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Demarcation And Identification Of Aquiferous Units For Groundwater Development Using Resistivity Method For Godogodo Town And Its Surroundings In Kaduna State, Northwestern Nigeria

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***Abstract*—The basement complex rocks of Godogodo town and its surroundings was probe for groundwater accumulation using the Vertical Electrical sounding, a total of thirty (30) VES points were conducted in the area with a maximum spread of 100m adopted. Four to Five Geoelectric layers of the subsurface were delineated from the different types of curves generated (KH, A, and Q),from the apparent resistivity values calculated. A topmost layer with resistivity range of 17-457.85 Ωm with an average thickness of 3m, this is underlain by a lateritic clay layer of resistivity that ranges between 51-1094 Ω m with average thickness of 7m. The third layer consists of sandy clay zone of resistivity range of between 37.82-935 Ω m with average thickness of 12m. A fourth layer of fractured bedrock with resistivity that range from 71.5-544 Ω m, this has an average thickness of 9m. The deepest layer is the fresh bedrock with resistivity of 1000 Ωm and above. The water bearing zones are the third and fourth layers; these have low resistivity values which represent zones of groundwater accumulation. Recommended drilling depth ranges between 40-60m which is expected to tap all the water bearing layers.**

Keywords—Geoelectric layer, Aquiferous units, Type curves, Apparent resistivity, GodoGodo

I. INTRODUCTION

Groundwater prospecting development in the basement complex areas has being a great challenge for decades; this is because of the high failure rate of boreholes drilled in the basement terrain which principally is due to the heterogonous nature of the basement rock in terms of groundwater accumulation and transmission. This is because of low permeability and discontinuity of the aquifer types in this terrain. Eduvie (2003) revealed a 3 to 5 layers sequence made up of the following. A top lateritic soil, sandy clay or clay sand layer with intercalation of silt/clay, a weathered regolith transition zone called the saprolite and a fresh bedrock layer. Jatau and Bajeh (2007) appraised the hydrogeology of part of Jema'a Local Government. The geophysical data were used to estimate aquifer potentials of the area. The findings show that a low resistivity value of 20 Ωm is an indication of a clayey regolith layer. Similarly water bearing weathered layer has moderate resistivity of between 50-150 Ωm. Also the saprolite (transition zone) with a thickness of 15-38 m is the major water bearing layer with resistivity of 40-200 Ωm. This present work is aim at demarcating the groundwater potential zones in the subsurface and recommending drilling depth for boreholes in the area, which will assist in the reduction of borehole failures. Arabi et al (2010) discovered a three to four layer sequence along the Gwoza-Danboa road in Borno State Northeastern Nigeria, a low resistivity range of between 10 Ωm-20 Ωm with thickness range of between 11-22 m was obtained for the water bearing zones. The fresh Basement has resistivity range between 600 Ωm -800 Ωm, they recommended a drilling depth of 55m in the area. Chikwelu and Udensi (2013) interpreted a three geoelectric layers for Pompo village Minna,the aquifer system in this area occurs in within the weathered and fractured Basement with a resistivity range of between 200 Ωm and 800 Ωm with thickness range of between 5m-20m with the southeastern part of the study area more promising. Yelwa et.al. (2015) obtained three to four geo-electric layers of the subsurface with the third weathered basement and a forth fractured basement rock constituting the aquiferous water bearing layers having resistivity ranges from 6Ωm -265Ωm with average thickness of 19m and 15m respectively along Kumbotso Local Government Area of Kano State Nigeria.

II .PHYSICAL CHARACTERISTICS OF THE STUDY AREA

The area under investigation is located at the southern part of Kaduna State, Nigeria and lies between latitude 9 ̇15 - 9 ̇30 N and between longitude 8.00 - 8.30 E, Fig. 1. It falls within the Guinea Savannah climatic belt of West Africa with two distinct seasons, namely the wet season and the dry. The wet season lasts for 7 months starting from March/April. The rainfall is greater in the eastern part of the area than in the other parts due to its proximity to the Jos Plateau. The average annual rainfall is about 1575 mm while the average annual temperature is about 27^{o}C. The dry season is characterised by the north – west trade wind known as the harmattan. This is dusty and dry with low humidity.

A. GEOLOGY

The geology of the area is made up of four (4) distinct rock units namely, porphyritic granites, migmatites, gneisses, and volcanic/basaltic units (McCurry, 1976; Okezie, 1970; Jacobson and Webb, 1946; and Nahikhare, 1971), Fig. 2.Varieties of granites include biotite granite and porphyritic granite. Their textures vary from coarse–, medium–, to fine-grained; the migmatite shows alternating and discontinuous dark and light coloured bandings and, the gneisses occur as ortho- and paragneisses, with former type characterized by layered structures while the latter has bands of light and dark alignment of minerals mostly of biotite and quartz. The basaltic rock occurs as boulders which are either vesicular or amygdaloidal. The boulders occur at the subsurface within the regolith at depths between 5–10 metres and sometimes as flow at the surface. Joints, pegmatite and aplite dykes, quartz veins and minor folds constitute some of the structural elements in the area.

A. MATERIALS AND METHOD OF INVESTIGATION

The vertical Electrical Sounding (VES). The electrical resistivity method of investigating the subsurface was used to identify the fractures and deeply weathered zones which are believed to be the principal water bearing units in the basement area. A total of 30 VES soundings were conducted in the field Fig 1, with spread of 75 to 100 m. An ABEM Terrameter SAS 300c and campus Ohmega digital resistivity meters were used to record the resistivity of the subsurface. Based on Philip Keareyet *et al* (2002) VES procedures were used in the field: Using the Schlumberger configuration in which the inner potential electrodes has a spacing of (2L). Philip Kearey et al (2002) shows that in using the Schlumberger array to determine the apparent resistivity the following equation is used

$$\delta_a = \frac{\pi}{2l}\frac{(L^2 - x^2)^2}{(L^2 + x^2)}\frac{\Delta V}{I} \quad (1)$$

Where:

δ_a = Apparent resistivity
l = inner (potential) electrode spacing
L = outer (current) electrode spacing
ΔV = potential difference
I = current
X = separation of the mid- points of the potential and electrodes

For the VES probing (symmetrical expansion) the apparent resistivity was obtained from the equation

$$\delta_a = \frac{\pi L^2}{2L}\frac{\Delta V}{I} \quad (2)$$

The resistivity curves were then interpreted using computer interpretation program for Schlumberger sounding data modified after Zohdy (1989).The VES curves were generated from the partial curve matching technique and were refined by computer iteration method. The electrical profiling curves were also interpreted qualitatively with the mapped surface geology.

III RESULTS

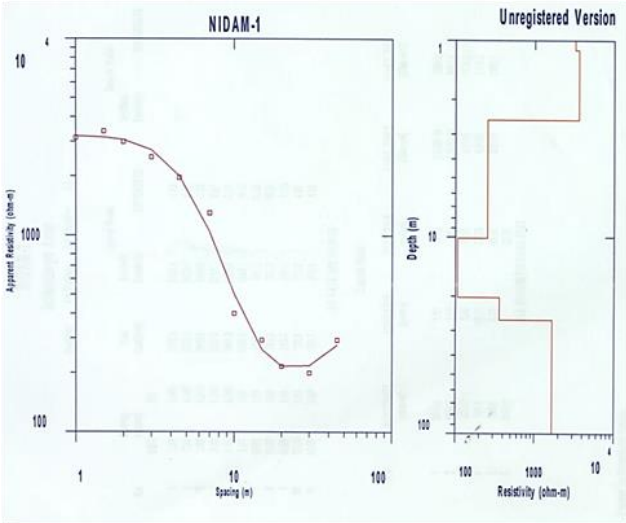
Thirty (30) VES soundings points were interpreted, table 1 gives the interpreted characteristics of the subsurface geology and layering, while figures 2a, 2b and 2c shows the curves generated. The estimation of the depth to bed rock, aquifer delineation and structural mapping, as well as the identification of a better drilling site and drilling depth were identified.

B. VES Curves Interpretation

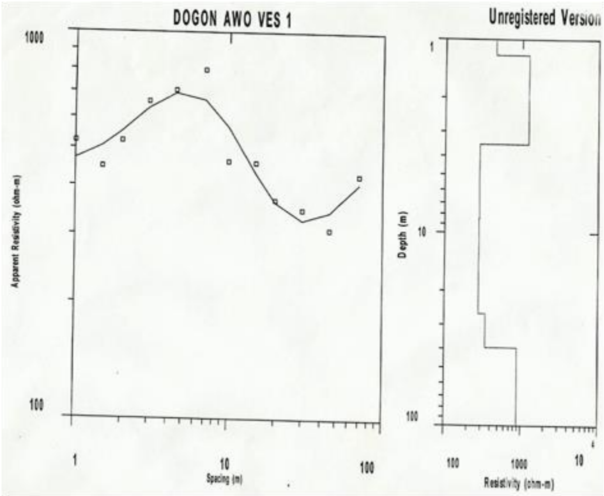
Based on the curves interpreted the subsurface is delineated into four to five geoelectric layers, an uppermost top soil layer with resistivity range of 17 Ω m -457.85 Ω m with an average thickness of 3 m which is underlain by a lateritic clay layer whose resistivity is between 51 Ω m -1094 Ω m and with average thickness of about 7 m. The weathered sandyclay layer with resistivity ranging between 37.82 Ω m -935 Ω m occurs from a depth of 6-33 m below the ground, this has a thickness of 12m A layer of fractured bedrock with resistivity values between 71.5 Ωm – 544 Ωm with average thickness of 9 m, while the fresh bedrock starts from a depth of 25 m . Based on the interpretation of the different layers of the subsurface and the recorded low resistivity value, two main aquiferous zones have been identified and demarcated in the area, these are the weathered regolith and the fractured basement aquifers.

IV *DISCUSSIONS*

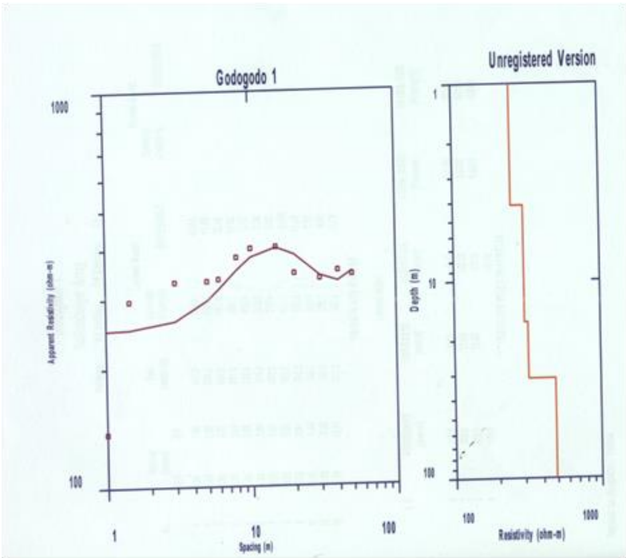
Different curve types were produced from the field data, these include the K, H, Q and A. The H type curve (minimum) is obtained when a layer of lower resistivity occur between two layers of higher resistivity. This curve can be either for a clayey formation with low resistivity but poor groundwater discharge or a fractured/gravely sandy layer of lower resistivity value with high yield. The Q type of curve is obtained when we have three layers of increasing lower resistivity giving rise to a doubled decreasing curve. An A type curve is obtained when a three or more layer sequence were superimposed on each other with increasing higher resistivity layer deposited between two layers of low resistivity. K type curve is generated when a layer of higher resistivity is deposited between two layers of low resistivity.



2a



2b



2c

Figure: 2a, 2b and 2c showing K H, A, and Q type curves

Fig: 1. Geologic Map of the Study Area

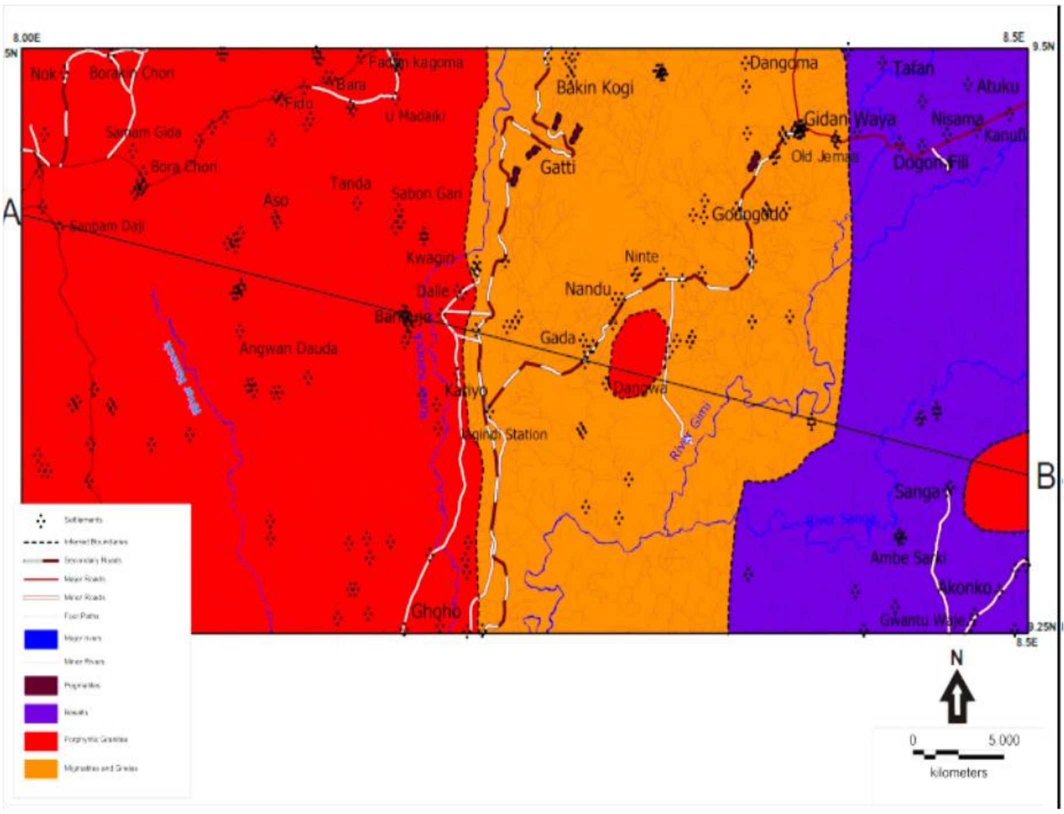


Table 1: Summary of geophysical results for the Basement Complex rocks in the area of study

S/NO	LOCATION	FIRST LAYER			SECOND LAYER			THIRD LAYER			FOURTH LAYER			FIFTH LAYER		
		Top Soil			Laterite/clay			Weather Basement			Slightly Fracture bedrock			Fresh Bed rock		
		Resistivity (Ωm)	Depth (m)	Thickness(m)	Resistivity (Ωm)	Depth (m)	Thickness(m)	Resistivity (m)	Depth (m)	Thickness(m)	Resistivity(Ωm)	Depth (m)	Thickness(m)	Resistivity(Ωm)	Depth (m)	Depth to Basement(m)
1	Gigira	184.465	0.2	2	156-214	2-15	13	225	15-22	7	510	22-33	11	1419	>33	34
2	Zakan kwano	68-268	0-5	5	91-94	5-10	5	129-191	10-33	23	7-4	7-33	26	>1000	>33	34
3	Mante Zankan	17-496	2.4	2.4	724-1094	24-16	8	546	15-22	7	369	22-33	10	>1000	>33	34
4	Ung. Madaki	108-177	0-5	5	85-116	5-15	10	165	15-25	10	215-218	22.94	17	>1000	>40	41
5	Nisama	53-187	0-2	2	266-660	2-14	12	121-130	14-29.8	15.8	250			>1000	>30	32
6	Ung. Gwandara	48.06-50.67	0-6	6	53-57.7	6-15	9	60.36 91-57	15-30	15	--	-		>1182	>30	31
7	Wazo	141.4-1558.9	0-4	4	60.50-106	4-10	6	37.8268-63	10-18	8	91-35-114.1	18-22	4	>1000	>22	26
8	Kariyo	140.8-188.2	0.3	3	208.3-330.4	3-15	12	305.3	2345.3	15-20	5	3173-341.3	20-30	>399.8	>30	34
9	Ung.DogoKwagiri	223.8-3846	0-3	3	443-544.6	3-10	7	388.8-422.5	10-20	10				>976	>20	25
10	Barde	85.2	023	3	146.7	3-10	7	163.3	10-23	13				>1000	>35	36
11	Dangwa	140.3	0.7	7	110.3	7-9	2	146.1	9-27	18				>1000	>30	36
12	Kayayya	178.8	0.3	3	172.8	3-12	9	136.4	12-36	24				>1000	>40	42
13	Choriugdadi	772-794	0-1	1	592	1-23	22	146-171	25-35	12	171-448	35-49	14	>1000	>49	51
14	ChoriBariki	160	0-2	2	300	2-6	4	250	6-15	9	400	15-25	10	>1000	>25	30
15	Ninte	500	0-2	2	700	2-10	8	400	10-35	25	500	35-40	5	>1000	>40	42
16	Godo-godo	250-296	0-2	2	316-379	2-6	4	340-401	6-20	14	328-385	20-35	15	>500	>35	37
17	DogonAwo	4550	0-2	2	650	2-8	6	300	8-25	17	250	25-30	5	>2300	>35	37
18	COE. G/WAYA	101	0-1	1	265-1870	1-12	11	225	12-22	10	93	22-42	20	>720	>42	44

19	Dangoma	137-175	0-3	3	201-224	3-7	4	207-318	10-18	8	242-332	18-25	7	>650	>25	26
20	GSSNok	1298	0-.57	.57	794	.57-6	5.4	118	6-24	18	177	24-35	11	537	>35	37
21	SambanDaji	542	0-3	3	1028	3-6	3	575	6-20	14	309-7	20-34	14	2771	>35	37
22	Bakinkogikaninkon	411-745	0-6	6	527-777	1-4	3	551-769	4-17	13	507-544	17-25	8	2000	>25	28
23	Barmogada	78-180	0-0.88	.88	207-235	0.88-10	9.12	203-381	10-18	8	305-441	18-22	4	>550	>22	26
24	Nindem	66-70	0-3	3	82.29-9055	3-5	2	109-173	5-16	11	205-237	16-28	12	>560	>28	36
25	3 QUARTER Jagindi	78-172	0-5	5	207-300	5-10	5	215-280	10-19	9	255-418	19-25	6	1300	>25	28
26	GSS G/waya	620-148.2	0—0.8	0.8	174-2010	8-10	2	465-935	10-17	7	270-330	17-28	11	942	28	33
27	S/Garikwagiri	99.4-192	0-1	1	202-358	1-10	9	279-325	10-18	8	346-453	18-30	12	>750	30	35
28	Tanda	88-121	0-5	5	68-96	5-10	5	745-125	10-18	8	71-85	18-35	17	>300	35	37
29	Ghauter	67-88	0-5	5	51-58	5-11	6	46-99	11-15	4	73-93	15-22	7	>254	>22	25
30	Pasakori	112-118	1-5	5	134-171	5-8	3	195-247	8-20	12	168-210	20-35	15	>210	>35	37

C. Relationship between geology and resistivity

Igneous and metamorphic rocks has high resistivity which depends on the degree of fracturing and number or percentage of fractures filled with groundwater. Sedimentary rocks being more porous with high groundwater content tend to have low resistivity, similarly wet soil and freshwater also has lower resistivity values. Clay soil has a lower resistivity compared to sandy soil. There is an overlap in the values of resistivity's of the different geological materials due to factors like; porosity, degree of saturation with water, and dissolved salts concentration. From the values of resistivity obtained in the study area, it can be seen that the resistivity of the sub surface varies and depends on the geology as well as the water saturation of the underlying rock type at that location.

V CONCLUSION

The area studied is made of two aquiferous (water bearing zones) based on the values of resistivity obtained for the subsurface geologic formations in the area, these are the weathered Basement which consist of sandy and clay materials and the fractured basement zone. These two geoelectric layers with low resistivity (37.87-937 Ωm and 71.5-544Ωm) are hydraulically connected and with thickness averages of 12m and 9 m respectively.

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