Comparative Assessment of half Schlumberger Configuration as an Alternative Method to the Conventional Schlumberger Configuration at Trade Centre, Mani-Nissi Village, Kaduna, Nigeria

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Abstract

This study seeks to evaluate the efficiency of half-Schlumberger array as an alternative method to the Convectional Schlumberger array at sites where there is a limited space. Ten (10) VES stations were investigated with both arrays and the resulting VES curves were generated using Res1D (version 1.00.07 Beta) software. The results of the study were analyzed and presented in tables and graphs. For the different locations investigated, the full Schlumberger and half-Schlumberger display an identical curve types and geoelectric sequence. The Interpreted data revealed that the study area is underlain with an average overburden thickeness of 33.0 m and 34.3 m for both full Schlumberger and Half-Schlumberger arrays respectively which is about 96% correlation. The overall estimated subsurface geoelectrical parameters show that both arrays are nearly the same (about 97% correlation). It is therefore established that the Half Schlumberger array is a practicable alternative method to the conventional Schlumberger array of resistivity depth sounding investigation in areas where the space is highly limited.

Keywords: *Schlumberger, geoelectrical parameters, efficiency, correlation, limited space.*

I. INTRODUCTION

The basic principle of the Schlumberger sounding method is to inject a current into the ground through current electrodes at the surface (Loke, 1999). This current creates a potential field in the ground. The subsurface resistivity can be inferred by measuring the resulting potential difference. Where large investigation is required, a large electrode spacing is chosen. In an urban development area where there is a limited space, a large linear electrode spread may be difficult to accomplish especially in a built up areas where often there is need to carry out resistivity depth sounding, most especially for groundwater development. Due to this inadequate space, the depth of investigation is reduced and geoelectrical results are inconclusive and recommendations may be difficult to make (Anjori and Olorunfemi, 2011).

However, the modified (Half) Schlumberger array could be an alternative method to the traditional Schlumberger array at sites with space constraints when its effectiveness is affirmed. This is because the half Schlumberger spread has the advantage of low man power requirement (Two persons can conveniently carry out the survey). More also, it can be conveniently carry out in a built up area (Anjori and Olorunfemi, 2011).

Due to this restriction, the study seeks to compare the traditional Schlumberger and Half Schlumberger arrays in terms of deduced geoelectrical parameters, in vertical electrical sounding, in a Northern basement complex environment, in order to evaluate effectiveness of the modified Schlumberger arrays for ground explorations in a developed areas with a limited space as an alternative to the traditional Schlumberger array.

II. Site and Geology Description of the Study Area

The study area, Mani-Nissi is located along Kafanchan road (Fig. 1.1) about 1.5 Km away from the Kaduna Refinery Junction. It lies on the geographical coordinate of latitude and longitude of 10° 26.324' N to 10° 26.412' N, and 007° 30.499' E to 007° 30.559' E respectively. The location covers a total landmass of 12,500 square meters and with the average height of 634 m above the sea level. The location is under development for an ultra-modern market. The relief of the area is characterized by undulating plain, gentle slopes, and consists of peneplains with eroded flat tops

(Fig. 1); often capped by layers of indurated laterites (Alao and Dogara, 2018; Dogara, et al., 2017). According to Dogara, et al., (2017), the superficial deposits, which overlie the basement rocks, act as recharge materials, especially where they are underlain by weathered basement. The rocks of the area are capped by laterites; the laterites are sometimes highly consolidated especially at the surface and weathered into lateritic nodules mixed with silty and sandy clays (Isaac, e tal., 2010). However, the general geology of Nigeria consists of two main lithological units (Fig 1). These are the Precambrian Crystalline Basement and Cretaceous-Tertiary sedimentary rocks (Oyawoye, 1970). The Deep chemical weathering and fluvial erosion, influenced by the bioclimatic nature of the environment have developed the characteristics high undulating plains with subdued interfluves (Mortimore, 1970). The crystalline basement complex composes mainly of metamorphic rocks (Oyawoye, 1970). Generally, studies have shown that the main aquifer components of the basement complex of Nigeria are weathered and fractured basement and water yielding capacities of wells drilled to these components always vary fom palces to places. The water-bearing units (aquifers) in basement rocks occur within the weathered residual overburden (the regolith) and the fractured bedrock (Isaac, et al., 2010).

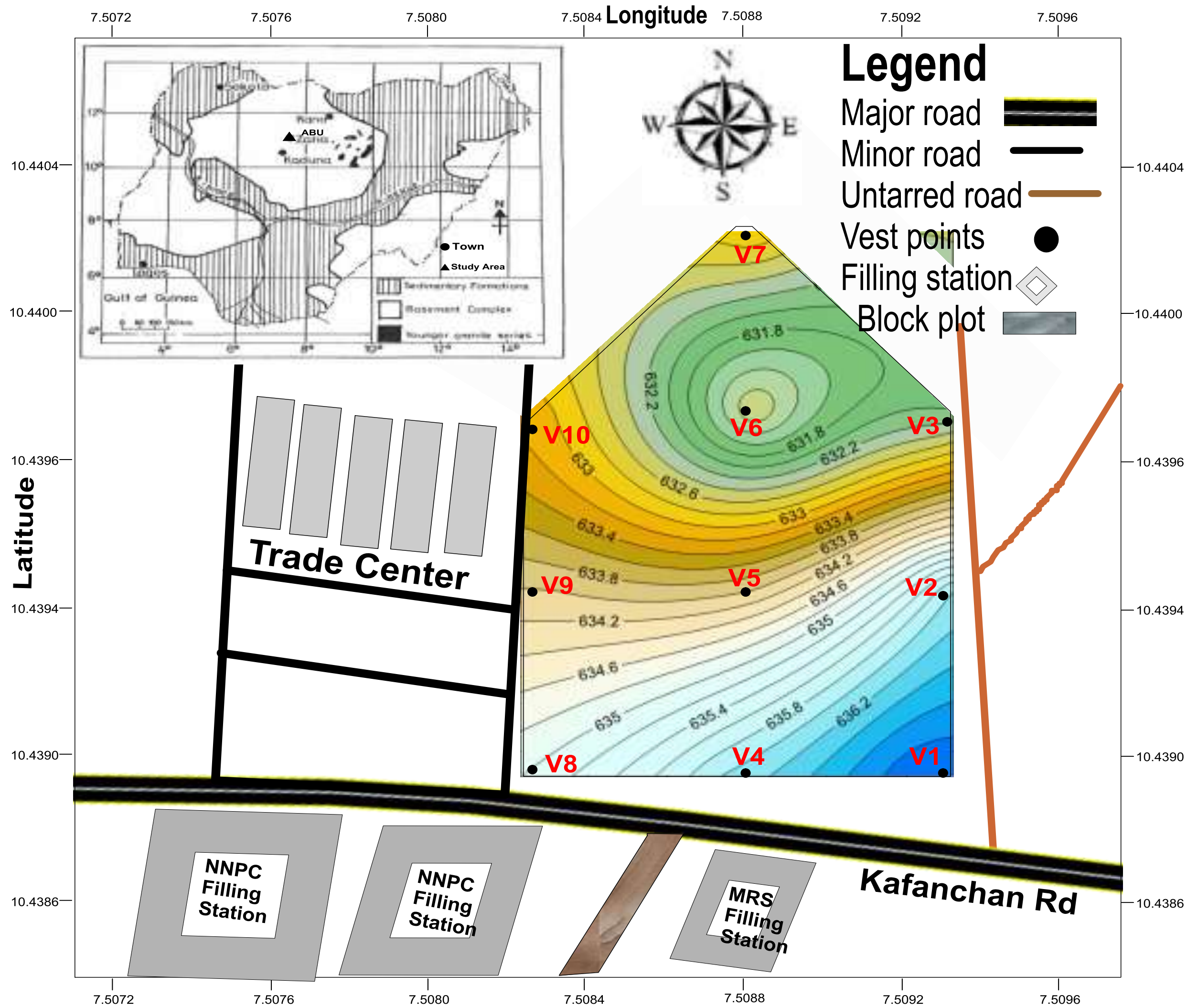

Fig.1: The Map of the Study Area

III. Theory of the Method Employed and Data Acquisition

Electrical resistivity is a geophysical survey in which an electrical current is injected into the ground in order to measure the electrical properties of the subsurface was employed. It is based on the response of the subsurface material to the current flow through electrodes to the ground (Alao and Dogara, 2018). It is a method that measures both horizontal and vertical variation of resistivity which invariably achieved base on the assumption that the earth is homogeneous and isotropic (Dogara and Alao, 2017). In this survey, a total of ten (10) Vertical Electrical Sounding (VES) points were digitized with an Omega Resistivity Meter using Schlumberger array with maximum current electrode spread of 200 meters. A typical arrangement with 4 electrodes (Fig 2) with the potential (V_c) at an internal electrode (P) is the sum of the potential contributions (V_A) and (V_B) from the current source at A, and the sink at B.

$$V_C = V_A + V_B \quad (1)$$

The potential gradient associated with this current density is; $\frac{\partial V}{\partial r} = -\frac{\rho I}{2\pi r^2} = -\rho I$ (2)

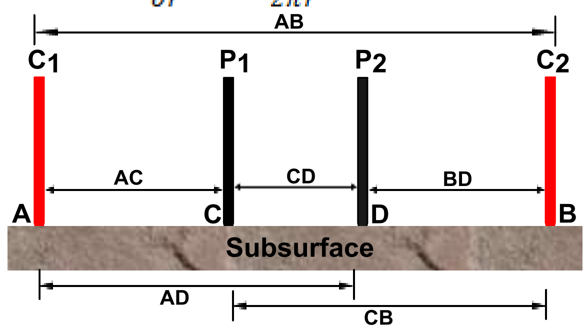

Fig. 2a: Schlumberger Configuration

The potential (V_r) at distance r is then obtained by integration;

$$V_r = \int \partial V = -\int \frac{\rho I \partial r}{2\pi r^2} = \frac{\rho I}{2\pi r} \quad (3)$$

From (3); $V_C = \frac{\rho I}{2\pi}\left[\frac{1}{AC} - \frac{1}{CB}\right]$ (4)

The potential difference is then given by;

$$\Delta V = V_C - V_D = \frac{\rho I}{2\pi}\left[\left(\frac{1}{AC} - \frac{1}{CB}\right) - \left(\frac{1}{AD} - \frac{1}{BD}\right)\right] \quad (5)$$

$$\rho_a = \frac{2\pi \Delta V}{I}\left[\left(\frac{1}{AC} - \frac{1}{CB}\right) - \left(\frac{1}{AD} - \frac{1}{BD}\right)\right]^{-1} \quad (6)$$

Hence, $\rho_a = RK$ (7)

Where $K = \frac{2\pi}{\left(\frac{1}{AC} - \frac{1}{CB}\right) - \left(\frac{1}{AD} - \frac{1}{BD}\right)}$ (8)

and R is resistivity ($i.e\ R = \Delta V / I$), and K is term called geometrical factor which depends on the arrangement of the four electrodes (Dogara and Alao, 2017). While (AC), (BC), (AD), and (BD) are the distances in meters between the respective electrodes, when $(AC) = (BD)$ and $(BC) = (AD)$; K can be defined from Fig. 2a. $K = \pi \frac{[AC][AD]}{[CD]}$ (9)

A. Half Schlumberger Array

The half Schlumberger array is much similar to the normal conventional Schlumberger array only that while electrode A is progressively moved during the process, electrode B is steadily positioned at an infinite distance about three times the distance AB/2.

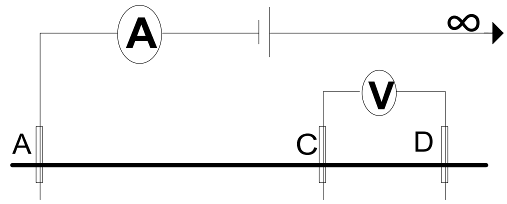

Fig. 2b: Half Schlumberger array

Practically, the electrode B is always at a distance L greater than 3(AB/2) in order to satisfy the condition for half Schlumberger (Barounis and Karadima, 2011). By using half Schlumberger configuration, only one electrode is moved and the other three remain in their initial position. By this technique a lot of time can be saved on site which can be used for taking more measurements. During the development of the array, the change of apparent resistivity reflects the distribution of resistivity with depth causing deeper layers to affect the value of resistivity. Whenever the distance AB/2 increases, the current intensity bulb penetrates deeper than the previous one (Barounis and Karadima, 2011). The geometric factor of the Half Schlumberger arrays was estimated to be twice that of the traditional Schlumberger array *K* (Oladunjoye and Jekayinfa, 2015). That is, the apparent resistivity ρ_a for the half-Schlumberger configuration is calculated with the formula:

$$\rho_a = 2K\frac{\Delta V}{\Delta I} = 2RK \quad (10)$$

Where ρ_a = apparent resistivity on Ohm m, K= geometrical factor for the half Schlumberger configuration given from equation (8)

IV. Data Processing

The data collected from the field were computed and processed by a computer software Res ID version 1.00.07 Beta to produce the resistivity curve for both full and half Schlumberger (Fig3). The resistivity produced by Res 1D shows a significant similarity for both array.

Fig. 3a: Typical resistivity curve for Full Schlumberger [VES 6]

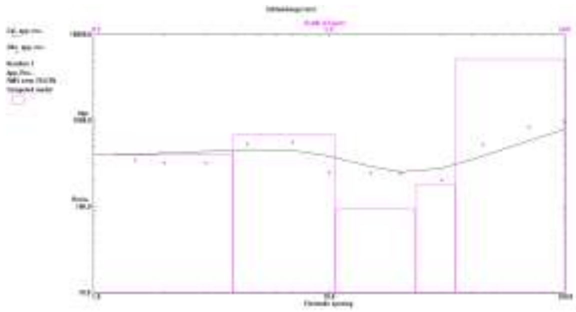

Fig 3b: Typical resistivity curve for Half Schlumberger [VES 6]

V. Results and Discussion

The processed data from the resistivity curve was used to generate the geologic section (Fig.4) of the terrane to reveal the variation in resistivity and layer thickness. The results show that the terrane is underlain with four to five layers which comprise of lithological units defined by the lateritic topsoil, indurated laterite, sand/clay; the weathered/fractured basement layer as well as the fresh basement. The average depth to the basement of the tarrane for both full and half Schlumberger is found at 33.0m and 34.3m respectively. The resulting curves and their final model parameters after quantitative interpretation are presented in Fig. 4 & 5 and Table 1. The final model geoelectric parameters across the sections of the study area were used to produce the geoelectric and geologic section (Fig 4) and graphs (Fig 5). Similarities were observed between the conventional Schlumberger array and the Half Schlumberger array at all points for the geoelectric and geologic section (Fig 4a and Fig 4b).

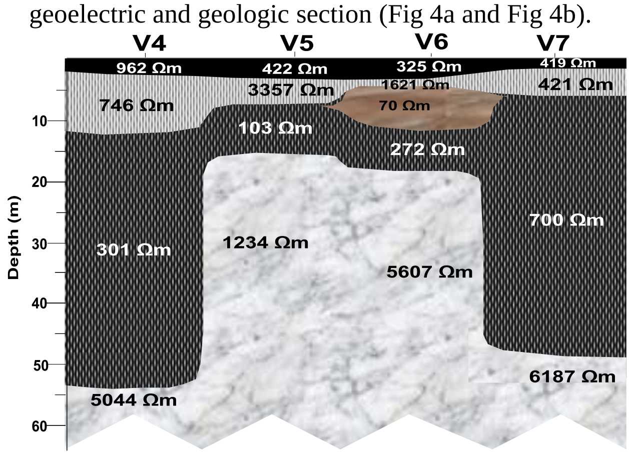

Fig. 4a: Geoelectric and Geoogic Section of Profle 1 for full Schlumberger

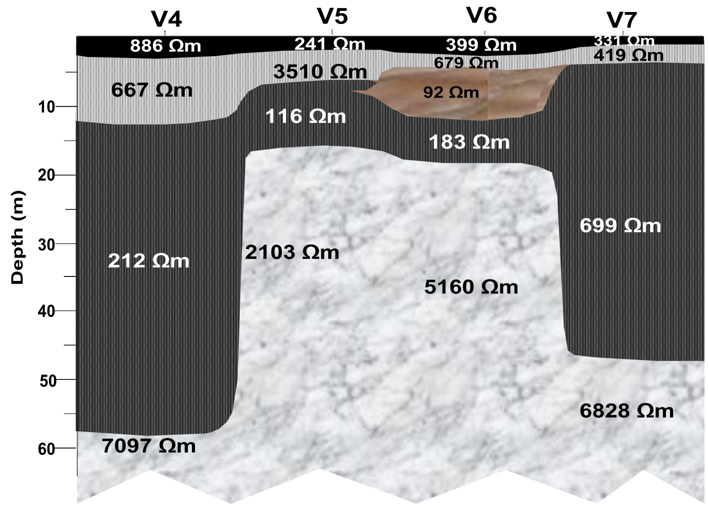

Fig. 4b: Geoelectric and Geoogic Section of Profle 2 for Half Schlumberger

Table 1 shows that the conventional full Schlumberger and half Schlumberger arrays were virtually the same for VES stations with 97% average percentage of correlation. Fig. 8(a-d) show that the topsoi thickness (95% average percentage correlation), topsoil resistivity (97% average percentage correlation), Average weathered/fractured (99% average percentage correlation), Average weathered/fractured Resistivity Thickness (99% average percentage correlation), basement resistivity (99% average percentage correlation) and overburden thickness (96% average percentage correlation) values from two arrays are very similar at all points. Fig 5c shows an interesting values being the overall thickness indicades nearly the same. This shows that conventional full Schlumberger and half Schlumberger arrays are very effective irrective of the array adopted in groundwater exploration.

Table 1: geoelectric parameters of the studyarea showing their difference and corelation in percentage for both arrays.

S/N	Lithology	Full Schlumberger	Half Schlumberger	Difference	Correlation percetage
1	Average Topsoil Thickness	1.46 m	1.54 m	0.5 m	95%

2	Average Topsoil Resistivity	475.6 Ωm	461.4 Ωm	14.2 Ωm	97%
3	Average weathered/ fractured Thickness	22.7 m	22.9 m	0.2 m	99%
4	Average weathered/ fractured Resistivity	281.3 Ωm	278.0 Ωm	3.3 Ωm	99%
5	Average fresh Rock Resistivity	4682.3 Ωm	4613.2 Ωm	69.1 Ωm	99%
6	Average Overburden Thickness	33.0 m	34.3 m	1.3 m	96%
	Average				97%

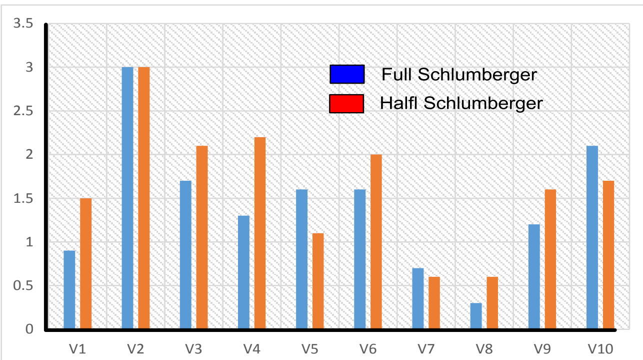

Fig. 5a: The Graph of Topsoil Thickness

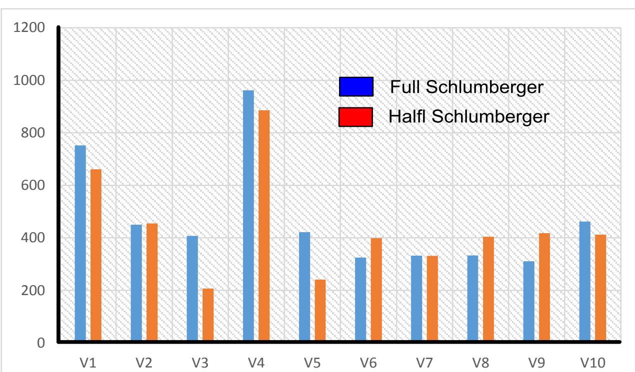

Fig. 5b: The Graph of Topsoil Resistivity

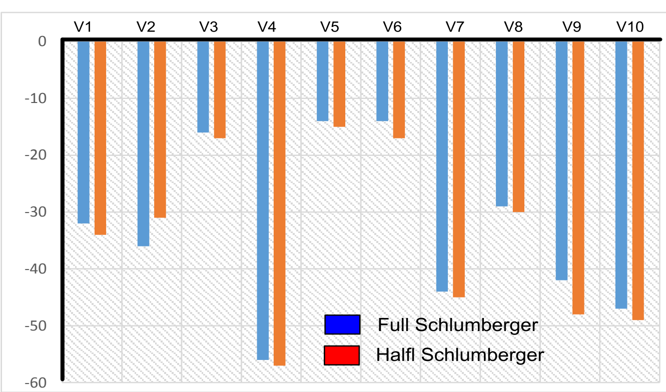

Fig. 5c: The Graph of Depth to the Bed Rock

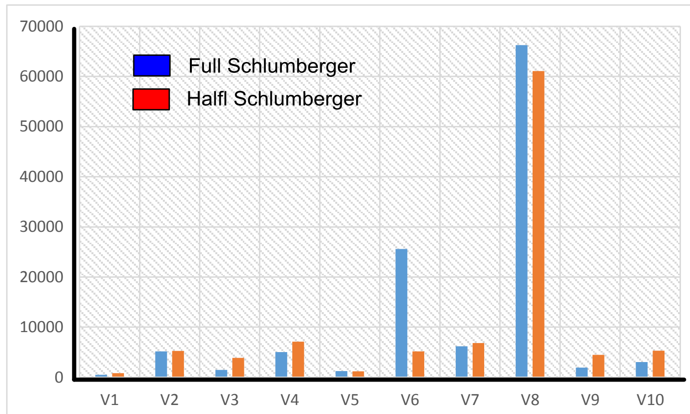

Fig. 5d: The Graph of Bed Rock Resistivity

VI. Conclusion and Recommendation

The study reveals that the terrane is highly variable in thickness and resistivities with four to five layers which comprise of lithological units defined by the lateritic topsoil, indurated laterite, sand/clay; the weathered/fractured basement layer as well as the fresh basement. Fig 4, 5, and table 1 show that the Schlumberger and Half Schlumberger are tremendously correlate at all VES stations of the study area. The practical use of half Schlumberger array measurement is less complicate in comparing with conventional full Schlumberger array. This is because the half Schlumberger spread has the advantage of low man power requirement, thereby saving a lot of time on the field which can be used for taking more measurements.

As a result of these, conclusion is drawn from the quantitative and qualitative comparison, and from the previous studies, that the half Schlumberger array is therefore recommended as reliable alternative method to the conventional Schlumberger array especially in an urban areas with limited space.

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