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ARTICLE SIZE DISTRIBUTION AND CONTROL ON BITUMEN SATURATION OF SOME TAR SAND DEPOSITS IN PARTS OF SOUTH-WESTERN NIGERIA

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ABSTRACT

Sedimentological analysis of some Afowo oil sands was carried out with the aim of characterising the reservoirs vis-à-vis their bitumen saturation and recovery efficiencies.

Fourty-four samples of tar sands of the Afowo formation (collected at three different localities namely; Idiobilayo, Idiopopo and Igbotako) were subjected to granulometric and petrological analyses to determine the particle size distribution as well as other textural characteristics. The bitumen saturation analysis was carried out with the use of toluene.

The result of sedimentological and particle size distribution studies showed that the sands are medium grained, moderately sorted and mesokurtic. The grain morphology can be described as having low to high sphericity, with shapes generally sub-angular to sub-rounded indicating a fairly long period of transportation.

The result of bitumen saturation analysis showed that both Idiobilayo and Idiopopo oil sands have an average oil saturation of 17.2% and 16.9% respectively, while Igbotako sands have an average oil saturation of 12.3%.

Consequently, Idiobilayo and Idiopopo oil sands deposits are therefore expected to have better reservoir quantities and possibly good oil recovery efficiencies.

KEYWORDS: Article size, distribution, Bitumen, Tar Sand Deposits, South-western Nigeria.

1. INTRODUCTION

The Dahomey basin (Fig. 1) is a marginal pull- apart basin (Klemme, 1975) or Margin sag basin (Kingston et al., 1983), which was initiated during the Early Cretaceous separation of African and South American lithospheric plates.

Occurrence of seepage and tar sand deposits over the Okitipupa ridge in the Dahomey basin provided the initial impetus for oil exploration in Nigeria. From the turn of 19th century up till date, no less than over twenty groups comprising public and private ventures have shown degrees of interest.

These bituminous deposits outcrop along an east-west belt, which is approximately 120km long and 4-6km wide, extending from the boundary of Edo and Ondo to Ogun State, (Enu,1987),see figure 2. A total reserve of heavy oil is estimated to be over 30 billion barrels (Adegoke et al, 1980).

The occurrence of these deposits has been known since early last century, however, intense investigations commenced from mid 70's till now. The pioneering efforts were initiated by the Geological Consultancy Unit of the University of Ife (now Obafemi Awolowo University). The geology of these deposits, oil saturation and reserve estimates as well as textural characteristics of the associated sands have been described (Adegoke et al., 1980, and 1981; Enu, 1987). The physicochemical properties of the bitumen in relation to production and processing have been studied (Adegoke et al., 1980; Oshinowo et al., 1982; Ekweozor, 1985; Oluwole et al., 1985). The origin of the bitumen has been considered (Coker, 1982; Ekweozor, 1985). Other relevant studies on the deposit include works done by Ako et. al (1983); Ekweozor (1986 and 1990); Ekweozor and Nwachukwu (1989); Enu (1987, 1990); Enu and Adegoke (1984). These works have highlighted relevant aspects of the geochemical and sedimentological characteristic of the deposit.

It is important to determine the reservoir characteristics (such as grain size parameters) in order to assist with future production procedures. This paper is based on detailed studies of 44 surface tar sand samples and will mainly emphasize the particle size distribution and mineralogical aspects.

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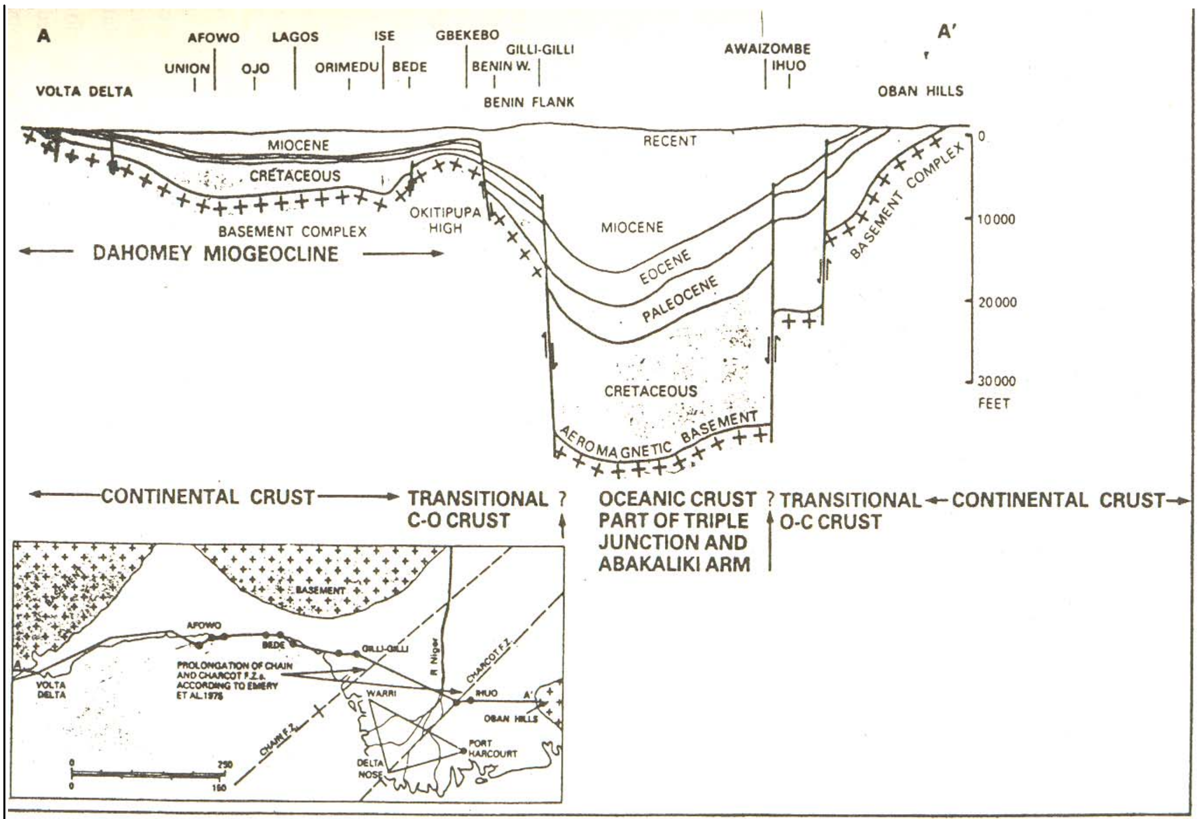

FIG. 1: East-West geological section showing the Dahomey Basin and upper part of the Niger Delta (After Whiteman, 1982).

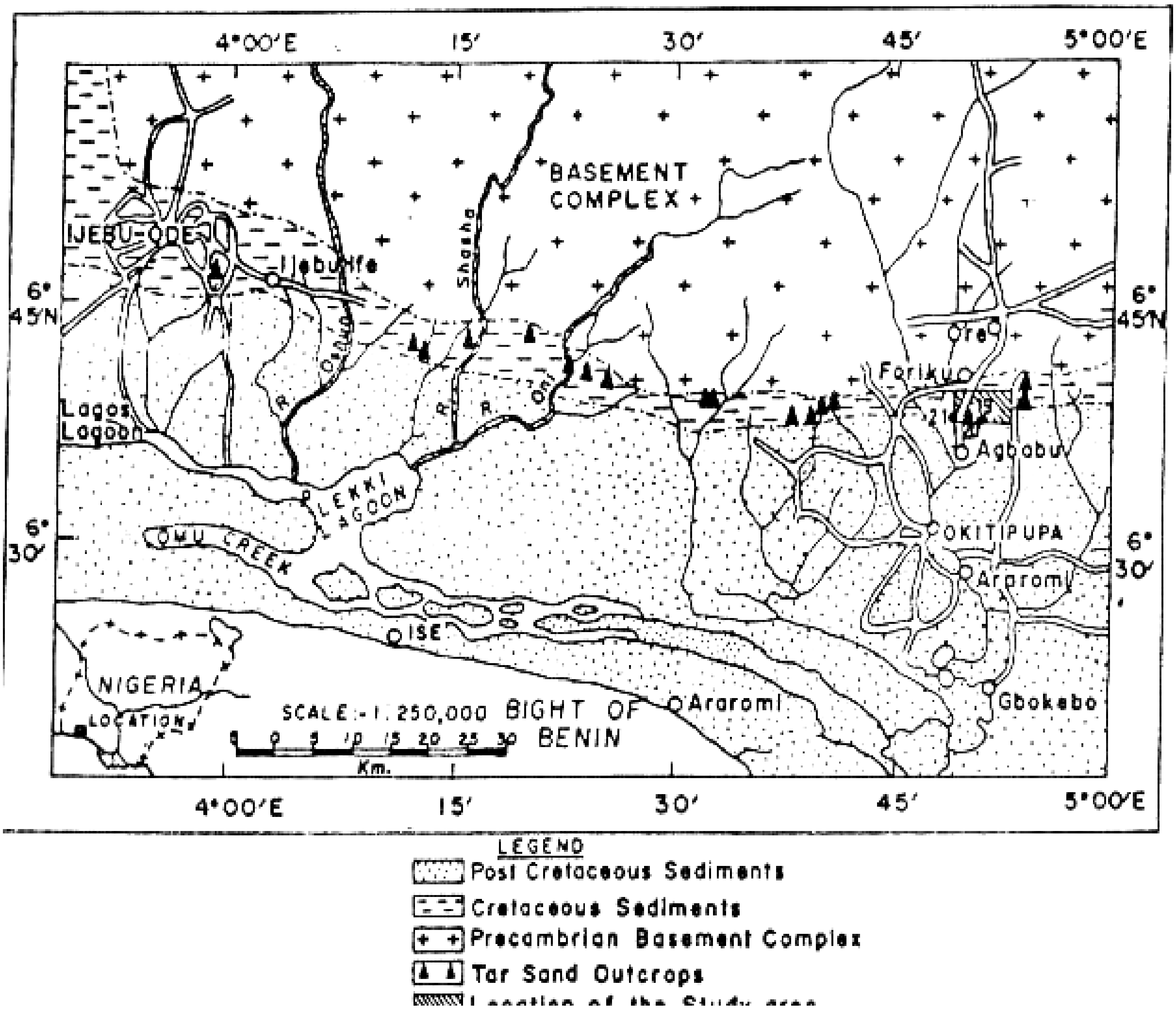

Figure 2: Geological map of southwestern Nigeria showing the Tar sands outcrop belt (Adapted from Enu, 1987)

2. REVIEW OF THE STRATIGRAPHY OF THE DAHOMEY BASIN

The study area lies between latitudes $6^0 30^1$ to $6^0 35^1$ N and longitudes $4^0 30^1$ to $6^0 45^1$ E and falls within the eastern Dahomey Basin (Fig. 3).The work of Omatsola and Adegoke (1981) on the Cretaceous stratigraphy of the Dahomey basin has recognized three formations belonging to the Abeokuta Group. These are: the Ise Formation, consisting essentially of continental sands, grits and siltstones, overlying the basement complex uncomformably. Neocomian to Albian age has been assigned to this formation. Overlying the Ise Formation is the Afowo Formation, which consists of coarse to medium-grained sandstones with variable interbeds of shales, siltstones and clay. The sediments of this formation were deposited in a transitional to marginal marine environment. Turonian to Maastritchtian age has been assigned to this formation. The Araromi Formation consists essentially of sand, overlain by dark-grey shales and interbedded limestone and marls with occasional lignite bands. The formation conformably overlies the Afowo Formation and Maastrichtian to Paleocene age has been assigned (Omatsola and Adegoke, 1981).

Overlying the Abeokuta Group conformably is the Imo Group, which comprises of shale, limestone and marls. The two-lithosratigraphic units under this group are: Ewekoro and Akinbo Formations. Ewekoro Formation consists of thick fossiliferous limestone. Adegoke (1977) described the Ewekoro Formation as consisting of shaly limestone 12.5m thick which tends to be sandy and was divided into three microfacies. Ogbe (1972) however, further modified this and proposed a fourth unit. The four microfacies making up this formation are described as follows: sandy biomicrite, shelly biomicrite, algal biosparite, and red phosphatic biomicrite. Ewekoro Formation is Paleocene in age and is associated with shallow marine environment due to abundance of coralline algae, gastropods, pelecypods, echinoid fragments and other skeletal debris. Akinbo Formation lies on the Ewekoro Formation and it comprises of shale, glauconitic rock bank, and gritty sand which is pure grey in colour and shows little clay. Lenses of limestone from Ewekoro Formation grades laterally into the Akinbo shale very close to the base. The base is characterized by the presence of a glauconitic band. The age of the formation is Paleocene to Eocene.

Overlying the Imo Group is the Oshoshun Formation. It is a sequence of mostly pale greenish-grey laminated, phosphatic marls, light grey to white-purple clay with interbeds of sandstones. It also consists of claystone underlain by argillaceous limestones with light grey shale at the bottom. There are inclusions of phosphatic and glauconitic materials in the lower part of the formation and the upper part is made up of medium to coarse-grained silty sandstone (Adegoke, 1969). The formation is Eocene in age (Agagu, 1985). The sedimentation of the Oshoshun Formation was followed by a regression, which deposited the sandstone unit of Ilaro Formation (Kogbe, 1976). The sequence represents mainly coarse sandy estuarine deltaic and continental beds, which show rapid lateral facies change.

The coastal plain sands are the youngest sedimentary unit in the eastern Dahomey basin. It probably overlie the Ilaro Formation unconformably, but convincing evidence as to this is lacking (Jones and Hockey, 1964). It consists of soft, poorly sorted clayey sand and pebbly sands. The age is from Oligocene to Recent.

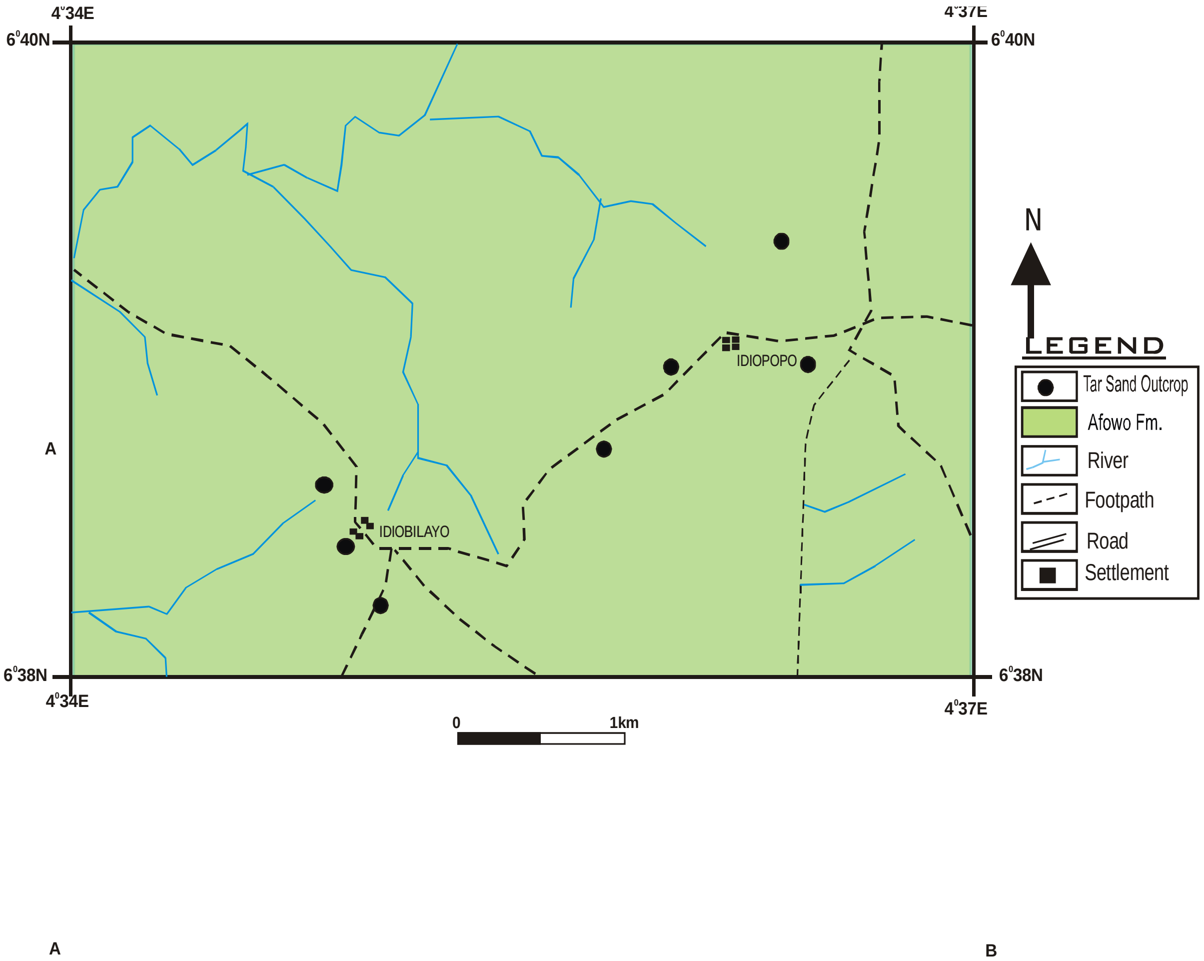

Fig. 3: Location Map of the Study Area Showing Tar Sands Outcrop Points.

3. METHODOLOGY

A total number of forty-four tar sand samples collected at outcrop points and along river channels in 3 different localities of tar sands area of Ondo state were used for this study. These localities include: Idiobilayo (13 samples), Idiopopo (12 samples) and Igbotako (12 samples).

After cleaning and drying, the samples 100g each were dry-sieved using vibrating sieving machine for 15 minutes with sieves of the following mesh sizes: 2.00mm, 0.180mm, 0.125mm, 0.075mm which are equivalent to –1.00, 1.25, 2.50, 3.00 and 3.75 phi values respectively.

The individual weight, cumulative weight, as well as individual and cumulative weight percentage were determined. These were subsequently used to plot histogram and cumulative frequency curve for individual sample on an arithmetic and semi-logs graphs.

The parameters were computed by using moment statements: mean, mode, standard deviation, Kurtosis, and Skewness (using formulae by Folk and Ward, 1957). Besides the particle-size distribution, grain morphology, chemical and mineralogical compositions were equally determined using standard procedures.

For the bitumen saturation analysis, ten (10) grams each of samples were weighed and put in a measuring cylinder into which toluene was poured and left for about 6o minutes. The samples were then washed and later decanted. This procedure was repeated until the samples were clean of bitumen. The washed samples were air dried and re-weighed. The new weights were noted, recorded and then subtracted from the initial weights. The difference in weight were converted to percentage (%) and recorded. An average for all the samples analysed for each facies type was taken as average saturation for the respective tar sand.

TABLE 3: Bitumen Saturation Result-

A

S/NO	SAMPLE NO	WEIGHT OF SAMPLE (gm)	WEIGHT OF BITUMEN (gm)	FACIES
1	A	10	1.9	Fine grained clayey sand
2	A	10	1.9	Fine grained sandstone with mm scale laminae
3	A	10	1.3	Medium grained sandstone with mm scale shale laminae
4	A	10	1.5	Fine grained sandstone
5	A	10	2.0	Coarse grained sandstone

Average bitumen saturation 17.2%

B

S/NO	**SAMPLE NO**	**WEIGHT OF SAMPLE (gm)**	**WEIGHT OF BITUMEN (gm)**	**FACIES**
1	**B**	**10**	**2.8**	**Medium grained sandstone with mm scale shale laminae**
2	**B**	**10**	**1.6**	**Fine grained clayey sandstone**
3	**B**	**10**	**1.15**	**Fine grained sandstone with mm scale shale laminae**
4	**B**	**10**	**1.7**	**Medium grained sandstone**
5	**B**	**10**	**1.2**	**Coarse grained sandstone**

Average bitumen saturation= 16.9%.

4. RESULTS AND DISCUSSION

Mean and standard deviation of particle-size distribution of Afowo bituminous sands are presented in Table 1. The particle-size frequency-distribution curves of almost all the sediments analyzed indicate bimodal distributions. The curves show substantial variation from one another. The sediments show wide broad, moderately negatively skewed curves and is reflected in the histograms (Figs. 4 and 5) which indicate a wide range of relatively higher values for the standard deviation. The sediments in Idiobilayo and Idiopopo are better sorted than the sediments in Igbotako as it can be seen in Table 1. While sediments from Idiobilayo and Igbotako are medium grained, Idiopopo sediments are however coarse grained all with variable quantities of fines.

The Afowo sands as observed in this study, are of the mean particle size that is coarse-medium and does not depend too much on standard deviation or percentage of fines (Figs. 6a-6c). Harison et al (1981) in the cold Lake area showed that a strong correlation exists between mean particle size and weight (wt) % mud (<63 um). Coarse particles and low mud content allow for high bitumen content. A factor that could prove very important in the recovery of bitumen is the heterogeneity of a reservoir, because the withdrawal efficiency is strongly reduced if clusters of fines occur in a coarser matrix (Morrow, 1971; Takamura, 1982).

The reservoir is expected to be better off in the sediments of Idiobilayo and Idiopopo, which are coarse grained and better sorted than the sediments in Igbotako area. This fact is equally confirmed from the bitumen saturation analysis. See Table 2.

Mineralogical composition of the sediments as identified under petrological microscope include quartz, mica and opaque minerals constituting 95%, 2% and 1% respectively. No feldspar was identified under the microscope, which can be indicative of mechanical maturity of the sediments, as shown on Tables 3,4 &5. The grain morphology shows low-high sphericity with shapes generally sub-angular to sub-rounded (Fig. 7).

Heavy mineral constituents of the sediments comprises of both opaque and non-opaque types. These minerals are of great importance in the study of provenance, transportation history of sediments, paleogeographic studies e.t.c. Minerals identified under the microscope are zircon, rutile, tourmaline, staurolite, sillimanite, kyanite, garnet and hormblende, (Figs. 7a and 7b). Average ZTR index calculated for some representative samples is greater than 75%.

Chemical composition of the samples as shown on Tables 5, 6 and 7, reveals $Si0_2$ as most abundant, averaging about 95% of the total oxides. This is followed by MgO, FeO and K_2O in that order. As observed from the mineralogical composition, the proportion of these oxides is indicative of the chemical maturity of the sediments, which makes it possible to classify the sediments as quartz arenites. Moreover, with high proportion of SiO_2 and low proportion of K_2O, the sediments can better be classified as arenaceous in nature (quartz arenite).

TABLE 1: Mean Particle-Size Parameters of The Three Localities

	LOCALITYA	REMARK	LOCALITYB	REMARK	LOCALITYC	REMARK
Number of samples	13		14		17	
Mode	1.56		1.58		2.29	
Mean	1.03	Medium Sand	0.80	Coarse Sand	1.43	Medium Sand
Standard deviation	0.92	Moderately Sorted	0.95	Moderately Sorted	1.11	Poorly Sorted
Skewness	0.02	Nearly Symmetrical	-0.71	Strongly Coarse Skewed	-0.04	Strongly Coarse Skewed
Kurtosis	1.04	Mesokurtic	-0.07	Mesokurtic	-0.04	Mesokurtic

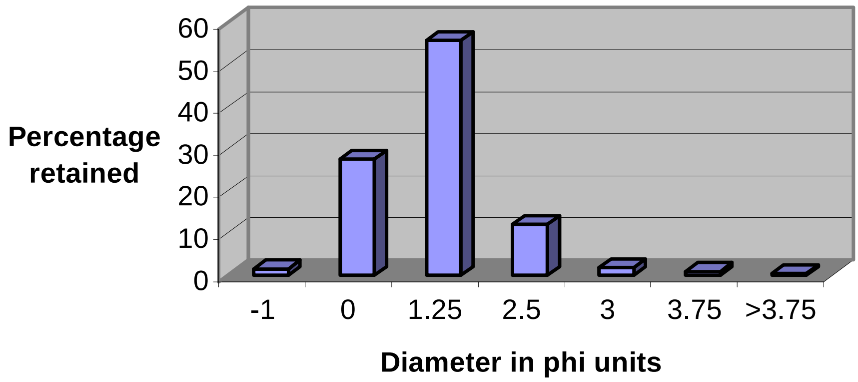

Fig 4A: Histrogram for particle size distribution in Locality A

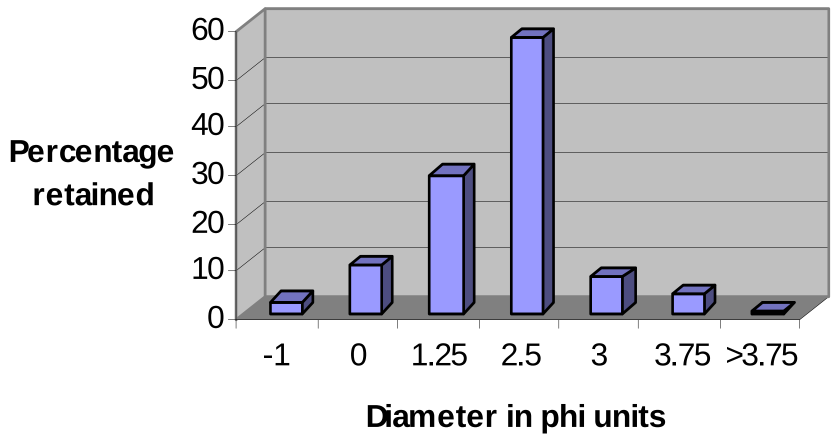

Fig 4B: Histogram for particle size distribution in Locality B

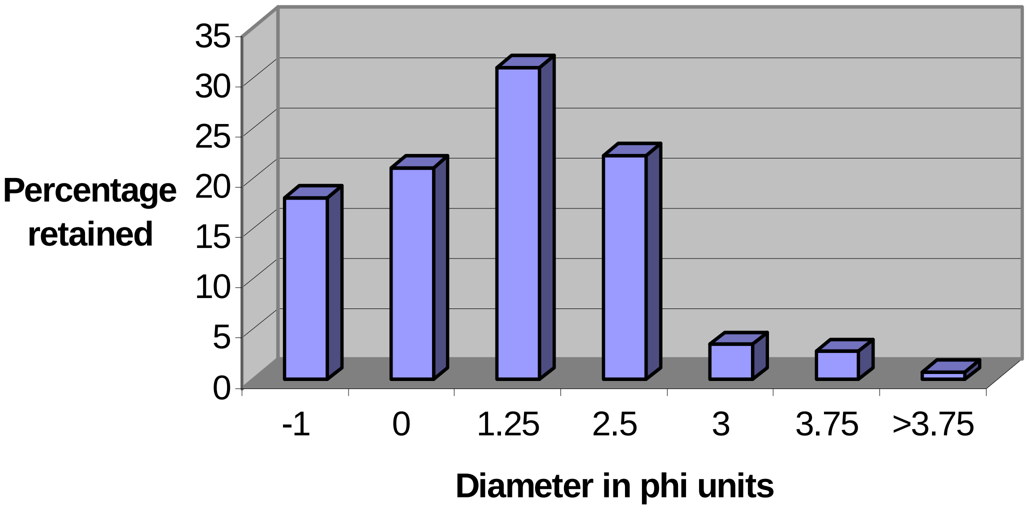

Fig 4C: Histogram for particle size distribution in Locality C

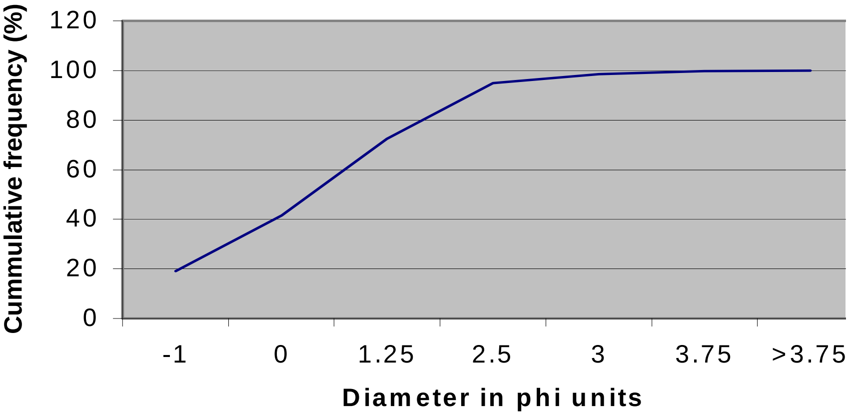

Fig 5A: Cummulative Frequency plot for Locality A

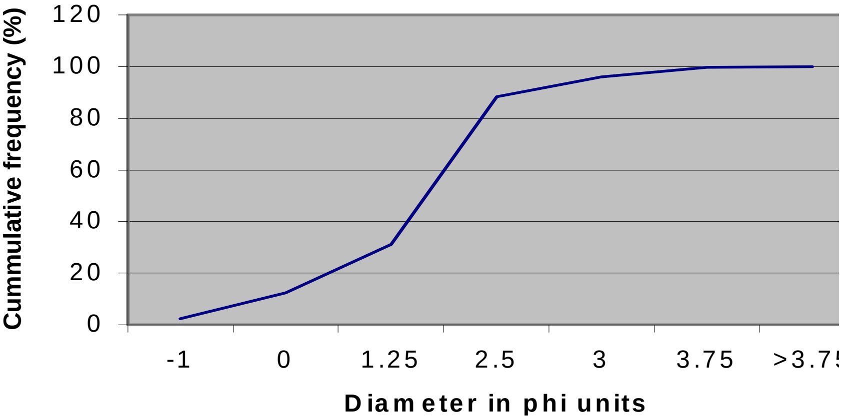

Fig 5B: Cummulative Frequency plot for Locality B

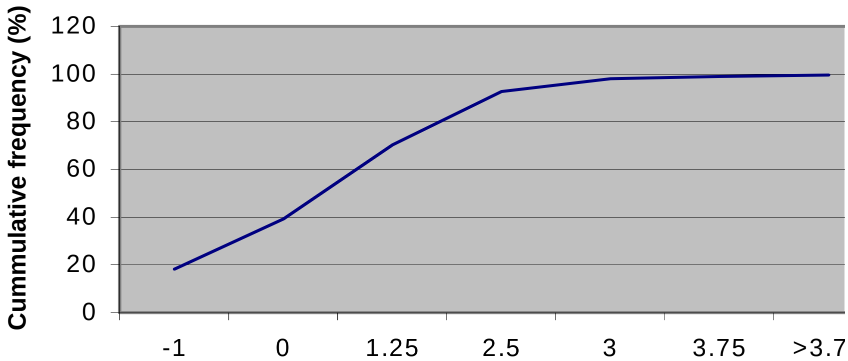

Fig 5C: Cummulative Frequency plot for Locality C

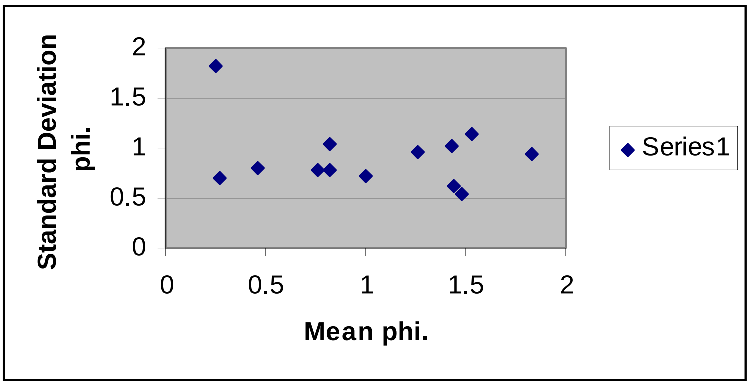

FIG. 6a: mean particle size vs standard deviation for locality A.

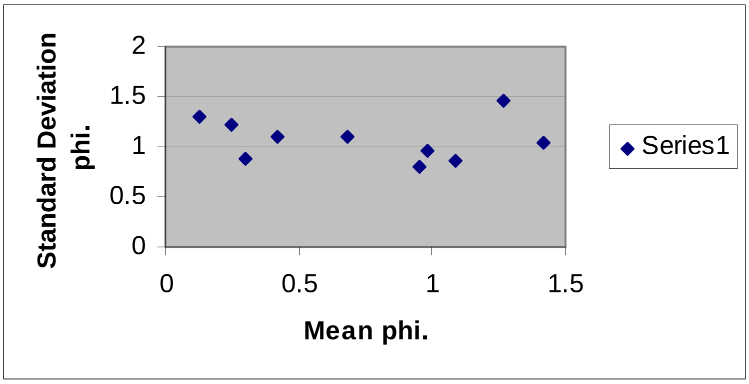

FIG. 6b: Mean particle size vs standard deviation for locality B.

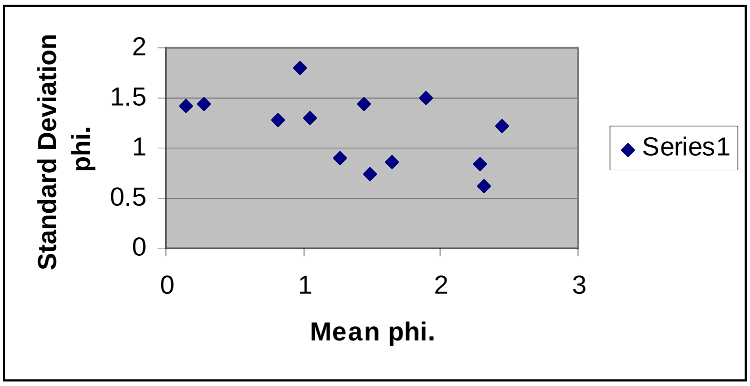

FIG. 6c: Mean particle size vs standard deviation for locality C.

POINT-COUNT DATA FOR REPRESENTATIVE THIN SECTIONS FROMTHE STUDY AREAS

TABLE 3: LOCALITY A

SAMPLE NO	QUARTZ	FELDSPAR	MICA	ACCESORY MINERALS
A1	95.5	TR	1.5	3.O
A2	96.0	TR	1.5	2.5
B1	96.5	TR	1.0	2.5
B2	95.5	_	2.0	2.5
E3	94.0	_	2.0	4.0
F1	96.0	TR	1.5	3.5

TABLE 4: LOCALITY B

SAMPLE NO	QUARTZ	FELDSPAR	MICA	ACCESSORY MINERALS
N1	96.5	_	2.0	1.5
N2	97.5	_	2.0	0.5
O5	96.0	TR	2.0	2.0
O6	97.0	_	1.5	1.5
P3	95.0	TR	2.5	2.5

TABLE 5: LOCALITY C

SAMPLE NO	QUARTZ	FELDSPAR	MICA	ACCESSORY MINERALS
Q3	94.5	TR	2.0	3.5
S1	94.0	TR	1.5	4.5
T1	93.0	TR	2.0	5.0
T3	93.5	TR	2.0	4.5
U6	95.0	_	1.5	3.5

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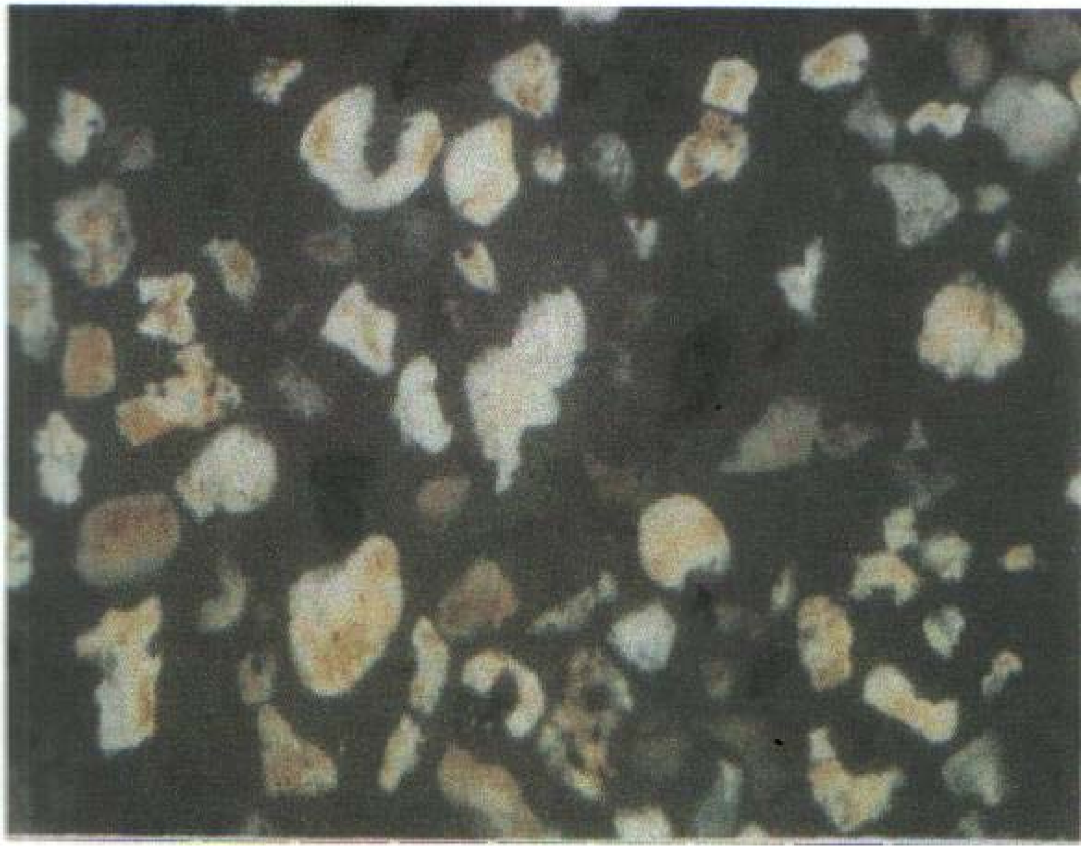

Fig 7: Quartz and other mineralogical composition of the sediments showing the shapes of individual mineral grain.

Minerals identified under the microscope are zircon, rutile, tourmaline, staurolite, sillimanite, kyanite, garnet and hormblende, (Figs. 7a and 7b). Average ZTR index calculated for some representative samples is greater than 75%.

Chemical composition of the samples as shown on Tables 5, 6 and 7, reveals $Si0_2$ as most abundant, averaging about 95% of the total oxides. This is followed by MgO, FeO and K_2O in that order. As observed from the mineralogical composition, the proportion of these oxides is indicative of the chemical maturity of the sediments, which makes it possible to classify the sediments as quartz arenites. Moreover, with high proportion of SiO_2 and low proportion of K_2O, the sediments can better be classified as arenaceous in nature (quartz arenite).

HEAVY MINERALS PHOTOMICROGRAPHS

Z = Zircon
K = Kyanite
Si = Sillimanite
S = Staurolite
O = Opaque mineral
T = Tourmaline
R = Rutile

FIG. 7a

Mag. X 100

FIG. 7b

Figs. 7a and 7b: Photomicrographs of the heavy mineral composition showing high quantities of Zircon and Staurolite

TABLE 5: ELEMENTAL COMPOSITION OF SAMPLES ROM THE LOCALITIES.

LOCALITY A

SAMPLENO	CaO	FeO	S_iO_2	Al_2O_3	MgO	SO_3	K_2O
A1	-2.23	0.28	94.19	-5.56	2.49	0.01	0.09
A2	-2.15	0.36	93.25	-5.45	2.30	0.02	0.06
B1	-2.35	0.18	93.60	-5.40	2.60	0.04	0.08
B2	-2.11	0.33	93.16	-5.24	2.35	0.00	0.10
F1	-2.30	0.35	94.45	-4.30	2.60	0.03	0.09

TABLE 6: LOCALITY B

SAMPLE NO	CaO	FeO	S_iO_2	Al_2O_3	MgO	SO_3	K_2O
N1	-1.95	0.09	93.37	-4.94	2.12	0.10	0.12
N2	-1.80	0.07	94.41	-4.76	2.31	0.09	0.41
O5	-1.87	0.06	96.42	-4.85	2.20	0.08	0.13
O6	-2.13	0.11	95.01	-4.90	2.41	0.12	0.14
P3	-2.16	0.16	96.45	-4.76	2.53	0.16	0.12

TABLE 7: LOCALITY C

SAMPLE NO	CaO	FeO	S_iO_2	Al_20_3	MgO	SO_3	K_2O
Q3	-1.70	0.85	92.46	-2.99	2.25	0.12	0.03
S1	-1.15	0.90	93.50	-2.78	2.30	0.15	0.01
T1	-1.65	0.87	91.50	-2.20	2.45	0.17	0.04
T3	-1.95	0.30	94.24	-4.04	2.28	0.12	0.02
U6	-1.90	0.60	93.25	-3.05	2.38	0.16	0.03

SUMMARY AND CONCLUSION

The bitumen sands of Afowo Formation as observed in this study can be characterized as being chemically and mechanically stable. The quartz content on the average is greater than 90% with little or no presence of feldspar. Minor components are mica (biotite and muscovite) and heavy minerals (mostly zircon and tourmaline).

The particle size of the sands varies irregularly. Mostly, the sands are coarse-medium grained and moderately sorted with no significant of fines-content. Except for few locations with poor sorting, bulk of the sediments are moderately sorted. This quality, coupled with insignificant fines content will in no doubt enhance both bitumen saturation and withdrawal efficiency positively.

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