



## Science Forum (Journal of Pure and Applied Sciences)

journal homepage: <https://atbu.edu.ng/science-forum/>



### Application of pebble morphometry and sedimentology in studying provenances and deposition environments of the Lokoja Formation in the southern Mid-Niger Basin as exposed in parts of Lokoja and its adjoining areas



Atabo N. Odoma\*, Simon Dalom Christopher, Mu'awiya Baba Aminu, Changde Andrew Nanfa  
*Department of Geology, Federal University, Lokoja, Nigeria*

#### ABSTRACT

Pebble morphometric and sedimentologic study was carried out for the Lokoja Sandstone Formation to understand its provenance and palaeodepositional environment history. The 3 axes in pebbles; the long (l), the intermediate (i), and the short (s) were measured for the 4 sets of 45, 50, and 50 pebbles collected from 3 outcrops of the Lokoja Formation exposed at Robinson Street (Lokoja), Felele, and Ozi. Pebbles form indices such as maximum projection sphericity index (MPSI), coefficient of flatness (FR %), elongation ratio (ER), and oblate-prolate index (OPI) were computed from these measurements. Roundness was estimated using Sames image sets. The mean values of the pebble form indices range from 52.5 to 55.3 for FR %. About 0.307–0.727 for sphericity, 0.273–1.182 for OPI, and 0.748–0.765 for ER. The calculated indices are suggestive of fluvial sedimentation for the Lokoja Formation. Bivariate plots of the FR % versus MPSI and plots of sphericity (MPSI) versus OPI indicate fluvial origin. Sedimentologic analysis to determine these parameters was also used. In the determination of the depositional environments for the basin, sorting values and binary plots with boundaries modified after Friedman, Moiola and Weiser, and Stewart were done for 30 samples of the sandstone unit of the Lokoja Formation gotten from 5 different locations exposed at Robinson Street, Sarkin Noma, Jamata, Banda, and Ozi using skewness, standard deviation, median, and mean values generated from the analysis with the results indicating fluvial processes of deposition.

#### ARTICLE INFO

##### Article history:

Received 07 February 2023 Received in revised form  
 06 February 2023  
 Accepted 08 February 2023 Published  
 Published 06 July 2023  
 Available online 06 July 2023

#### KEYWORDS

Southern Mid-Niger Basin  
 Lokoja Formation  
 Pebble morphometry  
 Pebble Form indices  
 Sedimentology

#### 1. Introduction

The Lokoja Formation is one of the formations within the southern Mid-Niger Basin. The formation is generally known for its pebbly nature. This distinguishes it from other sandstone formations found in the immediate vicinity such as the northern section of the northern/central Mid-Niger Basin (Bida Sandstone) and the adjacent Ajali Sandstone of the Anambra Basin. Studies on sections of the formations

found in the southern Mid-Niger Basin as exposed in parts of Lokoja, Felele (Lokoja) Banda, and Ozi were carried out. The Mid-Niger Basin is an NW-SE trending intracratonic basin that extends from Kotangora in Niger State to areas slightly beyond Lokoja to as far as Dekina in the south. The basin is roughly elliptical and runs perpendicular to the NE-SW trending Benue Trough Complex (Nwajide, 2013). The basin is unique among the other Nigerian sedimentary basins in that it is characterized by an absence of volcanic, carbonate

\* Corresponding author Atabo N. Odoma ✉ [coolatabo2000@yahoo.com](mailto:coolatabo2000@yahoo.com) ✉ Department of Geology, Federal University, Lokoja, Nigeria

rocks, and sediments of the Tertiary age (Rahaman et al., 2019) The Mid-Niger Basin is divided into the northern/central Mid-Niger also called the Bida Sub-Basin and the southern Mid-Niger which is equally known as the Lokoja Sub-Basin (Akande et al., 2005; Obaje, 2009). Sections of the successions in the southern Mid-Niger Basin (Lokoja Sub-Basin) as exposed in Robinson Street, Lokoja (N07°48'46.6" E006°44'40"), Felele (Lokoja) (N07°51'13" E06°42'58"), and Ozi (N08° 08'45" E006°46'48"), Central Nigeria (Fig. 1) were studied for the pebbles shapes (morphometry), sedimentology, and provenance. The rocks noticeable in these areas form parts of the Lokoja and Patti, and Agbaja Formations.

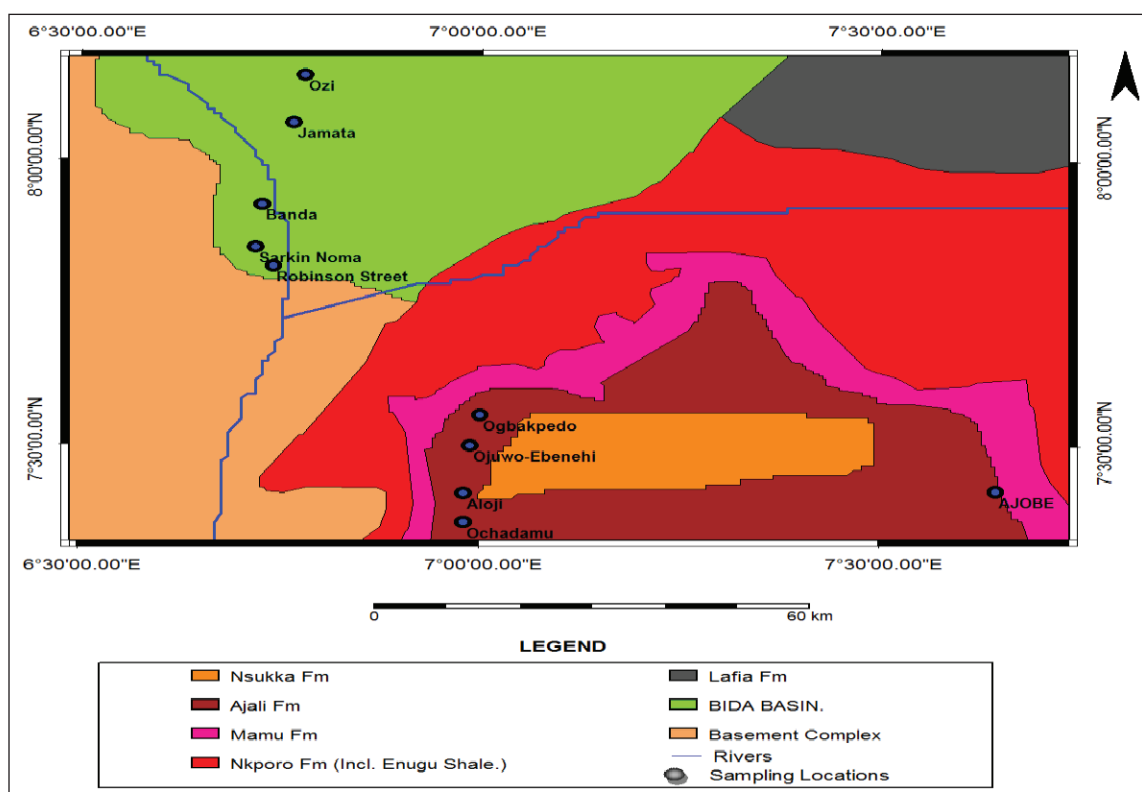
Several workers have used pebble morphometry to study the depositional environment in some basins. Omali et al. (2011) studied the sedimentological characteristics of Lokoja Sandstones as exposed at Mount Patti and noted a total average roundness of 41.8% for the pebbles in the sandstone. They concluded that the pebbles are dominantly sub-rounded indicating a short transportation history. Odumodu (2014) utilized pebble form indices to show fluvial origin for the outcropping Benin Formation as seen along Atamiri River, in Uli, Anambra State, and also used them as a tool

for the study of paleoenvironmental reconstruction. Ephraim et al. (2015) also used pebble morphometric investigations to suggest that the Benin Formation as exposed at Nsiele, in southeastern Nigeria was deposited by fluvial processes. Onyemasili and Odumodu (2019) studied the Ogwashi-Asaba Formation as exposed at Ubakala and its environs in the Anambra Basin in Southeastern Nigeria using the pebble morphometric indices.

This work is aimed at taking a look at the geomorphometry of the pebbles found in the sandstones unit of the Lokoja Formation as exposed in other areas within the Mid-Niger Basin such as Robinson Street, Felele, and Ozi and integrating it with other sedimentologic parameters gotten from Robinson Street, Sarkin Noma, Banda, Jamata, and Ozi to ascertain its sources (provenance), depositional environments, and the probable distance of travel of the sediments from the source area.

## 2. Geological Background

The Lokoja Formation of the southern Mid-Niger Basin comprises units that range from conglomerates, coarse to fine-grained sandstones, siltstones, and claystones that non-conformably overlie the basement.



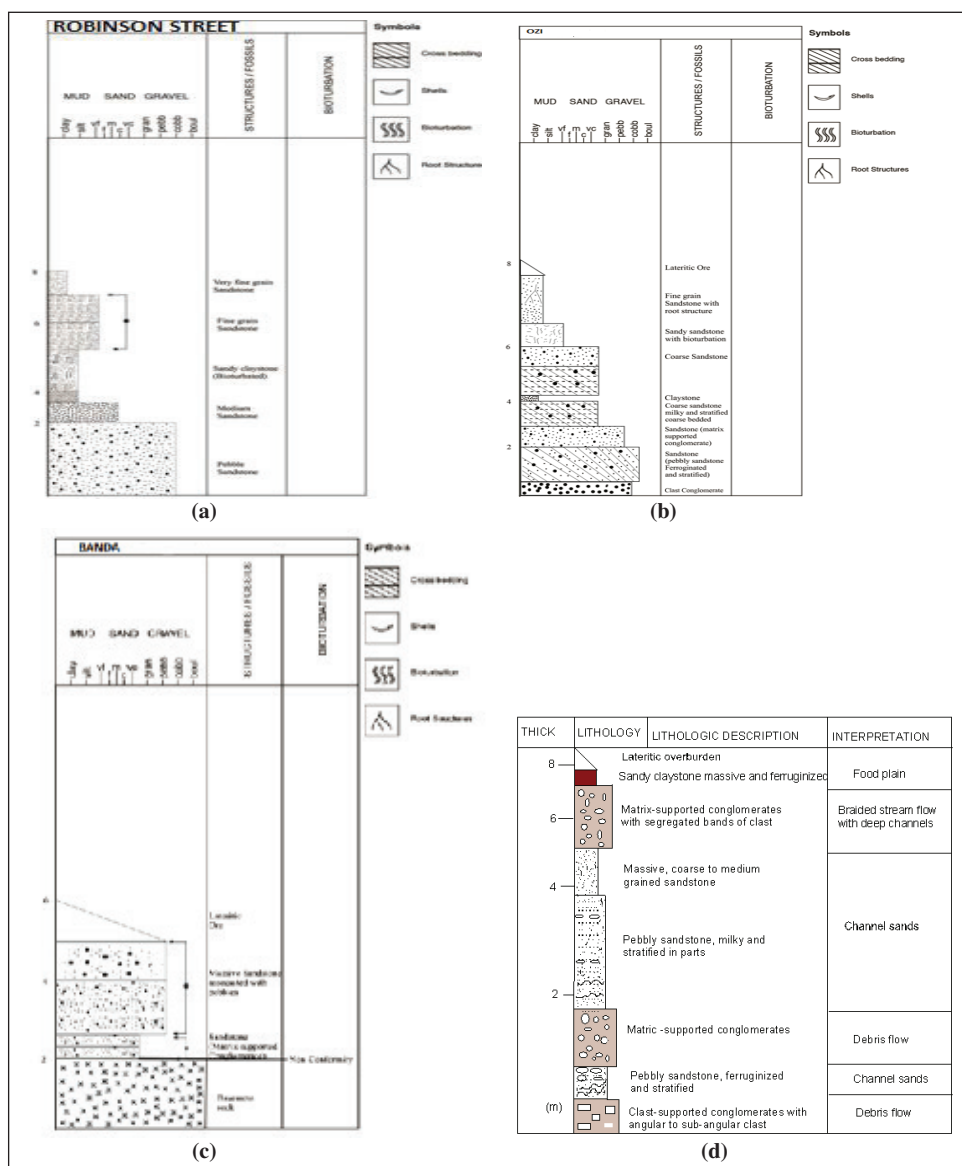
**Figure 1.** Map of the southern section of the Mid-Niger Basin and northern section of the Anambra Basin showing sample locations (Odoma et al., 2015).

Pebbles and granule-sized quartz grains in the units are frequently distributed in a clay matrix. The Patti Formation which conformably overlays the Lokoja Formation has been described by Jones (1958), Obaje et al. (2011), and Rahaman et al. (2019) among others as consisting of fine-medium grained, gray and white sandstones, gray clays, carbonaceous silts, and shales. Thin coals have been recorded and massive, white, gritty clays are common. The Agbaja Formation consisting entirely of oolitic Ironstone conformably overlays the Patti Formation and constitutes the third formation noticeable in the southern Mid-Niger Basin. The basin is underlain by mainly continental sediments with the minor occurrence of marginal/shallow marine to freshwater flood-plain deposits.

## 2.1. Sedimentary facies

Four outcrop sections of the Lokoja Formation were logged at roads cuts located at Robinson Street, Lokoja (N07°48'46.6" E006°44'40"), Felele (Lokoja) (N07°51'13" E06°42'58"), Banda (N07°55'01.3" E006°44'56"), and Ozi (N08° 08'45" E006°46'48") (Fig. 2a–e). Photographs of some sections as exposed at Robinson Street and Sarkin Noma (N07°51'49.6" E006°45'35.7") were also taken (Figs. 3 and 4). The lithology consists of fine, medium, and coarse-grained sandstones, pebbly, and sandy clay.

Four major sedimentary facies were observed in the studied area, which includes (i) very fine- grained to fine-grained sandstones. Sandy claystones (bioturbated), medium sandstone, and pebbly. These facies is



**Figure 2.** (a) Lithologic log of the section as exposed at Robinson Street. (b) Lithologic log of the section as exposed at Ozi. (c) Lithologic log of the section as exposed at Banda. (d) Lithologic log of the section as exposed at Felele





**Figure 3.** Section of the exposed Lokoja Formation at Robinson Street.



**Figure 4.** Section of the exposed Lokoja Formation at Banda.

very prominent at all the locations. (ii) Conglomeritic, fine-grained sandstone with root structures, sandy sandstone with bioturbation, coarse sandstone, clay sandstone, coarse sandstone milky, and stratified embedded with pebbles. Sedimentary structures present are planar cross-beds. These facies is noticed in Banda. (iii) The lithology in these facies consists of medium to coarse-grained bioturbated sandstones. The trace fossils present are burrows and borings. It is also planar cross-bedded. These facies was observed at Sarkin Noma. (iv) Planar cross-bedded sandstone facies. In this facies, lithology consists of planar cross

bedded sandstones. The thickness of this facies thins down southwards. These facies was observed at Ozi.

### 3. Materials and Methods

The methodology involved lithologic logging of quarries and road cuts where the pebbly units were encountered. The pebbles were carefully collected from the beds and later selected to exclude cracked or broken ones. A total of 145 pebbles were selected from the several pebbles collected from 3 locations, Robinson Street Lokoja, Felele, and Ozi. Pebbles selected were considered to be of the isotopic constitution and of

high resistance to wear. The vernier caliper was used to measure the three mutually perpendicular (Long, L; Intermediate, I; Short, S) axis of the pebbles based on Krumbein (1941), Sneed and Folk's (1958), and Dobkins and Folk's (1970) technique and results of the measurements are presented in Tables 1–3. Other morphometric parameters were computed in an excel spreadsheet, using the values obtained from the measurement of the three axes (Table 4). The pebbles were arranged into half-phi size groups using the intermediate axes (Table 5), which is known as the “sieve diameter” for pebbles (Tucker, 1981). The roundness of pebbles was evaluated using a visual comparison chart of images as compiled by Sames (1966) and used by Sneed and Folk (1958).

For the aspect of Sedimentology, sieve analysis was also carried out on 30 sandstone samples obtained from the exposed section of the Lokoja Formation within the basin. The samples (six each) were taken from Robinson Street, Sarkin Noma, Banda, Jamata, and Ozi (Figs. 3 and 4) using the method described by Tucker (1996). With the major aim of determining particle size distribution and other grain size parameters like sorting, skewness, mean, and kurtosis, we used the method of Folk and Ward (1957) to arrive at an average result of each of the sample's locations as presented (Table 6). For each samples, about 500 g of sediments were oven-dried at 100°C for an hour. The lumped or conglomerated sediments were disaggregated gently using a rubber pestle and mortar. About 200 g of the sample was then measured and recorded accordingly. Stack of sieves mesh #5, #10, #35, #60, #120, and #135, and the base pan were mounted, having the largest opening size sieves (#5) placed at the top of the stack and the smallest opening sieve size (#135) at the bottom before the base pan. Then, the sieve and the base pan were weighed separately and recorded. The measured sample was then poured into the stack of sieves from the top, mounted on the sieve shaker, and allowed to run for 30 minutes. The mass of the sieve with the retained sediments was measured and the exact mass of sediments retained was determined and recorded for each of the sieve sizes. The analysis was carried out at the Petrology Laboratory of the Kogi State University, Anyigba.

#### 4. Results

Calculations for the form indices as well as roundness data are listed in Tables 1–3. Lithologic log sections of the various studied areas are shown in Figure 2a–d.

#### 5. Discussion

Results of the measured parameter and the calculated form indices of the total mean of maximum projection sphericity index (MPSI) are 0.388 for Robinson Street, 0.727 for Felele, and 0.307 for Ozi. The scattered plots of the calculated form indices such as MPSI against OPI, MPSI, and roundness were plotted to depict the palaeoenvironment of the study area.

Some groups of pebble form indices are good indicators of the transport medium and environment from which the clasts particle were shaped. Dobkins and Folk (1970) assigned a lower limit of 0.66 as the mean sphericity for fluvial-derived pebbles. Also, the mean OPI for river pebbles has been suggested by the same authors to be greater than –1.5, whereas lower values indicate beach pebbles. Therefore, the above obtained mean values of MPSI and OPI for the Lokoja Formation fall within river transport sediments. The measure of equidimensionality (sphericity) of the pebbles was determined using the MPSI. The MPSI values of 0.388, 0.727, and 0.307 (Tables 1–3) for the various locations are compact bladed indicating wave-fluvial origin. The mean elongation ratio (ER) obtained is 0.748, 0.753, and 0.765 for Robinson Street, Felele, and Ozi, respectively, which indicates the current type flowing. This suggests that, the pebbles range from equate to prelate which indicates fluvial channels to dissocial pebbles, an indication of littoral channels. The scattered plots of MPSI versus OPI (Figs. 5–7a) suggest that the pebbles are concentrated more in river areas than in the beach areas, thus indicating a fluvial condition for the pebbles. Roundness is an indication of the extent of abrasion, determined by the distance of transportation of pebbles rather than the depositional environment. The form indices are represented in graphs of plots of sphericity against OPI (Figs. 5–7a), coefficient of flatness against sphericity (Figs. 5–7b), and plots of roundness against ER using environmental determination charts of Sames (1966) (Figs. 5–7c) for the various locations. The result obtained shows that, the pebbles have roundness values ranging from 30% to 70% (angular to rounded). The total average roundness of 41.27%, 42.86%, and 45.60% for the three studied locations shows that the pebbles are dominantly sub-rounded indicating a short distance of travel. Looking at the issue of provenance, we can deduce from the results that the pebbles of this formation were most probably been transported from the neighboring basement rocks of western Nigeria.

The assemblage of sedimentary structures in an environment can aid in deducing the type of

**Table 1.** Morphometric data of pebbles from Robinson Street.

	L-axis (cm)	I-axis (cm)	S-axis (cm)	F.R = S/L	F.R = S/L*100	E.R=I/L	L.I,I-L-S.L-I/LS	MPSI	OPI	Roundness (%)
1	3	2	1	0.33	33	0.66	5.67	0.17	0.83	45
2	5	3.5	2	0.4	40	0.7	14.9	0.11	1.33	45
3	5	3.6	2.2	0.44	44	0.72	13.91	0.12	1.57	43
4	2.4	2	1.6	0.666	66	0.83	1.66	0.33	-0.83	50
5	3	2.8	2.6	0.866	86	0.93	1.07	0.31	-6.38	55
6	2.4	2.2	2	0.83	83	0.92	0.75	0.49	-6.25	40
7	5.2	4	2.6	0.5	50	0.8	13.45	0.13	0.58	44
8	5.2	3.3	1.4	0.269	27	0.63	19.62	0.08	0.58	28
9	4.6	4.2	3.6	0.782	78	0.91	4.54	0.19	-0.78	50
10	7.2	4.6	2.6	0.361	36	0.64	33.07	0.08	1.49	25
11	5.2	3.1	1	0.192	19	0.6	21.65	0.06	1.26	30
12	3.2	2.8	2.4	0.75	75	0.88	2.43	0.27	-0.94	45
13	2.6	2	1.4	0.54	54	0.77	2.84	0.27	0.45	35
14	5.2	3.8	2.2	0.423	42	0.73	15.51	0.11	1.26	38
15	5	4.1	3.2	0.64	64	0.82	8.94	0.16	1.42	42
16	5.2	3.8	2.4	0.462	46	0.73	14.48	0.12	1.48	40
17	5.2	3.4	1.4	0.269	27	0.65	19.62	0.08	0.92	32
18	4.2	3.2	2.2	0.52	52	0.76	8.29	0.16	1.3	40
19	4.8	3.8	2.6	0.54	54	0.79	1.48	0.14	1.23	43
20	2.4	2	1.6	0.666	67	0.83	1.66	0.33	1.24	50
21	5.2	3.9	2.6	0.5	50	0.75	13.45	0.13	1.54	44
22	4.8	3.6	2.4	0.5	50	0.75	11.43	0.14	1.46	30
23	5	3.6	1.2	0.24	24	0.72	18.83	0.07	0.57	28
24	2.6	2.4	2.2	0.85	85	0.92	0.86	0.36	-12.5	35
25	4.2	3.6	2.4	0.571	57	0.86	7.46	0.16	0.2	50
26	6.7	3.1	2.6	0.388	39	0.46	0.88	0.68	9.5	30
27	4.6	3.6	2.6	0.565	57	0.78	0.55	0.64	0.88	50
28	3.8	3	2.9	0.76	76	0.79	0.88	0.42	5	30
29	4.9	3.8	2.7	0.551	55	0.78	0.5	0.74	0	30
30	4.7	4.9	2.9	0.617	62	0.85	0.39	0.45	-1.77	70
31	3.9	3.1	2.6	0.666	67	0.79	0.62	0.82	1.79	70
32	4.2	3	2.1	0.5	50	0.83	0.35	0.69	-2.88	50
33	4	3	2.1	0.525	53	0.75	0.52	0.72	0.38	30
34	4.8	3.4	2.2	0.458	46	0.71	0.54	0.67	0.87	40
35	4.1	3.5	2.3	0.561	56	0.85	0.33	0.72	-3.04	50
36	4.4	3.3	2.5	0.568	57	0.56	0.58	0.76	1.05	50
37	4.5	2.8	1.7	0.377	38	0.62	0.61	0.61	2.89	50
38	5.3	3.1	2.5	0.472	47	0.58	0.79	0.72	6.17	40
39	5	2.9	2.3	0.46	46	0.58	0.79	0.72	6.17	40
40	5	2.9	2.3	0.46	46	0.58	0.78	0.69	6.09	50
41	5.4	5	3.7	0.685	69	0.93	0.24	0.79	-3.77	40
42	8.1	6.7	4.2	0.519	52	0.83	0.36	0.18	-2.69	30
43	6.6	4.9	3.3	0.5	50	0.74	0.52	0.69	0.4	40
44	7.9	6.6	4.8	0.608	61	0.84	0.42	0.76	-1.31	30
45	7.4	3.7	2.1	0.283	28	0.5	0.69	0.4	6.79	30
				0.525111	52.53333	0.747778		0.387	0.567	41.26667

**Table 2.** Morphometric data of pebbles from Ozi.

S/no	L-axis (cm)	I-axis (cm)	S-axis (cm)	F.R=S/L	F.R = S/L*100	E.R=I/L	L.I,L-S.L-I/LS	MPSI	OPI	Roundness (%)
1	3.5	2.8	2.5	0.714	71	0.8	3.39	0.26	2.82	48
2	5	3.2	1.5	0.3	30	0.64	16.17	0.2	2.57	32
3	5	3.5	2	0.4	40	0.7	14.9	0.11	1.33	49
4	2	1.7	1.5	0.75	75	0.85	0.67	0.56	-3	53
5	1.5	1.3	1	0.667	67	0.86	2.17	0.51	-4	38
6	4	2.8	2.5	0.625	63	0.7	5.9	0.22	2.92	40
7	5	3.5	2	0.4	40	0.7	14.9	0.11	1.33	45
8	5.4	3.8	2.4	0.444	44	0.7	16.12	0.08	3.67	45
9	3.2	2.8	2.4	0.75	75	0.88	2.56	0.27	-0.94	54
10	5.2	3.2	1	0.192	19	0.62	20.51	0.06	0.68	30
11	5.2	4	2.6	0.5	50	0.77	12.93	0.13	4.04	43
12	3.2	2.8	2.4	0.75	75	0.88	2.43	0.27	-0.94	54
13	5	3.6	2.4	0.48	48	0.72	12.92	0.13	2.14	46
14	5.2	3.4	1	0.192	19	0.65	21.84	0.06	1.67	30
15	5.2	3.8	2.6	0.5	50	0.73	12.93	0.13	1.73	44
16	3	2	1	0.333	33	0.66	5.67	0.17	0.82	45
17	3	2.5	2	0.667	67	0.83	2.67	0.27	0	48
18	5.4	3.4	2.6	0.481	48	0.63	13.97	0.14	2.9	43
19	5.4	3.6	2.6	0.481	48	0.66	13.97	0.14	3.94	42
20	4.2	3	2.6	0.619	62	0.71	6.63	0.21	2.71	50
21	5.3	4	2.7	0.509	51	0.75	0.5	0.7	0	40
22	5.7	4.2	3.4	0.596	60	0.74	0.65	0.59	2.27	50
23	6.3	3.8	3.7	0.587	58	0.6	0.96	0.83	7.93	30
24	5	3.7	2.1	0.42	42	0.74	0.45	0.62	-1.19	40
25	5.1	4.1	2.2	0.431	43	0.8	0.35	0.61	-3.49	50
26	3.5	3	2.6	0.743	74	0.85	3.14	0.25	0	47
27	5.2	3.8	2.8	0.538	54	0.73	12.41	0.14	2.02	44
28	4.3	2.8	1	0.233	23	0.65	13.96	0.08	0.7	28
29	3.1	3.05	3	0.967	97	0.98	0.2	0.32	0	56
30	6	4.8	3.9	0.65	65	0.8	12.56	0.14	2.17	30
31	2.5	1.75	1	0.4	40	0.7	3.35	0.23	1.87	32
32	2.7	2.02	1.2	0.444	44	0.75	3.74	0.22	0.35	30
33	2.6	2	1.6	0.615	62	0.77	2.36	0.28	0.62	42
34	2.6	2	1.5	0.577	58	0.77	2.66	0.19	0.53	41
35	2.6	1.9	1.3	0.5	50	0.73	3.18	0.23	0.77	38
36	2.1	2	1.9	0.904	90	0.95	0.17	0.48	-18.18	58
37	2.6	1.8	1	0.385	39	0.69	3.77	0.21	0.71	34
38	5.2	3.8	1.6	0.308	31	0.73	18.6	0.08	0.78	32
39	2.8	2.4	2	0.714	71	0.86	2.06	0.3	0.27	56
40	4.2	4	3.9	0.929	93	0.95	1.2	0.23	-0.64	58
41	3.8	3	2.4	0.632	63	0.79	5.21	0.21	1.35	35
42	4.2	3.9	3.6	0.857	86	0.93	2.45	0.22	-2.89	56

Continued



S/no	L-axis (cm)	I-axis (cm)	S-axis (cm)	F.R=S/L	F.R = S/L*100	E.R=I/L	L.I,L-S.L-I/LS	MPSI	OPI	Roundness (%)
43	3	2.5	2	0.666	67	0.83	2.83	0.27	0	55
44	4	2.6	2.8	0.7	70	0.65	4.71	0.27	0.52	40
45	5	3.5	2.4	0.48	48	0.7	12.92	0.19	1.85	42
46	4.6	3.5	2.2	0.478	48	0.76	0.46	0.67	0.83	40
47	5.1	3.7	2.2	0.431	43	0.73	0.48	0.64	-0.47	40
48	4.8	3.8	2.2	0.458	46	0.79	0.38	0.64	-2.61	50
49	3.5	3.2	2.3	0.657	66	0.91	0.25	0.78	-3.79	30
50	3.3	3	1.9	0.578	58	0.91	0.21	0.71	-5	40
				0.55264	55.28	0.7646		0.3072	0.2734	42.86

**Table 3.** Morphometric data of pebbles from Felele.

S/no	L-axis (cm)	I-axis (cm)	S-axis (cm)	F.R = S/L	F.R = S/L*100	E.R = I/L	L.I,L-S.L-I/LS	MPSI	OPI	Roundness (%)
1	14.3	7.1	4.2	0.294	29	0.49	0.71	0.56	7.24	30
2	12.3	11.4	6.5	0.528	53	0.93	0.16	0.67	-6.42	50
3	8	5.8	4.6	0.575	58	0.73	0.65	0.77	2.59	70
4	10.1	6.3	4.2	0.416	42	0.62	0.64	0.65	3.33	70
5	10.3	7.3	3.5	0.339	34	0.71	0.44	0.55	1.76	50
6	8.9	6.4	5.5	0.618	62	0.72	0.74	0.81	3.87	40
7	9.4	7.9	6.9	0.734	73	0.84	0.6	0.86	1.37	40
8	9.4	7	5.5	0.585	59	0.74	0.62	0.86	2.03	40
9	8.4	7	3.1	0.369	37	0.83	0.26	0.55	-6.49	40
10	7.7	5.9	4.2	0.545	55	0.77	0.51	0.73	0.18	50
11	7.3	6.6	5	0.685	68	0.9	0.3	0.8	-2.94	40
12	8	6.4	3.3	0.412	41	0.8	0.34	0.59	-3.9	40
13	7.3	6.3	5.3	0.726	73	0.86	0.5	0.85	0	40
14	5.4	5	3.7	0.685	69	0.93	0.24	0.79	-3.77	40
15	8.1	6.7	4.2	0.519	52	0.83	0.36	0.18	-2.69	30
16	7.7	6.2	4	0.519	52	0.81	0.41	0.69	-1.73	40
17	8.8	6.2	4	0.454	45	0.7	0.54	0.66	0.89	70
18	7.3	4.9	3.3	0.452	45	0.67	0.68	0.67	4	50
19	17.5	5.6	4.6	0.262	26	0.32	0.92	0.59	16.15	30
20	6.6	4.9	3.3	0.5	50	0.74	0.52	0.69	0.4	40
21	5.7	4.6	4.6	0.807	81	0.81	1	0.93	6.17	50
22	6.7	4.5	3.2	0.478	48	0.67	0.63	0.69	2.71	50
23	7.3	5.6	3.8	0.52	52	0.77	0.49	0.71	-0.19	40
24	7.9	6.6	4.8	0.607	61	0.84	0.42	0.76	-1.31	30
25	12.2	6.9	5.6	0.459	46	0.57	0.8	0.72	6.52	50
26	8	6.5	2.3	0.288	29	0.81	0.26	0.47	-8.28	50
27	9.5	6.4	5.3	0.558	56	0.67	0.74	0.77	4.29	50
28	6.9	5.6	3.8	0.551	55	0.81	0.42	0.72	-1.45	70
29	6.6	4.4	3.7	0.561	56	0.67	0.76	0.78	4.64	50
30	5	4.5	4.3	0.86	86	0.9	0.71	0.94	2.44	50
31	6.5	5.8	5	0.769	77	0.89	0.47	0.87	-0.38	50



S/no	L-axis (cm)	I-axis (cm)	S-axis (cm)	F.R = S/L	F.R = S/L*100	E.R = I/L	L.I,L-S.L-I/ LS	MPSI	OPI	Roundness (%)
32	6	4.7	4.3	0.717	72	0.78	0.76	0.87	3.6	50
33	7.4	3.7	2.1	0.284	28	0.5	0.69	0.4	6.79	30
34	7	4.9	4.2	0.6	60	0.7	0.75	0.8	4.17	50
35	6.6	5.4	3.1	0.47	47	0.82	0.34	0.65	-3.4	40
36	5.8	4.5	3.4	0.586	59	0.78	0.54	0.76	0.67	40
37	7	5	3.1	0.443	44	0.71	0.51	0.65	0.23	40
38	6.3	4.5	2.8	0.444	44	0.71	0.51	0.65	0.23	30
39	5.5	4.2	3	0.545	55	0.76	0.52	0.73	0.36	30
40	6.6	4.6	4.2	0.636	64	0.69	0.83	0.83	5.16	70
41	6.4	4.7	3.4	0.531	53	0.73	0.57	0.73	1.32	50
42	5.5	4.3	2.8	0.509	51	0.78	0.44	0.69	-1.17	50
43	5.6	4.7	3.7	0.661	66	0.84	0.47	0.8	-0.45	40
44	7.4	5.2	4.3	0.581	58	0.7	0.71	0.89	3.62	40
45	5	4.4	4.2	0.84	84	0.88	0.75	0.93	2.98	50
46	6.4	5.1	3.7	0.578	58	0.79	0.48	0.74	-0.34	50
47	5.2	4.2	3.3	0.634	63	0.81	0.53	0.79	0.48	50
48	5.2	3.6	3.3	0.634	63	0.69	0.84	0.83	5.39	50
49	5.3	4.4	3	0.566	57	0.83	0.39	0.98	-1.93	40
50	4.9	3.8	2.8	0.571	57	0.78	0.52	0.75	0.35	40
				0.549878	55.06	0.7526		0.727	1.1818	45.6

**Table 4.** Standards for the interpretation of pebble morphometric analysis.

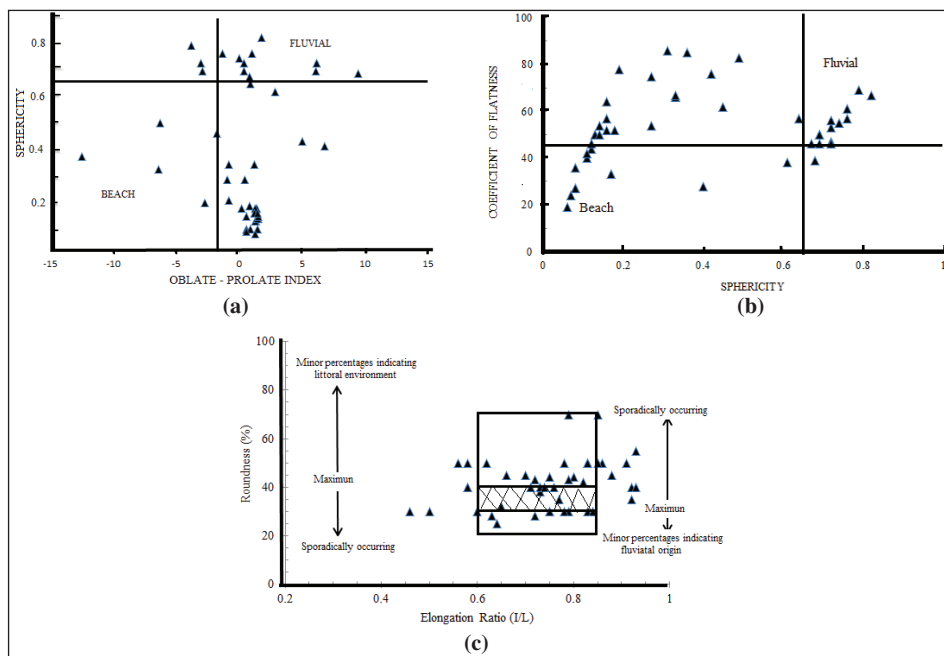
Parameter	Formula	Author
FR	Short axis/Long axis (S/L)	Lutig (1962)
ER	Intermediate/Long axis (I/L)	Lutig (1962)
MPSI	$\frac{3\sqrt{S^2}}{LI}$	Sneed and Folk (1958)
OPI	$\frac{10(L-I-0.5)}{L-S/\frac{S}{L}}$	Dobkins and Folk (1970)
Roundness	Visual estimation of the Pebbles	Sames (1966)

environment that gave rise to such structures. The lithofacies associations of the sandstone from the Lokoja Formation in the southern Mid-Niger Basin are mainly of fluvial processes. In establishing the depositional environment for this sub-basin, sorting values (Table 6) and binary plots (Fig. 8a–c) with boundaries modified after Friedman (1967), Moiola and Weiser (1968), and Stewart (1958) were adopted on the sandstone samples using skewness, SD, median, and mean values generated from the sedimentological sieve analysis. All the values plotted fell within the fluvial domains. From the results of the analysis carried out on the 30 sandstone samples, the average value

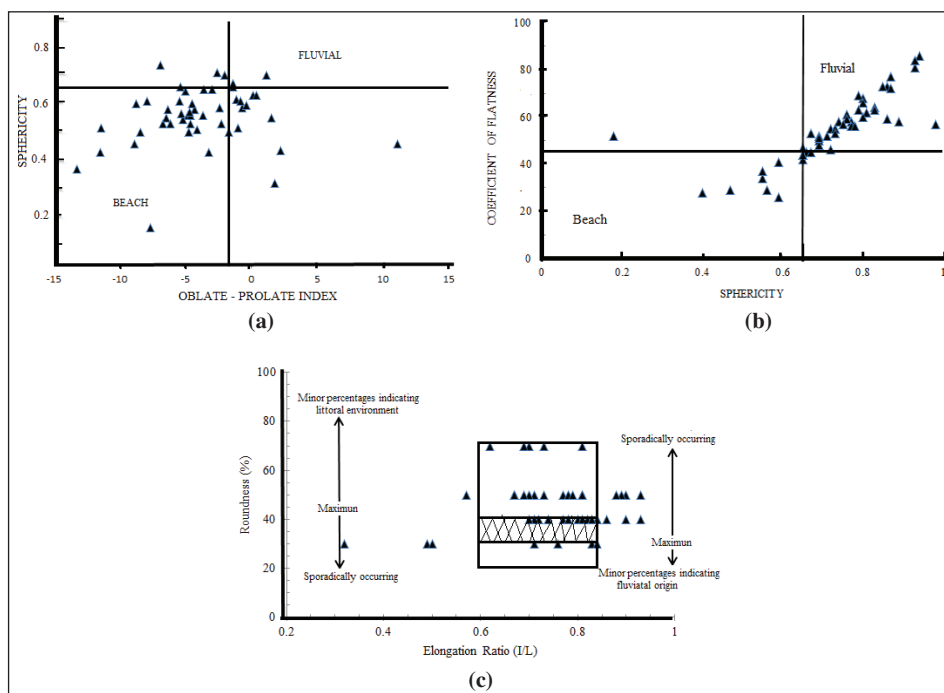
from the results and particle size distribution curves were plotted and the results are shown in Figure 8a–c.

The universal interpretation table for pebble Morphometric analysis is shown in Table 7 and the Summary of environmental diagnosis for pebble morphometric analysis for various areas studied within the Lokoja Formations is shown in Table 8.

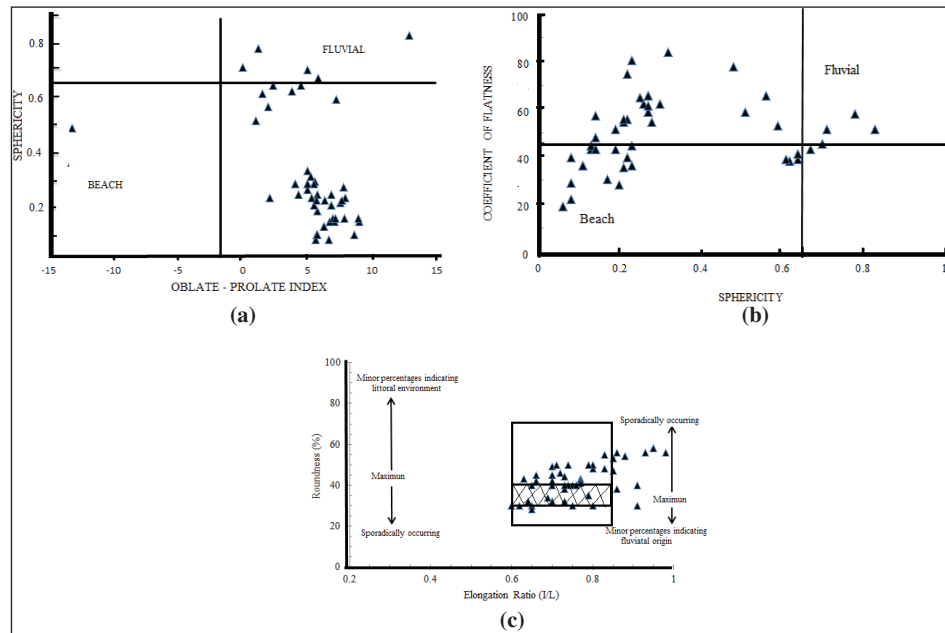
Grain size distributions have long been used to attempt to deduce the environment of deposition of sediments (Odoma et al., 2022). The grain size depends on source material, transport/deposition process, and diagenetic factors. Thus, grain size data alone is not a reliable indicator of the environment



**Figure 5.** (a) Plot of sphericity against OPI for pebbles of the Lokoja Formation at Robinson Street. (b) Plot of coefficient of flatness against sphericity for pebbles of the Lokoja Formation at Robinson Street. (c) Plot of Roundness against ER using environmental determination chart of Sames (1966) for Robinson Street.



**Figure 6.** (a) Plot of sphericity against OPI for pebbles of the Lokoja Formation at Felele. (b) Plot of coefficient of flatness against sphericity for pebbles of the Lokoja Formation at Felele. (c) Plot of Roundness against ER using environmental determination chart of Sames (1966) for Felele.



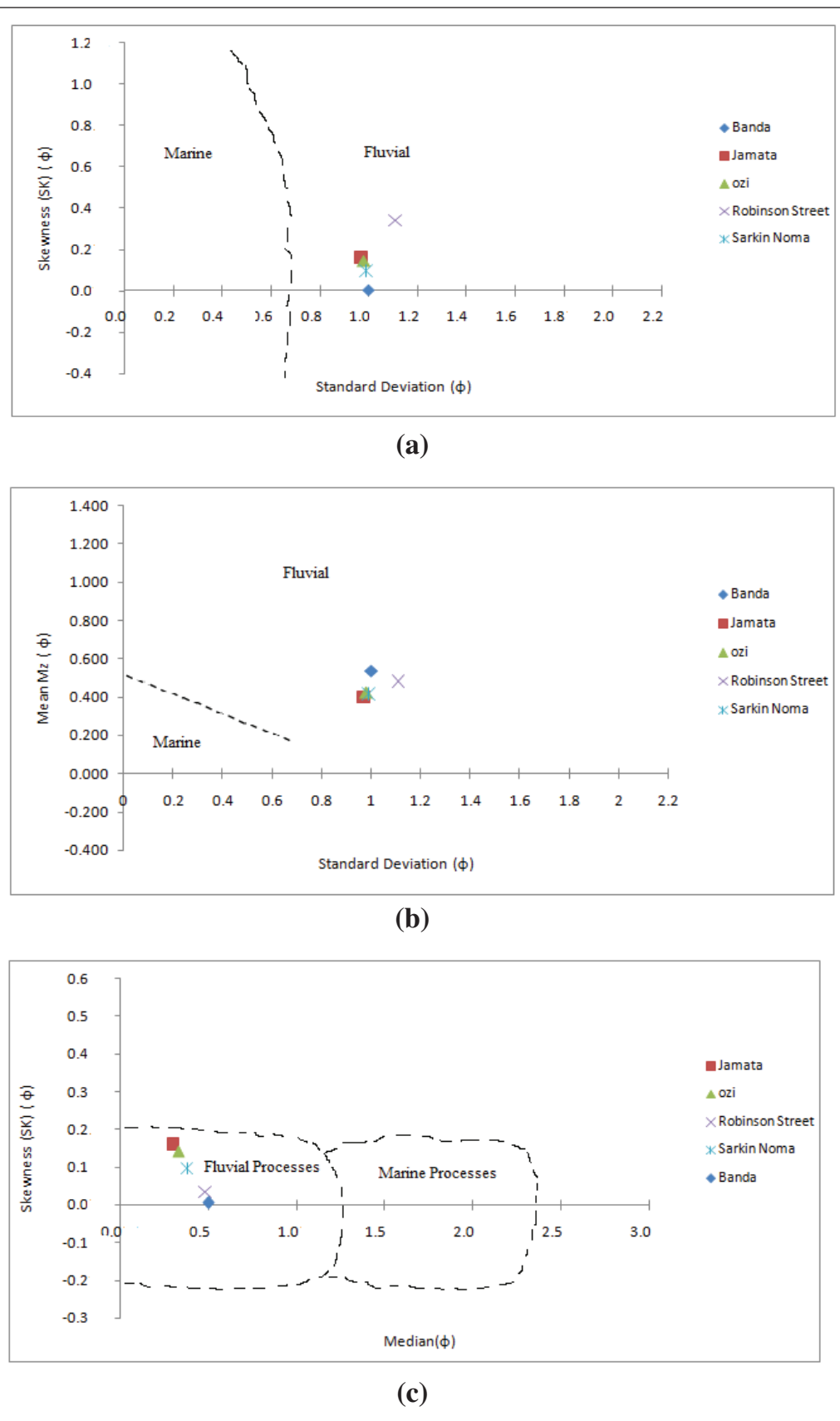
**Figure 7.** (a) Plot of sphericity against OPI for pebbles of the Lokoja Formation at Ozi. (b) Plot of coefficient of flatness against sphericity for pebbles of the Lokoja Formation at Ozi. (c) Plot of Roundness against ER using environmental determination chart of Sames (1966) for Ozi.

**Table 5.** Grain size scales for pebbles [modified from Tucker (1981)].

Mm	Phi	Class term
48–64	>–5.5	Pebble
32–48	>–5.0	
24–32	>–4.5	
16–24	>–4.0	
12–16	>–3.5	
8–12	>–3.0	
6–8	>–2.5	Granule
4–6	>2.0	

**Table 6.** Sedimentologic sieve data (average) values of samples from different locations.

Sample locations	Mean	skewness	SD	Median
Robinson street	0.48	0.03	1.11	0.48
Sarkin Noma	0.42	0.09	0.99	0.38
Ozi	0.43	0.14	0.98	0.33
Jamata	0.40	0.16	0.97	0.30
Banda	0.54	0.01	1.32	0.50



**Figure 8.** (a) Binary plots of Skewness versus SD for sand facies from parts of southern Mid-Niger Basin (Boundary modified after Friedman, 1967). (b) Binary plots of Mean versus SD for sand facies from parts of southern Mid-Niger Basin (boundary modified after Moiola and Weiser, 1968). (c) Plot of Skewness against Median for sand facies from parts of southern Mid-Niger Basin (boundary modified after Stewart, 1958).



**Table 7.** Universal interpretation table for Pebble Morphometric analysis.

Critical	Fluviatile	Wave
S	>0.45%	<0.45
MPSI	>0.65	<0.65
OPI	>1.5	<-1.5

After Waddell (1932).

**Table 8.** Summary of environmental diagnosis for pebble morphometric analysis for Lokoja Formation pebbles.

Morphometric indices	Morphometric indices	Environmental indications
Coefficient of flatness	Average values 52.5, 55.3, and 55.06	Fluviatile
ER	Average values 0.748, 0.765, and 0.753	Fluviatile
Maximum projection sphericity	Average values 0.388, 0.307, and 0.727	Wave- Fluviatile
OPI	Average values 0.568, 0.273, and 1.182	Wave
Roundness %	Average values 41.26, 42.86, and 45.6	Fluviatile
Plot of coefficient of flatness versus Maximum projection sphericity	Wavey @Robinson Street and Ozi, Fluviatile@Felele	Wave-Fluviatile
Plot of roundness versus ER	Majorly fluviatile	Fluviatile
Plot of OP index versus Sphericity	fluviatile@Robinson Street and Ozi, More of beach @ Felele	Fluviatile majorly

of deposition and care has been taken to be used in conjunction with the pebble morphometric analysis to deduce the environment.

## 6. Conclusion

Results from this study have yielded a sphericity value that varies from 0.307 to 0.727, coefficient of flatness values from 52.5 to 55.28 and OPI values from 0.273 to 1.182. All these values fall within the range required for fluvial pebbles. The entire cross plots of the bivariate parameters are also indicative of a fluvial environment of deposition. A short to not too long distance of transport is inferred from the roundness index. The lithofacies also supports a braided fluvial channel, swamps, and marshland as the depositional environments.

## References

- Akande SO, Ojo SB, Erdtmann BD, Hetenyi M. Palaeoenvironments, organic petrology and rock-eval studies on source rock facies of the lower Maastrichtianpatti formation southern Bida Basin Nigeria. *J Afr Earth Sci* 2005; (41):394–406.
- Dobkins JE, Folk RL. Shape development of Tahiti-Nui. *J Sediment Petrol* 1970; 40:1167–203.
- Ephraim BE, Amaechina C, Odumodu CFR. Pebble morphometric investigations on pebbles belonging to the Benin Formation at Nsie and environs, Southeastern Nigeria. *Adv Appl Sci Res* 2015; 6(6):47–54.
- Folk RL, Ward WO. Brazos river bar: a study in the significance of grain size parameters. *J Sediment Pet* 1957; 27:3–26.
- Friedman GM. Dynamic processes and statistical parameters compared for size frequency distributions of beach river sands. *J Sediment Petrol* 1967; 37:327–54.
- Jones HA. The Oolitic ironstones of Agbaja Plateau, Kabba Province. *Record of the Geological Survey of Nigeria, Kaduna, Nigeria, 1955*, pp 20–43, 1958.
- Krumbein WC. Measurements and geological significance of shape and roundness of sedimentary particles. *J Sediment Petrol* 1941; 11:64–72.
- Rahaman MA, Fadiya SL, Adekola SA, Coker SJ, Bale RB, Olawoki OA, et al. A revised stratigraphy of the Bida Basin, Nigeria. *J Afr Earth Sci* 2019; 151:67–81
- Moiola RJ, Weiser D. Textural parameters; an evaluation. *J Sediment Pet* 1968; 38:45–53.
- Nwajide CS. *Geology of Nigeria's sedimentary basins*. CSS Press, Lagos, Nigeria, 565 p, 2013.
- Obaje NG. *Geology and mineral resources of Nigeria*. Springer Books, Heidelberg, Germany, 221 p, 2009.
- Obaje NG, Musa MK, Odoma AN, Hamza H. The Bida Basin in north-central Nigeria: sedimentology and petroleum geology. *J Pet Gas Exp Res* 2011; 1(1):001–13.
- Odoma AN, Obaje NG, Omada JI, Ayuba R, Erbacher J. Evidences from palynomorphs assemblages depicting late cretaceous age for the straddles areas of Anambra and mid-Niger Basins. *Adv Appl Sci Res* 2015; 6(3):1–11.

- Odoma Atabo N, Ibrahim, Muyibat M, Gideon Yomi B, Christopher Simon D. Palynomorphs and lithofacies distribution of the cretaceous northern Anambra Basin, southeastern Nigeria: evidences depicting continental environment of deposition. *J Pure Appl Sci* 2022; 22:73–81.
- Odumodu CF. Pebble form indices as signature for the depositional environment of the Benin Formation along Atamiri River, Uli, southeastern Nigeria. *Int J Sci Technol Res* 2014; 3(1):23–32.
- Omali AO, Imasuen, OI, Okiotot ME. Sedimentological characteristics of Lokoja Sandstone exposed at Mount Patti, Bida Basin, Nigeria. *Adv Appl Res* 2011; 2(2):227–45.
- Onyemasili OC, Odumodu CFR. Pebble morphometric study of the Ogwashi-Asaba Formation at Ubakala and Environs in Southeastern Nigeria. *J Nat Sci Res* 2019; 9:6. Available via [www.iiste.org](http://www.iiste.org)
- Sames CW. Morphometric data of some recent pebble associations and their application to ancient deposits. *J Sediment Petrol* 1966; 36:126–42.
- Sneed ED, Folk RE. Pebbles in the lower Colorado River, Texas: a study of particle morphogenesis. *J Geol* 1958; 66:114–50.
- Stewart HB Jr. Sedimentary reflections of depositional environments in San Miguel Lagoon, Baja California, Mexico. *AAPG Bull* 1958; 42:2567–618.
- Tucker ME. Sedimentary petrology; an introduction. John Wiley and Sons Inc, New York, NY, p 25, 1981.
- Tucker ME. Sedimentary rocks in the field. John Weley and Sons, Chichester, NY, p 150, 1996.
- Waddell H. Volume, shape, and roundness of rock particles. *J Geol* 1932; 40:443–51.