolis out of which the fourth layer from the earth's surface with thickness of 30.8m and resistivity 176.17Ωm and which was interpreted as fissile shale bed had the best prospect for underground water development. The depth to this zone from the earth's surface was 42.6m. According to the result, the fourth and fifth geoelectrical layers of Kpiri Kpiri area which were interpreted as wet splintery shale and wet pyritized silty shale respectively both have the best prospect for underground water development in the area. The average depth to this zone of saturation was 46.0m and the average resistivity was 166.0Ωm.

At Nkaliki area, out of the five layers delineated by the current in the survey, the fourth layer which was interpreted as well compacted but fissile shale bed has the best prospect for underground water development. The resistivity and thickness of this layer were 489.41Ωm and 19.03m respectively. The depth to this layer from the surface was 35.28m. The results show that there is very high probability of success for exploitation of underground water from the area.

Keywords: Resistivity, Geoelectric, Schlumberger, Overburden

1.0 Introduction

In the universe, people and life in general cannot exist without good water. Groundwater, that is subsurface water contained in spaces within bedrocks[1], makes up 97% of the world's fresh water available for human use. It is found almost everywhere.

Since the inception of scientific research however, several methods of underground water exploration have been discovered such as electrical method, gravity method, magnetic method and seismic method. Of all these, the electrical resistivity method stands out as the most trusted for ground water exploration. The resistivity method can provide information on subsurface geology which might be unattainable by other geophysical methods. This method has extensively been used by researchers. Agha and Nnabo[2] carried out a direct current resisitivity survey at Nkwegu 20 km south of Abakaliki using the ABEM terrameter (SAS 300C). The aim was to determine the lithology of the area. Their result showed that the average resistivity and thickness of the earth layers in the area 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, 65.96Ωm and 21.5m for the fourth layer respectively. The result indicates that the first four layers of Nkwegu were made up of lateritic overburden, wet ferruginised clay, fissile dry shale and consolidated wet shale accordingly.

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2.0 Location and Geology of Study Area

The study area is situated within longitudes $8^0 05'$ - $8^0 10'$E and latitudes $6^0 17'$- $6^0 21'$N covering a total area of about $71km^2$(Fig. 1).

The area contains two major geological formations. From the east to west and in terms of age and sequence of exposure, the formations are the Asu river group of the Albian Age (lower cretaceous) made up of shales, sandstones and siltstones which occurred as a result of the folding and uplift of the Abakaliki-Benue fold belt in the santonian stage which produced the Anambra basin. This basin was predominantly filled with clastic sediments constituting several distinct lithostratigraphic units deposited from upper Campanian to recent time. The lithostragrphic units have a thickness of 2500m.

The study area is also characterized by pysoclastics, dolerite, dark gray shale and other magmatic formations. The formation is poorly fossilized. The Asu River group was folded during the tectonism that occurred in the early part of the Turonian stage. This activity gave rise to the Abakaliki anticlinorium with sediments that are gently warped along widely spaced areas which trend in N-E direction and pitch at low angle to the S-W. This brought about fissures, cracks and joints within the consolidated sediments. Probably following these major tectonic activities were igneous activities and a consequent lead-zinc mineralization of the adjourning rocks. Tectonism in the area seem to have continued although up till the Cenozoic Era when some igneous intrusions were emplaced[3].

3.0 Materials and Method

Materials: The resistivity survey equipment is designed to measure the resistance of layers of the earth to a very high accuracy. The resistance measurements obtained from the field and the spacing of the electrodes are used to calculate the apparent resistivity, $\rho_{a.}$ The materials used in this work include the ABEM terrameter (SAS 300C) for measuring potential difference when direct current is introduced into the ground; two potential and two current electrodes; power source (battery) and cables; connecting cords, global positioning system (GPS), knife, tape and hammer.

Method of Survey: In electrical resistivity survey, different types of electrode configurations have been designed[4]. These are Wenner, Schlumberger, three point system, double dipole system, etc. But as a result of the wide aid of interpretation and the purpose of this survey, the schlumberger array is chosen for this work and vertical electrical sounding (VES) was done.

The array consists of four electrodes mounted in a straight line out of which two are current electrodes, A,B and two are potential electrodes, M,N. see Fig.2. The current electrodes, A and B act as source and sink respectively.

At the detection electrode M, the potential due to the source A is given by:

$$A_M = \frac{+\rho l}{2\pi AM} \text{.............................}(1)$$

while the potential due to the sink B is:

$$B_M = \frac{-\rho l}{2\pi MB} \text{..........................}(2)$$

giving the combined potential at M as

$$V_M = \frac{\rho l}{2\pi}\left[\frac{1}{AM} - \frac{1}{MB}\right] \text{.........................}(3)$$

At the detection electrode, N, the potential due to the source, A is given by:

$$A_N = \frac{+\rho l}{2\pi AN} \text{..........................}(4)$$

while the potential due to sink at N is given by:

$$B_N = \frac{-\rho l}{2\pi NB} \text{.........................}(5)$$

giving the combined potential at N as:

$$V_N = \frac{\rho l}{2\pi}\left[\frac{1}{AN} - \frac{1}{NB}\right] \text{........................}(6)$$

Thus, potential difference measured between M and N is

$$\Delta V = V_{MN} = \frac{\rho l}{2\pi}\left[\left(\frac{1}{AM} - \frac{1}{MB}\right) - \left(\frac{1}{AN} - \frac{1}{NB}\right)\right] \text{..........................}(7)$$

Hence, the ground apparent resistivity can be expanded as

$$\rho_a = 2\pi \frac{\Delta V}{I} \overline{\left[\left(\frac{1}{AM} - \frac{1}{MB} \right) - \left(\frac{1}{AN} - \frac{1}{NB} \right) \right]}^{1} \text{........................(8)}$$

That is,

$$\rho_a = 2\pi \frac{\Delta V}{I} G(\mathrm{r}) \text{.........................(9)}$$

where $\frac{\Delta V}{I}$ is electrical impedance and G(r) is geometrical factor.

Since Schlumbeger array was used in this survey, the computation of the apparent resistivity (ρ_a) was made by multiplying the geometric factor by the resistance. That is, ρ_a = K x R

With the GPS, the azimuths of the selected parts of Abakaliki were determined. The azimuths were N 68^0 E for the Metropolis, 042^0 NW for Kpiri kpiri and N 24^0 W for Nkaliki area.

The apparent resistivities were then plotted against AB/2 on a log-log plot. Computer approach was used.

4.0 Results and Interpretation

Results: Figs.3 to 5 show the VES graphs of the resistivity data obtained in the three selected areas of Abakaliki

Interpretation: In view of the fact that the subsurface resistivity does not change so rapidly with depth, the resistivity values and depths which are fairly within very close range of values were grouped together as one layer[5] resulting in a maximum of five layers for the metropolis, Kpiri Kpiri and also for Nkaliki.

The grouping of these layers involved taking the average of resistivity values for a given depth range presumed to have fairly close range of resistivities[6]. After a careful interpretation of the log-log curves and the equivalence plots from the computer software Ip2m version 2.1, tables were obtained which present the deduced results in the form of stratigraphic units alongside their resistivity and thickness values.

5.0 Conclusion and Recommendation

The customary geometric layer and general hydrogeological features of all the selected areas show a strong indication that opinions regarding the ground water exploitation from there would best be guided by the foregoing.

With due consideration to the geology/hydrogeology of Abakaliki, the overriding inference is that there is a very high probability of success for exploitation of underground water from the area. Hence the following conclusions are drawn.

For the Metropolis, three layers in the area seem to be wet, including the second, the fourth and fifth layers. It is very likely that the wetness in the second layer, which is diagnosed as clay stone layer, might be as a result of the rainy season. Although the fifth layer, which is inferred to be a mineralized mud stone layer, seems also to be saturated with water; its water might be too rich in dissolving mineral ions thus rendering this layer unattractive. On the whole, the fourth geoelectric layer, which is diagnosed to be fissile shale seems to hold the best prospect for underground water development in the area. The geology of the area suggests that this zone is fractured and is wet with lower dissolved mineral ions than the fifth layer. It is hereby recommended that the borehole for the purposes of underground water development in the area, should be drilled to a maximum depth of 45.6m (149.60 ft) ± 3m (10 ft).

For Kpiri Kpiri area, the fourth and fifth geoelectric layers, jointly interpreted as wet splintery shale with clay bands have the best prospect for underground water development in the area. Hence, it is recommended that the best portion of the stratigraphic sequence for the purposes of underground water exploitation is
between 36.7m (120.4 ft) ± 3m (10 ft) to 55.3m (181.43 ft) ± 3m(10 ft).

For Nkaliki area, the fourth geoelectric layer which is interpreted as well compacted but fissile shale bed (fractured and wet) has the best prospect for underground water development.Thus for exploitation, the drilling should be to a maximum depth of 38.28m (125.57 ft) ± 3m(10 ft).

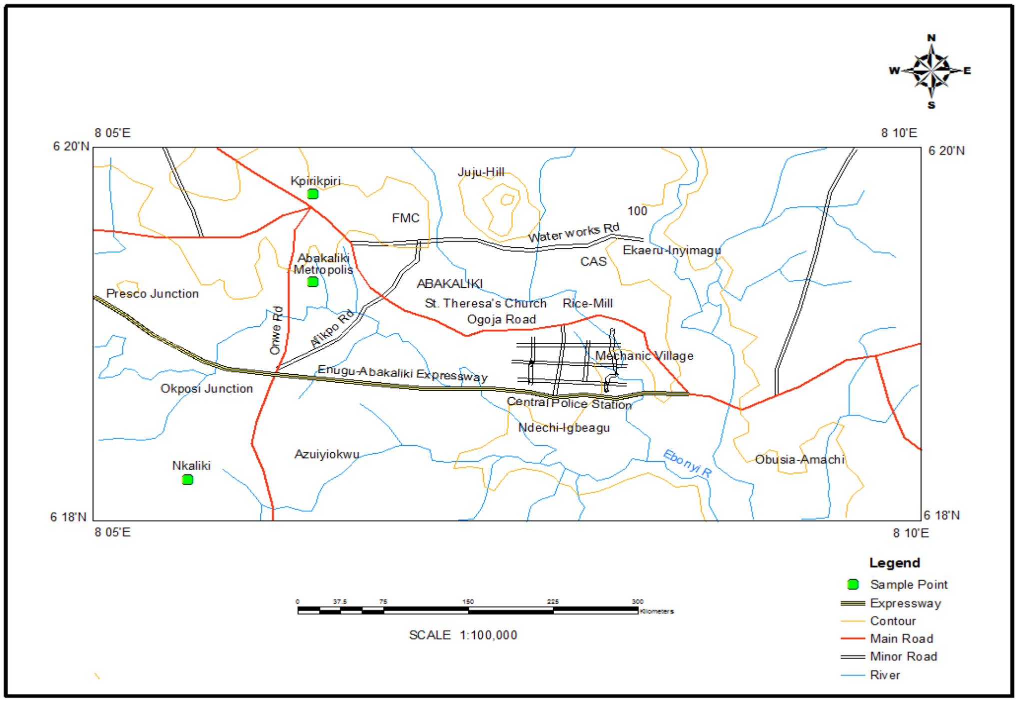

Fig. 1: Location Map of study area

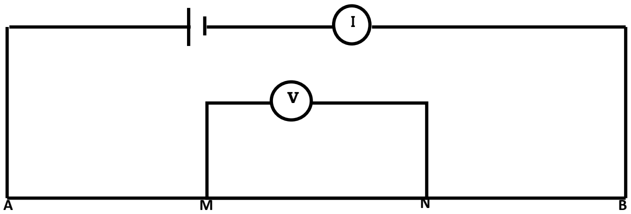

Fig.2: Schlumberger configuration

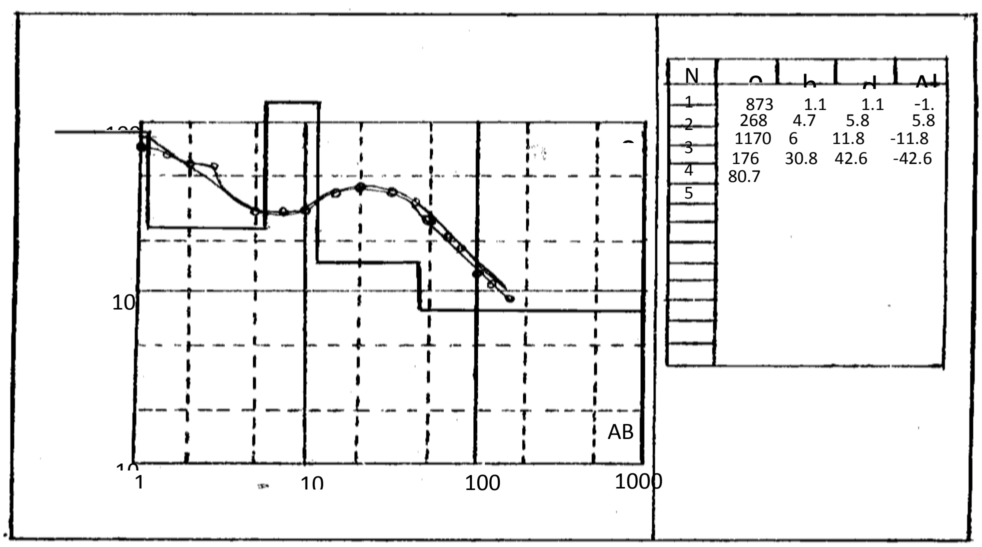

Fig.3: VES graph of resistivity data obtained at Abakaliki Metropolis

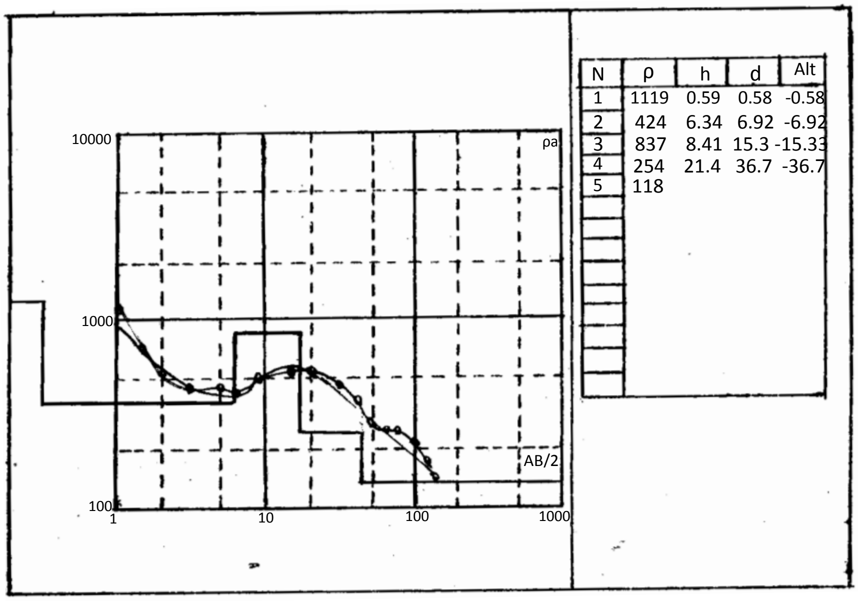

Fig. 4: VES graph of resistivity data obtained at Kpiri Kpiri area

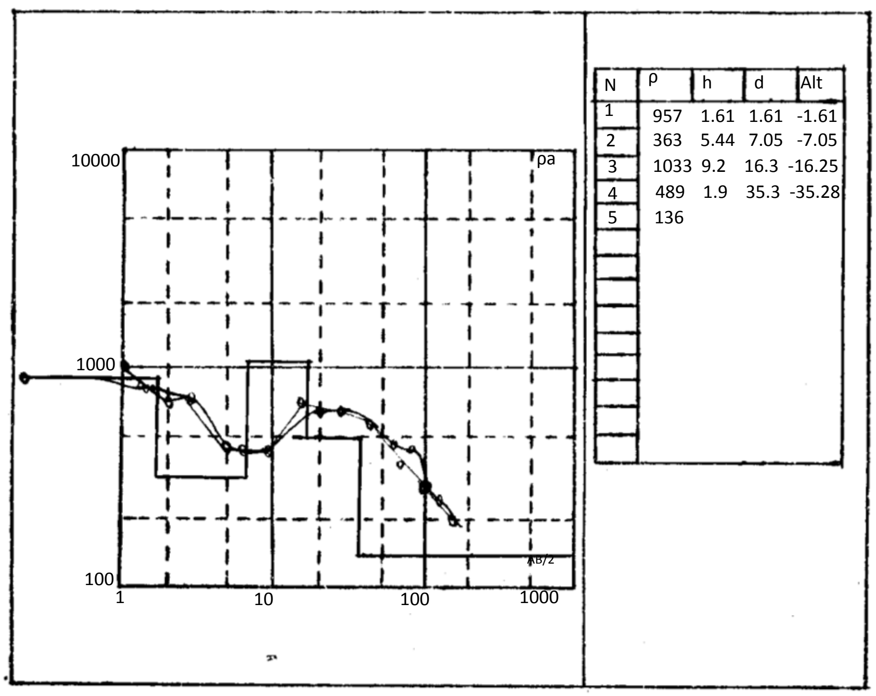

Fig.5 VES graph of resistivity data obtained at Nkaliki

Table 1. Interpretation of result from the Metropolis

LAYER	DEPTH (m)	THICKNESS (m)	RESISTIVITY ρa(Ωm)	LITHOLOGY
1	1.1	1.1	872.94	Lateritic overburden earth
2	5.8	4.7	268.34	Ferruginized clay concretions (probably wet)
3	11.8	6.0	1169.84	Siltstone bed (probably dry)
4	42.6	30.8	176.17	Well compacted but fissile shale bed (probably fractured and wet)
5	Base not reached	80.67		Well consolidated and mineralized mudstone

Table 2. Interpretation of result from Kpiri Kpiri

LAYER	DEPTH (m)	THICKNESS (m)	RESISTIVITY ρa (Ωm)	LITHOLOGY
1	0.58	0.58	1118.57	Lateritic overburden (including top soil)
2	6.92	6.34	424.49	Ferruginzed and highly compact stone (dry)
3	15.3	8.41	836.68	Fissile shale (well compacted and dry)
4	36.7	21.4	254.17	Splintery shale with clay bands (saturated)
5	Based not reached	118.41		Pyritized silty shale (wet)

Table 3. Interpretation of result from Nkaliki area

LAYER	DEPTH (m)	THICKNESS (m)	RESISTIVITY ρa (Ωm)	LITHOLOGY
1	1.61	1.61	956.68	Loose but lateritic over burden
2	7.05	5.44	363.49	Ferruginized clay concretions (probably wet)
3	16.25	9.20	1032.65	Limestone bed (probably dry)
4	35.28	19.03	489.41	Well compacted but fissile shale bed (probably fractured and wet)
5	Base not reached		136.17	Compact mineralized mudstone (probably wet)

6.0 References

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