~~2~~Two-Dimensional Electrical Resistivity Tomography of Bitumen Occurrence in Agbabu, Southwestern~~,~~ Nigeria.

ABSTRACT

The Electrical Resistivity Tomography (ERT) data was acquired within the area suspected to have high potential for bitumen occurrence using the ~~wenner~~Wenner-S~~s~~chlumberger configuration in Agbadu, southwestern Nigeria. PASI 16GL-N Earth resistivity meter instrument was used to acquire data along five (5) traverses with 5m electrode spacing and traverses length of 150m. The apparent resistivity values obtained was processed using RES2DINV software which helped to automatically obtain the 2D inversion model of the subsurface. This ~~work~~ studyhas shown ~~that~~ the occurrence of bitumen ~~was found~~ between the depth of 13.4m and 9.93m for Traverses 1,2,3 and Traverses 4,5 respectively in a 2-Dimensional electrical resistivity images ~~which corroborated by~~for boreholes with a depth of about 18m. The results ~~of this research indicated~~indicate that the bitumen is characterized by good lateral continuity and is sufficiently thick for commercial exploitation ~~(i.e. average thickness of 11.67m).~~.

Keywords: Electrical resistivity, butimenoccurrence,Agbabu, Nigeria~~;Traverse; Bitumen; Occurrence; Depth~~

~~1.~~ INTRODUCTION

The bedrock of Nigeria's economy before the discovery of petroleum deposit had been the solid minerals and agricultural sectors, but currently, it is the oil and gas sector. Over 80% of the country's revenue comes from export and domestic sales of oil and gas. As the hydrocarbon potentials of the prolific Niger Delta becomes depleted or in the near future may be exhausted due to continuous exploitation, attention needs to be shifted to other source of revenue.Bitumen which is known as asphalt or tar sand is the heavy oil in the bituminous sand which is a very dark coloured, sticky and highly viscous liquid or semi-solid form of petroleum. The occurrence and structural settings of the Agbabu tar sand (bitumen) deposits have been investigated due to the economic importance of bitumen as a readily available alternative source of energy [~~10~~1].

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Electrical resistivity tomography (ERT) is one of the most popular techniques for the shallow subsurface applications and is applied for hydrogeological, engineering, or agricultural ~~questions~~problems.. Applications cover a wide range of scales, from millimeter/centimeter scales at laboratory samples, decimeter to meter scale in soils, meter to decimeters for groundwater questions, but can reach several hundred meters or even kilometer for deep geological structures.

Variations in electrical resistivity (or conductivity) typically correlate with variations in lithology, water saturation, fluid conductivity, porosity and permeability, which may be used to map stratigraphic units, geological structure, sinkholes, fractures and groundwater. Resistivity data are then recorded via complex combinations of current and potential electrode pairs to build up a pseudo cross-section of apparent resistivity beneath the survey line. The depth of investigation depends on the electrode separation and geometry, with greater electrode separations yielding bulk resistivity measurements from greater depths.

The recorded data are transferred to a PC for processing. In order to derive a cross-sectional model of true ground resistivity, the measured data are subject to a finite-difference inversion process using the RES2DINV software.

Data processing is based on an iteractive routine involving determination of a two-dimensional (2D) simulated model of the subsurface. Convergence between theoretical and observed data is achieved by non-linear least squares optimization. The extent to which the observed and calculated theoretical models agree is an indication of the validity of the true resistivity model (indicated by the final root-mean-squared (RMS) error).

The true resistivity models are presented as colour contour sections revealing spatial variation in subsurface resistivity. The 2D method of presenting resistivity data is limited where highly irregular or complex geological features are present. ~~Constraints: ~~Readings can be affected by poor electrical contact at the surface. An increased electrode array length is required to locate increased depths of interest therefore the site layout must permit long arrays. Resolution of target features decreases with increased depth of burial.To interpret the data from a 2-D imaging survey, a 2-D model for the sub-surface which consists of a large number of rectangular blocks is usually use. A computer program is then use to determine the resistivity of the blocks so that the calculated apparent resistivity values agree with the measured values from the field survey [8]. The computer program RES2DINV will automatically subdivide the subsurface into a number of blocks, and it then uses a least-square inversion scheme to determine the appropriate resistivity value for each block. The location of the electrodes and apparent resistivity values must be entered into a number of blocks, and it then uses a least-squares inversion scheme to determine the appropriate resistivity value for each block. apparent resistivity values must be entered into text file which can be read by the RES2DINV program [9].

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~~2.~~ METHODOLOGY

~~1.1~~ Geology and description of the study area

The study area is located within the geographical grids of latitude 6º 35' 16.3" N and 6º 37' 13.9" N and longitude 4º 49' 29.0" E and 4º 50' 20.7" E in Odigbo local government area of Ondo State. It falls within the sedimentary terrain in the Dahomey basin of southwestern, Nigeria.

The Dahomey basin is an Atlantic margin basin containing Mesozoic-Cenozoic sedimentary succession reaching a thickness of over 3000m. It extends from south-eastern Ghana to the western flank of the Niger Delta. Its stratigraphy is classified by various authors into Abeokuta Group, Imo Group, Oshosun Formation, Ilaro Formation and Coastal Plain sands and Alluvium [1, 2, 6]. The Agbabu area is underlain by the sediments of the Imo group.

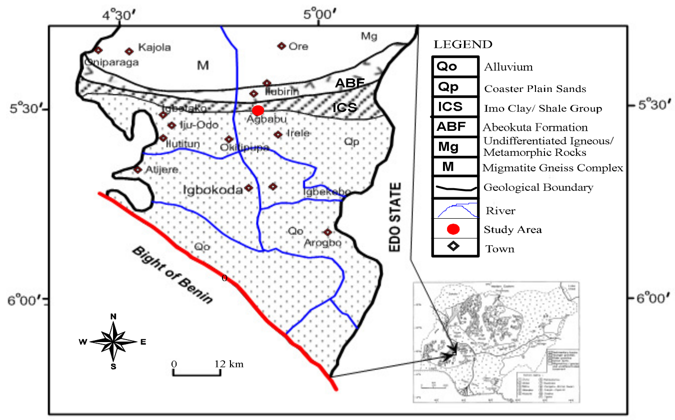

Figure 1: Geological Map of southern part of Ondo State showing the Study Area (Modified After PTF, 1997).

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~~2. METHODOLOGY~~

In this research work, the ~~wenner~~Wenner- ~~schlumberger~~ Schlumberger array in electrical resistivity survey was adopted. The investigation was carried out in Agbabu, southwestern, Ondo state, Nigeria. The basic field equipment for this study is the PASI 16 GL-N Earth resistivity meter.

This is a new hybrid between the Wenner-Schlumberger arrays arising out of the relatively recent work with electrical imaging surveys [10]. The classical Schlumberger array is one of the most commonly used array for resistivity sounding survey.The "n" factor for this array is the ratio of the distance between the C_1— P_1(orP_2— C_2) electrodes to the spacing between the P_1 — P_2potential pair. The sensitivity pattern for the schlumberger array is slightly different from the Wenner array with a slight vertical curvature below the center of the array, slightly lower sensitivity values in the regions between the C_1 andP_1($P_2$and C_2) also and electrodes. There is a slightly greater concentration of high sensitivity values below the P_1 — P_2electrodes. This means that this array is moderately sensitive to both horizontal and vertical structures. In areas where both of geological structures are expected this array might be a good compromise between the Wenner and the dipole-dipole-array. The median depth of investigation for this array is about 10% larger than that for the Wenner array for the same distance between the outer (C_1andC_2)electrodes. The signal strength for this array is smaller than that for the Wenner array, but it is higher than the dipole-dipole array [8].

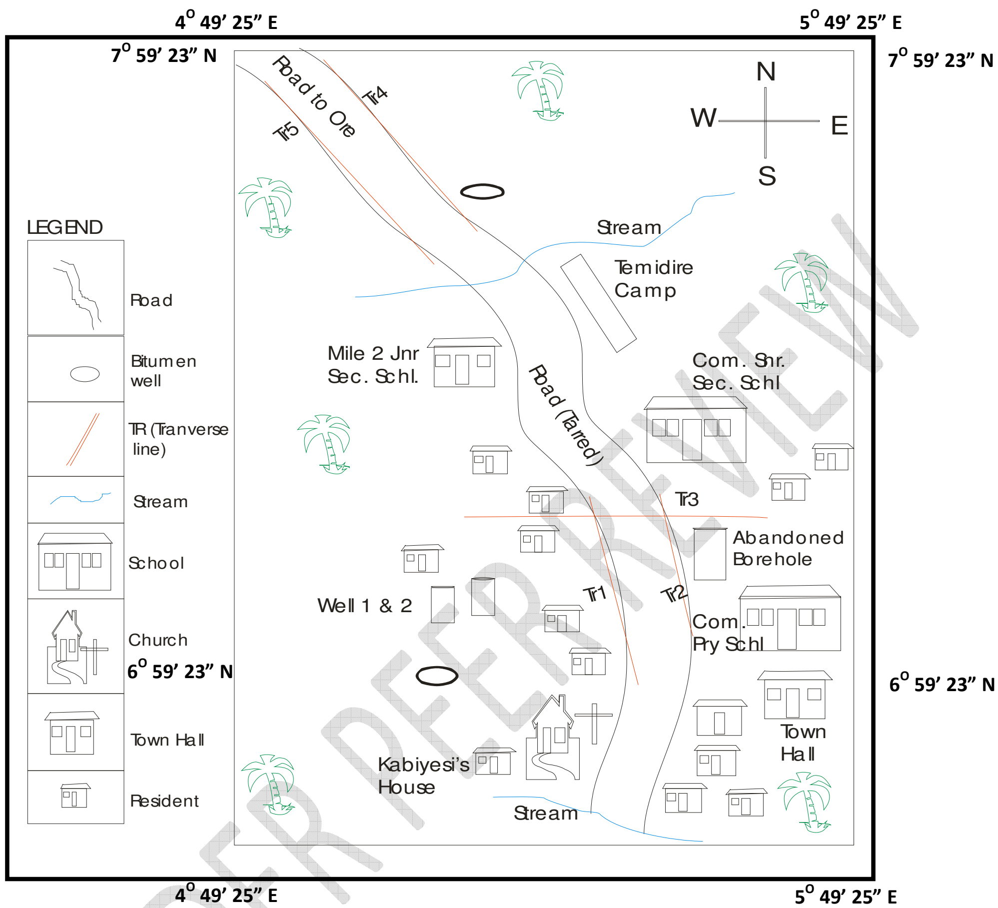

Figure 2: Base Map of ……showing the Study Area

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2.1 Theory of electrical resistivity method for wenner-schlumberger array

From the theory, we have that the potential at M due to A is

$$V_M = \frac{\rho I}{2\pi}\left[\frac{1}{a(n+1)} - \frac{1}{na}\right]$$

Where a = midpoint = electrode spacing

n = integer value , ρ = layer resistivity

The potential at N due to B is

$$V_N = \frac{\rho I}{2\pi}\left[\frac{1}{a(n+1)} - \frac{1}{na}\right]$$

The potential difference dV between the two potential is therefore given by

dV = $V_M - V_N$

$$= \frac{\rho I}{2\pi}\left[\left(\frac{1}{a(n+1)} - \frac{1}{na}\right) - \left(\frac{1}{a(n+1)} - \frac{1}{na}\right)\right]$$

$$= \frac{\rho I}{2\pi}\left[\left(\frac{1}{a(n+1)} - \frac{1}{na}\right) - \frac{1}{a(n+1)} + \frac{1}{na}\right]$$

$$= \frac{\rho I}{2\pi}\left[\left(\frac{1}{a(n+1)} - \frac{1}{na}\right) - \frac{1}{a(n+1)} + \frac{1}{na}\right]$$

$$= \frac{\rho I}{2\pi}\left(\frac{(n+1)-n-n+(n+1)}{an(n+1)}\right)$$

$$dV = \frac{\rho I}{2\pi}\left(\frac{2(n+1)-2n}{an(n+1)}\right) = \frac{\rho I}{2\pi}\left(\frac{2}{an(n+1)}\right)$$

Therefore, $\rho = \frac{dV\pi}{I}$[an(n+1)].

Where $\frac{dV}{I}$ = R$\rho = R\pi[an(n+1)]$

k = $\pi[an(n+1)]$

Then, $\rho = RK$

Where k is the geometric factor.

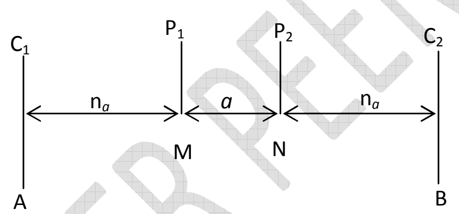

Figure 3: Sketch of Wenner- Schlumberger array

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3. RESULTS AND DISCUSSION

Agbabu Traverse One: The inverted 2-D resistivity section shows the image of the subsurface to a depth of 17.3m as shown in Figure 4. The length of this traverse is 150m and oriented in an approximately N – S direction. The first layer designated with green and yellow colour has resistivity values in the range of 75 - 210Ωm. It can be seen from this profile that the topsoil which varies between 0- 3.88m in depth with thickness of 3.88m could probably consist of sandy soil.

The second geo-electric layer has resistivity in the range of 200 - 700Ωm which is indicated by brown, deep brown, red and purple. This formation occurs at a depth of 3.88m – 13.4m between lateral distances 52m -53m, 63m-72m, 84m-107m and 121m-132m could possibly be accumulated of bitumen. Evidently, the profile length of 84m- 107m has a sharp increase of resistivity (500 - 700Ωm) which could now indicate possible accumulation of bitumen. The third layer has a low resistivity from 10 – 74.3Ωm. It has a thickness of about 3.9m and could be a possible aquiferous zone.

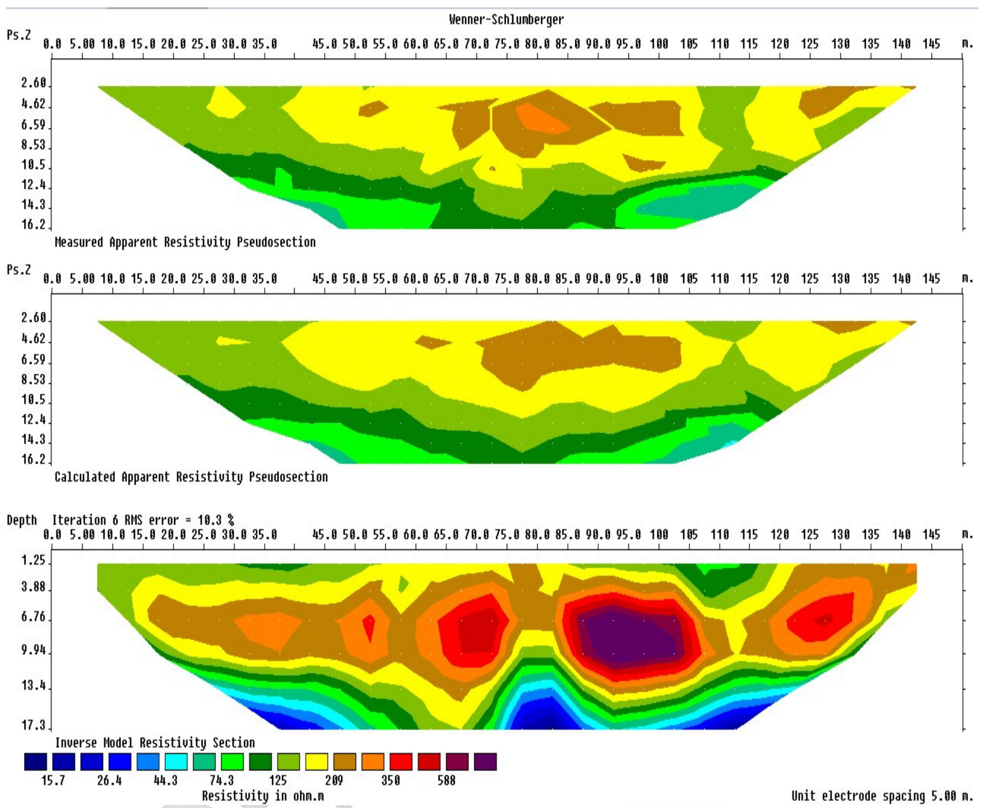

Figure4: Inverted 2D-Resistivity Section along Traverse one

Agbabu Traverse Two: The inverted 2-D resistivity section shows the image of the subsurface to a depth of 17.3m as shown in Figure 5. The length of this traverse is 150m and oriented in an approximately N–S direction. The first layer has an increase resistivity values ranging from 166 - 495Ωm designated with brown, deep brown, red and purple. This formation occurs at a depth of 0 – 13.4m between lateral distances 30m -40m, 60m-85m and 98m-132m could possibly be accumulated of bitumen. Evidently, the profile length of 30m -40m and 60m-85m having a sharp increase of resistivity (371 -– 495Ωm) which could now indicate possible accumulation of bitumen.

The second geo-electric layer has undulating thickness between 2.15 and 3.9m down the profile with resistivity values between 74.4- 166Ωm could probably consist of sandy soil. The third geo-electric layer extends to a depth from15.3~~m~~-17.3m along a lateral distances 30m-40m and 85m-110m has a low resistivity from 10 – 50Ωm. It has a thickness of about 2m could possibly serve as a perched aquifer.

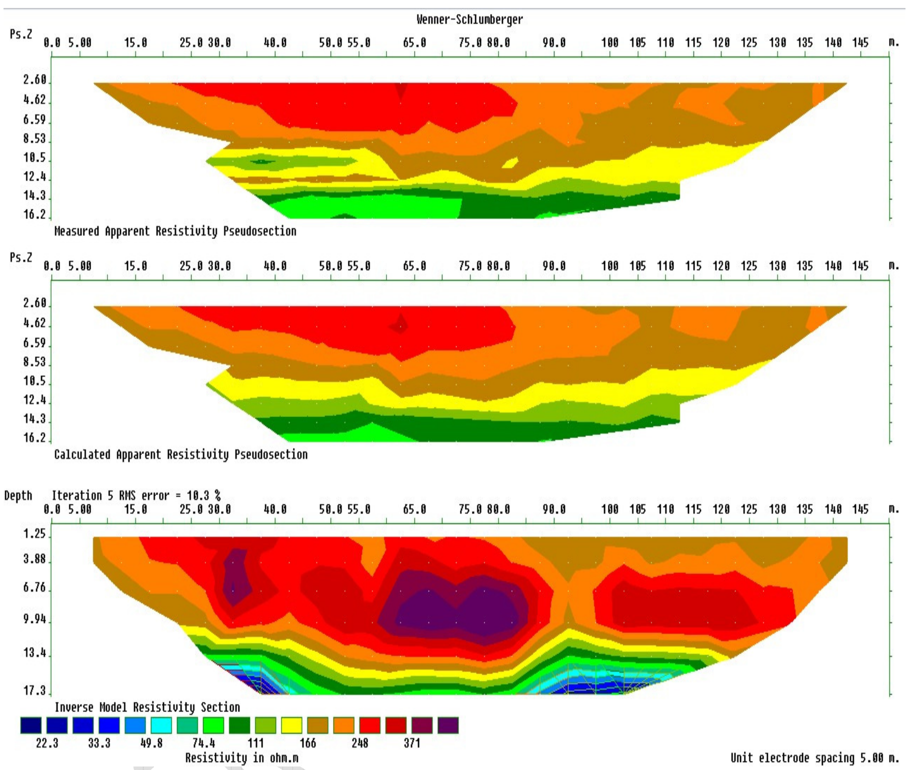

Figure 5: Inverted 2D-Resistivity Section along Traverse Two

Agbabu Traverse Three: The inverted 2-D resistivity section shows the image of the subsurface to a depth of 17.3m as shown in Figure 6. The length of this traverse is 150m and oriented in an approximately W–E direction. The first layer has an increase resistivity values ranging from 127 - 515Ωm designated with red and purple. This formation occurs at a depth of 0 – 13.4m between lateral distances 8m-125m could possibly be accumulated of bitumen. Evidently, the profile length of 8m -77m and 105m-117m having a sharp increase of resistivity(321 - 515Ωm) which could now indicate possible accumulation of bitumen.

The second geo-electric layer designated with brown yellow and green colour has undulating depth varies from 1.25 - 17.3m down the profile with resistivity values between 7.78- 127Ωm could indicate the presence of sandy soil of varying porosity and permeability. The third geo-electric layer designated with light blue and deep blue colour extends to a depth from13.4m-

17.3m along a lateral distances 65m-80m having a low resistivity from 0 – 7.78Ωm. It has a thickness of about 3.9m which could possibly serve as a perched aquifer.

The three traverses show similar features at depth 13.4m. This correlation could indicate the presence of possible accumulation of bitumen at this depth.

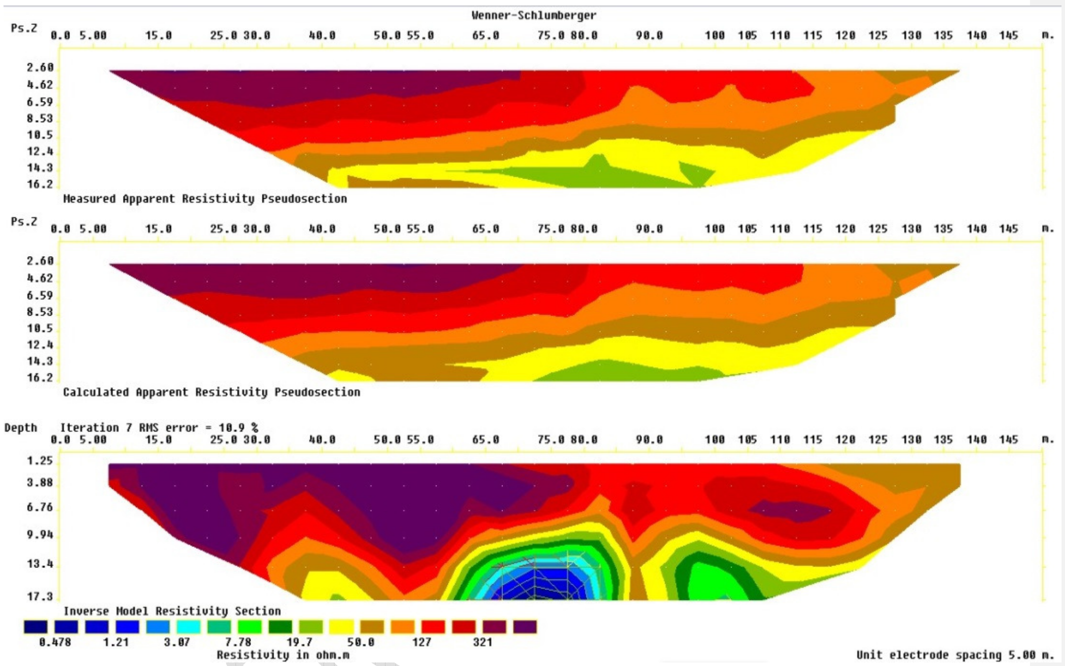

Figure 6: Inverted 2D-Resistivity Section alongTraverse Three

Agbabu Traverse Four: The inverted 2-D resistivity section shows the image of the subsurface to a depth of 17.3m as shown in Figure 7. The length of this traverse is 150m and oriented in an approximately N–S direction.

The first layer has an increase resistivity values ranging from 107 - 465Ωm designated with red and purple colour. This formation occurs at a depth of 9.94m along a lateral distances 17.5m-142.5m could possibly be accumulated of bitumen. It has a thickness ranging from 1.25m-9.94m. Evidently, the lateral profile length having a sharp increase of resistivity (286 - 465Ωm) could now indicate possible accumulation of bitumen.

The second geo-electric layer designated with brown, yellow and green colour has undulating along lateral distance 35m-55m. It has resistivity values between 5.61- 107Ωm could probably consist of sandy soil. This formation has a thickness varying from 9.94m-17.3m. The third geo-electric layer designated with light blue and deep blue colour extends to a depth from13.34m-17.3m along a lateral distances 34m-53m having a low resistivity from 0 – 5.61Ωm. It has a thickness of about 3.9m which could possibly host a large volume of underground water resources.

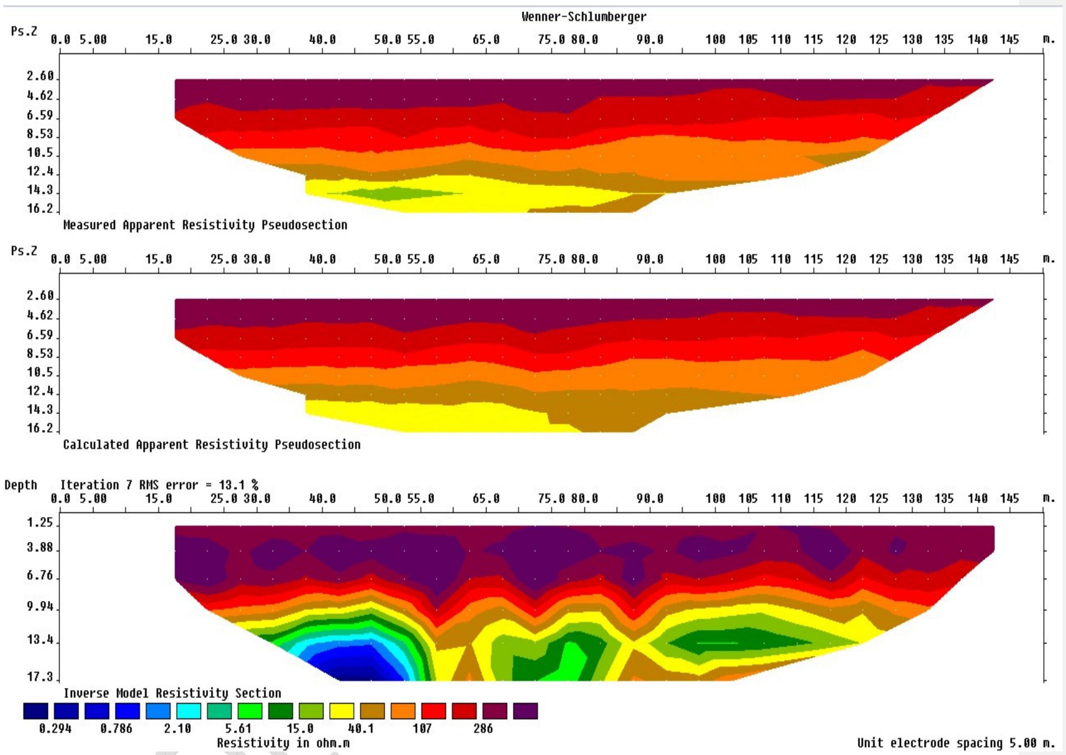

Figure 7: Inverted 2D-Resistivity Section along Traverse Four

Agbabu Traverse Five: The inverted 2-D resistivity section shows the image of the subsurface to a depth of 17.3m (~~as shown in~~Figure 8). The length of this traverse is 150m and oriented in an approximately N - S direction.

The first layer has an increase resistivity values ranging from 211 - 745Ωm designated with red and purple colour. This formation occurs at a depth of 9.94m along a lateral distances 12.5m-137.5m could possibly be accumulated of bitumen. It has a thickness ranging from 0-9.94m. Evidently, the lateral profile length having a sharp increase of resistivity (478 - 745Ωm) could now indicate possible accumulation of bitumen.

The second geo-electric layer designated with brown, yellow and green colour has undulating along lateral distance 47m-67m, 78m-62m and 105m 115m. It has resistivity values between

18.1- 211Ωm could probably consist of sandy soil. This formation has a thickness varying from 8.35m-17.3m. The third geo-electric layer designated with light blue and deep blue colour extends to a depth from13.4m-17.3m along a lateral distances 34m-53m having a low resistivity from 1m – 8.2Ωm. It has a thickness of about 3.9m which could possibly host a large volume of underground water resources.

Traverse 4 and 5 having correlation of the same depth of 13.4m that could possibly be accumulated of bitumen.

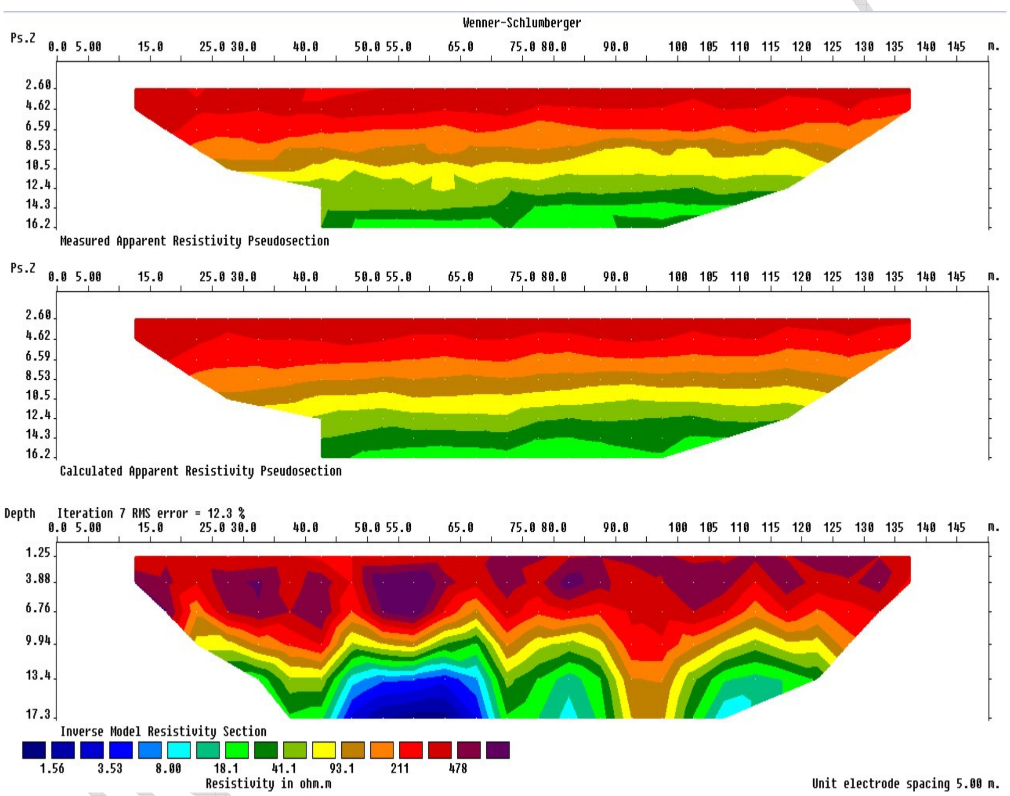

Figure 8: Inverted 2D-Resistivity Section alongTraverse Five

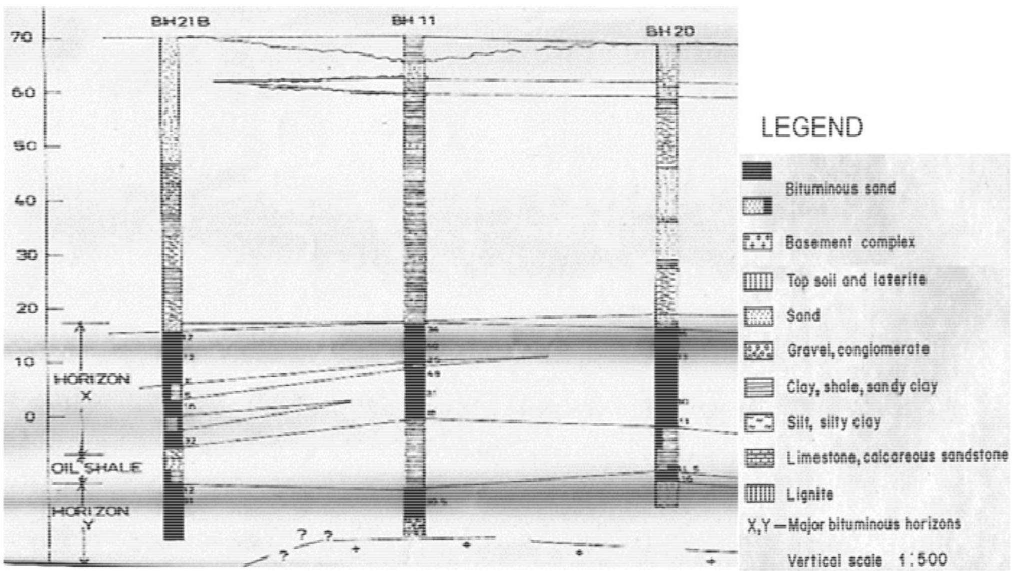

Figure 9:Lithofacies / Bitumen Saturation Correlation Panel of the Study Area
(Modified after GCU, Uni. of Ile-Ife, 1980) [4].

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5. CONCLUSION

This research has shown that the occurrence of bitumen ~~was found between~~at the depth of 13.4m and 9.93m for Traverses 1,2,3 and Traverses 4,5 respectively corroborated by boreholes with a depth of about 18m.The results of this research indicated that the bitumen is characterized by good lateral continuity and sufficiently thick for commercial exploitation (i.e. average thickness of 11.67 m). Bitumen and tar bearing sands formation are known to be characterized by high resistivity [3]. Low resistivity values are encountered in places where the bitumen is thought to be associated with saline water [5].

REFERENCES**Rearranged the references so that number 10 reference becomes No. 1**

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