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Evaluation of Paleoenvironment Using Quarzite Clasts In Odoro Ikpe Area, Southeast Nigeria

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Abstract: *This research focuses on using shape indices to determine the paleoenvironment of deposition using quartzite clasts, in the Pebble Belt (Odoro Ikpe) Area. Methodologies applied in this research include fieldwork and Pebble morphometric analysis which has been used to determine the depositional environment following parameters Maximum Projection Sphericity (MPS), Oblate – Prolate Index (OPI), Roundness, Elongation Ratio (ER) and Pebble Form for the study area. The range of values for MPS, OPI, Roundness and ER are 0.61 - 0.68, -1.17 - 2.02, 0.42 -1.02 and 61.04 - 68.90 respectively. Whereas the mean values of ER, MPS, OPI and Roundness is 0.72, 0.65, 0.44 and 65.6 respectively. Bivariate plots of MPS versus OPI and Roundness versus ER suggest the paleoenvironment as predominantly Beach/Littoral. The type of forms present in the studied samples shows that the most and least occurring forms are Bladed (B) and Very Elongate (VE) which are 23% and 3% respectively. The range of values of the morphometric parameters evaluated are interpreted as a beach/littoral environment with fluvial influence; also, the mean values of morphometric parameters are interpreted as beach/littoral environment with fluvial influence. A beach/littoral environment with fluvial influence is interpreted for the study area in contrast to purely fluvial and or alluvial fan interpreted byprevious researchers in the study area.*

Key Words: *Pebble belt, Beach / Littoral, Fluvial influence, Morphometric parameters*

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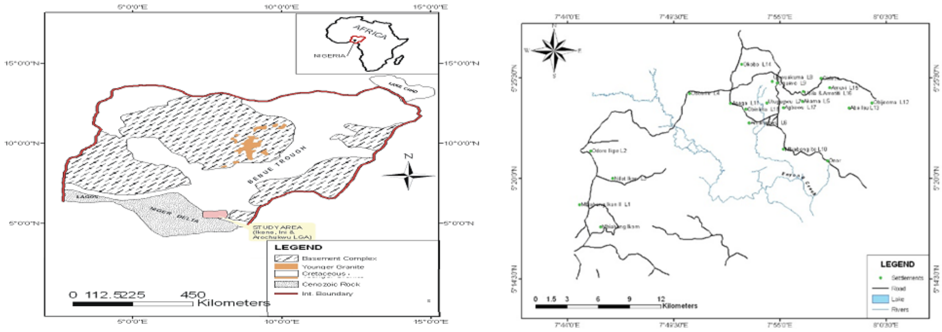
I. Introduction

Paleoenvironmental studies of ancient environments reveal conditions at the time of deposition; according to Zimmerle (1995) shape indices are good indicators of paleoenvironment and environment of deposition of sediments especially pebble conglomeratic or pebble belts. It is defined by the ratio between length, breadth and thickness with terms like equant, oblate (disc or tabular), blade and prolate (roller) shape. It is controlled by the parent rock and the transport history. Sphericity is the degree to which the shape of a sedimentary particle approaches that of a sphere (Zimmerle,1995). The primary objective of pebble morphometric analysis is paleo-environmental diagnosis, the analysis involves the measurement of the three mutually perpendicular diameters of particles (>2.0mm) using veneer calipers, (Okoro, 2009). For modern gravels, pebble shapes provide additional indicator of the environment of deposition. Classical work on pebbles include those of Sneed and Folk (1958) on pebble morphogenesis and Luttig (1962) on pebble shape of continental, fluvial and marine facies. Dobkkin and Folk (1970) noted that first cycle beach gravels tend to be discoidal whereas fluvial gravels are rod-shaped. They concluded that a maximum projection sphericity (MPS) value of 0.66 and oblate prolate index (OPI) of more than 1.5 distinguishes beach from fluvial pebbles. They also suggested that a plot of MPS vs OPI distinguished fluvial from beach pebbles. Detailed morphometric analysis by Petters (1989), suggests a fluvial origin for the pebble belt, because according to him the major fault trend (N-S) do not conform to the NE-SW trend of the conglomeratic beds and this negates the alluvial fan origin of the pebble beds by Amajor (1986), because alluvial fan deposition requires confinement of structural features or ancient mountain front (Rust, 1979). Inyang (2001) and Inyang and Enang (2002) using lithofacies analysis, morphometrics and grain size analysis suggested that these deposits have a fluvial origin. The study area lies within Afikpo Basin and it is within the Arochukwu – Obotme - Odoro – Ikpe axis in Arochukwu, Ini Local Government Areas of Abia and Akwa Ibom State (Longitude 7^{o}44'0''E - 8 ^{o}0'30''E and Latitude: 5 ^{o}14'30''N – 5 ^{o}25'30''N) Figure 1. The geology and stratigraphy of Afikpo Basin a sub-set of the Benue Trough is well established (Odeyemi, 1981; Oluyide,1988; Burke et al., 1971; Olade, 1975; Mascle et al., 1986; Popoff et al., 1989; Numberg and Miller,1991). The ranges of depositional environment typical of the Lower Benue Trough are marine, continental, and transitional represented by the Asu River Group, Eze Aku Group, Nkporo, Mamu, Ajali, Nsukka, Imo, Ameki Formations Nanka Sands and Benin Formation; these sequences are typically found in the study area. The stratigraphic framework is summarized in Table 1.



(a) (b)

Figure 1 a Geologic map of Nigeria indicating the study area; Inset map of Africa showing the position of Nigeria (After Ideozu, 2004). Figure 1.0 b: Location map of the study area (After Ideozu, 2004).

II. Materials and Methods

Materials

Standard field mapping and sedimentological techniques have been employed in this research; it involved field mapping and data sampling from outcrops. The spot sampling method was adopted for data collection during the field mapping exercise (Davies, 1973). Accurate and detailed geological description and recording of parameters such as sedimentary structures, rock type and composition, measurements of bed thicknesses, lateral extent of the outcrops was ensured in addition to informationfrom measurement of strike and dip. Tools used during the field mapping include compass/clinometers, Geographic Positioning System (GPS) and measuring tape, field notebook, camera and topographic map indicating the position of the study area (Ikot Ekpene sheet 322 on a scale 1: 50,000). The outcrops identified were examined for bedding contacts, bed thickness variation, sedimentary and biogenic structures as well as syn- and post- depositional structures in detail (Miall, 1984; Tucker, 1988).

Methods

Pebble morphometry involves direct measurements of individual particle axes (Briggs, 1977). The measurements and the computations that followed has been used to interpret the environment of deposition of the pebble belt in the study area. Eight hundred and fifty pebbles were morphometrically analyzed. The pebble beds in the study area were mostly unconsolidated and weakly cemented. For each bed that contained pebbles and sands after sieving, the pebbles were recovered for morphometric analysis and broken pebbles discarded. Orthogonal or principal axes (long, intermediate and short) of each pebble were measured using Vernier calipers and the values recorded. The procedure adopted for measuring of the principal axes of each pebble, is as follows:

1. Place the pebble on a flat surface and measure the length of the intermediate axis (I) determined as the shortest possible visible diameter.
2. The length of long axis (L) is at right angle to the intermediate axis is next measured; rotating the pebble by through 90° about that axes reveals the short axis.

Table 1 Lithostratigraphic units in Afikpo Basin Area after Oboh- Ikuenobe et al (2005).

Period	Epoch	Afikpo Basin
Tertiary	Pliocene-Recent	Benin Formation
	Miocene-Mid Eocene	Ogwashi-Asaba Formation
	Mid-Upper Eocene	Ameki Formation
	Paleocene	Imo Shale
Cretaceous	Maastrichtian	Nsukka Formation Ajali Formation Mamu Formation
	Campanian	Nkporo Shale
	Santonian/ Coniacian	Agwu Formation
	Turonian Cenomanian	Eze-Aku Formation Odukpani Formation
	Albian	Asu River Group

From the data generated, the following parameters have been determined, Maximum sphericity projection (MSP) after Sneed and Folk (1958), Oblate prolate index (OPI) after Dobkkins and Folk (1970), Disc rod index (DRI) and Flatness index or Flatness Ratio after Illenberger (1992). According to Tucker (1991), the ratios enumerated above are important in classifying the pebbles into four- end members (blade, discord, prolate and equant). From the combination of the L, I, and S axes above the following are defined:

1. Ratios I/L and S/I are used to classify the deposit whether they are beach or fluvial in origin.
2. Elongation Ratio (I/L): This is defined as the ratio of the length of the intermediate axis (I) to the length of longest axis (L).
3. Flatness Ratio (S/L): This is defined as the ratio of the length of the shortest axis to the longest axis (Folk, 1974). This formula is one of the commonest used as compared to that devised by Wentworth (1922) which earlier served as the first sphericity measurement (L+I/2S). The flatness ratio was arbitrarily chosen without regard to geometric or hydraulic principles, because it came close to reflecting the actual settling velocities of irregular particles in water (Folk, 1970; Okoro, 2009; Lutig, 1962; Sames, 1966).
4. Maximum Sphericity Projection (Ψp), is widely used in pebble morphometric studies as it compares the maximum projection area (MPA) of the pebble being measured with the maximum projection area of a sphere of the same volume. Since irregular particles tend to settle with their MPA horizontal and resisting downward movement, Sneed and Folk's (1958) measurement gives a much better indication of the true hydraulics of rods and discs.
5. Oblate Prolate Index: This measure was devised by Sneed and Folk (1958) and gives the ratio of discs to rod in a deposit. This index indicates the oblateness vs the prolateness of an object is based, mainly on the value of (L - I)/ (L - S) which defines whether the intermediate axis is closer in size to the short or long axis (Dobkin and Folk, 1970).

III. Result and Discussion

Results

The results of the research are presented in Figures 2 to 6, Tables 2 to 4 and Plates 1. Fieldwork results comprising the lithology and lithologic description of the study area is presented in Figures 2 and Plate 1. One thousand, two hundred and thirty (1,230) pebbles were analyzed (See Plate 1). The range of values for MPS, OPI, Roundness and ER are 0.61 - 0.68, -1.17 - 2.02, 0.42 -1.02 and 61.04 - 68.90 respectively (see Tables 1.0 and 2.0). The mean values of ER, MPS, OPI and Roundness is 0.72, 0.65, 0.44 and 65.6 respectively. The bivariate plot of MPS versus OPI values fall within the transitional (beach - fluvial environments) while the Roundness versus ER values plot within Transitional to Littoral environment (see Figures 3– 4).

Discussion

The lithostratigraphic units identified include Mamu, Ajali, Nsukka and Benin Formations (see Figure 2.0 and Tables 1.0). Imo Shale is absent from the stratigraphy of the study area, indicating that it may have been eroded or there was no deposition implying an unconformity. The sedimentary sequences comprise clays/shales, sand/sandstones, pebbly sand/conglomerates and limestones and make up the Mamu, Ajali, Nsukka and Benin Formations in the study area. This research reveals that the Nsukka Formation (Cretaceous sediments) is overlain by the Benin Formation. There is lateral continuity of the Nsukka Formation from Arochukwu to Odoro Ikpe areas, based on field relations and biostratigraphic data (Ideozu, 2014). Dobkkins and Folk (1970), Folk (1974), Humbert (1968) and Sneed and Folk (1958) in their works suggest that shape attributes and other parameters should classify a pebble into a distinct environment. This formed the basis for classification of the pebbles in the study area as beach / littoral with fluvial influence based on their works.

1. Pebbles of fluvial origin have lowest roundness, high sphericity and almost neutral OPI values. These values are uniform from one river to the next and all pebbles measured may have similar sizes.
2. High energy beach pebbles have highest roundness, low sphericity and are distinctly oblate. There is a wide variation in shape from one pebble size to the next in any one beach and from one beach to another.
3. Low energy beaches have intermediate roundness, sphericity ranges from extremely low on sandy beaches.
4. Small pebbles tend to be oblate while large pebbles are prolate. On sandy low energy beaches with waves under 15 feet, the smallest pebbles are almost discoidal.

Dobkins and Folk (1970), Stratten (1974) and Els (1988) have shown that the appropriate lower index limits for pebble shapes in the fluvial environment are: MPS; 0.65/0.66 and OPI; -1.5 (Odumodu, 2013). The MPS of pebbles are generally high for fluvial than beach environment. Beach pebbles usually show lower MPS of less than 0.40 whereas values greater than 0.40 tend towards fluvial setting. The 0.65/0.66-line separate beach from fluvial pebbles (Dobkkins and Folk, 1970; Ideozu and Ikoro, 2015). The MPS is 0.61 – 0.68 indicating a beach environment with fluvial influence. OPI values of less than -1.5 tend towards beach whereas values greater than -1.5 suggest fluvial setting the results from this research shows the OPI as -1.17 – 2.02 which suggest a fluvial environment with beach influence (See Tables 2 – 3). According to Sneed and Folk (1958), the roundness of pebbles under hydrodynamic transport has been observed to be a function of both inherited and acquired (environmental) factors. Roundness of less than 35% typifies fluvial environments while roundness greater than 45% characterizes littoral environments (Sames, 1966; Okoro et al, 2012). The roundness in this research is 61.04 - 68.90 and a typifies littoral environment. The dominant forms for pebbles of fluvial origin are compact, bladed, compact bladed and compact elongated whereas forms common in beaches/littoral environment are platy, very platy, bladed and very bladed. However, fluvial and beach environment share bladed form (Ikoro et al, 2014). The pebble formstypical for both beach/littoral and fluvial environments (see Figure 6) are prevalent with bladed form dominating in the study area. This suggestsa littoral/beach environment with fluvial influence (see Tables 2 – 4 and Figure 6). The paleoenvironment of the study area based on the pebble morphometric parameters is dominantly littoral/beach with influence of the fluvial environment. This result does not agree with the works of Ideozu and Ikoro (2015), Ideozu (2014), Mode and Udo (2013) and Amajor (1986) who have interpreted the paleoenvironment of the pebble belt in the study area as either alluvial fan or fluvial environment.

IV. Conclusion

Based on the findings of this research, the paleoenvironment is beach/littoral with fluvial influence. The evaluated pebble morphometric parameters dominantly suggest littoral/beach with fluvial influence. In contrast to other researchers in the study area who interpreted the pebble belt as either fluvial or alluvial fan.

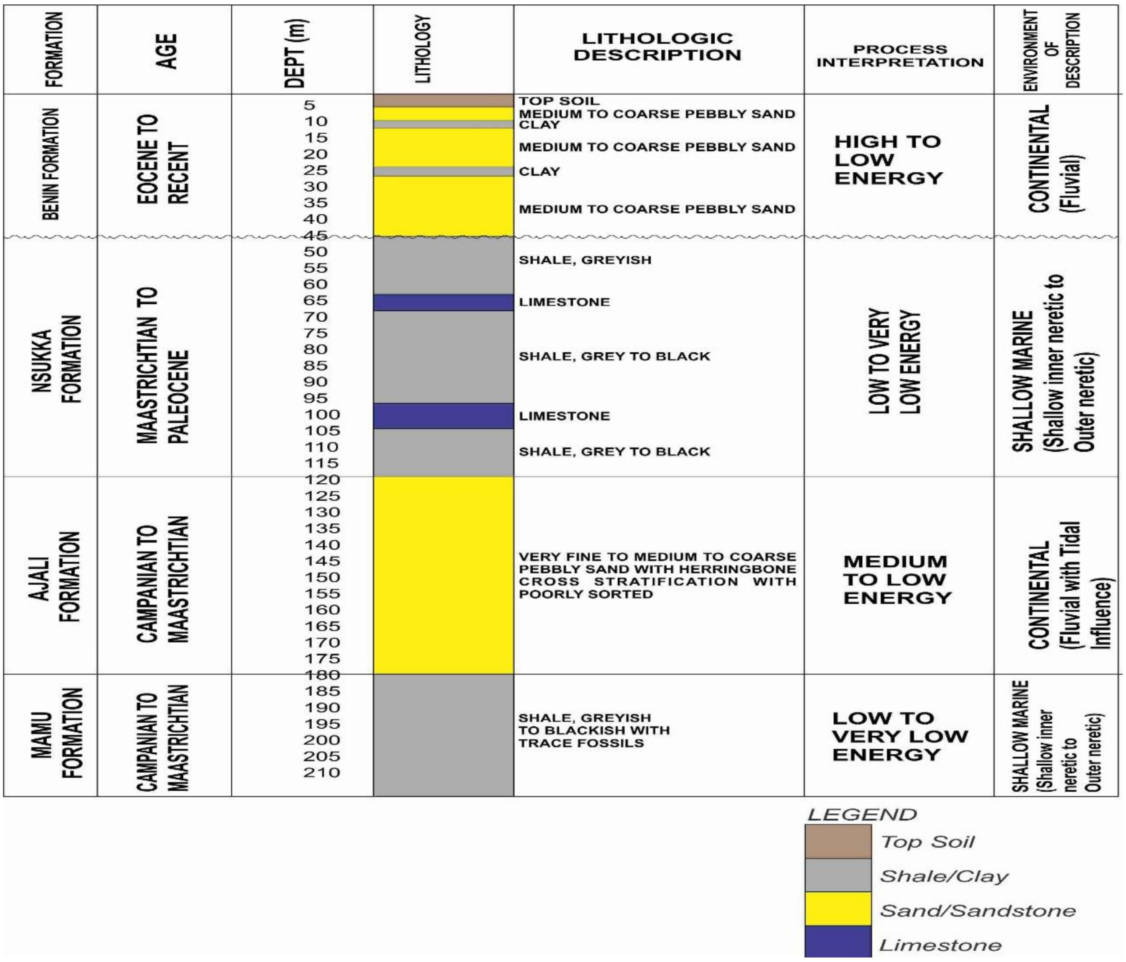
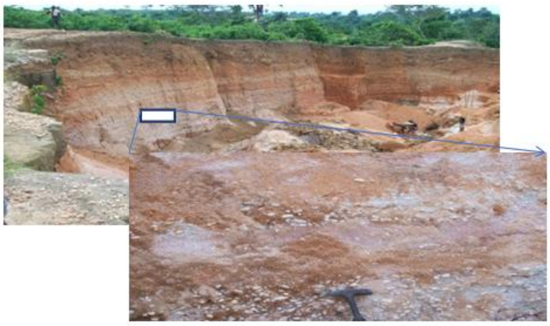


Figure 2 Composite log of the study area showing lithostratigraphic units of the Study

(a) (b)

(c)



(d)

(e) (f) (g)

L = 3.00cm
I = 3.00cm
S = 0.50cm
Pebble shape = VP

L = 4.00cm
I = 3.00cm
S = 2.50cm
Pebble shape = CB

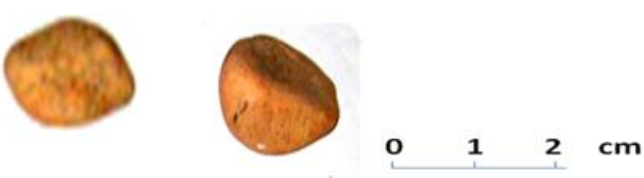
L = 5.00cm
I = 2.00cm
S = 1.80cm
Pebble shape = E

(h) (I) (j)

L = 5.90cm
I = 3.20cm
S = 1.50cm
Pebble shape = VB

L = 4.20cm
I = 2.50cm
S = 1.30cm
Pebble shape = B

L = 4.10cm
I = 3.00cm
S = 0.91cm
Pebble shape = VP



(k) (l)

L = 2.50cm
I = 2.20cmI = 2.20cm
S = 0.50cm
Pebble shape = VP

L = 4.10cm
S = 3.00cm
Pebble shape = C

Plates 1(a) Cross-bedding of Benin Formation at Location 2 (Odoro Ikpe). (b) Benin Formation at Location 2 (Odoro Ikpe). (c) Benin Formation at Location 2 (Odoro Ikpe), (d). Benin Formation at Location 3 (Ndot Ikpe) - Sedimentary structures of Benin Formation in the study area (Ideozu, 2014).
(e – l). Some representative Pebbles Sampled from the Study Area. (L = Long axis, I = Some representative Pebbles Sampled from the Study Area. (L = Long axis, I = Intermediate axis, S = Short axis, VP = Very Platy, CB =Compact Bladed, VB = Very Bladed, B = Bladed, E = Elongate and C = Compact (Ideozu, 2014)

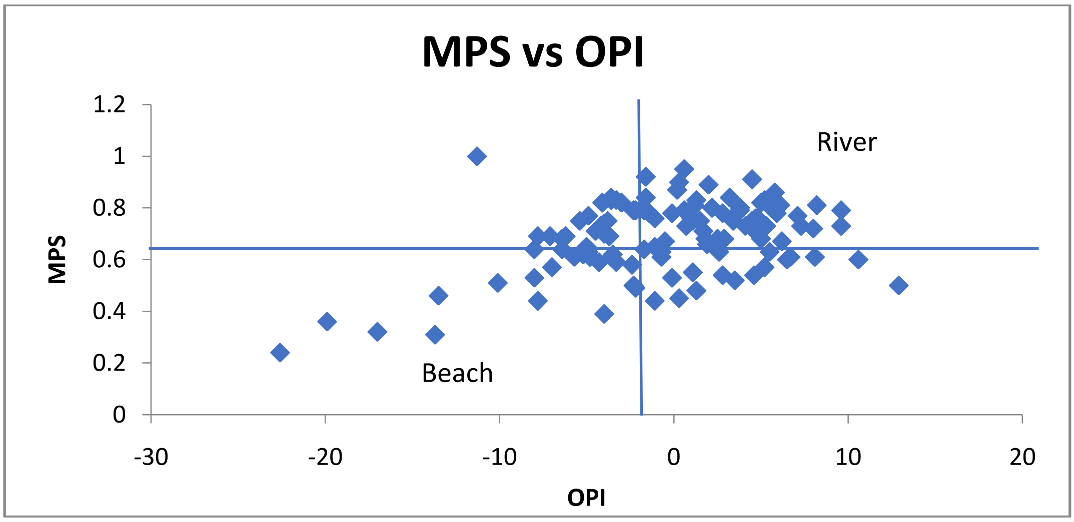


Figure 3 Graph of MPS versus OPI

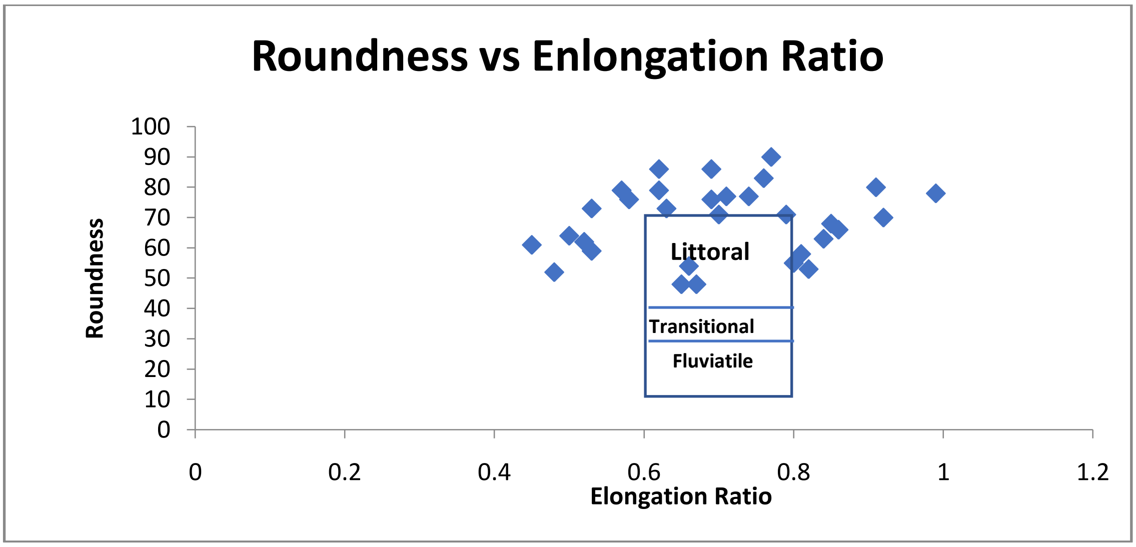


Figure 4 Graph of Roundness versus Elongation Ratio

Table 2: Mean Values for Morphometric Data

LOCATION NAME	L(mm)	I(mm)	S(mm)	MPS	OPI	FR	DRI	ER	S/I	R (%)	FORM
L1 S1	29.22	20.93	13.20	0.64	0.100	0.45	0.49	0.73	0.63	64.95	CB
L1 S2	28.15	18.68	11.74	0.64	0.028	0.44	0.51	0.72	0.64	64.98	CB
L1 S3	28.76	20.18	14.46	0.65	0.71	0.46	0.52	0.71	0.65	65.67	CB
L1 S4	29.82	21.15	13.31	0.64	0.004	0.44	0.50	0.72	0.63	64.61	CB
L1 S5	38.53	27.12	18.37	0.68	0.05	0.49	0.52	0.72	0.68	68.20	CB
L2 S1	16.96	13.10	8.73	0.68	-0.38	0.49	0.48	0.75	1.45	68.59	CB
L2 S2	17.91	12.62	8.74	0.68	1.96	0.47	0.58	0.72	0.68	68.90	CB
L2 S3	14.99	10.25	6.76	0.64	2.025	0.46	0.56	0.69	0.67	64.87	CB
L2 S4	19.03	12.85	8.13	0.63	2.05	0.42	1.10	0.67	0.61	63.13	CE
L2 S5	16.37	11.33	6.71	0.63	0.43	1.02	0.51	0.70	0.61	63.44	CB
L3 S1	18.16	12.65	8.34	0.66	0.97	0.47	0.55	0.72	0.66	66.97	CB
L3 S2	19.65	14.04	9.35	0.68	0.48	0.49	0.54	0.73	0.66	68.17	CB
L3 S3	20.97	15.10	9.84	0.66	0.22	0.47	0.49	0.73	0.64	66.96	CB
L3 S4	23.43	18.05	9.80	0.61	-1.17	0.42	0.46	0.73	0.58	61.04	CB
L3 S5	19.10	13.93	8.37	0.64	-0.88	0.45	0.47	0.74	0.61	64.48	CB

Table 3: FormOccurrence and Percentage

S/N	Location	C	P	B	E	CP	CB	CE	VP	VB	VE
1	L1 S1	12	15	16	12	12	16	15	6	7	1
2	L1 S2	2	4	7	1	1	5	9	0	1	1
3	L1 S3	2	2	6	2	0	2	5	1	2	2
4	L1 S4	6	11	28	17	5	9	10	5	8	10
5	L1 S5	2	11	23	10	3	10	9	5	3	3
6	L2 S1	14	12	22	15	5	9	13	6	4	2
7	L2 S2	14	10	21	14	4	15	19	4	9	0
8	L2 S3	12	13	28	17	12	9	13	1	11	5
9	L2 S4	4	12	6	6	4	11	6	7	11	2
10	L2 S5	8	16	29	8	8	11	9	4	7	1
12	L3 S1	3	7	23	3	6	10	7	5	3	2
13	L3 S2	3	7	13	9	10	7	10	2	8	1
14	L3 S3	2	9	21	13	8	6	7	1	3	1
15	L3 S4	2	9	24	9	7	16	12	2	5	3
16	L3 S5	6	6	14	12	2	17	4	0	3	0
17	Total	92	133	281	148	87	152	148	49	85	34
18	Percentage	7.50	11.00	23.00	12.04	7.10	12.40	12.04	4.00	7.00	3.00

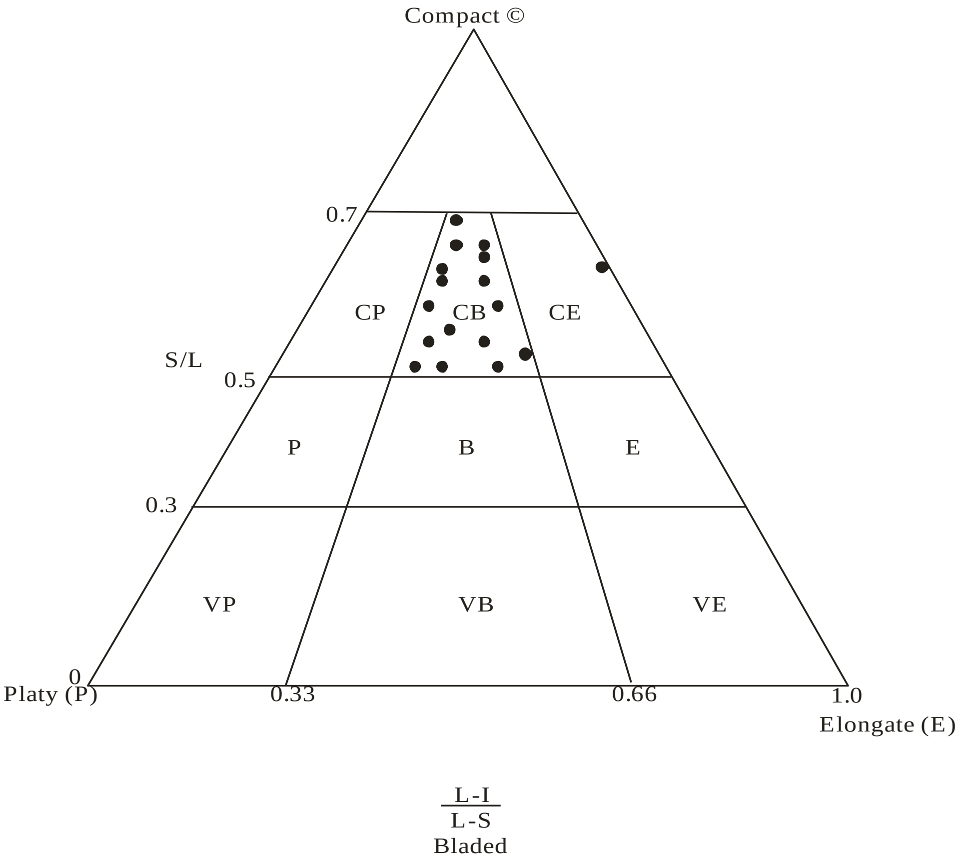


Figure 5 Form diagram of the mean values of the morphometric data

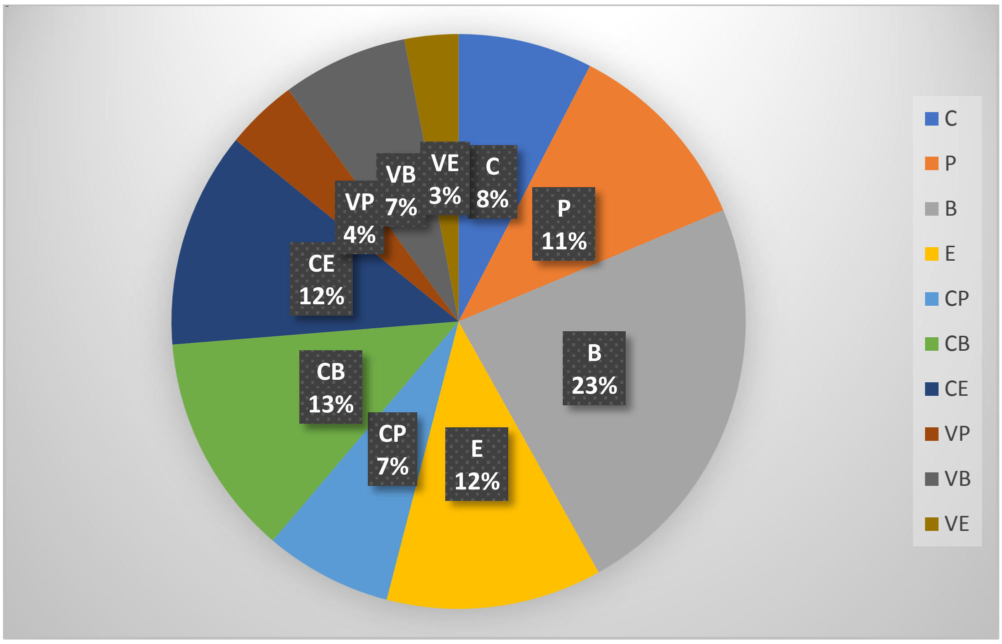


Figure 6 Pie chart of percentage form

Table 4 Characteristic Features and Paleoenvironmental Significance of the Various Computed Parameters

Pebble Morphometric Parameter	Range/Average values of Pebble Morphometric Parameters – this work	Defined Limits from Previous Studies	Interpretation of Depositional Environment/Processes
Elongation Ratio (ER)	Range: 0.42 to 1.02 Average: 0.72	Hubert,1968 Fluvial (0.6-0.9)	Fluvial Processes
Maximum Projection Sphericity (MPS)	Range: 0.61 to 0.68. Average:0.65	Dobkins and Folk, 1970 Beach (< 0.66) Fluvial (> 0.66)	Dominantly Beach with Fluvial influence
Oblate – Prolate Index (OPI)	Range: -1.17 to 2.02. Average: 0.44	Sneed and Folk,1958 Beach (< -1.5) Fluvial (> -1.5)	Dominantly fluvial with few beach influences
Roundness (R)	Range: 61.04 to 68.90. Average: 65.6	Sames,1966 Fluvial (< 0.35%) Littoral (>0.45%)	Mainly Littoral
Pebble Form	23%B, 13%CB, 12%E, 12%CE, 11%P, 8%C, 7%CP, 7%VB, 4%VP and 3%VE	Ikoro et al, 2014 Beach (P, VP, B and VB) Fluvial (C, B, CB and VB). Sneed and Folk,1958;Dobkins. and Folk, 1970; Gale, 1990; Essien et al 2017. Fluvial(C, E, CB, CE) Beach (P, VP, VB, B)	Dominantly Fluvial with Beach influence

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