*Available online at* www.scholarsresearchlibrary.com

**Scholars Research Library**

**Archives of Physics Research, 2014, 5 (1):84-94**
*(http://scholarsresearchlibrary.com/archive.html)*

**ISSN : 0976-0970**
**CODEN (USA): APRRC7**

# Comparative Study of Depth Sounding Using Square and Schlumberger Arrays in the University of Calabar, Calabar, Nigeria

**George, A. Michael[1] and Abong. A. Agwul[2]**

[1]*Department of Physics, University of Calabar, P.M.B 1115 Calabar- Nigeria*
[2]*Department of Physics, Cross River University of Technology, P.M.B 1123 Calabar-Nigeria*

---

**ABSTRACT**

*This study investigated depth sounding using Square and Schlumberger electrodes configuration. The study was conducted at the University of Calabar, Calabar. The instrument employed in the study was ABEM Terrameter SAS 1000 with other accessories. For the square array the largest A-size of the square was 192.0m and for the Schlumberger array, the largest length of spread was 200m. The data were interpreted with the aid of IPI2WIN software. From the interpretation of results, six (6) geoelectric layers with KHKQ curve were obtained for square array and seven (7) layers with HKQQH curve for Schlumberger. Square array had a penetration depth of 43.3m which is greater than the Schlumberger array technique of 19.1m. This implies that for depth sounding, square array penetrates deeper than Schlumberger array.*

**Keywords:** Square, Schlumberger, depth sounding, array, Terrameter

---

## INTRODUCTION

Surface geophysical methods are the most rapid, inexpensive and widely used methods in geophysical surveys. They are basically used in conjunction with hydrogeologic, geologic and borehole methods.

Direct current resistivity method using Schlumberger array has been used by many researchers [8];[10];[2]; [9] and [7] and has been proven successful on depth estimation, ground water potential and in hydrogeological estimation. It has been shown that a square array configuration is more sensitive to anisotropy in the subsurface and requires less surface area than collinear arrays [4]. Resistivity surveys using square array have been carried out to detect productive fracture zones in crystalline bedrock for groundwater supply [14], determination of fracture orientation [3] and in anisotropic studies [1]. Though the techniques for analyzing directional resistivity method offered by the square array have been developed, but the method has not been widely used by researchers both in Nigeria and other parts of the world. Few case studies or interpretative methods using square array are found in the literature, hence the present study.

### Location and Geology of the Study area

The study area is the University of Calabar, Calabar (Fig 1.0 and Fig 2.0). It is located between latitude $4^0 56'39''$ and $4^0 57'30''$N and longitude $8^0 20'38''$ and $8^0 21'43''$E with an elevation of about 15m above sea level. The area is accessible through tarred road from the University main gate.

Geologically, the study area falls within the coastal plain sands known as the Benin formation [11]. The Benin formation is the upper most unit of the Niger Delta complex and overlies the Agbada formation. The coastal plain sands are made of alternating sequences of gravels and sands of different grain sizes, silt, clay and alluvium [12]. Also Benin formation comprises sediments whose age is from tertiary to recent [13]. It consists of fine-medium coarse grained sands which sometimes are poorly sorted.

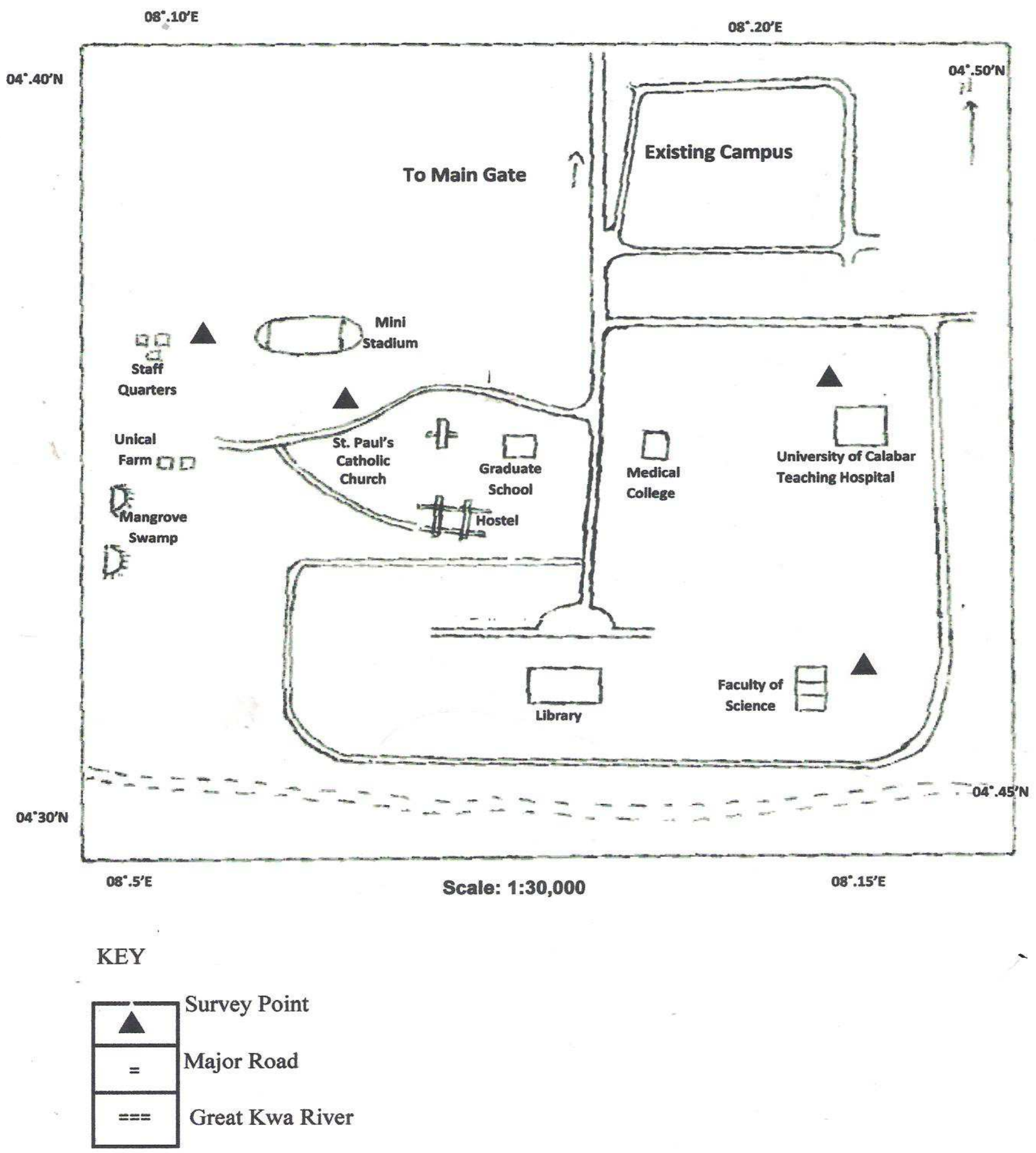



**Fig.1.0 Map of the study area**

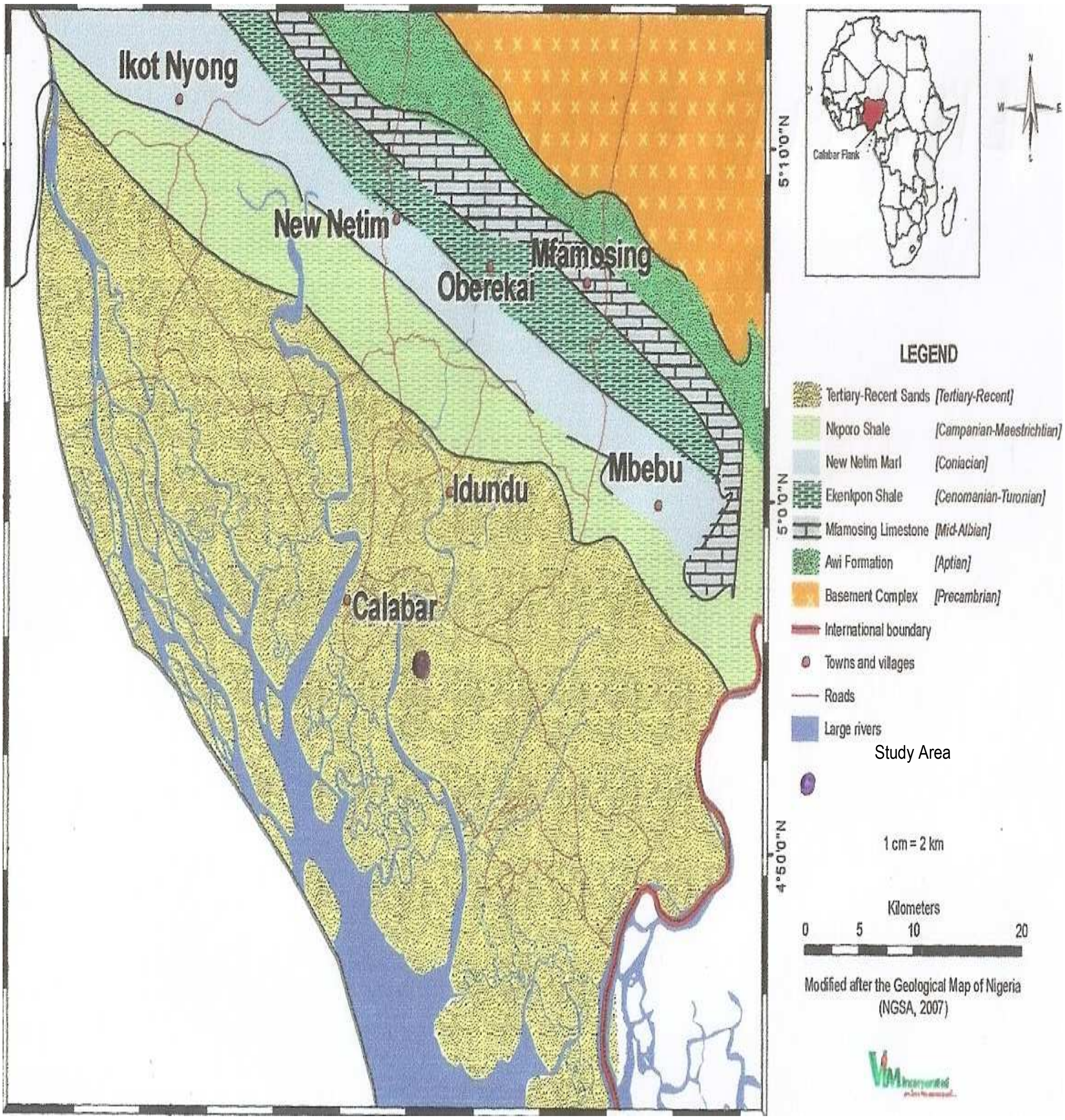



**Fig 2: Geologic map of the study area**

## MATERIALS AND METHODS

For data collection using square array, a square was mapped out within the site and electrodes were planted at the vertices of the square (Fig. 3.0). The square was increased in a symmetrical order from a centre point according to the formula $A\sqrt{2}$ where $A$ is the side length of the square. The electrodes were connected to the ABEM Terrameter Signal Averaging System (SAS) 1000 by current and potential cables. Expansion of the square with reference to the centre point was done using the diagonals of the square and then dividing by two to get the centre point of the square.

The measurement started with a square of length 3m with a square increment of length $A\sqrt{2}$, and then from this increment formula, the next square of length 4.2m was obtained until a square of side 192.0m was covered.

In Schlumberger array, the potential cables were connected to terminals $P_1$ and $P_2$ and the current cables were connected to their terminals $C_1$ and $C_2$ respectively.

The starting electrodes separations were 0.5m for potential electrodes and1.0m for current electrodes. A total of AB/2 spread of 200.0m was covered using Schlumberger array. Similarly, readings were taken at the same location where Schlumberger array data was collected using square electrodes array and a spread length of 192.0m was covered.

Other accessories used in the field include measuring tape, wooden pegs, hammer, and four reels of well insulated cables with crocodile clips.

For Square array, apparent resistivity is given by the equation

$$\rho_{a\alpha} = R_{\alpha} K \quad (1)$$

$$\rho_{a\beta} = R_{\beta} K \quad (2)$$

Where $\rho_{a\alpha}$ is apparent resistivity for alpha

$\rho_{a\beta}$ is apparent resistivity for beta

K is geometric factor and is given by

$$K = \frac{2\pi A}{2-(2)^{\frac{1}{2}}} \quad (3)$$

Where A = square array side length in metres.
For Schlumberger array configuration, apparent resistivity is given by the equation

$$\rho_a = KR \quad (4)$$

Where $K$ is the geometric factor and is given by

$$K = \frac{\pi a^2}{b}\left[1 - \frac{b^2}{4a^2}\right] \quad (5)$$

and $R = \frac{\Delta V}{I}$ (6)

Where $a$ is the current electrode spacing
$b$ is the potential electrode spacing

It has been proved that apparent resistivity data acquired with square array can be interpreted using published methods for Wenner or Schlumberger soundings [4] and [5].

First, the square array resistivity measurements are reduced to a single measurement

$$\rho_m = \left[(\rho_{a\alpha})(\rho_{a\beta})\right]^{\frac{1}{2}} \quad (7)$$

Where $\rho_m$ is the mean geometric resistivity

The square array data were converted to the schlumberger equivalent using
AB/2 = 1.11r and MN/2= 0.5s (8)

Where r = AM = current electrode and nearest potential electrode separation
s = MN = potential electrode separation.

The data were then analyzed for both Square and Schlumberger arrays using IPI2WIN software. The resistivity curves and results obtained are as shown (Figs. 5.0-12.0) and Table 1.

## RESULTS AND DISCUSSION

The results of the interpretation of the square array data and Schlumberger (VES) data revealed the different geoelectric layers in terms of their resistivities and depths in the study area. Six (6) layers for square array and seven (7) layers for Schlumberger were delineated with varying curves, showing the lithological variations with depth.

Fig. 5-8 shows a plot of data collected using square array from location 1 to 4 with six (6) geoelectric layers. These consist of medium sand, coarse sand, medium sand, coarse sand and fine sand. The first layer as interpreted using square array data in the four (4) locations is characterized by resistivity values ranging from 4558 to 5156Ωm and layer thickness ranging from 1.91 to 2.38m with depth range of 1.91 to 2.38m. The second layer represents coarse sand with resistivity values ranging from 14747 to 15227Ωm and thickness of range between 2.09 to 2.18m with depth range of 4.08 to 4.51m. The third layer indicates medium sand with resistivity values ranging from 1067 to 1145Ωm and thickness of range between 4.61 to 4.82m with depth range of 8.9 to 9.13m. The fourth layer is coarse sand with resistivity values ranging from 18700 to 19051Ωm and thickness of range between 10.6 to 10.9m with depth range of 19.5 to 20.1m, while the fifth layer has resistivity values ranging from 83.3 to 321Ωm and thickness of range between 11.0 to 23.8m with depth range of 31.1 to 43.3m.

Therefore the total depth of investigation obtained using the square electrodes array is 43.3m for the highest square size length of 192.0m.

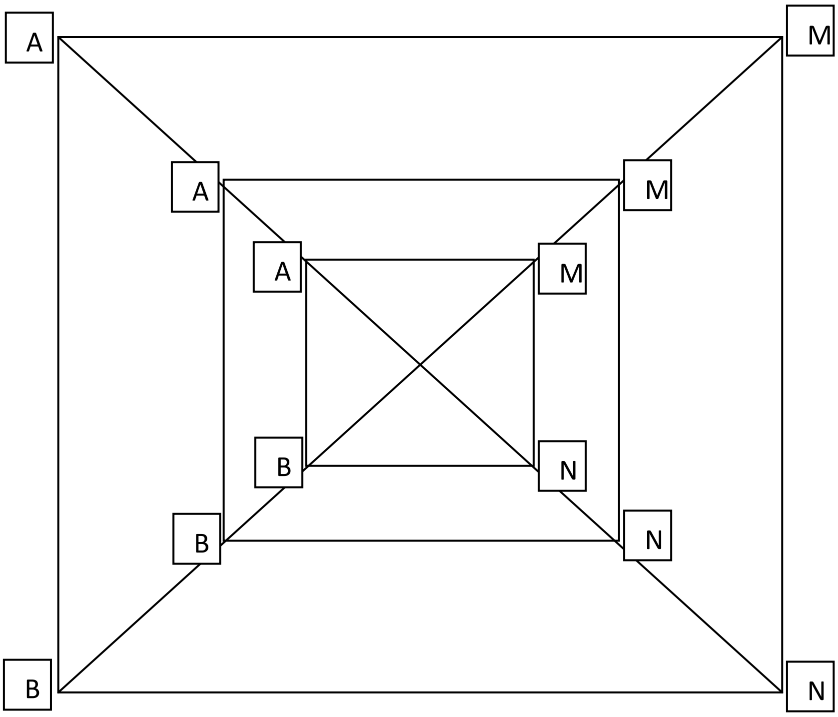



**Fig 3.0 Schematic Diagram of field expansion for Square array**

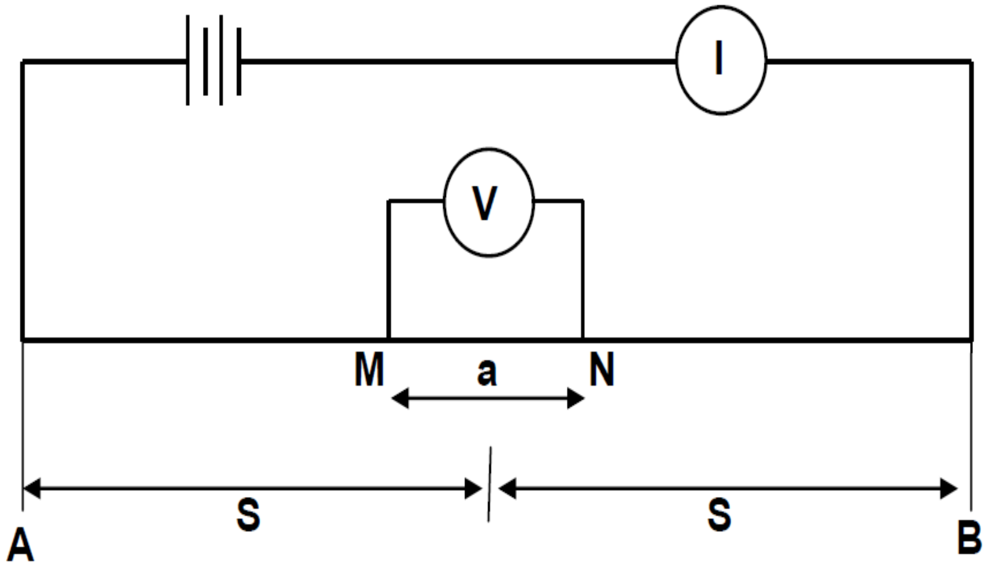
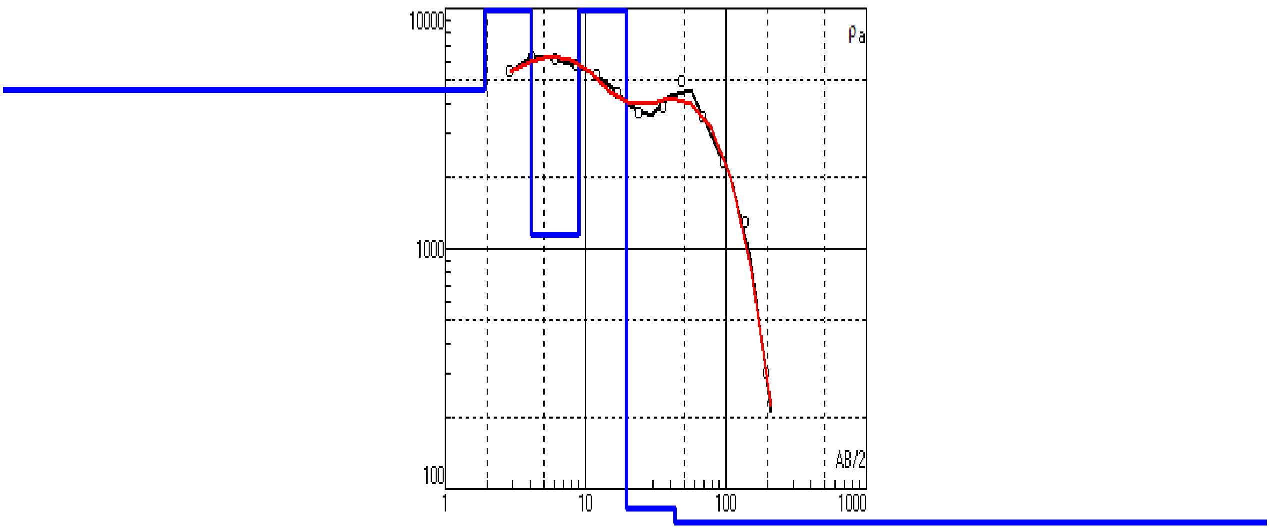
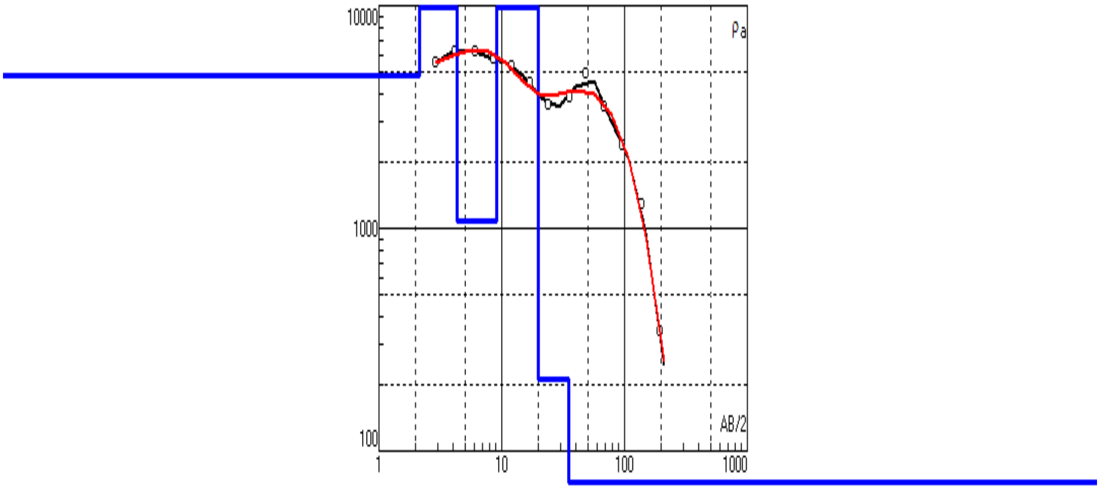



**Fig. 4.0 Schematic diagram showing Schlumberger electrode configuration**



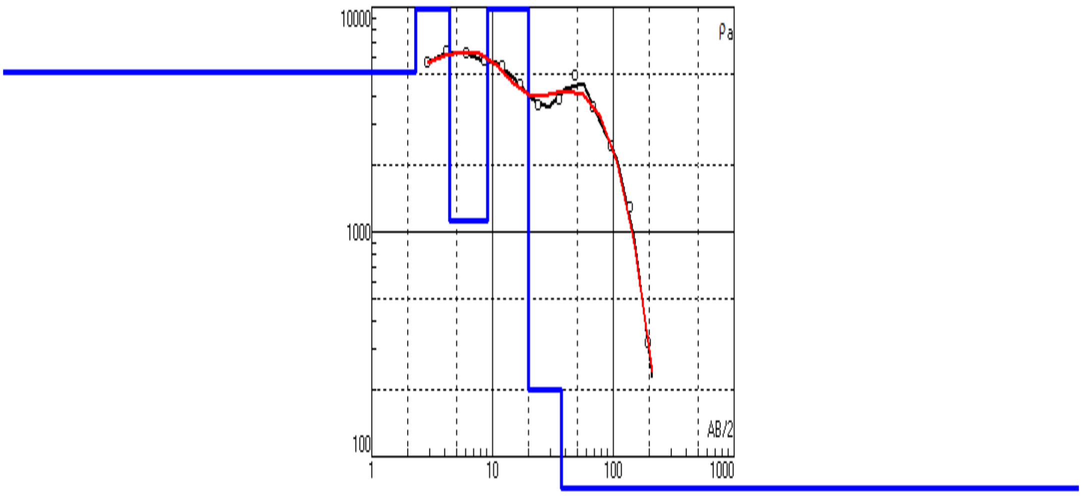

| N | ρ | h | d | Alt |
|---|---|---|---|---|
| 1 | 4558 | 1.91 | 1.91 | -1.906 |
| 2 | 14747 | 2.18 | 4.08 | -4.084 |
| 3 | 1145 | 4.82 | 8.9 | -8.901 |
| 4 | 19051 | 10.6 | 19.5 | -19.52 |
| 5 | 83.3 | 23.8 | 43.3 | -43.3 |
| 6 | 3.75 | | | |

**Fig. 5.0 Typical model of square array representing (KHKQ) curve at location 1**



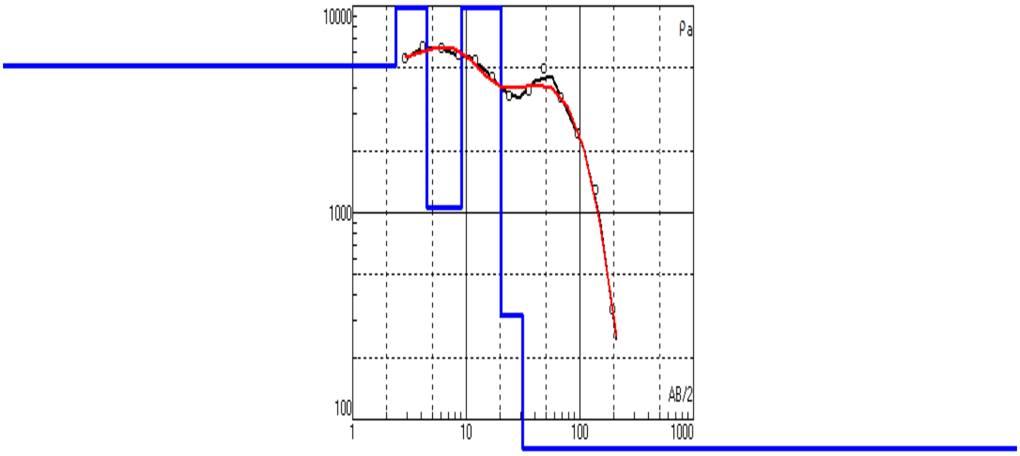

| N | ρ | h | d | Alt |
|---|---|---|---|---|
| 1 | 4880 | 2.16 | 2.16 | -2.16 |
| 2 | 15227 | 2.13 | 4.29 | -4.291 |
| 3 | 1075 | 4.73 | 9.02 | -9.02 |
| 4 | 18855 | 10.8 | 19.9 | -19.85 |
| 5 | 212 | 15.5 | 35.3 | -35.31 |
| 6 | 4.52 | | | |

**Fig.6.0 Typical model of square array representing (KHKQ) curve at location 2**



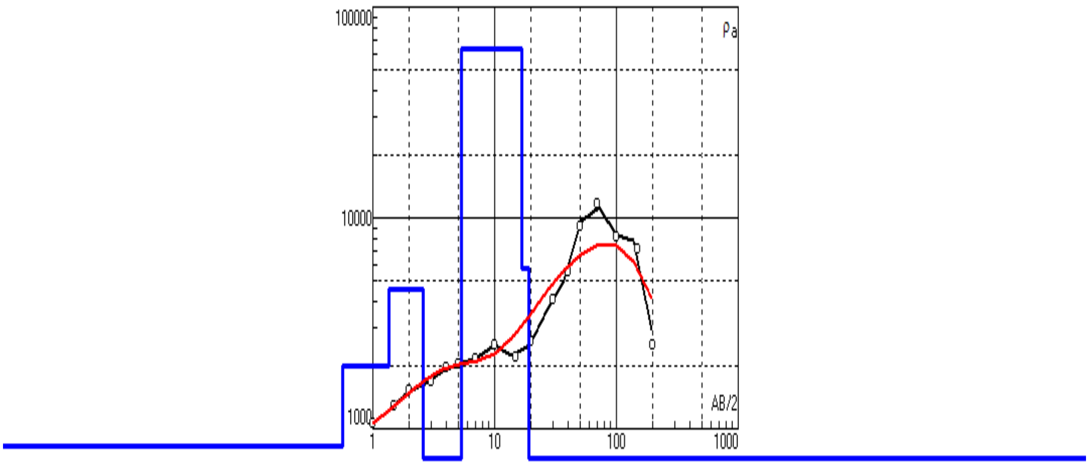

| N | ρ | h | d | Alt |
|---|---|---|---|---|
| 1 | 5089 | 2.3 | 2.3 | -2.301 |
| 2 | 15124 | 2.09 | 4.39 | -4.39 |
| 3 | 1118 | 4.74 | 9.13 | -9.135 |
| 4 | 19028 | 10.7 | 19.8 | -19.85 |
| 5 | 198 | 17.3 | 37.1 | -37.1 |
| 6 | 3.39 | | | |

**Fig.7.0 Typical model of square array representing (KHKQ) curve at location 3**



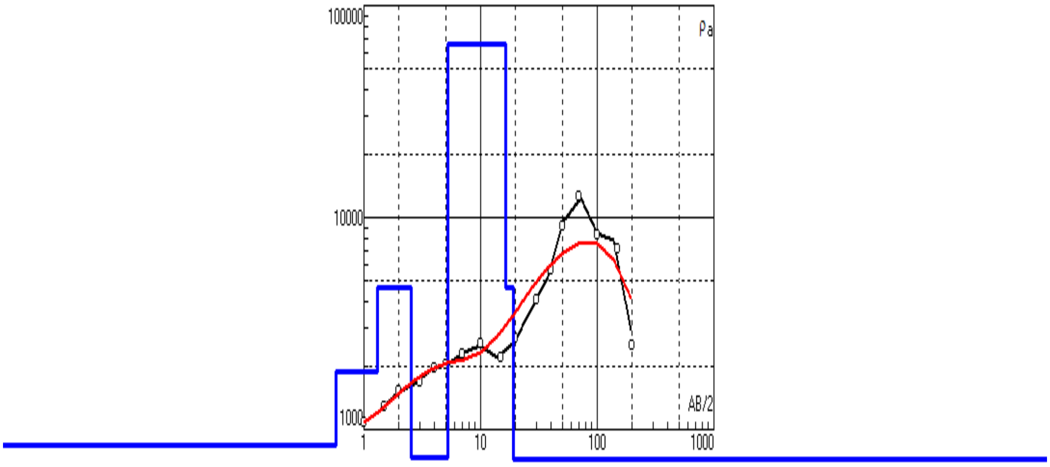

| N | ρ | h | d | Alt |
|---|---|---|---|---|
| 1 | 5156 | 2.38 | 2.38 | -2.384 |
| 2 | 14978 | 2.12 | 4.51 | -4.505 |
| 3 | 1067 | 4.61 | 9.12 | -9.12 |
| 4 | 18700 | 10.9 | 20.1 | -20.07 |
| 5 | 321 | 11 | 31.1 | -31.07 |
| 6 | 4.61 | | | |

**Fig.8.0 Typical model of square array representing (KHKQ) curve at location 4**



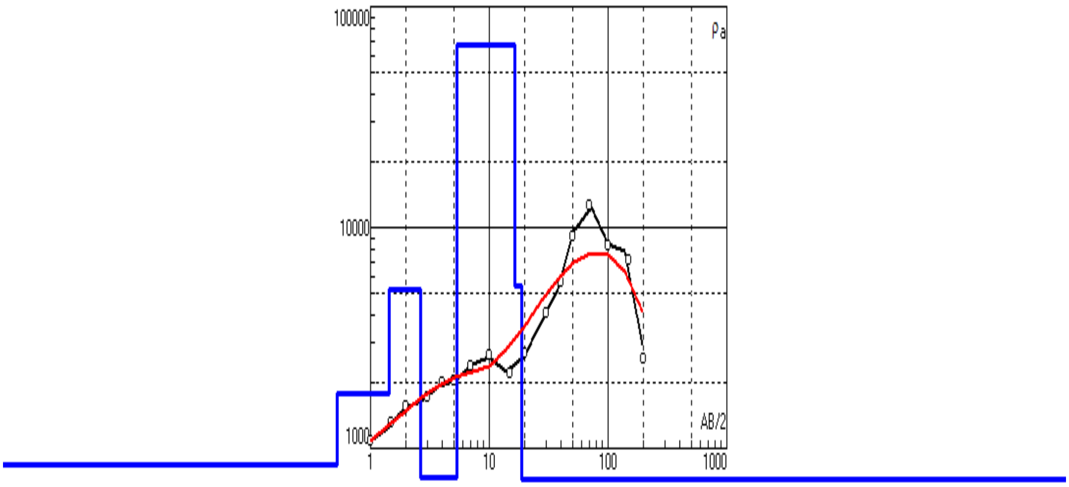

| N | ρ | h | d | Alt |
|---|---|---|---|---|
| 1 | 822 | 0.569 | 0.569 | -0.5693 |
| 2 | 2000 | 0.798 | 1.37 | -1.367 |
| 3 | 4566 | 1.22 | 2.59 | -2.591 |
| 4 | 722 | 2.72 | 5.32 | -5.316 |
| 5 | 63657 | 11.4 | 16.8 | -16.76 |
| 6 | 5723 | 2.38 | 19.1 | -19.14 |
| 7 | 79.8 | | | |

**Fig. 9.0 Typical model of Schlumberger array representing (HKQQH) curve at location 1**



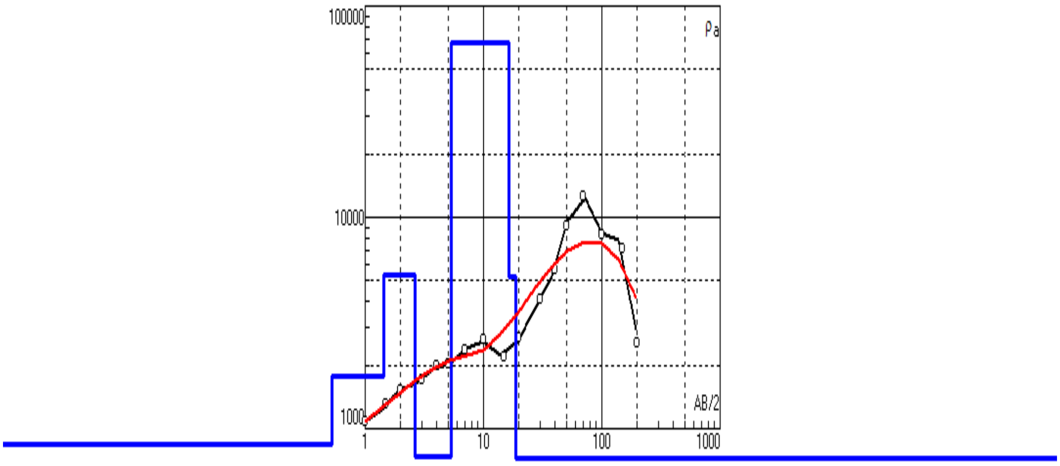

| N | ρ | h | d | Alt |
|---|---|---|---|---|
| 1 | 845 | 0.575 | 0.575 | -0.5753 |
| 2 | 1858 | 0.729 | 1.3 | -1.304 |
| 3 | 4699 | 1.26 | 2.56 | -2.563 |
| 4 | 734 | 2.7 | 5.26 | -5.262 |
| 5 | 65796 | 11.2 | 16.5 | -16.5 |
| 6 | 4669 | 2.43 | 18.9 | -18.92 |
| 7 | 75.2 | | | |

**Fig 10.0 Typical model of Schlumberger array representing (HKQQH) curve at location 2**




| N | ρ | h | d | Alt |
|---|---|---|---|---|
| 1 | 841 | 0.526 | 0.526 | -0.5257 |
| 2 | 1756 | 0.899 | 1.42 | -1.424 |
| 3 | 5283 | 1.21 | 2.63 | -2.632 |
| 4 | 740 | 2.69 | 5.33 | -5.325 |
| 5 | 66664 | 11.1 | 16.4 | -16.39 |
| 6 | 5412 | 2.38 | 18.8 | -18.76 |
| 7 | 74.6 | | | |

**Fig. 11.0 Typical model of Schlumberger array representing (HKQQH) curve at location 3**




| N | ρ | h | d | Alt |
|---|---|---|---|---|
| 1 | 840 | 0.523 | 0.523 | -0.5228 |
| 2 | 1753 | 0.904 | 1.43 | -1.427 |
| 3 | 5298 | 1.2 | 2.63 | -2.631 |
| 4 | 740 | 2.69 | 5.32 | -5.325 |
| 5 | 66633 | 11.1 | 16.4 | -16.4 |
| 6 | 5265 | 2.37 | 18.8 | -18.77 |
| 7 | 74.9 | | | |

**Fig.12.0 Typical model of Schlumberger array representing (HKQQH) curve at location 4**

Fig.9-12 depicts plots of VES data from location 1 to 4 with seven (7) geoelectric layers with different resistivity values and thicknesses. In the four (4) VES locations, layer one is fine sand with resistivity values between 822 and 845Ωm, thickness of range between 0.523 and 0.575m with depth range of 0.523 to 0.575m. The second layer and third layers are characterized by medium sand with second layer having resistivity values ranging from 1753 to 2000Ωm, and thickness of range between 0.729 to 0.904m with depth range of 1.30 to 1.43m, while third layer has resistivity values ranging from 4566 to 5298Ωm, and thickness of range between 1.20 to 1.26m with depth range of 2.56 to 2.63m. The fourth layer is fine sand with resistivity values between 722 and 740Ωm, and thickness between 2.69 and 2.72m with depth range between 5.26 and 5.33m. The fifth layer is coarse sand with resistivity values ranging from 63657 to 66664Ωm, and thickness of range between 11.10 to 11.40m with depth range of 16.40 to 16.80m. The sixth layer is medium sand with resistivity values ranging from 4669 to 5723Ωm, and thickness of range between 2.37 to 2.43m with depth range of 18.80 to 19.10m.

The highest depth of investigation obtained using the Schlumberger electrodes array is 19.10m for highest AB/2electrode spacing of 200m.

The square array has higher depth of penetration than the Schlumberger counterpart for almost the same AB/2 spread. This is because it samples a volume i.e. 3-dimesional distribution of resistivity while the Schlumberger samples line distribution of resistivity.

**Table 1.0: Summary of results**

| | Square Array | | | Schlumberger Array | | |
|---|---|---|---|---|---|---|
| | 1.11r =AB/2 | Depth(m) | No. of layers | AB/2 | Depth(m) | No. of layers |
| Location 1 | 193.4 | 43.3 | 6 | 200.0 | 19.1 | 7 |
| Location 2 | 193.4 | 35.3 | 6 | 200.0 | 18.9 | 7 |
| Location 3 | 193.4 | 37.1 | 6 | 200.0 | 18.8 | 7 |
| Location 4 | 193.4 | 31.1 | 6 | 200.0 | 18.8 | 7 |

## CONCLUSION

The findings of this study have shown that a plot of data using square electrodes array produces a (KHKQ) curve with six (6) geoelectric layers while Schlumberger electrodes array produces a (HKQQH) curve with seven (7) layers. But in terms of depth of penetration the square array technique was 43.30m which is greater than the

Schlumberger array technique of 19.10m. This implies that for depth sounding, most especially where the economy of space is required, square array is more effective than the Schlumberger array. Hence, it is advantageous to use square array for vertical electrical sounding (VES) work.

## REFERENCES

[1] C.N Ehirim and E.E Essien (**2009**) *Scientia Africana* 8(2):53-60

[2] A.C Ekwe, I.N Nnodu,K.I Ugwubahand O.S Onwuka (**2010**) *Online Journal of Earth Sciences* 4(1):19-26

[3] A.M. George, E.E Okwueze, A.E Akpan, and C.J Uchegbu (**2008**) *Nigerian Journal of Physics*, 20(1):136-144.

[4]G.M Habberjam, (**1972**) The Effects of Anisotropy on Square among Resistivity measurements. Geophysical Prospecting.

[5]G.M Habberjam (**1972**) and G.E Watkins (1967) The use of Square array configuration in Resistivity Prospecting. Geophysical Prospecting.

[6] J.W. Lane (Jr), F.P Haeniand W.M Watson (**1995**) *Ground water* 33(3):476-485

[7] M. Mohamed, S.R.M. Eslam, S.A.M Al Fouzan, and N.A Arifi (**2012**) *International Journal of the Physical Sciences* 7(2):317-326

[8] K. O Ozegin., D.O Isiwele and S.O Azi (**2007**) *Journal of the Nigerian Association of Mathematical Physics*, 11, 403-410

[9] C. Nwankwo, L Nwosu, and G. E Mujakpome (**2011**) *Journal of Economics and Sustainable Development* 2(8)

[10] S.A.Ugwu and J.I Nwosu (**2011**) *Journal of Applied Science and Environmental Management*, 13(1):85-89

[11] E. M. Mbipom, E. E. Okwueze and A. A. Onwuegbuche, *Nigerian Journal of Physics*, Vol. 85, **1996**, pp. 28-32.

[12] A.N. Ugbaja and A. E. Edet, *Global Journal of Geological Sciences*, Vol. 2, No. 2, **2004**, pp. 199-206.

[13] A. E. Edet and C. S. Okereke, *Journal of African Earth Sciences*, Vol. 35, No. 3, **2002**, pp. 433-441.

[14]A.S Sehli (**1990**). Contribution of electrical prospecting to geophysical study of discontinuous media, in International symposium on applications of geophysics to water prospecting in arid and semi-arid areas. Paris, France.