Combined Use of Electromagnetic and Magnetic Survey for Hydrogeophysical Characterization of Ijapo Housing Estate, Akure.

Ogungbemi O.S.[1*], Oladapo M.I.[2]

[1*]Department of Chemical/Petroleum Engineering, AfeBabalola University, Ado Ekiti.
[2]Department of Applied Geophysics, Federal University of Technology, Akure.

ABSTRACT

Very Low Frequency Electromagnetic (VLF-EM) and ground magnetic studies were carried out in Ijapo Housing Estate, Akure, with the aim of delineating hydrogeologic associated structures. The area is underlain by the Precambrian Basement Complex rocks of southwestern Nigeria. VLF-EM profiling was undertaken along 19 traverses with eight traverses aligned NW – SE and eleven aligned SW – NE. The traverse lengths varied from 180 to 1,200 m. Ground magnetic data were acquired along 35 traverses of lengths ranging from 120 to 1,060 m. Nine of the traverses were oriented E – W, thirteen traverses NE – SW while the remaining thirteen were oriented NW – SE. The VLF-EM readings vary from – 110.3 to + 99.9 % in the filtered real and imaginary components. Areas with positive peak anomalies are considered as probable fracture zones. The VLF-EM depth-structure map enables the classification of the area into zones of shallow and deep fractures. The western and eastern flanks are situated within zones of deep fractures. The relative magnetic values vary from -1290.38 to +835.38 nT. The low magnetic readings are presumably indicative of concealed linear features. The depths to the top of structures delineated vary between 14.5 and 46.6 m. Magnetic depth-structure map enabled the classification of the study area into shallow and deep fracture zones. The integrated result of the VLF-EM and the magnetic methods show that the deep structures delineated with the VLF-EM method coincides fairly well with zones where deep fractures were delineated with the magnetic method.The occurrence of groundwater in crystalline basement complex is highly localized;thereforegroundwater development programmeshouldbe limited to high groundwater potential (deep-fractured)zonewhere detailed geophysical survey would be carried out prior to drilling.It is important to sink boreholeswithin region of thick overburden for optimum yield of groundwater.

Deleted: The

Deleted: The ground

Comment [C1]: Rephrase the statements: There is no need to specify; a total of each method is ok! Include a statement on how the acquired data was processed and analyzed.

Deleted: The magnetic

Comment [C2]: Check all statements, starting with **THE:** You are just outlining.

Keywords: Electromagnetic, Magnetic, Hydrogeology, Structures, Depths

1. INTRODUCTION

The successful exploration and exploitation of groundwater requires a proper understanding of its hydrogeological characteristics [12]. Careful studies that are supported by improved drilling techniques yield very favorable results even in the problematic areas of the basement complex [7]. Geophysical methods are important in investigating near surface formations and modeling of aquifer units for groundwater development. Notable among the methods are the electric resistivity, electromagnetic, seismic refraction and magnetic methods [3].

The aquifer in the basement terrain is not only inhomogeneous but also localized; hence the description of aquifer parameters in this geological terrain may be difficult [6]. In such terrain thorough geophysical investigations must be carried out for optimum siting of viable boreholes for groundwater development.

VLF-EM method is more relevant in the delineation of near surface fractures than in the estimation of overburden thickness, because their anomalies aremoreinfluenced by the conductivity of the overburden (weathered layer) than the thickness [9].

Research work has been previously carried out in IjapoHousing Estate Akure to establish geoeletric parameters, the groundwater potential and susceptibility to environmental pollutions [1], [8]. In both

studies 30 vertical electrical soundings were carried out across the entire estate. However, in this survey the VLF-EM and the magnetic methods were adopted.The VLF-EM was adopted as a fast reconnaissance tool to map possible linear fractures such as faults and fractures zones while the magnetic method was used to investigate prominent magnetic anomalies and provide a structural image of the concealed structures.

1.1 Geographical and Geological settings of the Study Area

The geology of the study area can be explained within the context of the geology of the Precambrian basement complex of southwestern Nigeria which form a part of the crystalline basement complex of Nigeria[11] (Fig. 2).Ijapo Estate is situated on a gently undulating terrain with elevation between 330 and 364 m above mean sea level. The area lies in the tropical rain forest with mean annual rainfall of about 1300mm. The annual mean temperature is between 18 and 33℃. River Osisi cut across the estate at the central part and flows south into River Ala.Ijapo Estate as at the time of this study is the largest residential estate in OndoState. It is located northeast of Akure town within longitudes 5°12.307' E and 5°16.552' E and latitudes 7°15.859' N and 7°16.552' N. The esta te hosts some commercial centers such as petroleum products sales outlets, hotels and guesthouses and shopping malls.This has furtherincrease demand for portable water within the estate. Residents in the estate depend largely on hand-dug wells and motorized boreholes for domestic and commercial water supply (Fig. 1). Hence, there is need to investigate the estate in order to evolveitshydrogeologic setting. In this survey, the electromagnetic (VLF-EM) and the ground magnetic methods were therefore adopted.

Comment [C3]: Check this

Deleted: Complex

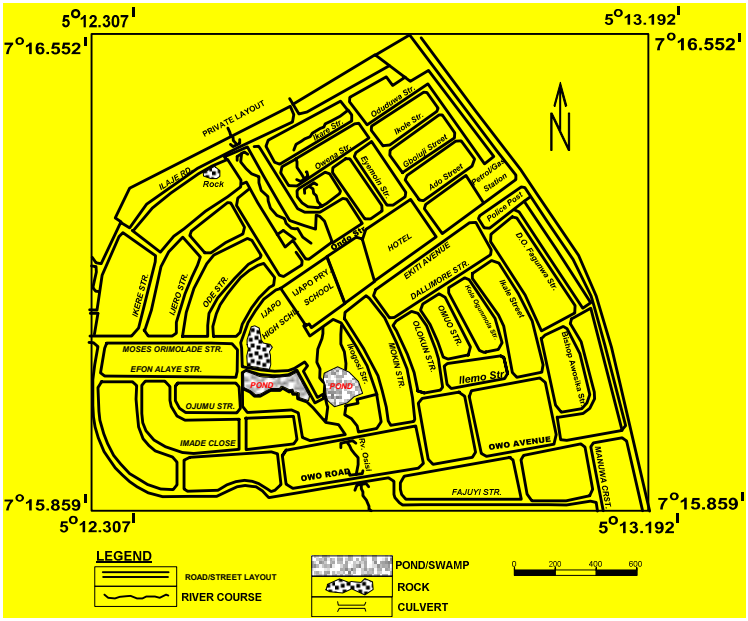

Fig. 1: Base map of the study area showing the street layouts.

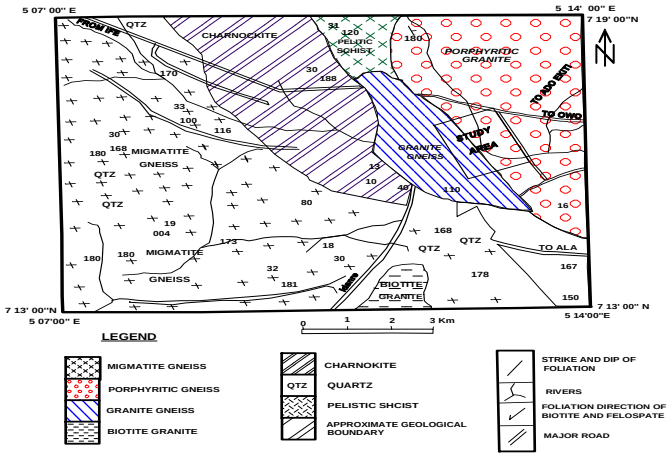

Fig. 2: A generalized geological map of Akure (after Owoyemi, 1996)

2. MATERIALS AND METHODS

The VLF-EM profiling was undertaken at 25 m station interval on 19 traverses. The traverses lengths vary from 180 to 1,200 m. The Ground Magnetic data were acquired on 35 traverses of lengths ranging from 120 to 1,060 m at 20 m station intervals. ABEM-WADI VLF instrument was utilized for Electromagnetic data acquisition while Proton Precision Magnetometer was used for the magnetic data acquisition.The very low frequency electromagnetic data were processed by downloading the filtered real and imaginary components from the AbemWadi VLF-EM equipment. The data are presented as profile and map (Figures 3a, 5 b and c). The AbemWadi measures the field strength and the phase displacement around the fracture zone. The EM data was interpreted and inverted into a 2-D section using the Karous-Hjelt filtering [5].The magnetic data were drift corrected and presented as profiles of relative magnetic intensity values against distance (Figure5a). The automated Euler deconvolution software was used to estimate depth to basement along the traverses. The generated profiles, sections and maps enabled the delineation of concealed geologicalstructures.The integration of the results of VLF-EM and ground magnetic survey enabled the hydrogeophysical characterization of the study area.

3. RESULTS AND DISCUSSION

3.1 VLF-EMRESULTS

Quantitative interpretation of the VLF-EM data involve the generation of the VLF-EM sections with the use of KarousHjelt (KH) filtering software which allows for the estimation of fracture length within the zone.Detailed descriptions of typical profile and sections generated along a selected traverse are given below.The VLF-EM profile shows positive peak filtered real values at 100 m, 400 m and 600 m and cross-over points at distance 50 m, 360 m, 700 m and 850 m which reveals the conductive zones along the traverse(Fig. 3a). The corresponding 2D-section reveals conductive zones at distance ranging from 60 m to 100 m, 320 m to 400 m and 620 m to 780 m respectively. The depth to the top and bottom of the conductive/fracture zones obtained from the 2D-section is between 20 m and 75 m corresponding to fracture lengths of 45 m, 20 m to 100 m corresponding to fracture length of 80 m and also 20 m to 100 m corresponding to fracture length of 80 m respectively(Fig. 3b).The 2D-inverse models reveal the depth to sources of anomalies which ranges between 37.5 and 100 m.

The interpretation of the different sections and profiles produced from the processing of results obtained from the VLF-EM reveal high degree of fracturing along this profile suggesting zoneof high groundwater potential.

Comment [C4]: Remove this

Deleted: Profileand Section

Deleted: ¶

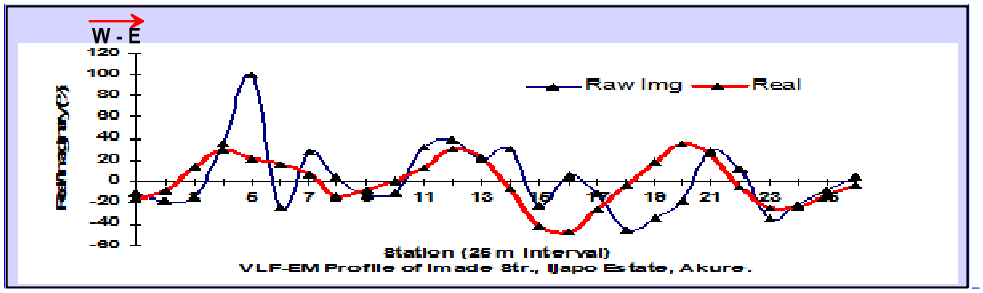

Fig. 3 VLF-EM Profile of Imade Street, Ijapo Estate, Akure.

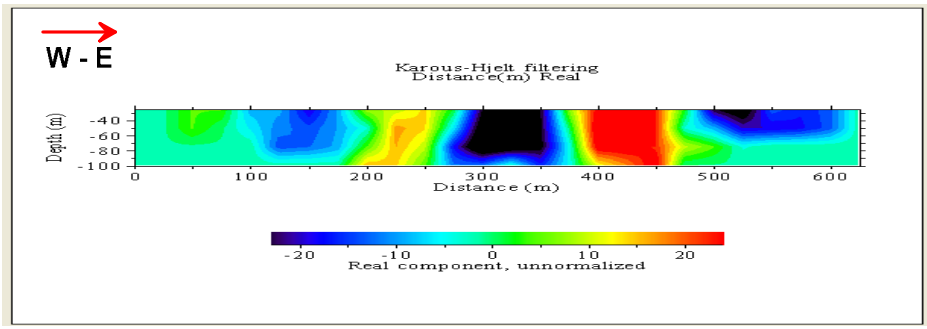

Fig 4Fig. 3(b): 2D-inverse model of Imade Street, Ijapo Estate, Akure.

WADI VLF-EM detects the ratio (in percentage) between the vertical and the horizontal components. This is an indication of the degree of inhomogeneity of the subsurface. The real component readings were plotted as a contour map of the study area (Fig. 3c). The map is characterized with zone of positive and negative anomaly, the readings range between - 50 to +35 %. The zones with positive anomaly occur as patches and are more prominent around the western part, also around the central region and the northern flank. VLF-EM anomalies were delineated at twenty-nine locations within the study area.The statistics show a number fairly-conductive, conductive and highly-conductive response at different locations across the study area.This indicates that these areas have concealed geological structureswhich are suspected to be linear steeply-dipping fractures that favourshigh groundwater accumulate.

Comment [C5]: Borders required

Deleted: 3(a):

Comment [C6]: Renumber your figures

Comment [C7]: Remove this

Deleted: ¶
Filtered Real Component Map

Deleted: ¶

Comment [C8]: This should be part of methods

Deleted: was characterized

Deleted: (29)

Fig.5): Filtered real component map of the study area

VLF-EM depth-structure map was obtained by computing the depths and locations of fractures delineated by VLF-EM methods across the entire study area. The map enables the classification of the study area into two, based on the depth of the delineated fractures i.e. the shallow-seated and the deep-seated fractures (Fig. 3d). The western and eastern flanks of the study area are classified as shallow-seated fracture zone; it covers Ikere, Ijero and Ode Street on the western flank and Dallimore, D.O. Fagunwa and Ikale and Kola Ogunmola Streets on the eastern flank. The central part is classified as moderately deep-fracture zone; it covers Ondo Road, Mokin Street, Ilemo Street, EfonAlaye Street and Ode Street. The northern and southern flanks are classified as deep-fracture zone. Most of the deep fractures delineated fall within the central region.

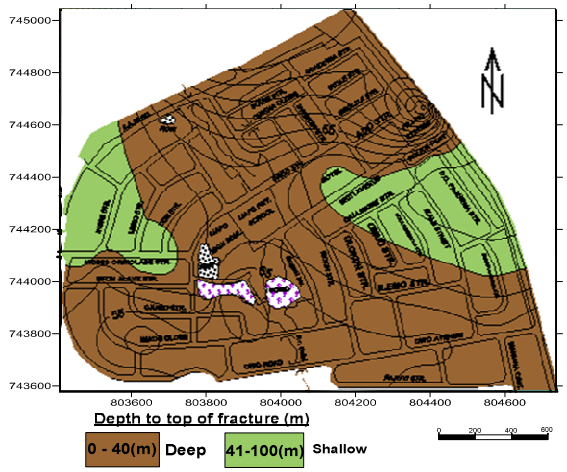

Fig.6: VLF-EM depth-structure map of Ijapo Housing Estate, Akure

3.2 GROUND MAGNETIC SURVEY RESULTS

Deleted: 3(c

Comment [C9]: Remove this

Deleted: VLF-EM Depth-Structure Map

Deleted: ¶

Formatted: Indent: Left: 0"

Formatted: Font: Not Bold

Formatted: Font: Not Bold

Deleted: This map

Formatted: Font: Not Bold

Formatted: Font: Not Bold

Comment [C10]: Revise

Deleted: 3d

3.2.1 Geomagnetic Profile and Section

Ground magnetic profile and section were produced from the data acquired through the Ground Magneticsurvey.The qualitative interpretation of the ground magnetic survey reveals that the varying amplitude of the anomaly signatures; the low magnetic intensity on the magnetic profilessuggest possible fracture zones. Any zone with high number of networks of fractures is believed to be zones of high groundwaterpotential.Quantitatively, the magnetic profiles were interpreted one by one using the automated freeware eulerdeconvolution techniques.

Figure 4(a)is atypical profile and section of ground magnetic survey along Imade Street. The traverse length is about 1,000 m and is oriented W – E. Low magnetic intensity values were observed at distance ranging from 5 to about 100 m and then from 300 to 800 m. Magnetic intensity contrast were observed between + 29.1 and – 14.5 nTat distance between 150 and 220 m, - 25.1 and + 13.5 nT at distance ranging from 250 to 280 m and + 29.1 and – 29.1 nT at distance between 850 and 950 m respectively. These identified zones of low magnetic intensities and magnetic intensity contrast are the probable fracture zones, and aresuspected to have high groundwater potential. The geomagnetic sections produced enabled the delineation of five probable fracture zones with estimated depth of 19 m at distance 250 m, 20 m at distance 400 m, 20 m at distance 425 m, 20 m at distance 700 m and 21 m at distance 900 m respectively. The probable fracture zones all occurred within the granite gneiss.

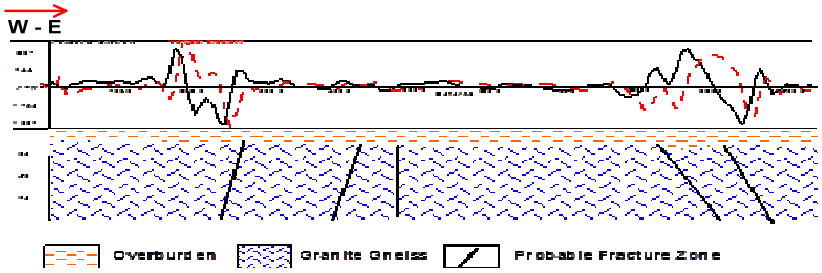

Fig.7 Ground magnetic profile and geosection

Magnetic depth-structure mapwas obtained by computing the depth and location of source of magnetic anomalies across the entire study area. Close observations of the map enable the characterization of the study area based on the depth of occurrence of the identified structures. Low magnetic intensity zones were delineated by the freeware eulerdeconvolution software producing a steeply dipping interface and are classified as the probable fracture zones for groundwater accumulation. The zone with concealed shallow features covers a major part of the study area, underlining Ojumu Crescent, EfonAlaye Street, Akoko Avenue, D.O. Fagunwa Street, Owo Avenue, Ondo Road, Mokin Street, Henry Fajemirokun 1, Ekiti Avenue, Eyemoin Street and Olokun Street. The remaining part of the study area i.e. region around Owo Avenue, Fajuyi Crescent, Henry Fajemirokun Street 2, Ilaje Road, parts of Imade Street, Moses Orimolade Street, Ondo Road, Ode Street, Ikole Street, Dallimore Street, Ikale Street and Owena and northern part of Ondo Road are all classified as zones with deep-fractures (Fig. 4b). Magnetic anomalies were delineated at one hundred and seventy-one (171) locations from the ground magnetic profiles.The deep structures are oriented NW – SE.

Deleted: 4(a):

Deleted: Magnetic Depth-Structure Map¶

Formatted: Font: Not Bold

Deleted: This map

Formatted: Font: Not Bold

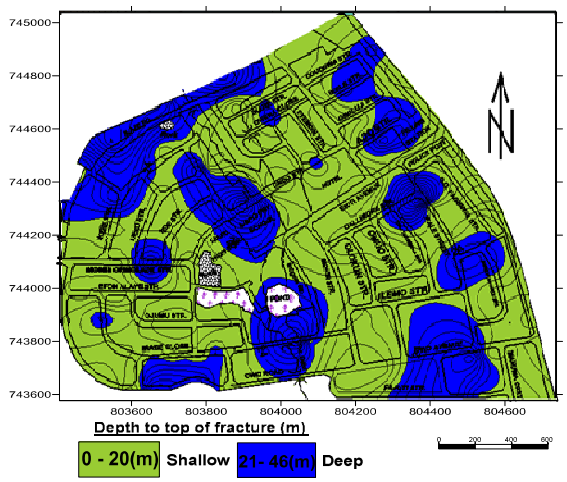

Fig. 8Magnetic depth-structure map of the study area.

3.3. Hydrogeophysical Characterization of the study area

The integration of VLF-EM and ground magnetic dataenabled the hydrogeophysical characterization of the study area. The VLF-EM depth-structure map is characterized by zones of shallow and deep-seated fractures, thus classified as the low and moderately-high water bearing potential zones. The western and the eastern flanks are marked by high altitudes which also coincide with zones of shallow-seated fractures. The depth to top of structures within these zones is below 40 m. The shallow buried structures may be due to the presence of ridges or/and thin overburden layers which may not favour groundwater accumulation within these zones. On the other hand, the northern, southern and the central regions are characterized by low altitude and deep-seated structures and relatively thick overburden, thus forming the groundwater collection center within the study area.

The ground magnetic depth-structure map is characterized by zones of high and low water bearing potential as a result of the deep and shallow fractures delineated within the study area (Fig. 5). The deep structures are oriented NW – SE coinciding with the trend of the water course within the study area. The shallow structures are buried within 20 m below the ground surface while structures buried within 21 – 46 m are classified as deep-seated structures. The deep structures occur at regions with depression, thick-overburden and river course thereby forming groundwater collection centers of the study area.

It is observed that the structures delineated occurred at the basement-overburden interface. The VLF-EM serves as a good reconnaissance tool for the Ground Magnetic survey. Most of the deep structures delineated with the Magnetic method fall within zones classified as deep-fractured from the VLF-EM method.

Deleted: 4(b):

Deleted: Integration of Ground Magneticand VLF-EM methods

Deleted: results of

Deleted: Ground

Deleted: Magnetic

Deleted: surveys

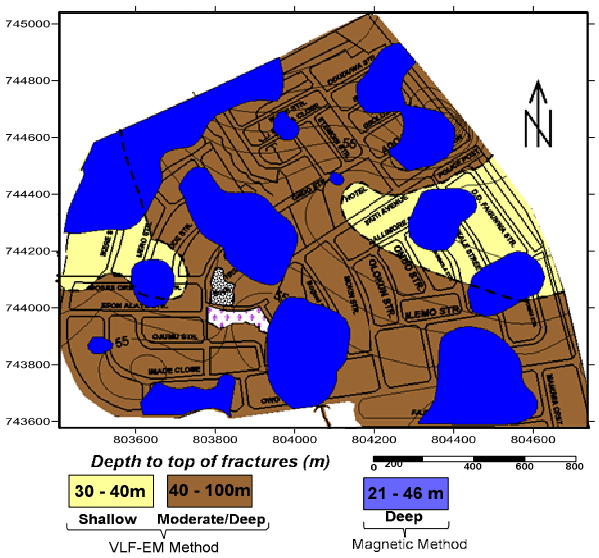

Fig.9: Integrated Magnetic and Electromagnetic map of the study area

Comment [C11]: Correct you figure numbering

Deleted: 5

Table 1: Summary of integrated ground magnetic and VLF-EM results

Traverses	Traverse Length (m)	Traverse Orientation	Geophysical Method Adopted	Location of Fracture (m)	Depth Top of Fracture (m)	Geology of the area
Dallimore Street	375	SW – NE	Ground Magnetic	75* 245 275 360	25 30 25 19	Porphyritic Gneiss
			VLF-EM	75* 275*	25 25	
Imade Street	1,000	W – E	Ground Magnetic	250 400* 425 700* 900	19 20 20 20 21	Granite Gneiss
			VLF-EM	100 400* 700* 850	20 20 20 20	
Fajuyi Street	450	W – E	Ground Magnetic	100* 225 275 405*	25 30 25 25	Porphyritic Gneiss
			VLF-EM	105* 300 420*	25 25 25	
Owo Avenue	1,100	W – E	Ground Magnetic	260 550 620* 660	15 24 26 30	Granite Gneiss &

			VLF-EM	885 975 325 625* 875 1,025	19 16 25 25 25 25	Porphyritic Gneiss
Ondo Road	900	SW – NE	Ground Magnetic VLF-EM	50* 200* 410* 480 650 700 775 50* 200* 400* 775	15 14.5 41.6 16.7 23.5 23.5 16.7 25 25 25 25	Granite Gneiss & Porphyritic Gneiss

Note: ***Locations where fractures are delineated by the two methods.***

4. CONCLUSION AND RECOMMENDATIONS

This integrated geophysical technique has proved very successful and cost effective;itenabled the delineation of concealed geological structures suspected to be steeply dipping linear conductors that are of varying length within the study area. Profiles and sections generated revealedconductive zones within the study area.The VLF-EM classifiedthe area base on the depth of fracturesas near-surface structures and deep-seated structures zones.Ground magnetic method gives an estimate of depth to magnetic sources andfractures lengthswhich enable the classification of the area as near-surface structure zone and deep-seated structure zone. The integration of the methods enabled the hydrogeophysical characterization of the estate.This estate is highly fractured; as observed from the results. The trends of the identified fracture zones are mostly in the NW-SE, the orientation of the structures agree with the physical trend of the river course and bedrock structures. Groundwater occurrence in this terrainis structurally controlledandhighly localized. Therefore, groundwater development programme should be restricted to the high groundwater potential (deep-fractured) zone and scrupulous geophysical survey should be carried out prior to drilling.

Deleted: The g

5. ACKNOWLEDGEMENTS

The authors would like to acknowledge the effort of Mr. AfolabiAbiodun who assisted during data acquisition. The support of colleagues who gave technical and moral assistance towards the success of the work is also acknowledged with thanks.

REFERENCES

[1] Ayolabi, E.A., Adedeji, J.K. and Oladapo, M.I. A geoelectric mapping of Ijapo, Akure Southwest Nigeria and its Hydrogeological Implications.Global Jour. of Pure and Applied Sciences.2003; 10(3), 441-446.

[2] Cooper, G.R.J. An improved algorithm for the Euler deconvolution of potential field data.The Leading Edge.2002; 21(12), 1197-1198.

[3] Freeborn, O.E.Geoelectric investigation for groundwater in Aniocha South Local Government Area, Delta state, Nigeria. 2006.

[4] Humill, L and Bell, F.G. Groundwater Resources Development, Publ. Buterworths, London; 334p.

[5] Karous, M. and Hjelt, S.E. Linear Filtering of VLF-EM dip angle measurements. Geophysical.1983; 31, 782-794.

[6] Lewis, M.A. The analysis of borehole yields from basement Aquifer. Common Wealth Science Council Technical paper.1990; 273(2), 171-202.

[7] Offordile, M.E. The occurrence andexploration of groundwater in Nigeria Basement rocks. Nigeria Jour. of Min. and Geol. 1983; 20, 131-146.
[8] Oladapo, M.I., Mohammed, M.Z., Adeoye, O.O. and Adetola, B.A. Geoelectrical Investigation of the Ondo State Housing Corporation Estate Ijapo Estate Akure, Southwestern Nigeria. Jour. of Min. and Geology.2004; 40(1), 41-48.
[9] Olorunfemi, M.O., Dan-Hassan, M.A. and Ojo, J.S. On the Scope and Limitations of the Electromagnetic Method in Groundwater Prospecting in a basement Complex Area – A case study. Jour. of African Earth Sciences.1995; 31(2), 151-163.
[10] Owoyemi, F.B.An updated Geologic map of Akure, Ondo State. 1996.
[11] Rahaman, M.A. Review of the Basement Geology of southwestern Nigeria. Geology of Nigeria.1976, 41-57.
[12] Van Overmeeren, R.A., A combination of Electrical resistivity, Seismic refraction and Gravity measurements for groundwater exploration in Sudan. Geophysics.1981, 46(6), 1304-1311.