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SEDIMENTARY TEXTURAL PARAMETERS OF OUTCROPS SAMPLE, EXPOSED ALONG A ROAD CUT IN CALABAR, CALABAR FLANK, SOUTHEASTERN NIGERIA

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ABSTRACT

Grain size and pebble morphometry analysis was carried out on 10 outcrop samples and 100 unweathered quartz pebbles exposed along a Road cut in Calabar which is a part of Calabar Flank, Southeastern Nigeria, to interpret textural parameters and paleoenvironmental deposits. The statistical granulometeric parameters of Mean Size ,Inclusive Standard Deviation, Skewness and Kurtosis yielded average values of 0.90φ (0.47 φ - 1.70φ) ,1.75φ (1.31φ -2.57φ) ,0.08 (-0.32 to +1.00) and 0.82 (0.41 to 1.29) respectively .These values infer deposits of coarse to medium grained, poorly to very poorly sorted, dominantly of negative skewed and very platykurtic to leptokurtic sediments. These values suggest medium to high energy fluvio- beach to shallow marine agitated environment of some turbidity current influence. Pebbles morphometric parameters of Flatness ratio, (FR), Flatness Index (FI), Elongation ratio (ER), Maximum Projection Sphericity Index (MPSI) and Oblate Probate Index (OPI) have average values of 0.44, 44%, 0.70, 0.65 and 1.07 infer variation in the environment of deposition for the pebbles from fluvial to beach/littoral settings.. The bivariate plots of the different parameters infer predominantly of fluvial and beach influences.

KEYWORDS: Grain size, pebble morphometry, paleoenvironmental deposits, Calabar Flank, fluvio-beach.

INTRODUCTION

Calabar Flank is a sedimentary basin located on the southeastern part of the Benue Trough in Nigeria. The youngest unit in the stratigraphy of Calabar Flank is the Tertiary Benin Formation and has not received much research attention. Most of the current geologic research are centered on the Cretaceous sediments of this basin. It is therefore imperative to understand the sedimentologic characteristics of sediments of this unit that caps the Cretaceous sequence in the Calabar Flank. The thrust of this study is to evaluate the sedimentary textural parameters of sections of the Benin Formation expose along a Road cut in Calabar, which is part of Calabar Flank, Southeastern Nigeria.

LOCATION OF THE STUDY AREA

The area under investigation is located along Lemna Road in Calabar Municipality of Cross River State , Nigeria.It lies between latitude N05^{0} 01′ 42′ ″ to N05^{0} 01 ′ 54 ″ and longitude E008^{0} 21 ′ 50 ″ to E008^{0} 1 ′ 57 ″ and is located in the Southeastern part of Calabar Flank (Figure 1).

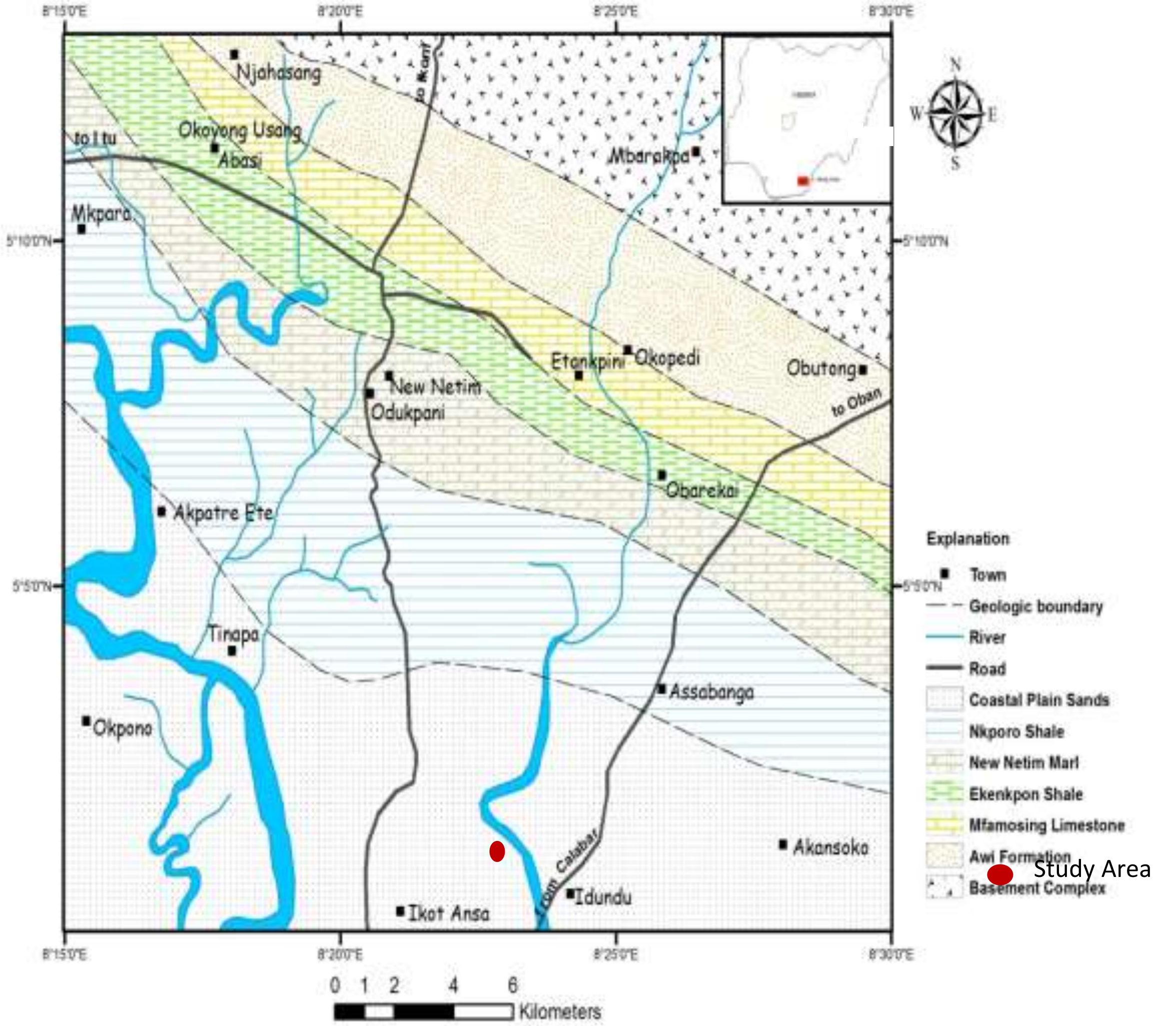


Figure 1: Geologic map of the study area.

The lithology of the study area is made up of reddish brown clay with some of woody materials at the base and overlain by a thick sequence of black shale intercalated with peat .The peaty material is rich in woody, leafy and root matters. A thin band of reddish-brown ironstone separates the underlying carbonaceous shale from the overlying variegated pebbly sandstone. The pebbly sandstone contains pebbles, coarse, medium and fine grained that is poorly to moderately sorted sand grain and the cyclic is capped by overburden earth materials with vegetation. This area form part of the Tertiary deposit of Calabar Flank, Southeastern Nigeria.

GEOLOGICAL SETTING

The Calabar Flank is an epirogenic sedimentary basin in southeastern Nigeria (Murat, 1972).The basin according to Nyong (1995) is bounded by the Oban Massif in the north, Calabar hinge line separates the basin from Niger Delta basin in the south, Ikpe platform and Cameroon volcanic trend delineate it in the west and east respectively (Figure 2) . The origin of this basin is associated with the opening of the South Atlantic in the Mesozoic era when the South American plate drifted away from African plate. The major structural elements within the basin include the Ikang Trough (graben structure) and Ituk High (horst) which were mobile depression and stable mobile submarine ridge that influenced the distribution of sedimentary facies (Murat, 1972 and Nyong, 1995).

The stratigraphic succession in the Calabar Flank is shown in Table 1. Sediment thickness is over 3500m with the onlap (or featheredge) of the outcropping units, along the fringes of the Oban Massif basement complex. The Formations are best exposed along Calabar –Ikom road and a succession consists of five (5) Cretaceous and a Tertiary lithostratigraphic units. Awi Formation is the oldest basal unit and sits nonconformbly on the basement complex of Oban Massif. The Formation is Aptian in Age (Adeleye and Fayose, 1978).This is overlain by Mfamosing Limestone of Middle- Upper- Albian age (Petters, 1982) deposited during the first marine transgression into the basin. This in turn is succeeded by Late Albian- Cenomanian to Turonian,, Ekenkpon Shale. Subsidence on the faulted blocks of horst and graben allowed wide spread deposition of shales with minor marl and mudstone intercalation. The New Netim Marl of Coniacian (Nyong, 1995) in age, succeeded the shale. The Santonian period was marked by a major unconformity in the study area. Nkporo Shale of Late Campanian to Early Maastrichtian (Edet and Nyong, 1994) capped marine transgression and Mesozoic sedimentation in the Calabar Flank .The Tertiary continental sands and gravel of the Benin Formation complete the sedimentation in the basin (Figure 1).

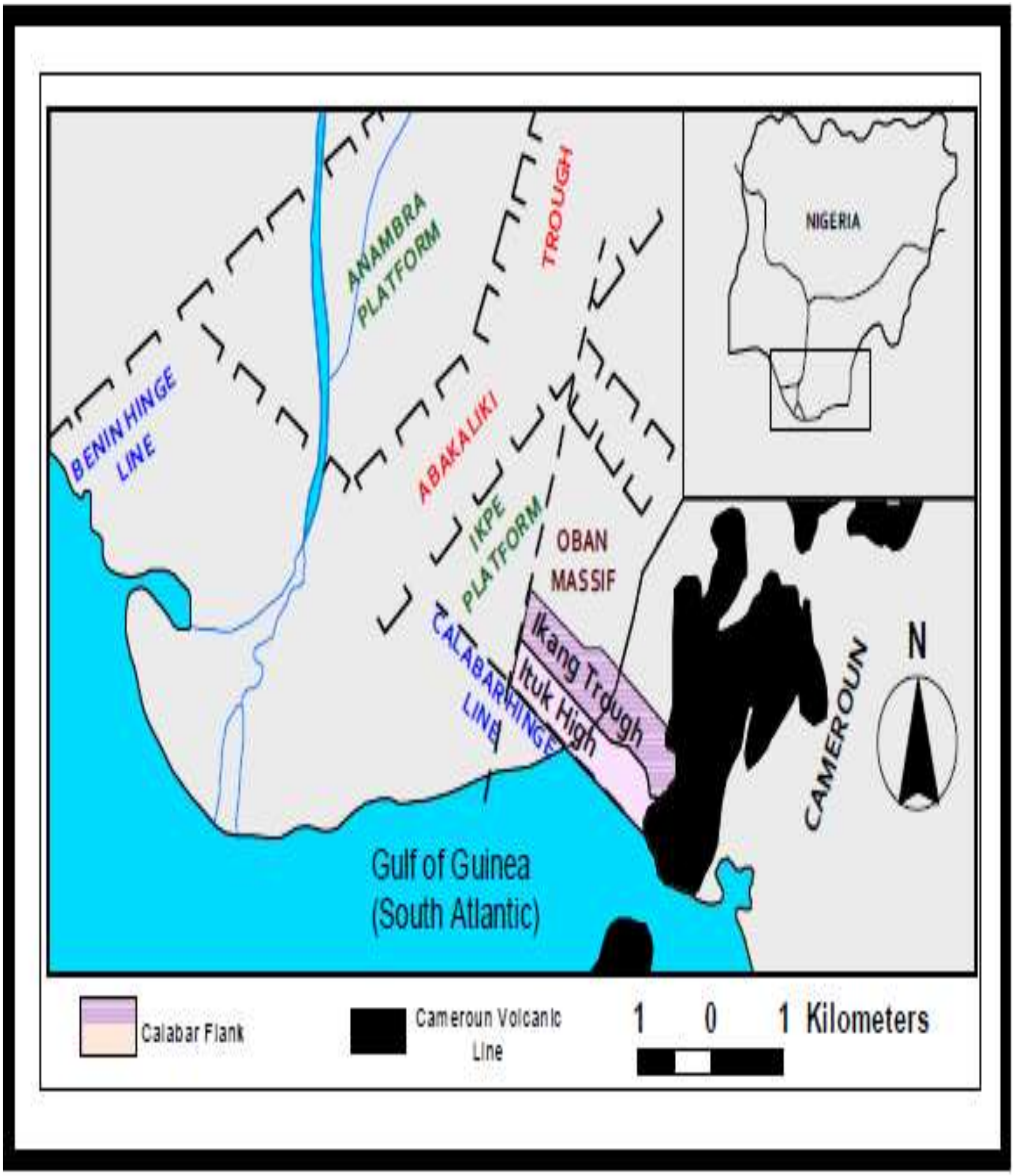
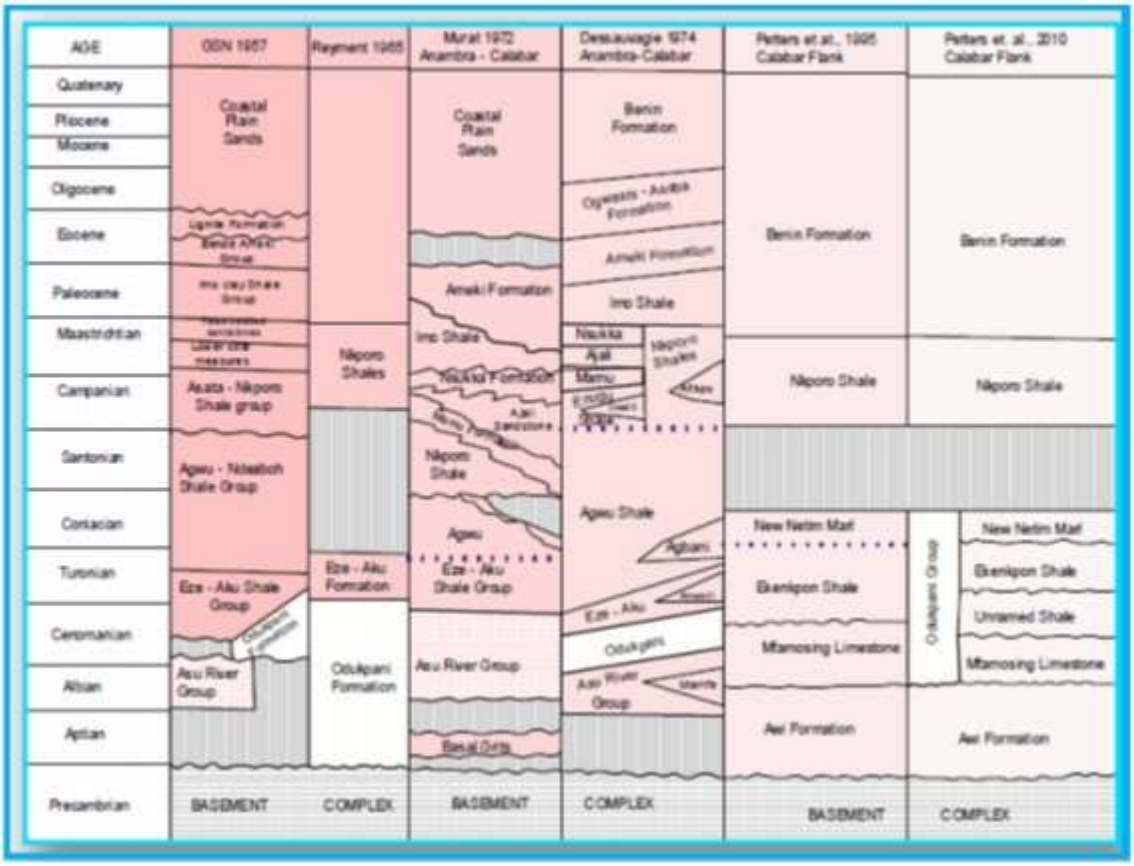


Figure 2: Structural map of the Calabar Flank and adjoining areas. (Nyong and Ramanatha ,1985)

Table1: Lithostratigraphic correlation between Calabar Flank. Abakaliki Trough, ,Anambra Basin and the Middle Benue Trough (Nyong,1995 and Petters et al;2010)



MATERIALS AND METHODS

A total of ten (10) outcrops samples and one hundred (100) unweathered quartz pebbles were collected for both sieve analysis and pebble morphometric analysis respectively.A standard sieve method was adopted and various grain size parameters determine based on (Folk,1984). Pebble morphometric measurements using Vernier caliper using Krumbeins (1941) method of the Long (L), Intermediate (I) and Short (S) axes of pebbles was carried out and the different pebble parameters computed.

RESULTS AND DISCUSSION

Grain Size Analysis

The result of the grain size analysis computed from the study area is shown in Table 2

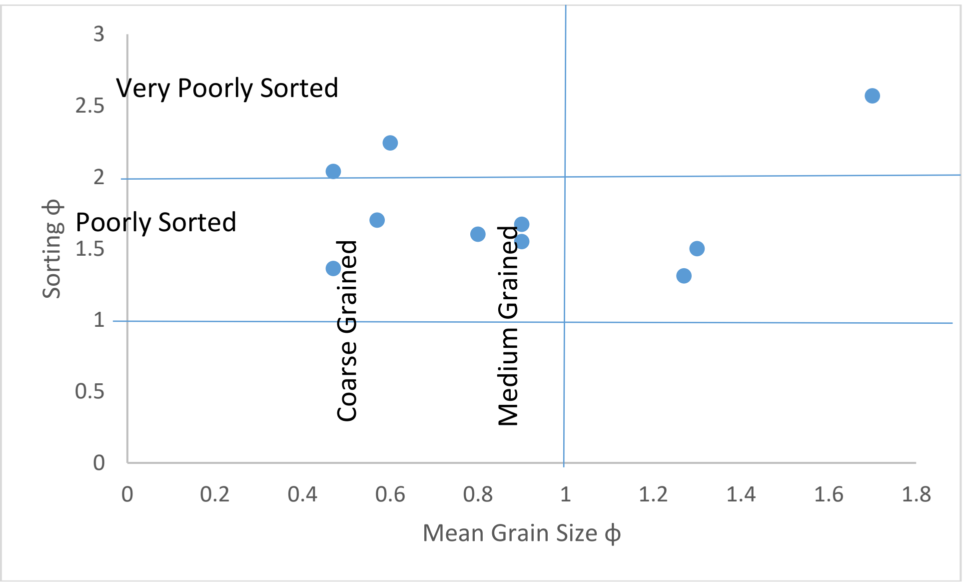
The mean grain size parameter ranges from 0.47 φ to 1.70φ with average of 0.90φ. Since the grain size is the factor of the hydrodynamic processes at the time of rock formation (Itam and Inyang, 2015), this suggest that the predominance of coarse grained deposit of the study area, was under a high flow energy. Standard deviation (sorting) has range of 1.31φ -2.57φ, with 80% of the sample being poorly sorted. The average value of sorting value is 1.75φ (shows fluvial setting) and this infer that the distribution contain different wide range of grain sizes, indicating multiples sources or wide range of energy. Skewness ranges from -0.32 to +1.00. The occurrence of both negative and positive skewness value shows a mixed environment of fluvial and beach. Kurtosis has a mean value of 0.82 and ranges from 0.41 to 1.29 (very platykurtic - leptokurtic) infer mixing of different size populations available from source areas.

Table 2 : Grain size statistical parameters from the study area

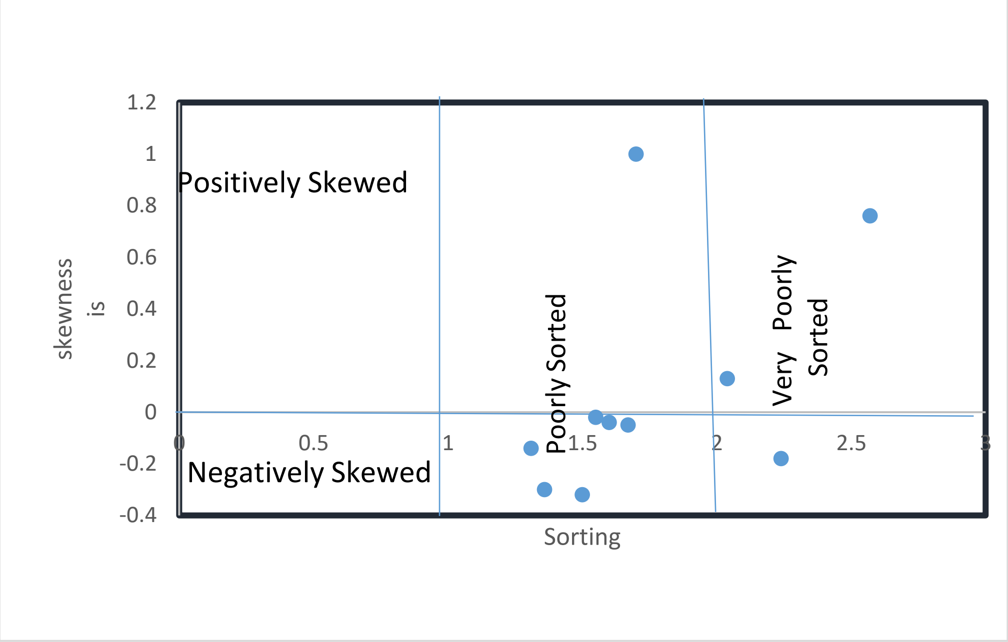
LOCATION	M_Z (φ)	σ(φ)	S_{k1}	K_G	INTERPRRTATION
1	0.9	1.55	-0.02	0.41	**cg,ps,ns,vp**
2	0.9	1.67	-0.05	1.29	**cg,ps,ns,l**
3	0.6	2.24	-0.18	0.67	**cg,vps,cs,vp**
4	0.47	2.04	0.13	0.51	**cg, vps,fs,vp**
5	0.57	1.7	1	0.6	**cg,ps,ns,vp**
6	0.8	1.6	-0.04	1.28	**cg,ps,ns,l**
7	1.7	2.57	0.76	1.1	**mg,vps,sfs,l**
8	0.47	1.36	-0.3	0.8	**cg,ps,cs,p**
9	1.27	1.31	-0.14	0.94	**mg,ps,cs,ms**
10	1.3	1.5	-0.32	0.6	**mg,ps,scs,vp**
AVERAGE	**0.90**	**1.75**	**0.08**	**0.82**	**cg,ps,sfs,p**

KEY : M_z-Graphic Mean; σ-Inclusive Standard Deviation; S_{k1} –Inclusive Graphic Skewness; K_G-The Graphic Kurtosis ;cg-coarse grained ; ms - medium grained; ps-poorly sorted ;vps- very poorly sorted ;ns-nearly symmetrical; cs- coarse skewed; fs-fine skewed; sfs- strongly fine skewed;scs-strongly coarse skewed ;platykurtic ;vp-very platykurtic ;ms-mesokurtic ; l-leptokurtic

Sorting of sediments vary with grain size and energy of deposition. The bivariate plot of sorting versus mean grained size (Figure 3a) shows that as sorting values increases, sediments become more and more poorly sorted The scattered plot of skewness against standard deviation (figure 3b) shows that negative and positive skewed constitute poorly to very poorly sorted . This may infer a mixed environment and fluctuation in the energy of deposition.



3a



3b

Figure 3: The bivariate plot of: (a) Sorting and mean grain size (b) Skewness and sorting

Some environmental discrimination functions (Y_1, Y_2, Y_3 and Y_4) of Sahu (1964), were used to characterize Benin Sandstone in the study area. Similar method has been adopted by Itam and Inyang (2015) in Awi Sandstone of the same basin. The discriminant functions used in this present investigation are presented Table 3

Table 3: Summary of the environmental discriminations functions (Y_1, Y_2, Y_3 and Y_4) from the study area

LOCATION	Y1	Y2	Y3	Y4
1	2.805	179.2	-20.67	1.72
2	6.975	220.3	-23.87	6.02
3	14.36	348.2	-42.87	0.75
4	11.16	292.6	-36.93	2.24
5	6.378	228	-30.02	9.15
6	6.453	203.7	-21.94	6.05
7	17.65	494.7	-61.04	9.50
8	3.507	138.3	-14.56	1.81
9	0.593	147.5	-13.94	4.26
10	1.404	173.5	-17.75	1.05
AVERAGE	**6.583**	**232.9**	**-27.07**	**4.25**

(1)For the discrimination between Aeolian and littoral (intertidal zone) environments, the equation is given as: $Y_1 = - 3.5688M_Z + 3.7016\ \sigma_I{}^2 - 2.0766SK_1 + 3.1135K_G$

Where M_Z is the Mean Grain Size, 6_1 is the Inclusive Standard Deviation (Sorting), SK_I is Skewness and K_G is the Graphic Kurtosis. When Y_1 is less than – 2.7411 it is an Aeolian deposit whereas if Y1 is greater than – 2.7411 a beach environment is suggested. A beach environment was infer, since all the computed values of Y_1 (100%) are greater than – 2.7411

2.For the discrimination between beach (back –shore) and shallow agitated marine environments (sub tidal environment) the following equation is used:
$Y_2 = 15.6534Mz + 65.7091\sigma_I{}^2 + 18.1071Sk_1 + 18.5043K_G.$

If the value of Y_2 is less than 65. 3650 a beach deposition is suggested, whereas if it is greater than 65.3650, a shallow agitated marine environment is inferred. 100% values of Y_2 calculated from the present area of investigation are concluded to be derived from shallow agitated marine environment **(**table3).

(3)For the discrimination between shallow marine and the fluvial environments, the discrimination equation is given as: $Y_3 = 0.2852Mz - 8.7604\ \sigma_I{}^2 - 4.8932Sk_1 + 0.0482K_G.$ If Y_3 is less than -7.419 the sample is identified as a fluvial deposits whereas if Y_3 is greater than - 7.419, the sample is identified as a shallow marine deposit. The analyzed results showed all the plotted Y_3 values from the total number of samples from the study area has values less than -7.419, suggestive of fluvial depositional environment .

(4) For the discrimination between fluvial deposition and turbidity current deposition, the discrimination equation is given as: $Y_4 = 0.7215\ Mz - 0.4020\ \sigma_I{}^2 + 6.7322\ Sk_1 + 5.2927\ K_G$

.If the value of Y_4 less than 9.8433, it would infer a turbidity deposition and if greater than 9.8433, it would indicate fluvial deposition. The values of Y_4 lie in between 9.50 and 0.75and values are less than 9.833, indicate the characteristic of turbidity current deposition.

PEBBLE MORPHOMETRIC ANALYSIS

The computed pebbles morphometry result shown in Table 4 has an average flatness ratio (FR) of 0.44 which is within the marine range (0.40- 0.50) following Luting (1962) scheme. The Flatness index (FI) of the studied pebbles ranges from 17% to 77% with average value of 44% respectively. These values suggest that pebbles are of mixed origin, consisting of fluvial and beach influences. The average elongation ratio (ER) is 0.70 (range of 0.39- 0.96) showing that majority of the pebbles fall within fluvial influence (0.60-0.90) of Hubert (1968). The maximum projection sphericity index (MPSI) has range of values of 0.41-0.90 with a mean of 0.65 inferring inter influence of fluvial and beach processes, based on Dobkins and Folk (1970)**.** The oblate-prolate index (OPI) has majority of the values greater than -1.5 which is the limit that separate beach pebble from fluvial pebble .This shows that the pebbles are influence by fluvial activity with little of beach activities. The bivariate plots of flatness index against maximum projection index sphericity and maximum projection sphericity index versus oblate-prolate index (Figure 4a and b) show that pebbles are of beach and fluvial origin.

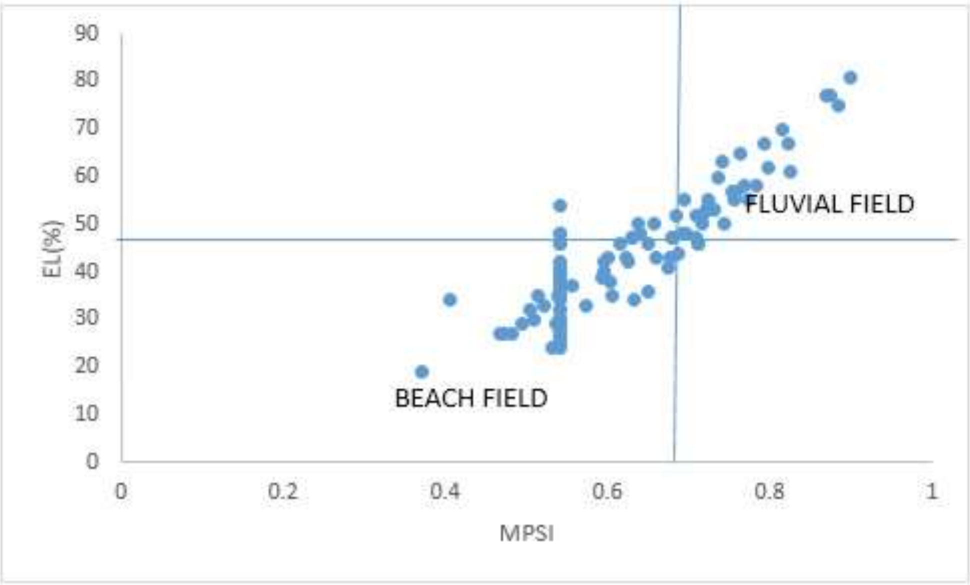
Table 4: Pebble morphometric analysis from the study area.

S/N	L/cm	I/cm	S/cm	FR	FI /%	ER	L-I/L-S	MPSI	OPI	FORM
1	3.3	1.9	1	0.30	30	0.58	0.61	0.54	3.59	B
2	4	1.8	1.1	0.28	28	0.45	0.76	0.55	9.40	VE
3	3.9	1.8	1.1	0.28	28	0.46	0.75	0.56	8.86	VE
4	2.7	1.6	1	0.37	37	0.59	0.65	0.61	3.97	E
5	3.7	1.9	1.1	0.30	30	0.51	0.69	0.56	6.47	E
6	2.7	1.3	0.8	0.30	30	0.48	0.74	0.57	7.99	E
7	2.8	1.6	1.1	0.39	39	0.57	0.71	0.65	5.24	E
8	3.8	1.7	1.2	0.32	32	0.45	0.81	0.61	9.74	E
9	2.6	1.7	1.1	0.42	42	0.65	0.60	0.65	2.36	B

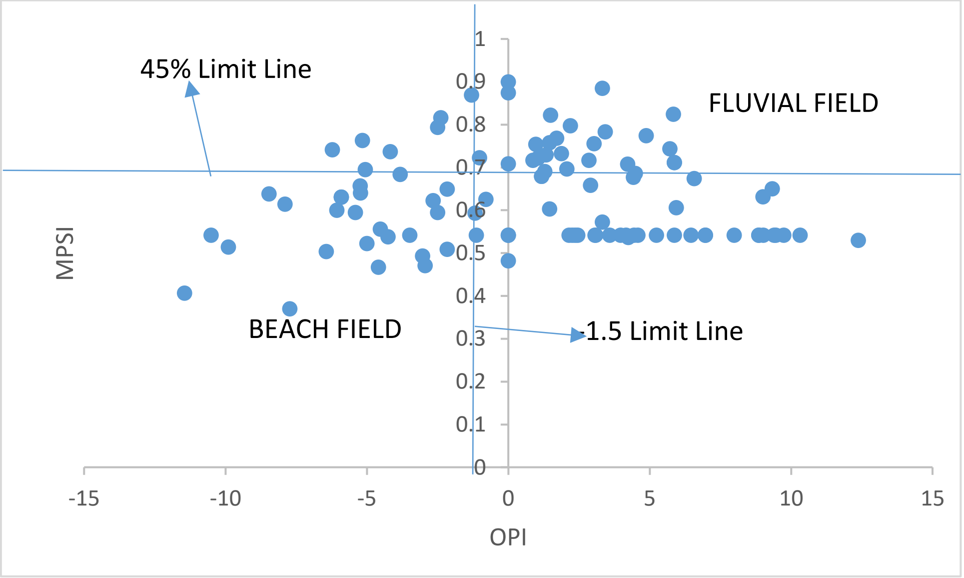
10	3.9	1.8	1.1	0.28	28	0.46	0.75	0.56	8.86	VE
11	3	1.3	0.9	0.30	30	0.43	0.81	0.59	10.32	E
12	2.7	1.7	1.1	0.41	41	0.63	0.63	0.64	3.07	E
13	2.3	1.6	0.9	0.39	39	0.70	0.50	0.60	-4.32	B
14	2.3	1.9	1.1	0.48	48	0.83	0.33	0.65	-3.48	B
15	2.4	1.5	1.3	0.54	54	0.63	0.82	0.78	5.87	CE
16	2.3	1.5	0.6	0.26	26	0.65	0.47	0.47	-1.13	VB
17	4.1	1.9	1.5	0.37	37	0.46	0.85	0.66	9.46	E
18	3.4	1.6	1.2	0.35	35	0.47	0.82	0.64	9.02	E
19	2.6	1.7	1.2	0.46	46	0.65	0.64	0.69	3.10	B
20	3.5	1.8	1.2	0.34	34	0.51	0.74	0.61	6.97	E
21	2.8	1.7	0.9	0.32	32	0.61	0.58	0.55	2.46	B
22	2.5	1.5	1	0.40	40	0.60	0.67	0.64	4.17	E
23	2.3	1.3	1.1	0.48	48	0.57	0.83	0.74	6.97	E
24	2.1	1.3	0.5	0.24	24	0.62	0.50	0.45	0	VB
25	2.4	1.3	0.6	0.25	25	0.54	0.61	0.49	4.44	VB
26	2.1	1.8	0.6	0.29	29	0.86	0.20	0.46	-10.50	VP
27	3.4	2	0.9	0.26	26	0.59	0.56	0.49	2.27	VB
28	3.3	1.9	1.2	0.36	36	0.58	0.67	0.61	4.58	E
29	2.8	1.9	1.3	0.46	46	0.68	0.60	0.68	2.15	E
30	2.6	1.8	0.7	0.27	27	0.69	0.42	0.47	-2.93	VB
31	3.3	1.3	0.8	0.24	24	0.39	0.80	0.53	12.38	E
32	3.2	1.5	1.1	0.34	34	0.47	0.81	0.63	9.00	E
33	2.5	1.9	1	0.40	40	0.76	0.40	0.59	-2.5	B
34	2.4	1.7	0.7	0.29	29	0.71	0.41	0.49	-3.03	VB
35	2.3	1.8	1	0.43	43	0.78	0.38	0.62	-2.65	B
36	2.7	1.6	0.9	0.33	33	0.59	0.61	0.57	3.33	B
37	2.4	1.4	1.1	0.46	46	0.58	0.77	0.71	5.87	E
38	2.2	1.6	0.6	0.27	27	0.73	0.38	0.47	-4.58	VB
39	2.6	1.9	1.1	0.42	42	0.73	0.47	0.63	-0.79	B
40	2.6	1.4	0.9	0.35	35	0.54	0.71	0.61	5.95	B
41	1.8	1.3	0.7	0.39	39	0.72	0.45	0.59	-1.17	B
42	3.4	1.9	1	0.29	29	0.56	0.63	0.54	4.25	VB
43	2	1.8	0.7	0.35	35	0.90	0.15	0.51	-9.89	P
44	2.8	1.8	1.2	0.43	43	0.64	0.63	0.66	2.92	B
45	2.4	2.3	1.5	0.63	63	0.96	0.11	0.74	-6.22	CP
46	2.9	2	1.4	0.48	48	0.69	0.60	0.70	2.07	B
47	2.8	2.2	1.3	0.46	46	0.79	0.40	0.65	-2.15	B
48	2.8	1.9	1.4	0.50	50	0.68	0.64	0.72	2.86	B
49	2.2	1.2	0.9	0.41	41	0.55	0.77	0.67	6.58	E
50	2.4	1.4	1.1	0.46	46	0.58	0.77	0.71	5.87	E
51	2	1.8	1.1	0.55	55	0.90	0.22	0.70	-5.05	CP
52	2.2	2	1.7	0.77	77	0.91	0.40	0.87	-1.29	C

53	2.4	1.8	1.4	0.58	58	0.75	0.60	0.77	1.71	CB
54	2	1.8	1.2	0.60	60	0.90	0.25	0.74	-4.17	CP
55	2	1.8	1.4	0.70	70	0.90	0.33	0.82	-2.38	CP
56	1.8	1.6	1.2	0.67	67	0.89	0.33	0.79	-2.50	CP
57	2.9	1.9	1.1	0.38	38	0.66	0.56	0.60	1.46	B
58	1.9	1.4	1	0.53	53	0.74	0.56	0.72	1.06	CB
59	2.3	1.4	1	0.43	43	0.61	0.69	0.68	4.42	E
60	3.7	3.2	1.6	0.43	43	0.86	0.24	0.60	-6.06	P
61	1.7	1.2	0.8	0.47	47	0.71	0.56	0.68	1.18	B
62	1.8	1.2	1.1	0.61	61	0.67	0.86	0.82	5.84	CE
63	2	1.6	1.1	0.55	55	0.80	0.44	0.72	-1.01	CB
64	2.8	2.1	1.6	0.57	57	0.75	0.58	0.76	1.46	CB
65	2.6	2.3	2	0.77	77	0.88	0.50	0.87	4.33	C
66	1.5	1.1	0.8	0.53	53	0.73	0.57	0.73	1.34	CB
67	2.6	2.5	1.3	0.50	50	0.96	0.08	0.64	-8.46	P
68	2.8	2.6	1.3	0.46	46	0.93	0.13	0.61	-7.90	P
69	2.3	1.7	1.2	0.52	52	0.74	0.55	0.72	0.87	CB
70	3.2	2.3	1.7	0.53	53	0.72	0.60	0.73	1.88	CB
71	3.2	2.6	2.4	0.75	75	0.81	0.75	0.89	3.33	C
72	4.2	3.7	2.1	0.50	50	0.88	0.24	0.66	-5.24	P
73	2.9	1.9	1.6	0.55	55	0.66	0.77	0.77	4.88	CE
74	3.2	2.9	2.6	0.81	81	0.91	0.50	0.90	4.12	C
75	2	1.4	1.1	0.55	55	0.70	0.67	0.76	3.03	CE
76	2.8	1.3	1	0.36	36	0.46	0.83	0.65	9.33	E
77	2.5	2	0.8	0.32	32	0.80	0.29	0.50	-6.43	P
78	2.3	2	1.1	0.48	48	0.87	0.25	0.64	-5.22	P
79	2.4	1.7	1.4	0.58	58	0.71	0.70	0.78	3.43	CE
80	2.6	2	0.9	0.35	35	0.77	0.35	0.54	-4.25	P
81	2.5	1.9	1.3	0.52	52	0.76	0.50	0.71	2.14	CB
82	1.7	1.5	0.8	0.47	47	0.88	0.22	0.63	-5.90	P
83	1.5	1.2	1	0.67	67	0.8	0.60	0.82	1.50	CB
84	1.7	1.6	1.1	0.65	65	0.94	0.17	0.76	-5.15	CP
85	2.1	1.8	1.1	0.52	52	0.86	0.30	0.68	-3.82	CP
86	2.1	1.6	1.2	0.57	57	0.76	0.56	0.75	0.97	CB
87	2.9	2.2	1.8	0.62	62	0.76	0.64	0.80	2.20	CB
88	2.8	1.7	1.4	0.50	50	0.61	0.79	0.74	5.71	E
89	2.7	2.1	0.9	0.33	33	0.78	0.33	0.52	-5.00	B
90	3.1	2.2	1.5	0.48	48	0.71	0.56	0.69	1.29	B
91	2.1	1.5	0.4	0.19	19	0.71	0.35	0.37	-7.72	VB
92	1.7	1.2	0.8	0.47	47	0.71	0.56	0.68	1.18	B
93	1.9	1.2	0.9	0.47	47	0.63	0.70	0.71	4.22	E
94	1.9	1.6	0.8	0.42	42	0.84	0.27	0.59	-5.40	P
95	1.7	1.4	0.4	0.24	24	0.82	0.23	0.41	-11.44	P
96	1.8	1.1	0.8	0.44	44	0.61	0.70	0.69	4.50	E

97	1.7	1.5	0.8	0.47	47	0.88	0.22	0.63	-5.90	P
98	3.3	2.3	1	0.30	30	0.70	0.43	0.51	-2.15	B
99	3	1.9	0.8	0.27	27	0.63	0.50	0.48	0	VB
100	1.9	1.5	0.7	0.37	37	0.79	0.33	0.56	-4.52	B
AVE	**2.59**	**1.78**	**1.11**	**0.44**	**44**	**0.70**	**0.54**	**0.65**	**1.07**	**B**



4a



4b

Figure 4: Bivariate plot of mean values of (a) Flatness index ,FI against Maximum projection spericity index, MPSI (b) MPSI against OPI

According to Sneed and Folk (1958), Dobkins and Folk (1970) and Gale (1990); Compact (C), Elongation (E), Compact Bladed (CB) and Compact Elongate (CE) are most indicative of fluvial action whereas Platy(P), Very Platy (VP),Very Bladed (VB) and Bladed (B) are diagnostic of beach setting. The roughly equal percentage occurrence of theses diagnostic pebble form of Compact Elongation (10%CE) ,Elongation (35% E), Bladed (40%B) and Very Bladed (15% VB) show fluvio- beach influences in the study area.

CONCLUSION

The outcrop unit of Benin Formation exposed along Lemna road in Calabar, South Eastern Nigeria was investigated for sedimentologic textural characteristics. Grains size parameters such as mean, sorting, skewness and kurtosis show that the study specimen is coarse-medium grained, poorly -very poorly sorted sand of river/beach to shallow marine agitated influence with turbidity current acting side by side. The different pebble morphological characteristics reflect fluvial and beach pebble processes.

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