PALEODEPOSITIONAL ENVIRONMENTAL DIAGNOSIS OF THE NSUGBE AREA AND ENVIRONS, ANAMBRA STATE, SOUTHEASTERN NIGERIA: AN APPLICATION OF PEBBLE MORPHOMETRIC STUDIES.

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ABSTRACT

The application of pebble morphometric studies in diagnosing the paleodepositional environment of Nsugbe area and environs was carried out using one hundred and seventy (170) vein quartz recovered from seventeen (17) outcrops widely distributed in the studied area. Results show that the pebbles are rounded to subrounded and dominantly compact to compact-bladed. Computed mean values for the flatness index (FI), elongation, maximum projection sphericity index (MPSI) and oblate-prolate index (OPI) are 0.47, 0.74, 0.67 and 0.40 respectively. When these values were integrated with bivariate plots of MPSI versus OPI and mean roundness versus elongation ratio, a dominantly fluviatile depositional environment with subordinate beach/littoral setting are indicated for the Nsugbe area and environs.

KEY WORDS: Pebble morphometry, Paleodepositional environment, Fluviatile, Nsugbe, Anambra basin.

INTRODUCTION

Paleodepositional environments have been determined using grain size analyses. The basic philosophy of this technique is that the sediment type (continental, intermediate and marine), can be distinguished from each other by careful statistical evaluation of their texture; Folk (1967), Moiola and Weiser (1968), Petitjohn et al. (1972), Freidman (1961, 1967, 1979) and Nwajide and Hoque (1982). This technique was applied to the pebbly siliciclastic sediments that underlie Nsugbe and environs, including parts of Onitsha and Otuocha, all within the Southern Anambra basin.

Statement of Problem

Nwajide (1979, p.192) informally designated the lithologic unit that borders the northerly boundary of the Nanka Formation as 'Nsugbe Formation'. The boundary was established on the basis of textural and mineralogical character (coarse-grain indurated and ferruginized sandstone) of the so-designated Nsugbe Formation, to distinguish it from the friable Nanka Formation. Nwajide (1979) further considered that the Nsugbe, the Nanka and the Ameki Formations are distinct clastic facies of the lithic fill of the early Eocene in Southern Nigeria though they are lateral equivalents. Nfor (2008) has however, frowned at the continuous usage and designation of the terminology 'Nsugbe Formation' in defiance of the due procedures prescribed by the International Commission on Stratigraphic Nomenclature (ICSN).

Location and Brief Geology of the Study Area

The study area covers a surface area of 55km^2 and is bounded by latitudes N06^{0}09'/N06^{0}21' and longitude E006^{0}47'/E006^{0}52'. It is bordered to the west by R. Niger, to the south by parts of Onitsha; to the east by Nteje and Awkuzu and to the north by Ayamelum Local Government Area of Anambra State (fig. 1). The main geologic units within the study area have been discussed extensively by geologists including Egboka (1993) and Reyment (1965). Table 1 summarizes the main geologic units within the Anambra basin. The main lithologies identified in the Nsugbe area are; conglomerates and ferrugnized sandstone with minor presence of siltstone and clays. The general dip of the rocks is westerly/southerly, with values ranging between 6^0 and 8^0. Seepages/springs abound in places where the road cuts have exposed clay/sand contacts towards the south or southwesterly sides.

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Table 1: T

AGE	STRATIGRAPHIC UNIT
Eocene	Ameki Group (including Nanka Sand)
Paleocene	Imo Shale
Maestritchian	Nsukka Formation, Ajali Sandstone, Mamu Formation
Campanian	Nkporo Group (including NkporomShale, Owelli Sandstone, Enugu Shale, Afikpo Sandstone, Otobi Sandstone)
Santonian	Non-deposition
Coniacian	Awgu Group (including Awgu Shale, Agbani Sandstone)
Turonian	Ezeaku Formation (Amaseri Sandstone)
Cenomanian	Odukpani Formation
Albian	Asu River Group
Precambrian	Basement Complex

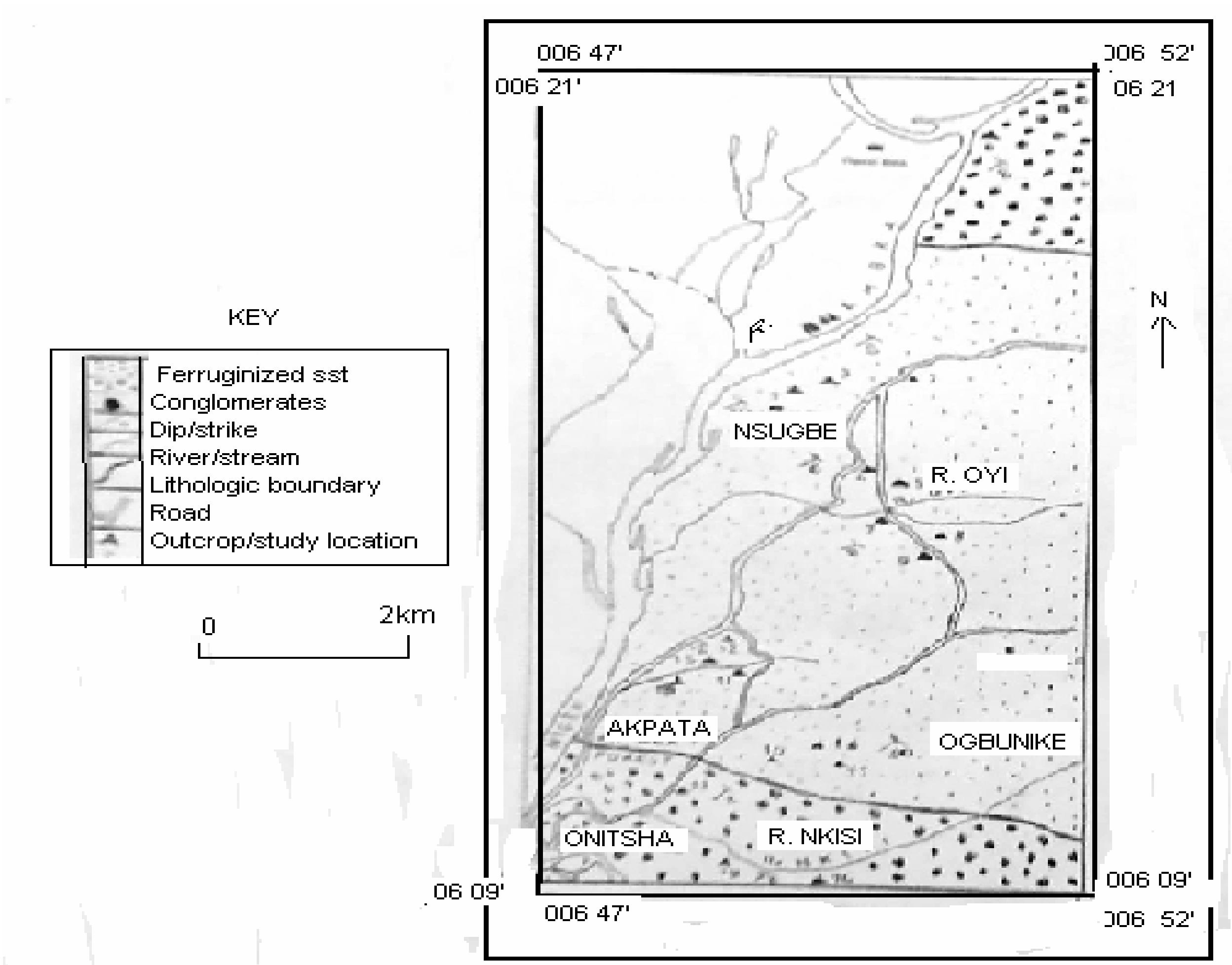

Fig. 1. Location/Geologic map of Nsugbe and environs

MATERIALS AND METHODS

Seventeen (17) outcrops (including road-cuts, river/stream cuts, gully erosion and quarry sites) were studied for paleodepositional reconstruction using pebble morphometry. Two types of pebbles were observed in the area; quartzose and mudrock pebbles. There was no preferred orientation of the long axes. There was an absence of metamorphic foliation and micacesous inclusions and quartz was monomineralic in nature. Quartz pebbles were chosen in preference to mudrock pebbles because they were relatively abundant and had isotropic wearing properties, while mudrock pebbles crumble during measurements. Furthermore, the original shapes and forms of vein quartz pebbles are largely preserved and modified only by attrition rather than by foliation-controlled cleaving and these characteristics are in line with those presented by Griffiths (1967). Subsequent methodology/procedures also adopted in measurement are as described by Griffiths (1967).

From each outcrop location, ten (10) unbroken large quartz pebbles were collected, washed and numbered. Their long (L), short (S) and intermediate (I) lengths were then measured using vernier calipers. The roundness of each pebble was taken as the proportion of the convex parts of the pebble along its maximum projection perimeter and it was measured using the pebble image set of Krumbein (1974) and Sames (1966). Sames's method is diagnostic for paleocurrent diagnosis. Average values of L,S and I and roundness of the pebbles were taken for each location and used to generate the following pebble parameters; Flatnesss Ratio, Elongation Ratio and Maximum Projection Sphericity, Oblate-Prolate Index, with the aid of standard empirical formulae.

Presentation and Analyses of Data

A spreadsheet of the measured values and some computations for the pebbles are presented in Table 2. Analysis of the form using the Sneed and Folk diagram (1958) shows that the bladed and compact-bladed forms each constitute 47.1% and only 5.8% are elongated. The average values for the pebbles are; 25mm, 18.4mm and 11.3mm for the long, intermediate and short axes respectively.

Sphericity

This is a measure of equidimensionality i.e. the relation between the particle intercepts to each other, or otherwise, the approach of a pebble to a sphere. In this research work, the maximum projection sphericity (MPS) of Sneed and Folk (1958) was used. This is the cube root of the ratio between the square of the short axis and the product of the long and the intermediate axes, mathematically written as $(S^2/LI)^{1/3}$. This parameter reflects the best behaviour of particles during transport in a fluid medium. The MPS values for pebbles from the study area range from 0.55 to 0.75 with a mean value of 0.67.

Form

This is a measure of the relation between the three mutually perpendicular dimensions of a pebble. Form is used to show that particles with the same numerical value of MPS may have different ratios between the three axes. The sphericity-form diagram of Sneed ad Folk (1958) was used to determine the form name of each pebble batch. Plotting the data into the sphericity-form diagram yielded three forms; compact-bladed (CB), bladed (B) and elongated (E) constituting 47.1%, 47.1% and 5.8% respectively as shown in figure 2.

Roundness

The roundness of a particle is the measure of the curvature of the corners and edges. Using the scale of Petitjohn (1975), roundness values for the pebbles were observed to range from 45 to 65%. Most pebbles in the study area were found to be rounded to subrounded.

Flatness

This is a measure of the ratio of the short axis (S) to the long axis (L) i.e. (S/L) (Sames, 1966 and Lutig, 1962). In this study, only quartzose pebbles were used in accordance with the provision of these authors. Results show that the average flatness ratio of the pebbles in the study area is 0.47.

Elongation

This is defined as the ratio of the intermediate to the long axis, (I/L), (Lutig, 1962 and Sames, 1966). Elongation of the pebbles of the study area range from 0.59 to 0.88, with a mean value of 0.74.

Oblate-Prolate Index (OPI)

This is a measure of the closeness of the intermediate axis to the long axis or to the short axis. This is mathematically represented as;

OPI = [{(L-I)/(L-S) – 0.5}/SL], (Dobkins and Folk, 1970). Computed OPI values range from -0.28 to 3.32 with an average of 0.40. Of the seventeen outcrops, only five i.e. 29.4% showed negative OPI values. This implies that disc-shaped pebbles are rare in the study area.

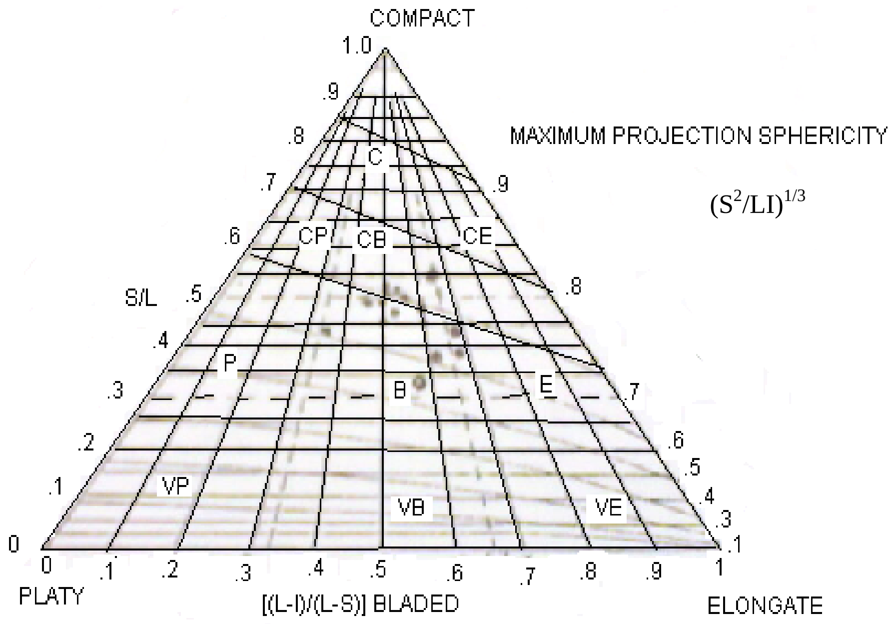

Fig. 2. Plot of average pebble shape on Sneed and Folk's (1958, fig. 2) sphericity-form diagram. Each point represents an average of ten pebbles.
C= compact, P = platy, B = bladed, E = elongate and V = very

Discussions – paleodepositional environment.

The absence of metamorphic foliation and micaceous inclusions and the presence of only monomineralic quartz suggest that vein quartz is the parent rock of the quartzose pebbles. This indicates basement rocks as the source area from which quartz veins fragmented in response to jointing, faulting, sheeting or exfoliation. These inherited factors are thus identified to be responsible for the initial random shape and size; hence the sphericity readings obtained. This is in consonance with the findings of Blatt (1959) and Smalley (1966). These inherited initial form and shape are persistent in the sediments despite the wear and tear that occur during transportation and impart overriding sphericity and roundness values (Krumbein, 1941 and Drake, 1970). When computed results of Table 2 are compared with the results from figure 2, it is evident that out of the three-end member forms, the platy forms of pebbles were completely absent, only 5.5% of the pebbles were elongate, while the compact and compact-bladed forms each constitute 47.1% of the pebble population. This indicates that the original forms released from the source area were dominantly bladed and compact bladed. Compact, compact-bladed and elongate pebble forms are diagnostic of a fluvial depositional environment, (Dobkins and Folk, 1970) for the Nsugbe pebbles.

Roundness values for the Naugbe pebbles range from 45% to 65%, indicating fluvial environment, in line with the upper limit value of Lutig (1962), who placed roundness limits for fluvial environment between 55% and 65%. The lower value, 45% suggests a near-provenance for the pebbles. The discrepancy (difference in the lower limits i.e. 45% in the study area and 55% Lutig's computation) is in line with Petitjohn's (1975) findings, that roundness is a poor indicator of depositional environment because pebbles become easily rounded even after only a short distance of transport.

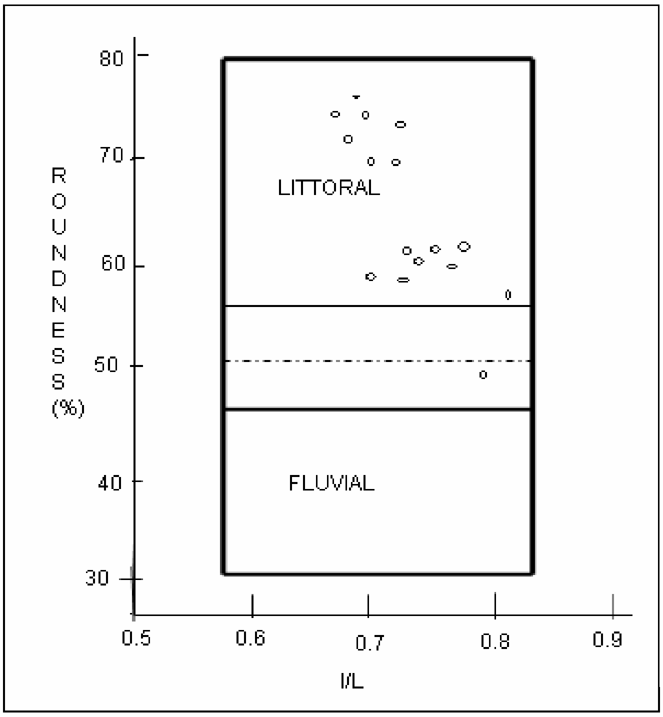

Fig. 3. Environmental determination using bivariate plot of pebble roundness (%) vs elongation ratio (I/L) (After Sames)

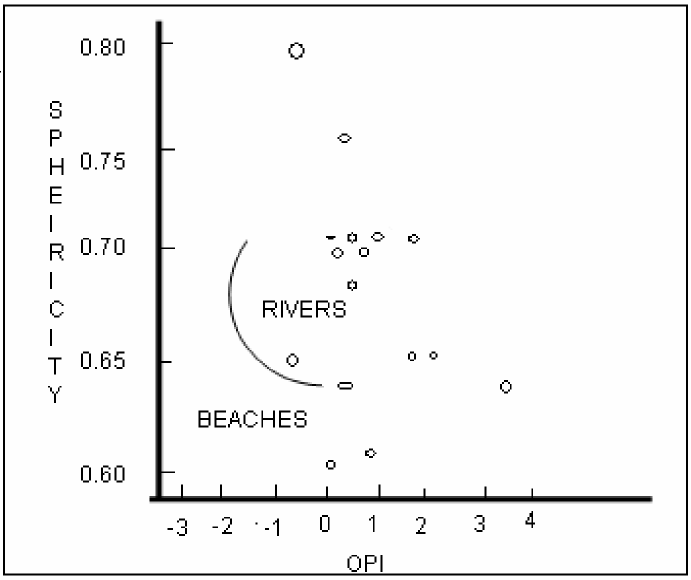

Fig. 4. Plot of MPI vs OPI indicating separation between River and Beach fields (shown by the curve) is the position of average values of the two parameters (Dobkins and Folk, 1970)

Generally, the pebbles here are rounded to subrounded. This discrepancy is further confirmed by bivariate plots of roundness versus elongation ratio (Sames, 1966). The plot (figure 3) shows that 82% of the samples were deposited under littoral environment and the rest (18%) were deposited in a transitional setting, while none reflected fluvial environment. Dobkins andFolk (1970), have used the 0.66 sphericity line to discriminate beach and river pebbles, the lower values (<0.66) are typical of beach, while the higher values (>0.66) are suggestive of fluvial environment. With about 76% of the pebble sphericity ≥0.66, and only 24% of the pebbles below the 0.66 line, a dominantly fluvial environment with minor beach contribution is suggested (fig. 4).

The range of OPI values (-0.28 to 3.32) with an average of 0.40 falls within the -1.00 to +5.00 range of Dobkins and Folk (1970), suggesting a fluvial environment. Negative values indicate pebbles whose intermediate lengths (axes) approach the long axes. Positive values are indicative of pebbles whose intermediate lengths approach the short axes. Of the seventeen outcrops, only five (29.4%) showed negative OPI values. This implies that disc-shaped pebbles are rare in the study area. Fluvial environment was further confirmed by computations from MPSI/OPI bivariate plots (fig. 2), which indicated a dominant contribution from fluvial activities (70.5%) over a 29.5% contribution from beach influence.

A summary of the computed pebble parameters showing the results of the environmental indicators from pebble morphometry is presented in Table 3. The paleodepositional environment most strongly indicated by the various parameters from the Nsugbe area and environs is fluvial, with subordinate beach/littoral influence. This is in line with the conclusions of Nwajide (1979), who suggested a continental facies for the Nsugbe area.

CONCLUSION

The use of pebble morphometry for paleodepositional diagnosis of Nsugbe and environs has proved to be very useful. The average lengths of the long, intermediate and short axes of the pebbles are 25mm, 18mm and 11.3mm respectively. The grains are rounded to subrounded. Ninety percent (90%) of the pebble forms are compact and compact bladed, while just 10% are elongate. The mean flatness ratio, elongation ratio, maximum projection sphericity index and oblate-prolate index are 0.47, 0.74, 0.67 and 0.40 respectively. When compared with published works, these values suggest that the pebbles from Nsugbe and environs were deposited in a fluvial setting, with minor contributions of littoral/beach influence. This deduction was further tested using bivariate plots. The mean roundness versus elongation plots showed that the pebbles were deposited in an entirely littoral setting, with minor contributions of beach influence.

Not withstanding the few limitations of the use of pebble morphometry in paleoenvironmental diagnoses, it has proven to be an excellent tool for deciphering that of Nsugbe and environs. This research thus constitutes a major contribution to the geology of the Anambra basin in two ways; firstly, sufficient data has been used to show that the geologic unit that lies north of the Nanka Sand was deposited in a fluvial setting, in contrast to the marginal marine setting of the Nanka Sand. Secondly, it is a step further for any eventual formal nomenclature of that lithologic unit either as a member of an existing formation or as a distinct geologic unit on its own.

Table 2. Mean values of pebble morphometry

Sample	Axes (cm)			S/L	I/L	(L-I)	(L-S)	(L-I)/(L-S)	OPI [(L-I)/(L-S)] – 0.5/(S/L)	LI	S^2	MPS $(S^2/LI)^{1/3}$	FI (S/L) X 100	Form name	Roundness
	L	I	S												
L2S_1	1.40	1.10	0.66	0.47	0.79	0.30	0.74	0.49	-0.02	1.54	0.44	0.66	47	B	50
L7	3.83	2.60	1.70	0.44	0.68	1.23	2.13	0.58	1.82	9.96	2.89	0.66	44	B	45
L3S_7	2.10	1.51	0.95	0.45	0.72	1.39	1.15	1.20	1.56	3.17	0.90	0.66	45	B	45
L1	4.88	2.86	1.83	0.38	0.59	2.02	3.05	0.66	0.42	13.96	3.35	0.62	38	B	40
L5	4.15	2.98	2.10	0.51	0.72	1.17	2.05	0.57	0.14	12.37	4.41	0.71	51	CB	63
PRISONS	2.86	2.05	1.46	0.52	0.72	0.81	1.40	0.58	0.15	5.86	2.13	0.71	52	CB	65
1_9	2.05	1.70	0.89	0.43	0.83	0.35	1.16	0.38	-0.28	3.49	0.79	0.61	43	B	45
2_7	1.59	1.17	0.72	0.45	0.74	0.42	0.87	0.48	-0.04	1.86	0.52	0.65	45	B	50
3_3	2.52	1.96	1.12	0.44	0.78	0.56	1.40	1.96	3.32	4.94	1.25	0.63	44	B	49
4_8	1.26	0.88	0.42	0.33	0.70	0.38	0.84	0.45	-0.15	1.11	0.18	0.55	33	B	40
6_1	2.80	2.06	0.55	0.55	0.74	0.74	1.25	0.59	0.16	5.77	2.40	0.75	55	CB	65
10_1	2.22	1.55	1.05	0.47	0.70	0.67	1.17	0.57	0.15	3.44	1.10	0.68	47	E	50
11B_5	1.96	1.48	0.99	0.51	0.76	0.48	0.97	0.49	-0.02	2.90	0.98	0.70	51	CB	66
11C_3	2.11	1.56	1.07	0.51	0.74	0.55	1.04	0.53	0.06	3.29	1.14	0.70	51	CB	60
12_4	2.06	1.55	1.03	0.50	0.75	0.51	0.51	1.00	1	3.19	1.06	0.70	50	CB	65
13_8	2.63	2.11	1.28	0.49	0.88	0.52	1.35	0.39	-0.22	5.55	1.64	0.67	49	CB	45
14_4	2.92	2.13	1.42	0.49	0.73	0.79	1.50	0.53	0.06	6.22	2.02	0.69	49	CB	49

Table 3. Summary of environmental diagnosis from pebble morphometry for Nsugbe and environs

Morphometric parameter	Characteristics exhibited by the pebbles	Environmental indications	References
Roundness	Mean value of 52%	Fluviatile	Lutig (1962)
Flatness Ratio	Mean value of 0.47	Fluviatile	Stratten (1974)
Plot of Roundness vs Elongation	0% fluvial, 82% littoral, 18% transitional	Littoral to transitional	Sames (1966)
MPS	0.67	Fluviatile	Dobkins and Folk (1970)
Pebble form	Compact bladed = 47.1% Bladed = 47.1% Elongated = 5.8%	Fluviatile	Sneed and Folk (1958)
OPI	0.40	Fluviatile	Dobkins and Folk (1970)
OPI vs MPSI	70.5% fluvial 29.5% beach	Fluviatile with some beach influence	Dobkins and Folk (1970)

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