The International Journal Of Engineering And Science (IJES)
|| Volume || 5 || Issue || 5 || Pages || PP -07-13|| 2016 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Application of Very Low Frequency- Electromagnetic (VLF-EM) Method to Map Fractures/Conductive Zones in Auchi South western Nigeria.

[1]ONWUEGBUCHULAM C.O.,[1]IKORO D. O., [1,2] NWUGHA V.N. , [1] OKEREKE,C. N.

[1]*Department of Geology, Federal University of Technology Owerri, Imo State*
[2]*Department of Basic sciences, Alvan Ikoku University of Education Owerri, Imo State*

ABSTRACT

Geophysical survey involving very low frequency electromagnetic technique was applied to investigate possible geologic features like fractured / conductive zones in Auchi and its environs in Edo state, Southwestern Nigeria. The study area is located within latitudes 7°05' N.to 7°10'N. and longitudes 6°11'E to 6°22'E The geologic Formations outcroping in the area are mainly Ajali and Nsukka. Three profiles were taken along the roads from Auchi to Igara, Auchi to Fugar and Auchi to Uloke using Abem Wadi Terrameter. Plots of the profiles were carried out using computer software (Excel) and contouring using Surfer 10 to delineate the fractured/conductive zones. The values range from 0.3 to 22.5 Siemens. Areas of low conductivity values indicate highly massive resistive rocks while Areas of high conductivity indicates the sedimentary terrain/ host rock or mineralized zones. The area is sparsely (few) fractured. Along profile A, two fractured zones were identified with conductivity values of 7.6 to16.8 Siemens between 100m(7.146°N,6.195oE) to 400m (7.150°N, 6.200°E) and 420m to 460m with conductivity value range of 11.0 to 22.5 Siemens. For profile B, one fractured zone was identified and a stretch of massive intrusive from 7.099°N and 7.102°N and 6.357°E to 6.364°E, with conductivity range of 0.9 – 5.2 Siemens at points 400m and 520m – 1000m. Profile C has identifiable fractured zones at 900m – 1100m with conductivity of (35 – 50) Siemens. The intrusive/ host rock conductivity values of (0.3 – 8.7) Siemens located at 380m to 880m 7.156°N and 6.308°E, 1100m to 2000m, 7.148°N and 6.3295°E. A total of five conductive zones were observed.

Key words: *electromagnetic, very low frequency, fracture, conductivity, intrusive, host rock.*

Date of Submission: 04 April 2016 Date of Accepted: 05 May 2016

I. INTRODUCTION

Exploration helps scientists to understand the earth and its interior. Exploration Geophysical method, aims at detecting or inferring the presence and position of ore minerals, hydrocarbons, geothermal reservoirs, ground water reservoirs and other geological structures using surface methods to measure the physical properties of the earth along with the anomalies in these properties (Alisa,1990).

The VLF-EM method of geophysical survey offers a relatively fast approach to delineate the fractures and this fractured zone has high conductivity which could be zones of mineralization or water aquifer (Benson, et al 1997).

Geology of the study Area

The study area lies between latitude 07°05'N and 07°10N' and longitude 06°11'E and 06°22'E. Its elevation ranges from 107m to 233m. The area is underlain by Cretaceous and Tertiary sediments of the Nkporo(Campanian) to Nsukka (Maastrichtian to Danian) Formations. The Campanian Nkporo Formation is essentially marine sediments of the third transgressive cycle. The basement rocks outcrops in Igarra area. The location and geological map of the study area is shown in fig. 1.

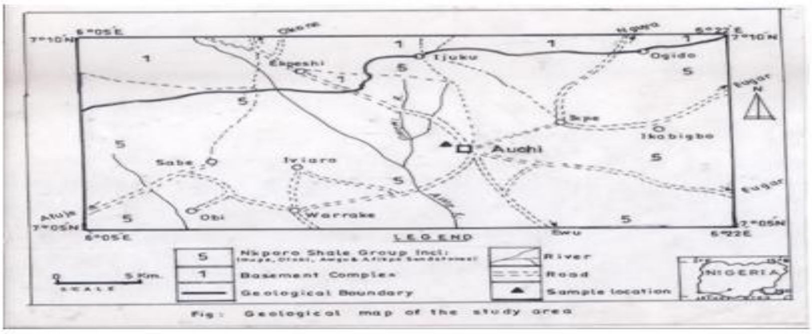

Fig. 1: Location and geologic map of the study area.

Materials and Methods

The VLF-EM method is an inductive exploration technique that is primarily used to map shallow subsurface structural features in which the primary electromagnetic (EM) waves induce current flow (Karous, and Hjelt,1983; Sinha, 1990; Karkkonen and Sharma, 1997).

In principle, it utilizes transmitters operating between 15khz to 25khz as the primary EM wave source. Ground and airborne very low frequency electromagnetic (VLF-EM) surveys have been used successfully to delineate electrical conductors and map geological contacts (Olurunifemi et al 2004; Sharma and Baranwal, 2005). VLF survey or measurement are made utilizing some special military communication transmitter which is located several kilometers away at the high powered military communication transmission stations. The signals generated can travel long distance and able to penetrate the subsurface to induce eddy current in buried conductors. The technique measures the components of very low frequency EM field which are related to the geo-electric structure of the subsurface (Saydam,1981).The electromagnetic method measures the bulk conductivity of subsurface material beneath and between the instrument transmitter and receiver coils. The readings are commonly expressed in the conductivity units of milli-ohms/meter/m-ohms/m or millisiemens per meter (ms/m) EM surveys are used for locating subsurface zones of highly fractured bedrock, buried steel drums and tanks, plumes of groundwater contamination, and clay rich horizons (McNeill,1990; Onu, and Ibe,1998) .

VLF magnetic field measurement makes use of E-Polarization in which a transmitter is selected in the direction of strike and measuring profiles are taken perpendicular to the strike direction. Generally, the vertical and horizontal components of magnetic fields are measured and real and anomalies are computed using the expression given by Sinha (1990).

$$\text{Tan } 2\propto = \pm \frac{\left(\frac{H2}{Hx}\right) COS\ \Delta Ø}{1-\left(\frac{H2}{HX}\right)2}$$

Where $\propto$ is the dip angles, e is the ellipticity, H_2 & H_x are the amplitudes, the phase difference, $\Delta Ø = Ø_2 - Ø_x$, in which, $Ø_2$ is the phase difference of H_2, $Ø_X$ is the phase of H_x, But, $ØL = H_2\, ei_{\Delta}\, Ø \sin \propto + H_x \cos \propto$

The tangent of the tilt angle is a good approximation of the radio of the real component of the vertical secondary magnetic field to the horizontal primary magnetic field. The ellipticity is a good approximation of the ratio of the quadrature components of the vertical secondary magnetic field of the horizontal primary field (Paterson and Ronka, 1997). The quantities are called the real (Tan=x100%) and imaginary (=ex100%) anomalies, respectively and they are normally expressed as percentage (Telford, et al, 1976, Lowerie;1997, Saydam,1981).

VLF data were collected using an Abem-Wadi instrument. The instrument was fitted to the operator at the base station facing the direction to be surveyed and the system was switched on. It scanned through to pick the most suitable transmitter located roughly perpendicular to the profile. The orientation, azimuth, signal strength and frequency measurement were recorded before the proper measurement were taken. A total of three profiles were established and readings were taken at intervals of 20 meters along each profile. The data were acquired under a favourable weather condition for the three profiles. The first traverse of 1000 meters (1km) was established along Auchi / Fugar road moving from east to west. The second transverse, 1900 meters(1.9km) along Auchi / Okene road moving from southwest to Northeast and the third of 1280meters(1.28km) traverse was located along Auchi / Igarra road moving from west to East. The results were recorded under columns of raw real, filtered real measurement with their corresponding coordinates and elevations.

II. RESULTS AND DISCUSSIONS

The VLF-EM data were presented as EM profiles, showing plots of raw real and filtered real values against distance (stations). The data were plotted using relevant computer programs. The real component data which are usually more diagnostic of linear features were processed for qualitative interpretation. This enabled the identification of profiles where positive amplitude of filtered real crossover the inflection points of the raw real as points of anomaly. The filtered real transform every genuine crossover or inflection points of the real anomaly to positive peaks while reverse crossover become negative peaks. The real and imaginary components are designated as conductance measured in Siemens and the distance measured in meter.

In most earth materials, the conduction of electric current takes place virtually entirely in the water occupying the pore space or joint spaces, since most soil and rock forming minerals are essentially non-conductive. Clays and a few other minerals, notably magnetite, carbon and other metallic sulfides may be found in sufficient concentration to contribute measurably to the conductivity of soil or rocks.

With reference to the geology of the study area, high conductivity may be as a result of metallic ores/materials, mineralized zones or water aquifer while low conductivity in the area may be as the result of hard rock like intrusive. Also in fractured zones for basement areas, conductivity is always higher than other areas. Since the area is purely sedimentary, shale and sandstone are a bit conductive. Low conductivity values suggest rock unit of high resistivity values like basements rocks and intrusives. The signals from the VLF equipment picked the underlain rocks of the intrusive. Therefore, correlating the geology and the conductivity variations from the signal responses from the VLF results to the electrical properties of rocks which shows that metals have higher conductivity than shale while very high resistivity indicates hard rocks (intrusive rocks). From the image produced using the sufer software, the violet to bluish in the colour code of the VLF values indicates intrusive, greenish to yellowish colour represents the host rocks of sands/sandstone while the reddish to pinkish represents shales rocks.

PROFILE A.

The trend of the profile is in the west to east direction (N120^{o}E), between latitude 7.145^{o}N to 7.15^0 N and longitude 6.194^{o}E to 6.204^{0}E(Fig1). It suggests a massive intrusive along the profile with two areas of possible fracture/conductive zones that gave high conductivity value. The first area is between 100m and 140m with conductivity range of (7.6 to 16.8) Siemens from the starting point. The second fractured /conductive zone of mineralization or water aquifer occurred from 420m to 460m with conductivity range of 11 Siemens to 22.5 Siemens. Along the profile, some areas between these high conductivity zones have low conductivity values in the range of 3 Siemens to 6 Siemens. This implies that along the profile from 180m to 300m has low conductivity values ranging from 4.8 Siemens to 5.6 Siemens. The section from 500m to 1260m has low conductivity of range between 3.5 Siemens to 4.6 Siemens but at 760m, high conductivity value of 9.4 Siemens which is likely to be part of the fractured zone. From fig1B displayed, the host rock which is predominately made of sands/sandstone occupies most of the area. The intrusive rocks are located at 120m (lat 7.15023^{0}N and long 6.19505^{0}E), 240m (lat 7.14957^{0}N and long 6.19587^{0}E) and 920m (lat 7.14625^{0}N and long 6.20072^{0}E).

***PROFILE B*.**

From the image produced, the profile lies between latitude 7.099^{0}N to 7.102^{0}N and longitude 6.357^{0}E to 6.364^{0}E (Fig 2). The trend of the profile is in the east to west direction. Along the profile between 480m and 500m, a high conductivity value of 13.2 siemens was obtained. Other areas that have low conductivity in the range of 2.0 Siemens to 5.2 Siemens. Low conductivity values suggest rock units of high resistivity values like basement rocks and intrusives. This implies that along the profile, the first 400m has low conductivity values ranging from 0.9 Siemens to 4.3 Siemens. The second section occurred from 520m to 1000m, with low conductivity values in the range of 0.9 Siemens to 5.2 Siemens. The profile is occupied by the host rock which is made up of predominately sands/sandstones. In fig. 3, the violet-bluish area which indicates a conductive zone, occurred at about 380m (lat 7.10152^{0}N and long 6.36147^{0}E) and from the remark, it indicates the presence of a river.

PROFILE C.

The trend of the profile is in the Northeast –Southwest direction N50^0 E direction (Fig. 4). Profile C suggests a massive intrusive along the profile with two areas of possible fractured zones that gave high conductivity of about 50 Siemens at 300m from the starting point. The second fractured zone of mineralization or water aquifer occurred from 900m to 1100m with conductivity range of 35 Siemens to 50 Siemens. Other areas between these zones have low conductivity values in the range of 4.0 Siemens to 7.0 Siemens. This implies that along the profile, the first 200m has low conductivity values ranging from 1.9 siemens to 8 Siemens. The second section from 380m to 880m also have low conductivity values in the range of 0.3 Siemens to 8.7 Siemens and the third section from 1100m to about 2000m have range of values from 0.9 Siemens to 9.4 Siemens except at 1140m with value of 15.4 Siemens which is likely to be part of the fractured zone. From fig. 5, violet to bluish colour indicates the intrusive, greenish to yellowish colour represent host rocks of sands/sandstone while the reddish to pinkish colour denotes shale rocks. From the result obtained, the host rocks are predominately sands and shales. The intrusive rocks are located in the mid of the profile about 1000m (lat 7.156^{0}N and long 6.328^{0}E) and in the lower range between lat 7.148^{0}N and long 6.3295^{0}E.

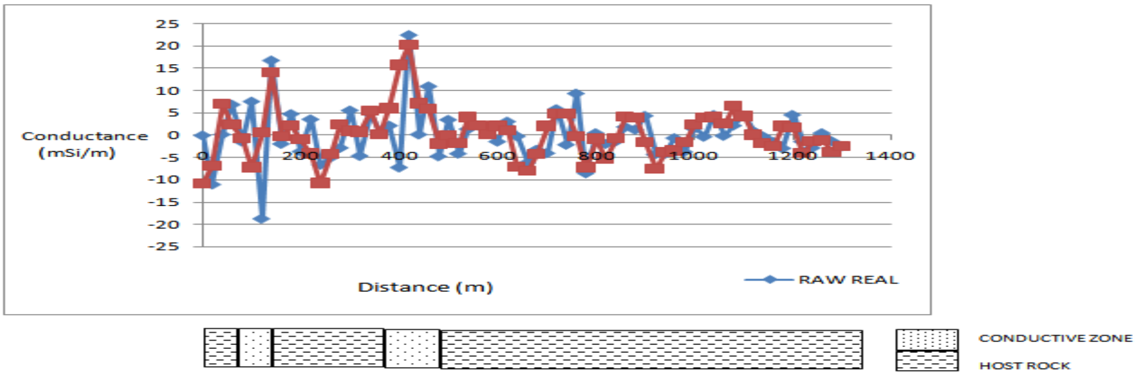

Fig.1 Profile A : Curve of signal responses along Ikpesi to Utami on Auchi-Igarra road.

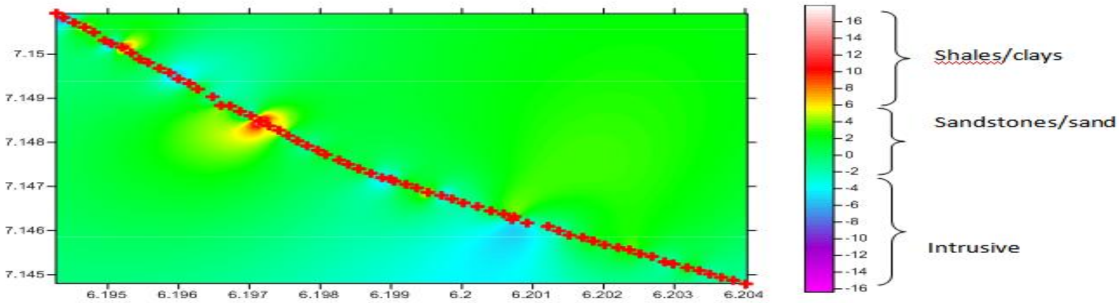

Fig 2: Image of VLF rawreal values of profile A along Ikpesi to Utami on Auchi-Igarra road.

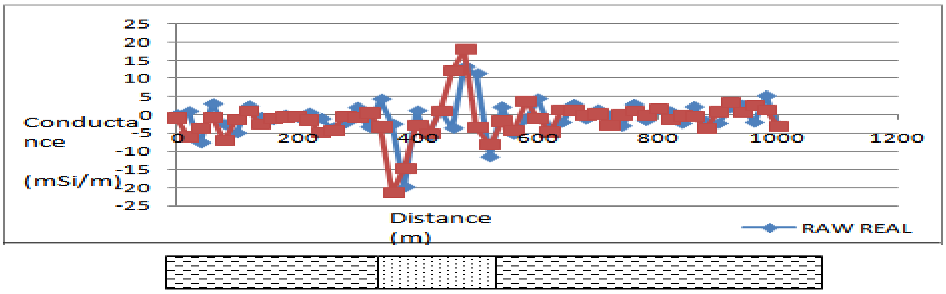

Fig. 3: Curve OF the signal responses of Profile B along Fugar – Auchi road.

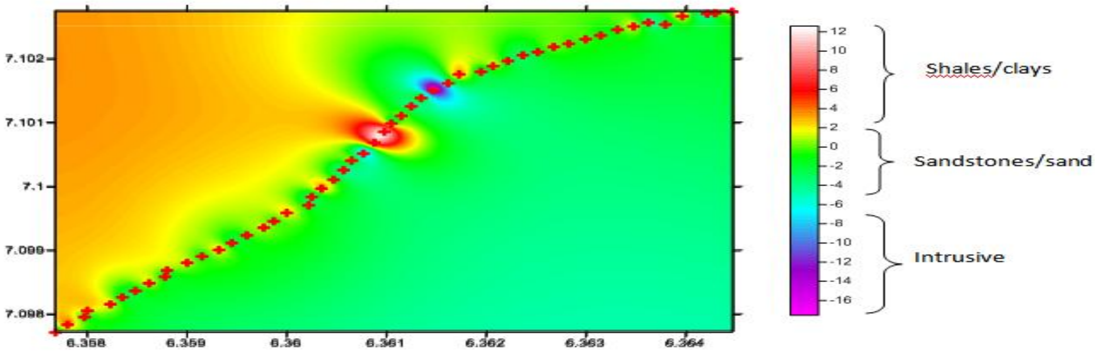

Fig 4: Contour of VLF raw real values of Profile B: Fugar – Auchi road.

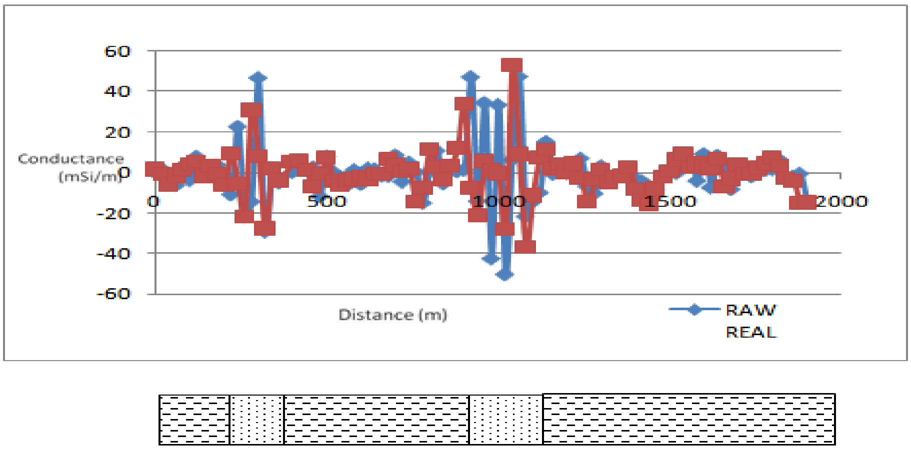

Fig 5 :PROFILE C : Curve of the signal responses Ogbeido-Uluoke alongAuchi-Abuja Rd.

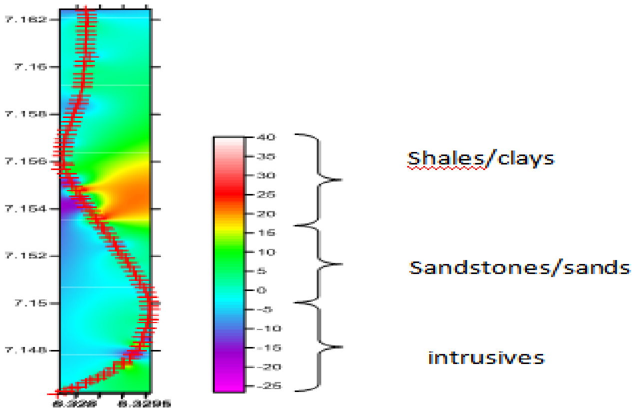

Fig. 6: CONTOUR OF VLF RAW REAL VALUES OF PROFILE C: (OGBEIDO TO ULUOKE) ALONG AUCHI – ABUJA ROAD.

TOPOGRAPHY/ELEVATION OF THE STUDY AREA

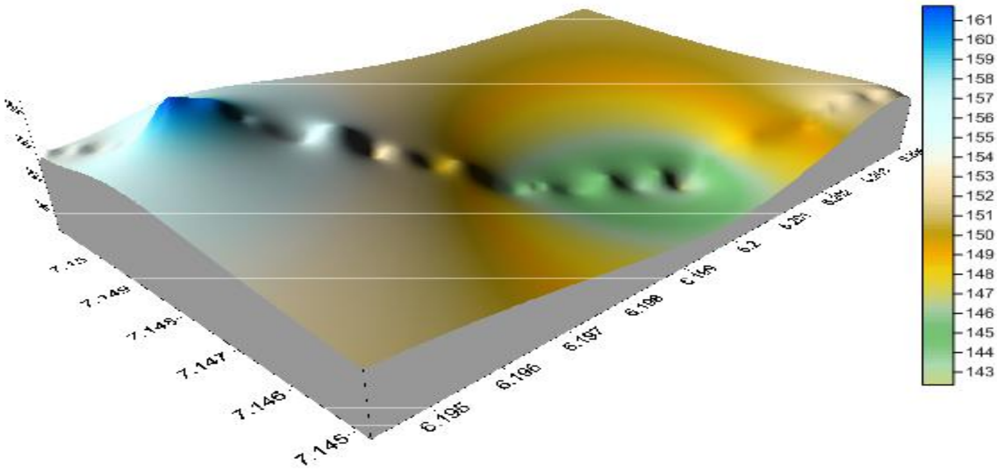

Fig. 7: ELEVATION MAP OF PROFILE A: (IKPESI TO UTAMI) ON AUCHI – IGARRA ROAD.

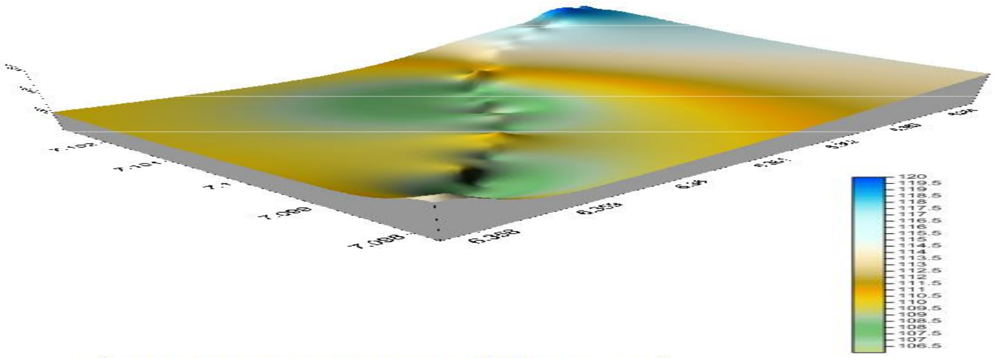

Fig. 8: ELEVATION MAP OF PROFILE B (FUGAR-AUCHI RD)

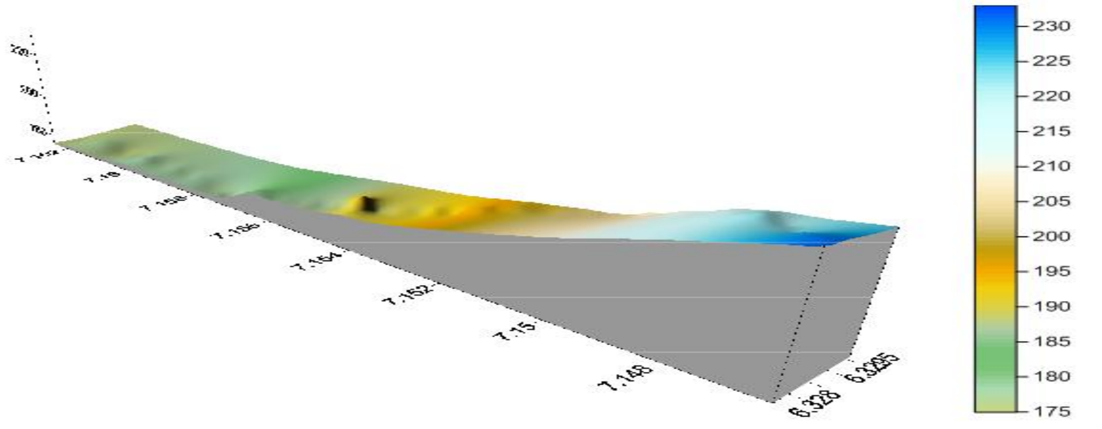

Fig. 9: ELEVATION MAP OF PROFILE C: (OGBEIDO TO ULUOKE) ALONG AUCHI – ABUJA ROAD.

From the elevation map of profile A (Fig 6), the North-West part is most elevated with 154m -161m (bluish area) while the greenish area shows points with the lowest elevation of 143m-146m and the South-East part has elevation of 147m -153m. The implication is that there may be water log in the area more than other places. In the elevation map of profile B (Fig 7), the North-East part is most elevated with 118m-120m (bluish area) while the midpoint is the lowest elevation of 106m-108m (greenish area) and the South-west part has 110m-114m (yellowish).Though the profile is undulating at certain locations. In profile C (Fig 8), run-off is likely to be higher since one of its parts is quite higher than the other with elevation difference of 55m.

CONCLUSION

The area is sparsely (few) fractured. The low conductivity values indicate highly massive resistive rocks. Along profile A, two fractured zones were identified with conductivity values of 7.6 to 16.8 Siemens between 100m to 400m from the start of the profile and 420m to 460m with conductivity value range of 11.0 to 22.5 Siemens. The intrusive occurrence is located between7.146 to 7.150°N and 6.195°E to 6.200°E with conductivity range of 3.0 to 5.6 Siemens. For profile B, one fractured zone was identified and a stretch of massive intrusive from 7.099°N and 7.102°N and 6.357°E to 6.364°E, with conductivity range of 0.9 – 5.2 Siemens at points 400m and 520m – 1000m. Profile C has identifiable fractured zones at 900m – 1100m with conductivity of (35 – 50) Siemens. The fractured zones are potential locations for ground water and mineral prospecting. The intrusive/ rock conductivity values of (0.3 – 8.7) Siemens located at 380m to 880m 7.156°N and6.308°E, 1100m to 2000m, 7.148°N and 6.3295°E. The intrusive rock is massive. From the quarries available within the study area, information obtained suggests massive intrusive rocks like dolomite.

REFERENCE

[1] Alisa Allaby Micheal Allaby (1990). "Telluric Current" A dictionary of Earth Sciences Ed. Oxford University press.
[2] Benson A.K., payne, K.I., and Stubben, M.A., (1997). Mapping Ground Water Contamination using DC Resistivity and VLF Geophysical Methods. A case study, Journal of Geophysics, 62(1),80-86.
[3] Bernard, J. And Valla, P. (1991), Groundwater exploration in fissured media with electrical and VLF methods, Geoexploration 27, 81-91.
[4] Kaikkonen, P. and Sharma, S.P. (1997). Delineation of near surface structures using VLF-EM and VLF-R data: insight from the joint inversion results. Leading Edge Vol. 16: 1683-1686.
[5] Karous, M., and Hjelt, S.E., 1983. Linear–Filtering of VLF dip-angle measurements: Geophysics. Prosp., 31,782-894.
[6] Lowerie W., (1997). Fundamental of Geophysics, EM Surveying Cambridge University press pg. 220-223
[7] McNeill, J.D., 1990. Use of electromagnetic Methods for Groundwater studies. In ward,S.H. (Ed). Geotechnical and Environmental Geophysics, Vol 1: Review and turorial, Society of exploration Geophysicists Investigation No.5, 107-112
[8] Olorunifemi, M.O., Fatoba. J.O and Ademilua,L.O. (2004). Integrated VLF-Electromagnetic and electrical resistivity survey for groundwater in a crystalline basement complex terrain of Southwest Nigeria. Global journal of geological sciences Vol 3,No1 2005: 71-80.
[9] Onu, N.N. and Ibe, K.M. (1998). Geophysical investigation for groundwater in Idah Lower Benue Trough, Nigeria, Nigeria Journal of Mining and Geology Vol. 34 No.1 p. 45 -53.
[10] Paterson, N.R. and Ronka, V., (1971). Five years of surveying with the very low frequency electromagnetic method, Geo-exploration, 9, 7-26
[11] Saydam, A.S., (1981). Very Low Frequency Electromagnetic Interpretation Using tilt angle and ellipticity measurements. Geophysics, 46, 1594-1605.
[12] Sharma S.P. and Baranwal, V.C. (2005). Delineation of groundwater bearing fracture zones in a hard rock area integrating Very Low Frequency Electromagnetic and resistivity data, J. Applied Geophysics 57, 155-166.
[13] Sinha, A.K. (1990). Interpretation of ground VLF-EM data in terms of vertical conductor models. Geoexploration, 26: 213-231
[14] Telford, W.M., Geldart, L.P., Sheriff, R.E., and Keys, D.A., (1976). Applied Geophysics. Cambridge University pree (2nd Edition), 670p.