



Geoelectric Investigation of the Subsurface Structures in Part of Gidan Kwano Campus of the Federal University of Technology, Minna, Nigeria

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ABSTRACT

Geoelectric investigations of the subsurface structures of parts of the Gidan Kwano campus Federal University of Technology (F.U.T) Minna, Nigeria were carried out using vertical electrical soundings technique. The area lies within the Pre-Cambrian Basement Complex of Northern Nigeria. This study was carried out with the aim of determining subsurface structures of the area for groundwater potentials and to possibly locate those areas that could be useful for civil engineering work at a very low risk. Thirty-six vertical electrical soundings along six profiles (A-F) were carried out during the geophysical survey. The survey was carried out on grid 500m x500m. The data obtained were interpreted using computer based program named Zohdy. The result of the interpreted vertical electrical soundings (VES) curves reveals three distinct geo-electric curves types were delineated: K, H and HK-curves with H-type having the most prolific aquifer. The result also shows 3 geo-electric layers which were confirm by borehole lithology. The aquifers in the study area are likely to be found in the fractured basement layers of eastern and southeastern parts of the study area. The civil engineering work can be sited in the northern and southwestern parts of the study area which are the region of shallow basement.

KEYWORDS: Minna, Vertical Electric Sounding, Aquifer, and Precambrian Basement Complex

1.0 INTRODUCTION

The Federal University of Technology, Gidan Kwano Campus, Minna, is located at Kilometer-12 along Minna, Kateregi, Bida Road (Fig. 1). The study area is located within F. U. T Minna, Gidan Kwano campus, and is in between Works Maintenance Department and staff quarter. Federal University of Technology, Gidan Kwano Campus, Minna, is known to be part of Minna N/W sheet 42, on a scale of 1:250,000. It lies between latitude 9° 20'N and 9° 37'N and longitude 6° 23'E to 6° 29'E. The site covers an area of about 250,000 square meters.

The growth of any locality depends on availability of basic infrastructural needs such as roads, water, electricity and industries among others. According to

Eduvie (1998), the Northern Nigeria parts are associated with annual rainfall of about 1000-1500 mm as well as few months of rainfall yearly and the surface water sources are often inadequate or non-existent for domestic, agricultural and industrial uses.

There is need for scientific identification of parameters governing ground water resources, assessment and management, particularly, if satisfactory living conditions of the inhabitants are to be catered for. This is paramount, due to the presence of five (5) Faculties of the Federal University of Technology, Minna on Gidan-Kwano Campus; there is an increasing demand for portable water supply to complement the existing one on the campus and the need to conduct hydrogeophysical survey of the area

in order to provide useful information on the possible sites for ground water exploration. Actually, the aim of vertical electrical sounding is to determine the variation of electric conductivity with depth, hence it has been the most important geophysical method of water prospecting in area of deep in situ weathering of fresh bedrock. The geoelectric resistivity method, particularly the (VES) method has been chosen for this particular work basically, because it has proven to be an economic, quick and effective means of solving most ground water problems in different parts of the world (Zohdy and Jackson, 1969; Frohlich, 1974; Chinwuko et al. 2015 and 2016). The VES method is also used to estimate the thickness of the overburden as it is presented in this work (Parasnis,1987).

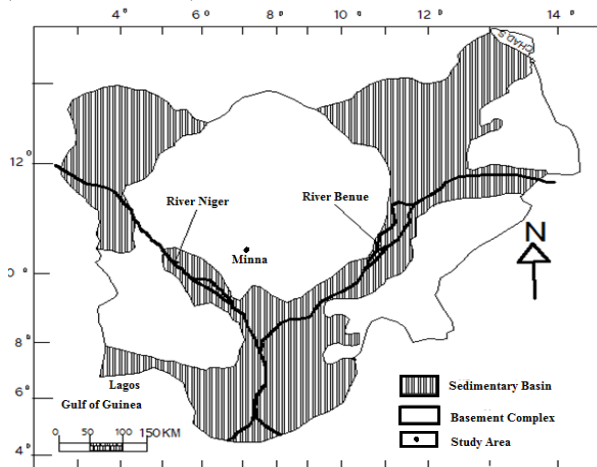


Fig. 1. General Geologic Map of Nigeria showing the location of the study area (GSN, 1999).

1.1 GEOLOGY OF THE STUDY AREA

The study area lies within the basement complex of Nigeria (Fig. 1). Basement complex of Nigeria lies within Pan Africa belt of West Africa Craton, which was affected by a major organic event about 600 my ago (Pan –Africa Orogeny). MC Curry (1976) described the rock in Minna and named them as older granites, schist and migmatite gneiss complex. Actually, the northern part of Gidan Kwano Campus,

Federal University of Technology, Minna, lies within the Northern Nigerian massif subdivision of the basement complex of Nigeria. But there are other subdivisions, which are West African Massif, Adamawa Sadanna Massif and Uban Massif. The Northern part of Gidan Kwano Campus, F.U.T. Minna, is also on the South Western portion of Northern Nigerian Massif. Eight-N-S trending schist belts have been recognized in the western portion of the Northern Nigerian Massif. According to (Ajibade, *et al.*, 1976), the schist belts are separated by migmatite- gneiss complex and older granites.

The rock types found here are believed to be part of the older granite suite and are mostly exposed along the river channel where they appear in most cases weathered. Based on relative grain size, the major rocks types are:

1. Porphyritic to coarse-grained granite:- this is mostly found outcropping along the river channels. They are believed to continuously underlay the region that is covered by thick overburden. They are mostly flat lying and ranges in sizes from few meters. North-South (N-S) trending quartz and aplitic veins ranging in length the outcrops are broken into boulders, which could be attributed to biological weathering.
2. Medium to fine grained granite: - these are flat lying out crop along the river channels and relatively high rising elongated outcrops on the surface, these are fresher (less weathered) compared to the first type. The rocks are found in East-West (E-W) trending vein and joints, which are at times filled by aplites or quartz. The rocks are in some places broken into boulders, and show the effect of weathering in form of colour change, and loose rock fragment.

2.0 METHODOLOGY

In this study the data collected were basically collected from main measuring mode of the Terrameter SAS 4000 (Resistivity). The profiling data were collected using Wenner electrical profiling method. 10m-electrode spacing was used and this corresponds to 15 m probe depth. Care was taken to ensure that the electrode layout follow a straight line along the N-S profile layout. Similarly, Schlumberger method of electrical sounding was employed for electrical drilling (VES data). The maximum current electrode separation of 200 m and potential electrode separation of 30 m were reached and this corresponds to 100 m probed depth (i.e. AB/2). There was no need for data reduction or repeated measurement since the receiver of SAS 4000 discriminates noise and measures voltages corrected with transmitted signal current. The system has the built-in function to average the best measurement of maximum of four staking with the standard deviation of unity or even less (ABEM instrument AB, 1999). The field layout is shown in Fig. 2.

The apparent resistivity values acquired from the measurement were plotted against half the current electrode spacing on a bi-

logarithmic graph in order to determine the apparent resistivities and thicknesses of various layers penetrated. Some many researchers have written on the need and uses of Schlumberger method in groundwater investigation (Zohdy and Jackson, 1969; Udensi, and Salako, 2005; Mohammed, 2007; Anakwuba *et al.*,2014; Chinwuko *et al.*, 2015; Osele *et al.*, 2016; Chinwuko *et al.*, 2016 and others). An iterative software computer program called the Zohdy graphical method was used to interpret the data (Zohdy and Bisdorf, 1989). This software performs automatic interpretation of the Schlumberger sounding curves which gives the equivalent n-layer model input from the apparent resistivity data of each sounding point. It converts the apparent resistivity as a function of electrode spacing to the true resistivity as a function of depth in two dimensions. The profile data were processed using computer iterative window-based application software called surface 8.0, from Golden software (2002) and Minitab 14, which gives a graphical presentation of the contour map. The software generates the resistivity contour map of both contour map and profiling data.

Table 1: Show the Profile Layout along which the Data were collected

	A1	A2	A3	A4	A5	A6
Works Dept.	B1	B2	B3	B4	B5	B6
N	C1	C2	C3	C4	C5	C6
	D1	D2	D3	D4	D5	D6
	E1	E2	E3	E4	E5	E6
Staff ↑ Quarters.	F1	F2	F3	F4	F5	F6

3.0 RESULTS AND DISCUSSION

3.1 Results of the VES Interpretation along the Profiles

From the digitized Zohdy curves (Fig.3), visual inspection of the curves based on their distinct geo-electric characteristics were used

to classify the curves types in the following order:

Group A: (K-type); The group consists of curves with 3 layers $\rho_1 < \rho_2 > \rho_3$ and there are few types in the study area, covering about 10% of the VES points (A6, A5, B5, B6, E2, E3, E3, F5 and F6) most of which have marked characteristics of water bearing formation (aquifer) because of its thick weathered layers.

Group B: (H-type) the group is made up of curves having 3 layers with $\rho_1 > \rho_2 < \rho_3$ and typical of VES locations (A1, A5, A4, B3, B5, C3, C5 and D6) which are either weathered or partly weathered layer. This layer is also potential aquifer

Group C: (HK-type); the group consists of curves with 4 layers $\rho_1 > \rho_2 < \rho_3 > \rho_4$ and there are few types in the study area. It has very limited aquifer potential.

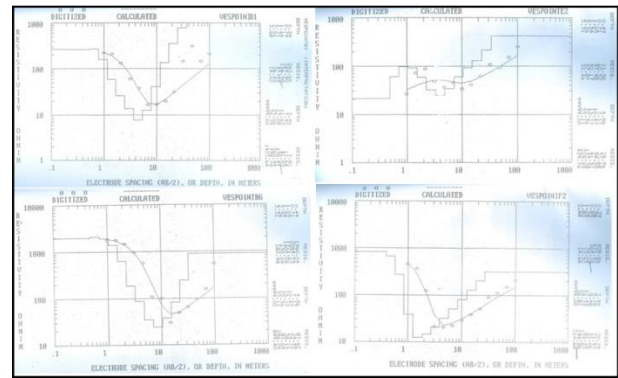
Table 2 contains the summary of the VES interpretation along some representative profiles. From the general interpretations (from Profile A-F), the following deduction could be made: the first layers have the resistivity value range from 19.25 Ωm to 2170.65 Ωm . It is highest at A5 (profile A

Geo-electric sections with geology

According to Jimoh (1998), there are three Lithological units that are found with FUT Minna axis from the borehole logs he produced after boreholes were drilled within the area (Fig. 4) and the following deductions were made from Jimoh (1998):

1. The first layer consists of weathered lateritic with thickness between 0.0 m -10.0 m.
2. The second layer consists of weathered basement with thickness between 10.0 m to about 28.0 m. The areas of fracture have good aquifer potential.
3. The third layer is the fractured basement and fresh basement which

VES point-5) and lowest at A1 (profile A VES point-1); the second layers have resistivity value from 21.31 Ωm to 4103.91 Ωm . It is highest at F5 (profile F VES point-5) and lowest at B3 (profile B VES point-3); the third layers have resistivity value range from 98.86 Ωm to 6229.26 Ωm . It is highest at D6 (profile D VES point-6) and lowest at C2 (profile C VES point-2). More so, the shallowest basement occur at F5 (2.32 m) and deepest at B3 (33.11 m). Thinnest topsoil thickness of 0.34 m occurs at F5 while the thickest topsoil of 2.03 m thick which occurs at VES A6.



constitutes the bedrock of the area and has infinite thickness.

Furthermore, Hockney (1986) wrote that it takes several thousand years before the geologic history of an area can change. Taking this into consideration, the geologic sections for profiles A to F can be deduced as follows:

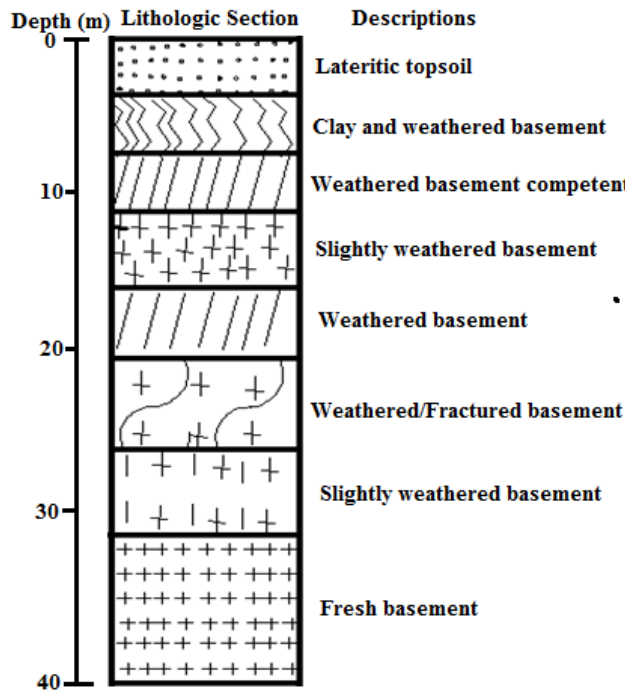


Fig.4: Drilling log for the borehole around student's hostel, Federal University of Technology, Gidan Kwano campus, Minna, Niger state. (Source: Jimoh, 1998)

Fig. 5 shows the composite for geo-electric sections with its equivalent geologic section of profile A within the study area. Fig. 5b is the equivalent geologic map of Fig. 5b) suggests the existence of three geologic sections namely weathered lateritic, weathered basement and fractured basement. The first layer has average resistivity value of about 747.53 Ωm with thickness of ranging from 0.44 - 2.03 m. The highest thickness occurs at VES A5 and A6, while the least thickness occur at A4. The layer is suggested to be weathered lateritic. The second layer consists of weathered basement, which is hydro-geologically called saprolite or saprock (Rao, 1987). The thickness ranges from 4.39m - 21.02 m with the deepest (thickest overburden) at A5 whereas the thinnest occurred at A4 (4.39 m). The third layer could constitute the fractured basement of good aquifer potential; it is deepest on A5 (22.56 m) and shallowest at A6 (6.42 m). The resistivity range varies

between 260 Ωm to 619.7 Ωm . The central part of the profile is shallow unlike the flanks. The combination of weathered lateritic, sandy, thick saprolite and thick saprock on the eastern flank of the profile (A3 – A6) makes it first choice for locating groundwater borehole which confirms the borehole lithology on Tables 5.1 – 5.3.

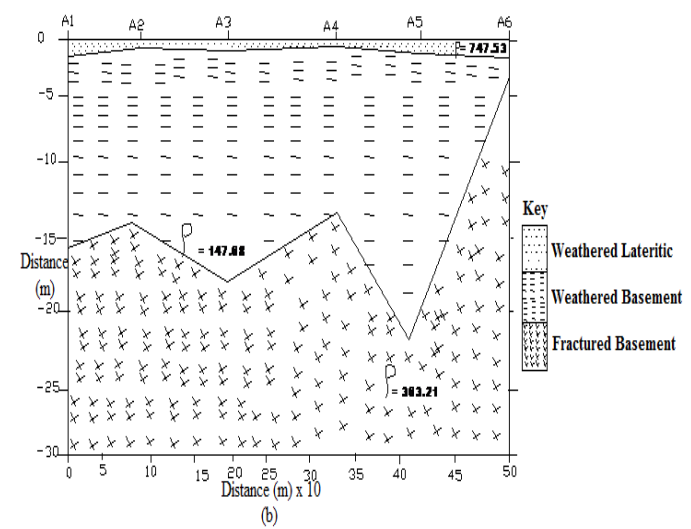
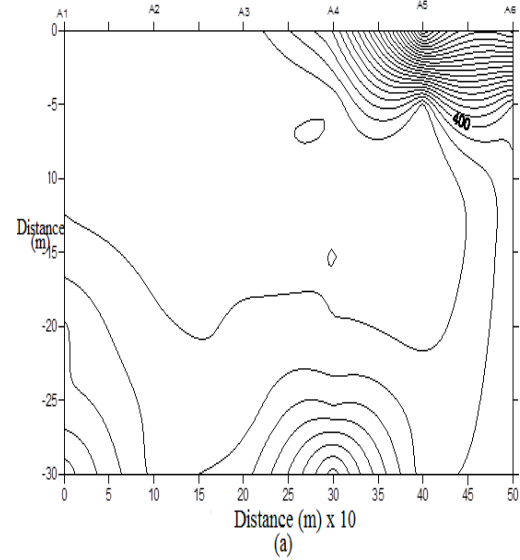


Fig.5: Correlation of geo-electric section with Geology of the area.

3.2 Iso-resistivity within the area

The iso-resistivity contour at 15 m and 30 m depth were generated as shown in Fig. 6. At 15 m depth, fresh basement rocks with resistivity values of 1000 Ωm and above begins to appear at this depth (Fig. 6a). The

southern part through the north-east part of the study area at the VES points (A2, C2, E2, and E4) has resistivity below 500 Ωm and are points that may likely be good for ground water development. The southern east central end of this map exhibit very high resistivity, (D2, D5, E6, and F5). These points also agree with the result obtained from the vertical section through profile and the VES interpretations. However, at 30 m depth, some parts of the study area are characterized moderate resistivity values of about 1000 Ωm , corresponding with VES points (A1, B1, B2, C1, E1, F1 and F4). The zone could be slightly weathered or fractured basement with reasonable aquifer potential. They have the ability of maintaining this resistivity value above 1000 Ωm , which are found around north central are, VES (D1, D2, D3, D5, E6, and F5) which corresponds to the points where depth is beyond 30 m in the vertical sections.

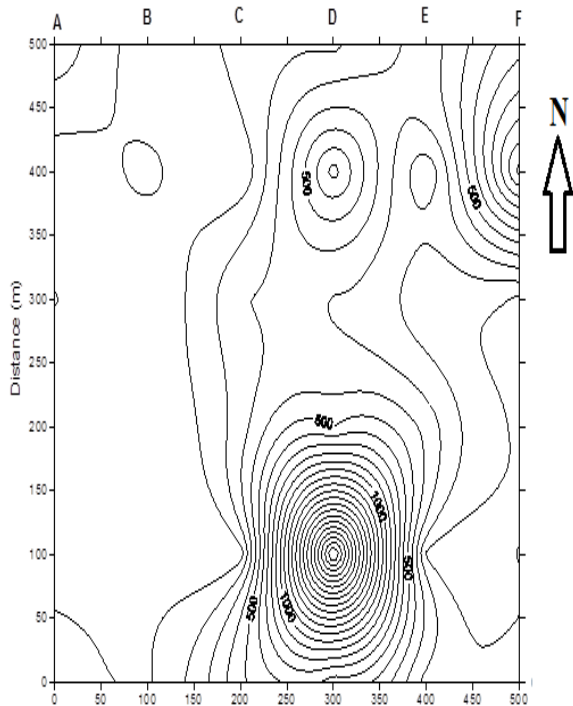


Fig.6a: Iso-Resistivity Contour Map at 15 m (Contour interval $\sim 100 \Omega\text{m}$)

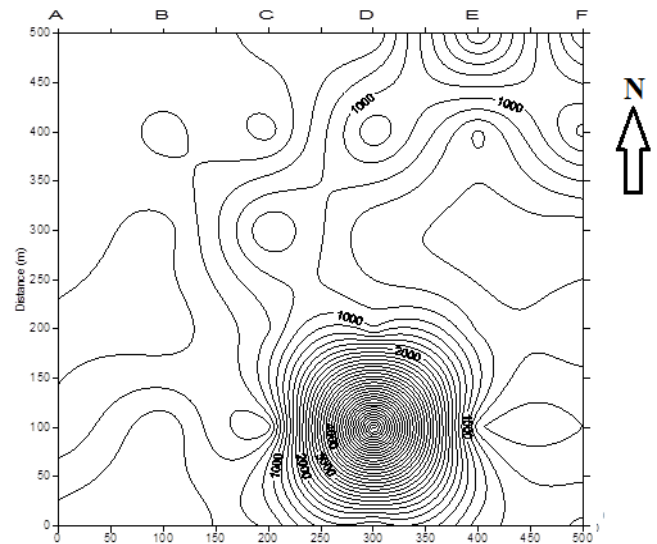


Fig. 6b: Iso-Resistivity Contour Map at 30m (Contour interval $\sim 200 \Omega\text{m}$)

3.3 Regolith Thickness Map

The regolith thickness represents the difference between the base of the weathered basement and the topsoil. According to Wright (1992) and Olayinka (1997), they infer thick regolith as weathered interval with optimum weathered and a high aquifer potential. At the southeastern and southwestern parts of the map (Fig. 7), there is a thin regolith section and non-conductive region for aquifer potential while at northwestern and eastern portions, there is thick overburden. The thick overburden region indeed suggests sites for further depth probing to ensure high aquifer reservoir.

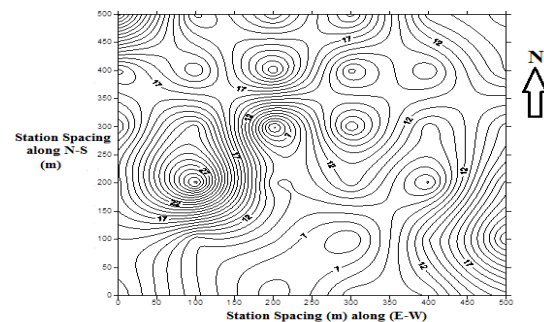


Fig. 7: Regolith Thickness Contour Map (Contour interval $\sim 1\text{m}$)

3.4 Depth to Basement Map

Fig. 8 shows the depth to basement from the surface. The depth values which correspond to the last layer were picked for the whole 36 VES points. The areas with the largest depth to basement are found at north region of the survey area (Fig. 8). The area that has the thickest overburden is B3, which conforms to Olorunmiwo and Olorunfemi (1987); Aboh and Osazuwa (2000). They suggested that areas with highest ground water yield in basement terrain are found in area, where thick overburden overlies fractured Zones which are characterized by relatively low resistivity. Similarly areas of deep basement depressions of shallow basement by the sides may probably serve as recharge point for groundwater. Hence, Fig. 8 also shows that those areas with depression valley are areas delineated as having good potential for ground water potentials. This also corroborates both the vertical section and iso-resistivity at various depths. Similarly, those areas with elevation basement could be better used for civil engineering works at very low risk. In any basement complex terrain like the study area, ground water is confined within weathered layer (saprolite) or fractured basement (saprock) columns (Afolayan et al, 2004 and Udensi and Salako, 2005). Therefore, this study satisfies the three conditions with good aquifer potential.

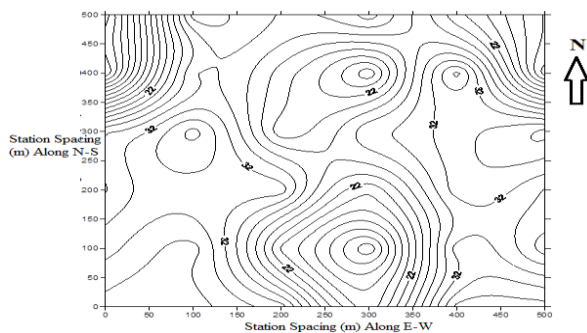


Fig. 8: Depth to basement map (Contour interval ~ 2m)

4.0 CONCLUSION

The following conclusions were reached after this research:

- From the digitized VES curves generated, three distinct geo-electric curves types were delineated namely K, H and HK-curves. With H-type having the most prolific aquifer.
- The overburden thickness and the resistivity values of different layers were also determined. Thinnest topsoil thickness of 0.34 m occurs at F5 while the thickest topsoil of 2.03 m thick which occurs at VES A6.
- There are three geologic units found beneath the VES stations, which revealed various lithological compositions. The geologic sections in the study areas also revealed that the first layer consist of Weathered lateritic. But the second layer suggests the presence of weathered basement, while the third layer constitutes the fractured basement, fresh basement.
- The iso-resistivity contour at 15 m and 30 m depth generated reveal zones that could be slightly weathered or fractured basement with reasonable aquifer potential.
- The regolith thickness map generated at the southeastern and southwestern parts of the area, there is a thin regolith section and non-conductive region for aquifer potential while at northwestern and eastern portions, there is thick overburden.
- Map of depth to basement shows that there is thick overburden (largest depth to basement) at north region of the study area and invariably it housed the highest groundwater potential in study area.

REFERENCES

- ABEM Terrameter SAS 4000/SAS 1000 Instrument Manual, ABEM Printed Matter, (ABEM Instrument AB) (1999); No 93101.
- Aboh O H and Osazuwa I B (2000), 'Lithological Deductions from a Regional Geo-electrical Investigations, in Kaduna Area', Nigerian Journal of Physics. Vol. 12, pp. 3-5.
- Afolayan J F, Olorunfemi M O, and Fulani O (2004), 'Geo-electric and Electromagnetic VLF Survey for Groundwater Development in Basement Terrain - A Case study', Ife Journal of Science. Vol. 6, No. 1, pp. 69-74.
- Ajibade A C, Rahman M A, and Wright J B (1976), 'Zungeru Xylonite, Nigeria, Recognition of a Major Unit', Journal of Mining and Geology. Vol. 12, pp. 223 – 239.
- Anakwuba E K, Nwokeabia C N, Chinwuko A. I. and Onyekwelu C U (2014), Hydrogeophysical Assessment of some parts of Anambra Basin, Nigeria', International Journal of Advanced Geosciences. Vol. 2, no. 2, pp. 72 -81.
- Chinwuko A I, Anakwuba E K, Okeke H C, Usman A O, Ovwasa M O, and Okoye I F (2015), 'Geo-electric Investigation for Groundwater Potential in Awka Anambra State, Nigeria', International Journal of Science for Global Sustainability (IJS GS). Vol. 1., no. 1, no. 1, pp. 85-95.
- Chinwuko A I, Anakwuba E K, Okeke H C, Onyekwelu C U, Usman A O, Osele C E, and Iheme, O K (2016), 'Assessment of Hydrogeophysical and Geotechnical Properties in Central Part of Anambra State, Nigeria', International Journal of Geophysics and Geochemistry. Vol. 3, No. 2, pp. 6-13.
- Eduvie M O, (1998), 'Groundwater Assessment and Borehole Characteristics, A case study from Part of Kaduna Metropolis' A Paper Presented at a Workshop Organized by Kaduna State Water Board. National teachers institute (NTI) Kaduna, Nigeria.
- Frohlich R K (1974), 'Combined geoelectrical and Drilled Borehole Investigations for Detecting Freshwater Aquifers in North-west Missouri'. Geophysics. Vol. 39, pp. 340 – 353
- Golden software Inc. (2002), Surface Mapping System, Surfer Version 8.01. Golden software Inc. Golden Colorado. 80401 – 1866.
- Hockney R O, (1986), 'The Geology of the Lokoja Auchi Area, Sheet 62', Geological Survey of Nigeria (GSN) Bulletin. No. 39.
- Jimoh M O (1998), 'Six Functional Boreholes Drilled at F.U.T Minna Permanent Site, Gidan Kwano)', A Report Presented to Federal University of Technology Minna.
- MC Curry P (1976), 'The Geology of the Precambrian to Lower Paleozoic Rocks of Northern Nigeria- A Review in Geology of Nigeria' (Editor Kogbe, C.A). Elizabeth and Publishing Co. Lagos, Nigeria.
- Mohammed L N (2007), 'A Regional Geo-electric investigation for Groundwater Exploitation in Minna Area, North – West Nigeria', Science World Journal. Vol. 2, no. 3, pp. 15–17.

- Nigeria Geological Survey Agency (NGSA,) (1999), 'Generalized Geological Map of Nigeria', Geological Survey of Nigeria Bulletin. No.39, pp. 46
- Olayinka A I, Akapn E J and Magbagbesola O A (1997), 'Geo-electrical Sounding for Estimating Aquifer Potential in the Crystalline Basement Area around Shaki, South-west, Nigeria', Water Resources. Vol. 8, no. 1& 2, pp. 71-87.
- Olorunmiwo M A, and Olorunfemi M O (1987), 'Geophysical Investigation for Groundwater in Precambrian Terrains, A case study of Ikare South -Western Nigeria', Journal of African Earth Science. Vol. 10, No. 2, pp. 6-11
- Osele C E, Onwuemesi A G, Anakwuba, E K, and Chinwuko, A I (2016), 'Hydrogeophysical Assessment of some Parts of Anambra Basin, Nigeria', International Journal of Advanced Geosciences. Vol. 4, No. 1, pp. 1-7.
- Parasnis D S (1987), 'Principle of Applied Geophysics', Chapman and Hall Ltd. London.
- Udensi E E and Salako K A (2005), 'Vertical Electrical Sounding (VES) Investigation of Western Part of the Federal University of Technology Minna, Gidan Kwano Campus' 1st Annual S.S.S.E Conference F.U.T. Minna, Book of Reading. Vol. 1, pp. 69 – 75.
- Wright E P (1992), 'The Hydrogeology of Crystalline Basement Aquifer in Africa. In : WRIGHT,E.P. Burgess,W.G.(Editors).The Hydrogeology of Crystalline Basement Aquifers in Africa' Geological Society Special publication. No. 66, pp.203-221.
- Zohdy A A R and Jackson D B (1969), 'Application of Deep Electric Sounding for Groundwater Exploitation in Hawaii', Geophysics. Vol. 34, No. 4, pp. 584 – 600.
- Zohdy A A R and Bisdorf R J (1989), Schlumberger Sounding. Data Processing and Interpretation (version 1.88). U.S. Geological Survey, Denver Co.

Table 2: VES interpretation along profiles

VES Pt	No of Layers	Types of Layer Curve	Average Resistivity (Ωm)	Layer Thickness(m)	Depth ()
Profile A					
A1	1		19.25	1.16	0
	2	H	49.32	15.92	1.16
	3		588.51	∞	17.08
A2	1		40.01	0.71	0
	2	HK	92.4	14.66	0.71
	3		321.81	∞	15.37
A3	1		28.74	0.85	0
	2	HK	38.75	17.42	0.85
	3		260.15	∞	18.27
A4	1		407.7	0.44	0
	2	H	26.13	13.39	0.44
	3		619.78	∞	13.83
A5	1		2170.65	1.54	0
	2	H	184.3	21.02	1.54
	3		388.97	∞	22.56
A6	1		1818.8	2.03	0
	2	HK	495.15	4.39	2.03
	3		284.53	∞	6.42
Profile B					
B1	1		229.94	1.16	0
	2	H	26.58	10.47	1.16
	3		674.96	∞	11.63
B2	1		228.13	1.16	0
	2	H	27.61	10.47	1.16
	3		687.28	∞	11.63
B3	1		42.78	0.71	0
	2	H	26.41	32.4	0.71
	3		416.2	∞	33.11
B4	1		40.39	0.79	0
	2	H	21.31	24.27	0.79
	3		200.91	∞	25.06
B5	1		381.05	0.44	0
	2	H	42.15	13.39	0.44
	3		782.83	∞	13.83
B6	1		1837.18	1.54	0
	2	H	154.62	21.02	1.54
	3		572.83	∞	22.56