Geoelectrical Investigation of Groundwater Potential of Dawakin Tofa Local Government Area of Kano State Nigeria

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Abstract

Over forty Vertical Electrical Sounding survey were carried out in Dawakin Tofa local government area of Kano state. Dynamic water level from open wells was also collected and was used as a guide for the selection of the electrode spread distance. The schlumberger array with a maximum electrode spread of 100 m was employed in all the points. Results from the sounding data indicates that the area is generally underlain by five geoelectric or geologic section which include Lateritic top soil or Lateritic sand, Silty sand or Sandy clay, Weathered basement or Clayey sand, Fractured basement and Fresh basement. Based on the result obtained the fractured and the weathered basement makes the aquiferous zone within the study area. The resistivities of these zones varies from 7.3 to 772 Ωm with an average value 178 Ωm, while the thickness varies from a value of 1.66 to 28 m with an average value of 14.33 m. Depth to this zone varies from 5 to 31 m with an average value of 16 m. The study also recommended the use of 80 m minimum electrode spread for future electrical survey to be used in the study area.

Key words: Geoelectrical, Vertical Electrical Sounding, Dawakin Tofa, Kano State, Resistivity sounding.

1. Introduction

Groundwater is one essential but necessary substitute to surface water in every society. It's no doubt a hidden, replenish able resource whose occurrence and distribution greatly varies according to the local as well as regional geology, hydrogeologic setting and to an extent the nature of human activities on the land. Groundwater occurrence in a Precambrian Basement terrain is hosted within zones of weathering and fracturing which often are not continuous in vertical and lateral extent (Jeff, 2006). There is a steady rise in the demand for groundwater in most hard rock areas most of which cannot boast of any constant surface source of water supply (Adanu, 1994). Kano area (Fig.1) is underlain by rocks of the Nigerian Basement Complex comprising migmatite-gneiss complex, Younger Metasediments, Older and Younger Granites. The aquifers of the Basement Complex rocks are the regolith and the fractures in the fresh bedrock which are known to be interconnected at depth (Mohammed, 1984; Alagbe, 1987; Adanu, 1989; Uma and Kehinde, 1994).

In a recent hydrogeological study carried out in parts of Kano area, Bala (2008) has shown that regolith aquifer derived from schists and gneisses of sedimentary origin (orthogneisses) proved to be a difficult groundwater terrain contrary to the observations in the earlier works that not only indicated similarity in aquifer performance across the different bedrock types, but also that these aquifers compare with those in other parts of the African Shield. He also noted that wells located in areas underlain by schists and similar rocks were generally deep and the depth to the water table in them is larger than in those located in the other rock types. The failure rate in most groundwater project recorded in Basement Complex aquifers has informed the general acceptance of a geophysical survey as a compulsory prerequisite to any successful water well drilling project (Dan Hassan, 1999). The electrical resistivity method involving the vertical electrical sounding (VES) technique is extensively gaining application in environmental, groundwater and engineering geophysical investigations (Zohdy *et al.*, 1980; Aina *et al*., 1996; Olorufemi et al., 1993 and 2004; Afolabi and Olorufemi 2004 and Abubakar and Danbatta 2012).

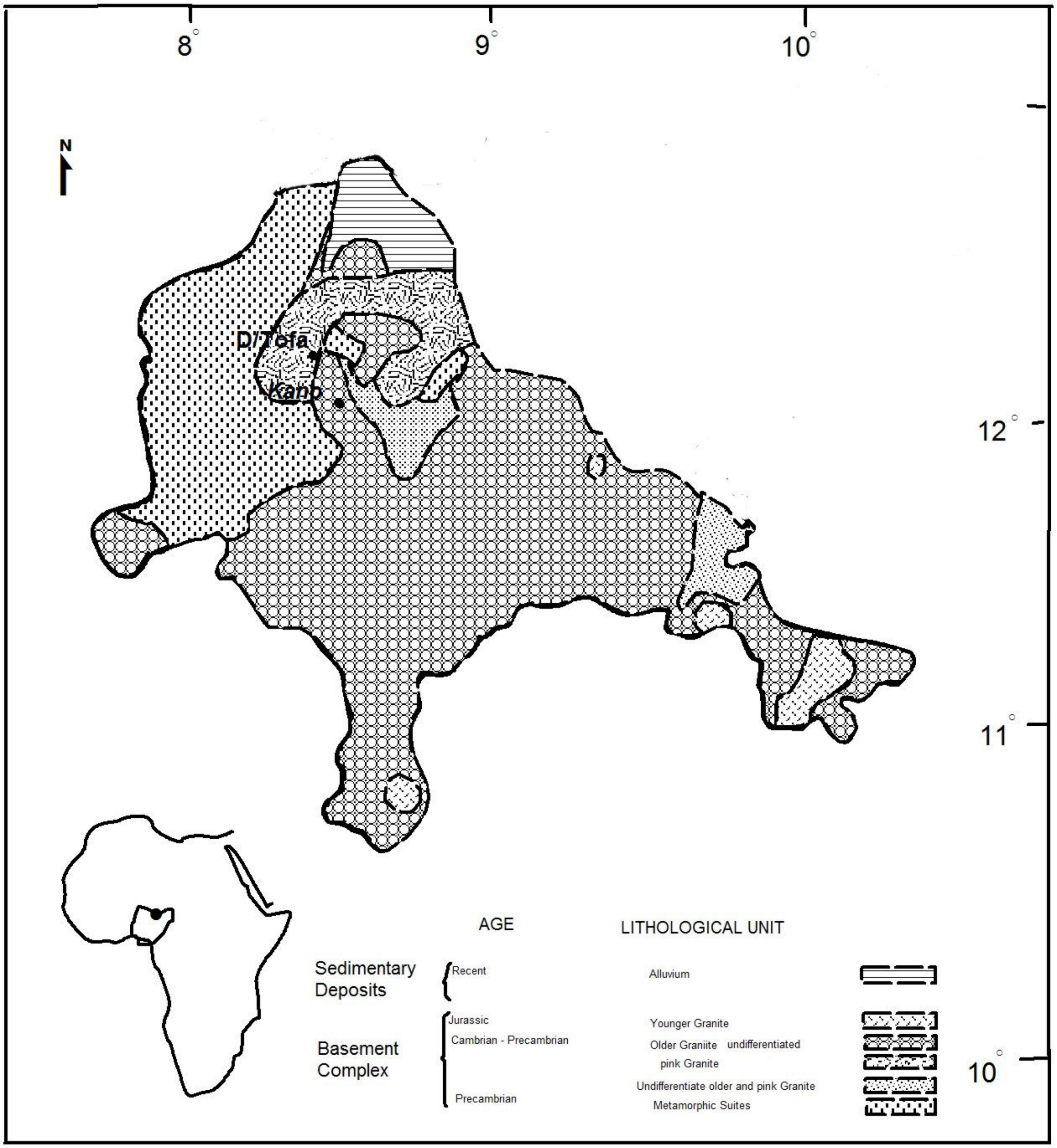

Fig.1: Geology of Kano and and parts of Jigawa State (KNARDA, 1989).

1.2 Geology of the Area

The Northern Nigerian Basement Complex comprises three groups of rocks namely, migmatites and (high grade) gneisses derived from Birrimain sedimentary rocks through high grade metamorphism and granitization; the Younger Metasediments of Upper Proterozoic age which are low grade metamorphic rocks that were folded along with the migmatite and gneisses during the Pan-African orogeny; and the Older Granite series which were intruded during the Pan-African orogeny (McCurry, 1989). In the study area, Hazell *et al*., (1988) also reports the occurrence of rocks of the Younger Granites series (Falconer, 1911), so termed because they are Jurassic in age (Figure 1), as well as volcanics, and occasional younger dykes and flows. Kano Agricultural and Rural Development Authority, KNARDA (1989) identifies the individual members of the Older Granite suite, but rocks of the Younger Metasediments and those of the migmatite-gneiss complex were simply grouped as the migmatite-gneiss complex in some places (Figure 1).

1.3 General Hydrogeology of the study Area

Mohammed in 1984 indicates that the aquifers of the Basement Complex area of Kano State are the weathered and fractured rocks in which groundwater exist under water table condition. Water table lies at a depth generally less than 20 m, and the maximum depth of boreholes rarely exceeds 60 m. The hydraulic conductivity of the aquifer ranges from 0.039 to 0.778 m/d with an average of 0.330 m/d; transmissivity varies from 3.756 to 36.600 m^2 /d with an average of 12.320 m^2/d; and specific capacity is between 0.054 and 1.200 m /m/d with an average of 0.360 m^3/m/d. Muslim (1984) resents a composite hydrogeological section for the basement rocks having a general sequence as follows: Lateritic sand or laterite top layer, silty sand, sandy clay, clayey sand or clay, weathered rocks and fresh bedrock. The mean depth to water table was put at 8.4 m while the maximum depth is 18.5 m.

1.4 Materials and methods

About forty groundwater levels were measured from open wells in the study area which serves as a guide to the electrode spread used in the present study. The data also serves as guide in understanding the local variation in groundwater level of the study area. Over forty (40) Vertical Electrical Sounding (VES) data points were acquired using an ABEM Terrameter SAS 300 within the study area (fig.6). The schlumberger electrode array was employed in all the sounding points with a maximum electrode spread of 100 meters. Most of the spread were oriented in an N-S direction depending on the trends of structures which were observed locally, a few however were oriented E-W. Location of the sounding points within the study area is presented in figure 2. The survey was carried out between the months of December, 2011 to January, 2012. The data were later reduced and subjected to both qualitative and quantitative interpretation.

1.5 Results and Discussion

Some of the data acquired from the forty two (42) soundings are presented in Table 1, and the field curves are predominantly three-layer A and H-types (Fig.5). Geoelectric models for the the study area in the form of Vertical Iso-ohms Section (VIS) and Iso-ohms Map (Resistivity contours) at different depths were plotted. These were used to delineate the aquiferous zone within the area of study. The acquired VES field curves were initially interpreted using the conventional partial curve matching technique and the Petrowski's method (Telford *et al.,* 1976). Initial estimates of the resistivities and thickness of the various geoelectric layers were deduced from this preliminary interpretation. The deduced parameters were later used as starting models in a "Interpex" computer program. This computer assisted resistivity interpretation is based on the calculation of theoretical VES curves, and gave the 'best fit' for the data obtained.

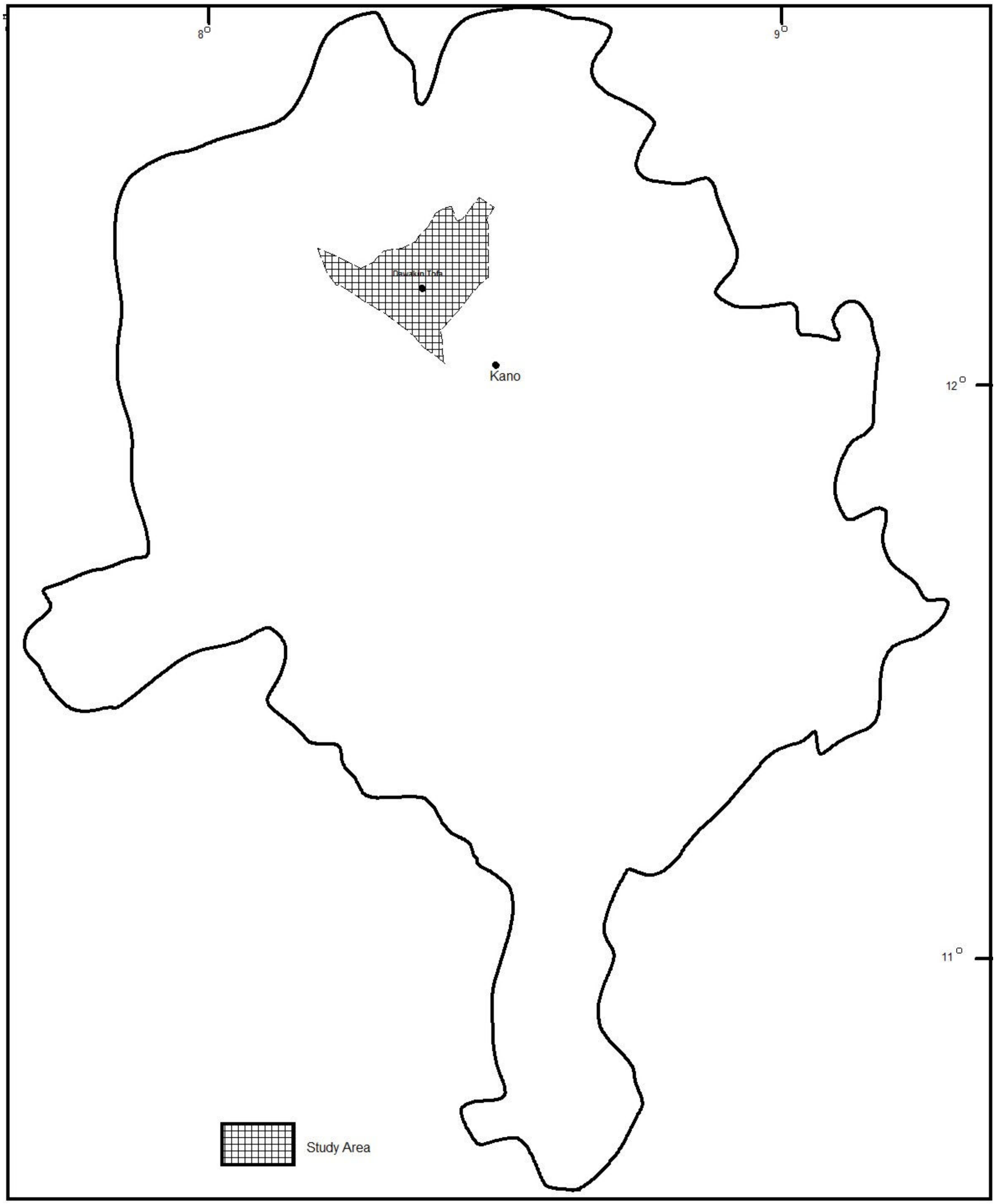

Fig.2: Map of Kano State showing the study area.

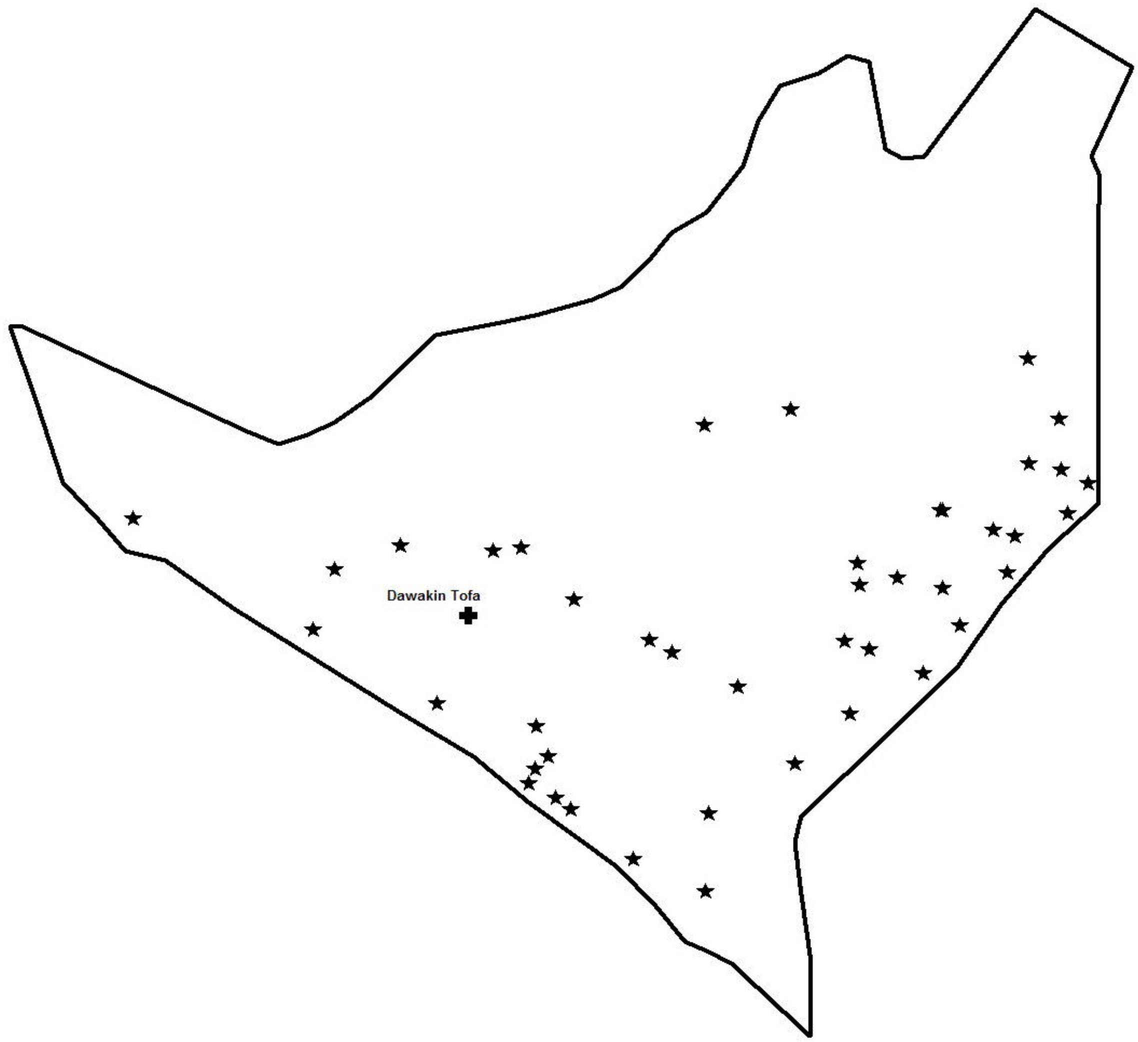

Fig.3: Map of the study area showing location of VES points.

The dynamic water level measured from open wells varies from 5.5 meters to 32 meters with an average value of 19.7 meters. There is a strong local variation in the water levels and this has been observed to be controlled by topography, thickness of overburden as well as the geology. Not all the wells however are high yielding even though the survey was carried out not at the peak of dry season, this could be attributed to the fact that some of the wells are taping water not from the main aquifer but rather from a patch aquifer. Open wells taping water from a depth of 16 meters and above in the study area tends to be productive as compared with the rest of the wells which has been shown from the geophysical results that this wells are tapping from the main aquiferous zone of the study area. Results from the sounding data indicates that the study area is underlain generally by five (5) geoelectric or geologic layers, these include; Lateritic top soil or Lateritic sand, Silty sand or Sandy clay, Weathered basement or Clayey sand, Fractured basement and Fresh basement. Based on the result obtained the fractured and the weathered basement makes the aquiferous zone within the study area. The resistivities of these zones varies from 7.3 to 772 Ωm with an average value 178 Ωm, while the thickness varies from a value of 1.66 to 28 m with an average value of 14.33 m. Depth to this zone varies from 5 to 31 m with an average value of 16 m. The general geoelectric or geologic section of the study is presented in figure 4. It is also seen from the results as well as the data collected from open wells that in order to have a productive well in the study, an average depth of 20 m is required, while for groundwater exploration within the study area using the VES schlumberger array the minimum electrode spread should be 80 m.

1.6 Conclusion

In conclusion it can be said that the study area is generally underlain by five (5) geoelectrical / geologic layer with an average low resistivity value of 178 Ωm, an average thickness value of 14.33 m and an average depth value of 16 m. It has been established also that a minimum of 20 m borehole depth is required for productive wells in the area. The study also recommended the use of 80 m minimum electrode spread for future electrical survey to be used in the study area.

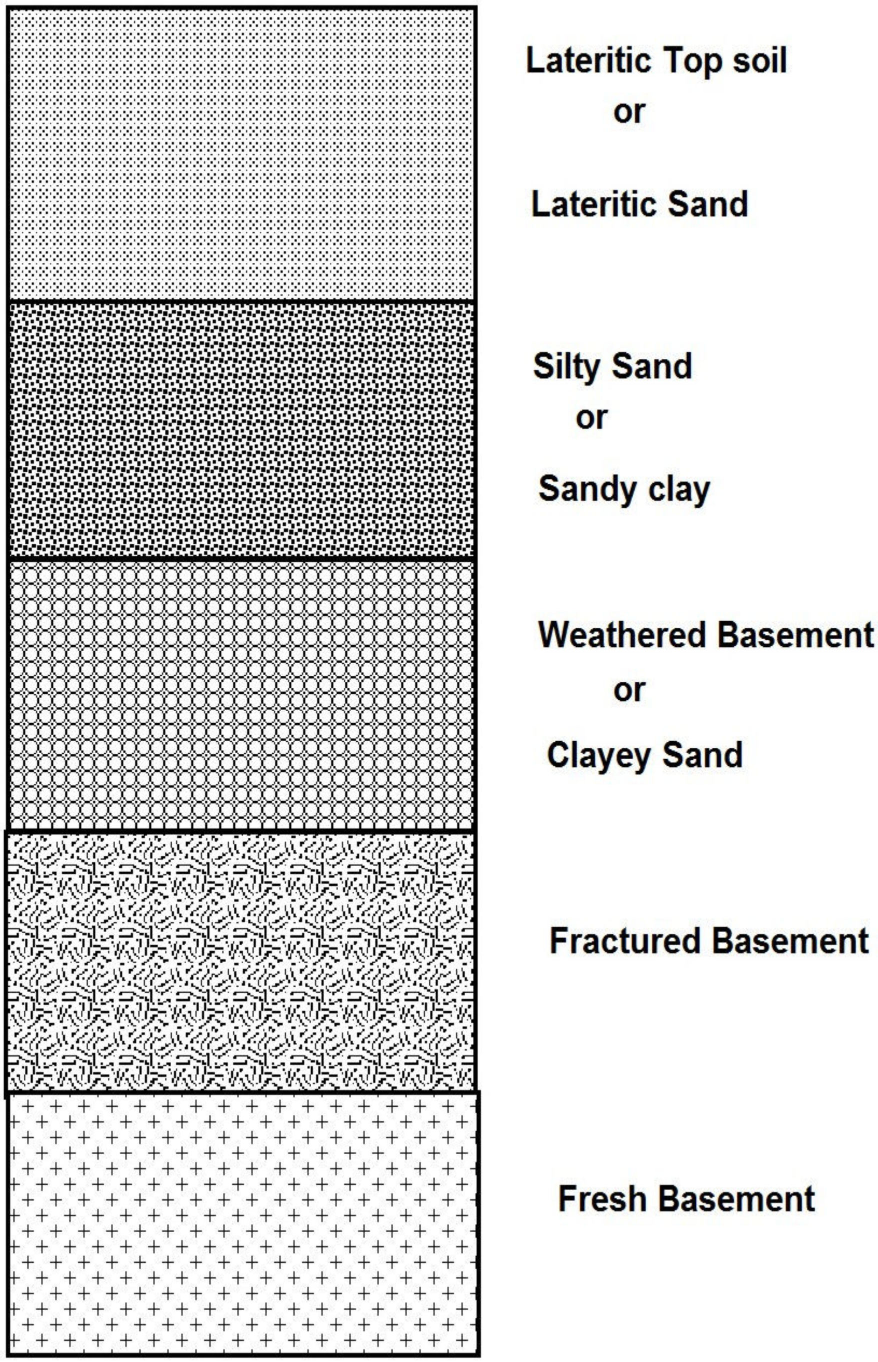

Fig.4: General geologic / geoelectric section of the study area.

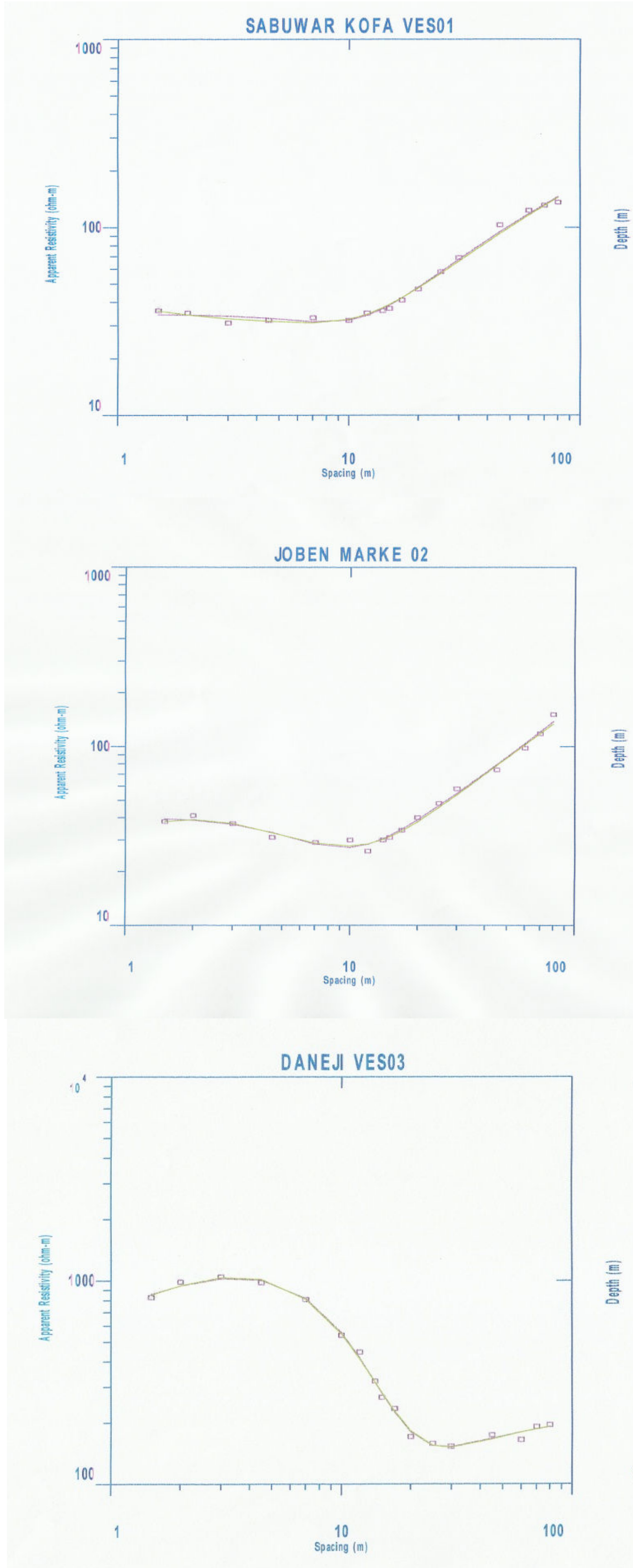

Fig.5: Some selected resistivity curve of the study area.

SABUWAR KOFA VES01

Schlumberger Array

Northing: 1159107.0 Easting: 831627.0 Elevation: 0.0

No.	Spacing (meters) AB/2	MN	Data Resistivity	Layered Model: Synthetic Resistivity	Layered Model: DIFFERENCE	Smooth Model: Synthetic Resistivity	Smooth Model: DIFFERENCE
1	1.50	0.500	36.00	34.23	4.89	35.93	0.194
2	2.00	0.500	35.00	34.12	2.48	34.19	2.30
3	3.00	0.500	31.00	33.73	-8.83	32.64	-5.31
4	4.50	0.500	32.00	32.83	-2.59	31.66	1.05
5	7.00	0.500	33.00	31.48	4.59	31.01	6.02
6	10.00	2.00	32.00	32.05	-0.163	32.38	-1.19
7	12.00	2.00	35.00	33.97	2.93	34.49	1.45
8	14.00	2.00	36.00	36.81	-2.25	37.26	-3.51
9	15.00	2.00	37.00	38.47	-3.97	38.82	-4.94
10	17.00	2.00	41.00	42.10	-2.68	42.19	-2.90
11	20.00	2.00	47.00	47.95	-2.03	47.58	-1.24
12	25.00	2.00	58.00	57.95	0.0765	56.90	1.88
13	30.00	2.00	69.00	67.70	1.87	66.18	4.07
14	45.00	10.00	103.0	94.56	8.18	92.47	10.22
15	60.00	10.00	123.0	118.1	3.93	116.1	5.54
16	70.00	10.00	131.0	132.3	-1.03	130.6	0.234
17	80.00	10.00	136.0	145.4	-6.97	144.2	-6.08

NO DATA ARE MASKED

Layered Model

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	DEPTH	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
				0.0		
1	34.33	4.74	4.74	-4.74	0.138	162.7
2	3.26	0.702	5.44	-5.44	0.215	2.29
3	50.67	1.09	6.53	-6.53	0.0215	55.27
4	369.0	1.39	7.93	-7.93	0.00379	516.0
5	187.7	0.551	8.48	-8.48	0.00294	103.6
6	402.3					

ALL PARAMETERS ARE FREE

JOBEN MARKE 02

Schlumberger Array

Northing: 1209601.0 Easting: 812447.0 Elevation: 0.0

No.	Spacing (meters) AB/2	MN	Data Resistivity	Layered Model: Synthetic Resistivity	Layered Model: DIFFERENCE	Smooth Model: Synthetic Resistivity	Smooth Model: DIFFERENCE
1	1.50	0.500	38.00	39.29	-3.41	37.93	0.174
2	2.00	0.500	41.00	38.67	5.67	38.93	5.03
3	3.00	0.500	37.00	36.73	0.729	37.11	-0.302
4	4.50	0.500	31.00	33.03	-6.56	32.90	-6.13
5	7.00	0.500	29.00	28.39	2.08	28.78	0.725
6	10.00	2.00	30.00	27.24	9.19	27.73	7.55
7	12.00	2.00	26.00	28.40	-9.24	28.54	-9.80
8	14.00	2.00	30.00	30.45	-1.52	30.19	-0.637
9	15.00	2.00	31.00	31.70	-2.25	31.24	-0.775
10	17.00	2.00	34.00	34.44	-1.31	33.67	0.967
11	20.00	2.00	40.00	38.93	2.65	37.87	5.32
12	25.00	2.00	48.00	46.79	2.50	45.60	4.99
13	30.00	2.00	58.00	54.77	5.55	53.68	7.43
14	45.00	10.00	74.00	79.05	-6.82	78.19	-5.66
15	60.00	10.00	98.00	103.9	-6.06	102.2	-4.37
16	70.00	10.00	118.0	120.7	-2.34	118.0	-0.0121
17	80.00	10.00	151.0	137.7	8.78	133.4	11.61

NO DATA ARE MASKED

Layered Model

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	DEPTH	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
				0.0		
1	39.83	2.38	2.38	-2.38	0.0599	95.07
2	37.60	0.362	2.74	-2.74	0.00964	13.63
3	17.47	6.28	9.03	-9.03	0.359	109.8
4	138.8	20.60	29.63	-29.63	0.148	2860.1
5	25135.8					

ALL PARAMETERS ARE FREE

DANEJI VES03

Schlumberger Array

Northing: 1210184.0 Easting: 825567.0 Elevation: 0.0

No.	Spacing (meters) AB/2	MN	Data Resistivity	Layered Model: Synthetic Resistivity	DIFFERENCE	Smooth Model: Synthetic Resistivity	DIFFERENCE
1	1.50	0.500	828.0	855.9	-3.37	850.5	-2.72
2	2.00	0.500	986.0	944.2	4.23	946.3	4.02
3	3.00	0.500	1045.0	1024.2	1.99	1036.0	0.859
4	4.50	0.500	979.0	1007.3	-2.89	1014.4	-3.62
5	7.00	0.500	807.0	818.4	-1.42	811.6	-0.572
6	10.00	2.00	539.0	554.4	-2.86	547.5	-1.57
7	12.00	2.00	446.0	416.8	6.53	413.7	7.24
8	14.00	2.00	321.0	317.3	1.13	317.3	1.13
9	15.00	2.00	267.0	280.2	-4.94	281.2	-5.32
10	17.00	2.00	235.0	225.9	3.85	228.0	2.96
11	20.00	2.00	171.0	180.4	-5.50	182.3	-6.63
12	25.00	2.00	158.0	154.5	2.18	154.7	2.02
13	30.00	2.00	153.0	152.4	0.343	151.4	1.00
14	45.00	10.00	174.0	167.3	3.83	166.1	4.51
15	60.00	10.00	165.0	179.8	-9.01	179.6	-8.85
16	70.00	10.00	191.0	186.0	2.57	186.3	2.44
17	80.00	10.00	195.0	191.0	2.02	191.7	1.68

NO DATA ARE MASKED

Layered Model

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	DEPTH	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
				0.0		
1	350.4	0.275	0.275	-0.275	7.862E-04	96.56
2	1293.5	3.82	4.09	-4.09	0.00295	4944.2
3	71.58	5.94	10.04	-10.04	0.0831	425.8
4	186.8	14.14	24.19	-24.19	0.0757	2643.6
5	220.7					

ALL PARAMETERS ARE FREE

Fig.6: Some selected table showing sounding data and their layered model.

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