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GEOELECTRIC GROUNDWATER INVESTIGATION, SOUTHWESTERN NIGERIA

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An electrical resistivity survey was conducted in Afuze which lies in the Basement Complex of Nigeria. The survey was carried out to investigate the groundwater potential of the area with a view to locating suitable sites for groundwater exploitation. The symmetrical Schlumberger electrode configuration was used and the interpretation was aided by computer. The interpretation of the vertical sounding curves revealed four main geoelectric layers. There were generally two thin resistive top layers underlain by a low thick layer. All these overlay the resistive crystalline Basement. Two borehole sites were recommended for drilling based on the interpretation of the data.

INTRODUCTION

Water is the basic need for any life to exist in this world. With the advent of civilization the use of water increased by leaps and bounds, first for drinking, then for supplementing agriculture, irrigation, municipal requirements and then for industrial growth. Naturally, when surface water is in short supply one has to depend partly or wholly on groundwater. Thus, groundwater is an essential and vital resource in all countries

Groundwater is more desirable than surface water for at least the six following reasons (Shankar, 1994); (1) it is free of pathogenic organisms and needs no elaborate purification (2) temperature is nearly constant which is a great advantage if the water is used for heat exchange, (3) turbidity and color are generally negligible, (4) chemical composition is generally constant, (5) groundwater storage is always greater than surface water storage, so groundwater supplies are not seriously affected by short duration droughts, (6) biological contamination in groundwater is seldom of concern.

Geoelectrical methods are employed in geohydrological investigations as they are more economical and effective than other geophysical techniques. The direct current resistivity method is an effective tool in groundwater exploration as it can determine aquifer thickness and depth to bedrock. It is also used for geothermal studies, civil engineering applications, and in monitoring water pollution, contamination and other geological problems. To achieve these objectives, conventional Schlumberger and Wenner soundings and electrical resistivity tomography (ERT) are currently employed worldwide (Zohdy, 1974; Stollar and Roux, 1975; Rogers and Kean, 1980; Urish, 1983).

The presence of water in crystalline rocks or weathered portions usually below the overburden decreases its electrical resistivity relative to the non-water bearing solid basement rocks (Palacky et al., 1981). Lateral variation in resistivity within these crystalline rocks and its weathered portion as well as the layer immediately above them are thought to reflect variations in the degree of weathering, joining and fracturing and hence their varying hydrogeological properties (Mallik et al., 1983). These distinctions were used to predict the availability of water in this area.

The main objective of the present study was to delineate the surface distribution of groundwater in Afuze, Nigeria. The study has been very useful in identifying sites that are suitable for groundwater exploration.

LOCATION AND GEOLOGY OF THE AREA

The study area is approximately located by the geographical coordinates, latitude 7^0 $10^’$ north and longitude 6^0 $2^’$ east (Figure 1). It is an area of about 1.3 x 1.5 km^2. Geologically, the area lies on the southern fringe of the Basement Complex of Nigeria. It is characterized by high hills and depressions that present a very rugged topography. The Basement Complex rocks in this area and its environs belong to the older granite complex of Pre-Cambrian to Upper Cambrian age. The older granites are largely believed to be of magmatic origin and are comprised of rocks whose composition vary from true granites through granodiorite to potassic syenite (Rahaman, 1976)

FIELD DATA ACQUISITION

Since the resistivity sounding method is more effective and cheaper than other geophysical techniques, it was adopted in the present study. Twenty-five vertical electric sounding (VES)

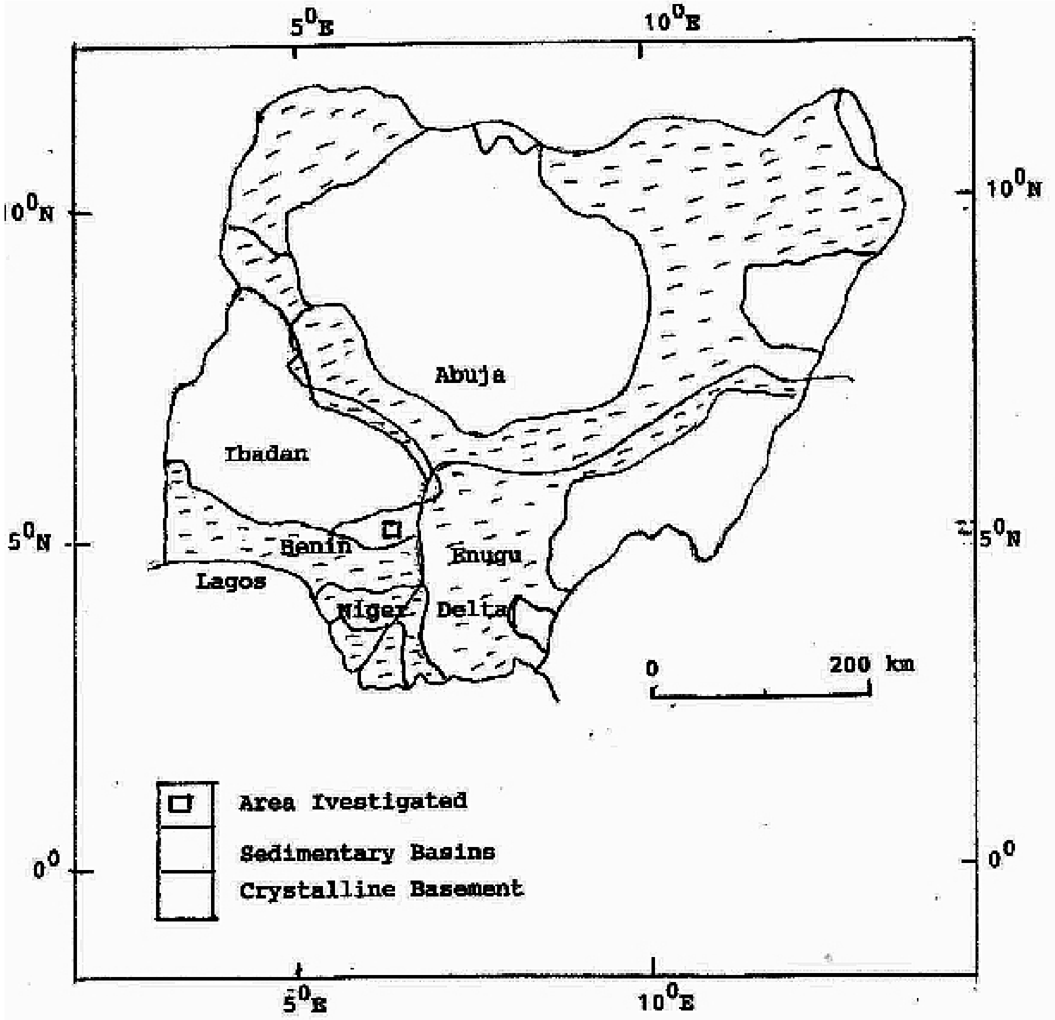

Figure 1. Geological map of Nigeria.

surveys were conducted to delineate the depth and thickness of the aquifers, and the entire area was covered. Profile direction was either N-S or E-W depending on convenience rather than being structurally controlled. The instrument used was the ABEM AC Terrameter with separate power and measuring units. Schlumberger resistivity soundings with maximum current electrode spacing (AB/2) of 200 m were carried out for delineation of the shallow aquifers and to probe deep into the Basement.

BRIEF MATHEMATICAL THEORY

The acquisition and interpretation of VES data are based on assumptions that the earth is composed of a finite number of horizontally stratified, homogeneous and isotropic layers. In the application of VES to groundwater exploration, water resources management and water pollution studies, the concept of an isotropic, homogeneous, stratified earth holds good. The theory and practice of VES is well documented in the literature (Keller and Frischknecht, 1966; Bhattacharya and Patra, 1968; Telford et al., 1984; Zhdanor and Keller, 1994).

The theory is based on the fact that the resistivities of rocks and soils are influenced by groundwater which acts as electrolyte in soils (Milson, 1992). The electrical resistivity technique utilizes the contrast in resistivity of ore bodies and their host rocks in determining the presence of good conducting minerals.

The apparent resistivity can be computed by measuring the potential difference between potential electrodes and the current injected into the ground through current electrodes. The apparent resistivity for various configuration can be computed from the expression for surface potential,

$$V = \frac{\rho_1 L}{2\pi}\left[\frac{1}{r} + 2\int_0^\infty K(\lambda) J_0(\lambda r) d\lambda\right] \quad (1)$$

where

L is the half spacing of current electrodes

r is the distance of the measuring point from the current source

ρ_1 is the resistivity of the surface layer

$K(\lambda)$ is the Stefanesco kernel function determined by thicknesses and resistivities of subsurface layers

$J_0(\ r)$ is a zero-order Bessel function of the first kind

λ an integration variable, a real number with dimensions of inverse length

The apparent resistivity can be computed by measuring the potential difference between potential electrodes and the current injected into the ground through current electrodes using the expression

$$\rho_a = \frac{K\Delta V}{I} \quad (2)$$

$$K = \pi \frac{(L^2 - d^2)}{2d} \quad (3)$$

where

ρ_a is the apparent resistivity observed in surface measurements

K is a geometric factor that depends on electrode array

ΔV is the potential difference between measuring electrodes

I is the current

d is the half spacing of potential electrodes

The geometric factor for Schlumberger array can be expressed in terms of current electrode spacing (L) and potential electrode spacing (d) and is defined in Equation (3). The depth of investigation in the Schlumberger configuration varies between 0.25L and 0.5L (Roy and Elliot, 1981).

DATA PROCESSING

Field data points were plotted for the VES survey sites on a bi-logarithm graph and curve matching procedures were carried out to obtain preliminary layer resistivity and thickness values. The geoelectric parameters obtained from the curve matching were adjusted, then transformed into apparent resistivity domains on a computer by the process of convolution. Ghosh (1971) nine point filter coefficients were used. This process was repeated until the best fit was achieved between modeled and field curves. Some typical observed and computed VES curves of the area investigated are shown in Figure 2. Some geoelectric cross sections are also shown in Figure 3.

RESULTS AND DISCUSSION

Qualitative analysis of the sounding curves indicate that the area is a typical hard rock region as shown by the K-H type curves (Figure 2). The interpretation of the VES curves shows that there are four distinct electric markers (geoelectric layers) with the following characteristics: a relatively thin and resistive upper layer of about 0.5 m and 4 m thick and resistivities ranging from 230 to 7400 ohm-meter. This layer was divided into two separate layers at some point. A second layer whose resistivities are less than that of the top layer. They range from 204 to 3000 ohm-meter and they vary in thickness from 2.2 m to 12 m.

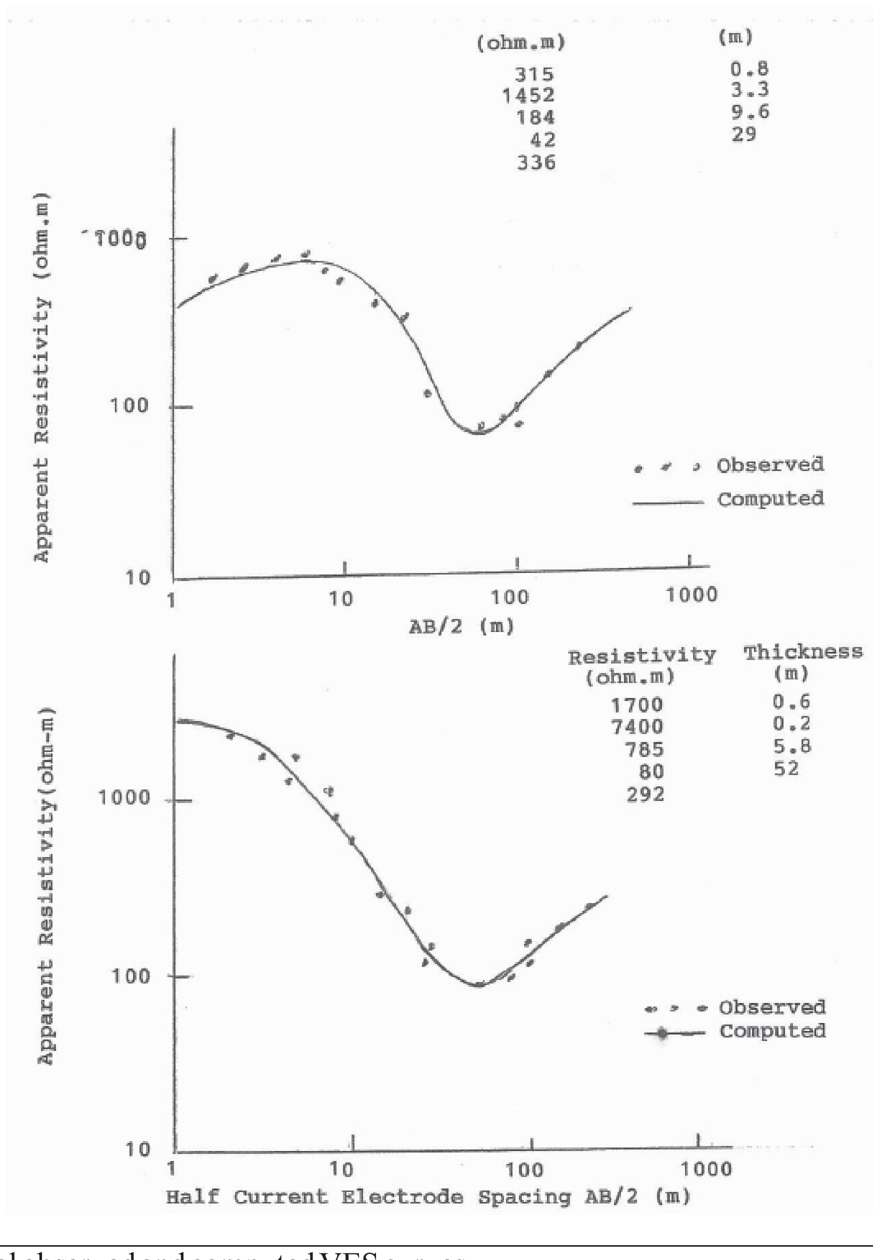

Figure 2. Typical observed and computed VES curves.

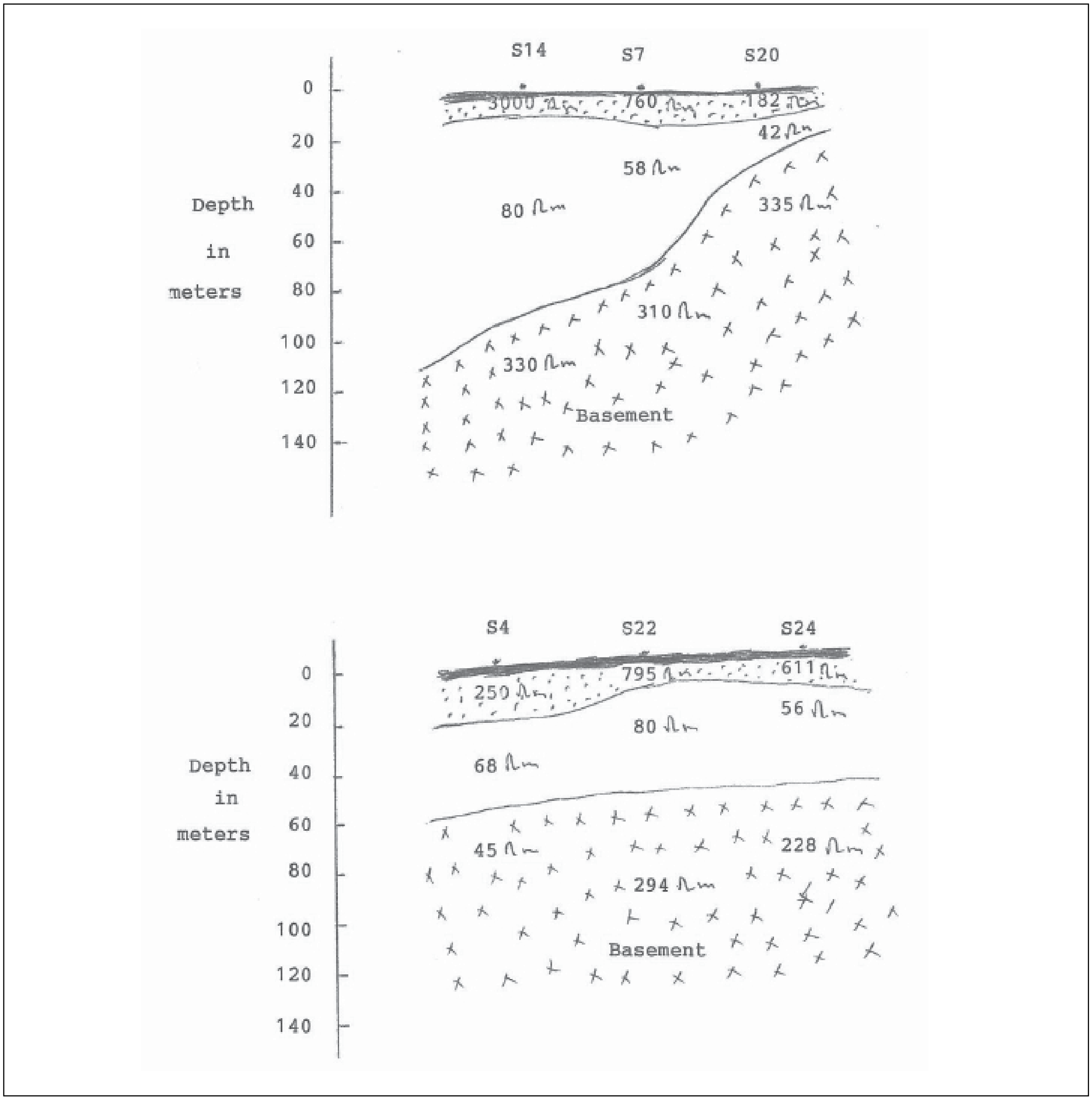

Figure 3. Selected geoelectrical sections across some VES points.

A relatively thick conductive layer having resistivities from 42 to 193 ohm-meter. This layer has thicknesses ranging from 15 m to 105 m. This could be regarded as the middle layer.

An infinitely thick unit, the crystalline basement with relatively high resistivities compared to the layer above it, ranging from 200 to 1900 ohm-meter. This is the bottom layer. Layers 1 to 3 are the overburden lying on top of the fourth layer, the crystalline basement.

Electrical properties of rocks largely depend on the degree of the wetness. Variations in their resistivities (or conductivities) is therefore an indication of their varying hydrogeological features. The main source of water in the basement complex of Nigeria is generally the weathered / fractured top of the crystalline basement besides buried river channel and fault zones. Usually a combination of low middle layer resistivity and low bottom layer resistivity is attributable to a favorable hydrogeological condition (Chilton and Smith-Carrington, 1984).

On the basis of the foregoing, the line joining VES points S20, S7 and S14 trending approximately N-S and the line joining VES points S6, S7 and S8 trending approximately E-W intersect at VES point S7. Since these lines are structurally controlled as suspected, then their point of intersection should provide high yields. Hence VES point S7 was recommended for drilling.

The line joining VES point S24 and S22 at the central portion of the investigated area was another point selected for drilling. The two aquifers demarcated are far apart. Thus, they are not interconnected but may be structurally related. Hence, another borehole site was recommended at the VES point S24. The recommended borehole sites are shown as geoelectric cross sections in Figure 3. The resistivity of the aquifer in the study area varies from 42 to 58 ohm-meter. The depth of the aquifer was in the range of 10.5 to 69 m and an average thickness of 50 m.

CONCLUSIONS

The application of electrical resistivity surveys in the exploration of groundwater has been effective in locating water borehole sites in the area of investigation. More geophysical work and drilling are needed in the investigated area to delineate the aquifer boundaries and to determine the fault zones.

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