A Geoelectric Survey for Ground Water: A Case Study In The North Central Basement Complex, Nigeria.

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Abstract: The Nigerian Army School of Military Police (NASMP), Zaria, located in the north central basement complex and bounded by longitudes 7°4'56.04"E and 7°41'43.06"E and latitudes 11°09'07.33"N and 11°09'34.06"N, is an institution that offers training to military personnel. In an attempt to investigate the ground water potential of the institution, geoelectric method was employed. A total of 49 soundings were carried out with symmetric Schlumberger configuration at stations located at 100m interval on 5x8 grids. 1D inversion of the data collected at the grid stations together with borehole information were used to provide information about succession and thickness of subsurface lithologies from which zones of ground water potential were delineated. In addition, Azimuthal Vertical Electrical Soundings (AVES) were carried out at three of the grid stations, with three soundings per station, to provide direction of fractured basement (an aquifer component) of the study area.

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KEYWARDS: Geoelectric, AVES, Aquifer.

1. Introduction

The Nigerian Army School of Military Police (NASMP), Zaria, located in the north central basement complex and bounded by longitudes 7°4'56.04"E and 7°41'43.06"E and latitudes 11°09'07.33"N and 11°09'34.06"N (Figure 1), is an institution that offers training to military personnel. In an attempt to investigate the ground water potential of the institution, geoelectric method was employed. Of all the techniques in electrical methods, resistivity has an important attribute of responding to different materials, especially to water content and salinity of subsurface units (Mooney, 1980). In this study, the D.C Resistivity method, considered to be the quickest and the most economic method, has been used to provide information on groundwater potential of NASMP, Zaria.

2. Materials and method

Geology and hydrogeology of the study area

The study area falls within the northern sector of the Nigerian basement complex (Figure 1). Details of the geology of the sector are contained in McCurry (1976). It is completely underlain by the basement rocks which form part of the Paleozoic basement complex of Nigeria. According to Eigbefo (1978), the superficial deposits, which overlie the basement rocks, act as recharge materials, especially where they are underlain by weathered basement. The superficial deposits of Zaria and its region are Older Laterite, Younger Laterite, Older Alluvium and Younger Alluvium (Wright and McCurry, 1970).

On structural evolution, Nigerian basement complex has according to Oyawoye (1964) been subjected to at least two major Orogenic cycles. The first corresponds to Eburnean Orogeny. The second which began in early Paleozoic resulted into a tight isoclinal folding (McCurry, 1970) in two successive phases, first about East-West axis and secondly about North-South axis. The second deformation phase being more intense than the first almost obliterated the former leaving a dominant North-South structural trend. Major transcurrent faulting and the development of a system of joints followed the second deformation phase. The intense regional tectonism that preceded and accompanied the emplacement of Older Granite during the later phases of the second cycle called Pan-African orogeny produced a well defined and extensive North-South trend in the north central Nigeria, including Zaria area (Ike, 1974). Ike (1974) also reported the existence of numerous joints, fractures, and faults in Zaria Granite batholiths in which a major NE-SW shear-fault complemented by numerous NW-SE shear-faults were emphasized.

The major aquifer components of the basement complex of Nigeria are weathered and fractured basement (Olowu 1967, Akpoborie 1972). These are commonly explored with D.C resistivity survey because of the resistivity contrast between the aquifer components and fresh basement.

Data collection and processing

Vertical Electrical Sounding (VES) data were collected in April; peak of dry season in Zaria when the ground water table is believed to be at its maximum depth. The data were acquired with Terrameter ABEM SAS 300b at stations located at 100 m interval on 5by8 grid (Figure 1). The Schlumberger electrode configuration with maximum electrode configuration of 200m was adapted. This separation was chosen on the report that an average depth to basement in Zaria is 40 m (Shemang 1990, Olowu 1967, Danladi 1984). The acquired data were processed and interpreted with the Zohdyôs iterative program for the automatic interpretation of Wenner and Schlumberger sounding curves (Zohdy, 1989). Figure 2 is a typical digitized model of interpreted VES station 15. The underlying geo-electric section of the station suggests four layers, on the principle that all maxima, minima and point of inflexion are indicators of existence of boundaries of different lithologies. Where value turns to infinity is an indication of fresh rocks (Telford et al., 1976, Zohdy, 1989).

Because geoelectric and geologic sections do not often correlate (Keller and Frischknecht, 1966), the geologic equivalent of the geoelectric layers of VES station 15 was obtained with guide from borehole log, nature of superficial deposit (Tokarski; 1972, Wright and Mc Curry; 1970) and published resistivity data (Telford et al; 1976, Shemang, 1990) that were used as control. The first layer suggests a topmost thin layer with an average resistivity and depth values of 238Ωm and 2.3m, respectively. This layer is underlain by a weathered basement layer with an average resistivity value of 127Ωm and thickness of 5.0 m. The weathered layer directly overlay a layer believed to be fractured rocks. It extends from a depth of 7.3m to 15.6m and has an average resistivity value 762Ωm. The final layer is characterized by an extremely high resistivity value of 10687Ωm, which suggests fresh basement. The remaining VES data were delineated as discussed above for VES15. Summary of the delineations are given in Table1. The notations S+C, LT, WB, FB and FRB respectively in the Table stand for silt + clay, laterite, weathered basement, fractured basement and fresh basement.

For a general overview of the result in Table 1 at a glance, contour map of interpolated aquifer thickness was plotted with Sufer9 program that creates grid base for XYZ data. This is displayed in Figure 3.

Three sets of azimuthal soundings were carried out at VES points 6, 18 and 32. Plots of these soundings (Figure 4) were carried out along N-S, NEïSW, EïW and SEïNW to determine the direction(s) of anisotropy at the VES stations. From the results, general change in fracture patterns (a component of aquifer) within the study area can be deduced. These measurements were taken as a function of azimuth about a common (fixed) point. The calculated apparent resistivity values, there obtained, were plotted in polar coordinates to show the variation of apparent resistivity with orientation. Basically, any observed change in apparent resistivity with azimuth is often interpreted as an indication of fracture anisotropy. That is, if the observed change in apparent resistivity forms a distinct ellipse on polar plot, the major axis of the ellipse is usually interpreted as an indication of strike direction of a subsurface fracture set or the direction of the greatest fracture connectivity (Taylor and Fleming, 1988, Busby, 2000).

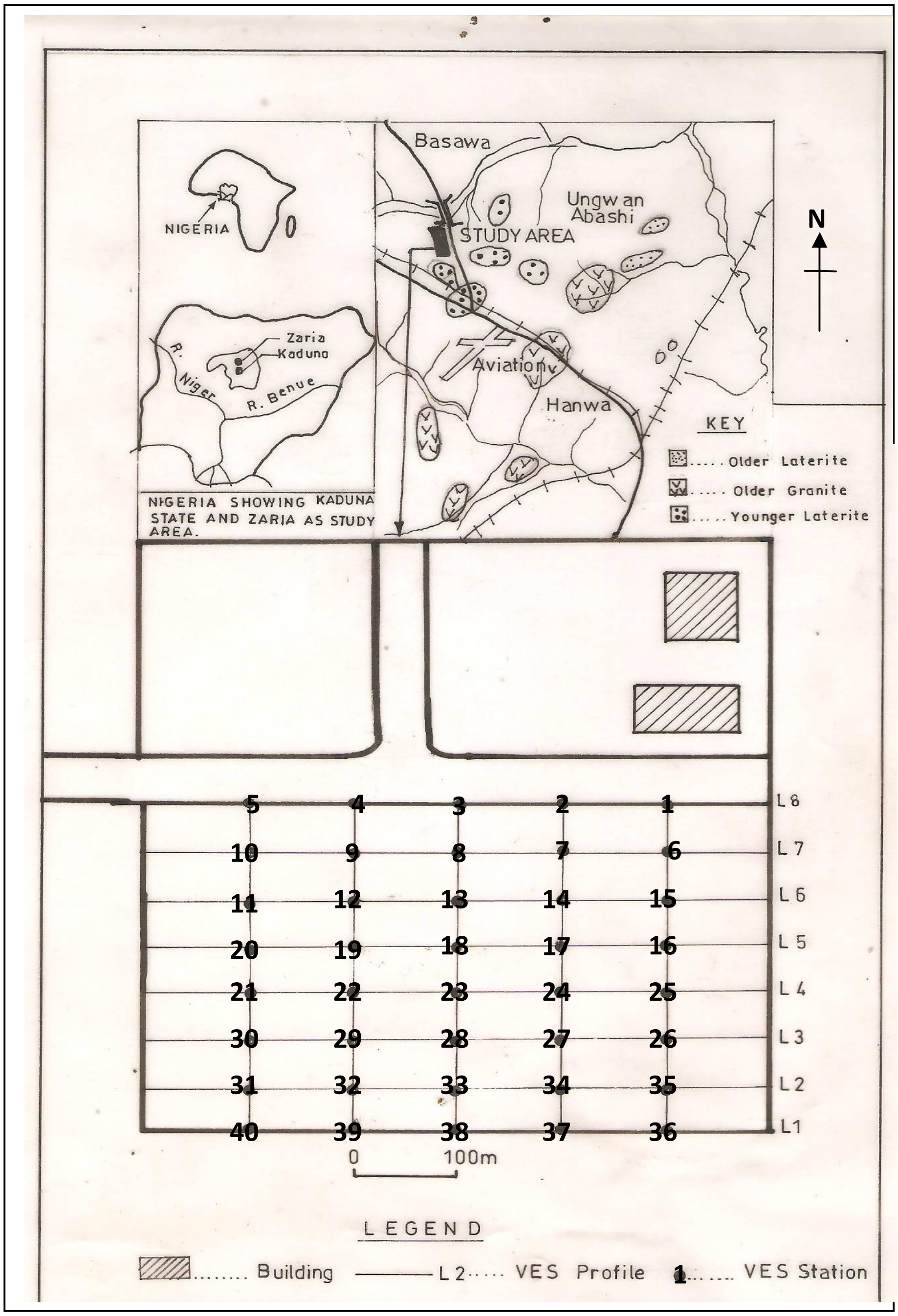

Figure 1: Geologic map of Zaria sheet 102SW showing location of the study area and the distribution of survey lines and VES stations

Table1: Summary of the Interpretation of the 40 Sounding Stations.

VES STATION NO	RESISTIVITY (*R*) OF LAYERS (Ωm)					THICKNESS (*T*) OF RESISTIVITY LAYERS (m)				REMARKS ON RESISTIVITY LAYERS				
	***R*1**	***R*2**	***R*3**	***R*4**	***R*5**	***T*1**	***T*2**	***T*3**	***T*4**	***R*1**	***R*2**	***R*3**	***R*4**	***R*5**
01	176	421	133	431	1236	1.7	19.0	16.0	10.8	S+C	LT	WB	FB	FRB
02	122	324	177	-	-	0.9	7.6	-	-	S+C	LT	FB	-	-
03	177	529	58	-	-	0.9	7.2	-	-	S+C	LT	FB	-	-
04	161	92	408	-	-	5.0	17.7	-	-	S+C	WB	FRB	-	-
05	171	651	800	2355	-	6.4	16.0	7.2	-	S+C	LT	FB	FRB	-
06	187	414	63	-	-	0.9	6.4	-	-	S+C	LT	FB	-	-
07	178	89	678	-	-	4.9	10.5	-	-	S+C	WB	FB	-	-
08	119	547	139	-	-	2.0	11.4	-	-	S+C	LT	FB	-	-
09	153	224	-	-	-	9.0	-	-	-	S+C	FB	-	-	-
10	150	83	-	-	-	23	-	-	-	S+C	FB	-	-	-
11	155	602	-	-	-	2.7	-	-	-	S+C	FB	-	-	-
12	162	194	-	-	-	2.4	-	-	-	S+C	FB	-	-	-
13	186	876	120	-	-	0.9	12.6	-	-	S+C	LT	FB	-	-
14	142	671	117	-	-	1.4	19.0	-	-	S+C	LT	FB	-	-
15	238	127	762	10687	-	2.3	5.0	8.3	-	LT	WB	FB	FRB	-
16	356	124	561	2960	-	1.1	14.3	17.7	-	LT	WB	FB	FRB	-
17	420	396	-	-	-	1.5	-	-	-	LT	FB	-	-	-
18	280	125	553	-	-	1.1	4.0	-	-	LT	WB	FB	-	-
19	300	98	606	-	-	0.5	6.6	-	-	LT	WB	FB	-	-
20	231	120	464	8418	-	0.9	5.5	7.4	-	LT	WB	FB	FRB	-
21	176	120	624	6044	-	0.9	8.5	10.9	-	S+C	WB	FB	FRB	-
22	303	114	353	-	-	1.0	2.3	-	-	LT	WB	FB	-	-
23	242	128	403	-	-	1.1	6.1	-	-	LT	WB	FB	-	-
24	326	185	78	654	-	0.8	7.0	17.3	-	LT	S+C	WB	FB	-
25	231	20	-	-	-	5.4	-	-	-	LT	FB	-	-	-
26	159	46	-	-	-	0.4	-	-	-	S+C	FB	-	-	-
27	303	54	-	-	-	1.1	-	-	-	LT	FB	-	-	-
28	227	1782	-	-	-	3.0	-	-	-	LT	FRB	-	-	-
29	209	106	442	9312	-	0.9	6.1	6.8	-	LT	WB	FB	FRB	-
30	193	82	575	4611	-	2.3	8.2	12.0	-	LT	WB	FB	FRB	-
31	99	45	-	-	-	10	-	-	-	S+C	FB	-	-	-
32	254	114	-	-	-	2.3	-	-	-	LT	FB	-	-	-
33	279	153	-	-	-	1.0	-	-	-	LT	FB	-	-	-
34	732	146	763	6653	-	2.5	14.6	8.0	-	LT	WB	FB	FRB	-
35	454	213	559	4319	-	0.6	13.2	6.5	-	LT	WB	FB	FRB	-
36	666	362	865	6032	-	1.4	5.6	13.3	-	LT	WB	FB	FRB	-
37	446	125	579	-	-	7.1	19.4	-	-	LT	WB	FB	-	-
38	215	121	638	3172	-	3.3	5.1	24.8	-	LT	WB	FB	FRB	-
39	478	103	578	-	-	7.1	26.0	-	-	LT	WB	FB	-	-
40	389	146	690	-	-	2.3	8.2	-	-	LT	WB	FB	-	-

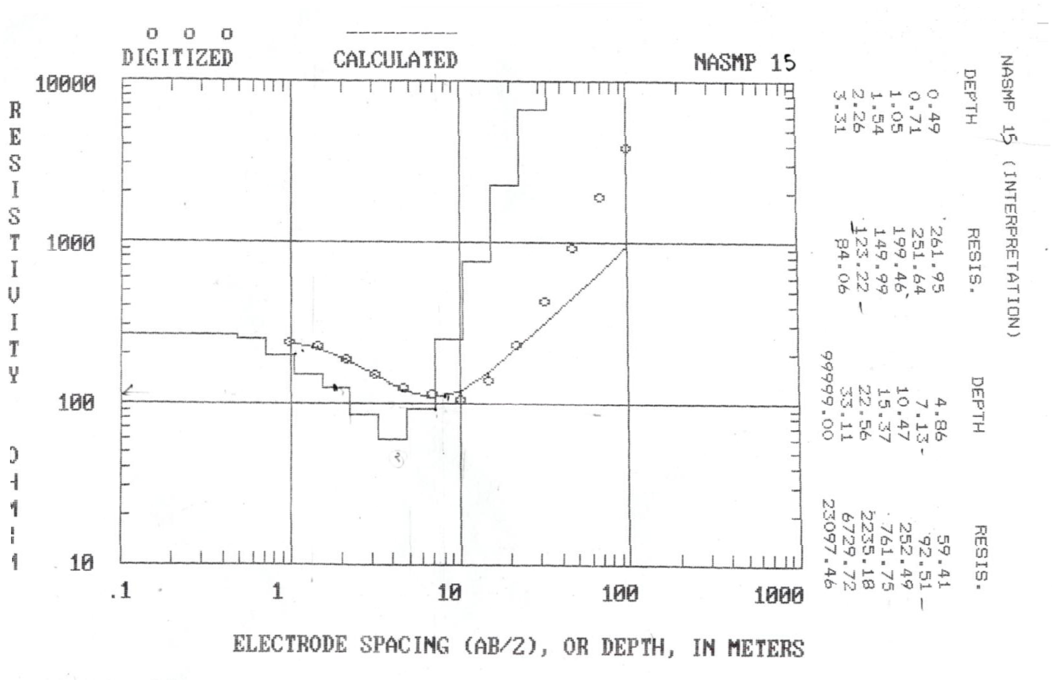

Figure2: Showing the digitized model of interpreted VES station 15

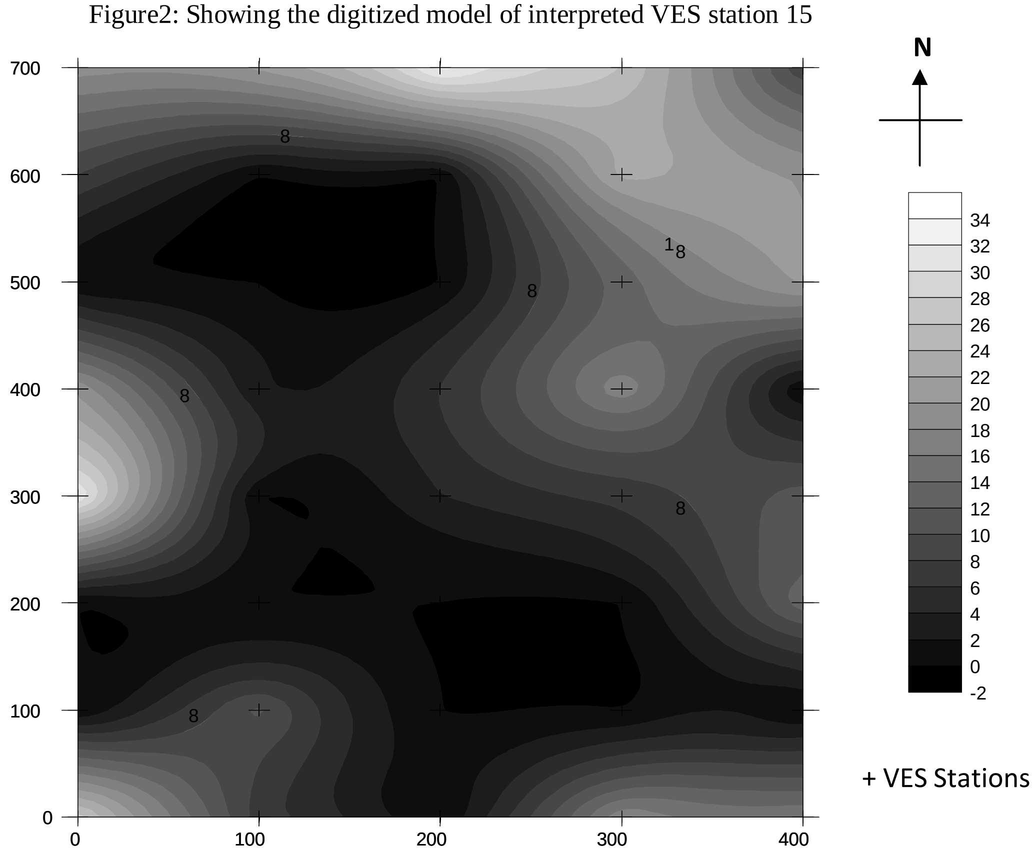

Figure3: Aquifer thickness map

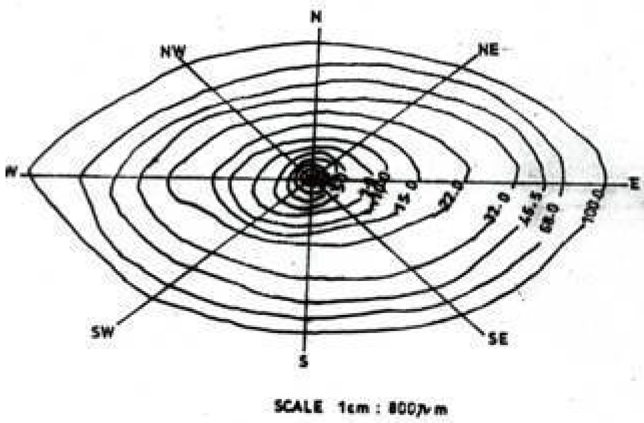

Figure (a): Plot for VES18

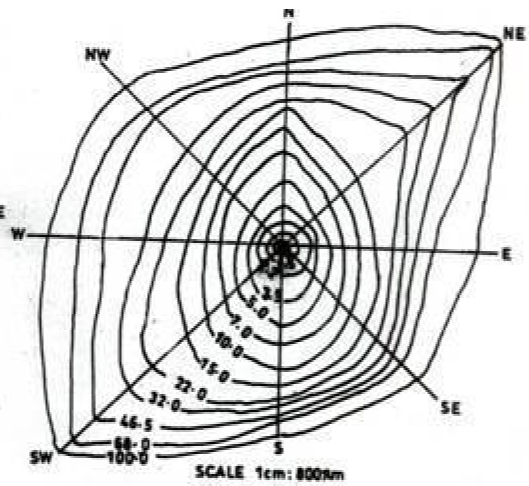

Figure (b): Plot for VES 6

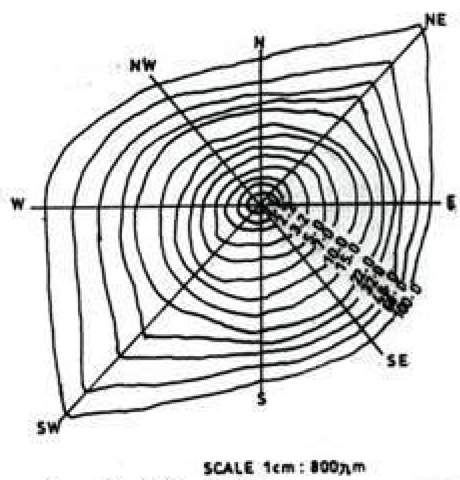

Figure (c): Plot for VES32

Figure4: Azimuthal apparent resistivity plots

3. Discussion of results

The interpreted depth and thickness ranges with corresponding resistivities and lithologies of all VES stations (Table1) have revealed a minimum of two and maximum of five lithologic successions. In all the delineations, the weathered basement and the fractured basement were considered the main aquifer, in respect of their importance in underground water storage in Zaria (Olowu 1967, Akpoborie 1972).

The weathered basement, considered the dominant rock type of second layer, with resistivity value as low as 78Ωm and thickness range of 2.3m to 26.0m, overlays the dominant lithology of the third layer at most VES stations; the fractured basement. The fact that the weathered basement is associated with low resistivity values at some VES stations suggest that it is most probable that it is highly weathered and/or saturated with water. On the other hand, resistivity values as high as 865Ωm and thickness range of 6.4m to depth penetrated by maximum current electrode separation were also obtained. High resistivity value of this rock type (fractured basement), at some stations, may be attributed to dryness of the fractured basement and the dryness may either be attributed to the fact that the fractures are probably not interconnected or to the peak of dry season when the VES data were collected. Absence of fluid within the fracture might have caused current flow along or across fracture to be greatly impeded; thereby resulting in the unusually high resistivity values recorded over such VES stations. The low resistivity values of the fractured basement that are associated with some VES stations may on the other hand, suggest highly fractured and/or probably saturated with water. Thus, the weathered and the fractured basement which respectively constitute the second and third geologic layers are collectively overlain and underlain, respectively by surface (topmost) layer and the fresh basement at most VES stations.

The topmost or first layer, associated with resistivity value range of 98Ωm to 724Ωm and depth range of 0.4m to 7.1m, strongly suggest composition of clay, silt and laterite. This soil composition agrees with the report of superficial deposits of Zaria by Tokarski (1972). According to Eigbefo (1978), the superficial deposits covering most of the basement rocks act as recharge materials, especially where they are underlain by the weathered basement. This recharging property of superficial material may not be ruled out in the study area. Silt overlying the weathered basement may, in particular, serve as the main medium of the topmost layer in recharging the aquifer systems in view of the fact that the hydraulic conductivity of the topsoil is most likely to be much higher than that of the other soil type (laterite) of the layer. The fourth layer is the basement. It has infinite thickness and resistivity values that are greater than 1000Ωm.

The aquifer thickness map, which constitutes both the weathered and fractured basement, revealed the aquifer to be thinnest along SE- NW of the study area.

From the azimuthal plots, no fracture patterns were deduced at shallow depths. At greater depths however, NE ï SW and E ï W fracture patterns were deduced. These observed fracture patterns are believed to be products of multiple stresses in action during the geological processes that evolved the basement. Ball (1980) attributed trans-current movements to be mainly responsible for deformational structures in the basement.

4. Conclusion

Deductions from the interpretations have provided results which addressed the motive of this work. The equivalent geologic sections suggest topmost layer (clay, silt, and laterite), weathered, fractured and basement rocks as the prevailing lithologies of the study area.

The weathered and the fractured basement are believed to be the main aquifer components of the study area. From the result of this study, VES stations that are most favorable for ground water exploitation, based on high thickness range (20m ï 32m) and low resistivity values of the aquifer layers are 1, 16, 30, and 39

The azimuthal results revealed the basement to be highly fractured. This is because the observed fracture patterns at depth are believed to be products of multiple stresses that were in action during the geological processes that evolved the basement.

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