GEOELECTRIC INVESTIGATION OF THE HYDROLOGICAL CHARACTERISTICS OF THE FRACTURED BASEMENT COMPLEX OVER IGEM CITY IN IBADAN, NIGERIA

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ABSTRACT

This study was carried out to establish a baseline geo-physical data and hydrological characteristics using the Schlumberger arrangement (a vertical electrical sounding) and drillers log from the study area. Vertical Electrical Sounding (VES) data were acquired from 4 locations evenly distributed around International Gospel Evangelical Mission (IGEM) city and her environs. This was an attempt to obtain useful information on the aquifer distribution within the area and hence delineate possible depths boreholes could be drilled for potable and sustainable water supply. The first aquifer consist of fine-grained sand formation at a depth between 1.60 - 8.70m and thickness between 1.60 and 7.10m. The first aquifer consist medium-topsoil, weathered basement and fresh basement formation and occurs at a depth, between 1.60 -8.70m. Prospective groundwater exploration was therefore recommended in the second aquifer at a depth, between 1.60 -8.70m to enhance sustainable and potable water supply in IGEM city and her environs. The basement thickness was considered adequate for any overlying pressure from the camp to locate effective water. The results obtained from the VES curves show a typical three layer model in all the parts. The area cannot experience any ground water failure, these layers include the topsoil, clayey weathered layer/partly weathered basement and the fresh/ crystalline basement. It has been discovered from this study that the weathered/ fractured zone are deeply seated and will not have any adverse effect on the structures that will be placed in the nearest future. The area is not likely to experience any ground water problem as the low resistivity weathered zone thickness is high enough for reasonable accumulation of water.
Keywords: *Geoelectric investigation, IGEM, Fractured Basement Complex, Hydrological characteristics, VES*

INTRODUCTION

This investigation offers an overview of one geotechnically geophysical method that is commonly applied to geotechnical projects. Geotechnical geophysics is the application of geophysics to geotechnical engineering problems; such investigations normally extend to total depths of less than 30m. Geotechnical geophysical surveys are performed on the ground surface, subsurface within boreholes and water, and from the air. A geotechnical site investigation is the process of collecting information and evaluating the conditions of the site for the purpose of designing and constructing boreholes on the camp site.

Whitely (1973) adopts resistivity method successfully in investigating groundwater potential. Oseji, Asoklia and Okolie (2006) use the method to investigate the aquifer characteristics and groundwater potential in Kwale, Delta State, Nigeria. Oseji ,Asoklia and Okolie (2006), also used the method to determine the groundwater potential in Obiaruku and its environs. Okwueze (1996) used the same method to explore for groundwater in a sedimentary environment. Okwuezel (1996) used the method to determine the groundwater potential at Obudu basement area. The objectives of this study therefore are to locate boreholes water that will be suitable on the camp site of IGEM city Ibadan and to determine the depth to which potable water can be located in site.

GEOLOGY OF THE STUDY AREA

The study area lies within the basement complex of southwestern Nigeria is characterized by migmatite gneiss, (in Figure 1). The local geological mapping of the study area revealed that the area is underlain mainly by a rock unit, granite gneiss. It is therefore suspected that the overburden is relatively thin within the study area. The rocks are generally trending in northwest-southeast direction and dipping to the west. Nigeria can be divided into two broad geological groups which are sedimentary basins and basement complex which occur in about the same proportions as depicted in figure1. The study area occurs within the basement complex of southwestern Nigeria of Precambrian age, as shown in the geological map of southwestern Nigeria in Figure 1.

Based on the petrological, lithological criteria and age determination, several authors such as Jones and Hockey (1964) and Odeyemi (1976) have attempted the classification of the basement complex of Nigeria. In his contribution, Rahaman (1976) classifies the rocks into five major groups which include the following Migmatite-Gneiss Complex, Meta-igneous rocks, Charnockitic rocks, Older granites and Unmetamorphosed dolerite dykes. Others are Deswadt (1953), Adekoya (2003) and Drake (1962).

The basement complex rocks are poor aquifers as they are characterized by low porosity and negligible permeability, resulting from their crystalline nature. The availability of groundwater resource in areas underlain by largely impermeable basement complex rocks has been attributed commonly to the development of secondary porosity and permeability resulting from weathering and fracturing which thus confers on the rocks the aquifer characters. Also crystalline rocks weather more easily and deeply under humid condition; hence groundwater storage already restricted by geological factors is further limited by adverse climatic conditions.

Figure 2 shows that the occurrence of groundwater in the basement complex terrains is found in three geological conditions (Bannerman and Ayibotele, 1938). There are: fractured poorly decomposed or fresh rock overlain by a relatively deep zone of well decomposed rock; the fractured rock; and Fractured veins (quartz and aplite) occurring in an otherwise non-water bearing crystalline rocks. Highly productive water wells are obtained by drilling in rock that is broken along joints and small fractures.

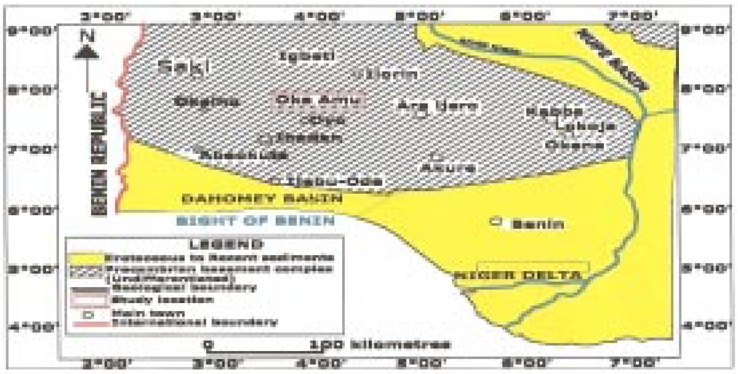

Fig. 1: Hydrogeology of the Basement Complex
Source:

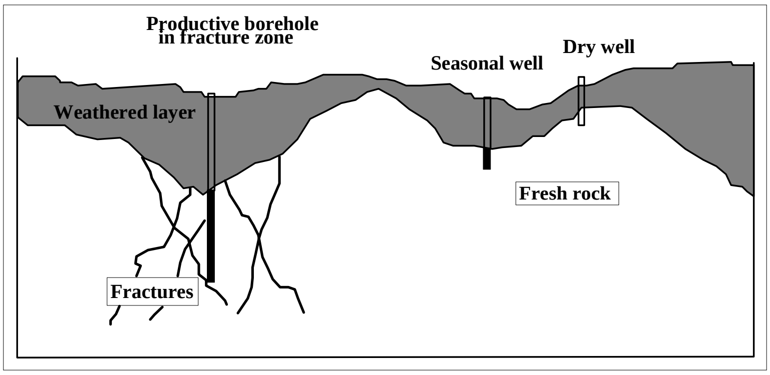

Fig. 2: Hydrogeology characteristics of fractured basement complex
Source:

MATERIALS AND METHODS

A total of four locations, spaced 2.00km apart were established and surveyed for 40 vertical electrical soundings using a method whereby readings were taken automatically and the results were averaged continuously with an ABEM SAS 300 terrameter and a maximum current electrode spacing of 55m. In this method, a fixed point called the VES station was marked and noted; two current electrodes ($C^1 C^2$) of equal distance on the opposite sides of the VES station were measured and driven into the ground with the aid of a sledge hammer for proper contact to be made with the ground. Similarly, two other electrodes called the potential electrodes ($P^1 P^2$) of equal distance and between the current electrodes were measured and driven into the ground with the aid of the sledge hammer. The arrangements of the current and potential electrodes were in such a way as to maintain a straight line. These pair of electrodes were connected to the Terrameter through points AB and MN as shown in Figure 1. The Terrameter was switched "ON" and current was introduced artificially into the earth through the pair of electrode ($C^1 C^2$) and the resulting potential difference due to the current were measured through the other pair of electrode ($P^1 P^2$), thereafter, the Terrameter was switched "off". The current electrodes were moved equally away on the opposite sides of the fixed point according to the designed acquisition parameter $C^1 C^2 > 5 P^1 P^2$ and the readings were recorded at every new position. From this method, the true resistivity depth and the thickness of each layer were obtained, this serves as input for an inversion algorithm, RESIST, as a final stage in the quantitative interpretation of the VES curves. The program takes the data through series of iteration and brings out an output of minimum root mean square error.

Table 1: Model interpretation of layers for the sounding data.

VES Station	Layers	Resistivity (Ohm-m)	Thickness (m)	Depth to Bedrock (m)	Curve type	P. Lithology
1	1	593	1.6			Topsoil
	2	170	7.1			z
	3	1339	-	8.7	H	Fresh Basement
2	1	615	1.4	5.8		Topsoil
	2	55	4.4		H	WB
	3	2999	-			Fresh Basement
3	1	90	0.5			Topsoil
	2	168	4.2			WB
	3	719	-	4.7	A	Fresh Basement
4	1	124	0.9			Topsoil
	2	23	1.9			WB
	3	6111	-	2.8	H	Fresh Basement
5	1	252	0.5			Topsoil
	2	28	5.5			WB
	3	368	-	6.0	H	Fresh Basement
6	1	296	1.2			Topsoil
	2	16	6.4			WB
	3	837	-	7.6	H	Fresh Basement
7	1	300	1.0			Topsoil
	2	56	4.7			WB
	3	1387	-	5.7	H	Fresh Basement
8	1	63	0.4			Topsoil
	2	160	2.2			WB
	3	1366	-	2.6	A	FB

Source: *WB = Weathered Basement, FB = Fractured basement, P. Lithology = Probable Lithology*

From the data presented on table 1 above, the Vertical Electrical Sounding (VES) has given a suitable interpretation on the layers one to three with electrical resistivity values 593^{o}hm-m for the fresh layer,170^{o}hm-m for the weathered basement and 1339^{o}hm-m for the fresh basement respectively; and the thickness of the top soil weathered and fresh basement are 1.6m, 7.1m and that of fresh basement is infinity respectively and the depth of this VES point is 8.7m while the curve type is H, shows the opposite effect; it falls to a minimum then increases again due to an intermediate layer that is a better conductor than the top and bottom layers H - Type ($P^1 > P^2 < P^3$). Hence, this point is the best out of all points for the best ground water. Basically, there are four curve types of sounding curves for VES. This explains the overall shape of the middle portion of the profile, giving us some ideas of the character of the beds between surface and basement. The curve types include the following:

A - Type $(P^1 < P^2 < P^3)$
Q - Type $(P^1 > P^2 > P^3)$
H - Type $(P^1 > P^2 < P^3)$
K - Type $(P^1 < P^2 > P^3)$
Where P^1, P^2, and P^3 are resistivity of the first, second and third layer respectively. The type **A** curve may show some changes of gradient but the apparent resistivity generally increases continuously with increasing electrode separation, indicating that the true resistivities increase with depth from layer to layer. The type **Q** curve exhibits the opposite effect; it decreases continuously along with a progressive decrease of resistivity with depth. The type **K** curve rises to a maximum then decreases, indicating that the intermediate layer has higher resistivity than the top and bottom layers. The type **H** curve shows the opposite effect; it falls to a minimum then increases again due to an intermediate layer.

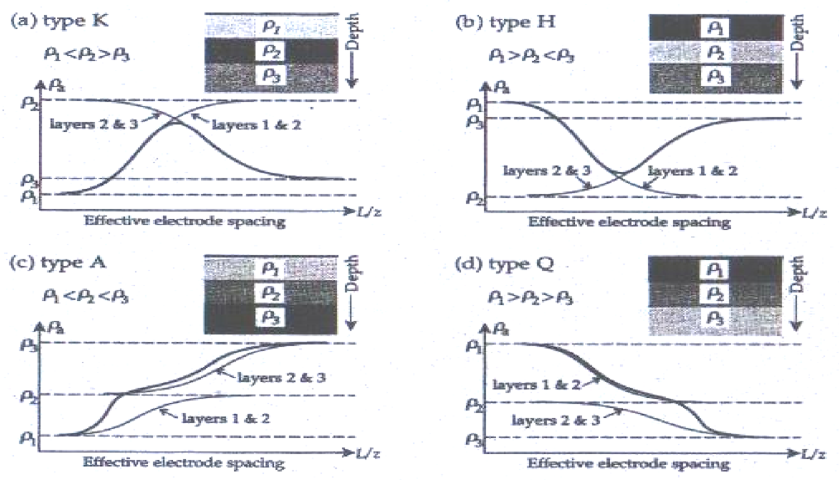

Figure 3(a-d): The four curve types for apparent resistivity for a typical three layered earth model.
Source:
In a situation where the subsurface layers are more than three, the curve types can be combined. For example, we can have KH - Type, HKA - Type etc. depending on the subsurface layers. Quantitative interpretation involves curve matching technique. This technique compares the field curve with a set or sets of pre-calculated theoretically plotted curves using specific values of layer resistivities and thicknesses (master curves). The log-log paper used for the field curve must be of the same scale with the pre-calculated theoretical curve and their axes must be kept parallel while overlaying the field curve on the theoretical curve. When the best match is obtained, the coordinates of the origin of master curve on the axes of the field resistivity plot become determinant for the layer parameters. The process which has both forward and inverse methods is now run by computer programs as a routine. Hence the layer parameters are automatically adjusted by the program if no match is obtained. An error tolerance limit is set for the program iteration and when this is achieved the model match becomes the interpreted layer parameters.

CONCLUSION AND RECOMMENDATIONS

The study revealed IGEM city and her environs as an extensive sandy unit. The interpretation indicates that the water-bearing formation (medium-grain to coarse grained sand formations) within the sandstone unit is between the range 1.60 -8.70m deep. The result of the interpreted data correlates well with the lithologic log from a nearby borehole. This depth has an average thickness of 10.00m and it coincides with the fourth relevant geologic layer in IGEM city and her environs. This layer is the best formation within which an appreciable quantity of water for sustainable groundwater development could be obtained. From the result and analysis obtained, it was shown that there are potable water in the VES of the first point and the water will serve the zone (environ) without water problem now and in the feature. VES 3 and 8 are not proper for shallow, foot and slab foundations because it suggest the presence of clay with little water main while deep foundation is required. Also from the result and analysis obtained, VES 1-2, and 4-7, has a top soil formation which is mainly sandy clay zone are deeply seated and will not have any adverse effect on the structures that will be placed on the working site in the nearest future. Also the topsoil zone thickness is large enough to accommodate any load without differential settlement.

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