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Geological and Geophysical Investigation of Groundwater in Parts of Paiko, Sheet 185, North-Central Nigeria

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Abstract:- Geological and geophysical investigation of groundwater potential was carried out in Paiko town, Niger state. The area is part of the Basement complex of north central Nigeria, comprising of granite-gneiss and granitic rocks varying in grain size, outcropping at different locations within the area. The Schlumberger configuration of electrical resistivity method was employed with a maximum AB/2 of 70m. A total of not less than 33 Vertical Electrical Soundings (VES) were established within the study area. Qualitative and quantitative interpretation of the obtained data were carried out, via visual inspection of the field curve, traditional curve matching involving the master and auxiliary curves as well as the computer iteration (Winresist software) to generate resolution curves. The dominant curve types in the area are: **H, HA,** and **HK** curve types. The pre and post drilling data obtained, also indicates the dominance of these curve types. Geoelectric sections generated from the geoelectric logs indicate three major layers exist in the Paiko Basement rocks at various depths. The topmost layer is the **Loess unsaturated topsoil** with resistivity value ranging between **50 - 125.9Ωm** and a depth of about **0.9-1.5m**. The topmost layer is underlain with the **slightly weathered/fractured Basement** with resistivity values ranging between **90-270Ωm** with a thickness of **4.6-12m** to the depth range **15-30m**. The last layer is the **Fresh Basement** unit with resistivity value ranging between **388-1800Ωm** to a fairly infinitive depth. Borehole depth in the study area ranges between 30-60m. The study also revealed that the fractures in the study area are discrete, localized and discontinuous.

Keywords:- Paiko, geo-electric log, geo-electric section, vertical electrical sounding, groundwater flownet.

I. INTRODUCTION

Paiko town is part of sheet 185, it lies within latitude 9°26^{I}59^{II}N and longitude 6°39^{I}05^{II}E. It hosts the secretariat of Paikoro Local Government Area, of Niger state, which has an estimated population of about 158,086, covering a total area of about 2,066km² with other small villages, settlements and hamlets. Civilizatied increasing demand on the supply of portable water for both domestic and industrial useon has plac. Surface water which is the most obvious source of water resource in the study area is not always available during the dry season. About 90% of the total population of the town rely on groundwater resource for fresh water supply. Hand dug wells which serves as a good alternative to surface water supply are mostly unsuccessful owing to the extreme seasonal variation of the static water level, most hand dug wells experience reduction in their static water levels during the dry season and as a result dry up completely at the peak of the dry season. The most available and reliable source of water supply in the area is groundwater resource through borehole drilling, hence the need for this investigation. Groundwater recharge in the area is greatly influence by rainfall, topography, overburden thickness and geology.

This study is aimed at investigating the groundwater potential in the area as well as the causes of borehole failure in the area with the view of providing scientific based solutions. It is believed that this research when completed will provide hydrological base information for stakeholders in the area.

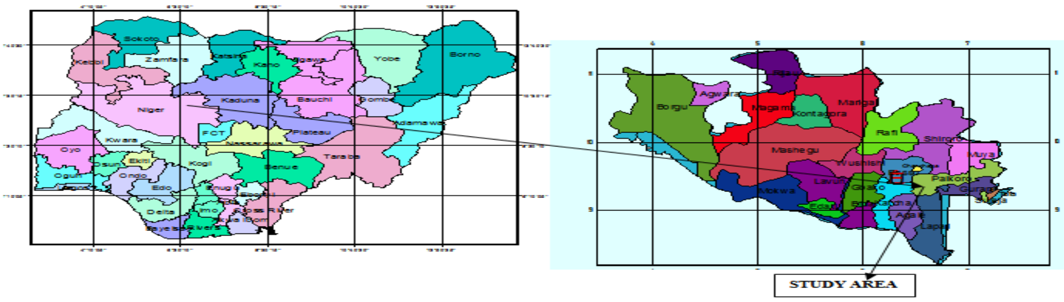

Fig.1. Location map of the study area.

II. CLIMATE AND PHYSIOGRAPHY OF THE AREA

The area is easily accessible by motorable roads. The vegetation of the study area belongs to the central savannah which is a transitional type between the forest zone of southern Nigeria and the Guinea Savannah types of the Northern Nigeria. This area is characterized by tall grasses with light forest, sparsely distributed trees in dry season and evenly distributed trees in wet (rainy) season. The area mapped lies within the middle belt of Nigeria; the annual rainfall distribution pattern shows a maximum of 1300mm rainfall and minimum of 900–1000mm. The rainy season is between April and October covering a period of six months. The topography of the study area is marked by high and flat terrain, with most of the highlands visible around the vicinity of the area.

III. GEOLOGY

The study area lies within the north-central portion of the Nigerian Basement Complex rock (fig.2), which is characterized by three lithofacies: the migmatite gneiss complex, the low schist belt and the older granites (Olarewaju, *et al*., 1996; Olasehinde, 1999). Particular to the area is the granite-gneiss and granitic rocks of different grain sizes, outcropping at different locations within the area, with noticeable fractures and joints. The joints are of two generations depending on their orientations, some trending NNE-SSW and the other NE-SW (fig.3). In most cases the joints are filled with Quartzo-feldspardic veins, while others are fairly well exposed along the river channel. The values of the joints directions range between 120° and 160°. Foliation was also noticed on some of the outcrops in the area. The outcrops in the area are randomly located at the south eastern parts.

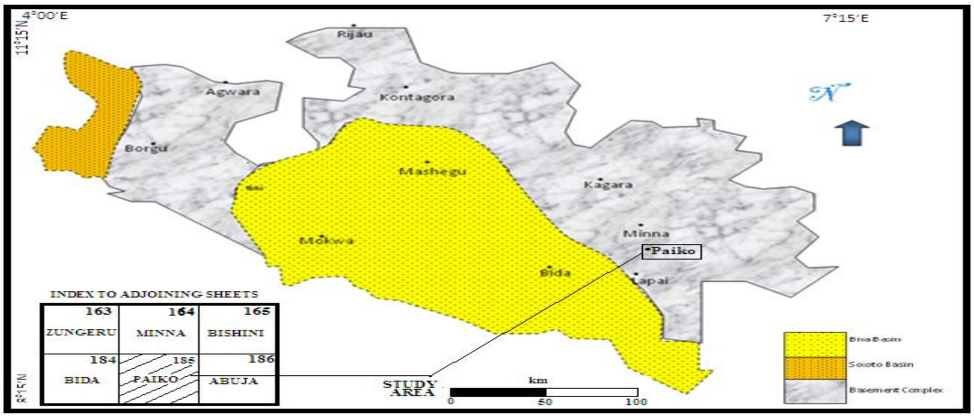

Fig.2: Geological map of Niger State indicating the study area

IV. HYDROGEOLOGY OF THE AREA

The land structure is related to the rock type underlying it. The impermeable igneous and metamorphic rocks underlying the North Central basement complex terrain are considered as poor sources of groundwater. However, tectonic features such as fracturing, jointing and fissuring often modify the water bearing characteristics of the rocks and make them amenable to containing water in discontinuous and isolated places through the development of secondary permeability. The capacity of these crystalline rocks to store and allow movement and yield water chiefly depend on the extent, pattern, size, openness and continuity of the fracture, and to the degree to which these fractures are hydraulically connected (Todd, 1980). The drainage pattern in the area is observed to be dentritic and reflects the uniformity of the geology of the area. The names of some of these rivers must have been forgotten due to their dryness. All these minor rivers drain into river Chanchaga and the direction flow is east to west.

Due to lack of interconnectivity of the joints and fractures in the study area, the weathered aquifer is the most important aquifer utilized. This is because all the pore spaces are well interconnected. Majority of the borehole drilled within the vicinity of the study area tap water from this aquifer in addition to the minor fractures that are encountered in some locations. These aquifers are recharged mainly by the rain water (precipitation) and as a result, during rainy season, the discharges of the boreholes tapping the perched aquifers are higher than during the dry season. The general trend of groundwater flow in the study area is of northeast-southwest direction (Fig.4).

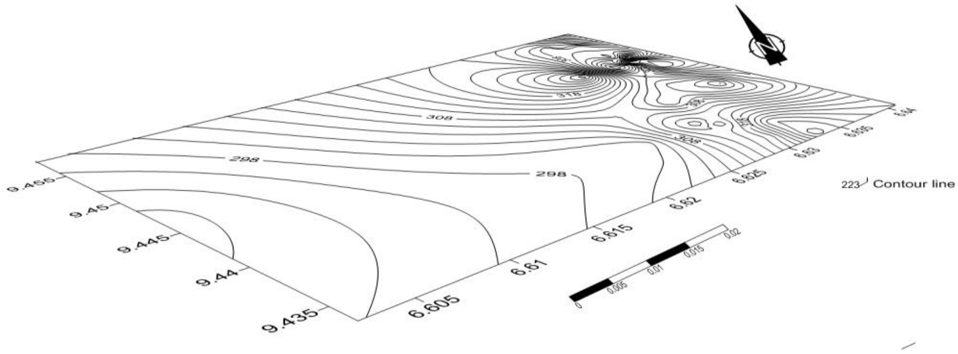

Fig.3: 2D Contour maps of the study area

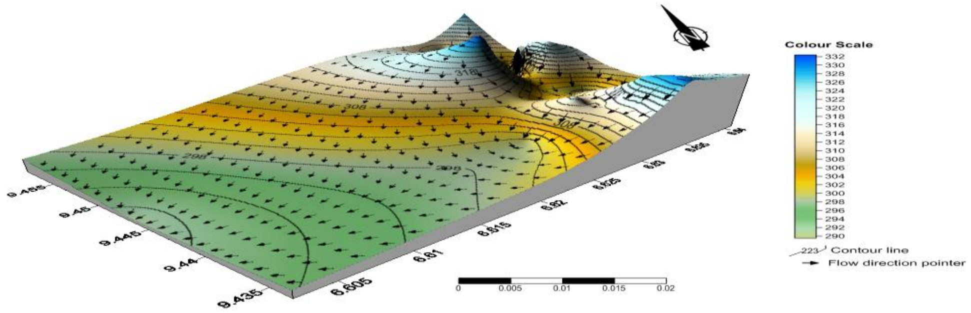

Fig.4: Groundwater flownet of the area

V. MATERIALS AND METHOD

In carrying out the geological mapping, desk study of the published regional geological map of the area was done before embarking on the field mapping. Join directions were measured in the field with the aid of compass clinometers and a Rosette diagram (fig.6) was generated to ascertain the principal joint direction while other features like faults and exfoliation were also observed. Investigation points (Fig.5) were established using a Garmin Global Positioning System (GPS) Etrex Legend. Data obtained using GPS were utilized to generate the contour map (Fig.3) and digital terrain model (DTM) of the study area. Rock samples were also taking and tin section slides were viewed with the aid of the petrographic microscope under cross polar and plane polar conditions in order to ascertain the actual rock type in the study area at Federal University of Technology Minna geology laboratory, the photomicrographs are shown in plate 1 and 2.

The Geotron Resistivity meter and the made in Nigeria Terrameter of high precision and accuracy were used for measurements. Separate transmitting (Power) and receiving (Potential) units eliminate errors due to mutual interference (Walker and Williams, 1981). The current and potential readings are taking separately after which Ohms law is used to derive the resistivity. Current was introduced into the ground through two steel coated electrodes and the potential difference as response was measured between two electrodes using the Schlumberger configuration. The data interpretations were integrated with some available borehole log data from the study area (fig.7-9).

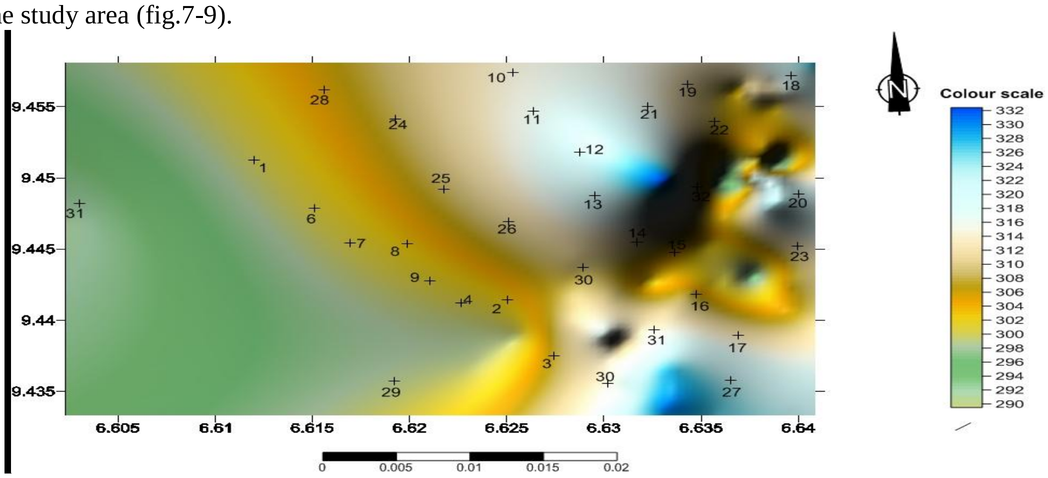

Fig.5: 3-D and 2-D Digital Terrain Models of the area showing VES points.

VI. GEOPHYSICAL INVESTIGATIONS

With a maximum AB/2 of 70m, 33 Vertical Electrical Sounding (VES) were established within the study area employing the Schlumberger configuration of the electrical resistivity survey method, the distance between profiles was not specific. Qualitative and quantitative interpretation of the obtained data were carried out, generating the curves, using the traditional curve matching involving the master and auxiliary curves to acquire the different layers at various depth and thereafter using the computer iteration (Winresist software) to generate resolution curves. The interpreted curves were joined to bring out the geoelectric logs (fig.7-9), geoelectric sections were then drawn from the logs (fig). (Fig7-9) shows a typical interpretation of the VES curve in part of Paiko using the Winresist interpretation software.

VII. RESULTS AND INTERPRETATION

Joint Directions

The Rosette diagram (Fig.6) indicate two major joint directions NE-SW as the principal joint direction, dominating the NN-SE part of the area and also the NW–SE joint directions typical of the NW-SW portion of the study area. The joint directions correspond to the groundwater flow direction of the area.

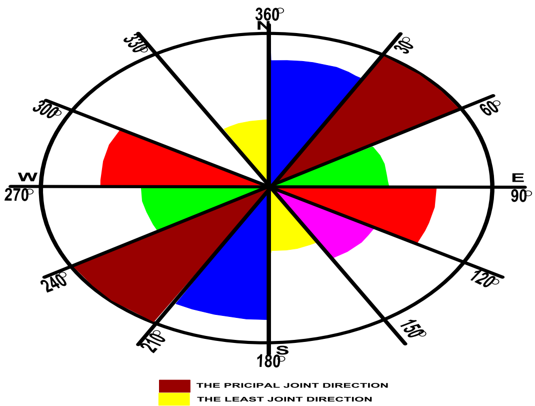

Fig.6: Rosette Diagram

Tin Section Analysis

In most geological materials the main factors governing resistivity are the concentration of ions in the pore water and the amount of pore water present since current is conveyed mostly by flowing ions in the pore water. It is therefore necessary to have knowledge of the particular rock type(s) of a study area, which will enhance the investigation of groundwater in such area. Two major rock types were identified based on the observation of the tin section under cross polar (CP) and plain polar (PP) conditions; these include biotite-granite and granite gneiss. This is necessary due to the fact that mineral composition, grain size arrangement, texture and other geological factors determine the nature and the extent of weathering.

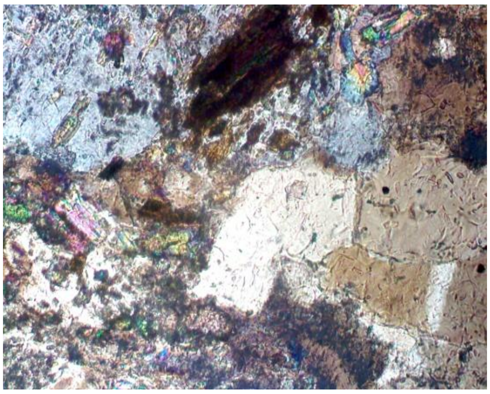

Plate.1: Biotite granite (CPL)

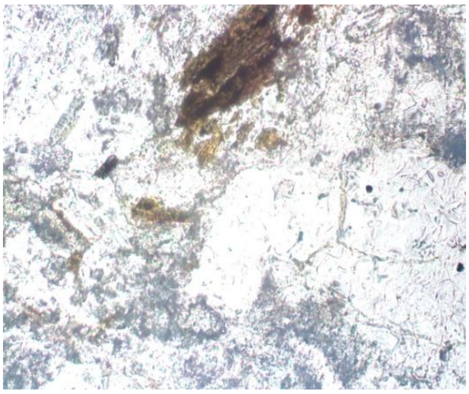

Plate.2: Biotite granite (PPL)

Vertical Electrical Sounding

At the initial stage of interpretation the obtained field data were plotted manually on the log- log graph to obtain the rough field curve. The model layers were obtained by curve matching using the auxiliary and master curves. The digital interpretation was carried out with the aid of the Winresist computer program for iteration (Van der Velpen and Sporry, 1992). Winresist is preferred to other interpretation software's, because it allows for the entry/inputation of certain parameters by the interpreter, thereby minimizing the RMS error, unlike other purely automatic inversion interpretation programs without any assumptions of the layering (Reinhard, 2006). The Winresist computer iteration program was used to calculate the theoretical curves, outputting the layers resistivity and thicknesses at various depths.

In the final stage of interpretation the geo-electric log were compared with the borehole lithologic log from the area (Fig.7-9). Although there were no much discrepancy between the lithologic log and the boring log in most cases, the three layered geoelectric logs reveal about four major lithologic strata's with negligible layers, while the four layered geoelectric log reveals five to six strata's with the lithologic logs. This could be attributed to the effect of electrical averaging. This is because resistivity contrasts and "effective" relative thicknesses within the aquifer are too small to be distinguishable (Amadi, 2010). This also implies that theoretically the aquifer layering can be calculated; but realistically, it cannot be observed on the field curves (Charles, 2002; Amadi *et al*., 2010).

Summary of the Vertical Electrical Sounding (VES) data, their simplified corresponding Geo-electric layers, geo-electric section and the curve types for each VES station are presented in Tables 1 to 4:

Table. 1: Vertical Electrical Sounding Data from 1-9

AB/2	MN/2	K	RESISTIVITY (Ohm-meter)							
			Gbadna	Abdullaziz	Gidan brodi	PDP Sec.	Ungwan Daji	Ungwan Ful	Serkin Pawa	Labbo
			VES 1	VES 2	VES 3	VES 4	VES 6	VES 7	VES 8	VES 9
1	0.5	2.36	300.2	165.2	264.1	70.9	123.7	133.4	789	403.2
2	0.5	11.8	100.6	80.2	150.3	40.3	69.7	65	318.6	170
3	0.5	27.5	55	78.7	105.3	23.9	66.4	42.9	198.6	122
5	0.5	77.8	42.1	66.4	61.4	30.5	64.5	29.2	109	88.1
6	0.5	112	38.9	64.1	57.6	36.8	66	29.7	104.4	84.8
6	1	55	42.3	75.2	61.8	45.1	70.1	40.4	74.5	100
8	1	99	48.2	57.9	60.9	42.6	69.9	38.1	95.3	107.2
10	1	156	62.4	76.1	70.6	58	72	42.5	98.2	142.6
10	2.5	58.9	70.5	92	85.4	71.2	77.6	56.7	142	180
15	2.5	137	111.1	96.5	93.4	80.3	83	61.4	124.5	161.4
20	2.5	247	141.1	110.2	115.3	123.5	89.3	79.6	138.7	232.3
30	2.5	562	260.5	158.8	150.7	180.9	110.4	117.8	178.4	320.6
40	2.5	1001	353.2	188.5	312.8	310.3	157.6	167.7	212.9	440.4
40	7.5	323	380	205.2	noise	300.1	145.4	200.2	189.7	367.2
50	7.5	512	412.9	281.6	noise	413.2	211.6	192	213.4	448.2
60	7.5	742	625.8	238.5	noise	noise	240.2	252.4	325.4	449.7
70	7.5	1014	797.2	noise	noise	noise	305.6	290.8	422.1	450.5

Table.2: Geoelectric parameters indicating Geoelectric Layers for VES 1-9

	RESISTIVITY ℓ (Ωm) / DEPTH d (m)							
	Gbadna	Abdullaziz	Gidan brodi	PDP Sec.	Ungwan Daji	Ungwan Fu	Serkin Paw	Labbo
LAYER	VES 1	VES 2	VES 3	VES 4	VES 6	VES 7	VES 8	VES 9
Layer1 ℓ1/d1	432/0.7	303/0.9	202.8/0.6	94.7/O.7	1120.5/0.7	160.7/0.8	935/0.8	515.4/0.7
Layer 2 ℓ2/d2	25.2/3.7	49/6.4	57/8.4	13.6/2.7	59.6/11.7	21.8/5.4	91.6/12.8	68.5/5.3
Layer 3 ℓ3/d3	5855/∞	456.2/∞	469/∞	2174/∞	694.7/∞	970.1/∞	981.6/∞	944.5/48.2
Layer4 ℓ4/d4								4802/∞
CURVE TYPE →	HA	H	H	HA	HA	HA	H	HK

Table. 3: Vertical Electrical Sounding Data from 10-17

AB/2	MN/2	K	RESISTIVITY (Ohm-meter)							
			Muku	Lapai Rd.	Paiko Quarte	Karma Yand	Ungwan Zagi	Jazu	Gongopi	Yandayi II
			VES 10	VES 11	VES 12	VES 13	VES 14	VES15	VES 16	VES 17
1	0.5	2.36	570.6	436.7	292.3	157.3	49.7	133	38.8	529.8
2	0.5	11.8	349.5	290.6	277.3	88.5	32.5	82	47.5	215.6
3	0.5	27.5	210.8	173.1	209	80.9	26.5	84	42.6	111.9
5	0.5	77.8	160.1	109.4	125.5	70.7	21.8	95.1	38	67.9
6	0.5	112	144	91.8	109.8	72.6	23.1	100.8	41.9	65.3
6	1	55	152	76.8	98.7	82	30.3	89.7	40.8	57.9
8	1	99	137.8	88.2	148.5	75	34	122.8	53.5	58.7
10	1	156	143.4	108.6	182.1	85.3	45.2	153.6	58	64.5
10	2.5	58.9	157.1	122	220	90.3	50.4	188.4	62.7	84.1
15	2.5	137	168.3	166.4	240	163.1	63.8	260.3	104	118.1
20	2.5	247	210.2	197.6	300.4	212.9	81.5	370.5	148.8	163.6
30	2.5	562	347.1	305.9	420.3	364.9	197.5	674.4	213.4	239.9
40	2.5	1001	479.8	261.3	560.3	433.9	276.1	951	274.8	348.2
40	7.5	323	502.1	340.3	622.1	488.2	312.8	1034.2	292.5	371.6
50	7.5	512	654.9	378	701.4	557.2	388.4	1280	433.9	489.7
60	7.5	742	772.9	403.9	848	668.4	485	1473.6	540.2	610.5
70	7.5	1014		332.5	904.3		690.1	1845.5	665.5	762.3

Table.4: Geoelectric parameters indicating Geoelectric Layers for VES 10-17

	RESISTIVITY ℓ (Ωm) / DEPTH d (m)							
	Muku	Lapai Rd.	Paiko Quarte	Karma Yand	Ungwan Zagi	Jazu	Gongopi	Yandayi II
LAYER	VES 10	VES 11	VES 12	VES 13	VES 14	VES 15	VES 16	VES 17
Layer1 ℓ1/d1	635/1.0	467.2/1.2	341.7/1.3	184/O.8	60.8/0.8	118/0.7	45.3/1.0	651/0.8
Layer 2 ℓ2/d2	115/9.8	59.8/5.6	80.3/5.6	50.3/4.8	14.6/2.6	60.4/3.2	30.3/4.3	46.1/5.9
Layer 3 ℓ3/d3	2058.4/∞	807.2/38.4	2505.2/∞	2337.2/∞	2108.7/∞	8653/∞	2790.7/∞	3494.8/∞
Layer4 ℓ4/d4		2822/∞						
CURVE TYPE →	H	HK	HA	HA	HA	HA	HA	H

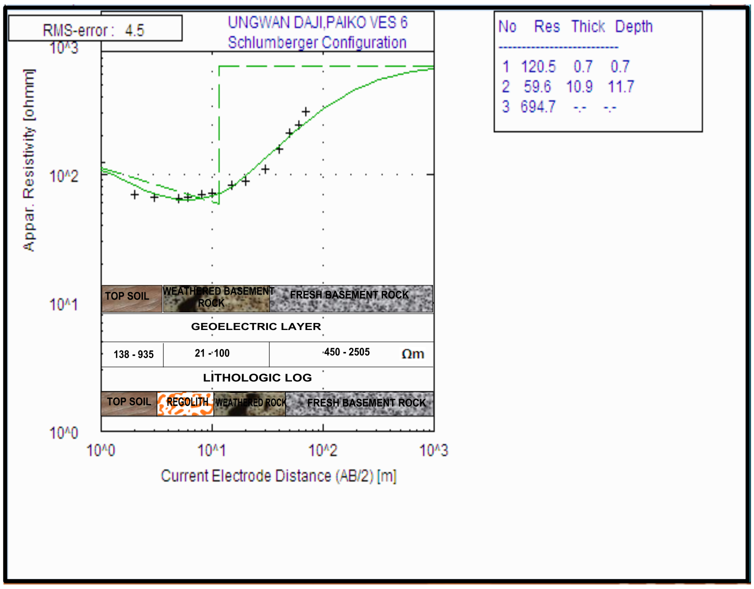

Fig.7: A typical HA VES curve of the area showing geoelectric and lithologic log sections

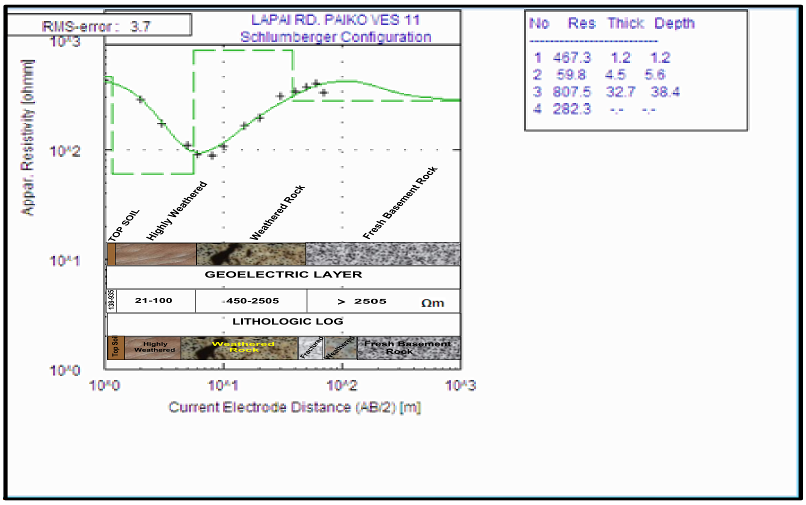

Fig.8: A typical HK VES curve of the area showing geoelectric and lithologic log sections

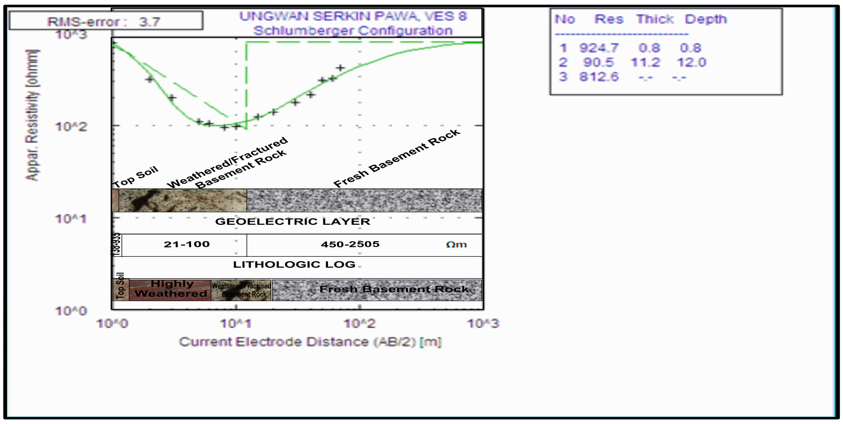

Fig.9: A typical H VES curve of the area showing Geoelectric and lithologic log sections

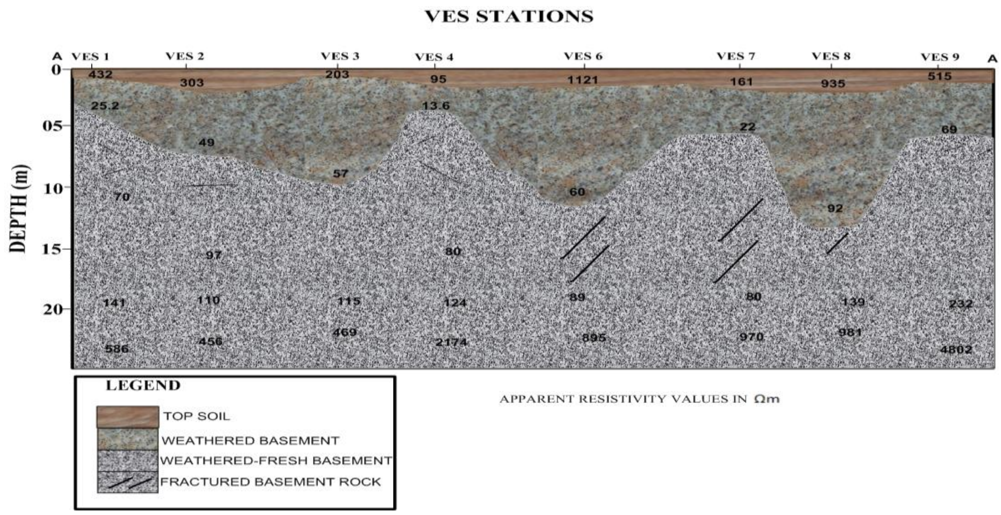

Fig.10. 2D geoeletric section along A-A profile

The geoelectric section along profile A-A (fig.10) drawn from the sounding curves shows both the vertical and lateral distribution of layer apparent resistivity, delineating the three major lithofacies, putting into consideration the principle of equivalence and evidence.

VIII. DISCUSSION AND CONCLUSION

The three layer curves indicate that the first layer is composed of loess unsaturated topsoil with resistivity values ranging between 50-125.9Ωm to the depth of about 0.6-1.5m. The topmost layer is underlain by a weathered/fractured Basement rocks, with varying degree of weathering. The resistivity value of this layer ranges between 90-270 Ωm with a thickness range of 4.6-12m to the depth of 15-35m. The ultimate layer is the fresh Basement rock unit (bedrock) with resistivity values ranging between 388-1800 Ωm to an infinite depth.

The four layer curves indicate that the two top layers are unsaturated, the third layers represent the weathered/fractured strata and the fourth layer is the fresh Basement rock (Bedrock). From the obtained result it is observed that the HA curves were obtained where the basement are near the surface, ranging from between 0.7-1.0m and this is typical of the eastern section of the town i.e. around Paiko quarters. The H curves which are dominant of the NW section of the study area are of intermediate depth to the basement, at the range of about 4-6 meters while the HK curve types shows the deeper depth to basement in reference to the study area, ranging from 6-12m. The HK curves are predominant of the central area of the town namely: Ungwan Daji, Ungwan Serkin Pawa and Ungwan Fulani. From direct observation it was noticed that some of the fractures encountered at the cause of drilling are of low saturation and in some cases dry, although present, leading to the poor performance of most drilled hole in the area. This phenomenal is a general trend within the study area and hence the justification for this study. Past experience has shown that inferences cannot be reached that a successful borehole drilled may not guarantee the success of the next borehole in the same vicinity. This confirms to the finding that the fractures in the area are localized, discrete and discontinuous. It is recommended that in further investigation profiling should be carried out in the NE-SW direction and NW-SE of the study area corresponding to the general principle joint directions and groundwater flow direction (Fig.5) of the study area.

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