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GEOELECTRICAL EXPLORATION FOR GROUNDWATER IN A CRYSTALLINE BASEMENT TERRAIN: THE CASE OF OBUDU, S. E. NIGERIA.

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ABSTRACT

Vertical electric sounding (VES) method using schlumberger electrode configuration was used to conduct a survey for groundwater in Obudu area, S.E. Nigeria, in an attempt to define the geoelectric structure, variation in thickness and potential groundwater zones in the subsurface of the area. The survey area is located between 6^0 $30'$ N and 6^0 $45'$ N latitude and between 9^0 $00'$ E and 9^0 $30'$ E longitude.

Nineteen vertical electric sounding (VES) points were surveyed using ABEM Terrameter SAS 300B with a maximum current electrode separation of 350 meters. Results of the survey and the computer modeling identified a three to four layer geoelectric model. The geoelectric structure has been differentiated into possible lithological units of sandy clay, clay and sand. The fourth layer shows a high resistive unit which is indicative of fresh rock. The resistivity values and thicknesses of the third layer indicate water saturation and potential aquifer in the area.

KEY WORDS: Vertical Electrical Sounding, Electrode Configuration, Geoelectric model.

INTRODUCTION

One of the primary constraints to economic and social development in Obudu area is the difficulty encountered in developing reliable water supplies for the rural populace. In the area, the surface water is not available on a permanent basis and within a distance. As a result, groundwater is, generally, the only permanent and safe source of water. However, the search for groundwater and its development in this area raises a number of problems like drilling of dry holes which until recently were considered almost impossible to solve. However, surface geophysical exploration for groundwater in the area offers considerable hope for the future of the area, and has been utilized in this work.

Crystalline basement rocks are generally impermeable and have no appreciable water storage capacity, however groundwater wells have been successfully developed in basement areas in parts of Nigeria and the world (Foster, 1984.) The availability of groundwater resource in these impermeable crystalline igneous and metamorphic rocks is largely due to the development of secondary porosity and permeability resulting from weathering and fracturing and the thickness of regolith. To ensure maximum yield, boreholes are sited at points where there is maximum thickness and fractured zone. Surface geophysical surveys have been used to determine the various weathered layers and their thicknesses as well as to determine the depth to fresh rock. These techniques have been successfully used for groundwater exploration in basement area of Nigeria, (Okbue & Olorunfemi, 1991; Olayinka, 1990; Etu-Efeotor, 1995).

Location and Geology

The Obudu area comprising of the following districts, Lisichie, Shikpechie, Busangfang, Ablesang, Kabun, Udeshi and Sankwala is located between 6^0 $30'$ N and 6^0 $45'$ N latitude and between 9^0 $00'$ E longitude (Fig. 1).

The area consists dominantly of the basement complex which has been intruded by acidic, basic and ultrabasic igneous rocks (Ekwueme, 1990). The metamorphic rocks are mostly gneisses, schists and amphibolites. They form prominent hills which have been eroded in parts to expose fresh rocks. The garnet sillimanite dominate some parts of the area. It is generally grayish and interbedded with quartzite, suggesting a sedimentary origin. These rocks are frequently dissected by quartzo feldspathic dykes and veins, pointing to anatexis as one of its modes of formation.

The structural features of Obudu are superimposed on the geology. The area has a rugged topography consisting of a series of northeasterly trending mountain ridges separated by lowlands. These ridges are sources of rivers and streams which later form structurally controlled drainage patterns down stream. Both planar and linear structures show an average of NE-SW trends, signifying the dominant influence of the pan African thermotectonic event (450-1100 Ma).

Data acquisition and Analysis

Nineteen vertical electrical soundings (VES) were undertaken in seven locations (Table. 1) using the Schlumberger electrode configuration with a maximum current of Ma and current Electrode Separation (AB) of 500m, Table 1 shows the distribution of VES per locality.

Table 1: VES distribution per locality in Obudu

Locality	VES cod	Number of VES
Lisichie	01	4
Shikpeshe	02	2
Busangfung	03	2
Ablesang	04	2
Kabun	05	2
Udeshi	06	3
Sankwala	07	4
Total		19

An ABEM terrameter, Signal Averaging System (SAS) model 300B resistivity measuring instrument with resistance as output was used for the survey.

A direct current was provided by the battery through two electrodes (A and B). The potential drop between the two potential electrodes (M and N) placed between the current electrodes was automatically converted to resistance. The apparent resistivity (ℓ_a) was obtained by multiplying the

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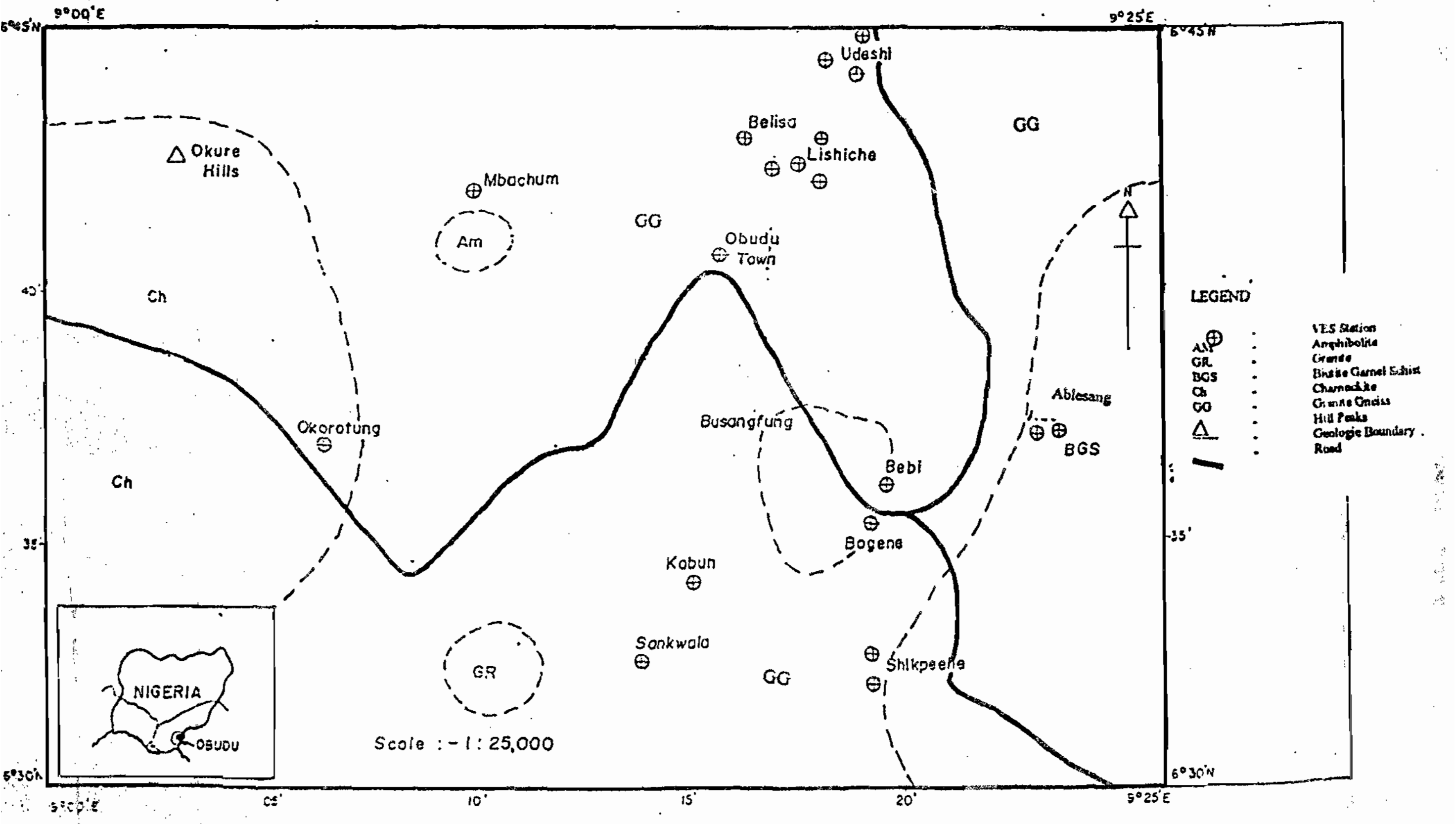

Fig. 1 Geological Map of OBUDU area showing VES stations

resistance value by the geometric factor (G). (Ushie, 1995).

$$\rho_a = \frac{\pi\left[\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2\right]}{MN} \times R$$

Where $\frac{AB}{2}$ = half current electrode separation

$\frac{MN}{2}$ = half potential electrode separation

$$\frac{\pi\left[\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2\right]}{MN}$$

The expression is generally referred to as the geometric factor (G) and its value depends on electrode separation.

Apparent resistivity, ρa = G.R where R is resistance value displayed on the instrument. The apparent resistivity values obtained from the field measurement at each sounding station was plotted against half current electrode spacing, $\frac{AB}{2}$ as abscissa on a bi-log graph scale and presented as sounding curves, mostly, KH, as shown in fig. 2. The quantitative interpretation of the field curves was initially carried out using the conventional partial curve matching technique using the auxiliary point method (Orellena and Mooney, 1988). The process provided the initial estimates of the resistivities and thicknesses of various geoelectric layers. These parameters were used as starting models for the computer iterative inversion program (RESINV) (Davis P.A 1979) for confirmation.

Data Presentation and Interpretation

The results of the data analysis show that the study area is generally interpreted as a four-layered sequence with three layers in a few cases. The interpretative geoelectric section (figure 3 for example), shows the thicknesses and resistivities of the various layers within the Sankwala, Shikpeche and Ablesang districts. The depth to the unweathered crystalline basement was estimated quantitatively as shown. Generally, the thickness of the top soil is variable and ranges from 0.8 meter to 2.1 meters. The resistivity values vary from 185 ohm-m to 1150 ohm-m

The top layers with resistivity values ranging from 190 ohm-m to 850 ohm-m occur at Sankwala, Shipeche and Ablesang (fig. 3). The second layers on the interpretative geoelectric section have resistivity values between 211 ohm-m to 2800 ohm-m. The thickness ranges from 1.4m to 5.2m. At Lisichie, Sankwala, Shikpeshe and Ablesang the second layers are highly resistive, ranging from 120 ohm-m to 10,000 ohm-m. Resistivity values for second layers ranging from 101 ohm-m to 1150 ohm-m are recorded at Kabun, Busangfung and Udeshi districts.

The resistivity values for the third layers generally range from 180 ohm-m to 1122 ohm-m with thickness ranging from 4.8 m to 57.3 m. At Lisichie, Kabun and Busangfung, the third layers have high thicknesses ranging from 8.5 meters to 57.3 meters. This layer is identified as the aquiferous zone. This zone is represented by the thick layer with low resistivity values in the transition zone in the geoelectric section. In

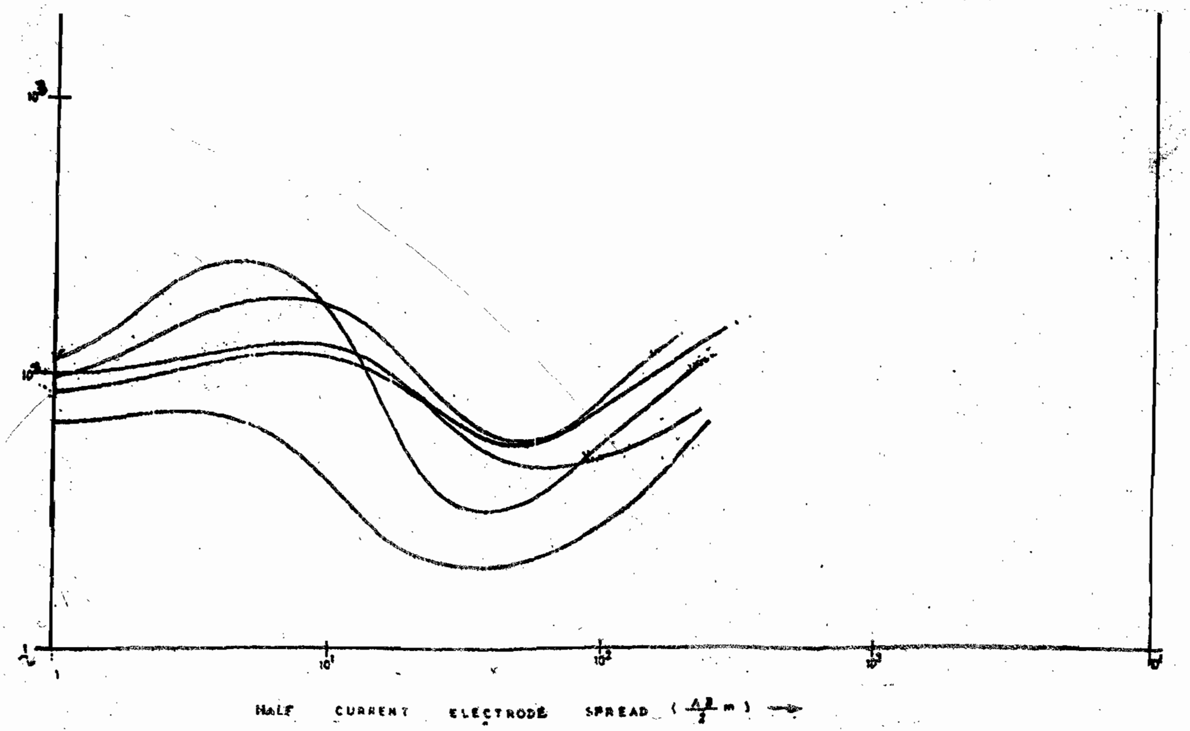

Fig. 2: Typical Sounding (Field) curves from the area

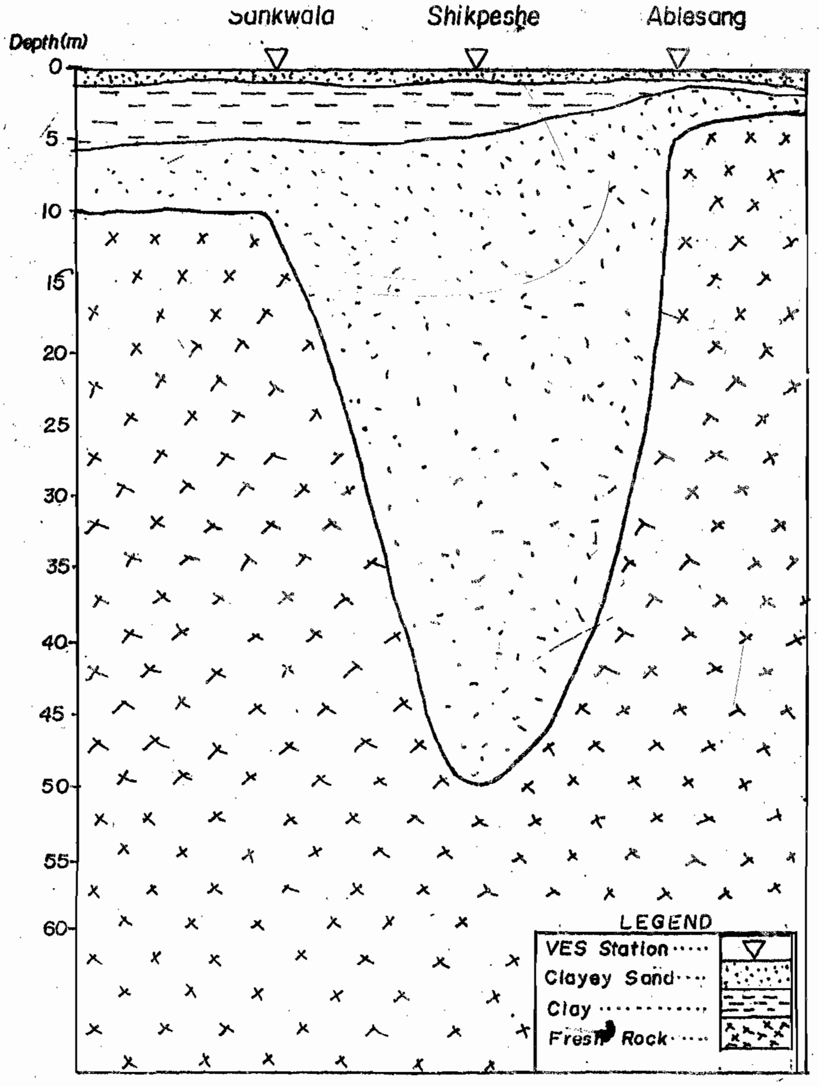

Fig. 3: Typical Geoelectric Section of Sankwala, Shikpeshe and Ablesang Districts

Table 2: Interpretation results showing thicknesses and resistivities of various layers

VES CODE	VES NO.	LAYER NO.	THICKNESS	RESISTIVITY
0.1	01	1	2.0	1160
		2	7.6	1700
		3	55.65	320
		4	-	2200
0.1	02	1	1.0	870
		2	10.0	1300
		3	39.6	360
		4	-	3000
0.1	03	1	1.0	680
		2	3.0	840
		3	57.3	160
		4	-	6500
0.1	04	1	1.13	1058
		2	1.2	10,000
		3	34.0	240
		4	-	4800
0.2	05	1		-
		2	-	-
		3	36.0	-
		4		510
0.2	06	1	1.0	850
		2	5.0	280
		3	50.4	440
		4	-	10,500
0.3	07	1	0.9	400
		2	3.6	590
		3	26.4	340
		4	-	12,000
03	08	1	0.9	480
		2	2.88	1150
		3	8.5	700
		4	-	5000
0.4	09	1	1.0	190
		2	1.4	460
		3	4.8	240
		4	-	3800
0.4	10	1	1.2	185
		2	5.28	120
		3	-	3400
0.5	11	1	1.1	362
		2	2.3	101
		3	-	960
0.5	12	1	0.8	420
		2	2.10	500
		3	11.48	201
		4	-	1100
0.6	13	1	1.41	360
		2	4.41	140
		3	12.4	344
		4	-	1111
0.6	14	1	0.92	410
		2	5.44	220
		3	-	961
0.6	15	1	1.1	644
		2	4.2	203
		3	-	1122
0.7	16	1	1.3	581
		2	5.2	211
		3	10.1	182
		4	-	1002
0.7	17	1	1.6	493
		2	6.6	333
		3	5.3	241
		4	-	998
0.7	18	1	1.2	441
		2	6.4	202
		3	-	1121
0.7	19	1	2.1	525
		2	3.2	311
		3	7.2	201
		4	-	1122

Sankwala, Ablesang and Udeshi districts, the thicknesses of the third layer are relatively thin ranging from 4.8 meter to 12.40 meters.

The fourth layers have resistivity values ranging from 2200 ohm-m to 12,000 ohm-m. This is indicative of the presence of fresh rock. Table 2 shows that the thickness of the regolith at various locations of the area range from 1.0 meter to 57.3 meters. Lisiche, Kabun and Busangfung have high thickness of regolith 8.5 – 57.3 meters. Udeshi has relatively low thickness of regolith (0.90 – 12.4 meters).

DISCUSSION AND CONCLUSION

The results of the interpretative models of the various sounding stations gave wide variation in resistivity both vertically and laterally. The geoelectric section revealed the presence of four types of distinct subsurface units or layers. The sections show the thickness of the weathering profile and depth to the basement. The typical profile progressing downwards from the ground surface is summarized below:

Layer 1: Sandy clay or clayey sand with not more than few meters thick
Layer 2: Clayey soil with a thickness up to 10 meters
Layer 3: Sandy soil with thickness ranging from 4.8 meters to 57.3 meters
Layer 4: Fresh rock.

The low resistivity values of the third layers is indicative of the sand nature of the unit and sufficient porosity and permeability to store water. This thick weathered layer contains the most viable and saturated layers. However, the relatively thin aquiferous layer VES 09 (4.8 meters) at Ablesang may contain no significant water bearing unit but may sustain perennial aquifers provided there is prevailing high recharge. For rural water supply, livestock or irrigation scheme, a productive well will tap aquifers in the third layer of the weathered profile. The resistivity values of the fourth layer are indicative of fresh bed-rocks.

CONCLUSION

The study area consist of four geoelectric layers with overburden overlying the crystalline basement. Generally, the decomposed weathering profile is well developed in the area and with a large thickness of over 50 meters in Lisichie. The results of the study show that the weathered layer(third layer) overlying the fresh rock functions as a reasonable good aquifer with sufficient thickness (4.8 meters to 57.3 meters) and enough permeability to store and transmit water. The surface geophysical survey adopted for this study identified permeable zones potentially capable of significant groundwater production. The geophysical technique increases the rate of success for location of site for borehole drilling and consequently the cost effectiveness of groundwater exploration. Surface geophysical exploration for groundwater in basement complex of Obudu area, Southeastern Nigeria, therefore raises hope for water supplies in the area.

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