Journal of the Nigerian Association of Mathematical Physics
Volume 51 (May, 2019 Issue), pp237 – 246
© J. of NAMP

EXPLORATION FOR GROUNDWATER AND DELINEATION OF LINEAMENT FEATURES USING GEOELECTRICAL METHOD IN THE TANKE AREA OF ILORIN, KWARA STATE, NIGERIA

A.K. Olawuyi and O.S. Adelodun

Department of Geophysics, University of Ilorin, Nigeria.

Abstract

The exploration for groundwater and delineation of lineament features using geoelectrical method in the Tanke area of Ilorin, Kwara State, Nigeria was carried out. Twenty Schlumberger Vertical Electrical Soundings (VES) were carried out with a view to establishing the different subsurface geoelectric layers, the aquifer units and the lineament features. Data collected from several VES points usingDDR1 resistivity meter equipped with an SAS 2000 booster were analyzed. From the quantitative interpretations of the data collected, using the usual method of curve matching with the Orellana-Mooney Master curves and 1-D forward modeling with IPI2Win™v2.0 software, between three to five geoelectric strata were identified in the area. These include: the topsoil, the lateritic soil, the weathered basement, the fractured basement and the fresh bedrock. The weathered layer and the fractured basement constitute the main aquifer units. The type curves in the study area include: H,QH, AKH, A, HA and KH. The H type curves are predominant. The depths to bedrock at the chosen VES locations vary from 2.8 to 27.5 m with a mean value of 11.92 min the study area. The depths to the top of aquifers range from 0.2m at shallowest pointto4.5m at the deepest point from the ground surface, with generally low resistivity values (≤ 100 Ω-m). The main river that drains the area coincides with the inferred lineament which suggests a structural control of the drainage. The general lack of thick overburden in the study area explains why the wells and shallow boreholes drilled in the area dry up during the dry season, a situation that makes the residents to engage in drilling deep boreholes sometimes as deep as 100m or more.

***Keywords:** Exploration, Groundwater, Lineament features, Electrical, Soundings, Weathered and Fractured.*

1.0 Introduction

The study area is bounded by latitudes $8°38'$ N and $8°39'$ N and longitudes $4°36'$ E and $4°37'$ E, covering a total area of approximately 3.5 km^{2}in the Tanke area of Ilorin South Local Government Area (LGA) of Kwara State in Nigeria(Fig. 1). The study area is underlain by the Basement Complex terrain of South western Nigeria. Groundwater is a major source of potable water in this area. According to [1], 'Groundwater serves as supplement to surface water supply in the area, because the average daily output from public water supply cannot sustain the needs of the teeming populace of the study area'. Ali [2] observed that, 'Among the known sources of potable water (that is, desalination, pipe borne, rain harvesting and groundwater), groundwater has been found to be the best option, particularly in Africa'.

In order to evaluate the geologic and geoelectric characteristics of the aquifers, the boreholes drilling must be preceded by detailed geophysical investigations. The Vertical Electric Sounding (VES) method was preferred for its simplicity, easy interpretation and rugged nature of the associated instrumentation [3]. Groundwater potentials of a Basement Complex area are often determined by geophysical means, which determines the thickness of the overburden and the network of fractures that may exist in the area[4]. Groundwater occurrence in Basement rocks is limited to the upper weathered section and fractured portion of the underlying fresh rocks[5].However, in the sedimentary environments groundwater resource is more reliable and sustainable[6].

Corresponding Author: Oluwayi A.K., Email: gideonola2001@yahoo.com, Tel: +2348052239989

1.1 Geology and hydrogeology of the area.

The area of investigation falls within the Basement Complex terrain of Southwestern Nigeria. The main lithologies of the Southwestern Nigeria Basement Complex include: the amphibolites, migmatite gneisses, granites and pegmatite. Other important rock units are the schist, made up of biotite schist, quartzite schist talk-tremolites schist and the muscovite schist. The crystalline rocks intruded into these schistose rocks [7].

The major hydrogeological units are the crystalline basement rocks (mainly the weathered and fractured basement). Generally only small amount of water can be obtained in the freshly unweathered bedrock below the weathered layers. Groundwater is found mainly in the variable weathered/transition zone and in fractures, joints and cracks of the crystalline basement[8]. The heterogeneity of groundwater occurrence and poor understanding of groundwater resources particularly in the Basement Cŏmplex terrain constitute a barrier to efficient groundwater resource management in Nigeria[9].The highest groundwater yield in the Basement terrains is found in areas where thick overburden overlies fractured zones[5].Generally, extremely low yield has been recorded for boreholes of the Basement Complex environment [9].

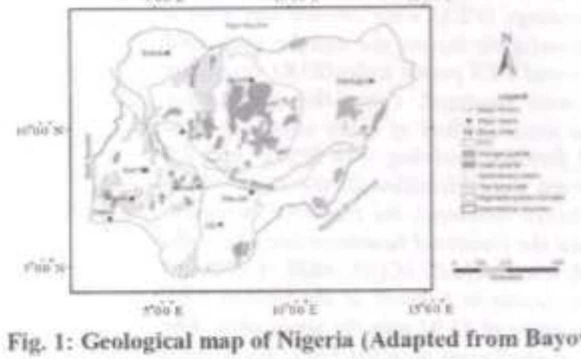

Fig. 1: Geological map of Nigeria (Adapted from Bayowa *et al.* [1]).

2.0 Methodology

Twenty vertical electrical soundings (VES) were conducted in the study area (Fig.2). The VES locations were chosen based on the needs of landlords of the existing houses in this community. The VES technique involves a maximum current electrode spacing (AB) of 200 m and the Schlumberger array. The DDR1 resistivity meter equipped with a SAS 2000 booster was employed for data collection at each station. The electrode spreading followed the description [11] where apparent resistivity (ℓa) for given geometric factor for Schlumberger electrode configuration (Fig. 3) is computed from the equation (1) below:

$$\ell_a = \frac{\pi a^2}{b}\left(1-\frac{b^2}{4a^2}\right)R;\ a \geq 5b \quad (1)$$

"*where a is half the distance between the current electrodes (C_1C_2 or AB), b is the distance between the potential electrodes (P_1P_2 or MN) and Ris the resistance*".

The data were first interpreted by the conventional partial curve matching technique with two-layer master curves in conjunction with an auxiliary point diagram. This gave an estimate of the layer resistivity and thickness, which were used as input data for computer-assisted interpretation with RESIST software to obtain the true resistivity and thickness of the various layers [12]. Typical sounding curves are shown in Figs. 4 – 8. The geoelectric layers for the sounding curves vary from three to five in the study locations.

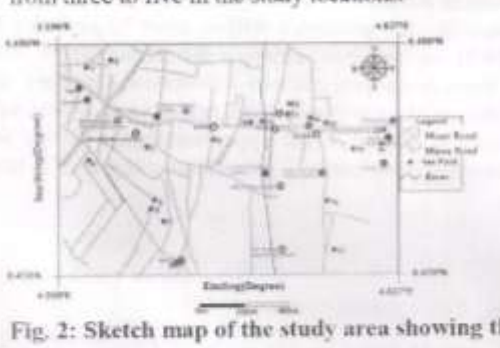

Fig. 2: Sketch map of the study area showing the study locations.

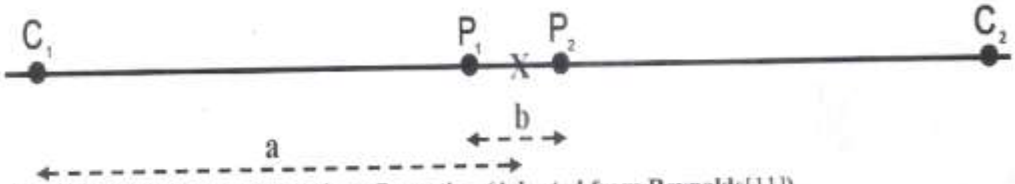

Fig. 3: Schlumberger electrical configuration (Adapted from Reynolds[11]).

3.0 Results and Discussions

3.1 The VES type curves

The typical VES curves are displayed in Figs. 4 - 8. The summary result from the interpretations of VES data is presented in Table 1. From the interpretation of the VES curves, 3 to 5 subsurface layers were identified within the study area. The type curves include: H, QH, AKH, A, HA and KH. The H type curve is predominant and account for 35% of the total number of VES curves obtained. The depths to bedrock at the chosen VES locations vary from 2.8 to 27.5 m with a mean value of 11.92 m in the study area. The VES interpretation results in the study area indicated between three to five geoelectric strata. These include: the topsoil, the lateritic soil, the weathered basement, the fractured basement and the fresh bedrock. The weathered and fractured basement constitute the main aquifer units and have varying resistivities and thicknesses while the fresh basement or bedrock is the last and most resistive for any given location. The main river that drains the area coincides with the inferred lineament which suggests a structural control of the drainage.

3.2 The iso-resistivity contour and 3D surface maps for AB/2 = 20m, 50m and 100m.

The iso-resistivity contour and3D surface maps for AB/2 = 20m, 50 m and 100m in the study area are shown in Figs.9- 11. The highest resistivities on these maps occur at the eastern part, followed by the northwestern and the southern parts. A generally low resistivity value is observed along the northwestern to southeastern axis in a linear manner with blue colour. This axis could be associated with a fault or fractures and it also coincides with a river that cuts across this area(Fig. 2), which implies that the river is structurally controlled. The orientation of the suspected fault and the main river that drains the area corroborate the fact that the effects of Pan African in Nigeria include conjugate strike slip fault systems which trend in the NE-SW and NW-SE directions and showed dextral and sinistral sense of displacement which cut across the earlier Pan African structures[13].

Another low resistivity zone occurs parallel to this axis at the western part of the study area. It could not be really defined because its full extent is not covered in this work. The resistivity range is shown on the colour legend bar with deep blue to black representing the lowest resistivity and the prospective areas for groundwater production.

3.3 The iso-depth contour of aquifer thickness.

The iso-depth contour map of the aquifer thickness is shown in Fig. 12. The thickest aquifers occur along the river channel at the northern and central parts of the study area. The presence of thick aquifers is generally favourable to groundwater exploration [5]. Generally, groundwater prospect is more favourable at the downstream side of the watershed of the river that flows northwards in the study area (Fig. 2). Other areas are generally known to contain little or no water especially in the dry season, a reason that has led to the drilling of many deep boreholes (sometimes 100-150m) in this area.

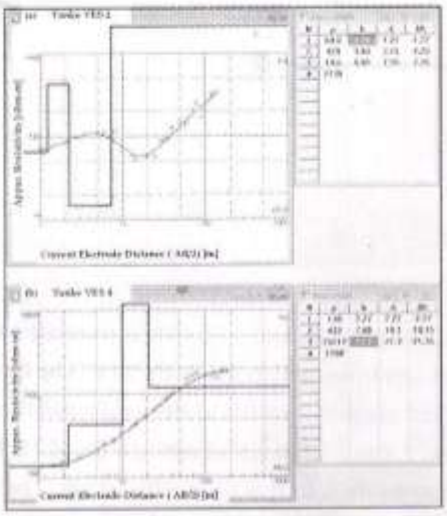

Fig. 4: Typical VES curve obtained at locations (a) 2 and (b) 4 in the study area

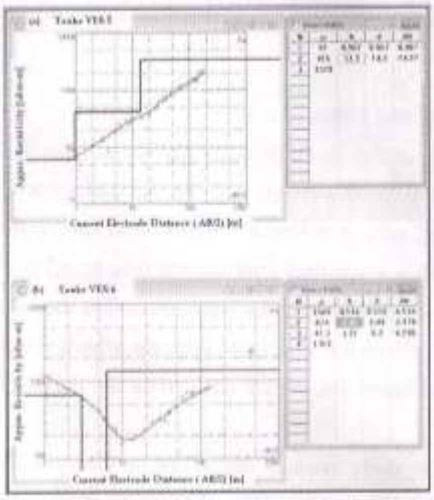

Fig. 5: Typical VES curve obtained at locations (a) 5 and (b) 6 in the study area

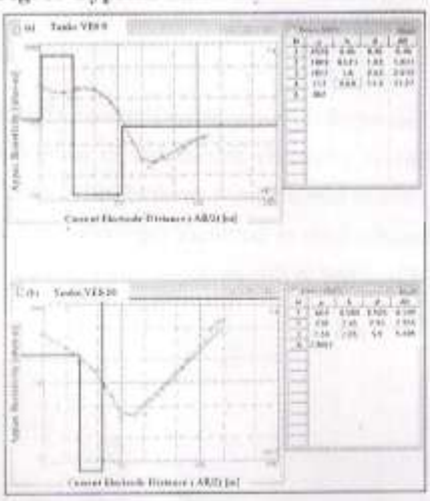

Fig. 6: Typical VES curve obtained at locations (a) 9 and (b) 10 in the study area

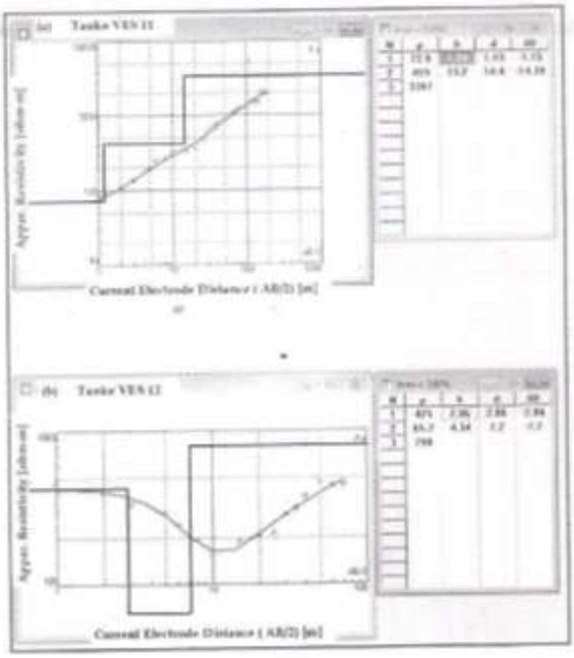

Fig. 7: Typical VES curve obtained at locations (a) 11 and (b) 12 in the study area

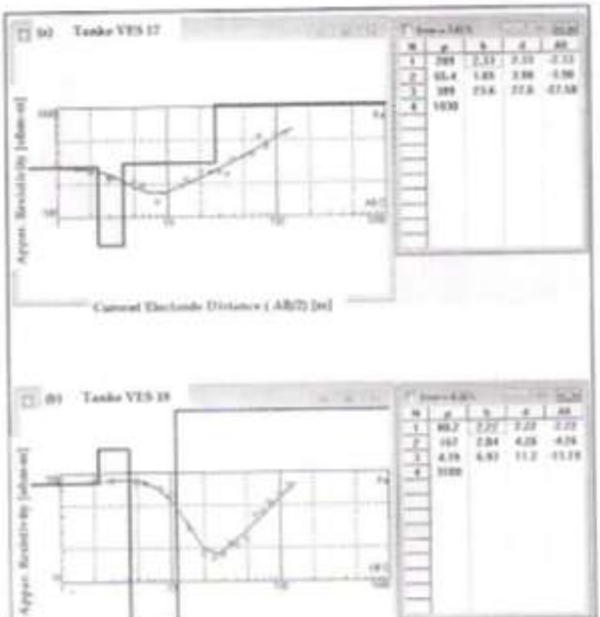

Fig. 8: Typical VES curve obtained at locations (a) 17 and (b) 18 in the study area

Table 1: Summary of results from the VES data interpreted for the study area

VES Point	Layer Resistivity (Ohm m) ρ_1,ρ_2,ρ_3,etc	Layer Thickness (m) h_1,h_2,h_3,etc	Depth (m)	Curve Type	Lithology
VES 1	323,101, 15.4,8769	1.11,7.35, 8.69, inf	1.11,8.46, 17.2,inf	QH	Top Soil, Weathered Basement, Fractured Basement, Fresh Bedrock
VES 2	64.6,429, 14.6,2138	1.22,1.03, 5.01,inf	1.22,2.25, 7.26,inf	AKH	Top Soil, Weathered Basement, Fractured Basement, Fresh Bedrock
VES 3	89.5,225.5, 818.7	1.0,1.8,inf	1.0, 2.8, inf	A	Top Soil, Weathered Basement, Fresh Bedrock
VES 4	138,432, 15212,1198	2.27,7.88, 11.2,inf	2.27,10.1, 21.4,inf	A	Top Soil, Weathered Basement, Fairly Weathered, Fractured Bedrock
VES 5	61,415,3370	0.967,13.3, inf	0.967,14.3, inf	A	Top Soil, Weathered Basement, Fresh Bedrock
VES 6	1588,674, 47.3,1363	0.518,2.46, 3.32,inf	0.518,2.97, 6.3,inf	QH	Top Soil, Weathered Basement, Fractured Basement, Fresh Bedrock
VES 7	391,91.1, 1140	4.31,0.69,inf	4.31,5,inf	A	Top Soil, Weathered Basement, Fresh Bedrock
VES 8	770,99.3,1596 5,225,10762	1.01,0.767,0.905,9.68,inf	1.01,1.7,2.68, 12.4,inf	HA	Top Soil, Lateritic layer, Weathered Basement, Fractured Basement, Fresh Bedrock
VES 9	4570,1089, 3027,117,862	0.465,0.573, 1.6,8.64,inf	0.46,1.03, 2.63,11.3,inf	KH	Top Soil, Lateritic Soil, Weathered Basement, Fractured Basement, Fresh Bedrock
VES 10	604,230,7.56, 23062	0.505,2.45, 2.85,inf	0.505,2.96, 5.81,inf	QH	Top Soil, Weathered Basement, Fractured Basement, Fresh Bedrock
VES 11	72.9,419, 3367	1.19,13.2,inf	1.19,14.4,inf	A	Top Soil, Weathered Basement, Fresh Bedrock
VES 12	425,65.2,398	2.86,4.34,inf	2.86,7.2,inf	H	Top Soil, Weathered Basement, Fresh Bedrock
VES 13	31.8,3.19, 23129	2.75,2.84,inf	2.75,5.58,inf	H	Top Soil, Weathered Basement, Fresh Bedrock
VES 14	464,111,788	1.5,26,inf	1.5,27.5,inf	H	Weathered laterite, Weathered Basement, Fresh Bedrock
VES 15	161,49.2, 3278,4.82	0.3216,8.28, 11.7,inf	0.3256,9.283, 21,inf	H	Top Soil, Weathered Basement, Fairly weathered Basement, Fractured Basement
VES 16	257,43.7,457	0.597,6.25, inf	0.597,6.84, inf	H	Top Soil, Weathered Basement, Fresh Bedrock
VES 17	289,55.4,309, 1050	2.33,1.65, 23.6,inf	2.33,3.98, 27.5,inf	HA	Top Soil, Weathered Basement, Fractured Basement, Fresh Bedrock
VES 18	80.2,167, 4.19,3109	2.22,2.04, 6.93,inf	2.22,4.26, 11.2,inf	KH	Top Soil, Weathered Basement, Fractured Basement, Fresh Bedrock
VES 19	100,17.9, 1008	3.38,4.58,inf	3.38,7.96,inf	H	Top Soil, Weathered Basement, Fresh Bedrock
VES 20	1049,186, 1038	1.71,3.73,inf	1.71,5.45,inf	H	Top Soil, Weathered Basement, Fresh Bedrock

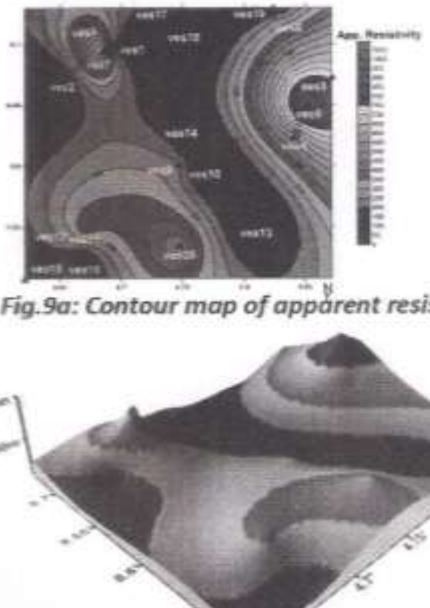

Fig.9a: Contour map of apparent resistivity at AB/2 = 20m

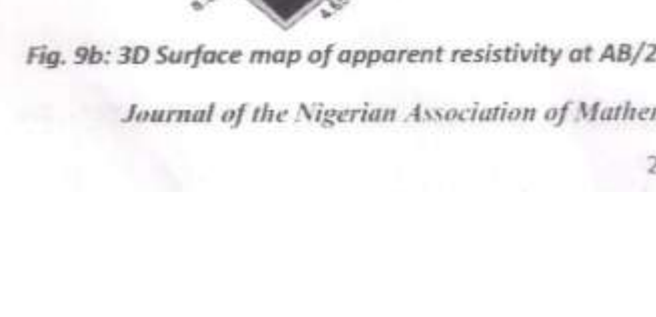

Fig. 9b: 3D Surface map of apparent resistivity at AB/2 = 20m

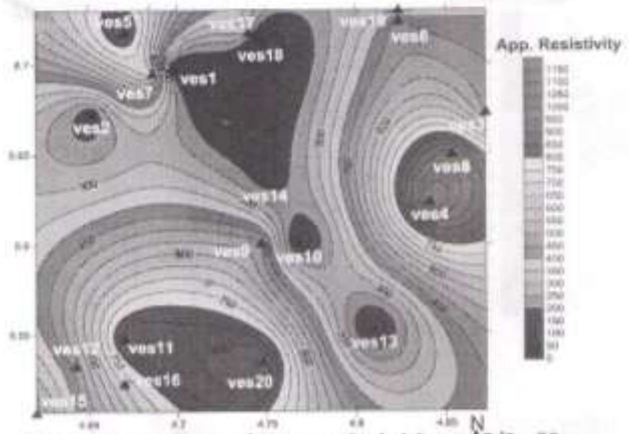

Fig.10a : Contour Map of Apparent Resistivity at AB/2 = 50m

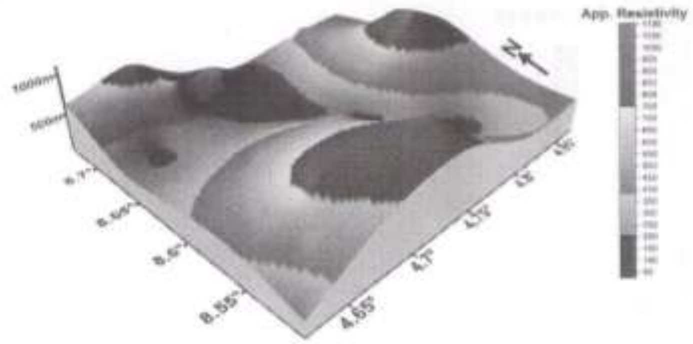

Fig.10b: 3D Surface map of apparent resistivity at AB/2 = 50m

Fig.11a: Contour map of apparent resistivity at AB/2 = 100m

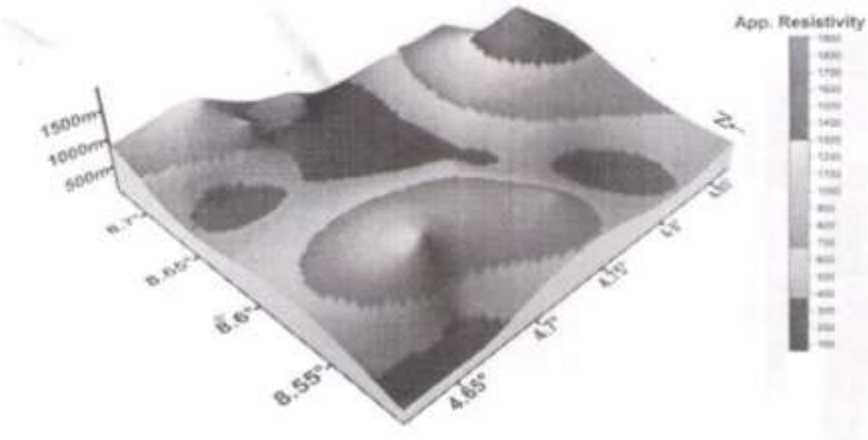

Fig.11b: 3D Surface map of apparent resistivity at AB/2 = 100m

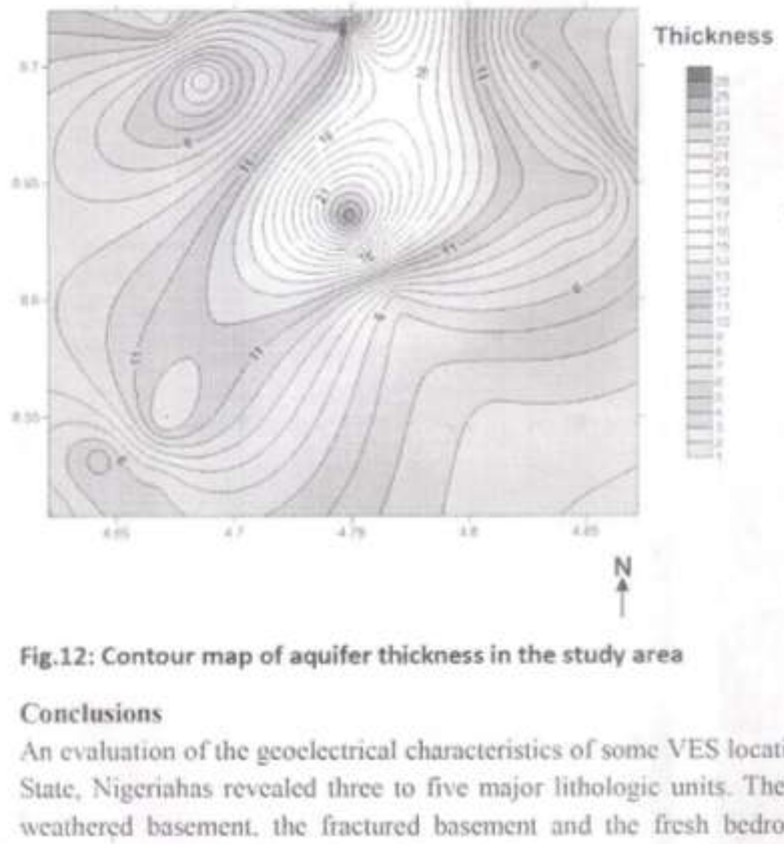

Fig.12: Contour map of aquifer thickness in the study area

Conclusions

An evaluation of the geoelectrical characteristics of some VES locations in the Tanke area of Ilorin city in Kwara State, Nigeriahas revealed three to five major lithologic units. These include: the topsoil, the lateritic soil, the weathered basement, the fractured basement and the fresh bedrock. The weathered layer and the fractured basement constitute the main aquifer units. The type curves include: H, QH, AKH, A, HA and KH. The H type curve is predominant and account for 35% of the total number of VES curves obtained. The depths to fresh bedrock at the chosen VES locations vary from 2.8 to 27.5 m with a mean value of 11.92 m in the study area. The main river that drains the area coincides with the inferred lineament which suggests a structural control of the drainage. Also, the orientation of the river in the north-south direction corroborate the fact thatthe effects of Pan

African in Nigeria include conjugate strike slip fault systems which trend in the NE-SW and NW-SE directions and showed dextral and sinistral sense of displacement which cut across the earlier Pan African structures [13].
The iso-depth contour map of the aquifer thickness (Fig. 12) shows that the thickest aquifers occur at the downstream part of the river channel. The presence of thick aquifers is generally favourable to groundwater exploration[5].Generally, groundwater prospect is more favourable at the downstream side of the watershed of the river that flows northwards in the study area (Fig. 2). Other areas are generally known to contain little or no water especially in the dry season, a reason that has led to the drilling of many deep boreholes (sometimes 100-150m) in this area. This act is not advisable with regards to the stability of this environment and the government and other policy makers are hereby advised to take quick decision to discourage this attitude.

References

[1] Sule, B.F, Balogun, O.S and Muraina, L.B. (2013): Determination of Hydraulic Characteristics of Groundwater Aquifer in Ilorin, North Central Nigeria. Scientific Research and Essays,8 (25): 1150 – 1161. DOI10.5897/SRE11.645. ISSN1992-2248.

[2] Ali, K.A. (2012): Development of Water Supply Infrastructure in Nigeria: Challenges and Prospects. *Nigeria Society of Engineers*.38p.

[3] Sharma, S.P and Baranwal, V.C.(2005): Delineation of Groundwater Bearing Fracture Zones in Hard Rock Area Integrating Very Low Frequency Electromagnetic and Resistivity Data. *Journal of Applied Geophysics*, 57:155–166.

[4] Mendoza, J.A and Dahlin, T.(2008): Resistivity Imaging in Steep and Weathered Terrains. *Near Surface Geophysics*, 105 – 112.

[5] Olorunfemi, M.O and Fasuyi, S.A.(1993): Aquifer Types and the Geoelectric/Hydrogeologic Characteristics of Part of the Central Basement Terrain of Nigeria (Niger State).*J. African Earth Sci.*, 16: 309-317.

[6] Ifabiyi, I.P.(2000): Predicting Borehole Yield in Precambrian Basement Complex and Sedimentary Rocks in Central Western Nigeria. Review of Growth and Change.

[7] Oyinloye, A.O. (2011): Geology and Geotectonic setting of the Basement complex rocksin the Southwestern Nigeria: Implications on provenance and evolution. Onlineat: https://www.intechopen.com /.../geology-and-geotectonic-setting-of-the-basement-com.

[8] Clark, L. (1985): Groundwater Abstraction from the Basement Complex Area of Africa. *Q. J.Engineering Geology*. London,18: 25 – 34.

[9] Akinwumiju, A.S and Olorunfemi, M.O.(2016): Shallow Aquifer Characteristics, Borehole Yield and Groundwater Resource Sustainability Assessment in the Osun Drainage Basin, Southwestern Nigeria. *Ife Journal of Science*,18 (2): 305 – 314.

[10] Bayowa, O.G, Olorunfemi, O.M, Akinluyi, O.F and Ademilua, O.L. (2014): A Preliminary Approach to the Groundwater Potential Appraisal of Ekiti State, Southwestern Nigeria. International Journal of Science and Technology, 4 (3):48 –58. ISSN 2224 – 3577.

[11] Reynolds, J.M. (1997): Introduction to Applied and Environmental Geophysics. Reynolds Geosciences Ltd. John Willey (Publisher), U.K.

[12] Anomohanran, O. (2015): Hydrogeophysical and Hydrogeological Investigations of Groundwater Resources in Delta Central, Nigeria. Journal of Taibah University for Science,9 (1): 57 – 68. https://doi.org/10.1016/j.jtusci.2014.06.003.

[13] Ball, E. (1980): An example of very consistent brittle deformation over a wide intra-continental area: The late Pan African fracture system of the Tuareg and Nigerian shield. Tectonophysics, **61**: 363-379.