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# THE PETROGRAPHY AND GEOPHYSICS OF ROCKS AROUND BAKUMBA OWORRO AND ITS ENVIRONS LOKOJA, NORTH WEST

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## ABSTRACT

Field geologic mapping of the Area around Bakumba in Lokoja local government Area of Kogi state, Located Between Latitudes $07^{0}53^{I}$N to $07^{0}54^{I}$N of the equator and Longitude $06^{0}39^{I}E$ to $06^{0}40^{I}E$ of the greenwich meridian on the topographic map sheet 247 NE on a scale of 1:2500 reveals the occurence of four major rock types including Granite gneiss, Biotite and Augen gneiss. The field relationship and petrographic studies of the rocks in the study area indicates that Granite gneiss, Augen gneiss, and Pegmatite are products of Polycyclic deformation episodes that affected the Nigerian Basement complex Between the Liberian to Pan African. While the geophysical investigation indicates that the study area comprises of seven geo electric layers underlain by gneiss/schist. The geophysical survey carried out along Agbaja road shows that aquiferous zone is suspected to be granite of different litho-facies.

**Keywords**: Petrography, Geophysics, Bakumba Oworro

## INTRODUCTION

The study area falls on the North-western part of Lokoja which forms part of the South-western part of the Nigerian basement complex. The three main rock types distinguished in this area include the Augen gneiss, Porphyritic granite and Migmatite. These rocks have undergone polycyclic deformation thereby causing the deformation of both micro and Micro structures as displayed on the field (Oyawoye 1972). The purpose of this field work is to carry out the geological mapping of the study area and to be able to produce an accurate geological map of that area, including the identification of the different rock types encountered during the field work and also to carry out groundwater prospecting with the help of the data gotten from the Vertical Electrical Sounding carried out during the field work. The objectives are;

- To carry out a detailed geologic mapping of the study area.
- To map the different rocks encountered in the plot.
- To generate an accurate geological map of the area, thus, updating the previous work.
- To obtain dominant trends of geologic structures like joints, veins, folds in the study area.
- To carry out petrographic studies of the rock samples obtained from the study area.
- To prospect for groundwater using the geophysical data obtained from the field.

This work covers an area of 3km2. The scope of this work is to present a detailed geological map by carrying out a systematic field mapping of the area on a scale of 1:2,500 through traversing and megascopic studies of the various rock types encountered in the area. Also the description of geologic history, the observation of outcrops i.e. the structures and the evolution of the rock types and evaluation of the economic mineral potentials in the area. The scope of this work also includes geophysical investigation of the subsurface in terms of hydro-geological applications (Vertical Electrical Sounding) which can lead to the determination of the presence of water through the use of the data gotten from the Vertical Electrical Sounding. Some geologic structures such as folds, fractures, and folliations were found in the rocks around this location, providing us with clues as to the ecologic history of the location. Most of the structures are secondary which developed either during metamorphism or after the emplacement of the rocks.

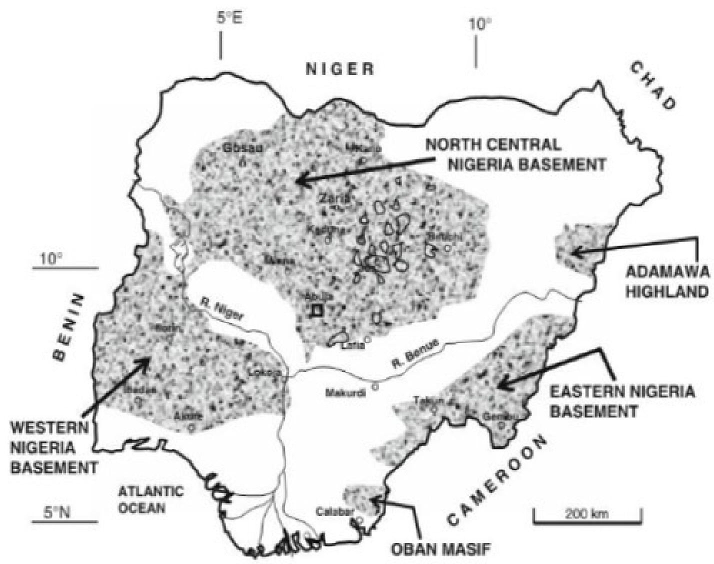



Figure 1: Geological map of Nigeria showing the Basement Complex, the Younger Granites and the Sedi- mentary Basins (After Murat, 1972).

## METHODS

### Sites and Sample Collection

Samples were collected from ecologically diverse sites in the vicinity by traversing the entire location. In addition to this, the ABEM SAS 300C Terrameter was used to carry out Vertical Electrical Resistivity sounding (VES) using the schlumberger electrode array.

### Geophysical Survey

The Vertical Electrical Sounding was carried out at Agbaja Road (Latitudes 07° 56′ 04.1″ N and Longitude 006° 39′ 32.5″ N) Electrical resistivity is one of the surface geophysical methods used in prospecting for groundwater, hydrogeological investigation (depth to aquifer and quantity of groundwater), and mining and geotechnical investigations as well as in environmental studies /survey. Vertical electrical sounding (VES) is a geophysical method for investigation of a geological medium. The method is based on the estimation of the electrical conductivity or resistivity of the medium. The estimation is performed based on the measurement of voltage of electrical field induced by the current electrodes.

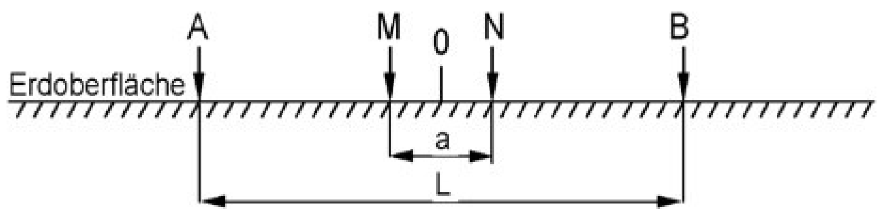



Figure 2: Electrical profiling using four-electrode probes in Schlumberger configuration.

**Description of the Method Used**

Vertical electrical sounding (VES) is a geophysical method for investigation of a geological medium. In a vertical electrical sounding (VES), apparent resistivity measurements are made at different electrode spacings, centered about a common point. As the electrode array size increases, we 'sound' to greater depths, as shown in the earlier examples. The Schlumberger array is commonly used for VES, keeping the potential electrode dipole (M and N) fixed and moving the current electrode dipole (A and B). This is a popular choice because the fixed potential electrode dipole means that not only the measurements are relatively insensitive to lateral variation in resistivity but also, from a practical standpoint, surveys can be completed more efficiently as only one of the dipoles is moved for each measurement.

## Field Procedures for Schlumberger Sounding

The potential electrodes were kept fixed, while current electrodes were move outwards symmetrically in steps. However, when the voltage falls below reading accuracy, the potential electrodes spacing was increased (5x or 10x), maintaining the MN « AB (i.e. potential electrode spacing is always far less than the current electrode spacing) condition. Then the results were plotted as ρa against AB or AB/2 depending on whether the sounding is full or half space Schlumberger, to obtain characteristic curves. These theoretical curves take into account, the change of depth penetration when current lines cross the boundary to a layer with different resistivity. There are four basic shapes known for the curves determined by the vertical sequence of resistivities in the layers;

- K type (or DA- displaced anisotropic): This rises to a maximum then decreases, indicating that the intermediate layer has higher resistivity than the top and bottom layers.
- H type (Hummel type with minimum): This falls to a minimum then rises again due to an intermediate layer being a better conductor than the top and bottom layers.
- A type (ascending): This may show some gradient changes, but ρa increases generally with in- creasing electrode separation indicating that the true resistivities increase with depth from layer to layer.
- Q type (descending): this is the reverse of the A type as resistivity decreases with increasing electrode spacing. I.e. resistivity decreases with depth from layer to layer.

## RESULTS

### Field Occurrences

The Major rock types in the study area include the Granite Gneiss and Porphyroblastic Granite Gneiss. The minor rock types include pegmatitic intrusions, quartz and quartzo-feldsparthic veins.

## Megascopic Analysis of Rocks

The Megascopic study involves the description of Rocks in hand, observed on the field. This consists of the description of the extent of coverage of the different rock types, the color, the texture, and Mode of occurrence. The following rock types characterized the study area.

Figure 3: Showing Porphyritic Granite in the study area

Figure 4: Showing Granite gneiss in the study area

## Porphyroblastic Gneiss

This is a medium to coarse grained Porphyroblastic, Mesocratic, weakly foliated rock which contains almost equal amounts of dark and light colored minerals. The minerals observed megascopically were Feldspar, Quartz, and Biotite. The feldspar crystals are also coarse and large grained but do not have a preferred orientation/alignments, hence having a weak foliation. The quartz and the Biotite are medium to coarse grained. The Porphyroblasts and the groundmass commonly show random orientation and inter- locking relationship. Some of the porphyroblast of the feldspar were up to 5cm long and 1.5cm wide while those of Quartz were as high as 3cm long and 1cm wide. They occur from a few meters to Bakumba town along Felele road, to peripheries of the Study area Through the Northeast to the Northwest and down to the southwestern corner of the study area. At some many meters away from Bakumba town, the rock unit appears mesocratic and porphyroblastic with numerous euhedral porphyroblasts of plagioclase feldspar- with zoned structures. The rock essentially lack Banding, but a closer observation reveals stretching and flow structures occassionally creating augen structures constituted by the feldspar porphyroblast.

**Granitic Gneiss**

Granitic gneiss is a rock consisting of an orthogenesis or paragenesis having the composition of a granite. The rock was found at location 8 (07° 53′ 18.3″ N and 006° 39′ 51.5″ E) in the study area. It consists of Quartz, Mica, and Felsdpar etc.

Fig. 5 Pegmatite Dyke observed on the field

Pegmatites are extreme igneous rocks that form during the final stage of a magma's crystallization. They occurred mostly in the study area as an irregular dyke in the host rock that contains them. The pegmatite dyke was observed in location 3 (07° 53′ 12.3″ N and 006° 39′ 38.2″ E), and location 9 (07° 53′ 31.3″ N and 006° 39′ 42.1″ E)

**Microscopic description of rocks (Thin Section)**

**Porphyroblastic Granite**

Microscopic studies revealed the presence of the following minerals in the rock; plagioclase Quartz, mus- covite, biotite, microcline, hornblende and other minerals (accessory minerals).Characteristics exhibited by minerals in the Fine to Medium Grained Granite

•Plagioclase: In cross polarized light (XPL), its colour ranges from dark grey to light grey while it is colourless under plane polarized light (PPL). It shows a polysynthetic twinning and it has a low relief. It constitutes about 12 percent of the sample.

•Quartz: it occurs as an irregular form that exhibits a whitish to greyish colour as the stage is rotated under cross polarized light (XPL), it is colourless under plane polarized light (PPL).

The relief is low and it shows no observable twining or cleavage with low interference colour and parallel extinction. It constitutes about 31 percent of the sample.

•Muscovite: it is colourless to pale green under cross polarized light (XPL) and it is colourless in plane polarized light (PPL). It is weakly pleochroic. Its cleavage is in one direction. It constitutes about 8 percent of the sample.

•Biotite: it occurs as prismatic elongate crystals having a moderate relief and a perfect cleavage in one direction, light brown to dark brown under cross polarized light (XPL) and also the same colour under plane polarized light (PPL). Shows no observable twinning. It constitutes about 24 percent of the sample.

•Microcline: occur as small anhedral to subhedral crystal which displays multiple twinning or cross hatched twinning under cross polarized light (XPL) and are colourless under plane polarized light (PPL). It has a low relief. It constitutes about 11 percent of the sample.

•Hornblende: it exhibits a variable light brown or green colour under cross polarized light (XPL) but it is colourless under plane polarized light (PPL), it is strongly pleochroic, the hornblende observed was mostly the brown hornblende and it constitute about 13 percent of the sample.

•Others (accessory minerals): It constitutes about 3 percent of the sample.

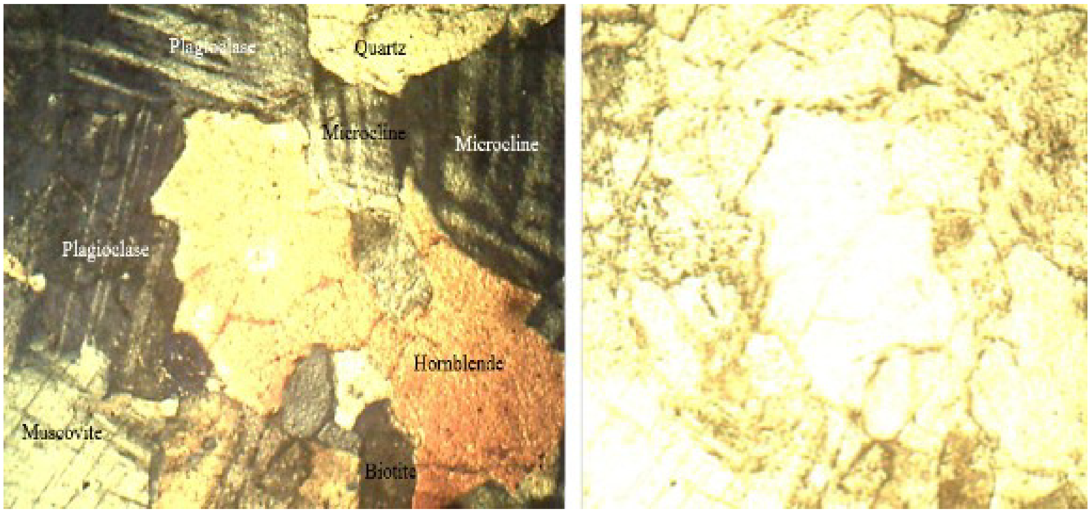



Figure 6: photomicrograph of Porphyritic Granite under xpl and ppl

**Granite Gneiss**

Microscopic studies revealed the presence of the following in the rock; biotite, quartz, hornblende, mi- crocline, plagioclase and other minerals (opaque and accessory minerals). Characteristics exhibited by minerals in the Fine to Medium Grained Granite Gnaeiss;

- Biotite: it occurs as prismatic elongate crystals having a moderate relief and a perfect cleavage in one direction, light brown to dark brown under cross polarized light (XPL) and also the same colour under plane polarized light (PPL). Shows no observable twinning. It constitutes about 22 percent of the sample.
- Quartz: it occurs as an irregular form that exhibits a whitish to greyish colour as the stage is rotated under cross polarized light (XPL), it is colourless under plane polarized light (PPL). The relief is low and it shows no observable twining or cleavage with low interference colour and parallel extinction. It constitutes about 32 percent of the sample.
- Hornblende: it exhibits a variable light brown or green

colour under cross polarized light (XPL) but it is colourless under plane polarized light (PPL), it is strongly pleochroic, the hornblende observed was mostly the brown hornblende and it constitute about 16 percent of the sample.

- Microcline: occur as small anhedral to subhedral crystal which displays multiple twinning or cross hatched twinning under cross polarized light (XPL) and are colourless under plane polarized light (PPL). It has a low relief. It constitutes about 7 percent of the sample.
- Plagioclase: In cross polarized light (XPL), its colour ranges from dark grey to light grey while it is colourless under plane polarized light (PPL). It shows a polysynthetic twinning and it has a low relief. It constitutes about 13 percent of the sample.
- Others (Opaque minerals and accessory): Opaque minerals are dark coloured minerals, which do not allow light to pass through them. It constitutes about 5 percent while accessory 5 percent of the sample.

In general, the sample of the Granite gneiss has about 20 percent feldspar (plagioclase, microcline), 27 percent mica (biotite, muscovite) and 5 percent amphibole (hornblende) while the sample of Fine to Medium grained granite consists 20 percent feldspar, 22 percent mica (biotite only) and 15 percent amphibole and lastly, the sample of Porphyritic Granite gneiss consists 16 percent feldspar, 29 percent mica and 18 percent amphibole. Other bands of granite gneiss contain platy or elongated minerals that show a preferred orientation that parallels the overall banding in the rock. It is this banded appearance and texture - rather than composition - that define a gneiss. The dark minerals found in Granite gneiss sometimes exhibit an orientation determined by the pressures of metamorphism.

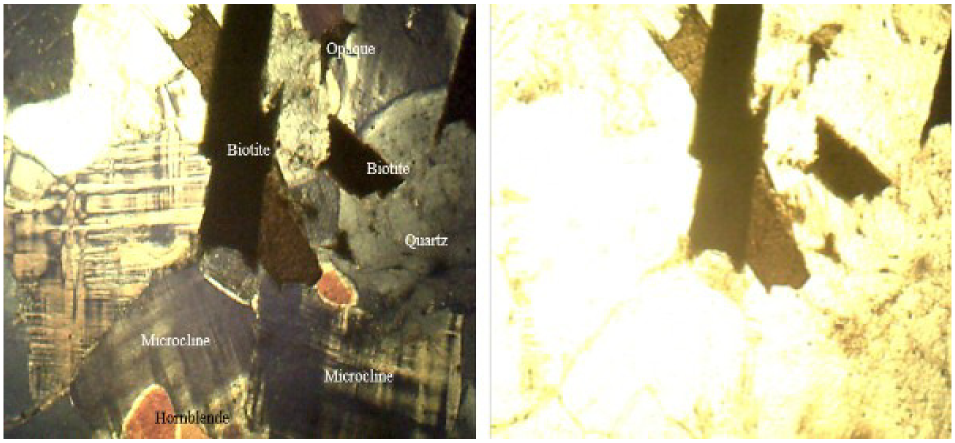



Figure 7: photomicrograph of Granite gneiss under xpl and ppl

Figure 8: Quartz vein discovered on the field

## Minor Rock types

The minor rock types in the area generally occur as intrusions:

## Quartz Veins/ Feldsparthic vein

A vein is a sheet-like or tabular, discordant, mineralized body formed by the complete or partial infilling of a fracture within a rock (The new penguin dictionary of geology, 2001). They are found almost in all the major rocks of the study area, with thicknesses varying from few millimetres to few centimetres. They cut across the country rock or host rock and trend in the WNW-ESE direction and they also occur as cross cutting veins.

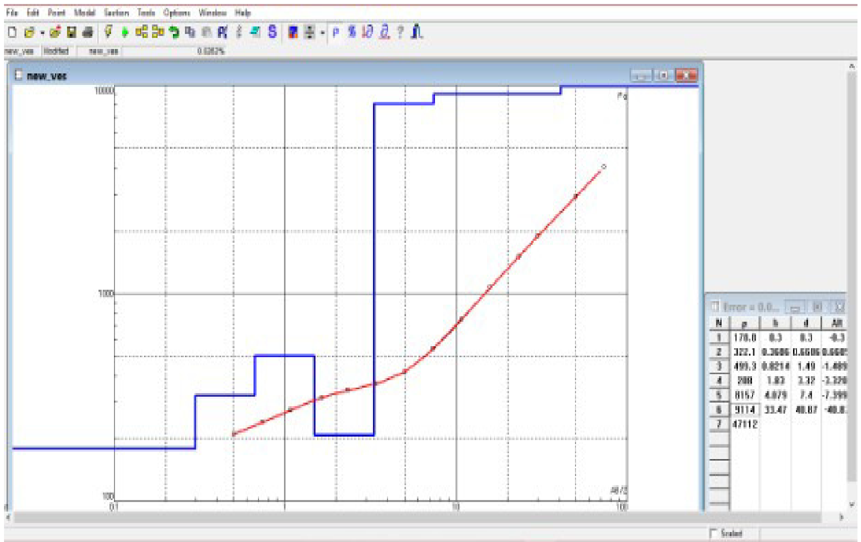
**Presentation of Geophysical data**

The following data were acquired from the geophysical sounding carried out at Agbaja road (Latitudes 07° 56′ 04.1″ N and Longitude 006° 39′ 32.5″ E). This Geophysical data can be used for geologic mapping, hydrology, environmental monitoring, slope stability assessment, infrastructure planning and monitoring. For this field research work, the Schlumberger configuration was used for the data acquisition.

Figure 10: Showing VES curve of data after processing.

| Current Electrodes {AB/2} (m) | Potential Electrode {MN} (m) | Resistance {R} (Ω) | Geometric Factor {K} (m) | Apparent Resistivity {$\rho_a$} (Ωm) | S.D (%) |
|---|---|---|---|---|---|
| 0.5 | 0.2 | 295.48 | 0.824775 | 243.7045 | 0.015 |
| 0.74 | 0.2 | 128.57 | 1.993599 | 256.317 | 0.097 |
| 1.08 | 0.2 | 71.41 | 4.423936 | 315.9133 | 0.078 |
| 1.65 | 0.2 | 34.498 | 10.53552 | 363.4543 | 0.0388 |
| 2.32 | 0.2 | 19.716 | 20.98228 | 413.6866 | 0.077 |
| 3.4 | 0.2 | 7.5021 | 45.2448 | 339.431 | 0.0558 |
| 5 | 0.2 | 7.9021 | 98.0304 | 774.646 | 0.941 |
| 5 | 1.0 | 22.315 | 18.852 | 420.6824 | 1.13 |
| 7.35 | 1.0 | 5.2517 | 41.64917 | 218.729 | 5.67 |
| 10.75 | 1.0 | 8.8127 | 89.98884 | 793.0447 | 3.21 |
| 15.8 | 1.0 | 1.9332 | 195.3067 | 377.567 | 18.9 |
| 23.2 | 1.0 | 21.993 | 422.002 | 9281.09 | 5.91 |
| 23.2 | 2.16 | 21.27 | 194.0383 | 4127.194 | 7.16 |
| 30 | 2.16 | 14.595 | 325.595 | 4752.059 | 5.92 |
| 50 | 2.16 | 0.746 | 907.4468 | 676.9553 | 277 |
| 73.5 | 2.16 | 78.686 | 1962.872 | 154450.5 | 3.39 |

Figure 9: Table showing the Summary of the Vertical Electrical Sounding Data in the study area.



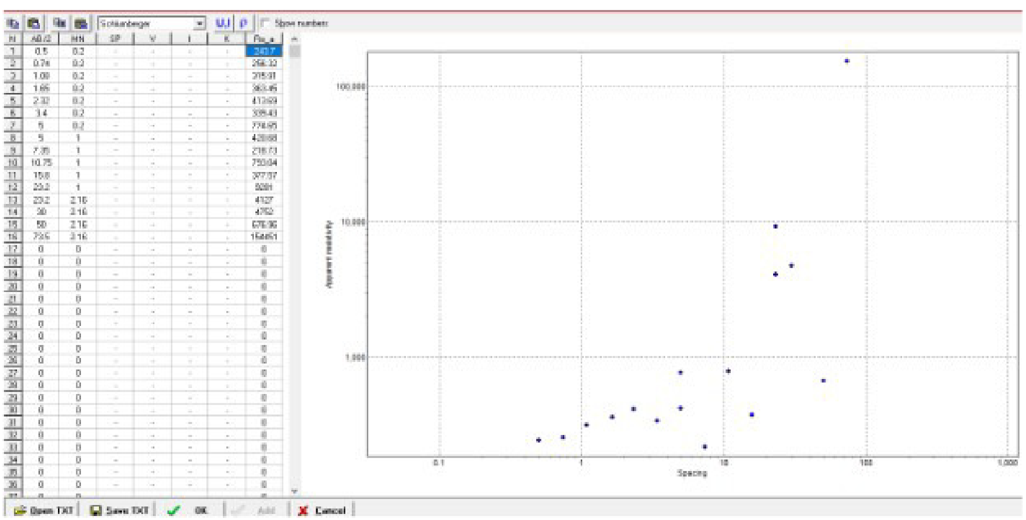




Figure 11: Showing the data points for VES curve

The resistance values of the different electrodes spacing were converted to apparent resistivity values using the apparent resistivity formula for the Schlumberger array. To calculate Geometric factor (K), it is expressed as; $K = 4L^2 \ a^2/a$ The apparent resistivity (ρa) is given by; ρa = $KxR$ Where, $p$ =

3.142, *L* = *AB* = Current electrode spacing (m), *A* = *MN* = Potential electrode spacing (m), R = Resistance (W), K = Geometric factor, ρa = Apparent resistivity (Wm). The apparent resistivity values were plotted against corresponding half current electrode spacing (*AB/*2) using VES curve Software, IP2Win.

The depth of penetration of the current is related to the current electrode spacing on the surface through this expression *X* = 3*d* where X is the current electrode spacing at the surface and d is the depth of penetration. From the relationship *X* = 3*d*, *d* = *X/*3. Total current electrode spacing on the surface (X) was 73.5*x*2 = 147. Therefore, *d* = 147/3 = 49*m*. The total depth of penetration of the current is 49m.

### Type of Curve

In the A curve type, ρa (Apparent resistivity) increases generally with increasing electrode separation indicating that the true resistivities increase with depth from layer to layer i.e. from topsoil to bedrock.

## DISCUSSION AND CONCLUSION

The figure below (adapted from Palacky, 1987) was used for the interpretation of the geophysical data in table 1, to get the lithologic interpretation of table 2. From the table below, the sandstone which is unconsolidated is abundantly filled with pore spaces due to its wide variety in particle size and degree of sorting. This acts as a solution channel for the water above (surface water) to infiltrate the ground to the subsurface. For a rock to be an aquifer, it needs to be porous and permeable and also saturated. Igneous rock and metamorphic rocks are poor aquifers unless they are fractured and this leads to the formation of secondary porosity, this enables these rocks become an aquifer. This can only occur in the event of tectonism or some geologic event. The resistivity obtained in layer 4 is very low and this indicates the possible presence of water (water has low resistivity), so this makes the basement rock fractured. The weathered basement aquifer in the study area formed the fourth layer for the 7 - layer formations, the depth of the layer ranges from 3.32 m to 7.40 m and the thickness ranges from 1.83 m to 4.08 m and the resistivity of the layer is 208.0 Wm while the depth to the water table as revealed by the geophysical investigation carried out is about 6m.

| S/N | LAYERS | DEPTH(M) | THICKNESS (M) | APPARENT RESSISTIVITY(Ω-M) | INFERRED LITHOLOGY |
|---|---|---|---|---|---|
| 1 | 1ST | 0.30 | 0.30 | 178.8 | Top soil (sandy) |
| 2 | 2ND | 0.37 | 0.67 | 322.1 | |
| 3 | 3RD | 0.82 | 1.49 | 499.3 | |
| 4 | 4TH | 1.83 | 3.32 | 208.0 | Weathered Basement Rock |
| 5 | 5TH | 4.08 | 7.40 | 8157 | Unweathered Basement Rock |
| 6 | 6TH | 33.47 | 48.87 | 9114 | |
| 7 | | ……………… | ……………… | 47112 | |

Figure 12: Summary of Lithologic Interpretation of the acquired data using Ipi2win software.

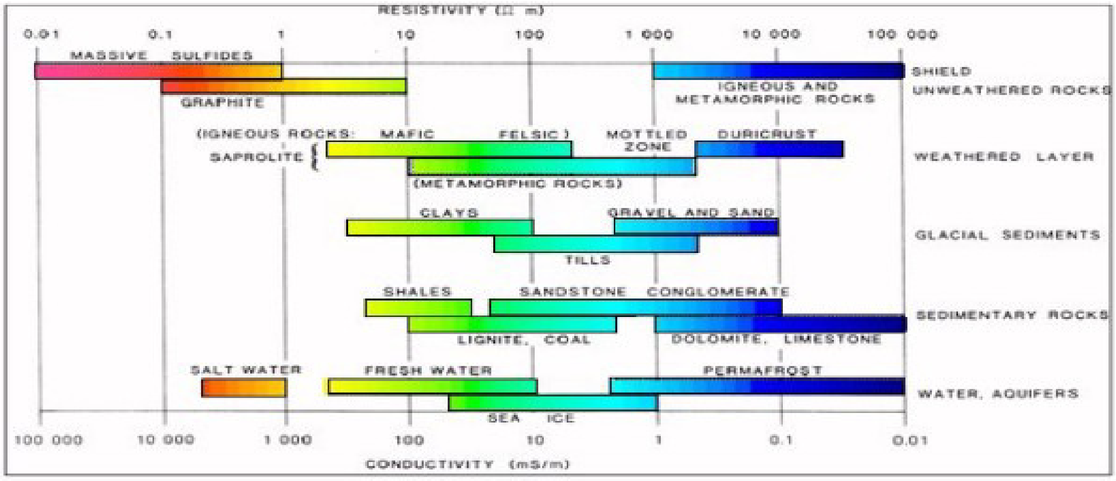



Figure 13: A representative chart showing resisitivities and corresponding rocks (adapted from Palacky, 1987)

## Hydrological Potential

The surface water in the study area is derived from the river channels or streams. The stream channels were seasonal therefore, they are not active and shallow during dry season and the only stream seen in the study area was at the study area.

## Ground Water

The crystalline rocks of the Agbaja road are fractured and jointed and this lead to the creation of secondary porosity in the rocks. The degree of weathering resulted in the accumulation of sediments forming a thick overburden and this enabled the ease of water infiltration to the subsurface. The water accumulated both within the weathered basement and the fractured bedrocks forming the aquifer.

## CONCLUSION

The petrographic study of the minerals in the study area showed the following mineral composition; the Augen gneiss consists 20% feldspar, 27% mica, 5% amphibole, opaque 3% and accessory minerals 2% while the Fine to Medium grained granite consists 20% feldspar, 22% mica, 15% amphibole, opaque 5% and accessory minerals 5% and lastly, the Porphyritic Granite gneiss consists 16% feldspar, 29% mica and 18% amphibole and accessory minerals 3%. Geophysical studies employing vertical electrical sounding was carried out at Agbaja road and revealed that the water table is about 6m from the surface and the aquifer is at a depth 3.32 m to 7.40 m and the thickness of 1.83 m to 4.08 m while the depth to the water table is about 6m. In the case of borehole drilling, water should be expected to be seen from 3m to 8m. The groundwater yield from this aquifer would depend on the density of the fractures in the fractured column, i.e. if the density of the fractures is high then the yield will be high. Also the thickness of the aquifer (1.83 m to 4.08 m) suggest that the yield will likely be low.

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