Geological and Electrical Resistivity Sounding of Olokonla Area in North-Central Nigeria

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ABSTRACT: Geological mapping and Electrical resistivity sounding were carried out in Olokonla area in Moro Local Government of Kwara State in order to determine the apparent resistivities of the subsurface lithologies and correlate them with the exposed rocks observed during the geological mapping. The studies also delineate the pattern of fractures in the area which form prefential pathways for ground water. Three vertical electrical soundings (VES) were performed radially adopting the Schlumberger electrode configuration, with half-current electrode separation (AB/2) varying from 1m to 100m. Anisotropy polygon was also constructed based on the radial electrical sounding. The geoelectric parameters revealed five subsurface layers which were interpreted as topsoil, lateritic soil, dry sand soil, weathered granite and granite respectively. The geological mapping showed that the area is underlain by crystalline rocks comprising biotite granite, granite-gneiss and migmatite. The anisotropy polygon showed that a major fracture direction along 60^0 (northeast to southwest) and the coefficient of anisotropy is 0.79. Based on the apparent resistivities and the structural disposition, a potential aquifer was inferred at a depth of 45m. The fracture pattern in the area was constrained to northeast to southwest direction. The data obtained would be useful in borehole drilling for water within the study area.

KEYWORDS: Vertical electrical sounding, aquifer, electrical resistivity, anisotropy polygon, geological mapping, fracture pattern

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I. INTRODUCTION

The electrical resistivity method is one of the geophysical investigation techniques which use the electrical properties of rock to differentiate the subsurface into geoelectric layers. It can give insight to the lithologic sections and potential aquifers located beneath the surface. Although electrical resistivity method has contributed immensely in the study of hidden subsurface features like fracture and rock types (Olasehinde, 1989) not much has been done to actually correlate the drilling logs with resistivity data interpretation. The main purpose of geophysical mapping is to obtain an impression of bedrock conditions, especially where soil or water covers the bedrock (Barnes and Lisle, 2003). Resistivity measurements are usually carried out to access the lithology of the profile several hundreds of meters underground. Variations in the electrical properties and the electromagnetic field provide information about the structures and contents of the bedrock. Geological mapping relies on direct observations from outcrop (Olayinka, 2007).

Potable water is an inevitable requirement for man's life and the depth at which it is found is related to its quality. Underground water is restricted to porous and permeable units within the subsurface and locating such anomalous zones requires geophysical investigation. The objective of this study, therefore, was to determine the subsurface lithologies, potential aquifer units and the fracture pattern of the Olokonla area northwest of Ilorin, Nigeria (Figure 1).

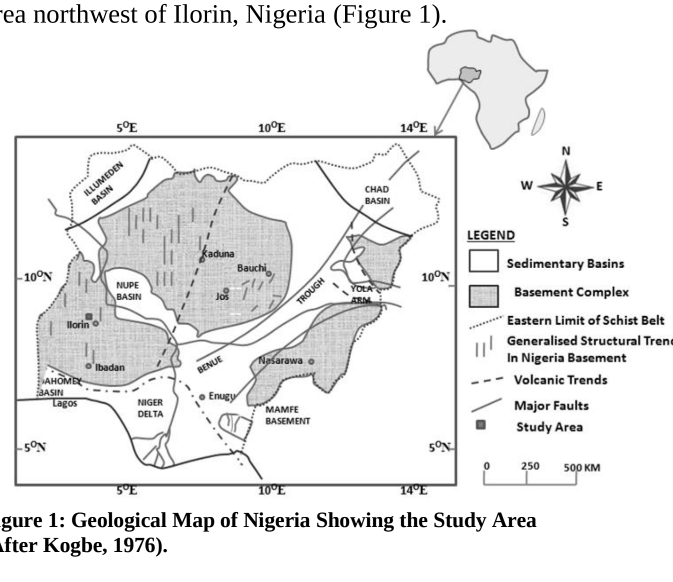

Figure 1: Geological Map of Nigeria Showing the Study Area (After Kogbe, 1976).

II. MATERIALS AND METHODS

A. Description of the Study Area

The location of the study is Olokonla area which lies within the crystalline basement complex of Nigeria bounded by longitude $04^{\circ}37^{1}$E – $04^{\circ}45^{1}$E and latitude $08^{\circ}45^{1}$ N - $08^{\circ}52^{1}$

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N. The study area has two seasons, namely rainy and dry season. The rainy season commences in April and ends in October while the dry season begins in October and ceases in April (McCurry, 1976). The annual rainfall in the region is about 1252 ± 239mm (Ejieji, 2004). The mean annual temperature is about 27.7°C with the maximum mean at 32.2° occurring from February to April (Iloeje, 1980). The vegetation of the area is of the guinea savannah, comprising of various species of shrubs and high forest plants along the streams and depressions in the area (Omotoso *et al.,* 2012).

B. Field Work and Laboratory Analysis

The geological mapping of the study area was conducted along footpaths, the roads leading to the outcrops which were also mapped. The strikes, dips and trends of the rocks were also taken using a clinometer compass where necessary. Detailed description of rocks was carried out at every outcrop found. The identification of each rock type was based on hand specimen. A hand-held lens was used in identifying the mineral composition of the rocks. The thickness of intrusions found on the outcrops was measured with a tape. Samples were collected at the outcrops using – a hammer and a chisel. The samples were carefully labelled for easy identification. They were later subjected to petrographic analysis in the laboratory. The rocks were classified based on the observable features. Igneous rocks were identified and described using textural characteristics, colour and mineralogical composition. Metamorphic rocks were differentiated into classes considering foliation, minerals composition, alignment of minerals and segregation of minerals. Identification of the minerals followed standard procedures (Galehouse, 1971; Shelley, 1985; Gribble and Hall, 1992). Thin slide sections viewed under the petrographic microscope were used to describe the variation in the mineralogy and texture of the parent rocks (Bayewu *et al.* 2012)

The equipment employed for the resistivity field data measurements was the RD–50 resistivity meter. Three vertical electrical soundings were radially conducted, using the conventional Schlumberger technique, with half electrode spacing (AB/2) varying from 1 to 100 m. The Vertical Electrical Resistivity Soundings (VES) involved radial sounding at angles 0°, 60° and 120°. At the selected degrees, Schlumberger array electrode configuration was adopted. The array consisted of four electrodes; two potential electrodes and two current electrodes (Figure 2). The largest current electrode spacing AB/2 used was 100 m. The potential electrode separation, MN, was also increased intermittently in order to maintain a measurable potential difference without exceeding one-fifth of the half-current electrode separation, AB/2, as suggested by Dobrin and Savit (1988). The apparent resistivity was measured along three Azimuths for a given ‘AB/2’ separation and was appropriately plotted in a polygon. For an isotropic homogeneous formation, this polygon was expected to assume a circular shape. Any deviation from a circle to an eclipse gives an indication of the anisotropic nature of the subsurface (Patra and Nath, 1999) and the direction of the fracture was inferred from the plotted polygon. The VES data presented as depth sounding curves were inverted with the aid of computer-aided iteration curve matching techniques using WinResist software (Vander Velpen, 2004). The VES curves generated yielded the thickness and the apparent resistivities of the different geoelectric layers.

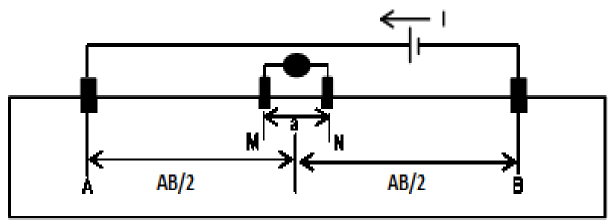

Figure 2: A schematic representation of the Schlumberger array.

III. RESULTS AND DISCUSSION

A. Geological Mapping and Petrographic Analysis

The petrographic analysis of the collected samples revealed presence of quartz, plagioclase, orthoclase, microcline, hornblende, biotite and muscovite in varying amounts. The modal compositions of these minerals coupled with field observation indicate that the study area is characterised by biotite granite, granite gneiss and migmatite (Figures 3 and 4). The modal composition of the minerals is presented in Table 1.

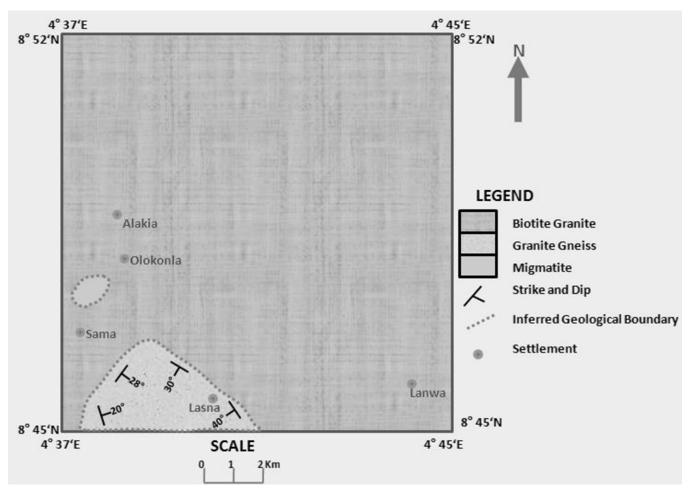

Figure 3: Geological map of the study area.

Table 1: Summary of the petrographic analysis.

Sample No	Q (%)	Pl (%)	Or (%)	Mi (%)	Hb (%)	B (%)	Mu (%)	Rock Type
	Mineral Constituents							
OL1	38	14	17	6	5	15	5	Biotite Granite
OL2	36	19	12	7	6	14	6	Biotite Granite
OL3	40	14	18	8	4	12	04	Granite Gneiss
OL4	32	15	10	5	10	20	08	Biotite Granite
OL5	35	14	15	5	06	15	10	Migmatite
OL6	35	16	17	05	07	15	05	Biotite Granite
OL7	33	20	10	08	10	12	07	Granite Gneiss

***Q = Quratz, Pl = Plagioclase, Or = Orthoclase, Mi = Microline, Hb = Hornblende, B = Biotite, Mu = Muscovite.**

Table 2: Summary of the geoelectric parameters obtained for the study area.

VES No	Layers	Depth (m)	Resistivity (Ωm)	Probable rock type
	1	1.34	1186	Top soil
At 0°	2	8.49	216	Weathered granite
	3	29.1	29.1	Clay
	1	0.224	6584	Top soil
	2	1.15	783	Lateritic soil
At 60°	3	6.5	160	Dry sandy soil
	4	6.97	32.8	Weathered granite
	5	> 6.97	294	Granite
	1	0.83	1026	Top soil
At 120°	2	0.891	310	Lateritic soil
	3	45	130	Weathered granite
	4	> 45	34206	Granite

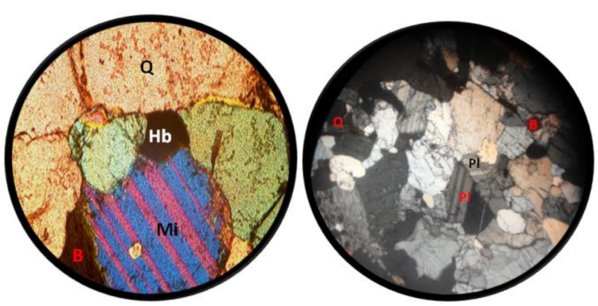

Figure 4: Photomicrographs of rock samples (a) In XPL with sample number OL4 (b) In XPL with sample number OL7 Q=Quartz, Pl=Plagioclase, B=Biotite.

B. *Resistivity Measurements*

The summary of the vertical electrical sounding interpretation is given in Table 2, whereas various VES sounding curves are presented in Figures 5 and 6. The VES at 0° showed three-layered formations which were interpreted as top soil, weathered granite and clay. The sound VES at 60^{0} indicated five-layered formations; the layers were top soil, lateritic soil, dry sandy soil, weathered granite and granite. The VES at 120° indicated four layers which were top soil, lateritic soil, weathered granite and granite. The resistivity of top soil ranged from 1026 Ωm to 1186 Ωm that of the lateritic soil was between 310 Ωm and 783 Ωm. The weathered granite had resistivity value between 32.8 Ωm and 130 Ωm while that of granite ranged from 294 Ωm to 34206 Ωm.

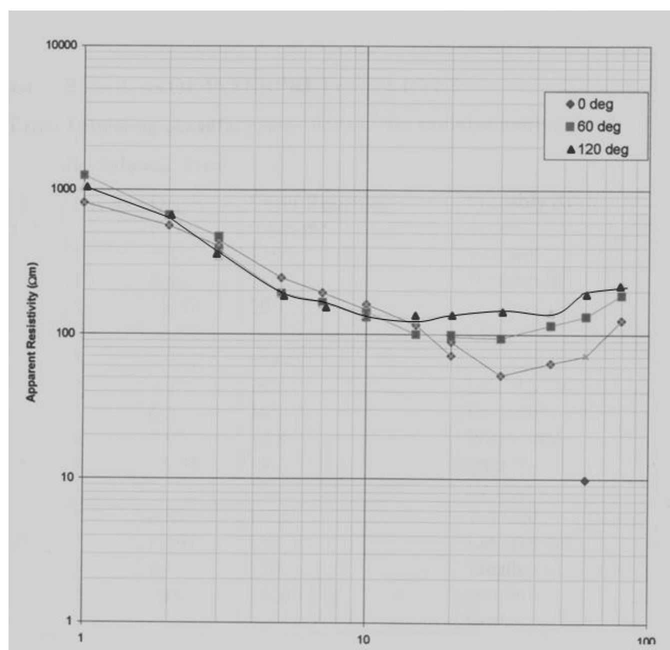

Figure 5: VES sounding curve of radial sounding (at 0°, 60° and 120°).

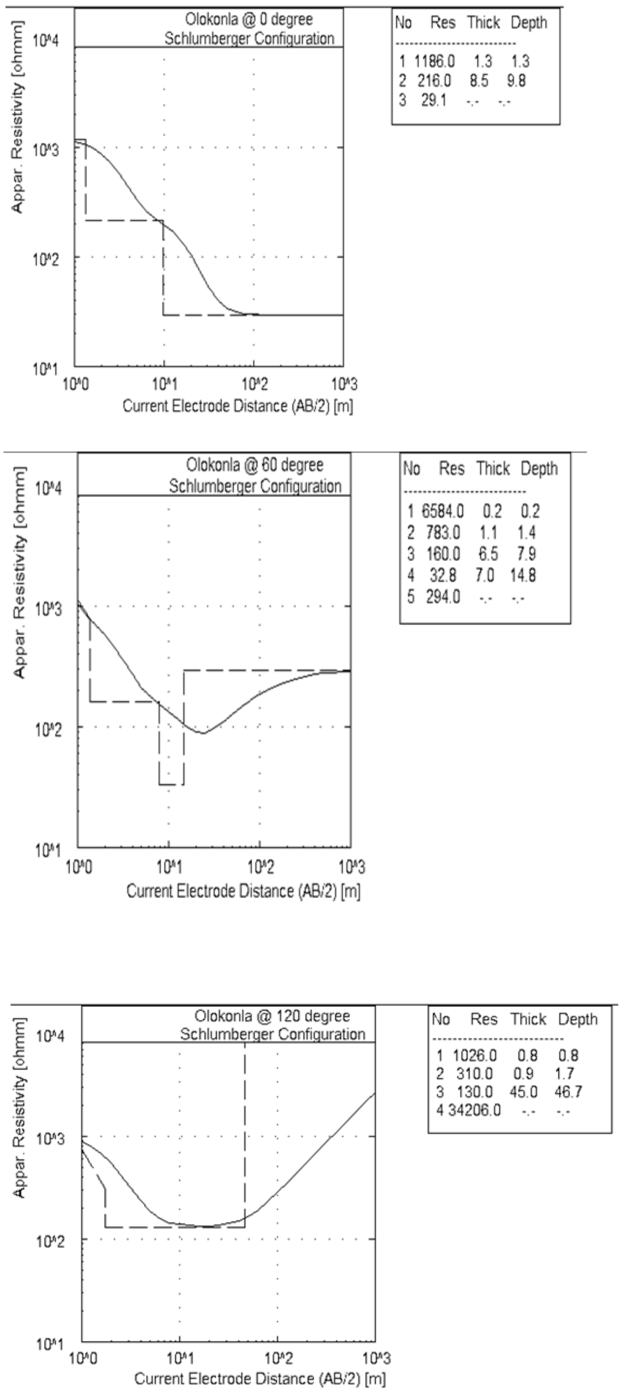

Figure 6: Typical VES Curves (at 0^0, 60^0 and 120^0).

The anisotropy polygon based on the radial sounding showed a major fracture along 60^0 (NE-SW) direction. The surface rock was fractured initially at 120^0 and at intermediate depth the fracture trend coincided with the depth of weathering which had a north-south direction. At deeper horizons, the fracture direction changed from northeast to southwest direction as shown in Figure 7.

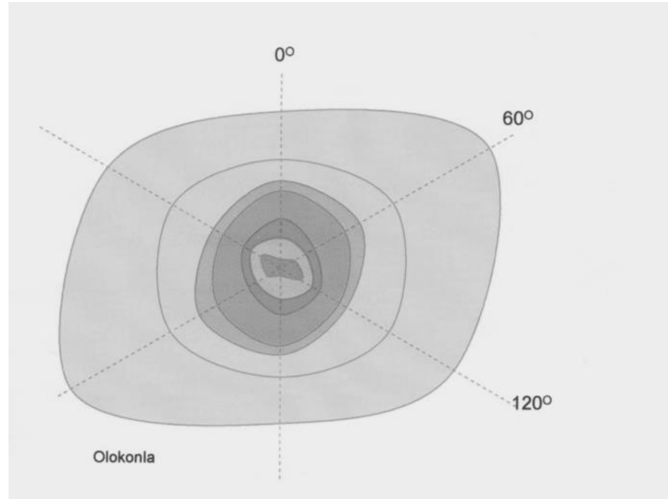

Figure 7: Anisotropy polygon of the study area.

IV. CONCLUSION

Olokonla area was investigated using geological mapping and electrical resistivity method. The two methods were adopted in order to correlate the exposed rocks in the study area with the radial sounding result so as to have a good interpretation of the geology of the area. The geological mapping and petrographic studies showed that the study area was characterized by three rock types namely biotite granite, granite gneiss and migmatite in order of abundance. Vertical electrical resistivity method (with radial sounding), showed five geoelectric layers. The first layer was the top-soil with apparent resistivity of 10262 to 1186 Ωm and thickness of 0.83 to 1.34m. The second layer was lateritic soil with apparent resistivity of 3l0 to 783Ωm and thickness of 0.891 to 1.15m while the third layer was dry sand 6.5 m thick and having apparent resistivity of 160 Ωm. The fourth layer was weathered granite with apparent resistivity of l30 to 216 Ωm and thickness between 8.49m and 45m while the fifth layer consisted of granite with apparent resistivity ranging from 294 to 34206 Ωm and thickness ranging from 6.97 m to more than 45m. The anisotropy polygon showed the major fracture direction to be 60^0 (NE-SW). The coefficient of anisotropy was 0.79. Based on the structural disposition that is, the presence of fractures, a potential aquifer was inferred at a depth of 45m. The fracture location and orientation identified could aid the exploration for groundwater in the study area.

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