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GRANULOMETRY AND PEBBLE MORPHOMETRY OF AWI SANDSTONES, CALABAR FLANK, NIGERIA

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ABSTRACT

Granulometry and pebble morphometry was carried out in the studying of depositional environment of Awi Sandstone of the Calabar Flank. Granulometric analysis of 15 samples show the formation has a graphic mean (M_{Z}) of 0.89ϕ, average sorting coefficient (σ_I) of 1.31ϕ, Skewness (Sk_i) is positively skewed and kurtosis (K_G), ranges from platykurtic to leptokurtic ranges. Pebble morphometric analysis of the conglomerates (360 pebbles) from 10 locations showed that the mean values of various morphometric ranges as follows: flatness ratio (FR = 0.52-0.59), coefficient of flatness ratio (CFR=52% to 59%), elongation ratio (ER =0.72-0.82), maximum projection sphericity (MPSI =O.70-0.76) and Oblate Prolate index (OPI = -1.23 to 2.31). Roundness index averaged 0.23 and ranges between 27% to 40%.The integration of the various granulometric parameters and pebble morphometric indices in different bivariate plots results, indicate a fluvial to shallow marine environment of deposition for Awi Formation.

Keywords: Granulometry, pebble morphometry, Awi Sandstone, bivariate plots, environment of deposition

INTRODUCTION

Granulometry and pebble morphometry was employed in the studying of depositional environment of Awi Sandstone of the Calabar flank. Awi Formation is the oldest basal unit in the Calabar Flank and rest unconformally on the Oban Massif basement complex of Nigeria (Figure1). The Formation is about 500m thick and consist dominantly of conglomerate and sandstone units with minor mudstone, shales and some carbonaceous materials in a cyclic finning upward unit (Nyong, 1995). The Formation type locality is a road cut along Calabar – Ikom road. Minor exposure are found at a cliff around the Mfamosing area overlain by the limestone. Also a very thick outcrop is in Nyahasang village nine (9) kilometers south of Awi.

The use of granulometric parameters (Graphic Mean M_Z; Inclusive Graphic Standard Deviation σ_I; Inclusive Graphic Skewness Ski; and The Graphic Kurtosis K_G) and pebble indices such as Flatness Ratio (FR) Coefficient of Flatness Ratio (CFR) Elongation Ratio (ER) Maximum Projection Sphericity Index (MPSI) And Oblate Prolate Index (OPI) with the visual estimation of pebble roundness using Roundness Chart of Sames (1966),was integrated in this Formation to evaluate the paleodepositional environment of Awi Formation. The result obtain will enhance comparison its equivalence in other localities.

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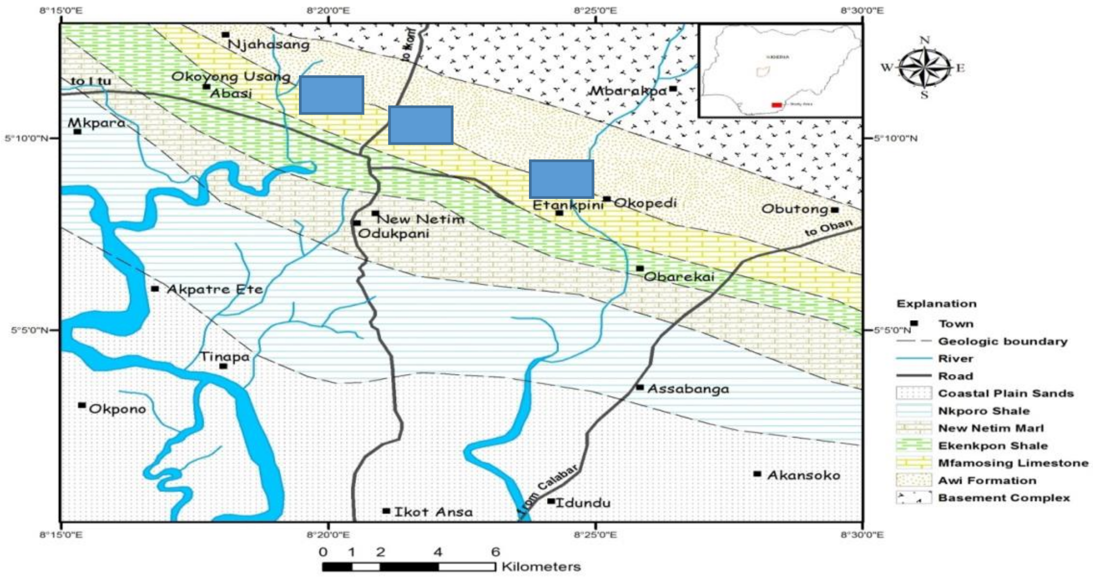

Study Area

Figure I: Map showing the stratigraphic units of Calabar Flank (Nyong, 1995).

Geological Setting

The Calabar Flank is an epirogenic sedimentary basin in southeastern Nigeria(Murat ,1972).The basin according to Nyong (1995) is bounded the southern rim of Oban Massif in the north, Calabar hinge line separates the basin from Niger Delta basin in the south,Ikpe platform and Cameroon volcanic trend in the west and east respectively (Figure 2) . The origin of this basin is

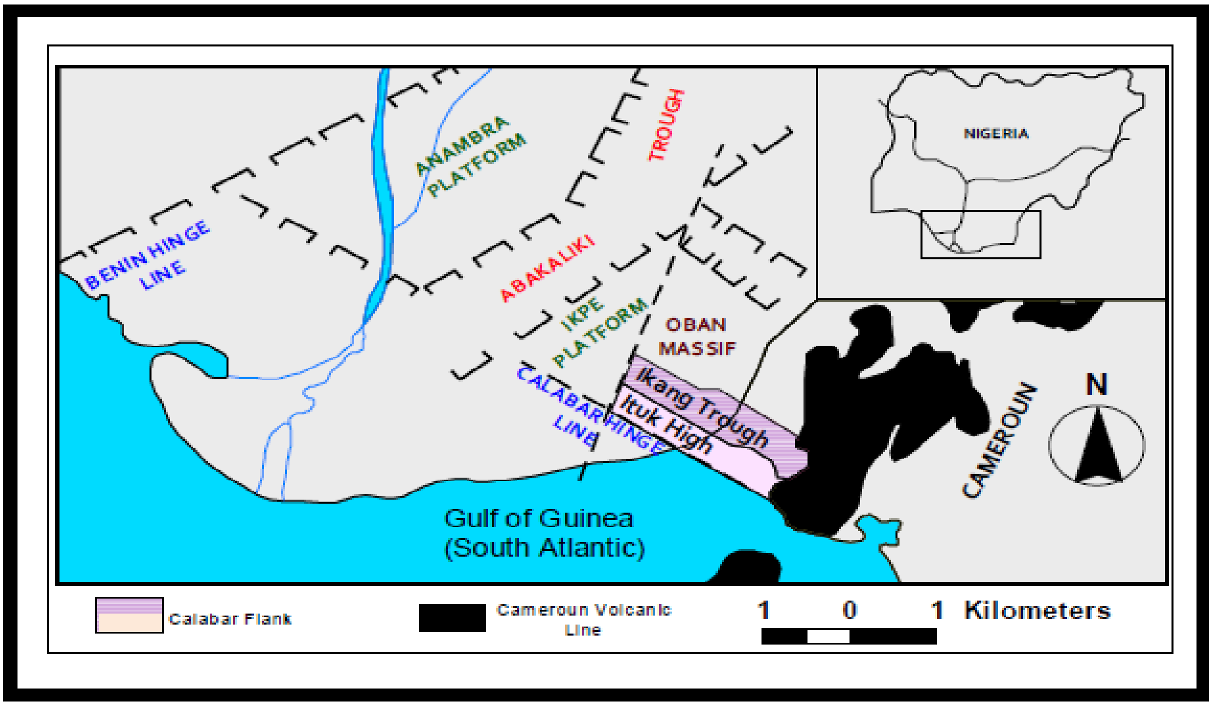

Figure 2: Map showing Calabar Flank location with respect to the Benue trough(Nyong and Ramanathan, 1985).

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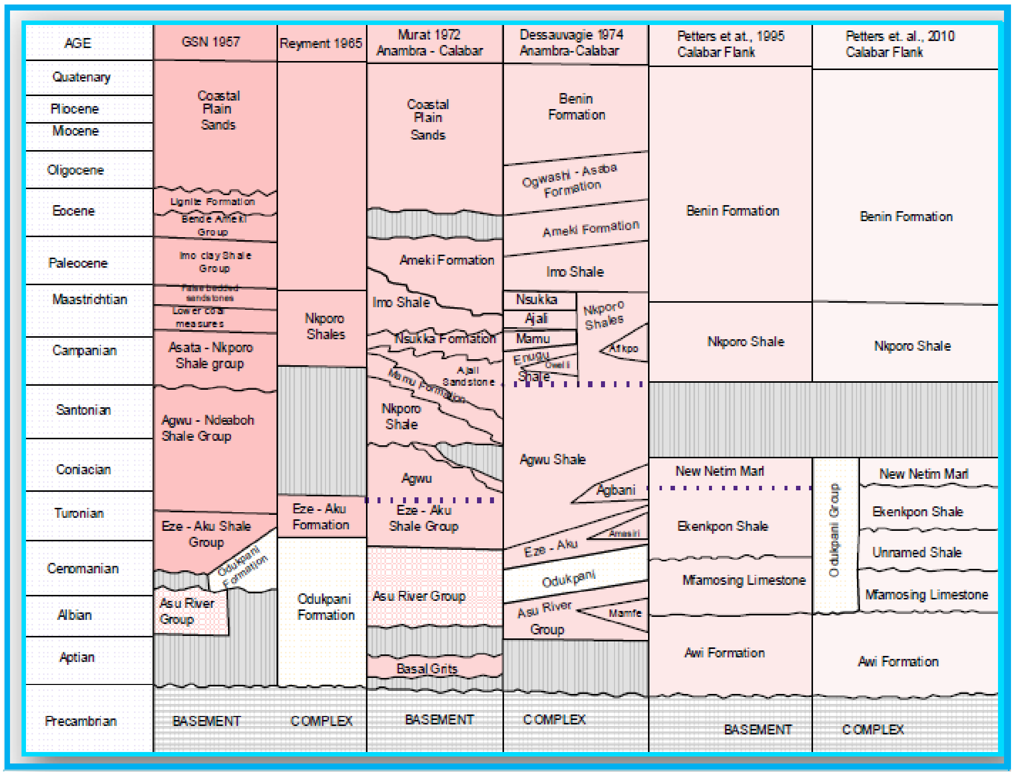
associated with the opening of the South Atlantic in the Mesozoic era when the South American plate drifted away from African plate .The major tectonic elements operating within the basin include the Ikang Trough (graben structure) and Ituk High (horst) which were mobile depression and stable mobile submarine ridge that initiated sedimentary distribution 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 north of Calabar, 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 Tartary 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 and Nyong and Ramanathana,1985), which the first marine transgression into the basin. This in turn succeeded by Late Albian- Cenomanian to Turonian, Ekenkpon Shale (Nyong and Ramanathan, 1985).Subsidence on the faulted blocks of horst and graben allow 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 Nigeria. Nkporo Shale of Late Campania to Early Maastrichtian (Edet and Nyong, 1994) capped marine transgression and Mesozoic sedimentation in Calabar Flank .The Tertiary continental sands and gravel of Benin Formation completes the sedimentation episode in the basin.

Table 1: Stratigraphic correlation between Calabar Flank and other Nigerian

Sedimentary basins (Nyong, 1995 and Petters et al ; 2010)



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2). MATERIALS AND METHODS

The study are is located within longitude and latitude (Figure1).Fifteen (15) fresh sandstone samples from quarry pits, road cuts and outcrops samples were collected from different locations within the Awi Formation. The indurated samples were crushed mechanically to disintegrate them, and sieved using a set of sieve arranged/stacked vertically with the coarsest sieved at the top and finest at the bottom, with a pan using an electrical shaker for about fifteen (15) minutes. At the end, each sieving material from different mesh size were poured carefully onto a glazed paper placed on top of electronic balance pan and the weight recorded. Cumulative graph were plotted and the different phi (ϕ) values, were derived from each sample together with the various statistical parameters (Folk, 1984) were presented in (tables

Also a total of three hundred and sixty (360) quartz pebbles from ten (10) different locations were collected. The long (L) Intermediate (l) and Short (S) axes of pebbles were measured using Vernier caliper, forms and their roundness were evaluated. The mean Values of morphometric parameters were calculated (Table 3).Table

Sample No	MZ	σ	SK_1	KG	Textural Interpretation
A1	0.47	1.54	0.35	0.63	Coarse grained, poorly sorted, fine skewed and very platy
A2	0.66	1.31	0.33	1.38	Coarse grained, poorly sorted, fine skewed and leptokurtic
A3	0.83	1.52	0.44	1.28	Coarse grained, poorly sorted, fine skewed and leptokurtic
A4	0.73	1.42	0.28	1.26	Coarse grained, poorly sorted, fine skewed and leptokurtic
A5	0.46	1.42	0.40	0.45	Coarse grained, poorly sorted, strongly fine skewed and very platy
A6	0.43	1.5	0.41	0.68	Coarse grained, poorly sorted, strongly fine skewed and platy
A7	0.53	1.41	0.85	0.72	Coarse grained, poorly sorted, strongly fine skewed and platy
A8	1.51	1.07	0.13	1.1	Medium grained, poorly sorted, fine skewed and mesokurtic
A9	1.4	1.3	0.3	0.9	Medium grained ,poorly sorted, strongly fine skewed and mesokurtic
A10	1.36	1.34	0.13	1.12	Medium grained ,poorly sorted, fine skewed and leptokurtic
A11	1.28	1.3	0.13	0.96	Medium graine,poorly sorted, fine skewed and mesokurtic
A12	0.9	0.97	0.08	1.2	Coarse grained, moderately sorted, fine skewed and leptokurtic
A13	0.98	0.8	0.14	1.3	Coarse grained ,moderately sorted, fine skewed and leptokurtic
A14	1.3	1.4	-0.32	0.6	medium grained, poorly sorted, strongly coarse skewed and very platy
A15	0.47	1.36	-0.4	0.82	Coarse grained, poorly sorted, strongly coarse skewed and platy
Mean	**0.89**	**1.31**	**0.22**	**0.96**	**Coarse grained ,poorly sorted, fine skewed and mesokurtic**

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Legend: M_Z=Mean Grained Size, σ_1 = Inclusive Standard Deviation (Sorting), SK_1 =Inclusive Graphic Skewness and K_G =Graphic Kurtosis

Table 3: Summary of pebble morpho-analysis of the study area

LOC	L (cm)	I (cm)	S (cm)	I/L	S/L	CFR = ((S/L)*100)	L-I/L-S	MPSI	OPI	Form	Roundness (%)
1	2.57	2.11	1.48	0.82	0.59	58.79	0.43	0.75	-1.23	CB	38
2	2.35	1.78	1.34	0.78	0.59	58.95	0.53	0.76	0.73	CB	34.5
3	2.69	2.09	1.36	0.77	0.52	51.98	0.47	0.70	-0.69	B	32.67
4	2.34	1.82	1.34	0.78	0.58	58.08	0.53	0.75	0.42	B	39.83
5	2.28	1.73	1.27	0.77	0.57	56.97	0.54	0.75	0.69	CB	33.5
6	2.14	1.60	1.19	0.76	0.57	57.18	0.57	0.75	1.23	CB	34.5
7	2.25	1.69	1.28	0.76	0.58	57.62	0.57	0.76	1.20	CB	34.83
8	2.59	1.95	1.41	0.75	0.55	55.07	0.59	0.74	1.29	CB	27
9	2.39	1.76	1.36	0.74	0.58	57.85	0.62	0.76	2.04	CB	40.83
10	2.51	1.77	1.35	0.72	0.55	54.75	0.62	0.74	2.31	CB	34.67
MEAN	2.41	1.83	1.34	0.77	0.57	56.72	0.56	0.75	0.79		35.03

RESULTS AND DISCUSSIONS

Statistical Analysis of the grain size parameters

The result of the granulometric analysis shows that the Awi Sandstone (Table 2), have a graphic mean (M_Z) of 0.89ϕ ranging from 0.43 Φ- 1.51Φ inferring medium to coarse grain sandstone. This mean grain size is a function of the hydrodynamic processes prevailing at the time of formation this rock and may infer high current velocity of the transporting medium. The standard deviation (σ_I), which signifies the uniformity of the grained particles averages 1.31ϕ and ranges from 0.79Φ - 1.54Φ,which infer moderately to poorly sorted grained. This reveal fluctuation in the energy of deposition. The Inclusive Graphic Skewness (Sk_i), has mean value of 0.22 and range from – 0.40 to + 1.12 with dominant values of positive skewness over negative skewness , the poorly sorted and positively skewed values infer that the sand is of fluvial origin (Ojo,2012). Kurtosis (K_G), values of the investigated area range from 0.45 to1.38 (averages 0.96) showing very platykurtic to leptokurtic values. This may suggest mixtures of 3 sediments populations in sub equal proportions having fine, medium and coarse grained sands

The plot of sorting values against mean grain size values in figure 3a shows that 13% of the values are moderately sorted and are medium, while 87% of the plotted values in the coarse grain field have higher sorting value hence poorly sorted. The bivariate plots of skewness versus standard deviation (Figure 3b) shows that sediment with higher values of sorting (poorly sorted) is positively skewed. From the plot in figure 3c, the presence of largely dominant coarse grain sand, with poorly sorted grain have over 90% percent of the plotted values in the leptokurtic zone .This suggest dominance of coarse grain sediment indicating moderately energy environment (Folk,1984)

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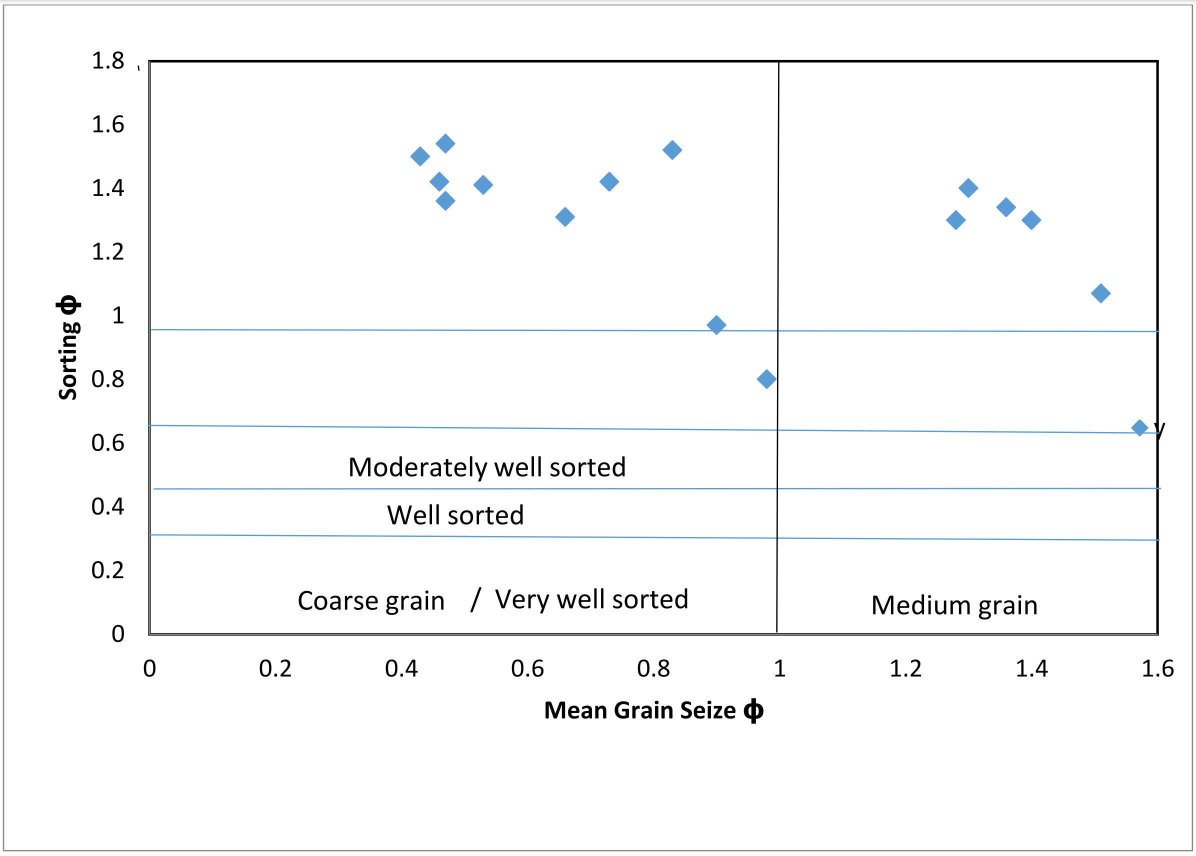

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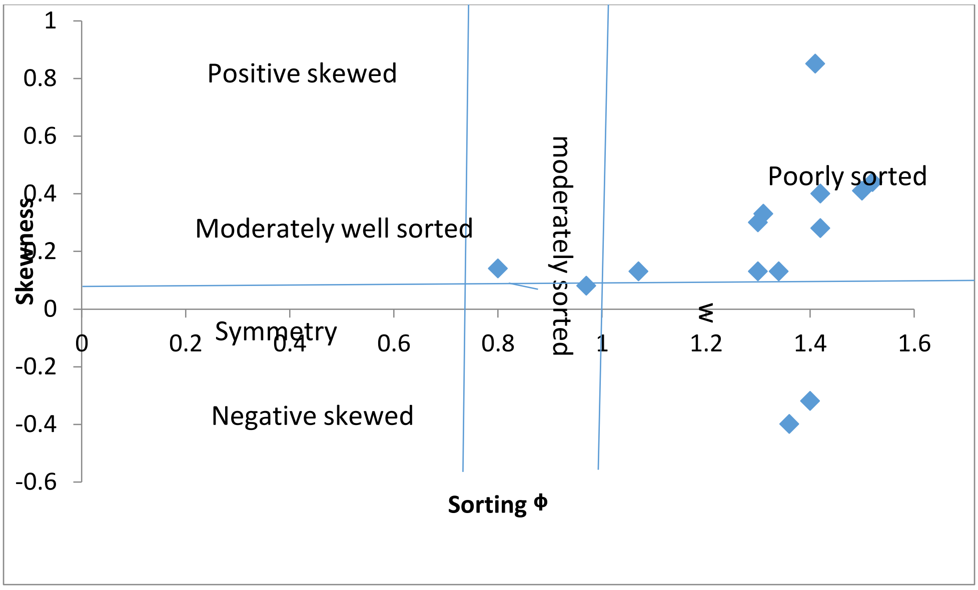

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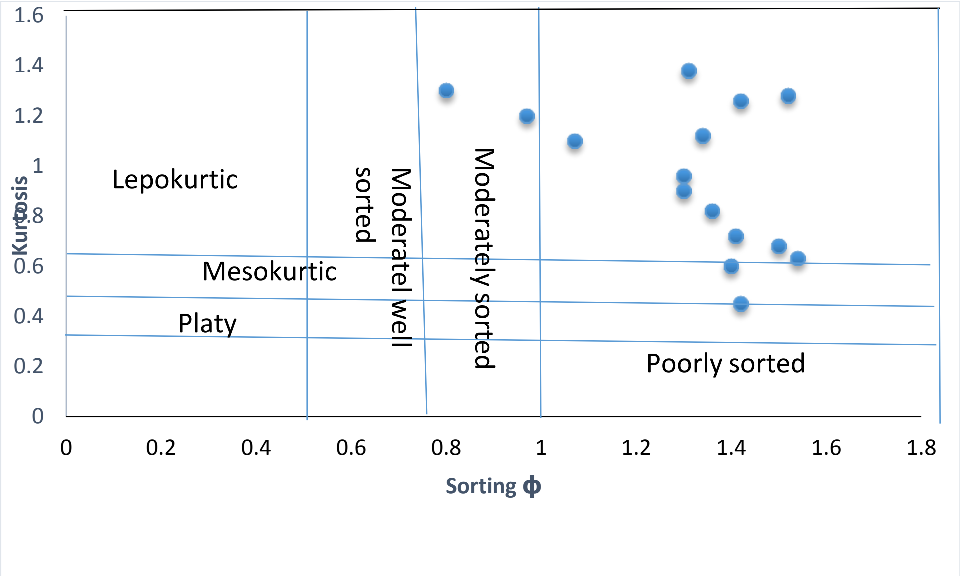

3c

Figure 3: The bivariate relationship plot of ; (a) Sorting and Mean grain szie (b) Skewness and Sorting (c) Kurtosis and Sorting

Some environmental discrimination functions (Y_1, Y_2 and Y_3) of Sahu (1964), were used to characterize Awi Sandstone. The discriminant functions used in this present investigation are presented table 3:

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

Sample No	Y_1	Y_2	Y_3
A1	8.3362	181.185	-25.505
A2	7.6101	154.6059	-16.3937
A3	8.6621	201.0589	-22.0947
A4	8.2004	172.3082	-18.9456
A5	4.2103	155.2662	-19.0543
A6	6.99967	174.5833	-21.5615
A7	5.9469	167.6401	-21.3889
A8	2.004	121.5809	-10.1997
A9	4.37334	155.0491	-15.8304
A10	4.8369	162.3678	-15.9262
A11	4.4066	151.2028	-15.76
A12	3.841	99.5675	-8.8427
A13	2.6284	83.9847	-5.9495
A14	5.1483	154.3875	-15.2049
A15	8.5528	136.8233	-14.0724
Mean	**5.7169**	**151.4407**	**-16.5722**

(1)

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

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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 values of Y_1 are greater than – 2.7411.

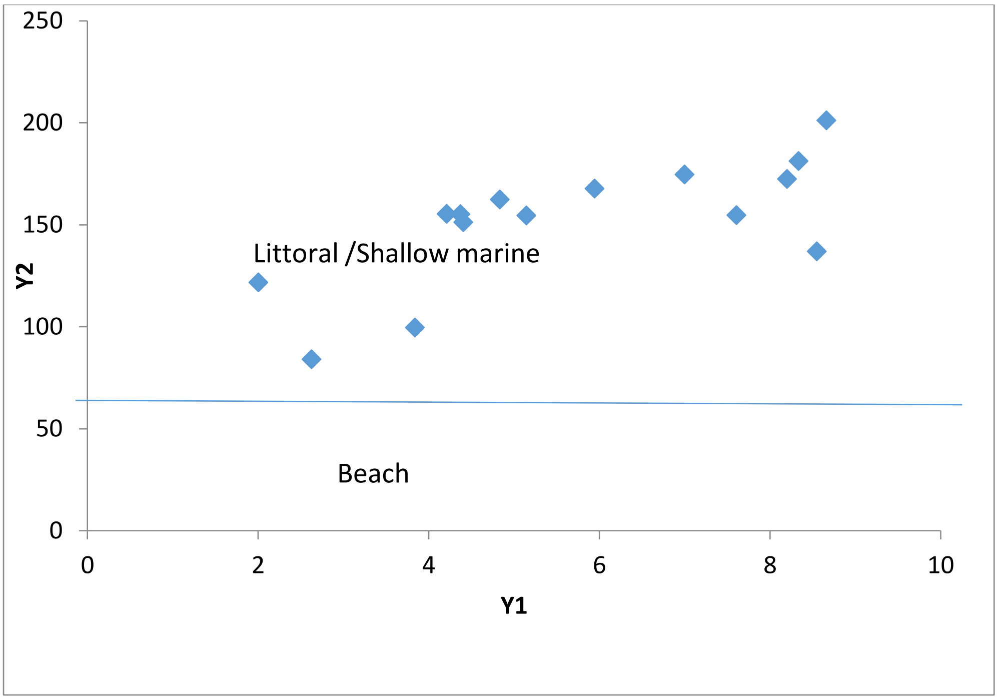
2. For the discrimination between beach (back –shore) and shallow agitated marine environments (sub tidal environment) the following equation is used:

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). This agitated marine environment may be taken to be a deltaic region, where Awi Formation is infer to as fluvial –deltaic in nature.

(3) For the discrimination between shallow marine and the fluvial environments, the discrimination equation is given as: Y3 = 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 93% of the plotted Y_3 values from the total number of samples from the study area has values less than -7.419, suggestive of fluvial environment while7 % has Y_3 less than -7.419 inferring marginal marine setting

A bivariate plot of Y_1 and Y_2 (Figure 4a) show most samples to be littoral or shallow agitated marine environment. A bivariate plot of Y_2 and Y_3 (figure 4b), show that most samples are of fluvial/deltaic environment



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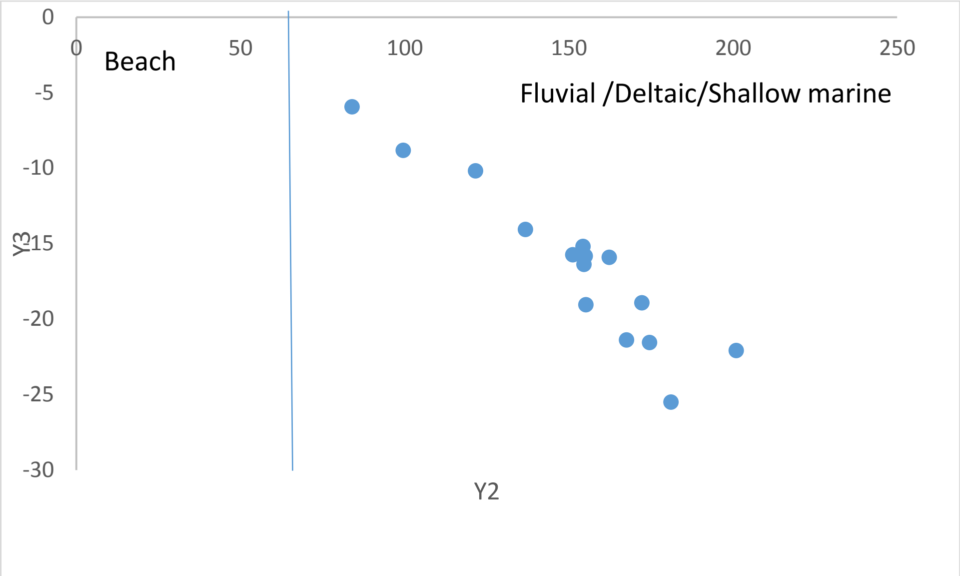

5b

Figure 4 : Relationship between the discriminate functions showing estimated environments of : (a)Y_2 and Y (b) Y3 and Y_2

Statistical Analysis of the Pebble morphometric parameters

The result obtained (Table 3) show that the mean flatness ratio (FR) of 0.57,the flatness index (FI) or coefficient of flatness ratio (CFR) ranges from 52% to 59% with average mean of 57% indicating depositional environment (Lutig,1962). The mean elongation ratio (ER) for pebbles of Awi Sandstone evaluated is 0.76 which is approximately within 0.60-0.90 range of Hubert (1968) fluvial setting.

The mean value of MPSI in Awi Formation is 0.75 (ranges from 0.70-0.76),suggesting fluvial environment (Dobkins and Folk,1970).The Oblate-Prolate (OP) index ranges from -1.23 to 2.31 with a total mean of 0.80 with 80% of the plotted values greater than -1.5; lower empirical limits of Dobkins and Folk,(1970) which distinguishes beach dominated pebbles from river.

Sames (1966) found that roundness values less than 0.350 are typical of river pebbles whereas values more than 0.450 suggest littoral environment. From the analyzed data70% of the mean roundness values fall within the fluvial limits while 30% of the samples is in the beach field

Morphometric scatter plots were constructed from pebble suites of the area under investigation. From Stratten (1974) bivariate plots of flatness index (CFR) vs; sphericity index (MPSI) in figure 6a, shows pebbles shaped by fluvial processed have CFR and MPSI above 45% and 0.66 limit lines and beach falls below these limit lines values respectively. From figure 5a, most plotted values signify fluvial setting. The plot of roundness against elongation ratio (ER) (Figure 5b**)**, shows short distance travel of river influence for the pebble from Awi Formation, which might arise from weathering of the basement rocks of Oban Massif of Nigeria. It infer pebbles shaped by predominantly river influence with little beach activity. The scatter plots of sphericity index (MPSI) against oblate-prolate index (OPI), in figure 5c, is based on Dobkins and Folk (1970). MPSI values above 0.66 line, is fluvial while values less than 0.66 indicates beach influence. The pebbles are more on the prolate side than the oblate side of the ternary (Figure 5d). The plotted values show over 80% of all the pebbles fall within the fluvial dominated area while less than 20% in the beach zone, indicating more river origin and less beach settings setting for Awi Formation.

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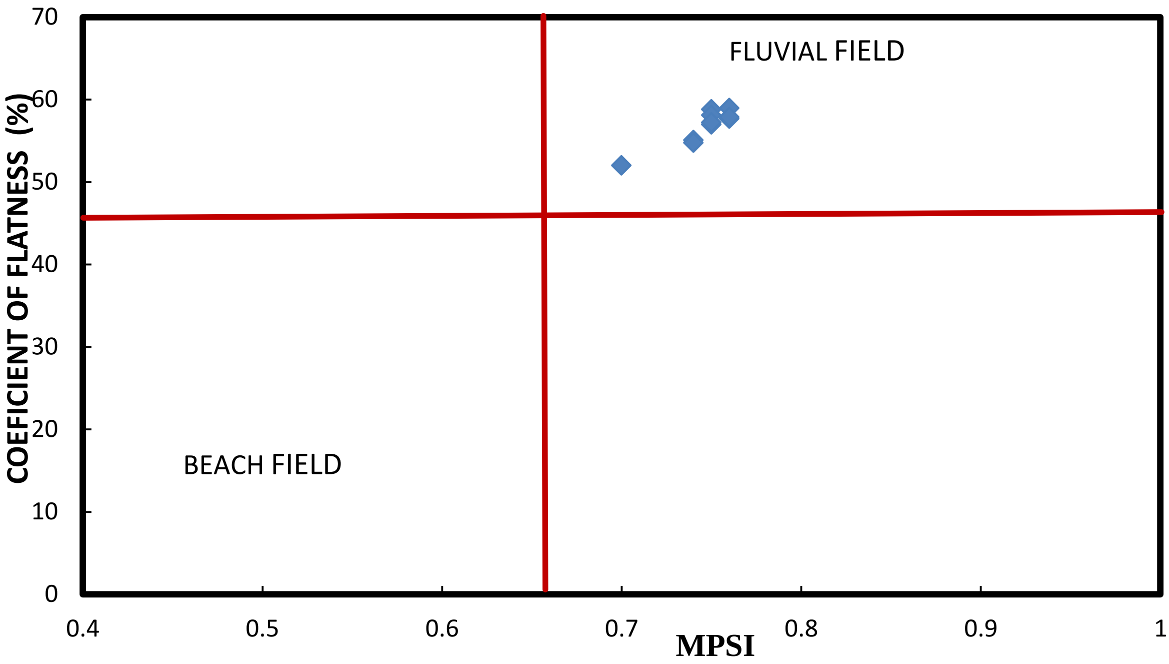

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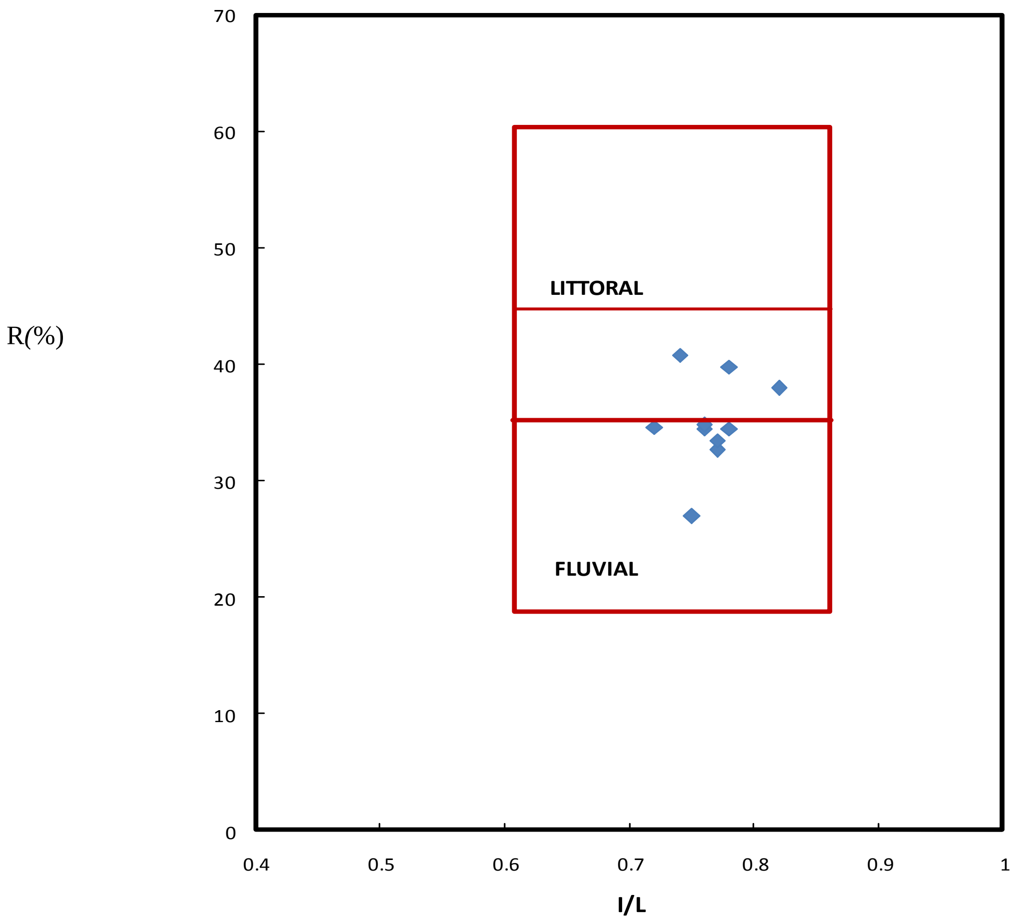

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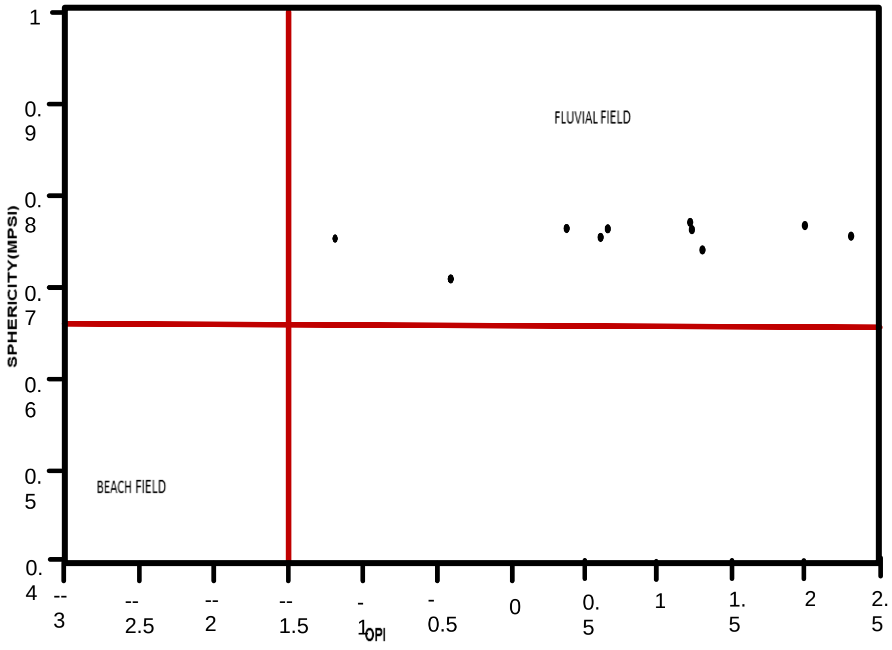

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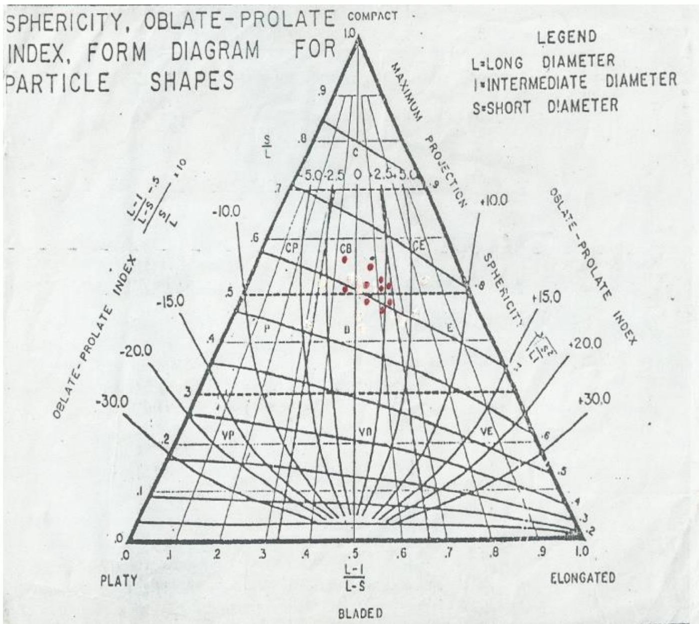

5d

Figure 5: Bivariate plot of mean values of (a) coefficient of flatness against MPSI;(b) roundness against flatness ratio (c) MPI vs.OPI (d) class ternary diagram

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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 predominant percentage occurrence of Compact Bladed (80%CB) over Bladed (20%B) show more fluvial activities less beach influence in the study area.

Conclusion

The integration of granulometric parameters and pebble morphometric parameters have proved beyond doubt to be good indicators in distinguishing paleodepositional environments in situations where fossils are lacking especially in a continental setting such as Awi Formation. The various combination of grained size parameters and those in pebble morphometric, with their different bivariate scatter graphs have shown that Awi Formation is fluvial to beach and shallow agitated marine depositional environment. Distilled from this study shows Awi Sandstone depositional setting radiate between fluvial and shallow marine environment (fluvial –tidal zone).

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