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HYDRO-GEOELECTRICAL STUDY IN THE NORTHEASTERN PART OF ADAMAWA STATE, NIGERIA

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Nineteen vertical electrical soundings (VES) with a maximum current electrode separation of (AB/2) 215 meters were carried out in the northeastern part of the Michika area of Adamawa State, Nigeria. Eighty-five percent of the VES indicate a three-layer earth model, while the remaining fifteen percent indicate a four-layer earth model. The first layer represents the topsoil and has a mean resistivity value of 166 ohm-m and a mean thickness of 2.2 meters. The second has a mean resistivity of 61 ohm-m and a mean thickness of 26.9 meters. This layer represents a highly weathered/fractured basement. The third layer has mean resistivity of 881 ohm-m and a mean thickness of 24.3 meters. This layer represents the weathered/fractured basement. Four layers were obtained in three vertical electrical soundings, and only VES6 with a resistivity value of 4170 ohm-m has reached the fresh basement rocks in the study area. Ten boreholes of a mean depth of 39 meters were drilled after the geoelectrical survey. A hydraulic conductivity value of 0.36 m/day and transmissivity value of 1.97 m2/day were obtained from data collected from the boreholes in the study area.

INTRODUCTION

The resistivity method is unique and can furnish information on subsurface geology. The method is most widely used in water exploration, and is relatively cheap when compared with the seismic refraction method. The present study area is in the northeastern part of the Michika area of Adamawa State, Nigeria, and is located between latitudes 10° 32’ N - 10° 40’ N and longitudes 13° 30’ E - 13° 35’ E (Figure 1). The area has a tropical climate marked by a dry and rainy season with a mean monthly temperature of about 27. 8 °C, and a mean annual rainfall of about 1000 mm (Adebayo and Tukur, 1999). The area is mountainous and the highest elevation of 3660 ft is found at the Ndille Hills in the southwest part of the area. High elevations also exist at the Chumekamole and Theka hills which are in the southern part of the study area (Figure 1).

The area is underlain by crystalline basement complex, where the occurrence of groundwater is due largely to the development of secondary porosity and permeability by weathering and/or fracturing of the parent rocks (Acworth, 1987; Olorunfemi and Fasuyi, 1993; Edet and Okereke, 1997). Experience throughout the world has shown that the rate of failure of boreholes is usually highest in the basement complex terrain. This is mainly due to an inadequate knowledge of the basement aquifers, which results from in-situ weathering and/or denudation of basement rocks. Geophysical surveys of the subsurface for aquifers can be very important in the basement complex where groundwater occurrence is erratic.

Nineteen vertical electrical soundings (VES) were carried out in the study area having a maximum electrode spacing of 215 meters. The results from this study are a contribution to better understanding of the aquifer systems in the area.

GEOLOGY AND HYDROGEOLOGY

Basement complex rocks, consisting of Gneiss-migmatite, Quartzite and other Granitoid rock series of Precambrian age, cover the study area. The Gneiss-migmatite rocks have undergone a weathering process that leads to the formation of laterite, gravels, sand, clays and silt materials. The Granitoids mainly contain feldspars, biotites, and occasionally microcline (Figure 2). The granitoids, also called older granites, are products of the Pan African Orogeny (about 1500 my ago).

The water supply of the study area is mainly from a few hand-dug wells and an inadequate number of boreholes. The exploration and evaluation of groundwater resources requires obtaining accurate geophysical data and information on aquifer parameters such as hydraulic conductivity, transmissivity, and storage coefficient (Uma et al., 1989). The aquifer unit in the study area is mainly in the weathered/fractured basement, and poor infiltration of the surface water during the rainy season results in shallow water table conditions because of the low permeability characteristics of these rocks. Accurate acquisition of geoelectrical data, subsequent analysis and interpretation of the data are valuable contributions in locating boreholes. Subsequent to the interpretation of the nineteen VES, ten boreholes were then located in the study area (Figure 2).

DATA COLLECTION, ANALYSIS AND INTERPRETATION

Nineteen Schlumberger vertical electrical soundings (VES) were carried out during a field survey in the northeast part of Michika using an SAS 1000 Terrameter. The second author collected the raw data in the second quarter of 2005 while he was with Hill Water Resources Nigeria. The readings of the resistance obtained from the terrameter at each point were multiplied the constant

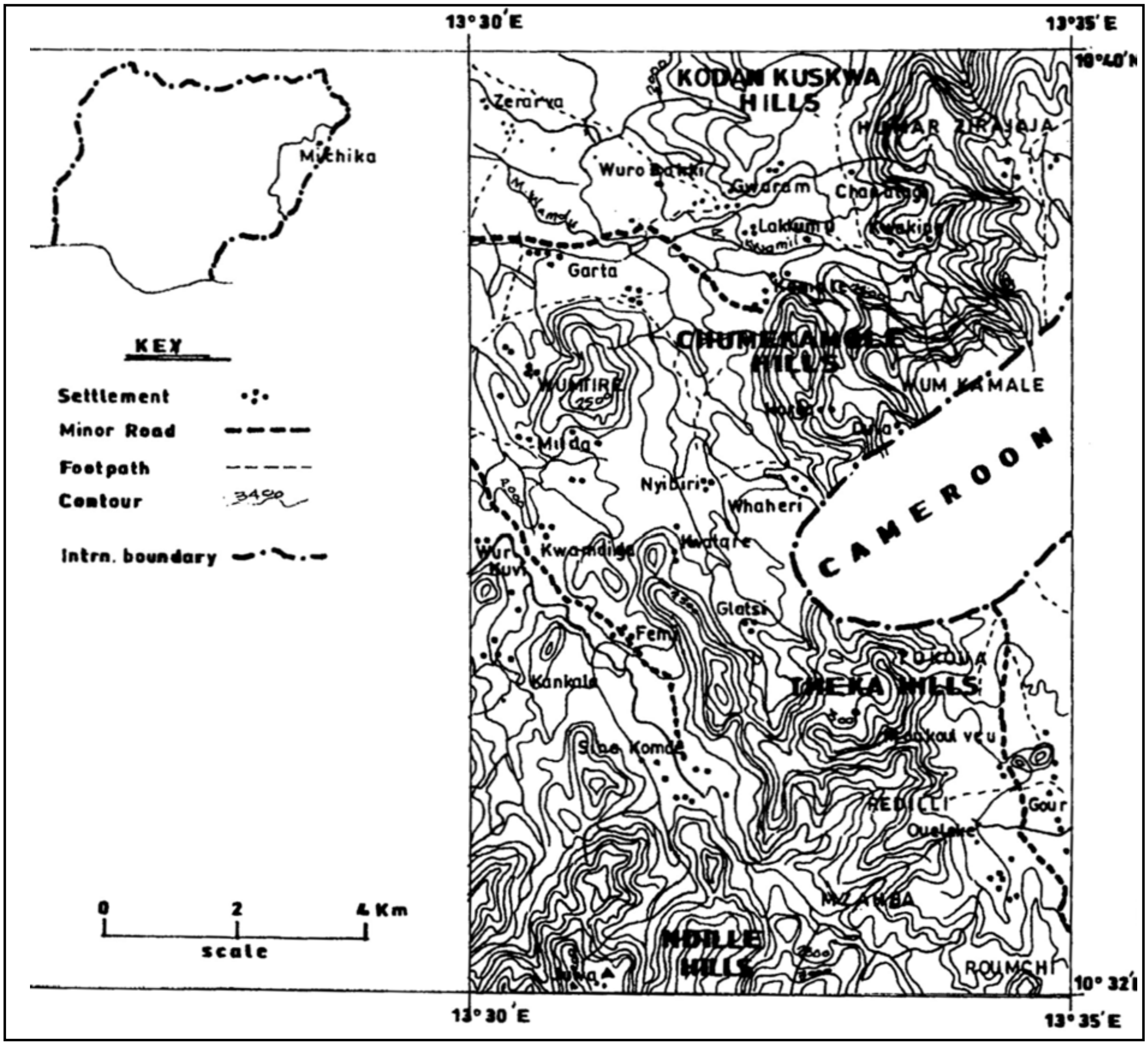

Figure 1. Topographic map of the study area (after Geological Survey of Nigeria, 1974).

geometric factor (k) and the apparent resistivity (ρ_a) at each point was obtained. The apparent resistivity at each location was then plotted on log-log graph paper. From the nineteen VES obtained during the fieldwork, fourteen VES showed an H-type curve, while the remaining five VES are HK, HQ and HA types. These curves are characteristic of the basement complex.

The initial interpretation of the VES data was carried out using partial curve matching techniques with two layer masters curves and auxiliary diagrams. The resistivities and thickness of the nineteen VES were used as the initial input to a computer program (Resist.for), which is based on optimization techniques. Details of the model parameters and the mathematical formulae used for this study can be found in Mbonu et al. (1991), Nur et al. (2001), and Nur and Ayuni (2004). During the interpretation, borehole information was also incorporated and the layered earth models from the vertical electrical sounding interpretation were kept as simple as possible. The results obtained from the computer modeling are presented in Table 1 while Figure 3 shows examples of four vertical electrical sounding (VES) curves and their interpretation. Sampling data collected from

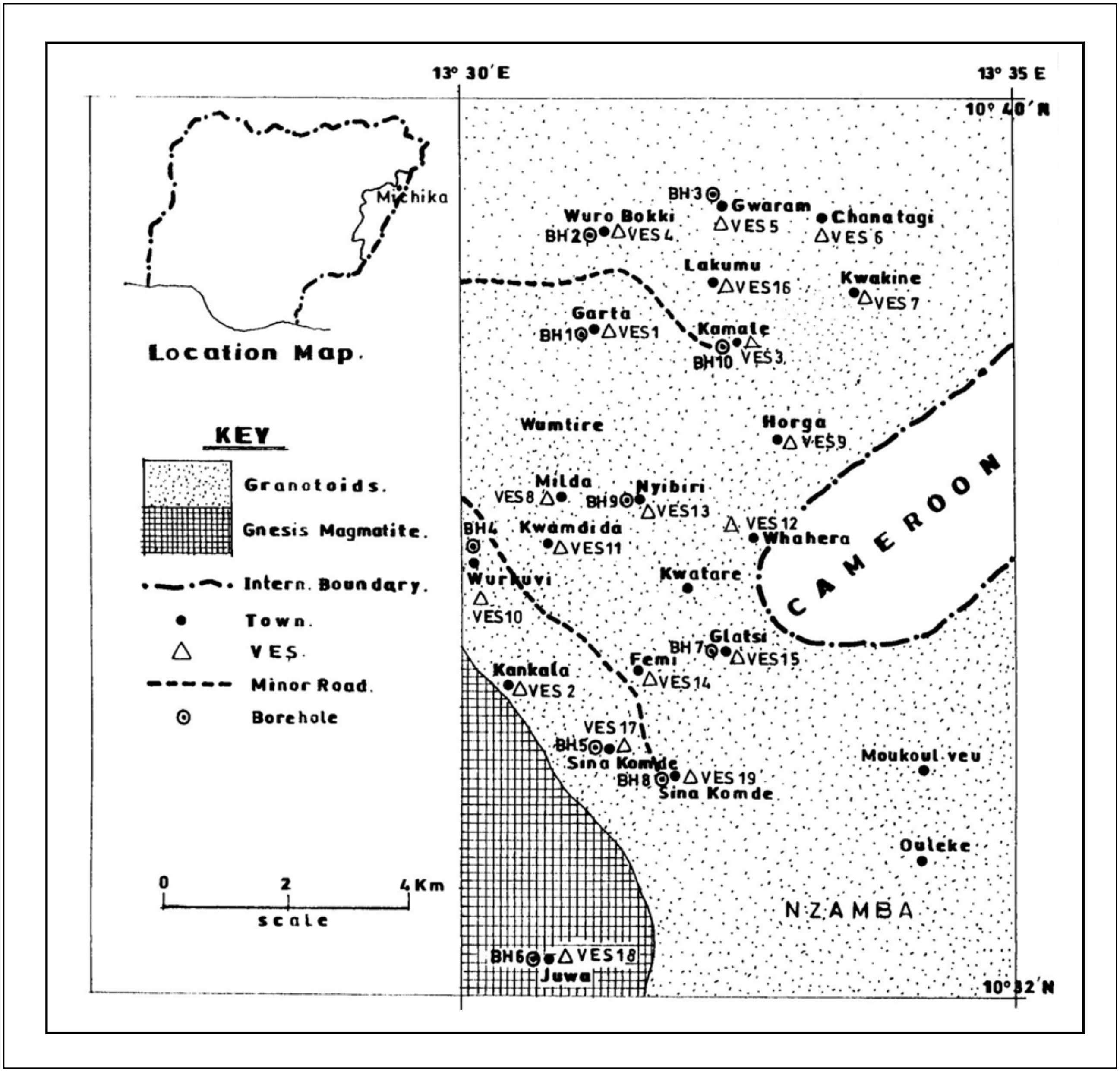

Figure 2. Geological map of the study area (after Geological Survey of Nigeria, 1994).

the ten boreholes drilled in the study area were analyzed and the results obtained are presented in Table 2.

DISCUSSION OF THE RESULTS

The qualitative and quantitative interpretation of the nineteen vertical electrical sounding (VES) has helped in the determination of the depth of the basement in the study area. The results have also helped in the identification of the topsoil, weathered basement and fractured basement rocks in the area. To understand better the geoelectrical conditions in the study area, the iso-resistivity value of AB/2 =70, which corresponds to a depth between 18 to 23 meters was contoured as shown in Figure 4. Two anomalies were found. The first one is located around Kamale in the north part of the study area, where the highest resistivity values of about 140 ohm-m were obtained. This anomaly has a circular shape and covers an area over 2 km². The second anomaly is an elongated one with a nearly north-south direction, extending from Sina Konde in the south to Nyibiri at the

Table 1. Summary of results obtained from the computer output of the nineteen (19) VES in the study area.

THICKNESS (M)			RESISTIVITY OF LAYERS (OHM-M)				CONDUCTANCE (SIEMEN)			RESISTANCE			ER %
H1	H2	H3	ρ1	ρ2	ρ 3	ρ4	σ1	σ 2	σ 3	R1	R2	R3	
2.6	36.6	-	145	22	719	-	0.018	1.664	-	377	805	-	3.8
4.2	23.2	-	634	184	81	-	0.007	0.126	-	2663	4268	-	6.7
1.4	41.7	-	276	81	2009	-	0.005	0.515	-	386	3378	-	9.8
4.2	19.7	-	41	21	376	-	0.102	0.938	-	172	414	-	2.8
1.0	24.7	-	96	21	2464	-	0.100	1.176	-	96	519	-	5.4
0.5	3.4	34.9	66	16	44	4170	0.008	0.213	0.008	33	54	1536	3.4
2.9	16.3	-	408	21	9195	-	0.007	0.776	-	1183	342	-	8.6
1.1	16.3	-	178	46	110	-	0.006	0.354	-	196	750	-	2.2
6.3	17.9	-	24	96	289	-	0.263	0.186	-	151	1718	-	6.5
1.8	0.8	21.8	148	188	116	116	0.012	0.004	0.188	266	150	2529	6.1
0.3	13.0	-	91	17	101	-	0.003	0.765	-	27	221	-	2.8
1.3	10.8	-	139	42	93	-	0.009	0.257	-	181	454	-	3.4
3.7	3.9	-	255	54	162	-	0.015	0.072	-	944	211	-	7.9
0.8	3.2	-	48	19	87	-	0.017	0.168	-	38	61	-	7.5
1.4	61.2	-	92	57	187	-	0.015	1.074	-	129	3588	-	2.3
1.3	0.5	16.1	37	112	100	100	0.035	0.004	0.161	48	56	1610	4.9
1.5	19.8	-	278	98	213	-	0.005	0.202	-	417	1940	-	6.2
2.7	4.9	-	124	28	88	-	0.022	0.175	-	335	137	-	6.4
2.1	32.1	-	75	44	313	-	0.028	0.729	-	158	1412	-	3.6
2.2	26.9	24.3	166	61	881	1462	0.036	0.495	0.119	411	1078	1892	5.6

Table 2. Hydraulic properties of some aquifer units in the study area.

S/N	LOCATION/ BOREHOLE NO.	TOTAL DEPTH (M)	DEPTH OF SWL (M)	AQUIFER THICKNESS (M)	HYDRAULIC CONDUCTIVITY (M/DAY)	TRANSMISSIVITY (T) (M^2/DAY)
1	Garta (BH1)	39	4.47	12	0.40	0.06
2	Wurro bokki (BH2)	40	5.42	11	0.11	1.65
3	Gwaram (BH3)	49	8.0	13	0.37	3.12
4	Wurkuvi (BH4)	33	3.57	11	0.32	5.36
5	Sina komde (BH5)	40	7.64	12	0.42	0.59
6	Juwa (BH6)	42	7.90	13	0.20	0.20
7	Glatsi (BH7)	40	6.74	11	0.65	0.98
8	Sina komde (BH8)	35	7.03	11	0.34	3.40
9	Nyibiri (BH9)	40	10.24	13	0.28	4.23
10	Kamale (BH10)	32	9.23	11	0.50	0.08
Mean		39	7.02	11.8	0.36	1.97

center of the study area (Figure 4). This anomaly is about 7 Km long, with the highest resistivity values of up to 140 ohm-m.

The results obtained from the nineteen-resistivity data interpretation (Table 1) assisted in the delineation of the thicknesses of the topsoil, and the weathered and fractured rocks, which in turn was used for the location of the boreholes drilled in the study area. The aquifer unit in the study area was identified in the weathered/fractured basement and ten boreholes of depths ranging between 32 and 49 m were drilled. The water table in the boreholes varied from 3.57 to 10.24 m. (Table 2). The hydraulic properties determined from statistical methods indicate a mean hydraulic conductivity (k) value of 0.36 m/day and a mean transmissivity (T) of 1.97 m^2 /day (Table 2). Comparisons were made to the hydraulic conductivity (k) reported in Todd (1980) and transmissivity (T) in Gheorghe (1978) classifications, and it was found that the study results of k and T are relatively moderate. According to Nur et al. (2005), the fractured aquifer in the basement complex areas has low to moderate hydraulic conductivity and transmissivity values, which give rise to low and moderate yields and specific capacities in boreholes tapping these aquifer systems.

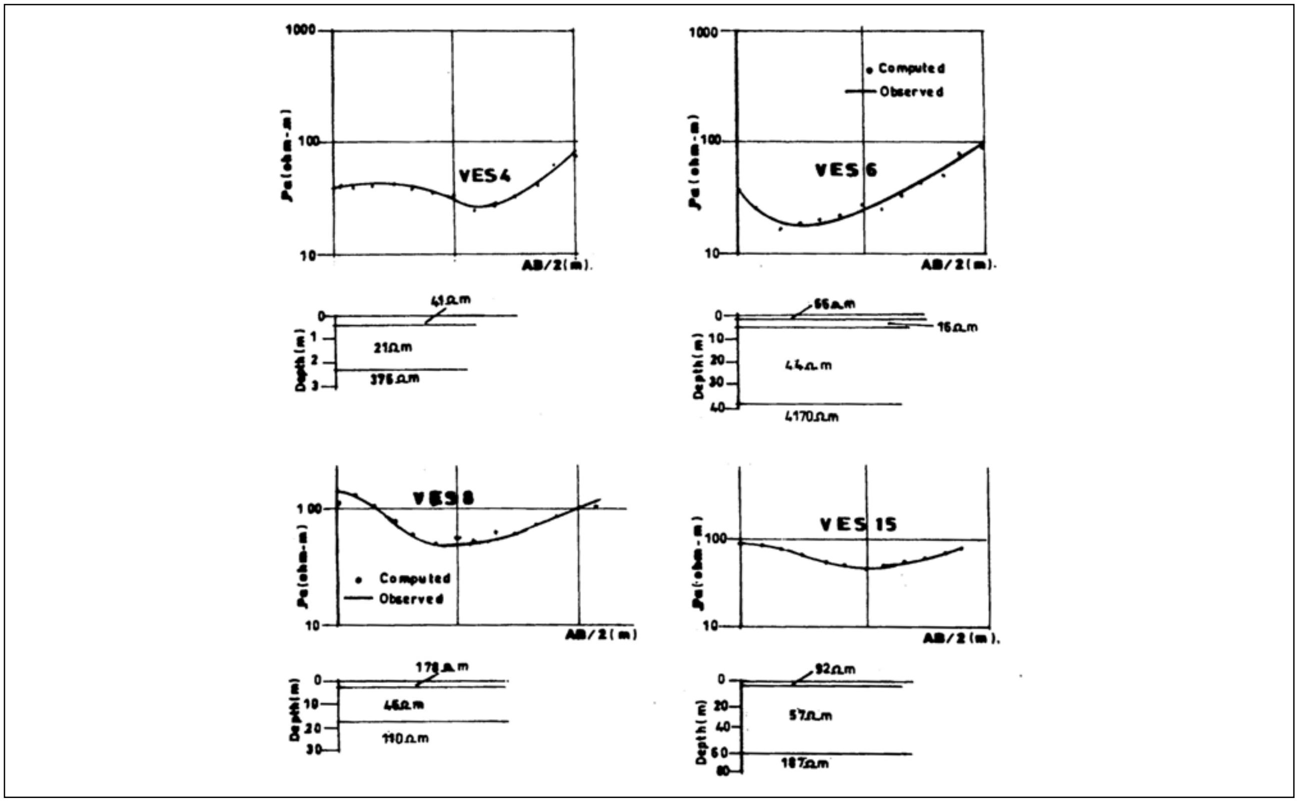

Figure 3.. Examples of computer interpretation for VES4, VES6, VES8 and VES 15.

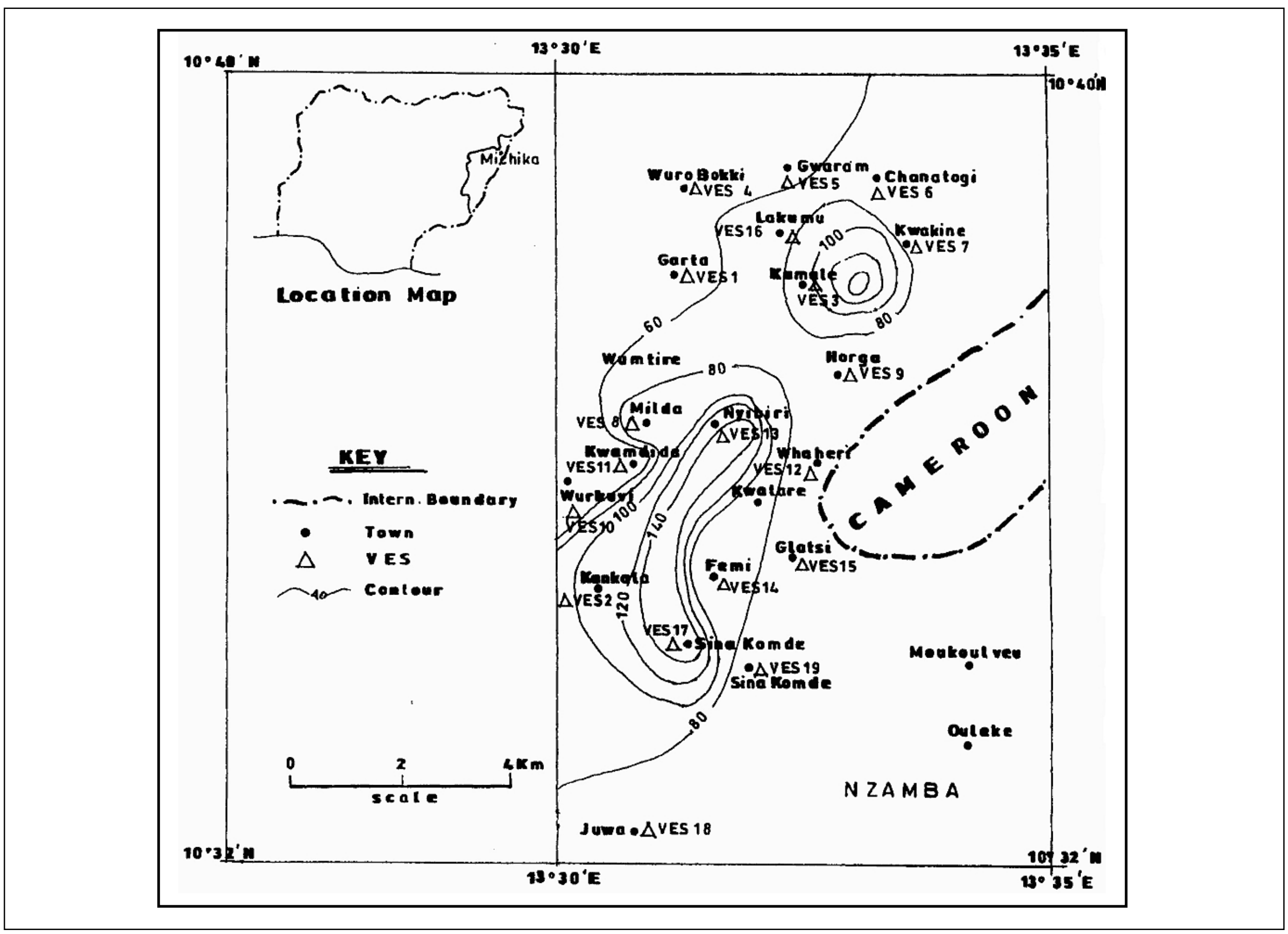

Figure 4. Iso-resistivity map for AB/2=70m (contour interval 20 ohm-m).

CONCLUSION

Nineteen Schlumberger vertical electrical soundings (VES) were carried out in the southeast of the Michika area of Adamawa State. In the study area, 85% of the VES showed an electro-stratigraphic three earth model, with the average resistivity of the second layer about 60 ohm-m. This is considered a potential water bearing zone and therefore is the target for the drilling operations. Ten boreholes of a mean depth of 39 m were drilled in the study area after the geo-electrical study and a mean hydraulic conductivity value of 0.36 m/day and a mean transmissivity value of 1.97 m2/day were obtained.

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