

Depositional Environment Discrimination using Statistical Parameters of

Conglomeratic Outcrop Sections, Obubra Southeastern Nigeria.

ABSTRACT

Statistical analyses reveal information of the hydrodynamics and environment of deposition of sedimentary rocks. The sediments of the outcrop sections from Uwakande 1, Obubra southeastern Nigeria were studied for their textural variations. Grain size analysis, and pebble morphogenesis carried out show that the sediments are coarse to very coarse in size, poorly sorted, and very positively skewed. This in conjunction with the various bivariate plots employed, aid in discriminating between beach and river depositional environments. Pebble morphometric analysis of the conglomerates showed that the mean values of the various morphometric parameters range as follows: flatness ratio ($S/L = 0.397$ to 0.514), elongation ratio ($I/L = 0.657$ to 0.784), maximum projection sphericity ($\Psi P = 0.605$ to 0.899), Oblate-Prolate index ($\bar{O}P = -1.738$ to 1.594), coefficient of flatness (39.70 to 51.37), and roundness (-0.367 to 0.722). This study is significant in providing evidence of fluvial conditions during the deposition of the Eze-Aku Formation in the Turonian, and reveals the type of transporting medium; the mode of sediment deposition; as well as the environment into which the sediments encountered in the study area were deposited.

Keywords: *Fluvial, Conglomerates, Environment, Pebbles, Deposition, Sandstone, Sedimentary, Morphometric.*

1.0 INTRODUCTION

The characteristic properties of sedimentary rocks are generated through the combined action of various physical, chemical, and biological processes that make up the sedimentary cycle. Sedimentary processes and conditions that constitute the depositional environment play primary roles in determining the textures,

structures, bedding features, and stratigraphic characteristics of sedimentary rocks. Environmental analysis thus involves identifying response elements or properties that have environmental significance [1] Environment of deposition is the location in which sediment deposition occurs. It can be defined in terms of physical, chemical, biological or geomorphic variables and is characterized by a unique set of processes operating at a specified rate and intensity which impart sufficient imprints on the sediment, so that a characteristic deposit is produced [2]. Environmental parameters can be grouped into three groups: physical, biological, and chemical. The physical processes are the most important, as it provides the most basic information for depositional environment interpretation [2]. In studying ancient sediments, it is important to record all the primary sedimentary structures, grain features and parameters, and try to interpret the hydrodynamic conditions under which the unit was probably deposited. This study presents an aspect of the depositional environment interpretation of the Turonian Eze-Aku Formation.

1.1 BRIEF GEOLOGY OF THE STUDY AREA

The study area is located at mile 6 (popularly called Tank) in Obubra, southeastern Nigeria. It is bounded by few other major villages such as Ogada 1 and 2, Imabana Iyamitet, and Uwakande 1; and lies between longitude 8°19'E and 8°23'E; and latitude 6°2'N and 6°7'N (Figure 1). It covers an area of 68.25 square kilometers. Good outcrop exposures are seen at stream channels, and local gravel mining sites.

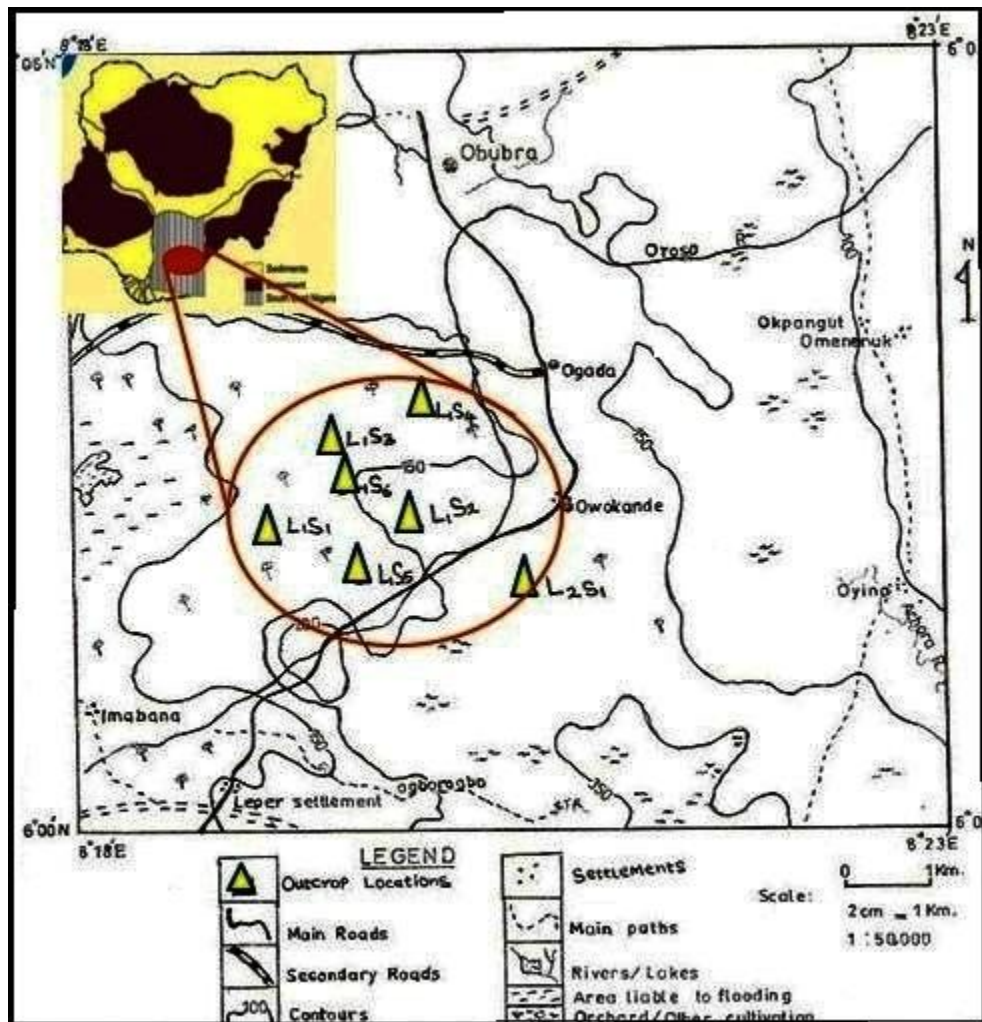


Figure 1: Geologic map of the study area.

The study area falls between the South Eastern Benue Trough and Ikom-Mamfe Embayment. Its geologic evolution dates back to the Albian (Middle Cretaceous) times, with the deposition of Mamfe Formation which is a member of the Asu River Group. This is predominantly a fluvialite clastic sequence. The type locality of the Mamfe Formation is on the bank of Cross River at Mamfe near Cameroun Republic, where about 800m of massive arkosic sandstones with Marl, sandy limestone and shale intercalations are exposed [3]. The sequence on the Nigerian part of this basin comprises of conglomeratic immature arkosic cross-bedded coarse-medium sandstones and mudstones [4]. The Asu River Group which lies uncomfortably on the basement represents the oldest stratigraphic unit exposed in the area. It is characterized by a thick sequence of marine shale with inter bedded siltstones and minor bands of sandstone and limestone.

The Turonian period marked the beginning of another marine transgression. During this period, the mantle upwelling resulted in the deposition of the Eze-Aku Formation [5]. The Turonian consists of fossiliferous marine series outcropping throughout the Benue Trough. This formation comprises of the Amasiri sandstone and the Ezillo Formation members. They consist of hard grey and black calcareous shale, limestone and siltstone. Locally the shale grades into sandstone [6]. The sandstone outcrops extend from Afikpo through Ugep, and then to Apiampu.

2.0 MATERIALS AND METHODS

Representative samples collected from 8 beds of 2 exposed outcrop sections were disaggregated and sieved through 4mm screen to separate the gravels from sand for pebble morphometric analysis and granulometric analysis respectively. In this work, simple dry sieving method of granulometric analysis was used. This is the simplest of all the methods of particle size analysis. It involves the separation of the sand grains into different size ranges. The statistical parameters used in the granulometric analysis are important for the interpretation of the grain size data. This gives an idea of the average diameter, uniformity, degree of sorting, asymmetry and peakedness of grains.

Also pebble morphometric method of [7] adopted by [8], was also used in this study. It is an analysis carried out on pebbles and cobble sized grains to determine the degree of abrasion/roundness; surface markings that could be as a result of sedimentation processes; surface features and general shape of the pebble grain (sphericity). [7] used the term form for overall particle shape that can be obtained from measurement of the three orthogonal axes of the pebbles, and plotted on a form triangle (figure 4). In this method, measurements of the three mutually perpendicular diameters (axes), that is the long axis (L), intermediate axis (I) and short axis (S) of each pebble were made.

Pebbles collected from the logged conglomerates outcrop sections were used in this study. These pebbles were found to be very abundant as dispersed pebbles and thin beds in the pebbly, cross stratified sandstone units. The surface of the pebbles were cleaned with brush, to remove dust particles that may cling to the pebbles and add error to the dimension of the pebble, hence a reason for their removal. The dimensions of the pebbles were measured with veneer caliper. Sampling was done in such a way as to represent all the facies hosting pebbles. Fifteen largest pebbles extracted at random from the sandstone beds were sampled, out of

83 which the best ten were selected to form a batch for analysis. Eighty (80) pebbles were assembled into eight
84 (8) batches and studied for morphometric indices. The values obtained were used for computing the statistical
85 parameters such as proposed by [9]; [10]; [8].

86 The shape, roundness, surface texture etc of pebbles has been intensively studied by many geologists. They
87 came up with lots of statistical parameters which include Flatness ratio (S/L), Elongation ratio (I/L), Maximum
88 Projection Sphericity index ($\frac{3\sqrt{S^2}}{IL}$), Wentworth ratio ($\frac{L-I}{L-S}$), and Oblate–Prolate index ($\frac{10(\frac{L-I}{L-S})-0.5}{\frac{S}{L}}$).

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90 3.0 RESULTS AND DISCUSSION

91 From grain size analysis results of 8 samples (table 1), the skewness values indicate that 12.5% of the samples
92 are positively skewed, and 87.5% are strongly positively skewed. The kurtosis values indicate that 25% of the
93 samples are mesokurtic, 25% are platykurtic, and 50% are leptokurtic. Sorting values indicate that 12.5% is
94 moderately sorted while 87.5% of the samples are poorly sorted.

95 The mean values of the various morphometric parameters range as follows: flatness ratio ($S/L = 0.397-0.514$),
96 elongation ratio ($I/L = 0.657-0.784$), maximum projection sphericity ($\Psi P = 0.605-0.899$), Oblate Prolate index ($\bar{O}$
97 $P = -1.738$ to 1.594), coefficient of flatness ($39.70-51.37$), roundness = $0.367-0.722$ (table 1). Considering the
98 mean geometric forms, 12.5% were compact, 37.5% compact bladed, and 50% of the samples were bladed
99 (table 2).

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106 TABLE 1: SUMMARY OF SIEVE ANALYSIS RESULT

Sample Number	ϕ_5	ϕ_{16}	ϕ_{25}	ϕ_{50}	ϕ_{75}	ϕ_{84}	ϕ_{95}	GM _Z	G _{SDϕ}	G _{SKϕ}	G _{Kϕ}	Remarks
L ₁ S ₁ B ₁	-1.25	-1.15	-1.05	-0.20	0.90	1.45	2.45	0.03	1.21	+0.35	0.75	PS,VPSK,P
L ₁ S ₁ B ₂	-1.25	-1.11	-1.09	-0.90	-0.50	0.20	1.15	-0.003	0.69	+0.69	1.05	MWS,VPSK, M
L ₁ S ₂ B ₁	-1.35	-1.25	-1.22	-1.00	0.55	1.70	3.78	-0.18	1.52	+0.85	1.19	PS,VPSK,L
L ₁ S ₂ B ₂	-1.40	-1.24	-1.15	-1.00	0.05	1.00	2.88	0.25	1-21	+0.80	1.46	PS,VPSK,L
L ₁ S ₂ B ₃	-1.36	-0.90	-0.75	-0.30	0.45	1.20	2.80	0.00	1.16	+0.71	1.46	PS,VPSK,L
L ₁ S ₃ B ₁	-1.37	-1.20	-1.10	-0.25	1.05	1.65	3.30	0.20	1.42	+0.43	0.89	PS,VPSK,P
L ₁ S ₃ B ₂	-1.42	-1.26	-1.19	-1.01	0.65	1.40	3.35	-0.29	1.39	+0.82	1.06	PS,VPSK,M
L ₂ S ₁ B ₂	-1.25	-1.05	-0.75	0.25	1.18	1.80	4.05	0.33	1.52	+0.26	1.13	PS,PSK,L
MEAN	-1.33	-1.15	-1.03	-0.55	0.54	1.30	2.97	0.04	1.27	+0.61	1.13	

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108 Legend

109 PS – Poorly sorted

110 MWS – Moderately well sorted

111 PSK – Positively skewed

112 VPSK – Very positively skewed

113 P – Platykurtic

114 M – Mesokurtic

115 L – Leptokurtic

116 LSB – Location, Section, and Bed

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118 TABLE 2: MEAN VALUES OF PEBBLES MEASURED

Sample Number	$\frac{\bar{I}}{\bar{L}} (\text{cm})$	$\frac{\bar{S}}{\bar{L}} (\text{cm})$	$\frac{\bar{S}}{\bar{L}} \times 100$	$\frac{\bar{L} - II}{\bar{L} - SS}$	$\frac{3}{\frac{\sqrt{S^2}}{\bar{L}}} - 1$	$\frac{10}{\left(\frac{\bar{L} - \bar{S}}{\bar{L}}\right) - 0.5}$	Form	Mean Roundness
L ₁ S ₁ B ₁	0.657	0.414	41.40	0.714	0.899	1.043	C	0.566
L ₁ S ₂ B ₁	0.681	0.418	41.80	0.581	0.688	0.862	B	0.394
L ₁ S ₂ B ₂	0.710	0.397	39.70	0.517	0.605	-0.798	B	0.367
L ₁ S ₃ B ₁	0.716	0.484	48.40	0.565	0.695	1.044	B	0.500
L ₁ S ₄ B ₁	0.741	0.401	40.10	0.428	0.618	-1.738	B	0.526
L ₁ S ₅ B ₁	0.784	0.514	51.37	0.456	0.688	-1.503	CB	0.546
L ₁ S ₆ B ₁	0.711	0.508	50.79	0.584	0.737	1.594	CB	0.600
L ₂ S ₁ B ₂	0.758	0.491	49.18	0.487	0.677	-0.415	CB	0.406
MEAN	0.720	0.453	45.30	0.542	0.701	0.011		0.488

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120 LEGEND

121 B – Bladed

122 C – Compact

123 CB – Compact Bladed

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129 From the graphic mean of the sieve analysis results, it can be deduced that the sediments are made up
 130 predominantly of coarse sand and a small amount of very coarse sand (values ranges from -0.003 to 0.33)
 131 which lies between coarse sands and granules on the Wentworth scale. According to [11], this indicates high

132 energy depositional environment. It also indicates that the sediments were deposited at the stream channels
133 when the energy and competency of the transporting medium has decreased, and thus coarser sediments are
134 being deposited.

135 The graphic standard deviation gave a clue to the sediment sorting. It is indicative of the hydrodynamic
136 conditions operating in the transporting medium and also suggestive of the distance of travel [12]. 87.5% of the
137 sediments are poorly sorted, while 12.5% are moderately well sorted. The poor sorting is related to a decrease
138 in velocity of the transport medium.

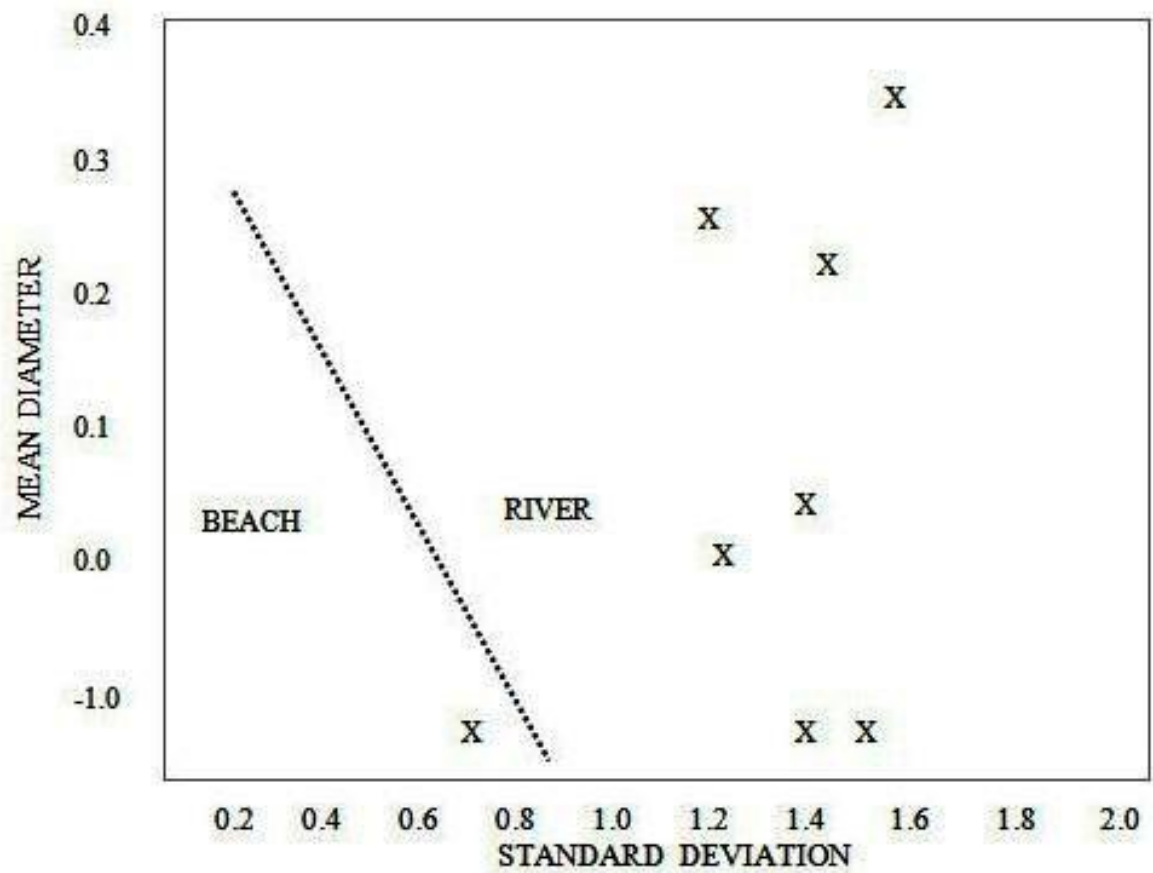
139 About 12.5% are positively skewed while 87.5% of the samples are very positively skewed. The average
140 skewness of (+0.61) corresponds to very positively skewed, indicating that coarse particles exceeds fines.

141 Kurtosis results show that 25% of the samples are platykurtic; 25% are mesokurtic; while 50% are leptokurtic.
142 The variation in the range of value of kurtosis indicates that the sediments were deposited at different regimes
143 of deposition.

144 Bivariate plots of mean diameter against graphic standard deviation, after [13] (figure 2); and a plot of graphic
145 skewness against graphic standard deviation, after [14] (figure 3), clearly show that the sediments were
146 deposited in a fluvial (river) environment. The predominance of coarse sands as can be deduced from the
147 graphical mean indicates a high energy transporting medium [11]. Decrease in the energy resulted in the
148 deposition of these sediments at the lower regimes of the river.

149 Poor sorting and positive skewness are consistent with river sands, whereas beach sands are generally well
150 sorted and negatively skewed. However, the sediments are poorly sorted and positively skewed, suggesting a
151 high energy fluvial environment. Although river sediments generally have many fine materials, it may happen
152 that in some rivers fine sediments are not available as seen in the study area so that the deposited sediments
153 lack fine grades. Thus it could be inferred that the provenance of the sediments is close to the environment
154 where they were deposited.

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157 **Figure 2:** Plot of Mean size against Standard Deviation [13].

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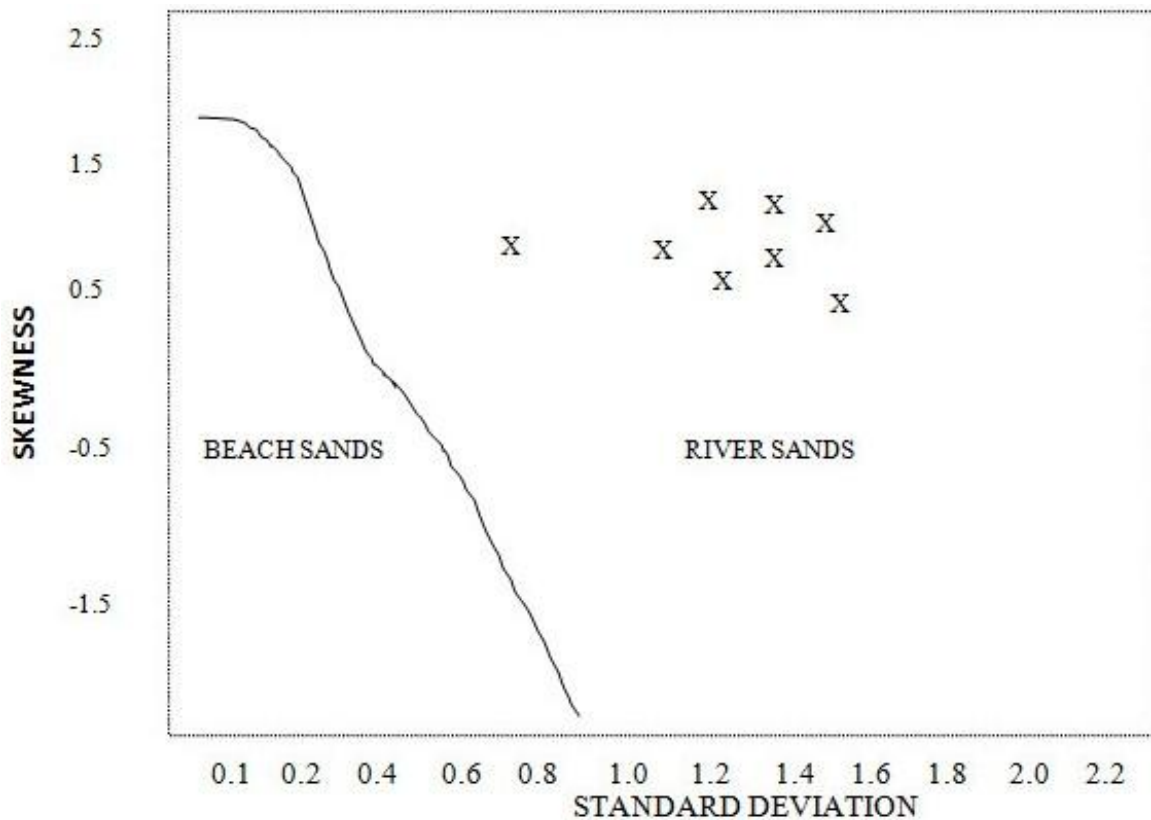


Figure 3: Plot of Skewness against Standard Deviation [15].

Pebble morphometric results show the dominant form (shapes) of the samples obtained from the study. The mean value of elongation ratio ranges from 0.657 – 0.741; flatness ratio ranges from 0.397 – 0.484; maximum projection sphericity index ranges from 0.605 - 0.899; while oblate–prolate index ranges from -1.738 to 1.044. Elongation ratio values for fluvial environment range from 0.6 to 0.9 [16]. All the elongation ratio values fall within this range.

Maximum projection sphericity of pebbles are generally high for fluvial (river) environment than for beaches, [8]; [16]; [7]. An imaginary “magic line” exist which distinguish pebble shape produced by surf processes from that which occur during fluvial transport. The range of value for this “magic line” is from 0.65 to 0.66 [8]. Pebbles whose value fall within 0.65 and above connote river environment. Pebbles whose values fall below 0.65 denote beach environment. All the values of maximum projection sphericity fell above 0.65. This is an excellent indication of fluvial action. The elongation ratio as well as the maximum projection sphericity result indicated fluvial setting.

174 The difference in oblate–prolate index between the river and beach are not as marked as much as sphericity
175 difference. Thus, if the oblate–prolate index for a suite of ten pebbles falls below -2, it is about 87% certain that
176 they are of beach environment, and if the values falls between -1 and +5, it is 69% certain that they are of
177 fluvial environment. From my results, the value ranges between -1.783 and 1.594. It therefore follows that the
178 pebbles are all of fluvial origin.

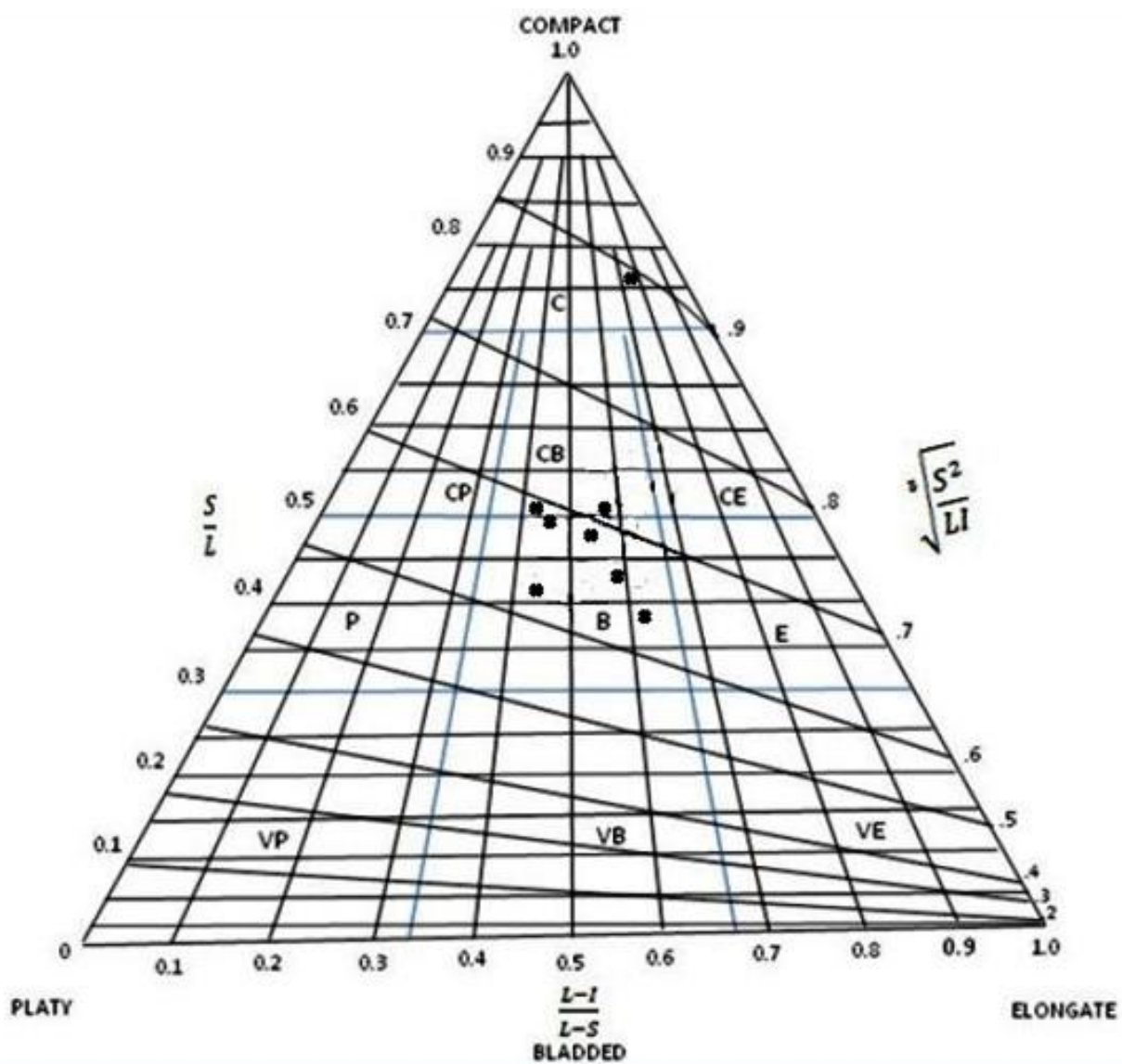
179 **[7]**, established pebble classification scheme which describe the three dimensional aspect of a pebble. These
180 geometric forms include: compact, compact bladed, compact elongated, compact platy, bladed, elongated,
181 platy, very platy, very bladed and very elongated. The dominant forms for river pebble are compact, bladed,
182 compact bladed and compact elongated. Forms for beaches are platy, very platy, bladed and very bladed.
183 Results of this research fall within bladed, compact and compact bladed, and clearly indicates that the pebbles
184 were deposited in a fluvial environment as seen in the sphericity form diagram (figure 4).

185 From the bivariate plots of maximum projection sphericity against oblate–prolate index (figure 5); coefficient of
186 flatness against sphericity (figure 6); and roundness against maximum projection sphericity (figure 7), there is
187 clear indication that the pebbles were deposited in a fluvial environment.

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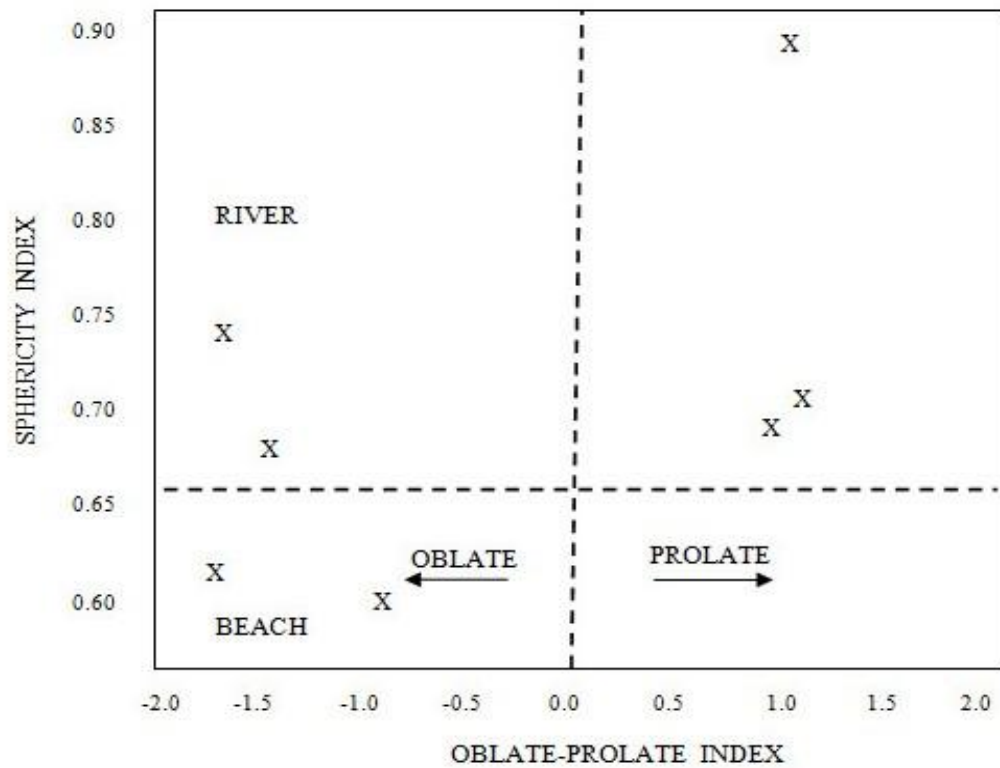
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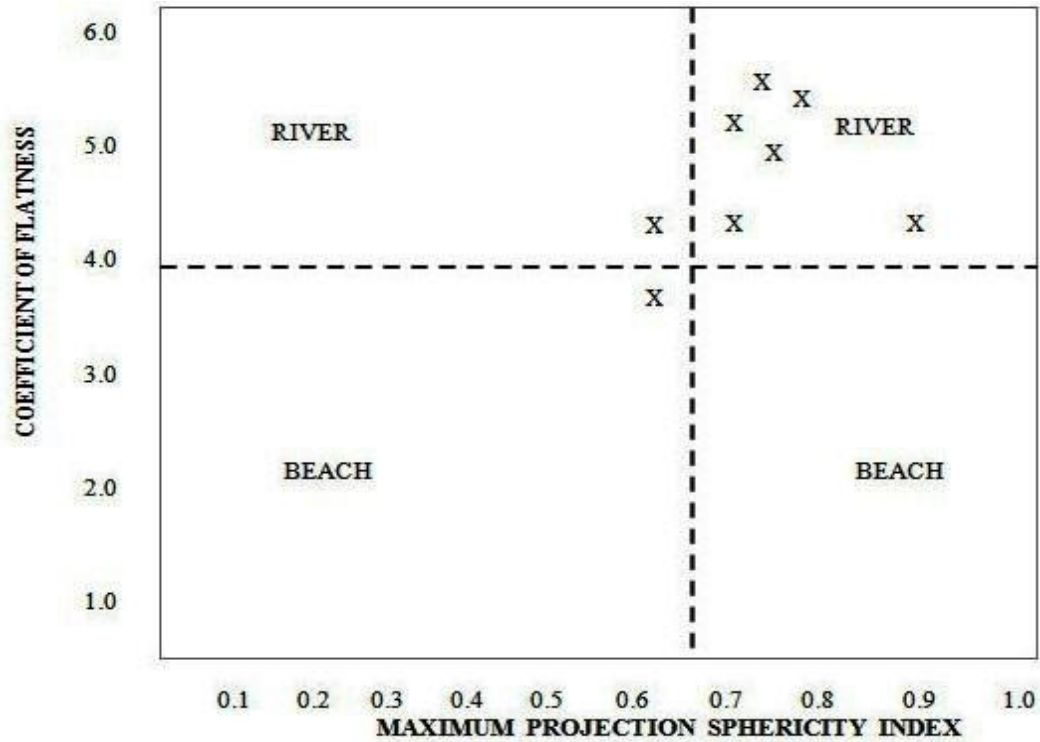
192 **Figure 4:** Form diagram for particle shapes [7].

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195 **Figure 5:** Plot of Sphericity against Oblate-Prolate Index [8].



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197 **Figure 6:** Plot of Coefficient of Flatness against Sphericity [17]

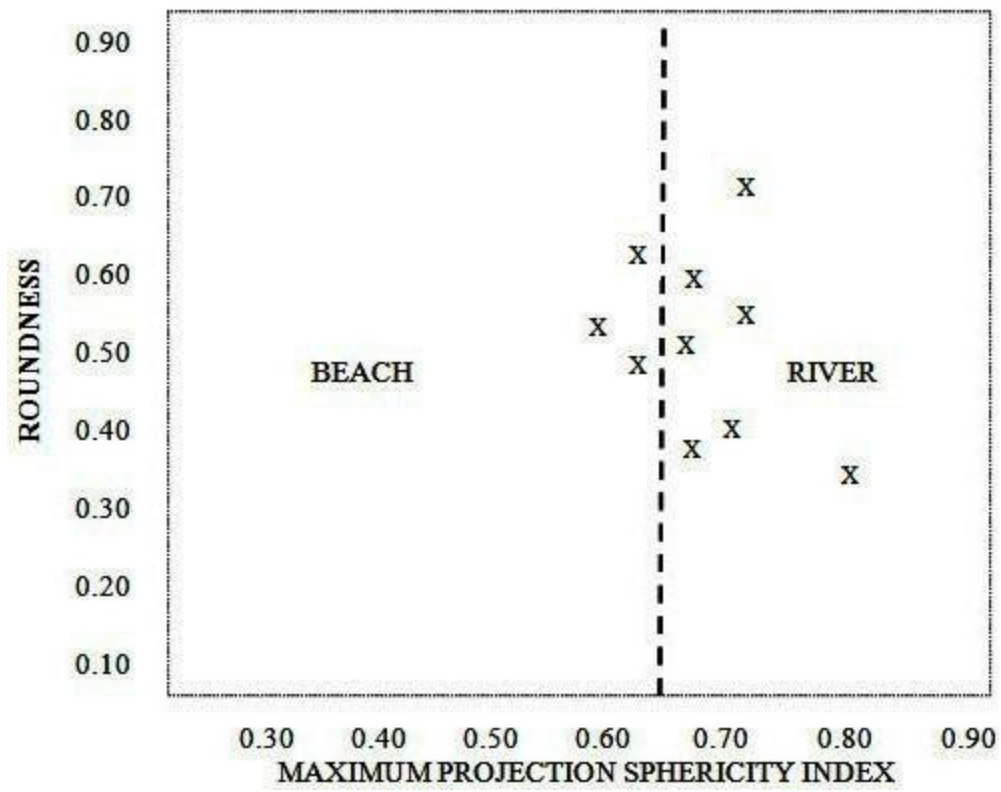


Figure 7: Plot of Roundness against Sphericity [8]

212 **4.0 CONCLUSION**

213 Textural characteristics of sand grains, pebble shapes and other morphometric properties employed in this
214 study, reveal that the conglomeratic sandstone deposits at Uwakande 1, Obubra Southeastern Nigeria was
215 deposited by a high energy fluvial (river) depositional system.

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