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GEOPHYSICS AS A VERITABLE TOOL IN RECONNAISSANCE STUDIES FOR DEVELOPMENT OF URBAN SETTLEMENTS

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Abstract

Geophysical Methods have been applied as tools in solving many earth problems. The earth properties measured has made it a veritable tool of reconnaissance/investigation in many parts of the world including urban planning with very high need of good foundation structure and groundwater for its development and future sustenance. This investigation was carried out in Abuja which is underlain mainly by the Gneiss – Migmatite complex. The geophysical method adopted is the electrical resistivity utilizing the Vertical Electrical Sounding (VES) technique. VES was conducted at 25 stations along 5 traverses. The quantitative interpretation through partial curve matching and computer aided 1-D forward modelling with the WingLink software revealed a sequence of four major geo-electric layers which are the topsoil, weathered layer, fresh basement and fractured basement. The topsoil range in resistivity from 102 to 2400 Ωm while the weathered layer resistivity ranges from 32 – 500 Ωm. The high resistivity of the topsoil in places is an indication of its lateritization which is good for construction foundation/materials in addition to the thin overburden in the area especially in the northern portion of the area. A fractured basement trend is observed in the N-S direction beneath points B1, F, I and O in the area which is believed to be interconnected with the strip of thick weathered layer in the southern flank of the study area to a depth of about 20 m. This could be indicative of a good groundwater zone in the area considering the shallow water table observed around the study area. Information obtained from this study indicates the area can be divided into two sections with relative uniformity thereby allowing for adequate cost effective planning of geotechnical explorations.

***Keywords**:*
Foundation structure, groundwater development, effective planning and cost effective

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1.0 Introduction

Two important factors to be considered in every settlement include shelter and water. Consequently, input from geotechnical engineers and hydro-geologists is very essential for planning of urban settlements. Both professions are concerned with study of materials beneath the surface of the Earth Crust with particular interest in stratification of the subsurface.

Interest of the geotechnical engineer, on one hand, hinges on the stratification of the subsurface vis-à-vis the engineering strength and behavior of materials constituting each strata while that of the hydro-geologist on the other-hand, borders on the stratification vis-à-vis the potential of each strata to act as an aquifer unit.

However, considering the cost, time and energy implication of drilling through the earth in order to ascertain its stratification, the use of a non-invasive, yet accurate method for reconnaissance is required. Thus, application of the Direct Current (D.C.) electrical resistivity method of geophysical prospecting is suggested. Various studies have shown that geophysical methods especially the electrical methods are very useful for pre and post construction investigation [7], [3], [4], [2].

Conductivity/Resistivity is a distinguishing property of rock types particularly in basement complex terrains where remarkable contrast exists in the resistivity of fresh crystalline rocks and the overburden materials. Thus, using the D.C. electrical resistivity method of geophysical prospecting, subsurface materials can be delineated into geo-electric layers approximating different rock units. Consequently, results obtained can be applied by geotechnical engineers for site characterization and hydrogeologists for groundwater exploration.

2.0 Materials and Methods

The study area is located within Abuja Municipality in the Federal Capital Territory, Nigeria and lies between Eastings 329007 mE and 329409 mE and Northings 1004852 mN and 1006534 mN on zone 32 of the UTM grid. Abuja Municipality is underlain by crystalline rocks of the Basement Complex of Nigeria essentially Granitoids and rocks of the Gneiss Migmatite complex, GSN, 1994 [5] (Fig. 1). However, the study area, in particular is underlain by rocks of the Gneiss Migmatite complex. Considering the nature of groundwater occurrence in basement complex terrains, a proper delineation of regions with high groundwater potential and least inimical structures/soils to foundation construction is required. The area falls within the Guinea Savannah having tropical woods with average annual rainfall within 1100 mm and 1600 mm like other regions in the tropics. Two climatic conditions are experienced in the area - the rainy and dry seasons. Although, no major rivers were observed around the study, seasonal streams were encountered and static water level as observed from hand dug wells varied from 2m – 3m.

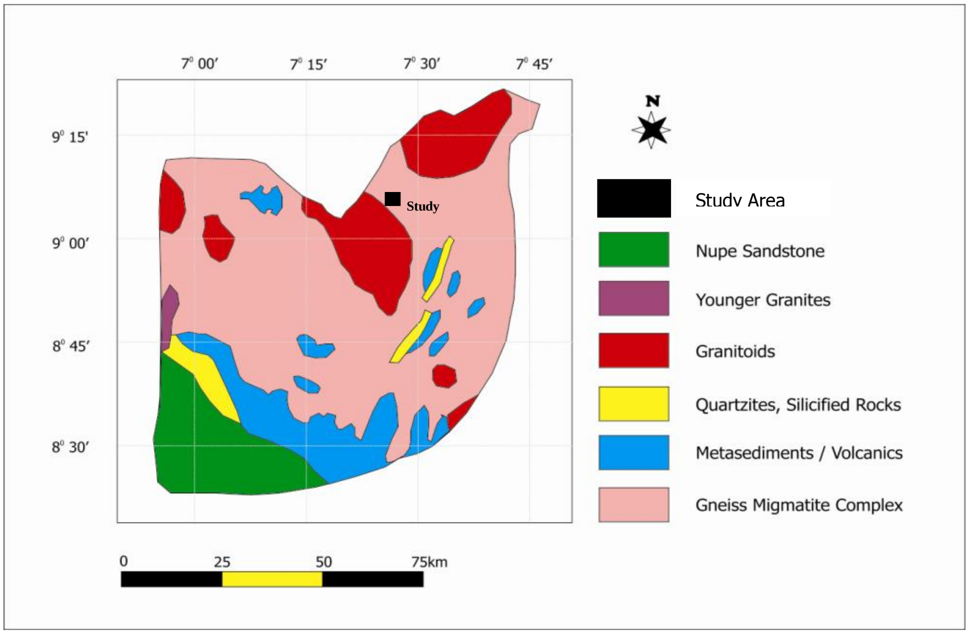

Fig. 1: Geologic Map of FCT Showing the Study Area (GSN 1994)

The electrical resistivity method of geophysical prospecting was employed using the Vertical Electrical Sounding technique. A digital resistivity meter; PASI 16GL Earth Resistivity Meter, was employed for the data acquisition and 25 Vertical Electrical Soundings were conducted along 5 traverses aligned approximately E – W using the Schlumberger electrode configuration (Fig. 2). Inter-traverse spacing of 400m was employed with inter station spacing of 80m along each traverse. The soundings were conducted while varying current electrode spacing between 2 m and 100 m in order to have appreciable probe of the subsurface. The VES data were plotted on bi-Log graphs and the VES curves were interpreted quantitatively by partial curve matching with 2-layer model curves of Orellana and Mooney, 1966 [8]; and a computer aided 1-D forward modelling with the WinGLink software. Thereafter, field type curves were examined for any discernable trend in geo-electric characteristics.

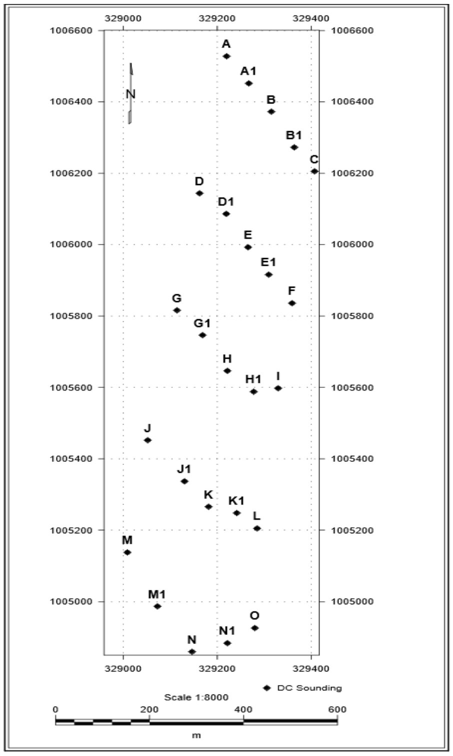

Fig. 2: Data Acquisition Map

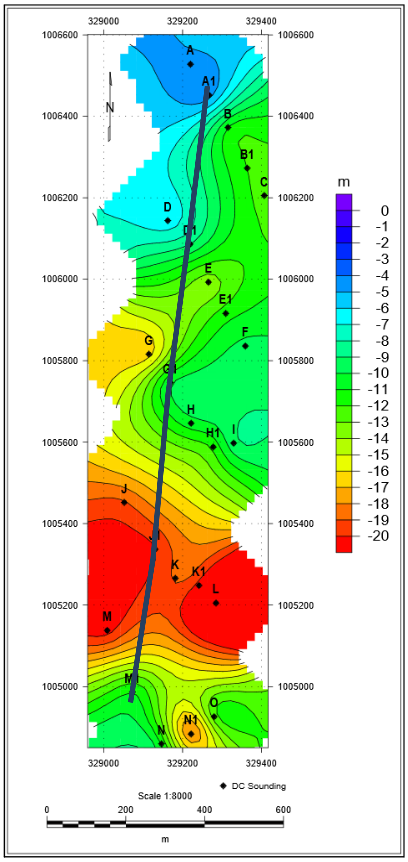

Fig. 3: Depth to Basement map beneath the study area

3.0 RESULTS AND DISCUSSION

The HA and QH type curves account for about 55 % of the total VES curves with the H and KH curves accounting for 20 % and HKH type curve, 16%. Therefore, approximately 91% of the total is characterized by HA, QH, H, KH and HKH type curves. This is in consonance with observations made by Ademilua *et al* 2014 as being the predominant curve types on migmatite gneisses from their study in Ekiti State. The remaining 9% is accounted for by the QHK type curve.

These type curves indicate the presence of weathered basement overlying the fresh basement, with weathered sequence being thicker for the QH and QHK curve types.

The HA type curves are concentrated in the northern section of the study area and the QH type in the southern portion. As a result, depth to basement is generally shallower on the northern portion of the area (Fig. 3).

A N-S trending profile across the area shows the presence of a basement depression towards the south (Fig. 4).

Generally, four geo-electric layers were delineated beneath the sounding stations, characterized by a variably thick weathered horizon overlying presumably fresh basement. The inferred sequence beneath the area is as follows:

- Topsoil
- Weathered Basement
- Fresh Basement
- Fractured Basement

Quantitatively, the topsoil is characterized by resistivity values ranging between 102 and 2400 Ωm, with the resistivity range between 430 and 840 Ωm accounting for 72 % of the area (Fig. 5). The upper limit of the range; between 944 and 2400 Ωm, is interpreted as an indication of lateralization of the topsoil.

Resistivity values of the weathered horizon vary from 32 to 500 Ωm. However, a distinct pattern in distribution of the resistivity values was observed.

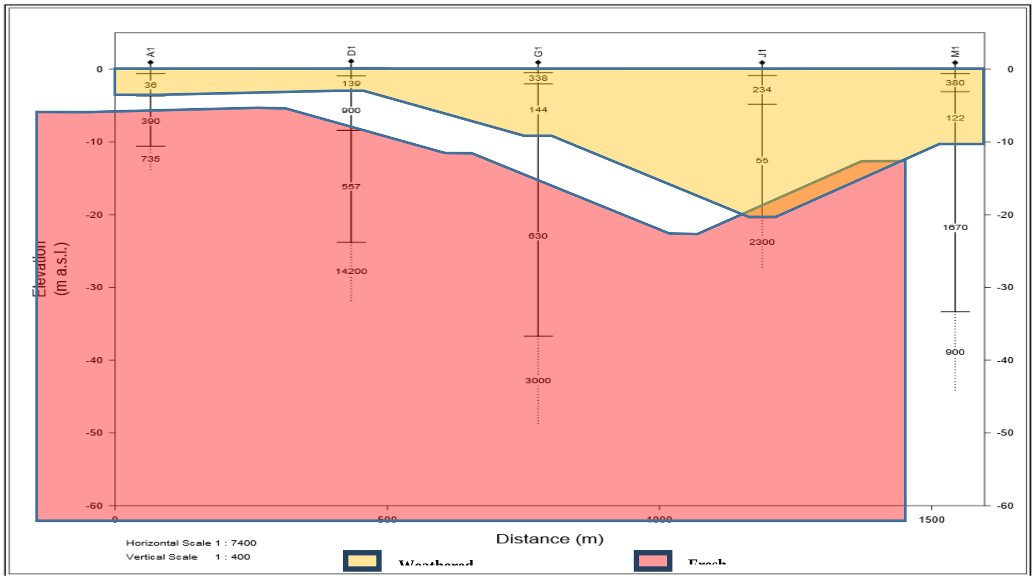

Fig. 4: N-S trending profile beneath the study area

The lower limit values; generally < 160 Ωm, dominate the upper half of the area, while the upper limit values; > 160 Ωm, characterize the south of the area (Fig. 6).

Deriving from the relatively high resistivity values of the topsoil and the weathered basement towards the south, the materials are expected to be predominantly sandy and lateritic in places. However, to the north of the study area where relatively low resistivity values were recorded for the weathered basement, fractions of clay materials are envisaged.

Underlying the weathered horizon is the fresh basement which has resistivity values varying between 200 and 4300Ωm. The lower limit of the resistivity values (between 200 and 1300 Ωm) were

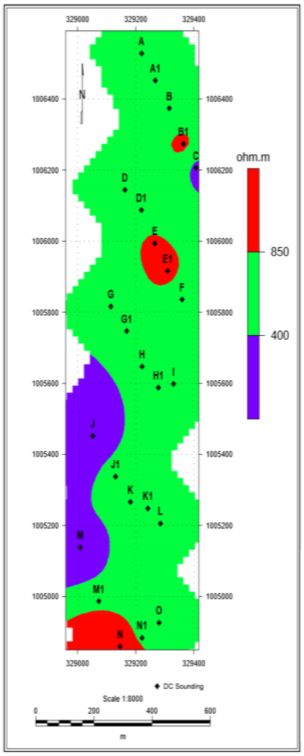

Fig. 5: Topsoil Resistivity Map of the Study Area

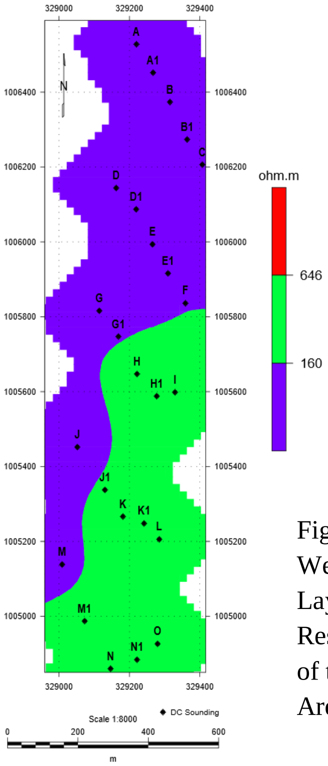

Fig. 6: Weathered Layer Resistivity Map of the Study Area

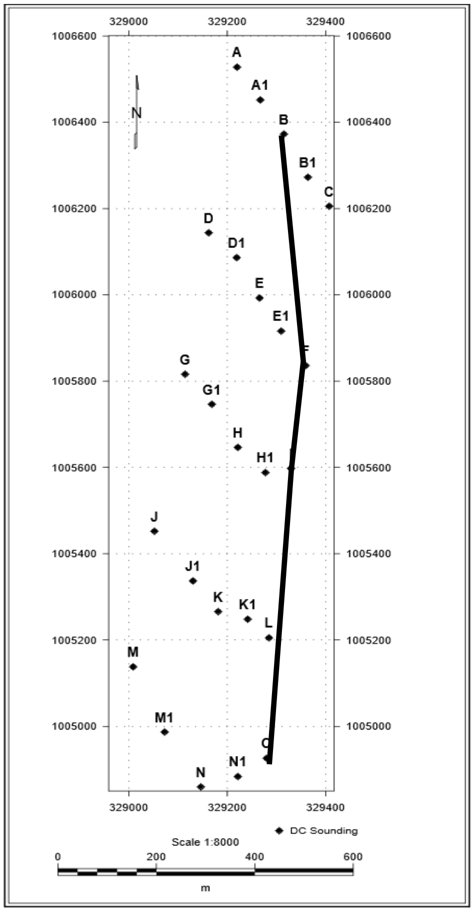

Fig. 7: Observed Fracture Trend beneath the Study Area

encountered beneath the clayey horizons while the upper limit (between 900 and 4300Ωm) were encountered essentially beneath the weathered column in the southern part of the area.

The fractured basement on the other-hand was delineated essentially beneath four (4) sounding stations between depth horizon of 23 and 56 m. These sounding stations are B1, F, I and O and roughly define a line through the area (Fig. 7). This has been interpreted as a N-S trending fracture line across the area and a profile through these stations is shown in Fig. 8.

For the geotechnical engineer, an idea of the environment is very pertinent in planning his investigations, viz: number of borings and cone penetration tests amongst others and the location of these test points, in order to have adequate coverage and ample data on the investigated area, while keeping cost minimal as much as possible.

A cursory look at the iso-resistivity map of weathering profile beneath the area shows distinct partitioning of the area into two sections with materials underlying the northern section having similar resistivity values of less than 160 Ωm and the southern section having higher resistivity values of between 160 and 646 Ωm. Thus, much variability is not expected in constituents of materials beneath the northern section as well as those in the southern section. Consequently, frequency of borings to be distributed around the site can be relaxed owing to the relative uniformity of materials beneath the northern and southern sections respectively.

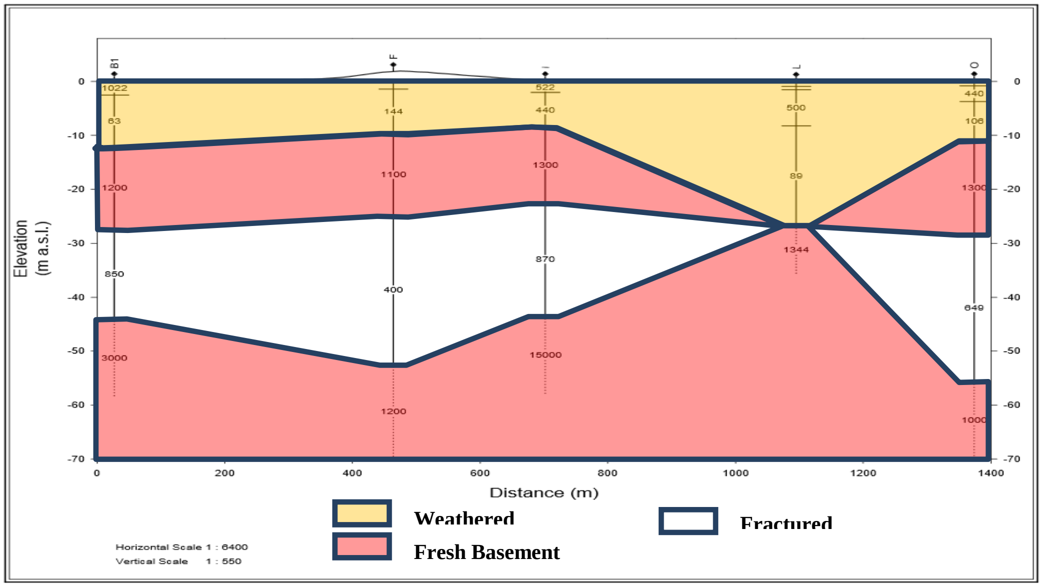

Fig. 8: Profile beneath stations defining a NS trending fracture line

In addition, the depth to basement map beneath the site indicates much of the area has depth to basement estimated at between 8 and 15 m with the exception of an E-W oriented strip towards the southern flank where depths in excess of 20 m were obtained.

In situations whereby heavy load is to be supported and soils within the weathered column lack sufficient bearing capacity; thereby requiring the use of piles to be installed in the crystalline basement rocks, the delineated E-W strip towards the southern flank should be avoided as much as possible. However, if construction on this strip is inevitable, distribution of Of these five combinations, two were identified in the study area:

- Weathered aquifer
- Weathered / Fractured (confined) aquifer

Considering the static water level in the area as measured from hand-dug wells (between 2 and 3m) and ubiquity of the weathered column beneath the study area (with the exception of the far northern flank where depth to fresh basement is delineated at less than 4 m), the weathered column beneath the study area is expected to serve as an aquifer unit. Thus, groundwater prospect of the weathered column will be highest within the E-W trending strip delineated towards the south where depth to basement is in excess of 20 m.

In regions underlain by crystalline rocks, presence of fractured zones serve as potential aquifer units. As observed from Fig. 7 and 8, a N-S trending fractured horizon was delineated beneath the study area. A combination of the weathered and fractured basement serves in improving groundwater potentials. Consequently, regions where the weathered column is thickest in the study area and also underlain by the N-S trending fracture line are expected to furnish highest groundwater potential beneath the study area. As noted in [1], the weathered column and fractured (confined) aquifer combination was prominent on migmatite gneisses within their study area and are characterized essentially by HKH type curve. This is in congruence with observations from this study which show that this aquifer combination is typified by the HKH type curve in the area (Fig.9).

5.0 Conclusion

This study has demonstrated the importance of the direct current electrical resistivity method in urban planning. It has shown the efficacy of the method as a reconnaissance tool in developing a cost effective and efficient geotechnical investigation programme. Furthermore, its veracity in groundwater exploration needs not be underscored as this has been demonstrated by several studies. Since for every

borings in the southern section can thus, be concentrated more within this strip. Furthermore, deployment of a CPT machine with appropriate capacity can be achieved as the probable depth of probe has been established a-priori. This reduces the cost of deploying a machine with higher capacity and eliminates the probability of deploying one with inadequate capacity. In a typical basement complex environment two main aquifer types are obtained. However, both can combine to five (5) different combinations [6].

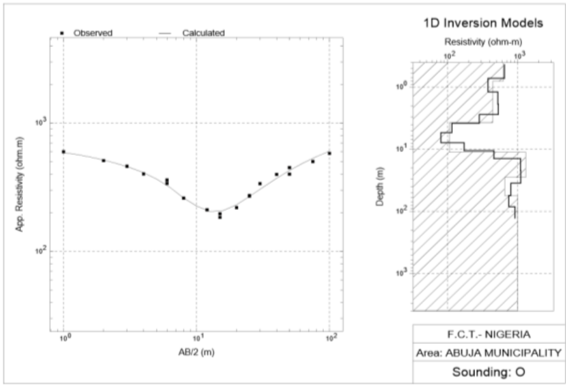

Fig. 9: Typical HKH curve observed in the area

human settlement, the two most essential parameters are shelter and water, geotechnical and hydrogeological studies remain relevant to urban planning. Consequently, the electrical resistivity method can go a long way in achieving proper planning.

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