Paleoenvironmental Indications From Textural Parameters: A Case Study Of The Paleocene To Eocene Sandstones In Some Parts Of Anambra Basin, South-Eastern, Nigeria.

Obinegbu I.R., Chiaghanam, O.I., Chiadikobi, K.C

ABSTRACT: Paleoenvironmental study of Paleocene to Eocene Sandstone in some parts of Anambra Basin was studied using textural parameters, which includes sieve analysis and pebble morphological methods. The sieve analysis suggested that the study area is basically coarse grained, poorly to moderately sorted sandstone, with mainly positively skewed, and its kurtosis ranging from very platykurtic to leptokurtic, while pebble morphological analysis suggested that the study area were mainly shaped in zone of interaction between wave and fluvial processes (Coastal Environment) generally suggesting that the paleoenvironment of the study area is a fluvial dominated, marine influence environment with tidal actions.

Keywords: Paleoenvironment, Textural Parameter, Pebble Morphology, Sieve Analysis, Anambra Basin

INTRODUCTION
This geological field study was carried out in the areas of Nnewi, Oba, Akwaukwu and Nsugbe environs. The outcrops in these above areas mentioned were studied in details; including the Formation noted. At the study areas, the outcrops encountered were basically pebbles, sandstones, siltstone, sand-silty clay, conglomerates, boulders, Shale with clayey sands. They were logged and their textural descriptions recorded. Samples were collected from different outcrops for sieve analysis and pebble morphometric study. The study areas were characterized by sedimentary aggregates of Ameki and Ogwashi-Asaba Formations. They lie in Anambra Basin which is one of the intracratonic/inland basins in Nigeria.

- *Obinegbu,I.R. is currently pursuing masters degree in Economic Geology in Anambra State University, Uli, Anambra State, Nigeria. He is a Senior Technologist in Anambra State University, Uli, Anambra State, Nigeria. Email: iobinegbu@yahoo.com*
- *Chiaghanam, O.I. is a Ph.D holder in Stratigraphy/Sedimentary Geology in Nnamdi Azikiwe University, Nigeria. He is a Senior Lecturer in Anambra State University, Uli, Anambra State, Nigeria. Email: oichiaghanam@yahoo.com*
- *Chiadikobi, K.C. is currently pursuing doctoral degree in Structural Geology in the Federal University of Technology, Akure, Nigeria. He is a Lecturer in Anambra State University, Uli, Anambra State, Nigeria. Email: kinsomino@yahoo.com*

OBJECTIVES
The main objective of this study is to use pebble morphology and sieve analysis to interpret depositional environment of Ameki and Ogwashi-Asaba Formations. The study involved the following:

- Geological study of pebbles in order to obtain data for pebble morphometric study;
- Geological study of sands in order to obtain data for grain size distribution and textural characteristics.
- Interpretation of the deposition processes responsible for the deposition of the pebbles and sands.

GEOLOGIC SETTING OF ANAMBRA BASIN
The Anambra Basin is located in the southeastern part of Nigeria; and is bounded to the North by Bida Basin and northern Nigeria Massif, to the East by Benue Trough to the west by West African Massif and to the south by Niger Delta complex. The Basin is a Cretaceous Basin having almost a roughly triangular shape with a total sediment thickness of about 9km; which covers an area of about 40,000sq.km. Anambra Basin is characterized by enormous lithologic heterogeneity in both lateral and vertical extensions derived from a range of paleoenvironmental settings. Anambra Basin is a structural synclinal depression and one of the intracratonic basins in Nigeria. Volcanic activity occurred at different times and places throughout the cretaceous history of the Benue trough, but minor intrusive are mainly confined to Albian sediments. The rocks appear to belong to both alkaline and tholeitic association and this may reflect subtle variation in the tectonic controls of magmatism during the evolution of Benue Trough at any event they are apparently all of mid-plate type [10]. Overlying these sediments are the late Upper Albian sediments of Awi Formation, Abakaliki Shale, Ngbo Formation [9]. In the Lower Benue Trough, these rocks form the Asu River Group which were affected by the localized Cenomanian folding [7] succeeding the Asu River Group is the sequence of sediments which include Agila Sandstone, Ibir Sandstone, Odukpani Formation all aged Cenomanian; Makurdi Sandstone, Ezeaku Shale [11], Nara

Shales, Agu-Ojo Sandstone and Amaseri Sandstone all aged Turonian. The Coniacian Awgu Shale which is bluish, well bedded shale with occasional intercalation of fine grain, pale yellow, calcareous sandstone and shaley limestone overlie the Cenomanian sediments. The extensive Campano-Maastrichtian transgression initiated sedimentation in the Anambra basin. The stratigraphy indicates that the Campanian Nkporo Shale from the base which is separated from the pre-Campanian strata by a type-1 sequence boundary [8]. The Nkporo Shale passes laterally into Owelli Sandstone in the Awgu area and Enugu Shale in the Enugu area. The Owelli Sandstone is a cross stratified fluvial deltaic sandstone while the Enugu Shale is composed of marginal marine-shallow marine carbonaceous mudstone and fine grain sandstone containing thin coal seam. These three Formations form the Nkporo Group. Succeeding the Nkporo group is the Mamu Formation or the Lower Coal Measure [14]. It is aged Maastrichtian and characterized by carbonaceous fossil shale and mudstone deposited in a shallow shoreface environment. Overlying the Mamu Formation is the Ajali Sandstone which is profusely cross bedded tidal channel/fluvial channel deposit and aged late Maastrichtian [5]. Capping the Campano-Maastrichtian succession is the Nsukka Formation characterized by carbonaceous mudstone and sandstone similar to Mamu Formation. It is also called the lower coal measure. A short Paleocene transgression deposited the Imo Shale. It is typically of high energy shoreface. Marine environment [1]. The Imo Shale is dark grey to bluish shale with thick sandstone bands as well as iron stone. It is fine textured, it is sandy and heterolithic upward [17]. The regressive Eocene Ameki Group forms the last succession in the Anambra Basin. This consists of the Nanka Sand and the Nsugbe Sandstone. The table 1 shows the regional stratigraphy described.

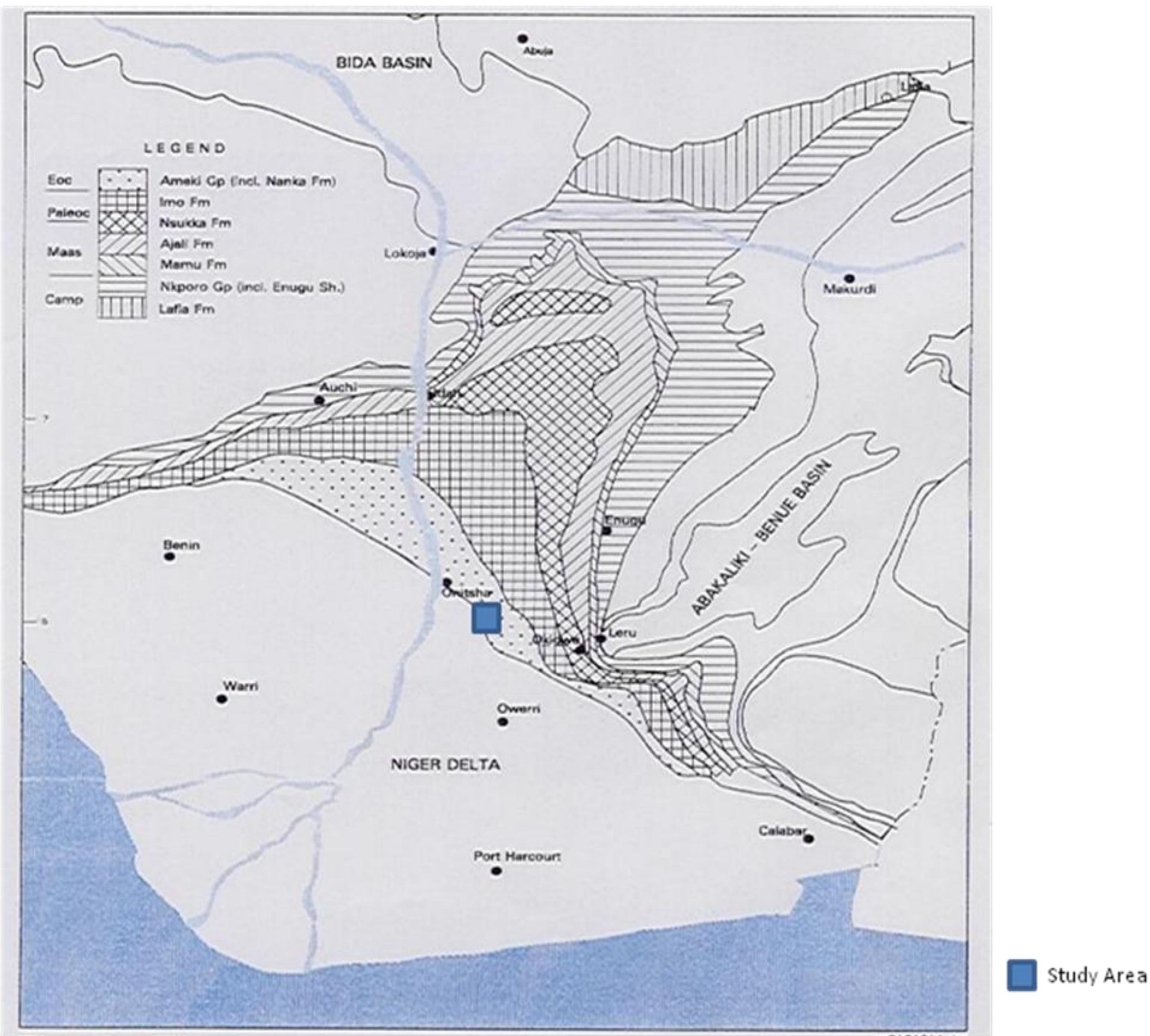

Fig. 1. Geologic Map of Anambra Basin and Afikpo Basin South-Eastern Nigeria showing the study area [4].

Table 1: Lithostratigraphic framework for the Early Cretaceous- Tertiary period in southeastern Nigeria [11].

AGE (M. Y)		*ABAKALIKI – ANAMBRA BASIN*	*AFIKPO BASIN*
30	*Oligocene*	*Ogwashi – Asaba Formation*	*Ogwashi – Asaba Formation*
54.9	*Eocene*	*Ameki/Nanka Formation /Nsugbe Sst.*	*Ameki Formation*
65	*Paleocene*	*Imo Formation* *Nsukka Formation*	*Imo Formation* *Nsukka Formation*
73	*Maastrichtian*	*Ajali Formation* *Mamu Formation* *Nkporo/Owelli Sandstone /Enugu Shale* *(Incuding Lokoja Sandstone and Lafia Sandstone)*	*Ajali Formation* *Mamu Formation* *Nkporo shale/Afikpo Sandstone*
83	*Campanian*		
	Santonian	Agbani Sandstone/ Awgu Shale	*Non deposition/Erosion*
87.5	*Conacian*		*Ezeaku Group* *(including Amasiri Sandstone)*
88.5	*Turonian*	*Eze Aku Group*	
93	*Cenomanian*		
100	*Albian*	*Asu River Group*	*Asu River Group*
119	*Aptian* *Barremian* *Hauterivian*	*Un-named units*	
Precambrian		*Basement Complex*	

METHODOLOGY

Sands and Pebbles Samples collected from the field were taken to the laboratory for analysis. The analysis carried out were Sieve analysis and Pebble morphometry respectively. The equipment/apparatus involved during the course of this laboratory studies include:Set of sieves, Weighing balance, Venier caliper, Weighing pan, Stop watch and Result sheet.

Method of Sieve Analysis

A more general form of mechanical analysis used to determine grain-size of sand sized particles is the sieving method. Fresh samples to be sieved are systematically collected from known horizons on each outcrop. The samples are disaggregated to create loose assemblage of grains. This is systematically done in a mortar using a rubber padded pestle, to avoid breaking and crushing the grains.

Table 2: Descriptive measures of grain size distribution [3].

Parameters	Formulas	Verbal terms
Mean size (Mz)	$Q_{16} + Q_{50} + Q_{84} / 3$	M_z= 0-1: coarse sand 1-2: medium sand 2-3: fine sand
Standard deviation (σ_i)	$Q_{84} - Q_{16} / 4 +$ $Q_{95} - Q_5 / 6.6$	σ_i = > 0.35: very well sorted 0.35-0.50: well sorted 0.50-1.0: moderately sorted 1.0-2.0: poorly sorted 2.0-4.0: very poorly sorted < 4.0: extremely poorly sorted
Skewness (SKi)	$Q_{16} + Q_{84} - 2(Q_{50}) /$ $2 (Q_{84} - Q_{16})$ + $Q_5 + Q_{95} - 2(Q_{50}) /$ $2(Q_{95} - Q_5)$	SKi = > +1.0-+0.3 very positively skewed 0.3-0.1: positively skewed 0.1-(-0.1): symmetrical skewed -0.1-(-3.0): negatively skewed -0.3-1.0: very negatively skewed
Graphic kurtosis (ka)	$Q_{95} - Q_5 /$ $2.44 (Q_{75} - Q_{25})$	K_G = < 0.67: very platykurtic 0.67-0.90: platykurtic 0.90-1.11: mesokurtic 1.11-1.50: leptokurtic 1.50-3.0: very leptokurtic > 3.0: extremely leptokurtic

Method of Pebble Morphometry

Pebble morphometric analysis was carried out for 160 pebbles randomly collected from different locations in the study area in order to decipher or interpret the depositional environment. The pebbles collected were washed and numbered serially. This is done to know pebble that has each measurement being recorded for accuracy. Before those measurements, a careful selection was carried out so as to select only pebbles of uniform composition and high resistivity to abrasion. Such pebbles with high abundance like vein quatz were selected. Only pebbles with intermediate diameter above 4mm were selected. A vernier callipers was used to measure the three perpendicular axes that is the long (L), intermediate (I), and the short (S) axes of each pebble. A pebble can exhibit different kinds of roundness like sub-angular, sub- rounded and rounded. The following form indices were computed:

(i) Maximum projection sphericity [15] = $(S^2/LI)^{1/3}$
(ii) Elongation ratio = I/L x 100
(iii) Flatness index [6] = (S/L) x 100
(iv) Oblate-prolate index [2] = $\frac{(L-I)/(L-S)-0.5}{S/L}$

RESULTS

Sieve Analysis

The computed grain size parameters and their verbal term for Nnewi, Akwaukwu, Oba and Nsugbe outcrops were shown in table 3.

Table 3: Computed grain size parameters and their verbal terms for outcrops from study areas

Sample name and number	Mean size (MZ)	Sorting (σ1)	Skewness (ski)	Kurtosis (KG)
SP.01 Nnewi I	0.73 Coarse sand	0.77 Moderately sorted	3.84 very positively skewed	0.36 very platykurtic
SP.02 Nnewi II	0.19 Coarse sand	1.59 Poorly sorted	3.68 very positively skewed	0.94 mesokurtic
SP.03 Akwaukwu	0.45 Coarse sand	0.75 Moderately sorted	2.38 very positively skewed	0.95 mesokurtic
SP.04Oba I	0.65 Coarse sand	3.86 v. poorly sorted	-0.37 very negatively skewed	1.93 very leptokurtic
SP.05 Oba II	0.15 Coarse sand	3.11 extremely poorly sorted	0.17 symmetrical	0.94 mesokurtic
SP.06Nsugbe I	0.35 Coarse sand	0.91 Moderately sorted	1.43 very positively skewed	0.54 very platykurtic
SP.07Nsugbe II	1.45 Medium sand	0.50 Moderately sorted	2.75 very positively skewed	1.37 leptokurtic

Pebble Morphological Analysis

The computed mean from indices are shown in Tables 4 to10.

Table 4: UMUEZENA STREAM UMUDIM ROADCUT NNEWI 1

	L	I	S	S/L	S/L*100	I/L	L-I/L-S	SPHE-RICITY	OP INDEX	ROUN-DNESS	Form Name
1	29.8	25.5	14.9	0.5	50	0.856	0.289	0.664	-4.228	0.82	CP
2	26.2	22.2	17.7	0.676	67.557	0.847	0.471	0.814	-0.435	0.82	CB
3	32.4	25.5	11	0.34	33.951	0.787	0.322	0.527	-5.23	0.83	P
4	28.6	22.3	13.4	0.469	46.853	0.78	0.414	0.655	-1.825	0.68	B
5	31	24	10.1	0.326	32.581	0.774	0.335	0.516	-5.067	0.75	B
6	24.5	20.2	7.1	0.29	28.98	0.824	0.247	0.467	-8.726	0.82	VP
7	24.8	12.8	12.2	0.492	49.194	0.516	0.952	0.777	9.1959	0.76	E
8	24.6	21.7	16	0.65	65.041	0.882	0.337	0.783	-2.503	0.84	CP
9	25	19.3	14.1	0.564	56.4	0.772	0.523	0.744	0.4067	0.84	CB
10	23.6	22.1	14.6	0.619	61.864	0.936	0.167	0.742	-5.388	0.69	CP
11	28.5	13.5	14	0.491	49.123	0.474	0.034	0.799	10.881	0.86	P
12	27.2	14.2	12.3	0.452	45.221	0.522	0.872	0.732	8.237	0.87	E
13	32.5	21.5	13.4	0.412	41.231	0.662	0.576	0.636	1.8413	0.86	B
14	24	20.3	8.4	0.35	35	0.846	0.237	0.525	-7.509	0.82	P
15	20	17.3	11.1	0.555	55.5	0.865	0.303	0.709	-3.543	0.87	CP
16	19.4	18.6	12.2	0.629	62.887	0.959	0.111	0.744	-6.184	0.97	CP
17	18.2	17	11.7	0.643	64.286	0.934	0.185	0.762	-4.906	0.81	CP
18	20.7	17.1	12.3	0.594	59.42	0.826	0.429	0.753	-1.202	0.75	CB
19	45.3	32.8	23.1	0.51	50.993	0.724	0.563	0.711	1.2367	0.98	CB
20	64.4	41.6	34.7	0.539	53.882	0.646	0.768	0.766	4.9678	0.95	CE
Mean	28.54	21.48	14.22	0.505	50.498	0.772	0.457	0.691	-0.999	0.83	CB
Standard Deviation		6.641	5.89	0.116	11.597	0.141	0.267	0.105	5.6156	0.08	VP

Table 5: AKWAUKWU(OSE STREAM)

	L	I	S	S/L	S/L*100	I/L	L-I/L-S	SPHE-RICITY	OP INDEX	ROUN-DNESS	Form Name
1	52	35	25	0.481	48.077	0.673	0.63	0.7	2.6963	0.89	B
2	55.5	48.5	34	0.613	61.261	0.874	0.326	0.754	-2.847	0.74	CB
3	67.5	57	37.5	0.556	55.556	0.844	0.35	0.715	-2.7	0.73	CB
4	36.1	36	13	0.36	36.011	0.997	0.004	0.507	-13.76	0.93	P
5	36.5	26	20	0.546	54.795	0.712	0.636	0.75	2.4886	0.94	CB
6	45.1	45	20	08	44.346	0.998	0.004	0.582	-11.19	0.93	P
7	30	25	14.5	0.443	48.333	0.833	0.323	0.654	-3.671	0.91	B
8	49	35.5	20	0.483	40.816	0.724	0.466	0.613	-0.845	0.98	B
9	57	47	40	0.408	70.175	0.825	0.588	0.842	1.2574	0.76	CB
10	42.5	24.5	20.5	0.702	48.235	0.576	0.818	0.739	6.5965	0.92	E
11	48	42	23	0.482	47.917	0.875	0.24	0.64	-5.426	0.73	P
12	41.5	34	16	0.479	38.554	0.819	0.294	0.566	-5.34	0.74	P
13	45	32.5	18	0.386	40	0.722	0.463	0.605	-0.926	0.85	B
14	39.5	29	16.5	0.4	41.772	0.734	0.457	0.619	-1.041	0.89	B
15	28	33.5	16.5	0.418	58.929	1.196	-0.48	0.662	-16.6	0.84	B
16	34	29	12.5	0.589	36.765	0.853	0.233	0.541	-7.274	0.78	P
17	28	22	12.5	0.368	44.643	0.786	0.387	0.633	-2.529	0.75	B
18	57	50	35	0.446	61.404	0.877	0.318	0.755	-1.961	0.78	CB
19	27	20	13	0.481	48.148	0.741	0.5	0.679	0	0.79	B
20	28	21	17.5	0.625	62.5	0.75	0.667	0.805	2.6667	0.89	CE
Mean	42.36	34.63	21.3	0.494	49.412	0.821	0.361	0.668	-3.07	0.839	0B
Standard Deviation		10.63	8.65	0.097	9.6756	0.135	0.286	0.089	5.7347	0.084	VP

Table 6: UMUEZENA STREAM UMUDIM NNEWI 2

	L	I	S	S/L	S/L*100	I/L	L-I/L-S	SPHE-RICITY	OP INDEX	ROUN-DNESS	Form Name
1	55.2	34.2	16.8	0.304	30.435	0.62	0.547	0.531	1.54	0.98	VB
2	26	24.2	17	0.654	65.385	0.931	0.2	0.772	-4.588	0.73	CP
3	49	23.3	17.1	0.349	34.898	0.476	0.806	0.635	8.758	0.92	E
4	31.6	25.8	17.2	0.544	54.43	0.816	0.403	0.713	-1.786	0.73	CB
5	45	37	15.7	0.349	34.889	0.822	0.273	0.529	-6.505	0.74	P
6	24.5	21.1	14.1	0.576	57.551	0.861	0.327	0.727	-3.007	0.75	CB
7	33.8	21.8	13.3	0.393	39.349	0.645	0.585	0.622	3.169	0.89	B
8	29.7	24.2	17.9	0.603	60.269	0.815	0.466	0.764	-0.562	0.72	CB
9	41.7	16.1	10.2	0.245	24.46	0.386	0.813	0.537	12.78	0.86	VE
10	35.5	32	21.7	0.611	61.127	0.901	0.254	0.746	-4.031	0.73	CP
11	42.7	31.2	22.1	0.518	51.756	0.731	0.558	0.716	1.126	0.89	CB
12	34.5	21.4	17.5	0.507	50.725	0.62	0.771	0.746	5.334	0.86	CE
13	31.4	29	15.6	0.487	49.682	0.924	0.152	0.644	-7.007	0.82	P
14	25.1	22.1	15	0.598	59.761	0.88	0.297	0.74	-3.396	0.75	CP
15	27	21.7	14.3	0.53	52.963	0.804	0.417	0.704	-1.561	0.89	CB
16	36.8	22.4	13	0.353	35.326	0.609	0.605	0.59	2.973	0.75	B
17	34.7	22.2	18	0.519	51.873	0.64	0.749	0.749	4.791	0.71	E
18	26.3	20	12.5	0.475	47.529	0.76	0.457	0.667	-0.915	0.87	B
19	33.2	23.3	15.4	0.464	46.386	0.702	0.556	0.674	1.211	0.85	B
20	38.6	23.4	17.6	0.456	45.596	0.606	0.724	0.7	4.909	0.75	E
Mean	35.12	24.8	16.1	0.719	47.719	0.727	0.498	0.675	0.612	0.8095	B
Standard Deviation		5.22	2.28	0.113	11.259	0.15	0.207	0.079	5.041	0.0818	VP

Table 7: UGWUOSA/OKPATAGU ROADCUT NSUGBE 1

	L	I	S	S/L	S/L*100	I/L	L-I/L-S	SPHE-RICITY	OP INDEX	ROUN-DNESS	Form Name
1	44	38.2	13.3	0.302	30.227	0.868	0.189	0.472	-10.29	0.93	VP
2	46.4	43.6	27.2	0.586	58.621	0.94	0.146	0.715	-6.042	0.78	CP
3	52.2	50	17.6	0.337	33.716	0.958	0.064	0.491	-12.94	0.93	P
4	39.4	38.3	25	0.635	63.452	0.972	0.076	0.745	-6.676	0.78	CP
5	40	8.4	13.7	0.343	34.25	0.71	0.441	0.549	-1.721	0.92	B
6	28.9	24.4	10.1	0.349	34.948	0.844	0.239	0.525	-7.458	0.97	P
7	33.4	29.4	19.7	0.59	58.982	0.88	0.292	0.734	-3.527	0.78	CP
8	37.7	33.6	18	0.477	47.745	0.891	0.208	0.635	-6.113	0.73	P
9	26.6	24.5	15	0.564	56.391	0.921	0.181	0.702	-5.656	0.78	CP
10	28.4	17.2	12.5	0.44	44.014	0.606	0.704	0.684	4.644	0.89	E
11	50	35	18	0.36	36	0.7	0.469	0.57	-0.868	0.87	B
12	28.8	23.2	14.4	0.5	50	0.806	0.389	0.677	-2.222	0.77	CB
13	27	20	14.3	0.53	52.963	0.741	0.551	0.723	0.9664	0.66	CB
14	35.3	22.7	20.5	0.581	58.074	0.643	0.851	0.806	6.0501	0.77	CE
15	37.1	32.2	18.3	0.493	49.326	0.871	0.255	0.654	-4.96	0.76	P
16	20.4	19.7	13.5	0.662	66.176	0.966	0.101	0.768	-6.023	0.73	CP
17	24.7	16.1	12.7	0.514	51.417	0.652	0.717	0.74	4.2139	0.83	CE
18	40.2	31.1	20.3	0.505	50.498	0.774	0.457	0.691	-0.846	0.66	CB
19	15.8	15.1	12.2	0.772	77.215	0.956	0.194	0.854	-3.957	0.99	C
20	31.3	21.2	18.8	0.601	60.064	0.677	0.808	0.811	5.1279	0.72	CE
mean	34.38	28.2	16.8	0.507	5-.704	0.819	0.367	0.677	-2.915	0.813	CB
Standard Deviation		9.535	4.41	0.124	12.386	0.122	0.249	0.108	5.1863	0.099	VP

Table 8: UGWUOSA/OKPATAGU NSUGBE 2

	L	I	S	S/L	S/L*100	I/L	L-I/L-S	SPHE-RICITY	OP INDEX	ROUN-DNESS	Form Name
1	43	34.5	27	0.628	62.791	0.802	0.531	0.789	0.4977	0.78	CB
2	51	45	32	0.627	62.745	0.882	0.316	0.764	-2.936	0.73	CP
3	48.5	41	26	0.536	53.608	0.845	0.333	0.698	-3.109	0.67	CB
4	57.5	47	28	0.487	48.696	0.817	0.356	0.622	-2.959	0.65	B
5	42	35.5	29	0.69	69.048	0.845	0.6	0.826	0	0.81	CB
6	57.5	41.5	22	0.383	38.261	0.722	0.451	0.588	-1.288	0.72	B
7	41.5	24.5	19	0.458	45.783	0.59	0.756	0.708	5.5819	0.89	E
8	47	40	29	0.617	61.702	0.851	0.389	0.765	-1.801	0.73	CB
9	42	34	17.5	0.417	41.667	0.81	0.327	0.599	-4.163	0.78	B
10	44	35	31	0.705	70.455	0.795	0.692	0.855	2.7295	0.72	C
11	60	38	25	0.417	41.667	0.633	0.629	0.65	3.0857	0.83	B
12	30.5	27.5	21	0.689	68.852	0.902	0.316	0.807	-2.675	0.99	CB
13	43	30	19.5	0.543	45.349	0.698	0.553	0.666	1.1729	0.62	B
14	48	42	33.5	0.698	69.792	0.875	0.414	0.823	-1.235	0.76	CB
15	69	44	25	0.362	36.232	0.638	0.568	0.59	1.8818	0.66	B
16	34	26.5	16	0.471	47.059	0.779	0.417	0.657	-1.771	0.78	B
17	23.5	21.5	10.5	0.447	44.681	0.915	0.154	0.602	-7.747	0.63	P
18	33	27	13.5	0.409	40.909	0.818	0.308	0.589	-4.701	0.78	P
19	33	26	16	0.485	48.485	0.788	0.412	0.668	-1.82	0.83	B
20	41.5	27	15	0.361	36.145	0.651	0.547	0.586	1.305	0.68	B
Mean	44.475	34.38	22.8	0.517	51.696	0.783	0.448	0.695	-0.998	0.752	CB
Standard Deviation		10.729	6.71	0.121	12.07	0.096	0.148	0.092	3.0917	0.0919	VP

Table 9: OBA 1

	L	I	S	S/L	S/L*100	I/L	L-I/L-S	SPHE-RICITY	OP INDEX	ROUN-DNESS	Form Name
1	36	25	19	0.528	52.778	0.694	0.647	0.737	2.7864	0.94	CE
2	36.5	20	12.5	0.342	34.247	0.548	0.688	0.598	5.475	0.86	E
3	31	28	12	0.387	38.71	0.903	0.158	0.549	-8.838	0.93	P
4	32	21.5	15	0.469	46.875	0.672	0.618	0.689	2.5098	0.85	B
5	41	26.5	20	0.488	48.78	0.646	0.69	0.717	3.9048	0.72	E
6	42.5	37.5	26.5	0.624	62.353	0.882	0.313	0.761	-3.007	0.93	CB
7	27	23	16.5	0.611	61.111	0.852	0.381	0.76	-1.948	0.74	CB
8	28	21	15	0.536	53.571	0.75	0.538	0.726	0.7179	0.98	CB
9	28.5	25	18.5	0.649	64.912	0.877	0.35	0.783	-2.311	0.74	CB
10	26	22.5	10.5	0.404	40.385	0.865	0.226	0.573	-6.79	0.74	P
11	26	13.5	9	0.346	34/615	0.519	0.735	0.613	6.7974	0.79	E
12	25	13.5	10	0.4	40	0.54	0.767	0.667	6.6667	0.92	E
13	30.1	25	14	0.465	46/512	0.831	0.317	0.639	-3.939	0.98	B
14	25	20.1	15	0.6	60	0.804	0.49	0.765	-0.167	0.75	CB
15	25	15.5	11	0.44	44	0.62	0.679	0.678	4.0584	0.86	E
16	28	18	13.5	0.482	48.214	0.643	0.69	0.712	3.9336	0.86	E
17	24	14.5	7	0.292	29.167	0.604	0.559	0.52	2.0168	0.92	VB
18	25.5	24	12	0.471	47.059	0.941	0.111	0.617	-8.264	0.93	P
19	27.5	25	12	0.436	43.636	0.909	0.161	0.594	-7.762	0.93	P
20	22	19	15	0.682	68.182	0.864	0.429	0.813	-1.048	0.84	CB
Mean	29.33	21.91	14.2	0.483	48.255	0.748	0.477	0.676	-0.26	0.8605	B
Standard Deviation		5.687	4.429	0.109	10.856	0.14	0.213	0.084	4.9877	0.0865	VP

Table 10: OBA -2

	L	I	S	S/L	S/L*100	I/L	L-I/L-S	SPHE-RICITY	OP INDEX	ROUN-DNESS	Form Name
1	20	20	15	0.75	75	1	0	0.825	-6.667	0.82	C
2	31	21.5	20	0.645	64.516	0.694	0864.	0.844	5.6364	0.84	CE
3	29	22	13.5	0.466	46.552	0.759	0.452	0.659	-1.039	0.72	B
4	24.5	19.5	14.5	0.592	59.184	0.796	0.5	0.761	0	0.69	CB
5	29.5	21.5	15	0.508	50.847	0.729	0.552	0.708	1.0172	0.89	B
6	33	23.5	15.5	0.47	46.97	0.712	0.543	0.677	0.9124	0.94	B
7	37	23.5	15.5	0.419	41.892	0.635	0.628	0.651	3.0533	0.98	B
8	34	31.5	20	0.588	58.824	0.926	0.179	0.72	-5.464	0.93	CP
9	34.5	32	15	0.435	43.478	0.928	0.128	0.588	-8.551	0.74	P
10	40	22.5	15	0.375	37.5	0.563	0.7	0.63	5.3333	0.98	E
11	23	15	9	0.391	39.13	0.652	0.571	0.617	1.8254	0.68	B
12	25	20	15.5	0.62	62	0.8	0.526	0.783	0.4244	0.73	CB
13	27	18.5	12	0.444	44.444	0.685	0.567	0.661	1.5	0.89	B
14	23	19	14.5	0.63	63.043	0.826	0.471	0.784	-0.467	0.81	CB
15	23	18.5	13.5	0.587	58.696	0.804	0.474	0.754	-0.448	0.74	CB
16	25	19.5	17.5	0.7	70	0.78	0.733	0.856	3.3333	0.74	C
17	41	32.5	19	0.463	46.341	0.793	0.386	0.647	-2.452	0.74	B
18	33.5	23.5	15.5	0.463	46.463	0.701	0.556	0.673	1.2007	0.72	B
19	23	15	9	0.391	39.13	0.652	0.571	0.617	1.8254	0.68	B
20	28	20.5	14	0.5	50	0.732	0.536	0.699	0.7143	0.88	B
Mean	29.2	21.98	14.93	0.522	52.191	0.758	0.497	0.708	0.0844	0.807	CB
Standard Deviation		4.932	2.903	0.109	10.936	0.107	0.202	0.08	3.6154	0.102	VP

KEY: B=Bladed, CP=Compact platy, P=Platy, E=Elongate, CB=Compact bladed, C=Compact, VP=Very platy, VE=Very elongate

The Bivariate plots of MPS against OPI and flatness FI against maximum projection sphericity MPS are shown in figures 2 and 3 respectively and the sphericity form diagram is represented in figure 4.

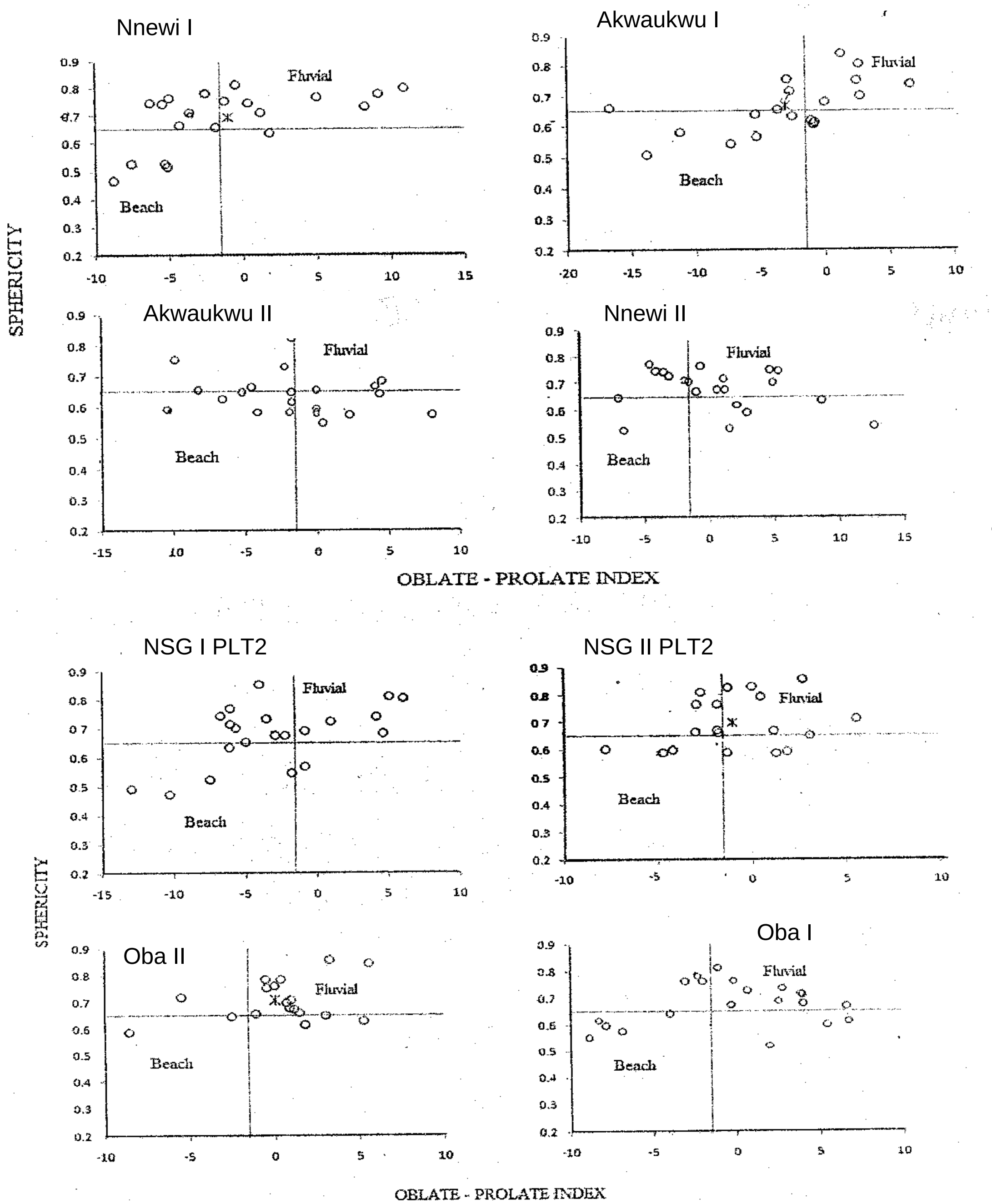

Fig. 2: Plots of sphericity against oblate prolate index of pebbles from the study areas

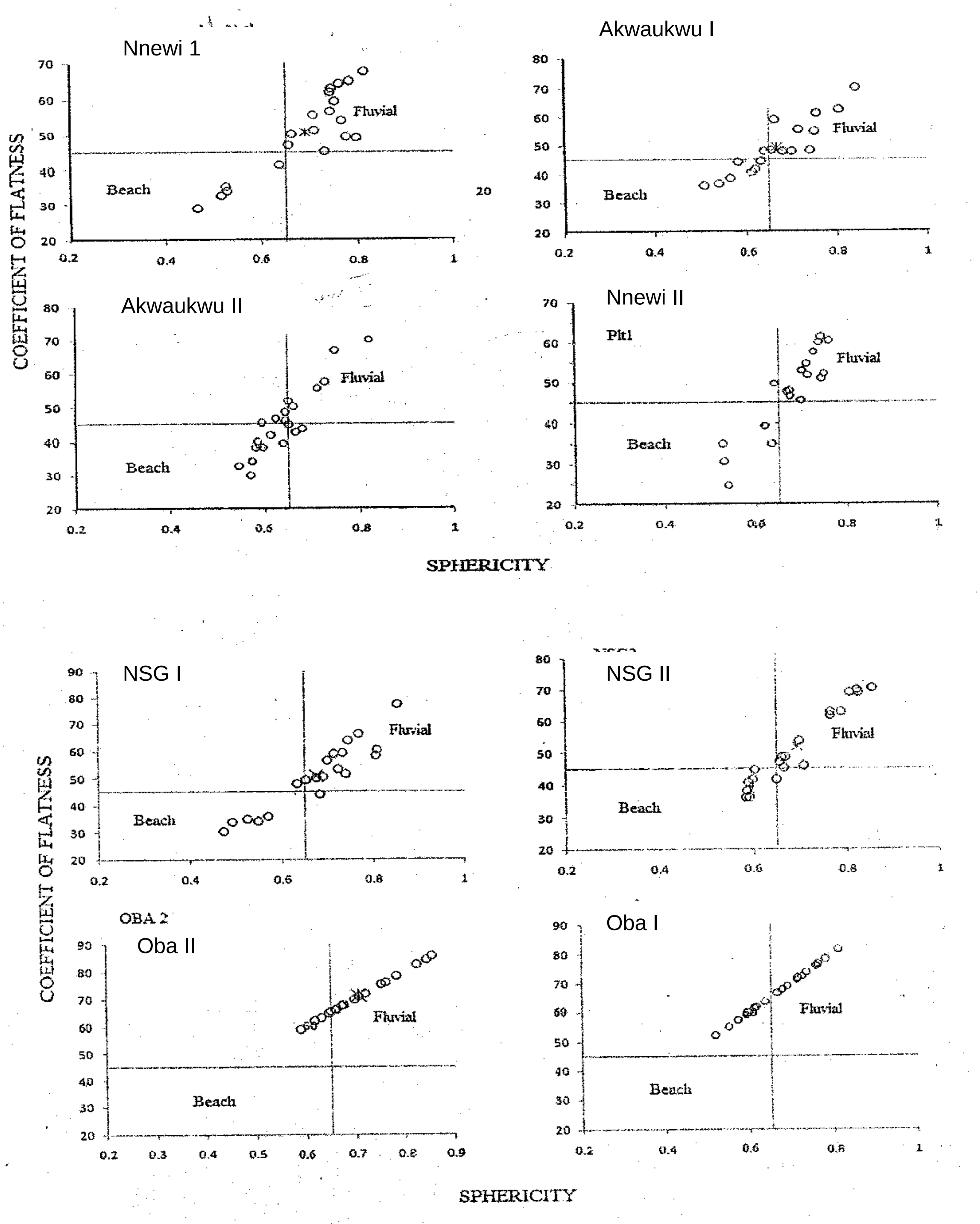

Fig. 3: Plots of coefficient of flatness against sphericity of pebbles from the study areas

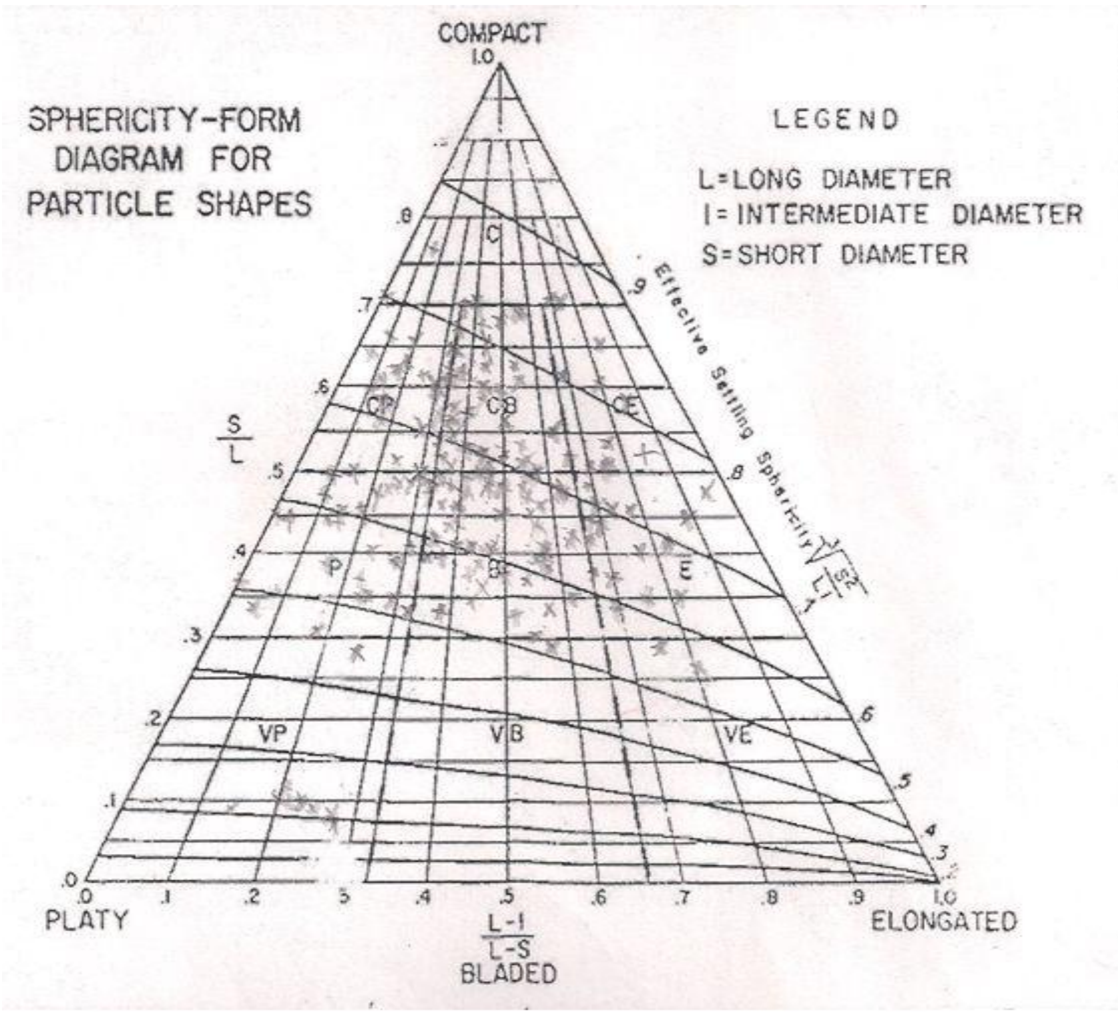

Fig. 4: Sphericity – form diagram for pebbles shapes from the study areas

DISCUSSION

Indications from Sieve Analysis

From the computed grain size parameters and their corresponding verbal terms, we can see that the samples were dominantly coarse grained sands. The samples designated SP- 01, 02, 03, 04, 05, 06, 07 from Nnewi, Akwaukwu, Oba and Nsugbe ranges from moderately sorted to very poorly sorted. Generally, the samples range from mesokurtic to very platykurtic.

Indications from pebble analysis

Univariate pebble parameters. The use of pebble indices in paleo environmental interpretation has been tested and found to be very useful, in both modern and ancient pebble deposits [2]; [16].

Table 11: Critical values of form indices for fluvial and wave (beach) processes [2]; [16].

Indices	Fluvial	Wave (Beach)	References
MPS- maximum projection sphericity	>0.65	<0.45	Dobkins & Folk (1970)
OPI-Oblate prolate index	>0.65	<0.45	Dobkins & Folk (1970)
FI Flatness index	>45	<0.45	Stratten (1974)

From the above table, it shows that whereas values of maximum projection sphericity MPS and flatness index FI of all the pebbles indicate wave processes (i.e. **>**0.65 and <45%. The values of OPI all suggest fluvial origin (i.e. **>**-4.5). In view of the observed inconclusiveness of the univariate interpretations, it was considered necessary to adopt the bivariate - plot technique to interpret the depositional processes of the pebble in a particular area Bivariate plots: plots of MPS Vs OPI and FI Vs MPS are commonly used to discriminate fluvial and beach processes. [2]; [6]; [13] and [16]. Plots of MPS against FI (fig. 1) indicate a dorminant beach process for all the pebbles sampled from the study areas. Though they all plotted within the wave field, the pebbles appeared in two clusters. This necessitated the adoption of the form – plot technique of [16] as a tool for palaeo environmental interpretation.

SUMMARY AND CONCLUSION

The textural analysis unveil that the univariate parameters indicate a fluvially dissected shallow marine environment with tidal imprints. Also, the log probability plots interpret tidal action while from the bivariate plots; a beach influenced by fluvial actions is interpreted. The pebble morphological (morphometrical analysis showed wave actions and its bivariate plots showed beach, while in multivariate aspects fluvially dissected shallow marine environment with tidal imprints interpreted. The summarized facts above prove that the paleoenvironment of the studied areas is a fluvial dominated, marine influence environment with tidal actions. In conclusion, the studied areas were previously deltaic. As a matter of facts, this work tallies with the previous works done in these areas. This means that there was regression of Atlantic Ocean according to [12], the onset of the regressive phase that lead to the formation of the present Niger Delta with the deposition of Ameki (Ameke) Formation during Eocene and that of Ogwashi Asaba Formation during Oligocene to Miocene.

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