# Two Dimensional Shallow Resistivity Investigation of the Ground Water Potential at Nuhu Bamalli Polytechnic, Zaria Main Campus using Electrical Imaging Technique.

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## ABSTRACT

A two-dimensional shallow resistivity survey of the groundwater potential at the main campus of Nuhu Bamalli Polytechnic, Zaria using electrical imaging technique was carried out. Six image lines were measured at different strategic locations of the study area based on the fractured map of the area and Borehole log data information obtained from the area. Results from the interpretation of the data collected suggest 2-4 layers in the area studied. However there are patches of core rocks in some part of the studied area. The resistivity value for the first layer (Topsoil) varies from 10 to 400 ohm-m with thickness ranging from 1-14m. The second layer (Weathered Basement) has resistivity values between 120 and 500 ohm-m and thickness ranging from 5-11m. The third layer (Fractured basement) has resistivity values ranging from 500-1000 ohm-m and thickness between 3 and 6m. The fourth layer is the Fresh Basement (Bedrock) has resistivity values greater than 1000 ohm-m and infinite thickness. The southwest (SW) of the study area does represent a promising Aquifer with reasonable thickness of Weathered Basement and Fractured Zone. Also, the area seems to be a zone of high hydraulic conductivity because of its low resistivity values. This area was recommended for possible groundwater exploration as it exhibited strong water-bearing potential in the subsurface rocks..

(Keywords: shallow resistivity survey, ground water potential, water exploration)

## INTRODUCTION

Over half the Nigerian people lived in semi-arid or arid areas where the perennial problems of scarcity of fresh drinkable water need to be tackled or addressed. Ground-water exploration appeared to be the solution to this log-jam, since it is free from bacteriological pollution, has an almost constant quality and temperature and is always available due to the natural water cycle. The only snag is that the rate of withdrawals of fresh water from the earth is faster than the rate of replacement by the natural water cycle, hence the level of ground-water gets farther from the surface and it becomes uneconomical and impractical to site boreholes on the bases of common sense instead of sound scientific data. The study area, Zaria, is a cosmopolitan city with increasing population growth and social infrastructural development, hence, the need for scientifically cited boreholes to meet its water need.

Geophysical methods such as magnetics and seismic refraction have been useful in investigating parameters like depth to water-table (aquifer), aquifer thickness, depth to basement, identification of weathered basement and fracture systems in rocks among others, however, the electrical imaging which is about the most recent advancement in resistivity method of geophysical prospecting have been found to provide a more detailed view of subsurface structure that can be obtained using the other techniques (Barker et al, 2001).

In a regional study of Zaria, Du. Preez (1952), reported the presence of prominent, steeply dipping joints in some outcrops of granite in the Kubanni basin. He also affirmed the presence of groundwater in some joints. Danladi (1985), equally confirmed the presence of water-bearing fractures, but stated that aquifers are isolated and located at shallow basement areas. This study site is located South-East of the area surveyed by Hassan (1987). He confirmed that the bedrock is undulating, with depths of buried increasing towards the southern part of the present survey area. He estimated the depths to vary between

5m and 60m in the North-South direction and that the area is likely to have been faulted or down-thrown. He further suggested the presence of a great depression in the South-Eastern (S-E) part. He inferred that the aquifer system in this area is constituted of the weathered basement and fractured basement which was well developed in the west-central part of the basin. He concluded that the weathered basement thickness ranges from 10m to about 45m with an average thickness of about 5m. Olatunji (1999), confirmed the above statement but suggested that the weathered basement in the study area does not entirely represent a promising aquifer as its thickness is not adequate in some areas.

Akpoborie (1973), in his study on Kubanni basin, reported that the older granite icebergs are intensively fractured giving way for easy recharge of weathered basement aquifer with rain water. Eigbefo (1978), in his study of the area reported two major deformations; the greater one is along North-South while the less prominent one is along East-West. He also confirmed that the depth to water table at various points in Kubanni basin ranges between 3 to 10m, and the range of thickness of weathered basement to be 1 to 30m.

Olowu (1967) in a regional study of sheet 102SW revealed that with the exception of Galma River all streams in the area are seasonal and that the depth to water-table increased progressively away from the banks of the river during the dry season. McCurry (1970) studied the basement geology of Zaria and confirmed that the basement complex rock is made up of older Granite and Biotite Granite Gneiss. Klinkenbera (1970) classified soils in Zaria under leached ferruginous tropical soils. He also revealed that the soil is weakly developed near the lingelbergs, and hydromorphic in nature and formed Fadama soils (i.e. subject to periodic flooding) and contains about 40 percent day at some depths. Hazell et al. (1992) affirmed that Zaria has tropical continental climate, which is most prominent in the dry seasons around December and January. He confirmed the mean daily temperature of 310C with maximum value of about 360C which usually occurs around April and a mean annual rainfall of 108.8mm in Zaria.

Hazell et al. (1992), in a study of the hydrogeology of crystalline aquifero in Northern Nigeria concluded that the crystalline basement outcrop has areas of deeply weathered regolith which constitute useful aquifers, separated by larger areas of relatively barren shallow regolith. He further affirmed that the aquifers are variable in extent and thickness ranging from broad areas of deep weathering to narrow joints and fracture zones. Olayinka (1999), in a geoelectrical imaging study for ground water in southwestern Nigeria confirmed the consistency of an inverted 2-D resistivity image data with that of borehole information. Barker et al. (2001), in a study of water supply in hard rock areas of India concluded that electrical images provide a more detailed view of subsurface structure than can be obtained using other geophysical technique and may therefore lead to a better understanding of the local hydrogeology.

In view of the above and because of the factors like cost effectiveness, availability of equipment and interpretation software, and easy-to-use, the electrical imaging technique was used in the investigation of the area.

## GEOLOGY OF THE SURVEY AREA

The study area is situated on top of the Zaria batholith, underlain by rocks of Precambrian basement complex made up mainly of migmatitegneiss complex, meta-sedimentary, meta-volcanic and the older granite series. It is approximately bounded by longitudes 70 421 26"E and 70 431 34"E and Latitudes 110 4130" and 110 51 17"N within the Zaria topographic map sheet 102 SW. Ike (1988), stated that the older granite outcropping of Zaria are exposures of a syntectonic to late tectonic granite batholiths which intruded a crystalline gneissic basement during the Pan-African Oregeny. This batholith is a N-S oriented body about 90 x 22 km, extending from Zaria southwest to the vicinity of Kaduna.

Eigbefo (1978), in his work on Kubanni Basin in general listed the different basement rocks found in the area viz:

- (i) Coarse perphyritic – biotitle granite which is distinctly foliated and aligned.
- (ii) Medium – coarse grained biotite granite gneiss.
- (iii) Aplite granite, pegmatites and quartz veins intrude most of the bodies; and
- (iv) Weathered basement. This is about 14% of the basin's total area and formed a storage aquifer.

(v) The surface of the older granite basement in the study area is overlain by a deposit of older laterite, young laterite, older alluvium and younger alluvium; the last two being quaternary deposits (Wright and McCurry, 1970).

The entire Zaria area is located on a Plateau at a height between 600 and 700m above sea-level and has a tropical continental climate (Ologe, 1971). The area can be reached through a federal high way from Kaduna through Zaria to Jos. The area is located at the extreme of the Southern part of the Kubanni River Basin. The area has dry (November to April) and wet (May to October) seasons with rain falling mainly during the wet season with an average annual rainfall of about 109.2mm (Olufemi,1985). The temperature of the area can be as low as a few degrees below room temperature and as high as a few degrees above 350C in the dry seasons. Groundwater occurrence in this area is therefore a consequence of hydrologic, geologic and climatic events. The area is also invaded by two air masses: the northern air mass – dry and continental in origin and southern air mass – moist and comes from the Atlantic .

The drainage system of Zaria area focuses on the River Galma, a major tributary to River Kaduna. It flows north-ward, away from the Eastern fence of the study area. Kubanni river flows Eastward away from the northern fence of the study area. The confluence of Galma and Kubanni is about 1.2km away from the fence of the study area at North-Eastern direction. Galma and Kubanni rivers carry water throughout the year (Thorp, 1970).

## AIM AND SCOPE OF THIS STUDY

The study site lacks detailed geophysical investigation as all previous geophysical works carried out around this site are regional in nature with the exception of the study done by Olatunji (1999) in Federal College of Education, Zaria using one-dimensional DC resistivity method which of course is not as sophisticated as the two-dimensional electrical imaging technique used in the work. The aim of this work was to determine the depth to bedrock, aquifer thickness and saturation, weathered layer thickness and fracture systems at the study area.

Areas for the successful siting of boreholes will be identified. It would also be possible to identify strategic positions for the citing of high-rise buildings and depth of waste disposal system in order to avoid contamination of ground water.

## LIMITATIONS

The campus has been substantially developed and it was not possible to lay out regular grid. However, random images of profile lines were selected all over as much as the physical developments could permit. The study area has only one functioning borehole and two others are under construction.

## FIELD TECHNIQUES AND INSTRUMENTATION

The fieldwork was carried out between 23rd October and 4th of November, 2008. This period was chosen because it was the dry season with the assumption that rest water would be about its mean maximum depth and aquifer thickness would be at its mean minimum and also a good ground-electrode contact is guaranteed.

Six profile lines/survey lines with one hundred and ninety data points (stations), on each, were randomly chosen for imaging in the survey area as much as the structures in the area would permit.

## CHOICE OF ELECTRODE CONFIGURATION

For this resistivity work, a Wenner array was chosen for the following reasons:

(i) The number of measurement required to construct a pseudosection is generally much smaller than with the other arrays (Barker, 2001).
(ii) It has a greater depth range when compared with the Dipole-dipole array and does not have the practical problems of the two-electrode array and pole-dipole array that required that the electrodes be placed considerable distances from the imaging line.
(iii) The effects of near-surface lateral resistivity variations are substantially reduced by measuring ground resistance at two electrode array positions.

## DATA COLLECTION

The location of the profile lines was made to cover the whole area of Nuhu Bamalli Polytechnic, Zaria, Campus land so as to achieve the stated objectives. Each imaged profile line is of length 200m, in the E-W directions as far as the physical structures on the premises can accommodate to give an effective maximum depth of imaging of around 30m to 40m. A summary of the lines is given in Table 1 and their locations are shown in Figure 1.

•**Profile line, 10m to Borehole.**

The data was collected utilizing an automatic multi-electrode switching system which passes an electrical current along multiple paths at various depths and measures the resulting associated voltages. The number of electrodes for a typical imaging survey ranges from 28 to 106 electrodes. In this survey 42 electrodes were used and a spacing of 5m. The electrical imaging system utilizes two arrays of multi-core cables which extend outward in opposite directions from the centrally located switching unit and resistivity meter. Resistivity measurements are recorded from all possible combinations between two electrodes. As the spacing increase, the resistivity meter measures at greater depths and increasing volume of ground. Data can be collected with a variety of electrode arrays, but the Wenner electrode arrangement is used here because of its ability to speed up data collection and reduce the number of required measurements.

In this survey, the Abem lund imaging system and Abem Terrameter signal averaging system (SAS) 4000 were the principal instrument used. No booster was used because the expected depth-basement in the area is within the range of penetration of the instrument. In the Terrameter signal averaging system (SAS) 4000 consecutive readings are taken automatically and the results are averaged continuously and the updated running value is automatically displayed on its digital read out screen and saved in the its built-in PC compatible memory system where it can be retrieved by a computer system for analysis and interpretation. The Terrameter signal averaging system (SAS) 4000 has four input channels including clip-on battery trays, SAS EBA (External Battery Adaptor), multi channel adaptor (with banana connector take-out for the four channels, and RS232 cable while the lund imaging system is a multi-electrode system, consisting of 4x64 channels unrestricted switching, battery operated unit, robust water proof design, links to connect the ABEM Terrameter and Standard IBM PC compatible computer, data acquisition software and software for graphical presentation and depth interpretation (ABEM, 1994).

Table 1: Lines Locations In The Study Area

| S/N | LINE | NUMBER OF ELECTRODES | LOCATION | LENGTH M | DIRECTION |
|---|---|---|---|---|---|
| •1 | LINE 1 | 42 | NEAR BOREHOLE (SW) | 200 | E-W |
| 2 | LINE 2 | 42 | NEW MALE HOSTEL CONSTRUCTION SITE(SW) | 200 | E-W |
| 3 | LINE 3 | 42 | MURRAY ROAD (NW) | 200 | E-W |
| 4 | LINE 4 | 42 | KONGO ROAD (N) (SW) | 200 | E-W |
| 5 | LINE 5 | 42 | MOH. BASHAR ROAD (NE) | 200 | E-W |
| 6 | LINE 6 | 42 | SAM RICHARDSON ROAD (S) | 200 | E-W |

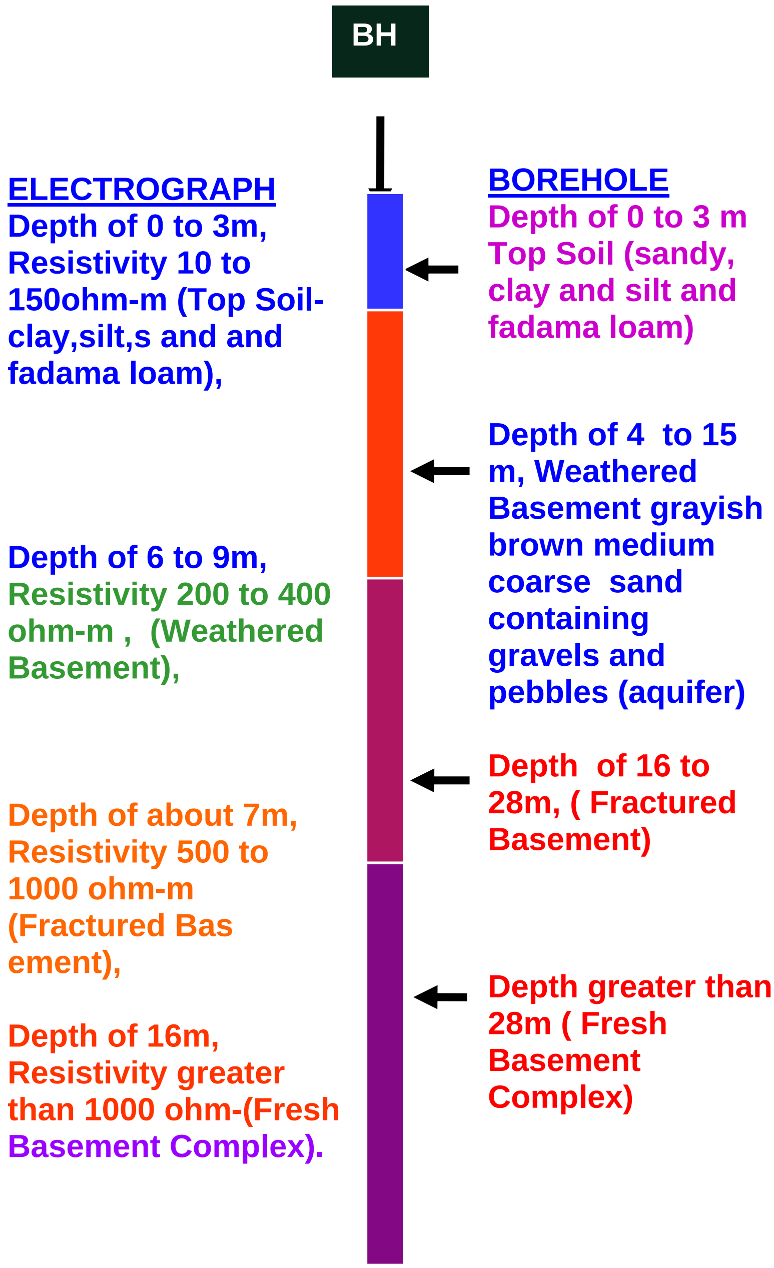


Figure 1: Log Data for a Borehole Located within NBP Campus of Zaria (after Hydro Drilling and Engineering Limited, Zaria, PLC.).

The Terrameter SAS 4000 can operates in three modes:

(i) Resistivity survey mode: It comprises a batter powered, deep-penetration resistivity meter with an output sufficient for a current electrode separation of 2000 meters under good surveying conditions. Discrimination circuitry and programming separates DC voltages, self potentials and noise from the incoming signal. The ratio between voltage and current (V/I) is calculated automatically and displayed in digital form in kiloohms, ohms or milliohms. If array geometry data is available, apparent resistivity can be displayed. The overall range this extends from 0.05 milliohms to 1999 kiloohms.

(ii) Induced Polarization (IP) mode: It measures the transient voltage decay in a number of time intervals. The length of the time intervals can be either constant or increasing with time. The IP effect is thus measured in terms of chargeability (m.sec. v/v).

(iii) Voltage measuring mode: It comprises a self potential instrument that measures natural DC potentials. The result is displayed in V or mV. The overall range extends from 1 μV to 400 V.

## DATA REDUCTION

The apparent resistivity pseudo-section was produced which is an initial very approximate `image' produced by plotting each apparent resistivity on a vertical section at a point below the center of the four measuring electrodes and at a depth that is equivalent to the median depth (Barker, 1989; Edward, 1977). Subsequently, inversion technique is applied to the pseudo-section in order to remove geometrical effects so as to produce the image of the true depth and formation resistivity and plots them as cross-section. The program creates a resistivity cross-section, calculates the apparent resistivities for that cross-section, and compares the calculated apparent resistivities to the measured apparent resistivities. The above task was done by the use of resistivity inversion computer processing software (RES2DINV), (Loke and Barker, 2001). The final output of the inversion software is a resistivity cross-section that can be compared to geological cross-sections.

## 2-D PICTURE OF THE SUBSURFACE

To obtain a good 2-D picture of the subsurface, the coverage of the measurements must be 2-D as well. As an example, Figure 2 shows a possible sequence of measurements for the Wenner electrode array for a system with 20 electrodes.

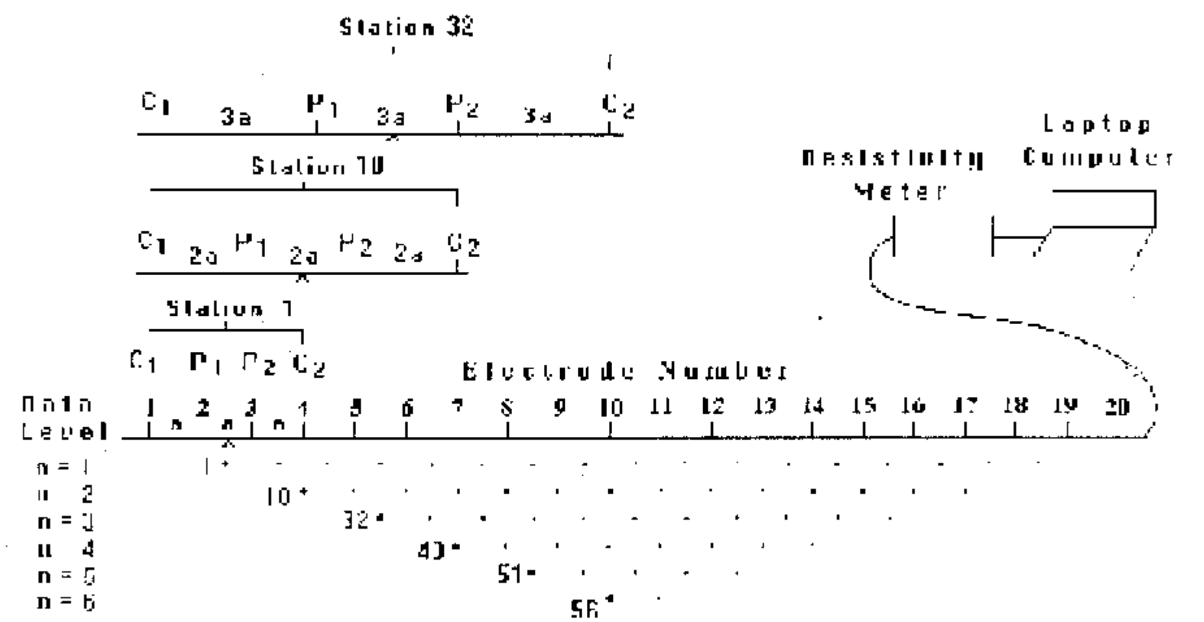


**Figure 2:** The Arrangement of Electrodes for a 2-D Electrical Survey and the Sequence of Measurements used to build up a Pseudosection.

In this example, the spacing between adjacent electrodes is "a". The first step is to make all the possible measurements with the Wenner array with electrode spacing of "1a". For the first measurement, electrodes number 1, 2, 3, and 4 are used. Notice that electrode 1 is used as the first current electrode C1, electrode 2 as the first potential electrode P1, electrode 3 as the second potential electrode P2 and electrode 4 as the second current electrode $C_2$. For the second measurement, electrodes number 2, 3, 4, and 5 are used for C1, P1, P2, and $C_2$, respectively. This is repeated down the line of electrodes until electrodes 17, 18, 19, and 20 are used for the last measurement with "1a" spacing. For a system with 20 electrodes, note that there are 17 (20-3) possible measurements with "1a" spacing for the Wenner array.

After completing the sequence of measurements with "1a" spacing, the next sequence of measurements with "2a" electrode spacing is made. First electrodes 1, 3, 5, and 7 are used for the first measurements. The electrodes are chosen so that the spacing between adjacent electrodes is "2a". For the second measurement, electrodes 2, 4, 6, and 8 are used. This process is repeated down the line until electrodes 14, 16, 18, and 20 are used for the last measurement with spacing "2a" for a system with 20 electrodes. Note that there are 14(20-2x3) possible measurements with "2a" spacing.

The same process is repeated for measurements with "3a", "4a","5a", and "6a" spacings. To get the best results, the measurements in a field survey should be carried out in a systematic manner so that, as far as possible, all the possible measurements are made. This will affect the quality of the interpretation model obtained from the inversion of the apparent resistivity measurements (Dahlin and Loke, 1998).

Note that as the electrode spacing increases, the number of measurements decreases. The number of the measurements that can be obtained for each electrode spacing, for a given number of electrodes along the survey line, depends on the type of array used. The Wenner array gives the smallest number of possible measurements compared to the other common arrays that are used in 2-D surveys.

The survey procedure with the pole-pole array is similar to that used for the Wenner array. For a system with 20 electrodes, firstly 19 of measurements with a spacing of "1a" are made, followed by 18 measurement with "2a" spacing, followed 17 measurements with "3a" spacing, and so on.

For the dipole-dipole, Wenner-Schlumberger and pole-dipole arrays, the survey procedure is slightly different. As an example for the dipole-dipole array, the measurement usually starts with a spacing of "1a" between the $C_1$-$C_2$ (and also the $P_1$-$P_2$) electrode. The first sequence of measurements is made with a value of 1 for the "n" factor (which is the ratio of the distance between the $C_1$-$P_1$ electrodes to the $C_1$-$C_2$ dipole spacing), followed by "n" is equal to 2 while keeping the $C_1$-$C_2$ dipole pair spacing fixed at "1a". When "n" is equal to 2, the distance of the $C_1$ electrode from the $P_1$ electrode is twice the $C_1$-$C_2$ dipole pair spacing. For subsequent measurement, the "n" spacing factor is usually increased to a maximum value of about 6, after which accurate measurements of the potential are difficult due to very low potential values. To increase the depth of investigation, the spacing between the $C_1$-$C_2$ dipole pair is increased to "2a", and another series of measurements with different value of "n" is made. If necessary, this can be repeated with larger values of the spacing of the $C_1$-$C_2$ (and $P_1$-$P_2$) dipole pairs. A similar survey technique can be used for the Wenner-Schlumberger and pole-dipole arrays where different combinations of the "a" spacing and "n" factor can be used.

## RESULTS AND INTERPRETATION

The quantitative interpretation of continuous vertical electrical sounding (CVES) has its limitations similar to that of VES among others which introduce inaccuracy to the final interpretations. Keary and Brooks (1984) identified the following problems;

(a) Interpretation data surfers from non-uniqueness arising from problems known as equivalence and suppression. The problem of equivalence is the difficulty in distinguishing between two resistive layers of different thickness and resistivities where products of these parameters are the same. Similarly, two consecutive layers may not be distinguished if the ratios of their thickness to resistivity are the same. The problem of suppression applies to resistivity curves in which apparent resistivity progressively increases or decreases as a function of electrode spacing. The problem is associated with those layers whose resistivities are intermediate between the resistivities of the enclosing layers. If their thicknesses are small, they will have no practical effect on the resistivity curve for sounding.

(b) The assumption that the resistivity changes in the vertical direction, as well as in the horizontal direction along the survey line and not in the direction that is perpendicular to the survey line may only be reasonable for surveys over elongated geological bodies. Deviation from these assumptions results in error in the final interpretation.

## INTERPETATION

The data analysis for the CVES was performed using resistivity inversion processing software, which performs smoothness constrained inversion (automatic model interpretation) using finite difference forward modeling and quasi – Newton techniques (Loke and Barker 1996). Figures 3 (a – c) are typical CVES electrical image over profile KONBH 7. Figure 3 is the image or model showing true depth and true formation resistivity. These final images are equivalent to the geological sections of the subsurface of the profiles taken. The image is interpreted as shown in Table 2. Similar plots and interpreted model were obtained for each of the other six interpreted CVES profiles.

The interpretation of these images is based on the principle of resistivity contrast, for example, dry materials have higher resistivity than similar wet material because moisture increases their ability to conduct electricity. This resistivity change, if indicated in the observed electrostratigraphy (electrical image), can represent water table depths. Beneath the water table, silt and clay free sands and gravels will have a much higher resistivity than silts or clay under similar moisture conditions due to finer-grained material acting as better conductors.

In bedrock, more competent bedrock with less fracturing typically has a higher resistivity than fractured, less-competent bedrock. Also, very low resistivities could indicate conductive fluids (plumes) or very conductive clays. It is worth noting here that the standards CVES data with the Wenner array has a maximum of ten layers (where the layers thickness are set to a constant using a depth reduction factor of 0.5, a close estimate of the average depth of surveying (Barker, 1989)), plotted in colors to make it easier to see the variations in resistivity which is important as small changes in resistivity in one part of a long profile may be significant even if there is very large variation along the profile. Also, the perception of the plotted data is strongly controlled by the colours, a suitable selection of resistivity limits based on geological reference (borehole log) from the study area was used to optimized the data interpretation.

The resistivity ranges of various rocks materials in the area were compiled from past information (Table 3) after a comparative analysis of material from the north central area of the basement complex (Kano and Kaduna).

**Table 2:** Interpretation of Profile KONBH7.

| Layer No. | Resistivity (ohm-m) | Average Thickness (m) |
|---|---|---|
| 1 | 150 | 3.0 |
| 2 | 450 | 12.0 |
| 3 | 550 | 13.0 |
| 4 | Greater than 1000 | …………….. |

*The average depth to basement at profile KONBH7 is 16.0 m.*

**Table 3:** Materials Resistivity Values used for this Work.

| Rock Type | Resistivity Range(ohm-m) |
|---|---|
| Fadama loam | 20 – 90 |
| Clay, silt and sand | 70 – 300 |
| Weathered basement | 100 – 500 |
| Fractured basement | 501-1,000 |
| Fresh basement | Greater than 1000 |

***Source:*** *Shemang (1990), Olatunji (1999) Dogara and Ajayi (2001), Oahimure (2004).*

## RESULTS AND DEDUCTIONS FROM CVES DATA

For an analytical discussion of the electrical images obtained in this work the following controls were used:

1. Subsurface geological information provided by a borehole on the study site (Figure1).

2. Typical resistivity values compiled from previous works in the area were adopted for various earth materials in this work (Table 3).

3. Rock samples collected from outcrops in the survey area were assumed to be a good representative of the subsurface materials.

It should be noted that there is vertical exaggeration factor of two for Wenner array both in the pseudosection plot and the inverted interpreted image showing true depth and time formation resistivity. This means that the depth scale is multiply by a depth penetration factor of 0.5 for Wenner array. This is done to reflect the average depth of survey and to give a more meaningful interpretation image model.

## DISCUSSIONS

The imaging technique has proved to be a powerful one in investigating the depth to bedrock, depth and thickness of weathered basement, fractured basement and areas with good ground water potential. Six images were measured at different locations of the study area and the results revealed that the subsurface to be mainly of four layers.

The predominant layers are the top soil consisting of clay, silt, sand and fadama loam soil having resistivity as low as 10 ohm-m and a thickness ranging from 1 – 14m. The weathered basement forms the second layer in some with resistivity value between 120 – 500 ohm-m and thickness ranging from 5 – 11m on the average. The next is the fractured basement of thickness between 3 – 6m. The fourth layer is the fresh basement of infinite thickness and resistivity as high as 3495 ohm – m.

These findings agreed with the report of Hydro Drilling and Engineering Company Limited in their search for suitable location for borehole facility on the study site. However, the Image model of the profile taken near the Borehole site clearly shows that its position would has been enhanced if it was sited further down where an aquifer seems promising. Fractured zone associated with thick overburden serves as principal aquifer in the study area. This combination would most likely provide a zone of low resistivity (or high hydraulic conductivity). This layer is confined in nature with ground water occurring under water table conditions. Figures1 and 3 suggest that the basement structure is weathered and depress probably caused by block faulting. This agrees with earlier findings of Shemang (1990), that there exist buried structures such as faults and fractures around west to south-western part of Kubanni basin where this present work was carried out. Hassan et al (1988), also adduced that the deep seated structures is either a basement subsidence due to faulting or an erosional surface. All the images shows lateral variation of resistivity.

Also the images displayed in these figures registered resistivities greater than 1200 ohm-m at the NW, and NE areas of the study site.

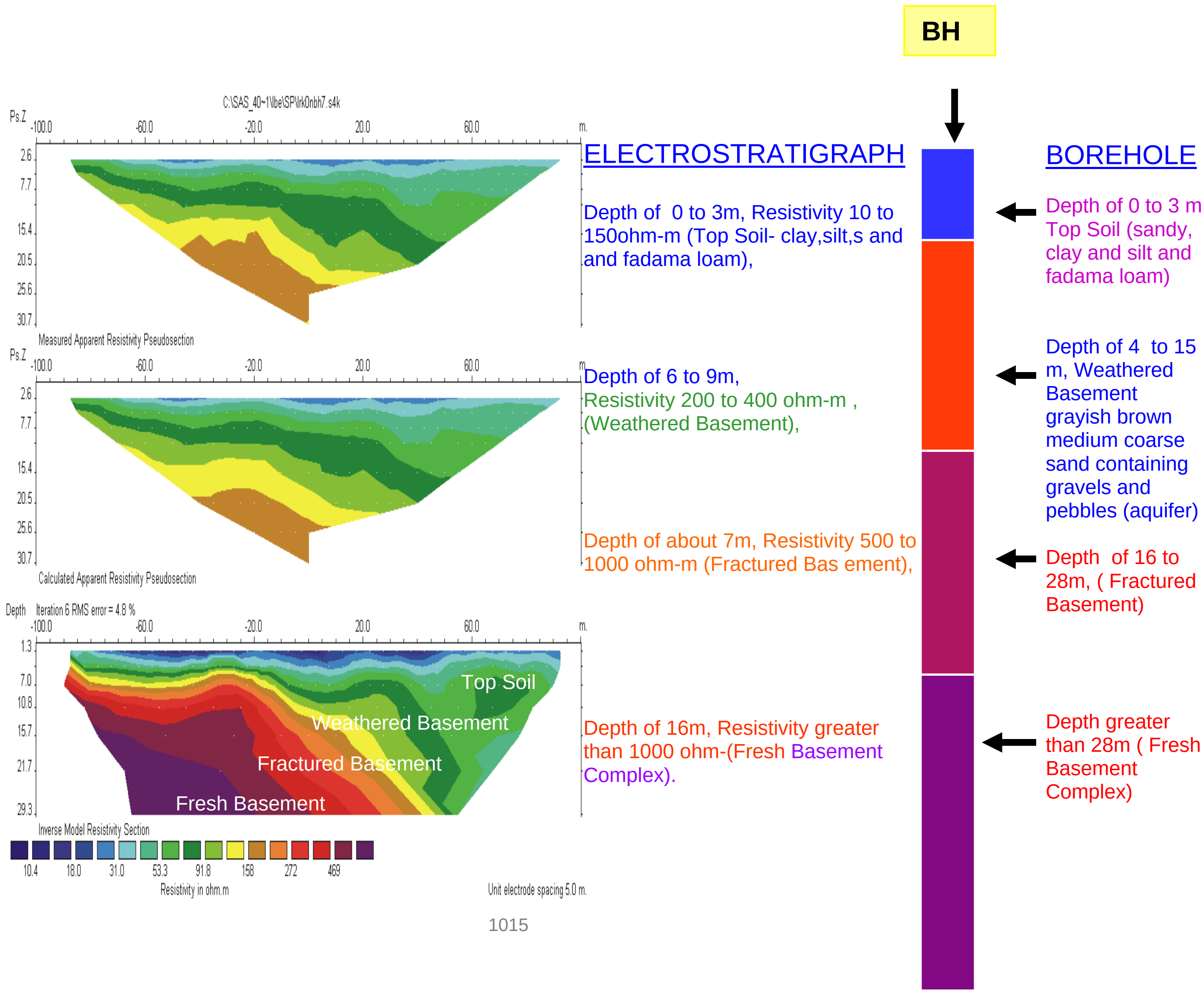


**Figure 3:** Pseudosection Plot and Inverted Model.

This according to Dogara and Ajayi (2001) may suggest likely basement uplift. Aboh (2001) adduced that these basement rocks are fresh and may contain insignificant quantity of water (probably ions in pores).

On the basis of large thickness of weathered basement, fractured zone and resistivities below 200 ohm-m (accepted range of water saturation), Figure 3a (LNE 1) can be recommended as an area of high ground water potentials. This is in agreement with the views of Barker et al (2001).

## LIMITATIONS

1. Profiles were offset to avoid buildings and outcrops.

2. Missing or Bad data points as a result of a bad electrode can distort the real anomaly and affect the interpretation accuracy.

3. Ambiguity in interpretation may yield several models which could account for the observations. This was minimized by comparing the results obtained with previous works within the region, log data of a borehole sited in the study area, and surface rock materials in the area.

4. The inversion process (program software) assumes Two–dimensional geometry in which the resistivity remains constant perpendicular to the profile Line.

5. The program averages resistivity values over data blocks. These blocks range from 5m wide by 3m tall near the ground surface to 5m wide by tall at the base of the profile.

6 The inversion algorithm factors images where neighboring data blocks have similar resistivity values.

## CONCLUSIONS

The study area is underlain by rocks of different lithological compositions viz: the topsoil consisting of clay, silt, sand, and fadama loans, weathered basement fractured and fresh basement rocks.

The depth to basement varies from an average of 12m to 29 m (Figure 3). The south western part of the study area is the most promising for ground water exploration on the criteria of low resistivities, great thickness of weathered basement, and fractured basement.

Figure 3 also shows areas of patches of weathered bedrock of unusually high resistivity values at shallow depths. This may be as a result of material form the earth fissure, (Intrusion of high resistive materials from great depths). The changes in anisotropy signify the tectonic activities of the basement terrain. The areas having these patches are the North – west, North, and North – east of the study area.

## RECOMMENDATIONS

The images measured were randomly chosen at areas yet to be physically developed and along roadsides and there is no record of previous geophysical work done in the study area. Also the selection of resistivity limits for interpretation is to some extent subjective. This will no doubt introduce some level of errors into the results. Base on the above, the following recommendations are made.

1. Areas to be image should be selected using other techniques such as electromagnetic (EM) or resistivity traversing, satellite imagery, or the restricted demands of a local community.

2. Electrical imaging should be combined with rapid electromagnetic traversing technique. This will produce better results than employing only the electrical imaging system.

3. Since the number of data points on a given profile depend on the type of the array used and the more the data points, the more accurate the interpretation, then the Wenner-Schlumberger and Dipole-Dipole arrays should be used to carry out further geophysical survey on the site as they will produce more data points on a profile than the Wenner array.

4. Seismic refraction and magnetic methods can be used to compliment the present study as the combination of methods will provide more detailed information in the investigation of the nature of subsurface materials and in determining depth to bedrock.

5 The result should be put into consideration in future siting of borehole in the area.

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