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Characterization of a bitumen seepage in Eastern Dahomey Basin, SW, Nigeria

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ABSTRACT

Bitumen represents an alternative energy source. They are found in boreholes and as seepages in south western Nigeria. Geophysical survey and sedimentological analysis was carried out on the bitumen seepage at onikitibi (longitude: 04° 18' 18" E and latitude: 06° 39' 39" N) with a view to elucidate its electrical and lithological characteristic. Electrical resistivity profiling and one vertical electrical sounding along a profile of inter-electrode spacing of 5m-30m, and 1000m were carried out using the Wenner and Schlumberger electrode configuration along the seepage zone. Three samples collected from the exposure were subjected to granulometric analysis in order to determine their particle size distribution and textural characteristics. The samples are gravelly and muddy sandstones that are unimodal, coarsed skewed and poorly sorted. The three samples are mesokurtic and platykurtic. The provenance suggests a single source of sediment supply that is close to the study area which implies the sediments are texturally immature. The bitumen seepage has resistivity value of >4219Ωm on the 2D profile and it could not be detected with the Vertical Electrical Sounding (VES) method. Geometrically, the seepage extends ~14m (West to East) and 11m deep. The VES result imaged the Ise Formation which underlain the Afowo Formation in which the Bitumen is housed. The study established that the bitumen has high resistivity in contrast to previous values obtained in other parts of the basin. Therefore, bitumen in the basin has both low and high resistivity values.

Keywords: Bitumen, Seepages, Facies, Resistivity, Profiling, VES, Afowo, Ise.

INTRODUCTION

The occurrence of bitumen in southwestern Nigeria has been recorded from boreholes and seepages (Omatshola and Adegoke, 1981). The oil sand outcrops in an E-W belt, approximately 120km long and 4-6km wide, extending from Edo/Ondo-Ogun States (Enu, 1985). Occurrence of the seepage and tar sand deposit over the Okitipupa ridge in the Dahomey basin provided the initial impetus for oil exploration in Nigeria. The bitumen occur**s** in two horizon-bearing sediments designated as "X" and "Y" horizon, the X-horizon, being the shallower of the two deposits, constitutes the prominent outcropping unit in most areas, though significantly eroded in the north western part of the basin. The thickness varies from 9m to about 22m with an average of 15m. The Y- horizon is the prominent outcropping sequence in the northwestern part of the structure where "X" has been largely eroded. Its thickness varies widely from 3m in the east to 22.6m in the west with an average of about 12m.

As part of our effort to provide a research data base for the bitumen occurrences and Geology of the Eastern Dahomey in Ogun state, we attempt to establish the bitumen electrofacies of the study area owing to contrasting values obtained in different part of the basin; very low resistivity value in Idiobiolayo and Idipopo (BEECON, 2004, Odunaike et al, 2010), and Imobi (Ikhane et al 2011) in contrast to very high resistivity value expected for hydrocarbon. In this work we aim to (a) identify the lithofacies of the Tar sand using grain size analysis (b) determine the depth of occurrence of the Bitumen seepage (c) define its geometry (d) and use VES to validate results from electrical profiling over the seepage.

In so doing the following assumptions were made (1) that the occurrence of bituminous seepages is limited to the Afowo formation. (2) Subsurface occurrences of bituminous sands and heavy oils are known from flows and shows in drilled and cored wells in the onshore, coastal and offshore areas of the Dahomey basin. (3) The bitumen will have high resistivity values except when associated with saline water or any other conductive fluid (Haliburton, 2001).

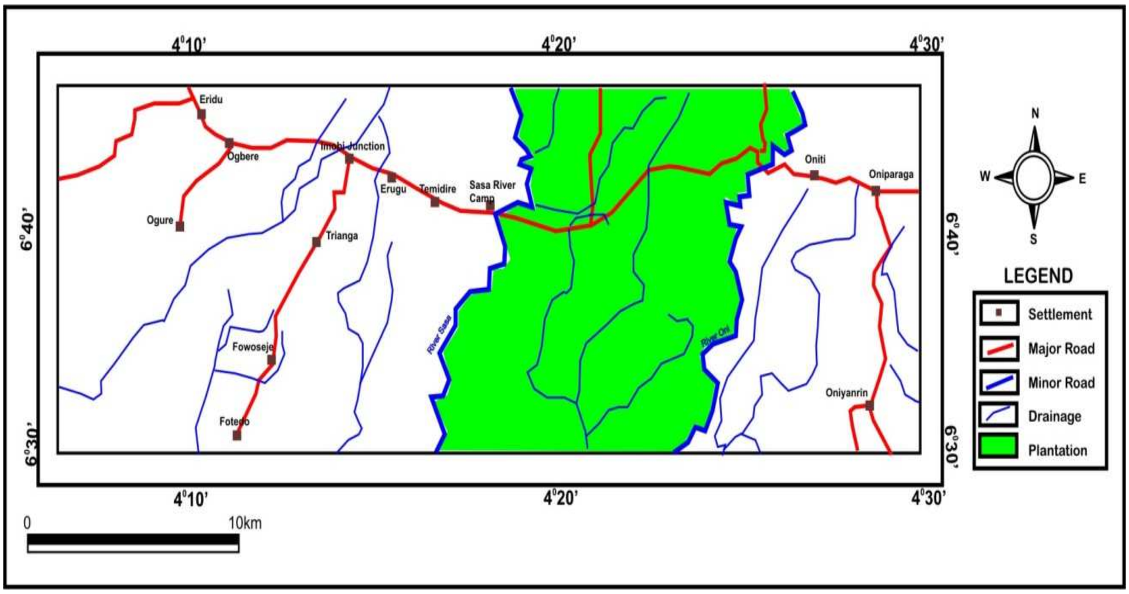

Fig 1: Map of the study Area

Local Setting

The study area lies on longitude 004° 18' 18" E and latitude 006° 39' 39" N, an area of lowlands with few ridges. Relative to the lowlands, the hills are very high which are characteristic of the tropical rain forest of south western Nigeria. The temperature is relatively high during the dry season with temperature reaching about 30°C. The harmattan brought in the northeasterly winds from December to February, which has ameliorating effects on the dry season high temperatures. Low temperatures are experienced during the rains, especially between July and August when the temperatures could be as low as 24°C (Akintola, 1986). The distribution of rainfall varies from about 1000mm in the western part to about 2000mm in the eastern part; the high rainfall promotes perennial tree growth with varying height. The area is well drained by NE-SW trending rivers such as Lekki, Ogun, Shasha, Oba and Opeki.

Previous research works on the bitumen of the area include Jones and Hockey (1964), Fayose (1970), Kogbe (1976), Omatsola and Adegoke (1981), Enu (1985), Odunaike et al (2009), Akinmosin et al (2011), Akinmosin and Shoyemi (2010). Recent application of electrical geophysical method in studying sedimentary sequence in around the dahomey basin include Ogungbe et al 2010, George et al 2011, Jegede et al 2011, Ozegin & Oseghale, 2012, Nwozor et al 2012 just to mention a few.

Regional Geologic Setting and Stratigraphy

The Benin (Dahomey) Basin constituting part of a system of West African peri-cratonic (margin sag) basin (Klemme 1975; Kingston et al 1983) developed during the commencement of the rifting, associated with the opening of the Gulf of Guinea, in the Early Cretaceous to the Late Jurassic (Burke et al, 1971; Whiteman, 1982). The crustal separation, typically preceded by crustal thinning, was accompanied by an extended period of thermally induced basin subsidence through the Middle – Upper Cretaceous to Tertiary times as the South American and the African plates entered a drift phase to accommodate the emerging Atlantic Ocean (Storey, 1995; Mpanda, 1997).

The Ghana Ridge, presumably an offset extension of the Romanche Fracture Zone, binds the basin to the west while the Benin Hinge Line, a Basement escarpment which separates the Okitipupa structure from the Niger Delta basin that binds it to the east. The Benin Hinge Line supposedly defines the continental extension of the Chain Fracture Zone.

The onshore part of the basin covers a broad arc-shaped profile of about 600 km^2 in extent. The onshore section of the basin attains a maximum width, along its N-S axis, some 130 km around the Nigerian – Republic of Benin border. The basin narrows to about 50 km on the eastern side where the basement assumes a convex upwards outline with concomitant thinning of sediments. Along the northeastern fringe of the basin where it rims the Okitipupa high is a brand of tar (oil) sands and bitumen seepages (Nwachukwu and Ekweozor, 1989).

The lithostratigraphic units of the Cretaceous to Tertiary sedimentary sequence of eastern margin of Dahomey basin according to Idowu et al.,(1993), are summarized in Table 1. The study area belongs to the Ise Formation of the Cretaceous Abeokuta group, the oldest group of sediment in the basin unconformably overlying the basement (Jones and Hockey, 1964). Omatsola and Adegoke (1981) on the lithostratigraphy of Dahomey basin recognized (3) formations belonging to the Abeokuta group based on lithologic homogeneity and similarity of origin. This group is the thickest sedimentary unit within the basin. The formations from oldest to youngest are Ise, Afowo and Araromi formation.

Ise formation unconformably overlies the basement complex of Southwestern Nigeria, consisting of conglomerates and grits at the base which is in turn overlain by coarse to medium grained sands with interbeded kaolinite. The conglomerates are imbricated and at some locations ironstones occur (Nton, 2001). An age range of Neocomian-Albian is assigned to this formation based on paleontological assemblages.

Afowo formation overlies the Ise formation, and composed of coarse to medium grained sandstone with variable but thick interbedded shale, siltstone and claystone. The sandy facies are tar-bearing while shales are organic-rich (Enu, 1985). Using palynological assemblage, a Turonian age is assigned to the Lower part of this formation, while the upper part ranges into Maastrichtian.

The youngest Cretaceous formation in the group is Araromi formation, which conformably overlies the Afowo formation. It is composed of fine-medium grained sandstone at the base, overlain by shales, silt-stone with interbedded limestones, marl and lignite. Omatsola and Adegoke (1981) assigned a Maastrichtian to Paleocene age to this formation based on faunal content.

The Abeokuta group is overlain by the Imo (Ewekoro and Akinbo formation- Adegoke, 1977, Jones and Hockey, 1964, Ogbe, 1972, Nton and Elueze, 2005, Nton 2001), the Oshosun formation (Jones and Hockey, 1964; Nton, 2001), Coastal plain sands and the Recent Alluvium(Jones and Hockey, 1964)

Table 1: The stratigraphic units of Eastern Dahomey Basin

Jones and Hockey(1964)		**Omatsola and Adegoke (1981)**			**Agagu (1985)**	
	Age	Formation	Age	Formation	Age	Formation
Quaternary	Recent	Alluvium			Recent	Alluvium
Tertiary	Pleistocene- Oligocene Eocene Palaeocene	Coastal Plain Sand Ilaro Ewekoro	Pleistocene- Oligocene Eocene Palaeocene	Coastal Plain Sand Ilaro Oshosun Akinbo Fm	Pleistocene- Oligocene Eocene Palaeocene	Coastal Plain Sand Ilaro Oshosun Akinbo Ewekoro
Cretaceous	Late Senonian	Abeokuta	Maastrichtian- Neocomian	Araromi Afowo Ise	Maastrichtian- Neocomian	Araromi Afowo Ise
Precambrian Crystalline Basement Rocks						

MATERIALS AND METHODS

Sample Preparation

The seepage samples were collected randomly based on visual discrimination of the material housing the bitumen, where a facies change was suspected, a sample was collected. Three facies were identified visually on the field and were labeled A-C from West to East of the outcrop (fig.2c&d). The samples were collected with the aid of a trowel**,** labeled according to their point of collection and were packed in polythene bags. The samples were later soaked in detergents for a day, washed and the tar or filtrate subsequently decanted. The procedure was repeated till the samples were clean of bitumen. The unwashed ditch cutting sample was initially rinsed to remove mud and dried. A heap of 500g of sand and gravel are collected into a cone. The cone is cut into quarters with a spatula. A quarter is picked. A standard weight of about (20g to 30g) of each dried sample is soaked for four hours in kerosene, followed by water soaking overnight. The disaggregated sample is then washed under a shower of water over a 63 micron mesh sieve. The washed residue was then dried over a hot plate. A set of sieves was arranged, in which at the top coarser and downward to finer (4, 2, 1, 0.425, 0.250, and 0.0625). Then the set of sieves vibrated mechanically by using a shaker for 15 minutes. The weight of the remaining sand in each sieve is obtained separately using a weight balance.

Fig 2: (a) The Ohmeter Resistivity Meter used for the resistivity survey (b) Reeling of the Cables through the thick vegetation above the Seepage (c) The Bitumen Seepage, associated with is water running down the hill (d) Sample collection point for the lithofacies description

Statistical Analysis

A size-frequency curve was made by plotting the proportion, in per cent, of various particle sizes whose class limits are expressed by the units on the phi scale. Conventionally, frequency is plotted along the vertical axis (ordinate) and the phi sizes along the horizontal axis (abscissa). The particles sizes in millimeter were converted to phi values. The principal advantage of the phi scale are that (1) the distribution of particle sizes can be plotted with ease on arithmetic graph paper, obviating the necessity of logarithmic graph paper, and calculation of various statistical parameters; limiting particle diameters for each size class become whole numbers instead of fractions of millimeters or micron values employing two or three digits and (3) because of this negative log usage, increasing phi values correspond to decreasing particle sizes; this usage agrees with geological practice. The statistical parameters estimated include Median (Md), Graphic Mean (Gm), Graphic Mean, Sorting and Graphic Kurtosis (Gk)

Geophysics

2D profiling

Electrical resistivity profiling was done in order to delineate the lateral and vertical variation in subsurface resistivity properties along the seepage; a pointer to the geometry of the seepage and subsurface lithological distribution. The wenner electrode configuration was used with an assumption that the resistivity doesn't change in a direction perpendicular to the survey line.

The Wenner configuration entails that constant electrode spacing is maintained between the adjacent electrodes as the whole spread is transverse along the survey line. The electrode spacing between the adjacent electrodes was assigned "a" with initial spacing of 5m used and subsequent spacing being multiples of 5. The maximum electrode spacing used was 30m with a view to making observation at approximate depth of 18m over a survey line of 100m across the outcrop of the seepage. The survey method is described below:-

For a system with 20 electrodes, it has to be noted that there are (20-(1x3)), (20-(2x3), (20-(3x3), (20-(4x3) possible measurements for "1a", "2a", "3a", "4a" electrode spacing respectively and so on, for Wenner array. This implies that, as the electrode spacing increases, the number of measurement decreases.

The first procedure is to carry out all the possible measurements for the Wenner array with an electrodes spacing of "1a". For the first measurement, electrodes number 1, 2, 3 and 4 were used. Electrode 1 was used as the first current electrode (C_1), electrode 2 as the first potential electrode (P_1), electrode 3 as the second potential electrode (C_2) and electrode 4 as the second current electrode.

For the second measurement, electrodes number 2, 3, 4 and 5 were used for C_1, P_1, P_2 and C_2 respectively. This is repeated down the line of electrodes until electrodes 17,18,19,20 are used for the last measurement with "1a" spacing for Wenner array.

After completing the sequence of measurement with "1a" spacing, the next sequence of measurement with "2a" is made. Firstly, electrodes number 1, 3, 5 and 7 were used for the first measurement. The electrodes were chosen so that the spacing between the adjacent is "2a" for the second measurement, electrodes 2, 4, 6 and 8 were used. This process is repeated down the last measurement with spacing "2a".

The same process is repeated for measurements with "3a", "4a", "5a"and "6a" spacing. To obtain the best result, the measurements in this survey were carried out in a systematic manner so that, as far as possible, the possible measurements were made (Loke and Baker, 1996a&b). This will affect the quality of interpretation model obtained from the inversion of the apparent resistivity measurements.

Vertical Electrical Sounding (VES) Survey

This resistivity procedure was used to estimate the depth of occurrence of the bitumen seepage due to the depth limitation of the profiling technique. The Schlumberger electrode array was adopted; the current and potential electrodes were progressively expanded symmetrically about a fixed central point (station) along a well defined profile. In VES Schlumberger array, the current electrode separation was ensured to be at least five times that of the potential electrode. As the distance between the current electrodes was progressively increased, the potential electrode remained unchanged until the voltage was too small to measure. The potential electrode separation was then increased in order to be moved between successive readings. A VES station was chosen opposite the bitumen Seepage over a profile length of 500m.

RESULTS AND DISCUSSION

Granulometric Analysis

The result of the granulometric analysis is shown in the table 1&2; other than the well established fact that tar/bitumen are found in sands, occurrences of tar in shale are also well documented. The main objective of this section is to determine whether the tar bearing material is sand or shale. From the plot of the histogram (Fig. 3), the three samples are unimodal implying the sediments are derived from a single source, there is a dominance of the phi 3 & 4 sediment size this however does not provide any result on the closeness of the sediment to their source area.

An estimation of the textural maturity of the sediments revealed the sediments are poorly sorted suggesting heterogeneity of sediments size and high matrix content, and texturally immature sediments. The sediments are derived from a nearby source or rock.

The skewness provides information on the symmetry of the frequency curve. A positive value for skewness indicates a trailing off of the curve to the right of the mean and an excess of fine particles. A negative number means a trailing off of the curve to the left of the mean and an excess of coarse particles. The three samples have a negative skewness values indicating an excess of coarse particles. Sample A, -0.5 (Strongly coarsed skewed); Sample B, -0.27 (Coarse skewed); while Sample C, -0.15 (Coarse skewed).

The frequency distribution curve (Fig.3&5) shows that the sediments are mostly derived from near beach sands, the frequency distribution of beach sands are symmetrical, negatively skewed, and the slope of the cumulative curve reflected the degree of sorting. The slopes of the segments implied that the sediments are product of saltation and not of suspension, traction, and sliding. A plot of skewness against sorting means that the sediments plotted in the field of near beach sands (fig 5).

Sample A is platykurtic with a kurtosis of 0.96, Sample B is very platykurtic (0.86) while sample C is Mesokurtic with a kurtosis of 1.11. All these values are indicative of the peakedness of the frequency curve and dominance of a particular class size.

The sediments can be characterized as follows:-

Sample A: Sandy pebble gravel, moderately sorted, strongly coarsed skewed, platykurtic

Sample B: Very fine muddy sand, very poorly sorted, coarse-skewed, very platykurtic.

Sample C: Sandy pebble gravel, moderately sorted, coarsed skewed, mesokurtic.

Resistivity Analysis

The results obtained from the 2D profiling is plotted as a pseudosection in Fig 4. The apparent resisitivty value obtained on the field were inverted using both smooth and robust inversion on the RESINV 2D ver 3.55 software in order to obtain the true geometry of the seepage, plot electrode spacing as true depth, and also produce a geological model (Fig 4). The resistivity pseudosection was interpreted using two (2) different approaches; (a) On the basis of regional stratigraphy and (b) several 1D interpretation along the pseudosection. The results obtained were compared with those of the VES station below the point of the seepage. The inferred geology and resitivity of the layers from the VES is shown in table 3 and those of the 1D points on the pseudosection in Table 4.

The result from the resistivity profile is presented as follows:-

Method 1: Three Sandstone facies were identified from the pseudosection and were labeled AF_1, AF_2 and AF_3 with resistivity value of >4219Ωm, 1925-2850 Ωm and 878- 1300 Ωm respectively, this units are thought to belong to the Afowo Formation of the Abeokuta group in the Eastern Dahomey basin. The AF_1 is thought to house the bitumen seepage; the high resistivity value recorded is indicative of the presence of Hydrocarbon, implies less conductivity, and the absence of saline water or conductive water. Other units interpreted are the conglomeratic sand with resistivity value in the Domain of 593- 878 Ωm and the weathered basement with value of < 593 Ωm. regionally; the conglomeratic sand is thought to belong to the Ise Formation of the Abeokuta group.

Lithologically, the AF_1 abuts on the conglomeratic sand and weathered basement; with these two units being overlain by the AF_3 sandstone facies. The Tar bearing AF_1 is overlain by the AF_2 which is not present on the eastern end of the profile.

The bitumen seepage is estimated to extend at ~14m along the East-West direction and at depth to about 11m.

Method 2: Four (4) lithological units, resistive sandy topsoil, sandstone, tar sand and sandstone with resistivity value of 878-1925, 1925-2850, >4219, and 2850 Ωm were interpreted from Point A, B to C. Underneath point B and C, three and two layers were identified respectively, resistive sandy topsoil, conglomeratic sandstone, and weathered basement, and sandy topsoil and weathered basement respectively.

The bitumen seepage is 5.62m thick at point A and was not detected on point B and C, which justifies the interpretation that the bitumen Seepage is restricted to the western end of the profile.

Three lithological units were identified from the VES results, the VES point was chosen directly opposite and at depth beneath the bitumen Seepage in order to ascertain the occurrence of the bitumen at greater depth. The topmost layer is interpreted as sandy clayey topsoil with resistivity value of 176.00Ωm, underlain by another sandy clayey layer with resistivity value of 150.94Ωm; the third layer is interpreted to be a weathered basement. Three interpreted layers have thickness of 1.05m, 12.18m, and infinity.

Regionally the Bitumen is housed by the Afowo Formation which overlies the Ise Formation; it therefore means that the VES has only imaged the Ise Formation which is stratigraphically lower than the Afowo Formation. Evidence of the bitumen was seen at lower stratigraphic layers some few distances from the point of the seepage; the outcrop is flat lying with relicts of bitumen on it (see fig 5). On the other side of the road, opposite this layer is an outcrop of reddish brown conglomeratic sandstone of the Ise Formation.

Table 1: Grain Size analysis for the samples collected for the lithofacies analysis

SAMPLE A	Nomenclature	Grain size(inches)	Weight(g)	Weight (%)	Cum. Weight (%)
A1	Granule	0.157	3	9.175	9.175
A2	Very Coarse	0.787	4	12.23	21.405
A3	Coarse	0.394	5	15.3	36.705
A4	Medium	0.0165	20	61.16	97.865
A5	Fine	0.0098	0.5	1.523	99.388
A6	Very fine	0.0049	0.2	0.612	100
A7	Silt	0.0025	0	0	100
		Gravely Sandstones	32.7	100	
B	Nomenclature	Grain size(inches)	Weight(g)	Weight (%)	Cum. Weight (%)
B1	Granule	0.157	0	0	0
B2	Very Coarse	0.787	3	16.67	16.67
B3	Coarse	0.394	5	27.78	44.45
B4	Medium	0.0165	4	22.22	66.67
B5	Fine	0.0098	2	11.11	77.78
B6	Very fine	0.0049	2	11.11	88.89
B7	Silt	0.0025	2	11.11	100
		Muddy Sandstones	18	100	
C	Nomenclature	Grain size(inches)	Weight(g)	Weight (%)	Cum. Weight (%)
C1	Granule	0.157	2	16.667	16.667
C2	Very Coarse	0.787	2	16.667	33.334
C3	Coarse	0.394	4	33.333	66.667
C4	Medium	0.0165	2	16.667	83.334
C5	Fine	0.0098	1	8.333	91.667
C6	Very fine	0.0049	0.6	5	96.667
C7	Silt	0.0025	0.4	3.333	100
		Gravelly Sandstone	12	100	

Table 2: Calculated statistical parameters from the cumulative frequency curve.

Sample	Median	Graphic Mean	Sorting	Skewness	Kurtosis
A	0.2	-0.083	1.625	-0.5	0.96
B	0.2	-0.62	2.63	-0.27	0.86
C	-0.5	-0.62	2.7	-0.15	1.11

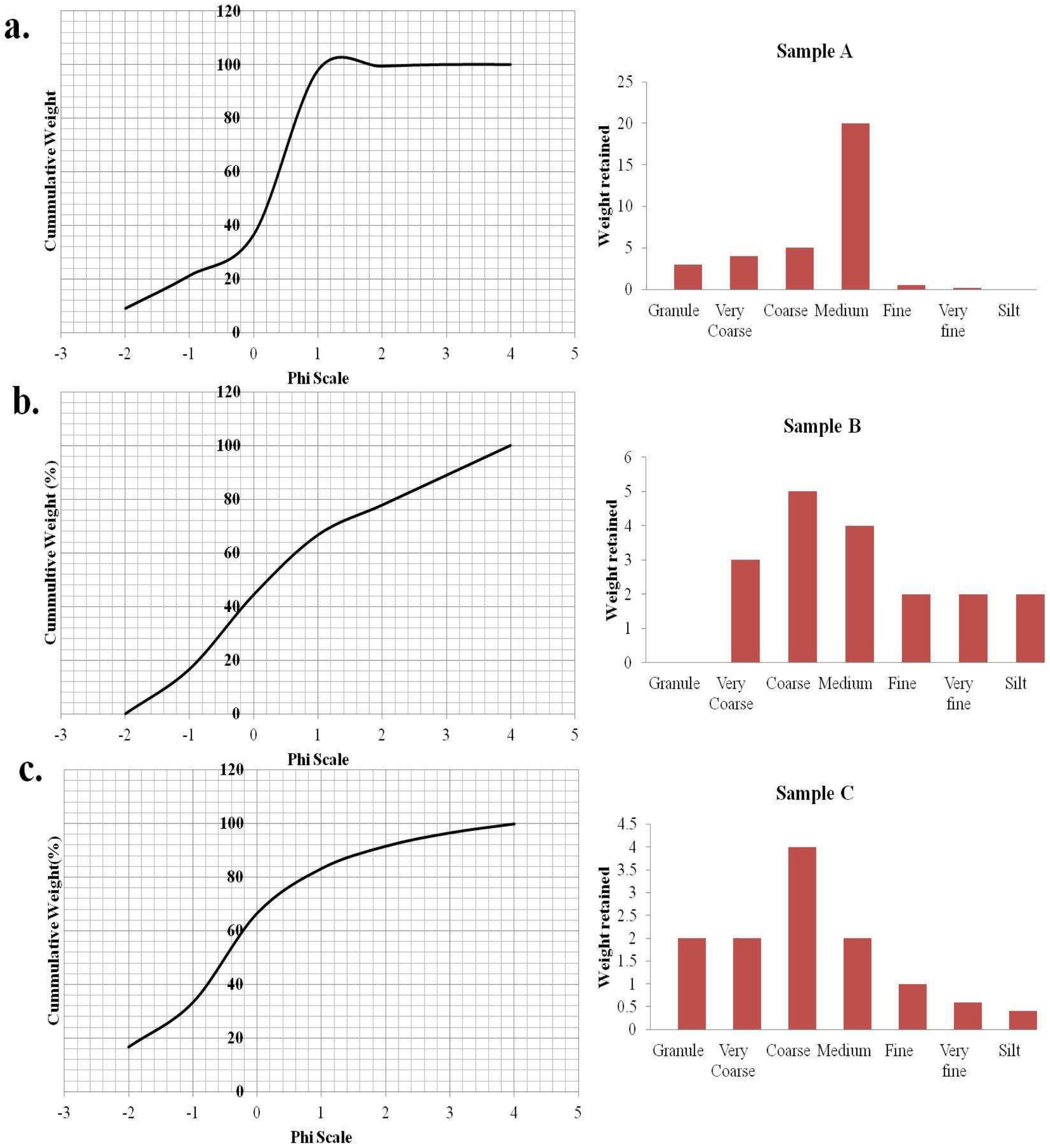

Fig 3 (a-c) Cummulative frequency plot for sample A-C and the Histogram for the amount of sediments retained on the sieve for samples A-C

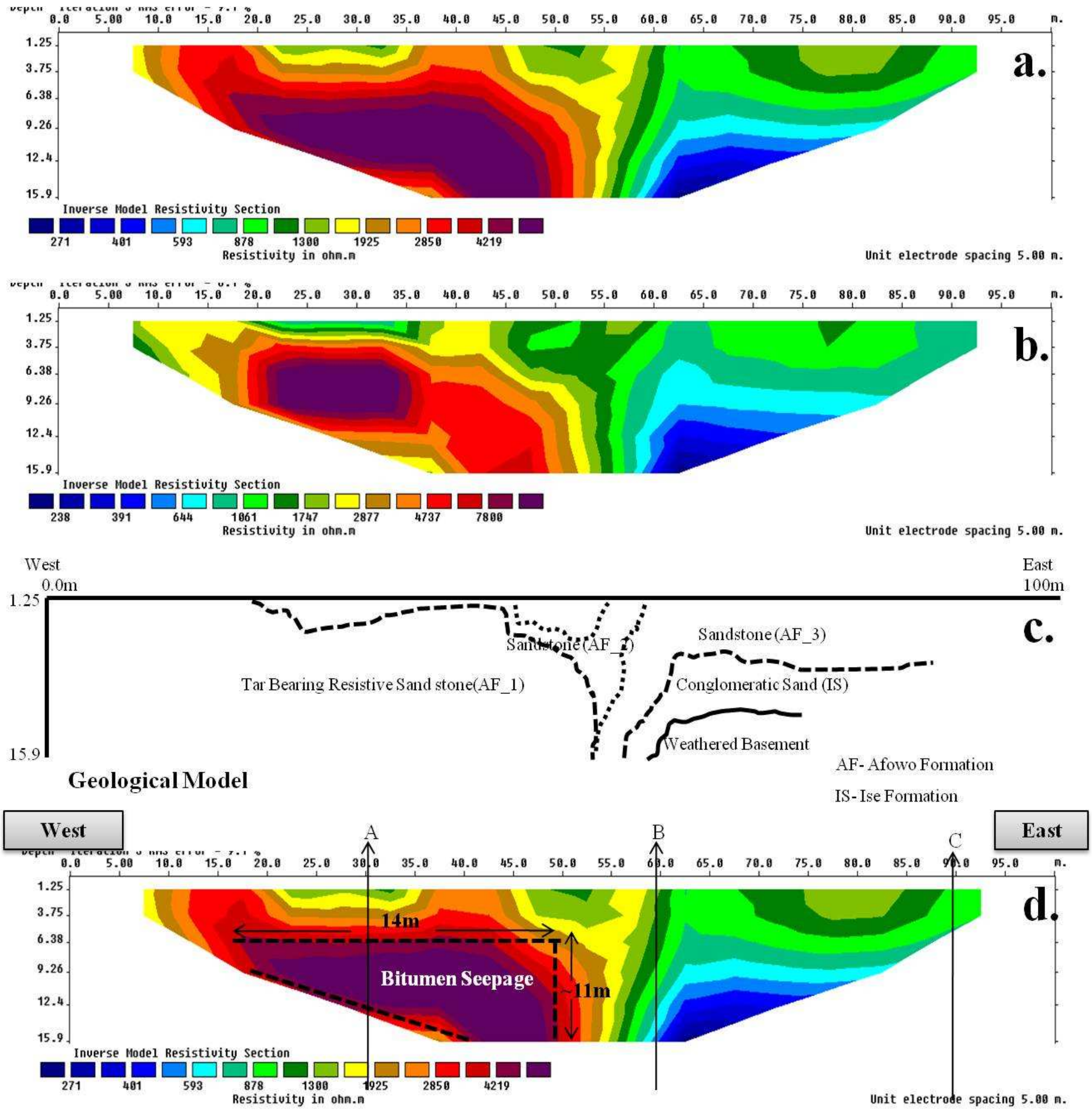

Fig 4 (a) The resistivity pseudosection across the survey line; Wenner Array- Smooth Inversion (b) Robust Inversion of fig 4(a), (c) Interpretation of the 2D profile using three (3) well points (d) The Inferred Geological Model

Table 3: Interpreted geology, thickness and resistivity of the layers from VES

Layer	Thickness	Resistivity	Lithology
1	1.05	176.00	Sandy Clayey Topsoil
2	12.18	150.94	Sandy Clayey Layer
3	infinite	998.26	Weathered basement

Table 4: The Interpretation from the ID points along the pseudosection in Fig 4

S/N	Point	Depth	Thickness	Resistivity value	Lithology
1	A	0-4	4m	878-1925	Resistive Sand Topsoil
		4-6.38	2.38	1925-2850	Sandstone
		6.38-13m	5.62	>4219	Tar Sand Horizon
		13-∞	-	2850	Sandstone
2	B	0-4	4m	1000	Resistive Sand Topsoil
		4-13m	9	1000-1300	Conglomeratic Sandstone
		13-	-		Weathered Basement
3	C	0-5	5	878	Sandy Topsoil
		5-∞	-	<593	Weathered Basement

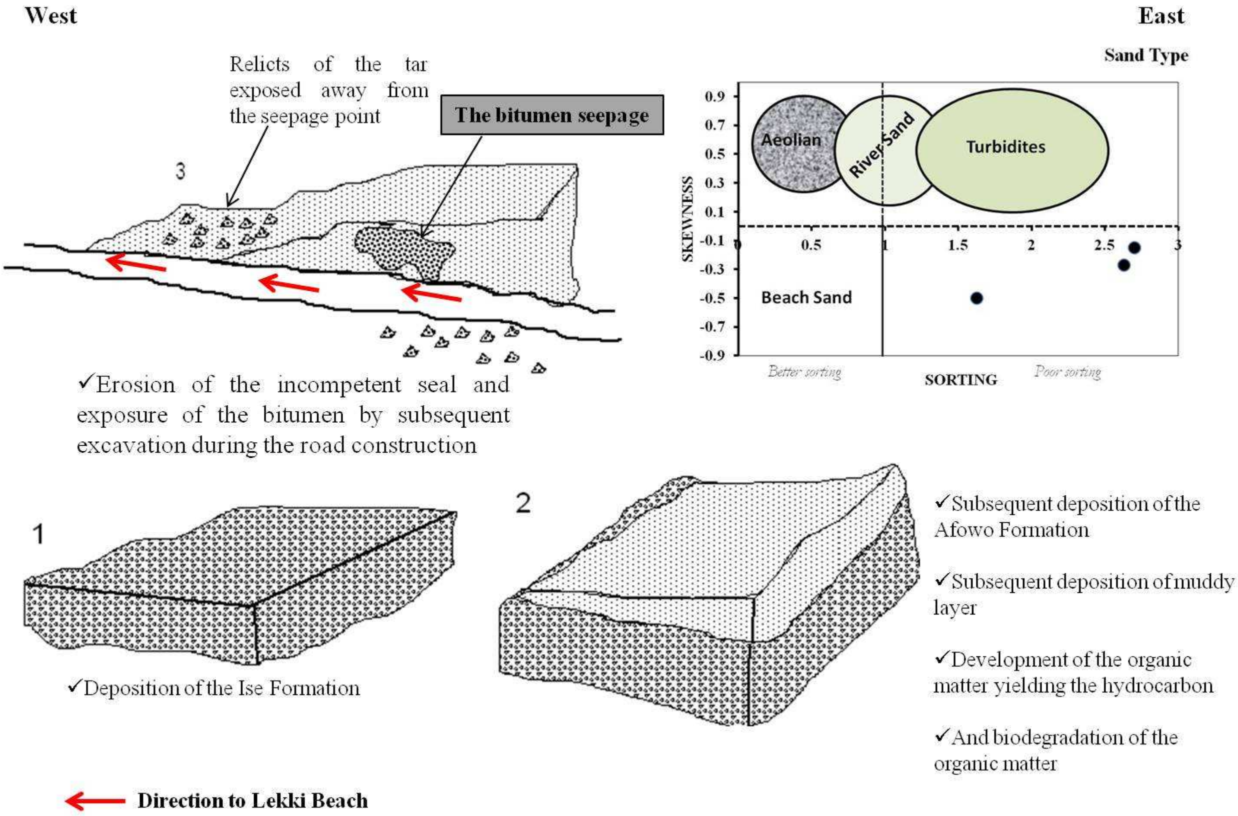

Fig 5: Model for the development of the bitumen seepage

CONCLUSION

The bitumen seepage in the study area is housed by a poorly sorted variety of sand of the Afowo Formation, which is thought to be derived from a single source that is close to the environment of deposition; texturally the sediments are immature and are near beach sands. The bitumen seepage in the study area has a resistivity value of >4219 Ωm and with a dimension of 14m (length) x 11m (height). It developed as a result of the deposition of the Afowo Formation on the Ise, followed by maturation and biodegradation of the organic matters in the Afowo Sand, subsequent urban development resulted in the excavation of the area and subsequent exposure of the seepage along the J4-Lekki beach road.

The resistivity value of the bitumen clearly belongs to a certain facies which corroborates result obtained by Akinmosin et al 2011(Bitumen Seepages at Imeri, southwestern Nigeria with resistivity value of 2206-4398Ωm), but contradicts values obtained by the BEECON in Ondo State (< 250 Ωm), Ikhane et al (2011) at Imobi, Southwestern

Nigeria (<350 Ωm), and Odunaike et al, 2010 (~164.9Ωm). It implies that the axis of the high resistivity bitumen is restricted to areas in Ogun State, and low resistivity bitumen is deposited in Ondo state.

This work has given impetus for further characterization of the bitumen or tar sands present in the Eastern Dahomey Basin based on their physical properties; further facies characterization may include the use of near surface geophysical methods like GPR and Refraction seismic to further corroborates result from the resistivity survey.

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REFERENCES

[1] A.A. Akinmosin, Omosanya, K.O, Folorunsho, A.F, Ariyo, S.O & Aiyeola, S.O, *International Journal of Basic and Applied Sciences*,**2011.** Vol. 11(1): 93-103
[2] A.A.. Akinmosin, Shoyemi. O, *Pacific Journal of Science and Technology*, **2010.** Vol.11:1. 526-536
[3] A.D. Halliburton, *Basic Petroleum Geology and Log Analysis*. Halliburton Company, SOP. **2001**
[4] A.J. Whiteman, *Nigeria: Its Petroleum Geology, Resources and Potential*, Vol. 2, Grahan and Trontman, London, **1982.**
[5] Beecon Report On the Sub-Surface Mapping Of Block 307b, **2004**
[6] B.C. Storey, *Nature*, **1995** v. 377, p. 301-308
[7] C.A. Kogbe, *Paleogeographic history of Nigeria from Albian times. In: Kogbe, C.A. (Ed.), Geology of Nigeria*. Elizabethan Publishers, Lagos,**1976** pp. 237–252.
[8] D.R. Kingston, Dishroon, C.P, Williams, P.A, *AAPG. Bull*, **1983.** Vol. 67, pp. 2175-2193.
[9] E.A. Fayose, *Jour. Min Geol*.,**1970.** Vol. 5 ,pp 3-9
[10] E.I. Enu, *Sedimentary geology.* **1985** Vol. 44, pp. 65-81.
[11] F.G.A. Ogbe, *Stratigraphy of Strata Exposed in the Ewekoro Quarry, Southwestern Nigeria In: T.F.J Dessauvagie and Whiteman (Eds) African Geology*, University Press, Nigeria, **1972,** pp 305.
[12] H.A. Jones, Hockey, R.D, *The Geology of part of southwestern Nigeria*. Geological Survey of Nigeria (GSN) Bulletin, **1964.** vol 31, 101.
[13] H.D. Klemme, *Geothermal Gradients, Heatflow and Hydrocarbon Recovery*. In: A.G. Fischer and S. Judson (eds), Petroleum and Global Tectonics. Princeton, New Jersey, Princeton Univ. Press, **1975**. pp. 251-304
[14] J.O. Akintola, *Rainfall Distribution in Nigeria1982-1983*, Impact Publishers Nigeria Limited, Ibadan , Nigeria.**1986,** Pp 371.
[15] J.O. Idowu, Ajiboye, S. A, Ilesanmi, M. A, Tanimola, A, *Journal of Mining and Geology*, **1993.** 29, 9-15.
[16] K.C.B. Burke, Dessauvagie, T.F.J., Whiteman, A.J., 1971. *Nature Physical Science*, **1971.** vol 233 (38), 51–55.
[17] K. K. Nwozor., B. N. Nfor., O. I. Chiaghanam., A. O. Ederoh., Chiazor J..E, *Advances in Applied Science Research*, **2012**, 3 (1): 188-200
[18] K.O. Ozegin, Oseghale A.O, *Advances in Applied Science Research*, **2012**, 3 (1):469-474
[19] M.E. Omatsola, Adegoke, O.S., *Nigeria Journal Mining and Geology*, **1981,** 18 (01), 130–137.
[20] M.E. Nton, *Sedimentological and geochemical studies of rock units in the eastern Dahomey basin, south western Nigeria, unpublished P.H.D thesis*, University of Ibadan, **2001,** pp 315.
[21] M.E, Nton, Elueze, A.A. 2005. *Journal of Mining and Geology*. **2005,** 412 Pp. 175 -184.
[22] M.H, Loke, Barker, R.D, *Geophysical Prospecting*, **1996a**. vol 44, 131-152.
[23] M.H, Loke, Baker, R.D, *Geophysical Prospecting*, **1996b** 44, 499.523.
[24] N.J. George, Obianwu V.I. Obot, I.B, *Advances in Applied Science Research*, **2011**, 2 (1): 163-177
[25] O.K. Agagu, A geological guide to bituminous sediments in Southwestern Nigeria. Unpubl. Report, Department of Geology, University of Ibadan.**1985.**
[26] O.S. Adegoke, *Bull. Am. Palaeontol*.,**1977.** Vol. 71, No. 295, 357pp.
[27] O.S. Adegoke, Ako, B.D., Enu, E.I, *Geotechnical Investigations of the Ondo State bituminous sands* Vol. 1. Geology and Reserves Estmate. Unpub. Rept., Geological Consultancy Unit, Department of Geology, University of Ile-Ife, **1980.** 257pp.

[28] P.R. Ikhane, Omosanya K.O, Afolabi A.O, *Research Journal of Earth and Planetary Studies*, **2011.** Vol 1.(2) pp.033 – 045

[29] R.K. Odunaike, J. A. Laoye, O. O. Fasunwon, G. C. Ijeoma, and L. P. Akinyemi. *African Journal of Environmental Science and Technology*,**2010.** Vol. 4 (1) pp. 034-044.

[30] S. I. Jegede, Osazuwa, I. B., Ujuanbi, O. C.C. Chiemeke, *Advances in Applied Science Research*, **2011**, 2 (6):1-8

[31] S. Mpanda, *Acta Universities Stockholmiensis*, **1997.** v. 45, 121p.

[32] S. Ogungbe, J. A. Olowofela, , O. J. Da-Silva, , A.A. Alabi, E. O. Onori, *Advances in Applied Science Research*, **2010**, 1 (1): 174-181