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DELINEATION OF ALL-SEASON-RECHARGED GROUNDWATER RESERVOIR FROM TWO VALLEYS, ZARIA, NIGERIA

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The dependence on boreholes and hand-dug wells for water is increasing rapidly in Zaria, Nigeria, because of the inability of Water Works Department in the area to meet the water consumption requirement of the people. Almost all the boreholes and wells in the area fail to yield during dry seasons due to drastic reduction in groundwater table. This results in acute water shortage in the area. Virtually all the boreholes are located outside of valleys. Electrical resistivity tomography was conducted in the vicinity of two valleys in the area to delineate their underlying aquifer zones. The data were collected along five profiles laid perpendicular to the valleys' strike. The data were tomographically inverted. Interpreted results show that the resistivity ranges of the bedrocks on either side of each of the valleys differ significantly which suggests sharp differences in the properties of the bedrocks on either side of the valleys. It suggests contacts of different rock blocks at the valleys' floors. The results also suggest that the basement on either side of each of the valleys slopes towards the valleys' floors. The basement underlying the valleys' floors is characterized by fault zones between the different rock blocks that are identified on the tomograms as low resistivity zones flanked by high resistivity zones. The resistivity ranges within the fault zones suggest that they are aquifers. The results generally suggest that the valleys in the Zaria area most likely have tectonic origins with fault zone aquifers. The study infers that aquifers which underlie the valley floors are most likely recharged during all seasons compared to those outside the valleys.

INTRODUCTION

The Zaria area, north western Nigeria, in recent years has witnessed high population growth. Based on the population census of the Federal Republic of Nigeria, the population of Zaria Metropolitan Area, comprising Sabon Gari, Zaria and Giwa Local Government Areas, has grown from about 679,446 in 1991 to 981,496 in 2006 (Federal Republic of Nigeria, 2007). This high population growth is owing to the establishment of many tertiary institutions and research institutes in the area by Nigerian Government. Zaria is an important centre of education and research, with Ahmadu Bello University and affiliated institutions such as the Institute for Agricultural Research, National Animal Production Research Institute, Federal College of Education and National Research Institute for Chemical Technology located in it. It is also the site of the Nigerian Civil Aviation Training Centre and Nuhu Bamali Polytechnics. Therefore, people from all parts of Nigeria and some foreigners converge to study or work in these institutions. The high population density in the area has resulted to high infrastructural demand. One of the infrastructures in high demand in the area is water. In the urban and semi urban cities in the area the tertiary institutions and research institutes are in high demand for water for their daily activities. In the rural places in the area, farmers are in high demand for water for their livestock and irrigation farming. According to Baba (2007) and Ahmadu Bello University, Zaria (2008) the unit water demand of the people of Zaria Metropolitan Area is 0.1 m^3/d.

In Zaria Area, piped water was the major source of water followed by boreholes and hand-dug wells. The source of the piped water is Zaria Dam which was inaugurated in 1975. The dam presently has capacity of supplying 16000 m^3 of water per day. This does not meet the daily water demand of the residents of Zaria Area. Also, inadequate electric power supply to water treatment plant of Zaria Water Board makes it impossible for the plant to operate at it maximum capacity. These and other similar factors most likely are responsible for the acute water scarcity experienced in Zaria Area in recent years. In order to ameliorate this condition, residents of the area massively embark on drilling boreholes and sinking hand-dug wells.

Generally water table is shallow in the area. Garba and Schoeneich (2003) observed from repeated water level measurements from twelve hand-dug wells in the area that the depth to water table ranges between 1.0 m and 8.7 m below ground level in wet season and between 5.0 m and 13.7 m below ground level in dry season. Most of the boreholes and hand-dug wells in the area fail during dry seasons and this could be owing to drastic reduction in groundwater table and this results to acute water shortage in the area. A number of measures have been adopted or suggested to ameliorate the acute water shortage in the area. For example, Ahmadu Bello University (ABU), Zaria, which is the biggest institution in the area, recently constituted a committee on Protection of the Kubanni Dam Drainage Basin whose responsibility was to carry out measurement of the remaining storage in Kubanni impounding reservoir and to make proposal for upgrading the environment in Kubanni Drainage Basin. However, the result expected from the ABU's measure will only be beneficial to ABU community and not to entire Zaria Area.

Some hydrogeologists in Zaria had suggested that the high rate of drying up of wells in Zaria Area is caused by technical faults and inadequate skills of drillers. Adequate measures have been taken to guide against these factors most recently. In spite of the measures taken, the wells are still not yielding during the peak of dry seasons. There is a factor which has received little or no emphasis and consideration in guiding against very poor wells' yield during the peak of dry seasons. Before 1970, geologist in Zaria area had observed that outside the vicinity of valleys, wells are dug to the water table which falls progressively throughout the dry season; the amount of fall depending on the location. Wright and McCurry (1970) observed that since the removal of water from the wells is principally for domestic uses and probably of negligible overall importance, the fall is mainly due to surface percolation of water through to the larger river valleys. Wright and McCurry (1970), Garba and Schoeneich (2003) and Ahmadu Bello University, Zaria (2008) had all observed that wells sited closer to valleys in Zaria area are of higher yield than those sited away from the valleys. However, this conclusion was based only on mere inspection and measurements of depth to water table made on hand-dug wells. There is need to carry out geophysical studies in the vicinity of valleys to confirm the conclusion made in the foregoing. Also, the ground water potentials in Zaria area had been mapped by some researchers using geophysical methods. The researches include those of Olowu (1967), Messrs Preussag Ltd (1981 – 1982), Adanu (1987), Shemang (1990), Olatinwo (1994) and Hydro-Skill and Engineering Services, Kaduna (2005). Most of the boreholes and hand-dug wells sited at the places these researchers had delineated as aquifers failed to yield at the peak of dry seasons. It was generally observed that none of these researches was conducted in the immediate vicinity of valleys. This present study was conducted in the immediate vicinity of valleys with the aim of delineating aquiferous zones which most likely yield in all seasons in Zaria area.

THE STUDY AREA

Zaria area is bounded approximately by longitudes 7º 12' to 7º 47' E and latitudes 11º 03' to 11º 11' N. It is located on a plateau at a height of about 670 m above sea level and more than 640 km away from the sea (Hore, 1970). The area is located within the sparsely populated Guinea Savannah. It has a typical savannah climate of distinct wet and dry seasons, with a moderate rainfall of about 1047 mm/a (Garba and Schoeneich, 2003). The rainy season usually starts in May and ends in October and the dry season lasts from late October to April.

This study involved geophysical measurement in the vicinity of two valleys in Kubanni Basin (Figure 1), Zaria, Nigeria. The Kubanni Basin is characterized by high concentration of valley networks. Most of the valleys in the basin are dry. Others are seasonal except the Kubanni River itself. Almost all the tertiary institutions in Zaria area are located in the Kubanni Basin. The settlement within the basin has the highest population in Zaria area with over 300,000 people living there (Federal Republic of Nigeria, 2007).

One of the valleys (Figure 2), referred to as north–south (N-S) valley in this study, is about 2.30 km long and has an average width of about 15.00 m. It has approximately a north-south strike with its southern end approximately perpendicular to a long east-west valley through which Kubanni River flows. The portion of the valley studied lies between latitudes 11º 08' 30.0'' N and 11º 09' 09.8'' N and between longitudes 7º 39' 41.9'' E and 7º 39' 42.6'' E.

The second valley (Figure 3), referred to as east–west (E-W) valley in this study, is a tributary or branch of the north - south Valley. It is about 230.00 m long and has an average width of about 15.00 m. It has approximately a west-east strike. Its eastern end has confluence with the north-south valley almost perpendicularly at about 500.00 m from the northern end of the north-south valley. The valley lies between latitudes 11º 08' 52.9'' N and 11º 08' 53.9'' N and between longitudes 7º 39' 28.6'' E and 7º 39' 36.4'' E.

GEOLOGY AND HYDROGEOLOGY OF ZARIA AREA

The area belongs to the Precambrian basement complex of northern Nigeria. It is composed of three rock types which include gneiss, porphyritic granite and medium grained granite. The porphyritic granite and medium grained granite were intruded into the gneiss during the Pan

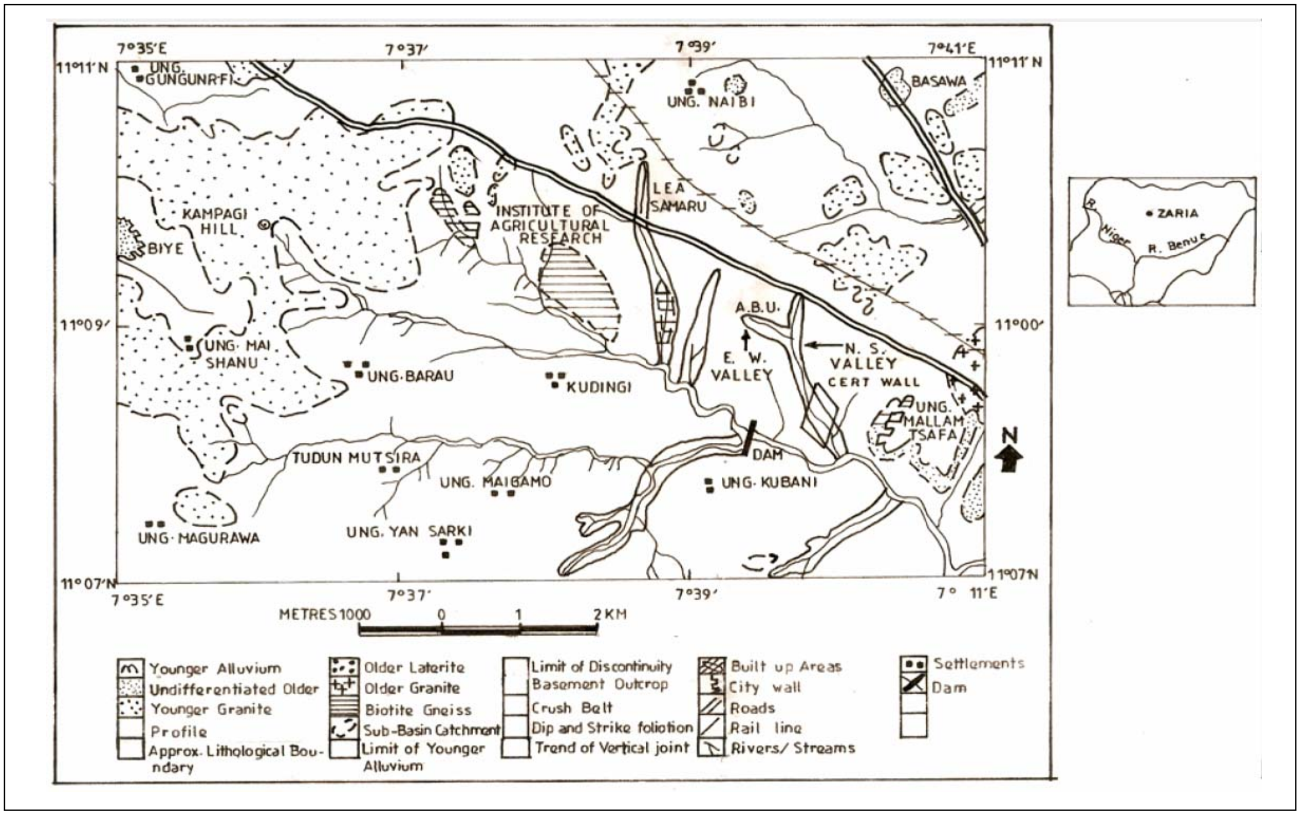

Figure 1. Location of the north-south (N-S) and east-west (E-W) valleys on the map of Kubanni Basin, Zaria, Nigeria (adopted from Geology Department, Ahmadu Bello University, Zaria).

African (McCurry, 1973; Garba and Schoeneich, 2003). The greater part of the area is covered with thick regolith mainly derived from in-situ weathering of the basement rocks.

According to Garba and Schoeneich (2003) and Ahmadu Bello University, Zaria (2008), there are two types of aquifers in the area: (a) the regolith (soft overburden) aquifer and (b) the fractured bedrock aquifer. The regolith aquifer is the main aquifer and the only available source of water to the majority of the population via hand-dug wells. This type of aquifer varies in thickness from 0 m (on outcropping solid rocks) to a maximum of 50 m (Adanu, 1987) depending on the local geology, topography and the climate of the area (McCurry, 1973).

METHOD OF STUDY AND DATA COLLECTION

Four profiles (L1, L2, L3, and L4) perpendicular to the strike of the north-south valley (Figure 2) and almost equally distributed along its length were established for the study. Similarly, one profile (L5) perpendicular to the strike of the east-west valley (Figure 3) and located almost mid way of its length was established.

An ABEM Multichannel Terrameter, model SAS4000 (ABEM Instrument AB, Terrameter SAS 4000 / SAS 1000, 1999) aided with an Electrode Selector, model ES464 (ABEM Instrument AB, Lund Imaging System, 1999) was used for the data collection along the profiles. The length of each profile is 200 m and the centre of each spread is located at the floor of each of the valleys. The electrodes were placed in a straight line at 5 m interval along each profile. In this study, WEN32SX protocol file (Continuous Vertical Electrical Sound with two cables) was used for data collection. The Continuous Vertical Electrical Sounding (CVES) is a 2D resistivity prospecting method which yields information about both the lateral and vertical resistivity distribution of the earth's

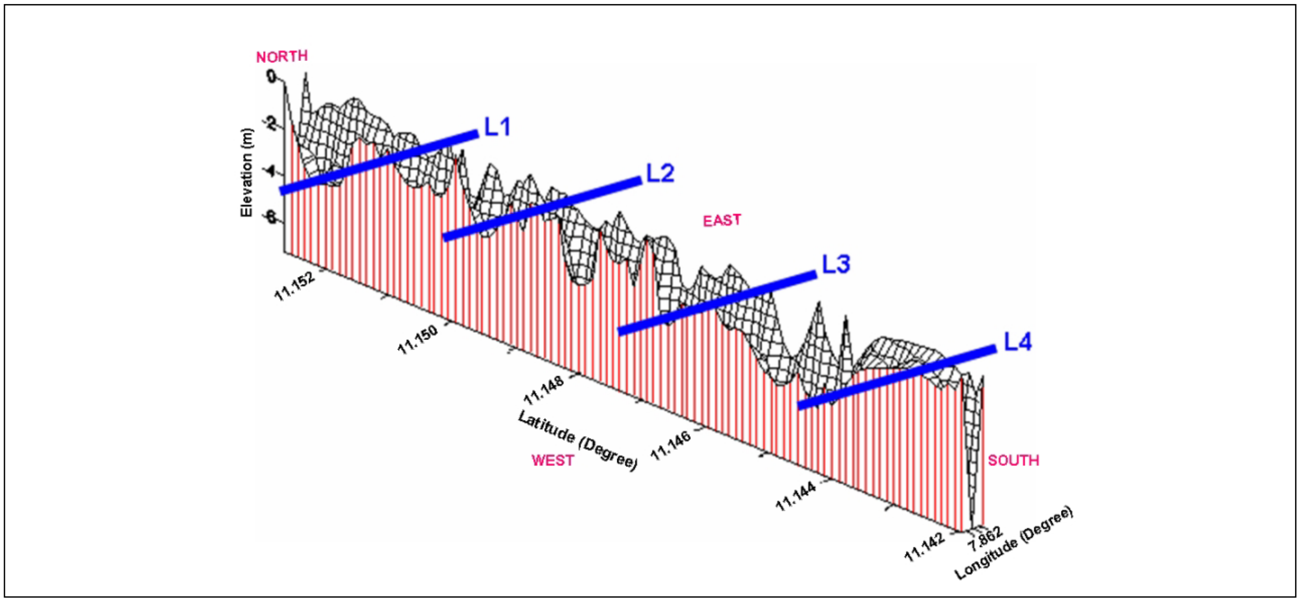

Figure 2. The north-south valley showing topography variation along its flanks and the profiles where data were collected (the north south valley is as shown in Figure 1).

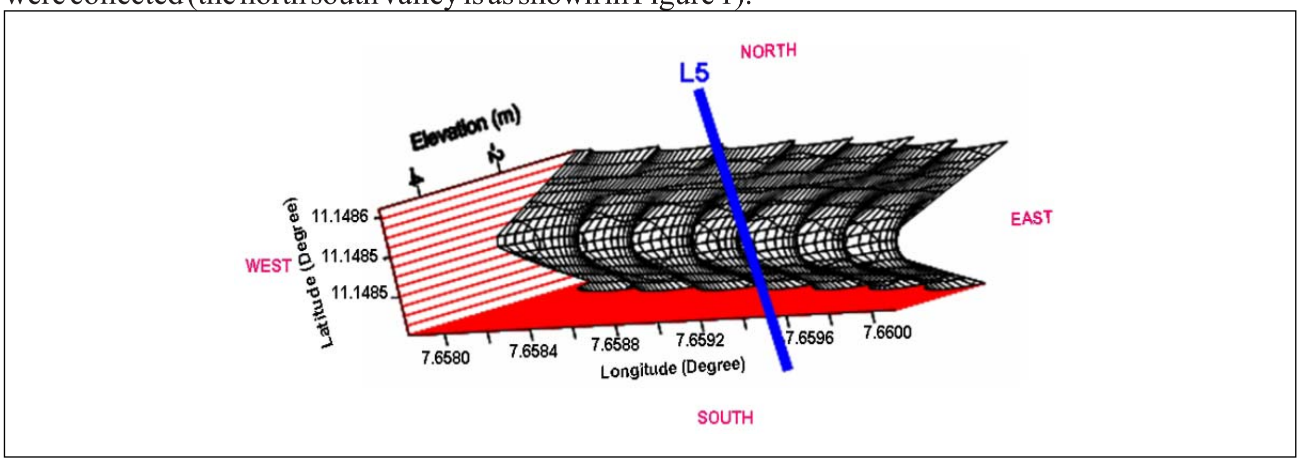

Figure 3. The east-west valley showing topography variation along its flanks and the profiles where data were collected (the east-west valley is as shown in Figure 1).

subsurface. It can therefore, be used for the identification of structures and buried depths of features at shallow depths.

DATA PROCESSING AND RESULTS

The raw field data was processed using RES2DINV Software (RES2DINV Ver. 3.4, 2001). The RES2DINV Software is a computer program that automatically determines a two dimensional resistivity model of the subsurface for the data obtained from electrical imaging survey (Griffiths and Barker 1993). After reading the data from a text file, they were edited to exterminate bad data points. The edited resistivity data were tomographically inverted. The results of the inversion of the resistivity data over two of the profiles on the north-south valley and over the profile on the east-west valley are shown in Figures 4, 5 and 6 respectively. To arrive at plausible interpretations the geology of the study area was considered and used to place control in the interpretation. Also, a log of the nearest borehole to the valleys (determined in 2005 by Hydro–Skills and Engineering Services Limited, Kaduna, Nigeria) which is located at approximately latitude 11° 09' 11.0'' and longitude 7° 39' 48.0'' or about 70 m in the north–west of the north-south valley was used to place additional control on the interpretations. The log of the borehole is placed by the side of each pseudosection (Figure 4-6).

The results show the presence of low resistivity zone at the centre of each of the spreads, corresponding with the floor of each of the valleys and which extends beyond 40 m depth. The low resistivity zone is flanked by high resistivity zones on both sides. However, the average resistivity range of about 6007–20000 Ωm of the high resistivity zone on the eastern side of the north-south valley is significantly higher than the average resistivity range of about 1250–3750 Ωm of the high resistivity zone on the western side of the north-south valley. Similarly, the average resistivity range of about 3920–5150 Ωm of the high resistivity zone on the northern flank of the east- west valley is significantly higher than the average resistivity range of about 1400–3920 Ωm of the high resistivity zone on the southern flank of it. The results also suggest that the basement on either side of each of the valleys slopes towards the valleys' floors.

DISCUSSION

The results of the tomographic inversion of the resistivity data over the study area have suggested that the minimum depth to the basement in the area is about 5 m while the maximum depth is over 40 m. These results agree well with the results of previous works in the Zaria area. For example, Olantinwo (1994) deduced that the depth to the basement in the Zaria area ranges from about 1 m to 65 m and according Shemang et al. (1992), the depth to the basement in the area varies from 3-44 m. The maximum basement depths are seen on the pseudosections to occur at the floors of the valleys.

The resistivity tomography inversions have shown on all the profiles that there are zones of low resistivity flanked by high resistivity structures. These low resistivity zones correspond with the floors of the valleys and these are flanked by high resistivity basement structures in the subsurface of the valleys' walls. The presence in the basement of low resistivity zones flanked by high resistivity zones on the tomograms suggests the presence of fault zones in the basement oriented mainly in the direction parallel to the axes of the valleys.

The results of the tomographic inversion of the resistivity data suggest that the resistivities or properties of the basement rocks on either side of the valleys differ significantly. This further suggests that the bedrocks underlying the valleys are characterized by rocks of different lithology separated by elongated rock contacts. The areas of contact most likely constituted weak zones that facilitated the inferred fault zones. These faults facilitated the grabenation of the rock block in-between them which resulted to the formation of the valleys. Hence, the valleys in the area generally are most likely fault controlled. This further suggests that the valleys in the Zaria area are of geotectonic origin. The fault zones constitute aquifers with average resistivity range of about 8-155 Ωm and since the wells in Zaria area are phreatic in character especially in the recharge areas (Garba and Schoeneich, 2003) the recharging of the fault zones is most likely facilitated by the basements which slope into the faults. The results have shown that the thickness of the inferred fault zone aquifers exceed 40 m and this in general is much greater than the thicknesses of the aquifers in areas of higher elevations in Zaria area which have been delineated by other researchers (Robinson, 1985, Adanu, 1987, Shemang 1990, Olatinwo 1994 and Garba and Schoeneich, 2003).

The N-S and E-W trends of the faults delineated in this work agree well with the general trends of the faults in Zaria area, suggested by Oluyide and Udoh (1989) in their work on fracture systems in Nigeria. Early workers in the Kubanni valley have inferred the presence of deep, well developed faults and fractures in the area. Between 1981 and 1982, Messrs Preussag Ltd carried out a resistivity survey in Jamaa Kubanni village with the aim of siting a borehole in the village. They

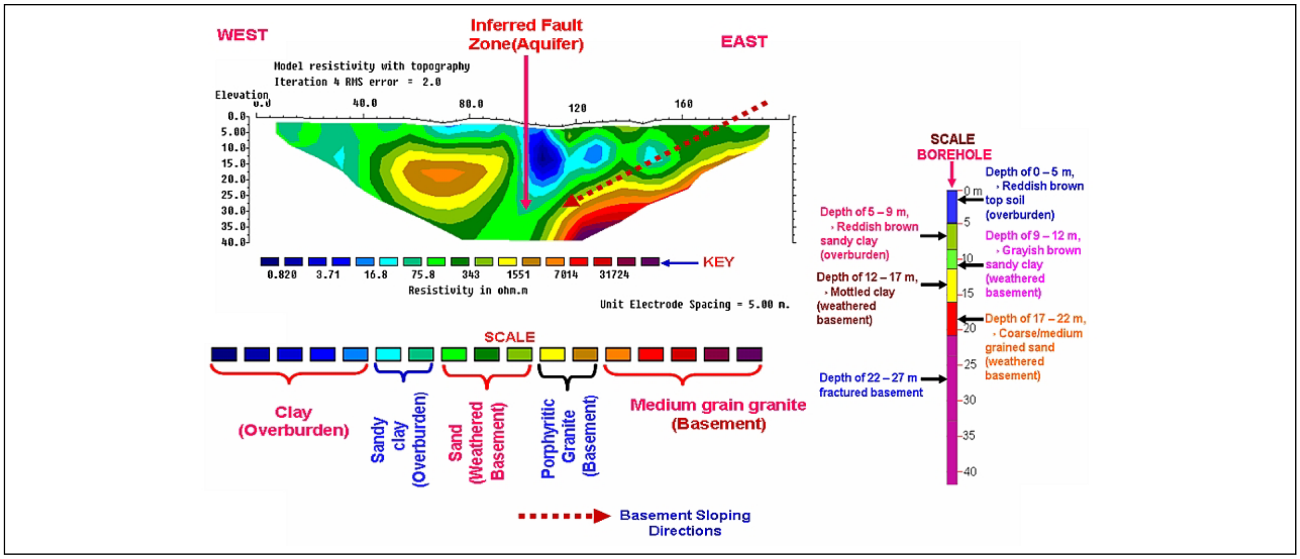

Figure 4. Geologic interpretation of geoelectric section for profile L1.

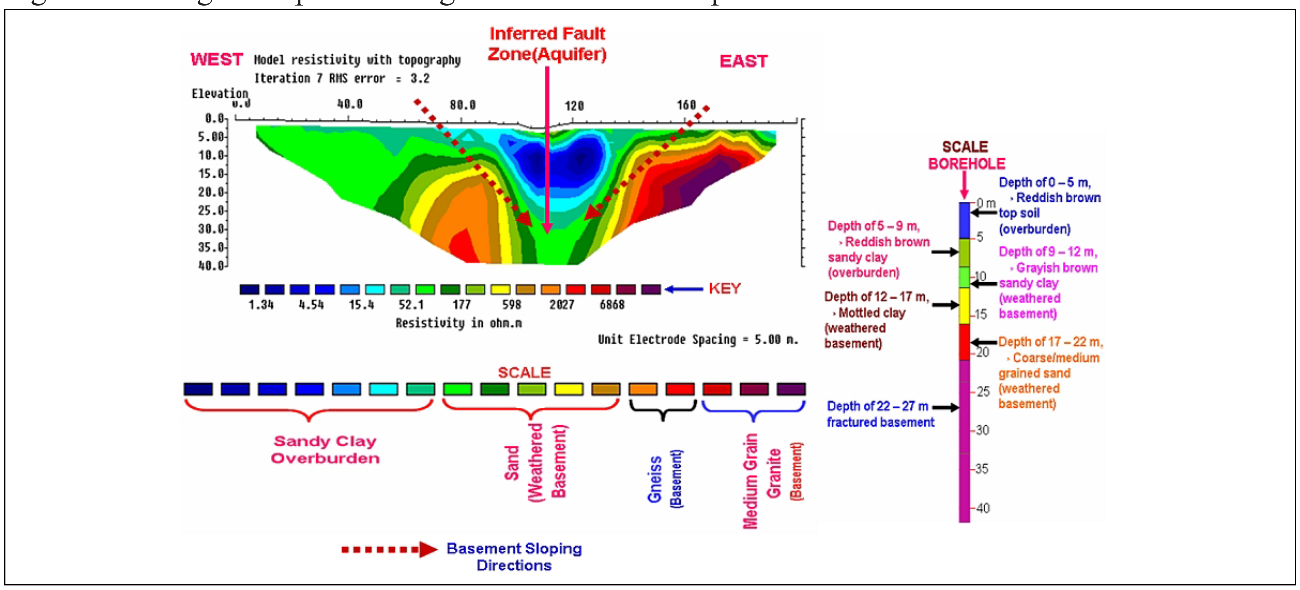

Figure 5. Geologic interpretation of geoelectric section for profile L4.

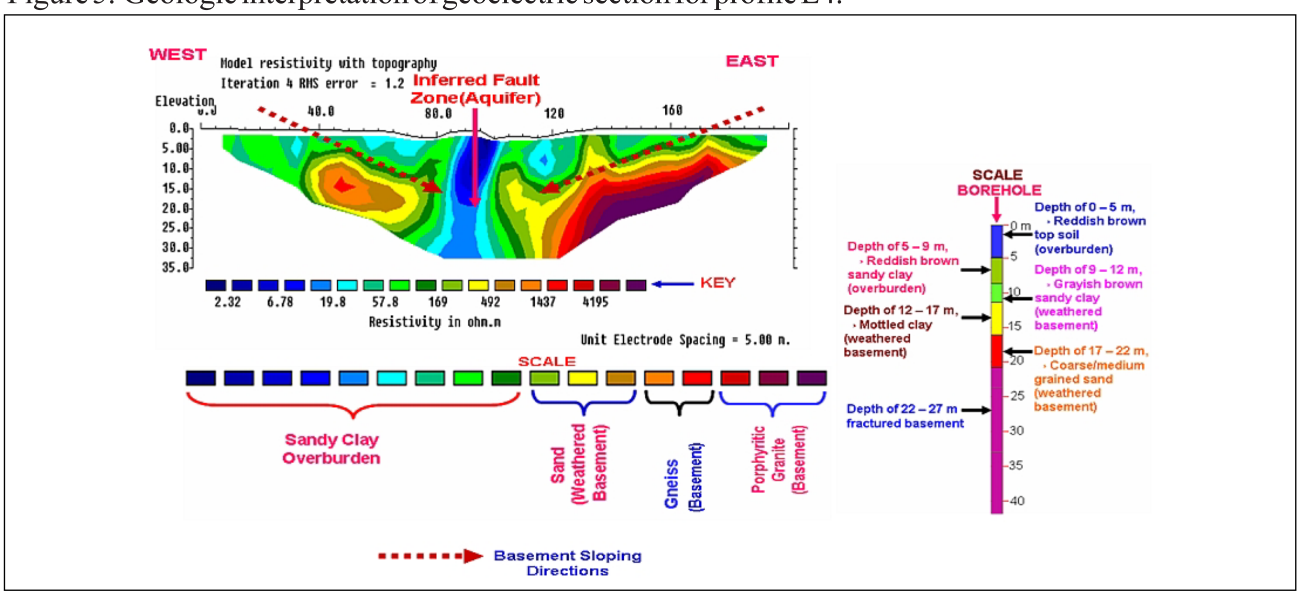

Figure 6. Geologic interpretation of geoelectric section for profile L5.

inferred from the results of their resistivity data the presence of faults within the bedrock which have caused the downthrow of certain portion of the bedrock, especially, in the south-east part of the area.

This study has delineated the elongated contacts of rocks of different lithology underlying the floors of the valleys in Zaria area. Similar contacts of rocks of different lithology have been reported in Zaria area by earlier researchers (McCurry, 1970, Webb, 1972 and Shemang, 1990). While McCurry, (1970) suggested that the contacts are gradational, Shemang, (1990) suggested that the contacts are sharp and not gradational.

CONCLUSION

This study has delineated the potentials of the bedrocks underlying the floors of the valleys in Zaria area, Nigeria, in solving the perennial water shortage in the area. The bedrocks underlying the floors of the valleys in Zaria area have the following characteristics:

(a) the bedrocks are made up of rocks of different lithology, separated by elongated rock contact and fault zones.

(b) the inferred fault zones constitute aquifers with average resistivity range of about 8–155 Ωm.

The aquifers have the potentials of yielding in all seasons in Zaria than those aquifers located on higher elevation because of the following characteristics:

(i). the thicknesses of the aquifers underlying the valleys' floors are much greater than the thicknesses of the aquifers underlying the areas of higher elevations in Zaria area which have been delineated by other researchers.

(ii) the recharging of the fault zones underlying the floors of the valleys is most likely facilitated by the basements which slope into the fault zones.

These characteristics favour continuous yielding of aquifers. The problem of acute water scarcity in Zaria area, resulting from wrong siting of wells and boreholes may likely be solved when the wells and boreholes are sited at areas of low elevation such as valleys' floors. The aquifers in these areas have the potential of yielding in all seasons.

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