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# Depth Estimation of Bitumen Deposit Using Integrated Geophysical Methods in Ijebu Itele Ogun State, Southwestern Nigeria

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Magnetic Survey,
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Ijebu Itele.

**ABSTRACT**
Bitumen is a good source of alternative hydrocarbon because it possesses a relatively large quantity of naphthene, aromatics and asphaltenes that are similar to those in conventional oil. The depletion of crude oil reservoir all over the world has necessitated many countries to encourage many research works in the development of the resource, hence the motivation for this research work. This study investigates the subsurface structures of a portion of ijebu - itele, Ogun State Southwestern Nigeria with the objective of estimating the depth to the top of bitumen deposits. Five (5) profiles were used for the data collection using ground magnetic survey and electrical resistivity techniques. The Oasis Montage program and the Peter half slope method were used to process in order to enhance the accuracy of the interpretation. The results revealed majority of the bitumen deposits occurred at a shallow depth of 27.6 meters and 27.8 meters through electrical and magnetic methods, respectively. The results provide vital information for upcoming exploration and extraction activities.

## INTRODUCTION

Bitumen is the heavy oil in tar sand. It is a sticky, black and highly viscous liquid or semi liquid form of petroleum. It may be occur as refined product or in natural deposits and it is a substance classified as a pitch (Muhammad, 1992). It is not soluble in water and its viscosity range is between 8 to 10 API degrees. It lies between density (kg/m) ranges of 1.0 to 1.18. It's boiling point is higher than $300^0$C with melting point ranging from $54^0$ –$173^0$C and flash point greater than $200^0$C (www.aboutcivil.org). Nigeria tar sand is made up of 84% sand, 17% bitumen, 4% water and 2% mineral clay (Enu, 1985, 1990). There are many geophysical methods and techniques that are used to delineate the subsurface structure of the earth (Marchetti et al., 1998; Gibson et al., 1996; Foley, 1994). Some of these methods includes electrical, magnetic, gravity, electromagnetic methods to mention a few (Musset and Khan, 2000; Kearey and Brooks, 2002). The electrical and magnetic methods which are suited for shallow exploration because oil sand occur at shallow depth of less than 1000m (Chopra and Lines, 2008; De-Hus et al.,2008 ), were made use of in this study. The electrical geophysical methods are used to determine the electrical resistivity of the earth's subsurface. The resolution, depth, and areal extent of investigation are functions of the particular electrical method employed (Nekut and Spies, 1989). 2D electrical imaging techniques can be used to define region of oil sand and obtain apparent resistivity and chargeability of the sub-surface of bitumen (Anukwu, *et al.,* 2014). Magnetic method is one of the geophysical methods used in prospecting for both oil and minerals. Magnetic method gives information about the depth to the basement rocks location and defines the extent of sedimentary basins where the basement rocks are brought near the surface and magnetic anomalies are large and characterized by strong relief (Adagunodo, *et al.,* 2015). Oil seepages, a reliable sign of bituminous sand, and its shallowness (Adeyemi and Dairo,2015; Adekoya, et al. 2024) found in ijebu – Itele Ijebu East Local Government of Ogun State, Southwestern Nigeria, both indicate the presence of bitumen in the study region. For this research work, the aim is to estimates the depth to the top of the bitumen deposits in a portion of ijebu - itele area Ogun State Southwestern Nigeria using electrical and magnetic methods.

**Geological Setting**

Ijebu-Itele is one of the major towns in Ijebu Kingdom. The community is part of Ijebu East Local Government. The study area is located within the eastern part of the Dahomey basin, Southwest of Nigeria between latitude 06°44' – 06°44' and longitude 003°58' – 003°60'. The study area belong to the Abeokuta group, the oldest group of sediment in the basin (Jones and Hockey, 1964). The Federal Ministry of Solid Minerals Development, (2006) also gives its age from ``Neocomium to Palaecocene. Omatsola and Adegoke (1981) recognised three (3) Formations in the Abeokuta group based on lithological homogeneity and similarity of origin. They include Ise, Afowo and Araromi Formations; a group, they represent the thickest unit within the basin. The study area belong to the Afowo formation. It is composed of coarse to medium grained sandstone with variable but inter bedded shale, siltstone and clay stone. The sandy facies are tar bearing while the shale are organic rich (Enu, 1985).

## MATERIALS AND METHODS

### Electrical Method

Five (5) 2D resistivity were carried out using the wenner configuration. The resistivity for the study areas was obtained using earth resistivity meter (Terrameter) ABEM model to determine the depth to bedrock and thickness of the bitumen deposit**.** This was done by injecting current into the ground and the resistivity is measured.The 2D data are processed with RES2DINV software that automatically represents the data into suitable 2D imaging pictures of the subsurface for each of the five profiles as shown below in figure A to E.

### Magnetic Method

The ground magnetic survey was carried out using portable proton precession magnetometer over at the study area. The global positioning system (GPS) was used to measure longitude and latitude along the traverse. The survey line was 300m and with a spacing of 5m. Raw ground magnetic data collected on the field sheet were transferred on the excel sheet for diurnal and international geomagnetic reference field IGRF corrections to filter out the regional anomaly from the total magnetic intensity to determine the residual anomaly. Magnetic curves for each profile was generated to estimate the depth of the bituminous sand using Peter half slope method.This technique calculate the depth estimation of buried magnetic body to the top of the basement rocks. The slope of the curve created by the anomaly in each profile data determine the estimation of the depth of magnetic anomaly. This is done by determining two points at which lines with half the maximum slope are tangent to the magnetic profile and by dividing the horizontal distance by an index value of 1.2, 1.6.and 2.0.

## RESULTS AND DISCUSSION

### Results of Electrical Resistivity

**Table 1: Summary of Profiles, Stratified Layers, Depth and Their Electrical Resistivity Estimates on Electrical Data in Ijebu-Itele**

| Profile | Stratified Layer | Depth (M) | Electrical Resistivity(≈ Ωm) |
|---|---|---|---|
| 1 | 1 | 2.75 -6.5 | 820 -1200 |
| | 2 | 6.6 – 24.7 | 720 -2500 |
| | 3 | 15.2 – 42.0 | 238 -850 |
| | 4 | 42.2 – 53.5 | 20.5 – 190 |
| | 5 | 45.6 – 53.5 | 238 – 380 |
| | 6 | 50.7 – 53.5 | 525 – 3015 |
| **2** | 1 | 2.75 – 15.4 | 845 -2850 |
| | 2 | 9.35 – 31.25 | 450 – 950 |
| | 3 | 31.3 – 45.2 | 225 – 320 |
| | 4 | 32 - 55.7 | 55 – 195 |
| 3 | 1 | 2.75 – 44.2 | 445 – 1850 |
| | 2 | 12.75 – 54.5 | 175 – 420 |
| 4 | 1 | 2.75 – 44.2 | 525 – 4355 |
| | 2 | 44.3 – 48.9 | 168 – 375 |
| | 3 | 49.0 -54.0 | 4.4 – 150 |
| 5 | 1 | 2.57 – 19.4 | 545 – 1396 |
| | 2 | 19.7 – 55.5 | 85 – 375 |
| | 3 | 18.5 – 52.5 | 386 -745 |

**Table 2: Depth Estimates of Bitumen Deposit in Ijebu–Itele**

| Profile | Depth Estimate for Electrical Data (m) |
|---|---|
| 1 | 19.4 |
| 2 | 8.0 |
| 3 | 12.9 |
| 4 | 27.6 |
| 5 | 13.9 |

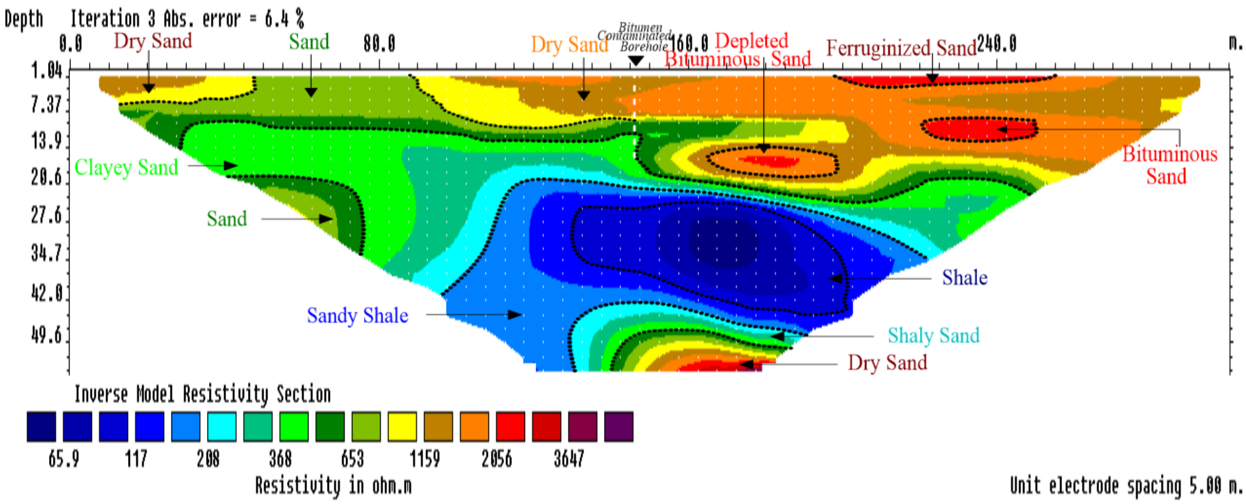


Figure 1: Electrical Resistivity Section Along Profile 1

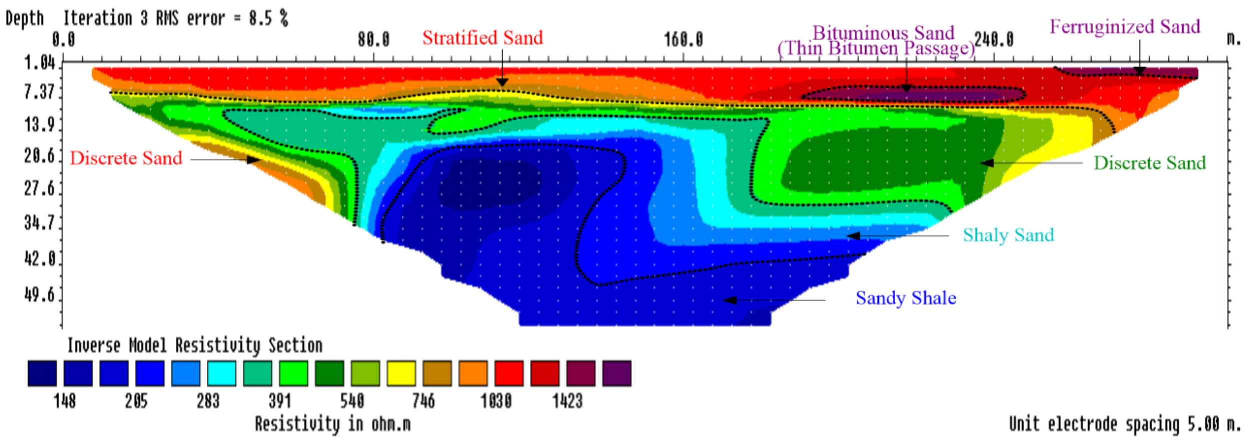


Figure 2: Electrical Resistivity Section Along Profile 2

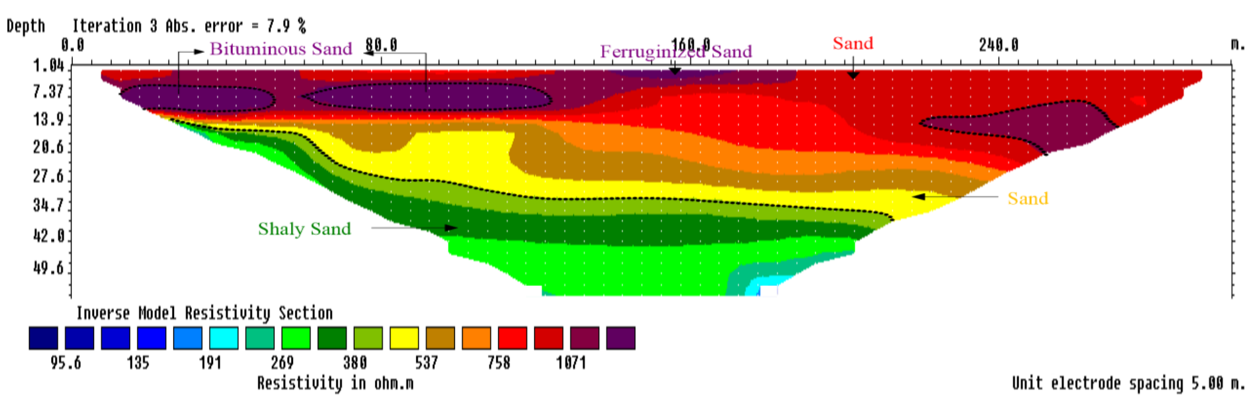


Figure 3: Electrical Resistivity Section Along Profile 3

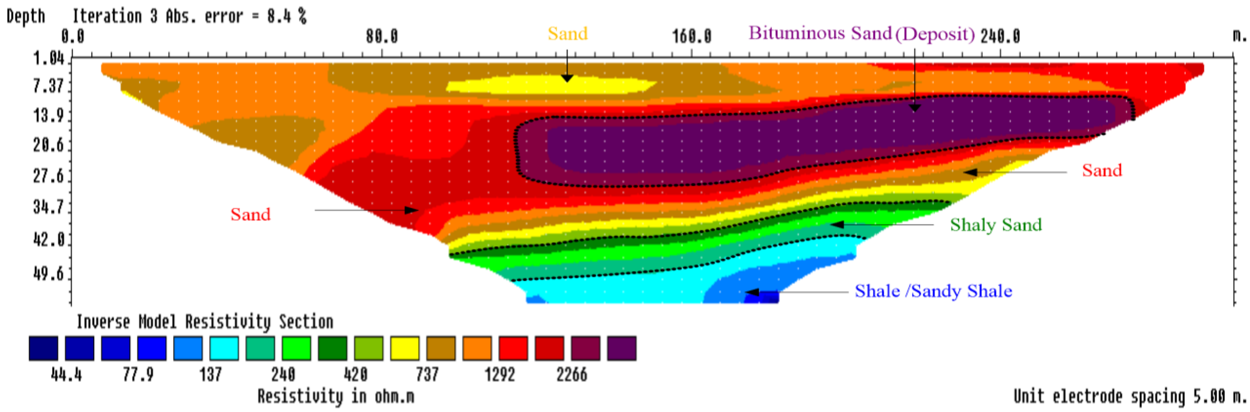

Figure 4: Electrical Resistivity Section along profile 4

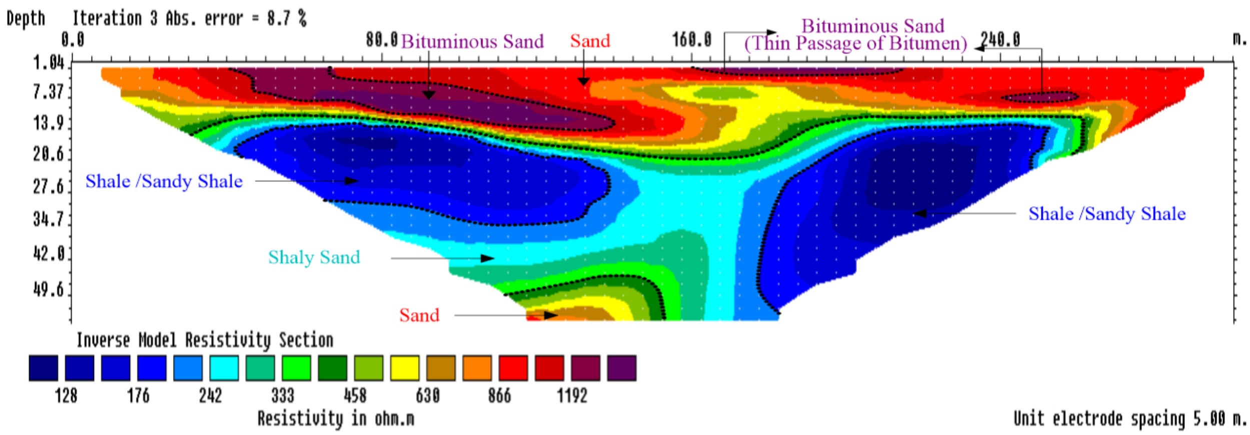

Figure 5: Electrical Resistivity Section along Profile 5

## Discussion of Results

### *Discussion of Result on Electrical Resistivity*

Lithostratigraphic revelations on the resistivity sections along profile 1(Figure 1) can be broadly divided into three (3) major geo-electric strata. The first stratum is extensively composite stratum comprising of four geo-electric units which uniquely varied from 208 Ωm – 421 Ωm for clayey sand, 501 Ωm – 1035 Ωm for sand, 1159 Ωm – 2056 Ωm for dry sand and > 2056 Ωm indicative of bituminous sand (Akinmosin, et al., 2013; Coker, et al., 2020). The stratum is inferentially a composite sand stratum of varying composition, texture and temperature. With respect to the stratigraphic positioning, the ferruginized sand unit is apparently the youngest within the stratum; occurring between distance-mark 200 m – 250 m., and depth 0 – 2.5 m. It is underlain by a composite sand stratum running from the 100 m mark to the end of the profiles between a depth interval of 0 – 20 m. This sand stratum is impregnated by bitumen bulges between distance-mark 165 m – 195 m and depth 13.9 m – 19.4 m; and also between distance-mark 220 m – 250 m and depth 9 m – 11.2 m. Near the start of the profile, between distance 35 m – 90 m, a contrasting electro-facies comprising of a repetitive layering of sand and clayey sand is delineated, to a thicker depth of 37.1 m (fig. 1). On comparative basis, the lithologic variation exhibited by the stratum can be apparently linked to changes in depositional condition which brought about the upward hydrocarbon migration and subsequent ferruginization of the segment. Stratum-2 underlies the thick composite sand stratum. It is a relatively conductive 60 Ωm – 178 Ωm layer inferred as a shale / sandy shale stratum, encountered at an irregular depth of about 20 m – 42 m while ranging in thickness from 21 m to infinity – with respect to the probed depth on the resistivity section. Below the shale/sandy shale stratum lie a thin 205 Ωm – 421 Ωm transitory layer inferred as clayey sand. The termination of the layer graded into a highly resistive 505 Ωm – 3605 Ωm sand stratum (fig. 1) which extended to infinity.

Geo-electric setting presented by the resistivity section along profile 2 (fig. 2) differ slightly. By inference, from top to bottom, it revealed an approximately 9.5 m thick, 450 Ωm – 1213 Ωm laterally extensive composite sand stratum which run through the entire stretch of the profile; and between distance-mark 190 m – 247 m and depth 6.2 m – 8 m impregnated by 1423 Ωm – 1713 Ωm resistive body indicative of bituminous (Akinmosin, et al., 2013; Coker, et al., 2020). Occurring beneath the upper stratified composite sand stratum, are thick discrete geo-electric units which between distance-mark 0 – 75 m and 180 m – 300 m and depth 7.0 m – 34.7 m possessed a resistivity range of 391 Ωm - 1031 Ωm and thickness range of 21 m – 24 m; corresponding to the discrete sand units. These two units are laterally separated by a pseudo-diapiric structure whose summit is characterized by a resistivity of 205 Ωm - 391 Ωm between distance 85 m – 150 m and depth 12 m – 17.5 m (fig. 2). Lithologic inference is shaly sand. At the flank of the shaly sand structure between distance-mark 155 m – 175 m, the shaly sand is drastically thicker; ranging from 17.6 m to 32 m, between a depth interval of 12 m to 44 m. the basal part of the structure is by a far a thicker and relatively conductive unit possessing a resistivity range of 121 Ωm – 196 Ωm, and by inference, a sandy shale body whose thickness extend to infinity – with respect to the maximum probed depth.

Along profile 3, the resulting resistivity section (fig. 3) depicted an electrostratigraphy characterized by decrease in resistivity with depth. This stratigraphic setting can be broadly divided into two (2), namely; the *resistive upper stratum* which ranges between 431 Ωm – 1057 Ωm, and the *weakly-resistive lower stratum*, characterized by an inherent resistivity range of 265 Ωm – 409 Ωm (fig. 3). Corresponding inference for the upper and lower stratum is sand and shaly sand respectively. From distance-mark 0 m – 188 m and depth 0 – 10 m, the sand stratum possessed closures of isolated anomalous resistivity impregnations which can be secondarily inferred as shallow bituminous sand (Akinmosin, et al., 2013; Coker, et al., 2020). Thickness of this inclined sand stratum varied between 12 m from the origin to 30 m at the end of the profile. The underlying shaly sand stratum extends to infinity.

A well sequenced electro stratigraphy is also reflected on the resistivity section along profile 4 (fig. 4). Its geo-electric settings, from top to bottom, similarly revealed a very thick resistive top with a thickness range of 32.3 Ωm – 44 m, and an infinitely extended conductive base of 100 Ωm – 175 Ωm. Lithologic inference for the resistive stratum is composite sand, and sandy shale for the conductive stratum. Between these two strata, there is a 6 m-thick 205 Ωm – 362 Ωm transitory shaly sand stratum (fig. 4); which is quite indicative of a conformable stratigraphic relation. The most prominent resistivity impregnation (> 2266 Ωm) which is an indication of bituminous sand (Akinmosin, et al., 2013; Coker, et al., 2020) within the delineated sand stratum of the area occur along this profile, between distance-mark 115 m – 275 m, and depth 8 m – 27.6 m as a 160 m long near-surface economically viable bituminous sand deposit with an appreciable thickness-range of 8 m – 13.9 m.

Electrical resistivity section – 5 (fig. 5) similarly replicated the intercalated electro stratigraphic settings revealed along profile 1. Resulting geo-electric sequence, from top to bottom, revealed a 405 Ωm – 1191 / 1191 Ωm – 1315 Ωm composite sand stratum, underlain by two discrete conductive clay bodies exhibiting a resistivity range of 103 Ωm - 186 Ωm, and the latter are separated from each other by a weakly resistive unit of 221 Ωm – 386 Ωm (shaly sand). These discrete and separating units are in turn partly underlain by a basal stratum of higher resistivity range of 413 Ωm – 630 Ωm (fig. 5). The stratigraphic interpretation of sequence, by inference, is a succession of bitumen-impregnated upper composite sand stratum, underlain by discrete conductive sandy shale units, which are separated weakly resistive shaly sand block. Both the shaly sand and sandy shale are in turn underlain by the relatively resistive lower sand, thereby setting up a repetitive deposition cycle. Thickness of the upper composite sand stratum varied between 12 m near the margins to about 20 m at the centre. The main bitumen impregnation within this stratum occur directly over the isolated sandy shale block near the origin with a resistivity range of 1191Ωm to 1315Ωm (Akinmosin, et al., 2013; Coker, et al., 2020). It is a shallow obliquely inclined deposit, positioned between distance mark 40 m – 140 m and depth 1m – 13.9 m. Stratigraphic thickness of the shale/sandy shale near the origin is essentially 15 m but can be mapped between depth 13.5 m – 35 m (fig. E) due to its inclined orientation. However, the thickness of the other shale/sandy shale block near the profile-end extends to infinity with respect to the penetrated depth on the section.

***Result of Ground Magnetic Data***

**Table 3: Summary of Depth Estimate from Ground Magnetic Data in Ijebu–Itele**

| Profile | Very Thin Body (M) | Intermediate Thickness (M) | Very Thick Body(M) | Average (M) |
|---|---|---|---|---|
| 1 | 23.8 | 17.8 | 14.3 | 15.3 |
| 2 | 18.9 | 15.1 | 12.1 | 15.7 |
| 3 | 20.1 | 18.5 | 14.8 | 19.3 |
| 4 | 27.8 | 20.9 | 16.6 | 21.8 |
| 5 | 18.7 | 22.0 | 17.6 | 23.0 |

**Table 4: Comparison of Depth Estimates Between Electrical Data and Ground Magnetic Data in Ijebu-Itele**

| Profile | Depth Estimate for Electrical Data (m) | Depth Estimate for Ground Magnetic Data(m) |
|---|---|---|
| 1 | 19.4 | 23.8 |
| 2 | 8.0 | 18.8 |
| 3 | 12.9 | 20.1 |
| 4 | 27.6 | 27.8 |
| 5 | 13.9 | 18.7 |

***Discussion of Result on Magnetic Survey***

The result obtained by using Peter Half Slope method on the magnetic curves are tabulated in table 3. The magnetic curves for each of the profile were generated and are as shown below. The estimates of the depth gotten from the method as shown in table 3 collaborate the result obtained using the electrical method. Also the comparison between the estimates of the depth gotten from the integrated method as shown in table 4 shows that the bitumen deposit occur at a shallow depth less than 30 m. in the study area (Akinmosin, et al., 2013; Coker, et al., 2020).

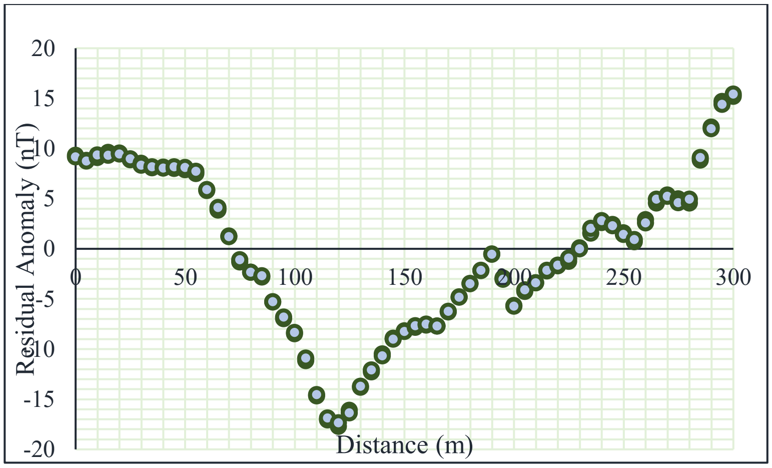

Figure 6: Magnetic Anomaly Curve on Profile 1

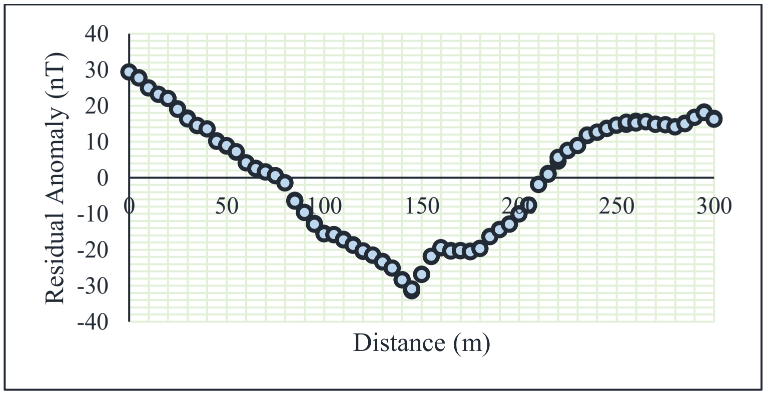

Figure 7: Magnetic Anomaly Curve on Profile 2

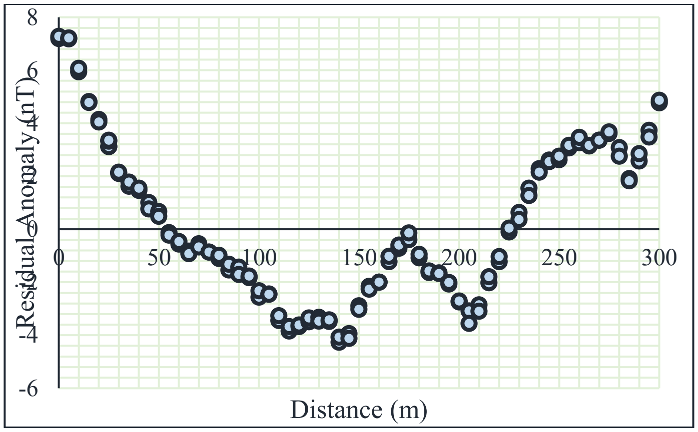


Figure 8: Magnetic Anomaly Curve on Profile 3

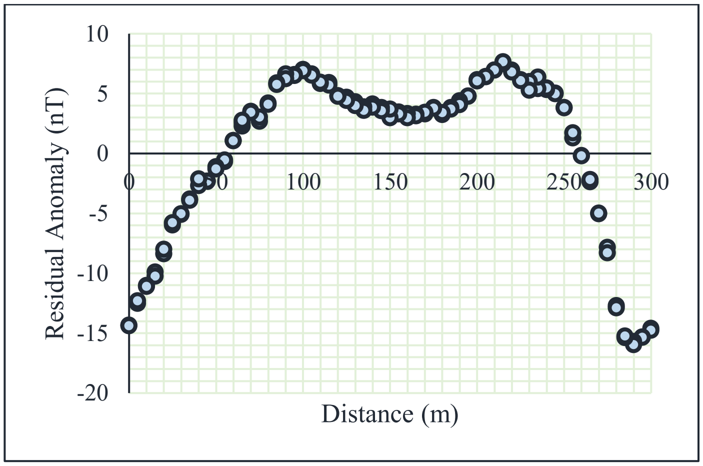


Figure 9: Magnetic Anomaly Curve on Profile 4

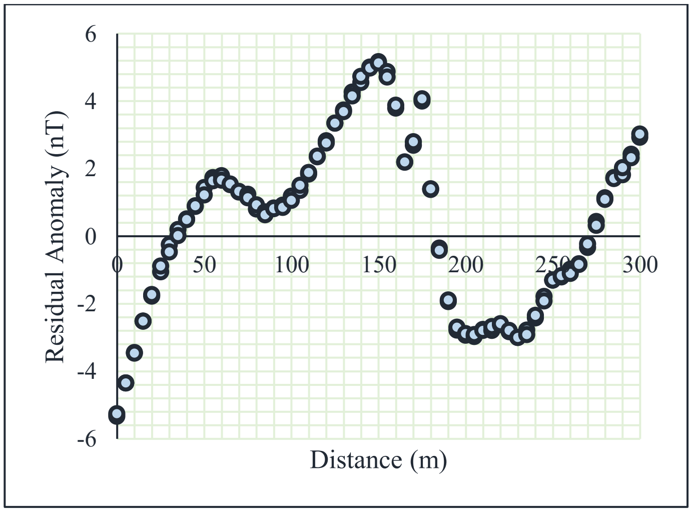


Figure10: Magnetic Curve on Profile 5

**CONCLUSION**

Oil sand thickness relative to depth and also the difference in its high resistivity with respect to the reistivity of the host geology are characteristics that have made geo electric exploration useful in mapping out region of occurrence. The bitumen deposit of the study areas abounds within the upper composite sand stratum of the investigated segments of Afowo formations, at a general prospective shallow depth less than 30 m.

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