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Subsurface Lithology and Aquifer Zones Using Vertical Electrical Sounding Method in Kano Metropolis, Northwestern Nigeria

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Abstract: *The study area is located in the Kano Municipal. It is bounded by latitudes 11°51´ to 12°06´N and longitudes 8°23´ to 8°38´ E covering an area of about 770.063 km^2.This paper examines the geoelecric layers in Kano metropolis, as indicated by the results of electrical resistivity method. Vertical Electrical method (VES) using Schlumberger array was carried out at the twenty (20) VES stations in the area. Ohmega resistivity meter was used for the data acquisition. The field data obtained has been analysed using computer software IPI2win, which gives an automatic interpretation of the apparent resistivity. The results suggest that, three-four geoelecric layers exist in the area, consisting of Topsoil layer, with resistivity that ranges from 12.93 ohm m to 2783.2 ohm m, its thickness varies from 1.12m to 11.5m. Weathered layer has resistivity value ranging from 28.48ohm m to 216.3 ohm m; thickness varies from 5.29m to 54.34m. Fractured/fresh basement layer (s). The resistivity value ranges from 26.13 ohm m to 9779.3 ohm m. The thickness varies from 23.18 m to 68.60 m. The weathered layer serves as an aquiferous zone; where it is extensively thick. Bedrock could also serves as an aquifer where it is extensively fractured.*
Keywords: *Aquifer, fractured, resistivity, thickness, vertical electrical soundings, weathered layer,*

I. Introduction

The science of geophysics was originally concerned with the study of the shape and structure of the earth. From 1920 onward geophysical techniques have been increasingly used on smaller scales to search for minerals in the earth's crust. Recently, geophysical methods (VES inclusive) have been widely applied to the study of shallow geological structures, where depths are measured in tens and hundreds of metres. This gives information on the nature of subsurface geological structures.

According to [1], an electrical method in which current is applied by conduction to the ground through electrodes depends on the fact that, any subsurface variation in conductivity alters the form of current flow within the earth and this affects the distribution of electrical potential. The degree to which the potential at the surface is affected depends on the nature, size, shape, location and electrical resistivity of the subsurface masses. It is therefore possible to obtain information about the subsurface distribution of these bodies from potential measurements made at the surface. This method is used in finding of suitable target for groundwater development in a basement complex terrain.

The aim of this study is to identify different geoelecric layers, and groundwater potentials in the study area using Vertical electrical technique (VES).

II. Physiography, Geology and Hydrogeology of the Study Area

The study area is bounded by longitudes 11°51´ to 12°06´N and latitudes 8°23´ to 8°38´ E. It is accessible through the Kano-Zaria, Kano-Maiduguri, Kano-Katsina, Kano-Hadejia highway roads and numerous intra state roads, as well as footpaths. It is drained by the River Challawa which flows from the west to the eastern part of the study area and its numerous seasonal tributaries, also by River Watari, which together with River Challawa join River Hadejia and empties into the Lake Chad. While Rivers Gari and Jakara flows from the study area and disappear into the sands of Chad formation further east.

Kano area is underlain by rocks of the Nigerian basement complex comprising migmatites-gneiss complex, younger metasediments, older and younger granites [2]. [3] established that, it is dominantly underlain by undifferentiated metamorphic suite, older granite, coarse pink granite and porphyritic biotite granite. The predominant rock type is older granite. The older granite is composed of coarse-grained granite, granodiorite, diorite and aplite. The lithological varieties are less common than in metamorphic suite. They were emplaced during the Pan African orogeny which was dated about 650-850 ma. The most abundant and typical member of the older granite suite is a coarse porphyritic granite [4]. It is typified by the abundant large feldspar set in a ground mass rich in biotite or hornblende. The feldspar may be white, purple, pink, yellowish brown and dark grey.

[5] shows that granidiorite constitute a significant part of Kano area. It outcrops as large, massive boulders or as low-laying bodies. The rock is porphyritic in texture, with phenocrysts of plagioclase easily recognizable on hand specimens. Generally, light in color, but with segregation of more mafic portion which are mainly hornblende and biotite.

The schists are considered to be Upper Proterozoic supracrustal rocks which have been infolded into the migmatites-gneiss-quartzite complex [6]. They occupy an area within the ''walled city'' to the north central part of Kano. In hand specimen, the schists are fine to medium grained. They are reddish to greenish grey in colour and highly weathered. They are found to be associated with diorite. This association indicates that schists have been intruded by small dioritic bodies, and are considered older than diorites in the area.

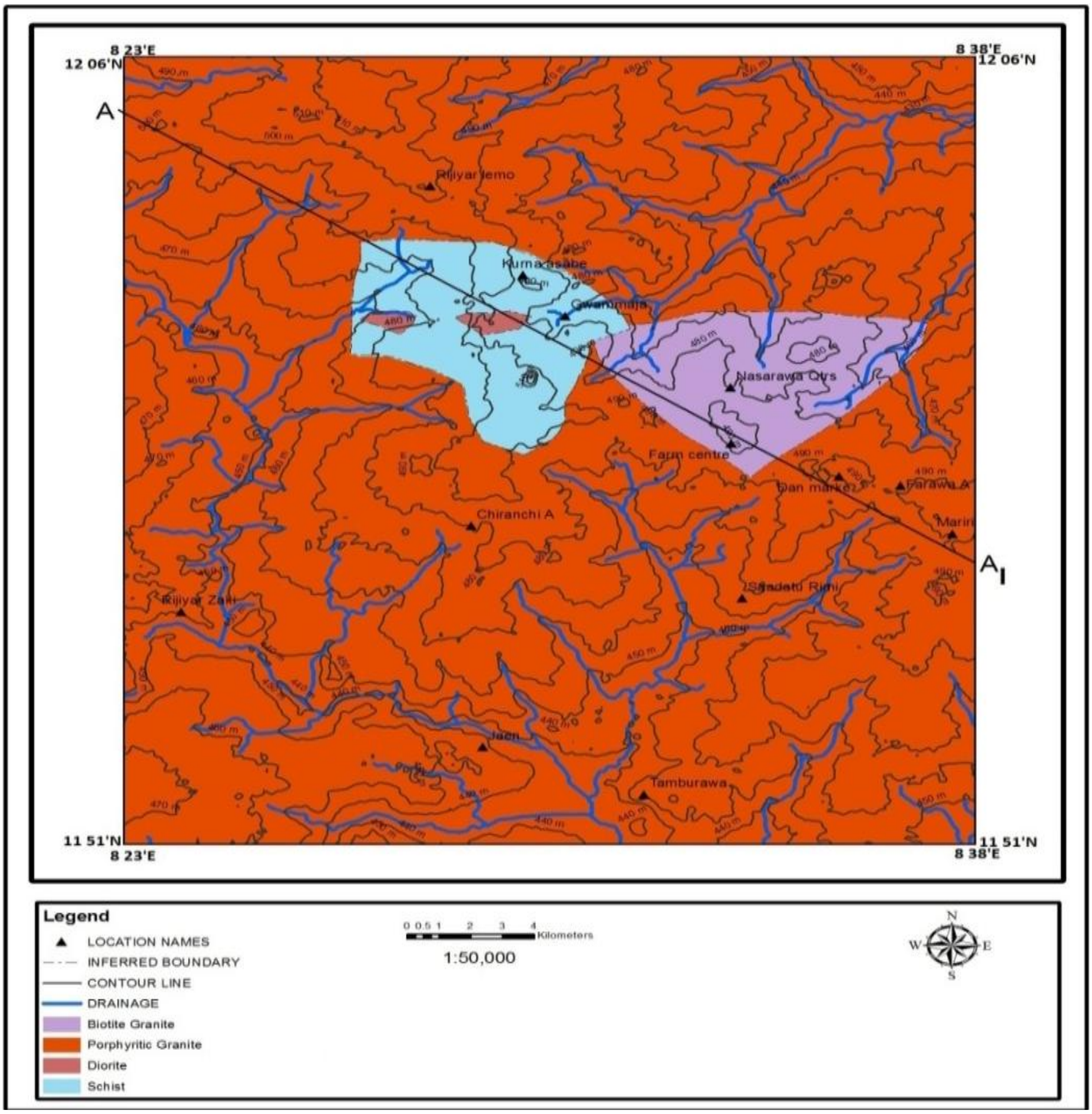


Fig. 1: Geological map of the study area

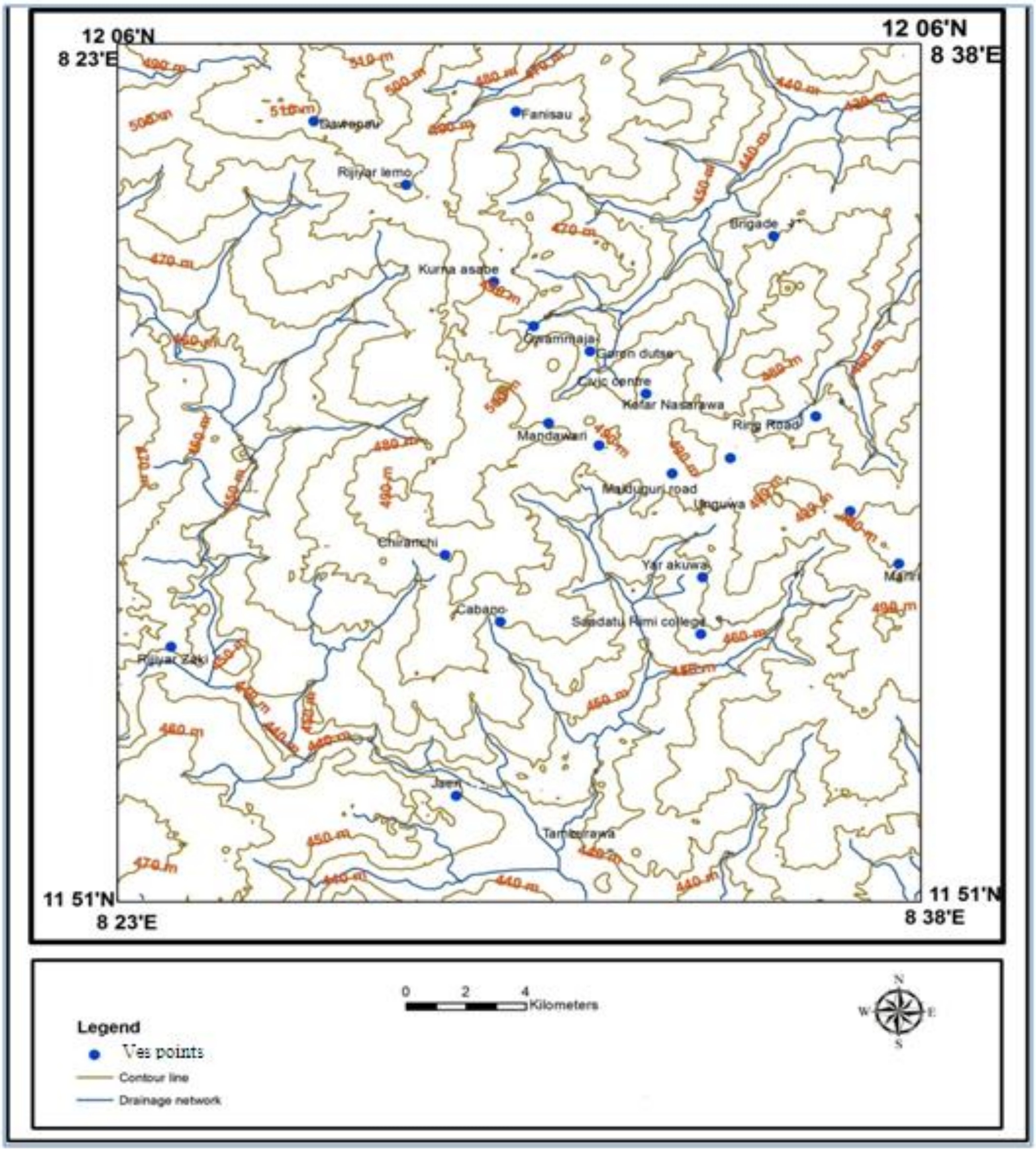


Fig. 2: Topographical map of the area showing ves points

In the study area, groundwater occurs within the weathered mantle or in the joint and fracture systems of the unweathered or partly weathered rocks [3]. [7] proposed that aquifer is located in the weathered mantle and fractured rock where permeability and porosity are sufficient to allow appreciable amount of water to accumulate in storage. The high groundwater yield in the area is found where thick overburden overlies fractured zones. The older granite has been subjected to many tectonic movements and pressure through geologic history such that they often have several fracture lines.

III. Methodology

A vertical electrical sounding (VES) of electrical resistivity method was carried out using Ohmega resistivity meter with Schlumberger configuration. According to [8], the VES principle is based on the fact that sub-strata is a resistor to the flow of electric current and that any sub-surface variation in conductivity will alter the current which affects the electrical resistivity of overburden and bedrock varies considerably in relation to moisture content.

Electric current is passed into the ground between to outer electrodes while the resultant potential difference is measured by two inner electrodes. The electric field produced is measured by the instrument in the form of Resistance which when multiplied by a constant (k) gives the apparent resistivity value.

The electrode spacing was progressively increased keeping the centre point of the electrode array fixed. The maximum half current electrode separation (AB⁄2) was between 1 and 80m while the half- potential electrode separation (MN⁄2) was maintained between 0.5 and 8m. The apparent resistivity measured at each point was plotted on a log-log paper. The plots gave a rough idea of position and forms of the interface. A total of twenty (20) VES points were collected. The interpretation of the field data was done quantitatively using a computer program to identify thickness and resistivity of different layers, so as to give information on deeply weathered and fractured zones.

IV. Results And Discussions

Twenty (20) VES soundings data were analysed. Table 1 below shows the values of resistivity, and thickness of each layer.

S/N	Location ID	1st layer			2nd layer			3rd layer			4th layer			Type of Curve
		Resistivity (Ωm)	Depth(m)	Thi ckness (m)	Resistivity (Ωm)	Depth(m)	Thickness (m)	Resistivity (Ωm)	Depth(m)	Thickness (m)	Resistivity (Ωm)	Depth(m)	Thickness (m)	
1	BUK 1	272	0.75	0.75	150	4.56	3.81	29.3	9.19	4.63	425	16.0	-	QH
2	UBA 1	2783.2	1.12	1.12	48.82	18.12	16.99	9779.3	43.32	25.20	31.67	43.32	-	QH
3	ASH 1	78.63	9.18	9.18	116.0	17.43	8.24	333.2	72.05	54.62	231.4	72.05	-	HA
4	ALI 1	375.3	1.81	1.81	28.48	56.16	54.34	76.91	84.89	28.73	209.6	84.89	-	QH
5	GPL 1	119.8	1.75	1.75	43.74	26.75	24.99	79.04	73.44	46.69	64.99	73.44	-	QH
6	RAS 1	26.60	1.72	1.72	67.89	8.91	7.18	26.13	42.64	33.72	64.07	42.64	-	KA
7	KZR 1	22.09	4.93	4.93	36.22	18.71	13.77	176.6	62.31	43.60	62.85	62.31	-	A
8	ABK 1	303.2	1.92	1.92	93.69	28.04	26.12	129.1	67.55	39.50	115.9	67.55	-	QH
9	RLM 2	12.93	2.73	2.73	103.0	26.76	24.03	339.9	73.06	46.30	269.4	73.06	-	A
10	RLM 1	147.3	6.74	6.74	119.7	15.45	8.70	262.6	56.90	41.45	150.5	56.90	-	HA
11	FCT 3	115.7	11.57	11.57	119.8	28.45	16.87	262.4	85.10	56.64	161.2	85.10	-	HA
12	BDW 2	55.62	2.87	2.87	136.9	10.14	7.27	48.81	61.01	50.87	57.07	61.01	-	K
13	FCT 1	151	1.25	1.25	42.8	21.8	20.6	156	32.26	34.96	257	55.31RTTT	-	QH
14	PAV 1	35.71	6.70	6.70	88.45	27.18	20.48	101.9	74.09	46.90	107.2	74.09	-	HA
15	BHT	78.45	2.42	2.42	32.19	8.19	5.76	77.27	61.71	53.52	124.5	61.71	-	H
16	MHB 1	273.6	4.20	4.20	62.01	25.48	21.28	145.4	68.09	42.60	92.19	68.09	-	QH
17	GWD 1	26.36	7.85	7.85	216.3	21.04	13.19	138.5	44.23	23.18	597.9	44.23	-	HA
18	SOK 1	421	1.59	1.59	38.8	9.59	9.59	16.8	28.4	28.4	2826	39.58	-	QH
19	AHL 1	208.4	2.20	2.20	108.1	18.29	16.08	87.27	86.90	68.60	53.66	86.90	-	Q
20	IDR 1	141.0	3.84	3.84	95.49	16.02	12.18	236.9	48.81	64.83	245.5	64.83	-	H

The aim of Vertical electrical Sounding is to determine the different geoelecric layers in the subsurface, the aquifer units and their characteristics, as well as general hydrogeological condition. Four layered-type curves were obtained from the VES points in the study area. They have varying geologic characteristics, showing different degree of weathering and other second porosity in form of fracturing of the bedrock. Plots of some calculated apparent resistivity in ohm-m against electrode spacing in m are presented in Fig. 3. These layers could be grouped as follows:-

1st layer - Top soil;
2nd layer – Weathered layer;
3rd layer – Fractured layer;
4th layer – Bedrock.

4.1 Top soil

This is a surface dry layer of high resistivity that ranges from 12.93 ohm m to 2783.2 ohm m. Its thickness varies from 1.12m to 11.5m. The low resistivity end is diagnostic of sandy clay and clay while a high resistivity end indicates laterite. However, very high resistivity could be an intruded fresh basement.

4.2 Weathered layer

This layer is thought to be highly decomposed crystalline rock. The resistivity value ranges from 28.48ohm m to 216.3 ohm m. The thickness varies from 5.29m to 54.34m. According to [9], it consists of clayey sand/ sandy clay layer. The layer is highly decomposed by weathering to form sand and clayey sand depending on the local variation of the mineralogy.

4.3 Fractured layer

The resistivity value ranges from 26.13 ohm m to 9779.3 ohm m. The thickness varies from 23.18 m to 68.60 m. [9] identified this layer to be the major aquifer unit. In some places, fractured zones occur immediately beneath the weathered horizon. The fractured zones are difficult to detect geophysically, unless it is of greater thickness. Where the fractured zone is saturated, a high groundwater yield can be obtained from borehole penetrating such a sequence. If the depth of weathering is sufficiently thick as exhibited by most of the VES points in the study area; the weathered mantle could contain water in storage large enough to produce a successful borehole. Therefore, based on thickness and resistivity of weathered layer; the following VES points are identified as good potentials for groundwater development; BUK 1, SOK 1, FCT1, BRJ 2, BMP1, CLB 1, DKT 1 and BDW 2. However, layer 2 (weathered) is believed to be the regolith. Invariably, they have a range of resistivity values. [10] made it clear in their geophysical assessment of Kano crystalline aquifers that, the range reflects the preferred lithological range, high value indicates a granular regolith, and intermediates values indicating silty clayey regolith.

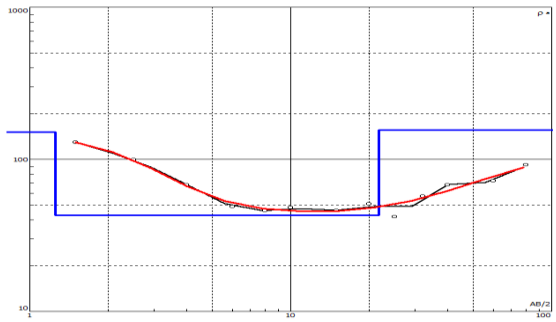
4.4 Bedrock

This is fresh basement layer. Ordinarily, it has a very high resistivity with infinite thickness. But where it is fractured and saturated; the resistivity reduces. It is not a source of groundwater unless fractured. However, when the shape of the VES curves approaches a very steep gradient of about 45° (steady increase in resistivity), it may indicate a fresh basement rock without fractures.

V. Conclusion

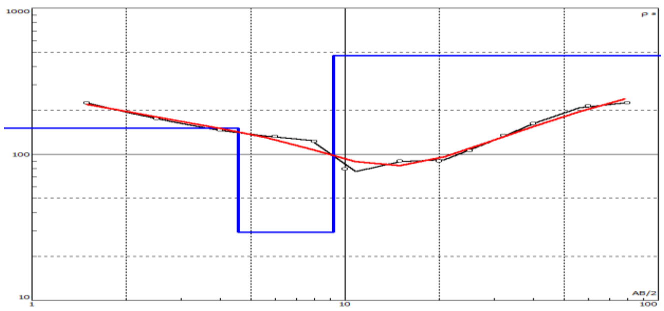
Based on the hydrogeological condition and geoelectrical resistivity findings; geoelectric layers identified in the study area are; Top soil, highly weathered layer, weathered layer, and bedrock. Weathered layer (layer3) has been identified as the major aquifer unit, and where it is extensively thick as in VES BUK 1, SOK 1, FCT1, BRJ 2, BMP1, CLB 1, DKT 1 and BDW 2; could serve as good points for groundwater development. Boreholes drilled in the recommended VES points; can provide sufficient water to sustain a motorize scheme. But the yield cannot be ascertained until when they are drilled. Therefore, a VES technique has proved to be cost effective in the location and delineation of aquifer in crystalline basement area. Thus the study area can be said to have a fairly good groundwater potential.

A less than 12% fitting error is considered appreciable to warrant a good orientation of VES profile in basement area. It was observed that in all the 20 VES points, a fitting error of <12% were obtained, except in; VES FCT 1, BMP 1, BRJ 2, DKT 1, and KRN 1.



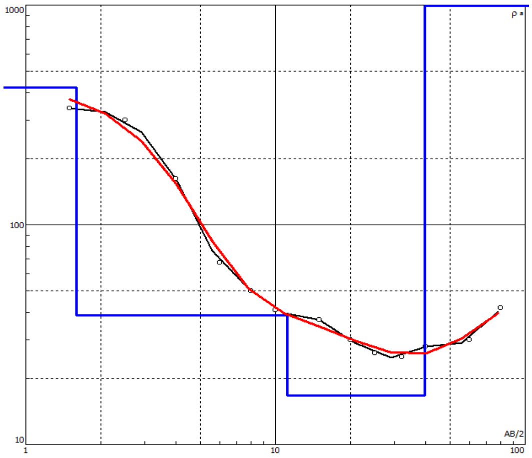
N	ρ	h	d	Alt
1	151	1.25	1.25	-1.25
2	42.8	20.6	21.8	-21.8
3	156			

a. FCT 1 VES station



N	ρ	h	d	Alt
1	272	0.75	0.75	-0.75
2	150	3.81	4.56	-4.558
3	29.3	4.63	9.19	-9.186
4	475			

b. BUK 1 VES station



N	ρ	h	d	Alt
1	421	1.59	1.59	-1.595
2	38.8	9.59	11.2	-11.18
3	16.8	28.4	39.6	-39.61
4	2826			

c. SOK 1 VES station

Fig.3: Some selected resistivity curves of the study area

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