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PALEO-ENVIRONMENTAL DEDUCTION FROM PEBBLE MORPHOMETRY AND TEXTURAL STUDIES OF SANDSTONE DEPOSITS OF ISUOCHI AND ENVIRONS, ANAMBRA BASIN, SOUTH EASTERN NIGERIA.

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ABSTRACT

Textural analysis and pebble morphomentric were carried out on the sandstone deposits of Isuochi area in Anambra Basin, in an attempt to reconstruct the paleoenvironment of deposition. Field observation shows that the sandstone samples, collected from various locations were analyzed for sieve analysis, while two hundred fresh quartz pebbles that are greater than 2.00mm in diameter were collected for pebble morphomentric. Morphomentric parameters include; elongation ratio, flatness index, oblate index, and maximum projection sphericity were computed. Bivariate plots of Maximum Projection Sphericity against Oblate Prolate Index show that about 69% of the pebbles are of fluvial origin, while 31% is surf, bivariate plots of Flatness Index against Maximum Projection Sphericity show that about 57% is of fluvial origin, while 43% show surf; these imply that the associated pebbles are of fluvial origin. Bivariate plots of sandstone textural parameters such as skewness against standard deviation also suggest that the sediments are more of fluvial origin while multivariate parameter shows partly shallow marine environment.

KEYWORDS: Pebble Morphometry, Oblate-Prolate Index, Paleoenvironment.

INTRODUCTION

Sedimentation in the south eastern Nigeria started during the middle Albian which led to the deposition of the oldest sediment in the Southern Benue Trough mainly around Abakaliki; although some pyroclastics of Aptian Early Albian ages have been sparingly reported. Ojoh, (1990).

Isuochi and environs, which is the study area is composed of sediments of Ezeaku Shale, Nkporo Shale, Mamu Formation, Ajali Formation and Nsukka Formation. Major area covers includes: Umuokwu, Amuda, Ngodo, Lekwesi, Ugwueme and Lomara, with major outcrops being exposed along stream channels, quarries, Enugu-Port Harcourt express way and road cuts (figure 1). It lies between latitudes 05° 56^{1} 0^{11}N and 06° 01^{1} 00^{11}N, and longitudes 07° 22^{1} 0^{11}E and 07° 27^{1} 0^{11}E. Covers an areal extent of about 86km^{2} approximately.

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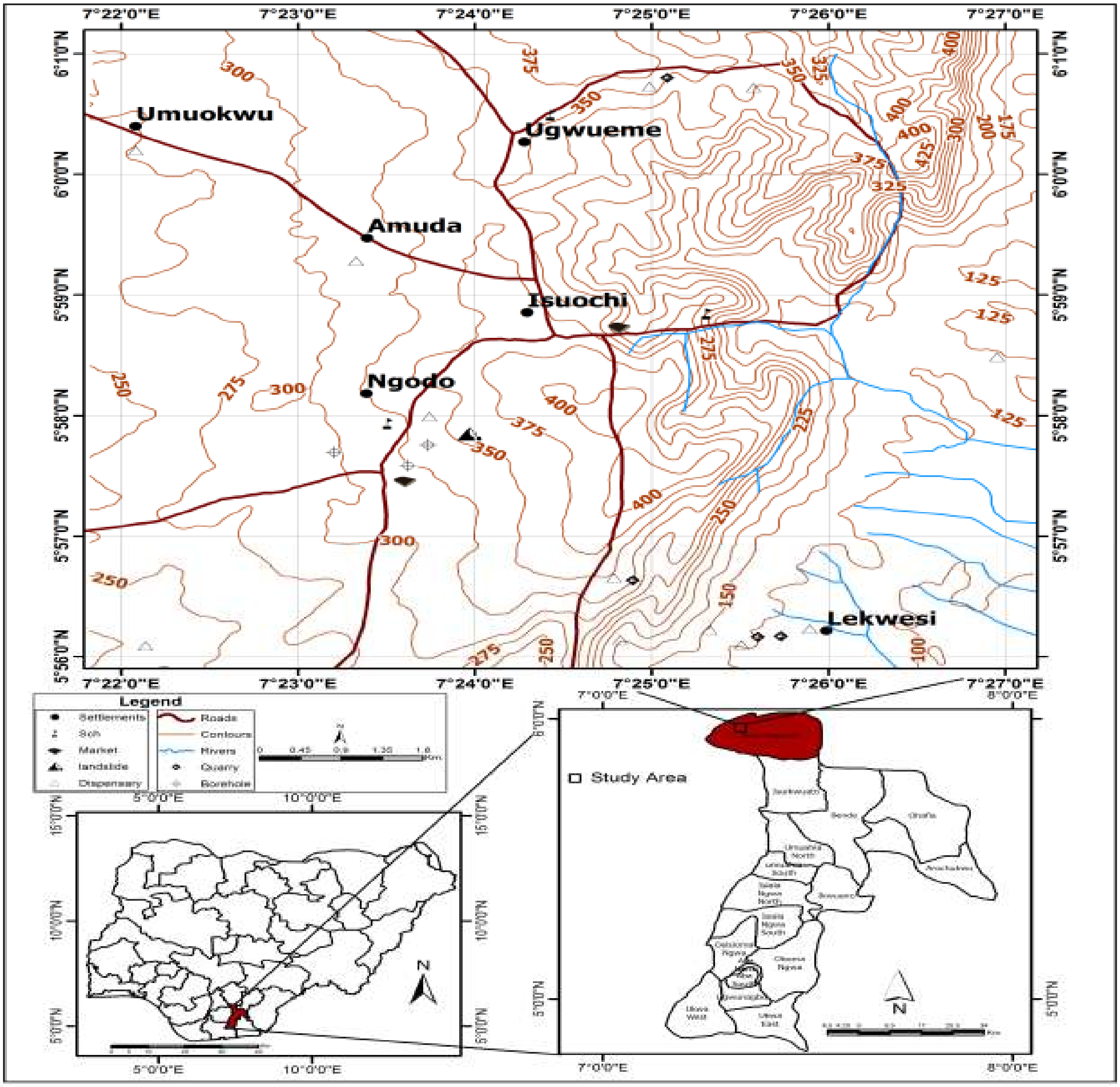

Figure 1: Location, Extent, and Accessibility map of the Study Area.

Simpson, (1955) and Reyment, (1965) noted that Asu River Group was deposited in a moderately deep water environment during the Albian, moderately folded, with NE-SW trending fold axes, abundant ammonites, forams, radiolarian, and pollens. The first marine regression in Benue Trough took place during the Early Cenomanian to Turonian; this led to the sediment deposition of Odukpani Formation. Burke, (1972), Reyment, (1965), and Murat, (1972) recorded that Eze-Aku Formation consist of dark grey to black shales, sandstone, subordinate limestone and siltstone which was deposited in a shallow marine environment, the sandstone deposits mark a period of regression, while the shale deposits indicate a period of transgression.. Offodile, (1976) noted that; there was an unconformity between the Turonian Eze-Aku Formation and the overlying Campanian-Maastrichtian Nkporo Shale. This explained the omission of the Awgu Formation in the syncline as a result of extensive erosion of older beds which accompanied the Santonian uplift. Sedimentation of the post-deformation in the Lower Benue Trough comprises of Anambra Basin Obaje, (2009). Agagu et al, (1985) and Reyment, (1965) were able to established stratigraphic sequence of the Anambra Basin which consists of Nkporo Shale, Mamu Formation, Ajali Formation, and Nsukka Formation in ascending order.

Tattam, (1944), Reyment, (1965, and Nwajide and Reijers, (1996) described Nkporo Shale as dark-light brown ferruginous shale, highly fissile shale and mudstone with thin beds of sandy shale. Oboh-Okuenobe et al, (2005), Simpson, (1955), and Dessauvagies, (1970) described Mamu Formation to composed of shale, sandy shale, mudstone, siltstone with coal seams at different horizon. Formed under low salinity condition of the sea. Kogbe, (1989), Murat, (1972) and Reyment, (1965) described Ajali

Sandstone as poorly sorted sandstone, friable, white with iron-stained, with sparse cement of whitish clay. Tattam, (1944) first described Nsukka Formation as the "Upper Coal Measure" which marked the onset of another transgression in the Anambra Basin during the Paleocene (Obaje, 2013). The Nsukka Formation which overlies the Ajali Sandstone consists of medium to coarse grained sandstone, sandy shale with thin coal seams and carbonaceous dark shale (Obi, 2001, Murat, 1972 and Reyment, 1965).

The study presents detailed sedimentological pebble morphomentric and sandstone textural study of the area in order to depict the paleo environment of deposition.

GEOLOGY AND STRATIGRAPHY OF THE STUDY AREA

The geology of Isuochi is explicated in the geologic map (figure 2). Isuochi is underlain by six major lithological facies and five formations. These lithofacies are; the dark gray baked shale, light gray flaky shale, dark gray shale, dark mudstone, cross bedded sandstone and dark bluish mudstone while the formations are Ezeaku Shale, Enugu Shale, Mamu Formation, Ajali Formation and Nsukka Formation. The dark gray baked shale is fissile, light gray calcareous with dolerite sill intrusion overlies by carbonaceous mudstone. The light gray flaky shale is highly micaceous, calcareous and bears distributed limestone boulders within it. It appears dark coloured in some places. The dark gray shale is massive and highly homogeneous, fissile, poorly preserved wood fragment with thin bands of ironstone and claystone. The dark mudstone is carbonaceous, bluish shale with gastropod imprints and recies of wood fragments interbedded with sandstone and grayish siltstone. The sandstone within this facies is fine to medium grained with well exposed wave ripples and well preserved planolite and thalansinoid imprints. The cross bedded sandstone is friable, whitish to yellowish which consolidate towards the base. Averagely coarse and moderately to well sorted with clay at interval and ironstone capping it at the top. The sandstones are angular to sub-angular in shape with incidence of pebbles. Ripple marks, vertical symmetrical pellet wall of Ophiomorpha burrows, overturned beds, trough cross bedding, liesegang ring and wave rippled lamination are found within this facies. The dark bluish mudstone is carbonaceous with thin layers of coal and siltstone compacted together. The mudstone is reddish at weathered surface, interbedded with shale, sandy shale, sandstone and pyritic noodles.

The regional trend is NE-SW trend with an average dip of 8°. The afore mentioned facies are correlatable to the Ezeaku Shale, Enugu Shale, Mamu Formation, Ajali Formation and Nsukka Formation.

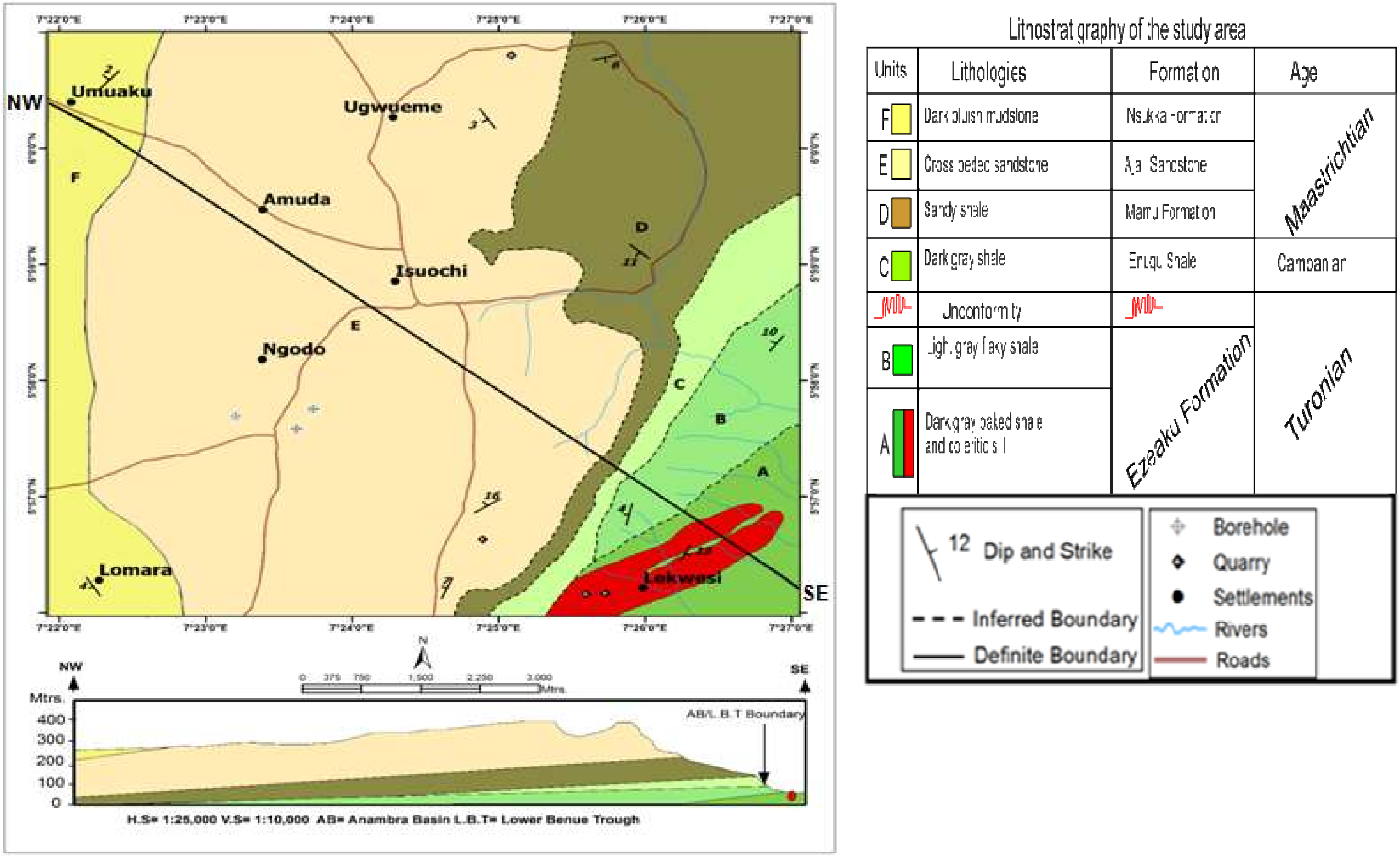

Figure 2: Geologic map of Isuochi

MATERIALS AND METHOD

The desk study of the mapped area was conducted, followed by field mapping and laboratory analysis of the pebbles and sandstones. The desk studies involved the assemblage of all the available materials on the area in order to procure information on Isuochi and its environs. The field work involved the depletion of the lithofacies and collection of sandstones and pebble samples.

PEBBLE MORPHOLOGY

200 fresh unbroken pebbles were handpicked at discrete beds randomly within the study area. The samples were washed and numbered before taken to the laboratory. The analysis involves the measurement of the three mutually perpendicular diameters of pebbles using venier calliper. The three mutual perpendicular axes taken are: Long axes (L), Intermediate axes (I) and Short axes (S) of the pebbles according to (Zingg, 1935, Krumbein, 1941, Sneed and Folk, 1958 and Dobkins and Folks, 1970) the measurement obtained were recorded and used to determine parameters such as form (Zingg, 1935), mean, roundness and form indices (Dobkins, 1970 and Stratten, 1974), from which the bivariate plots are derived.

The average of “L” long, “I” intermediate, and “S” short axes for each samples were computed and applied in the computation of pebble morphomentric parameter are as follows:-

Flatness Index (FI): (S/L) * 100 (Lutig, 1962, and Sames, 1966)

Elongation ratios (ER): I/L * 100 (Lutig, 1962, and Sames, 1966)

Maximum Projection Sphericity (MPS): $(S^2/LI)^{1/3}$ (Sneed and Folk, 1958)

Oblate Prolate Index (OP): $\frac{(L - I) / (L - S) - 0.5}{S/L}$ (Dobkins and Folk, 1970)

Univariate pebble morphology parameters and their indications Form

This describes the relationship between the long, intermediate and short axes. It involves using the comparison of the ratio of the intermediate axis to the long axis (I/L) and the ratio of the short axis to the intermediate axis (S/I) in order to determine the shape classes which the pebbles as proposed by Zingg (1935) defined four shape classes, namely oblate, equiaxial, prolate and bladed based on these ratios (table 1).

Table 1: Shape classes according to (Zingg, 1935)

I/L	S/I	Shape class
>0.67	<0.67	Oblate
>0.67	>0.67	Equiaxial
<0.67	<0.67	Bladed
<0.67	>0.67	Prolate

SIEVE ANAYSIS

Four sandstone samples were collected from various locations, samples were disaggregated in the laboratory with a rubber padded pestle as suggested by PettiJohn, (1975) 50gm of each disaggregated sample was measured using a weighing balance as test portions for sieve analysis. The test portions were sieved with a Ro-tag shaker for 15 minutes using a set of sieves with mesh size 0.5 phi apart. Cumulative curves of the grain size distribution were plotted from the sieve result. The univariate, and bivariate parameters were computed based on Folks and Ward (1957), Miola and Weiser (1977), and Sahu (1964). (Table 2).

Table2: Statistical parameter, their formula and verbal terminology (Folk and Ward (1957)

Mean Size	Sorting	Skewness	Kurtosis
$\mathbf{M_Z} = \frac{\boldsymbol{\phi_{16} + \phi_{50} + \phi_{84}}}{\mathbf{3}}$	$\sigma_I = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6.6}$	$Sk_I = \frac{\phi_{16} + \phi_{84} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_5 + \phi_{95} - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$	$K_G = \frac{\phi_{95} - \phi_5}{2.44(\phi_{75} - \phi_{25})}$

Sorting ($\boldsymbol{\sigma_I}$)		Skewness (Sk_I)		Kurtosis (K_G)	
Very well sorted	< 0.35	Very finely skewed	$^+0.3$ to $^+1.0$	Very platykortic	< 0.67
Well sorted	0.35 – 0.50	Finely skewed	$^+0.1$ to $^+0.3$	Platykortic	0.67 – 0.90
Moderately well sorted	0.50 – 0.70	Symmetrical	$^+0.1$ to $^-0.1$	Mesokortic	0.90 – 1.11
Moderately sorted	0.70 – 1.00	Coarsely skewed	$^-0.1$ to $^-0.3$	Leptokurtic	1.11 – 1.50
Poorly sorted	1.00 – 2.00	Very coarsely skewed	$^-0.3$ to $^-1.0$	Very leptokurtic	1.50 – 3.00
Very poorly sorted	2.00 – 4.00			Extremely leptokurtic	< 3.00
Extremely poorly sorted	> 4.00				

RESULT AND DISCUSSION

Pebble morphometry

The pebble morphometry results obtained from the analysis are tabulated in table 3 to 4 and figure 3. The results show that 33.333% of the pebbles are equiaxial, 33.33% are oblate, 16% are prolate, while 10% are bladed. Based on mean roundness, 29% of the pebbles are very angular, 25% are angular, while 31% are sub-angular and 13% are sub-rounded pebbles. Only 2% of the pebbles are rounded. Roundness of pebbles tend to increase from rivers to beaches, hence with the low percentage of round pebbles (sub-rounded and rounded), it is likely that the pebbles have been affected by fluvial processes. The high amount of equiaxial pebbles compared to the oblate, prolate and bladed pebbles (38%) shows a greater tendency towards sphericity, which decreases from rivers to beaches. This means that the pebbles have been affected by fluvial process (Dobkins and Folk, 1970).

From the limits for form indices given by Dobkins and Folk (1970) and Stratten (1974), it is observed that the larger percentages of the pebbles fall within the limits of form indices for fluvial processes. The values of the average OPI, MPS and FI also fall within the limits of form indices for fluvial processes. These indicate that the environment of deposition of the pebbles was fluvial dominated.

The bivariate plot of MPS vs. OPI (Figure 4) shows 73% of the plots in the fluvial portion of the graph; 1% in the beach portion of the graph, while 26% plots in the lower portion non-diagnostic portion of the graph. The high percentage plots in the fluvial field of the graph indicates fluvial dominated environment.

Grain Sizes of sandstone

The result of the grain size analysis for sandstone shown in table 5. It can be observed that mean sizes of the sandstone are predominated by coarse sand, ranges from 0.608 – 0.856. The standard deviation (sorting) shows that the sandstone are moderately sorted, ranging from 0.818-0.963. The skewness values indicate symmetrical (-0.005-0.093) expect for unit 2 that is fine-skewed (0.293). The coefficient kurtosis ranges from platykortic-mesokortic-leptokortic (0.769-1.197).Bivariate plots of mean size against standard deviation (figure 5), and skewness against Standard deviation (figure6) shows that sandstone are predominated with fluvial processes.

Table 3: Univariate pebble morphology parameters and their interpretation

Sample	Univariate parameters	Amount of pebbles (%)						Interpretation
	Form	Equiaxial 33.333%	Oblate 36.66%	Prolate 20%	Bladed 10%			Fluvial
	Mean roundness	Very angular 29%	Angular 25%	Sub-angular 31%	Sub-round 13%	Rounded 20%		Fluvial
	From indices	OPI		MPS		FI		
		(>1.5) 100%	(<1.5) 0%	(>0.65) 74.1%	(<0.65) 25.9%	(>45) 100%	(<45) 0%	Fluvial

Table 4: Percentage Proportion of pebble Shape

Sneed & Folk classes	Count	Percent
Compact	4	2.00
Compact-Platy	7	3.50
Compact-Bladed	32	16.00
Compact-Elongate	25	12.50
Platy	19	9.50
Bladed	68	34.00
Elongate	27	13.50
Very-Platy	1	0.50
Very-Bladed	15	7.50
Very-Elongate	2	1.00

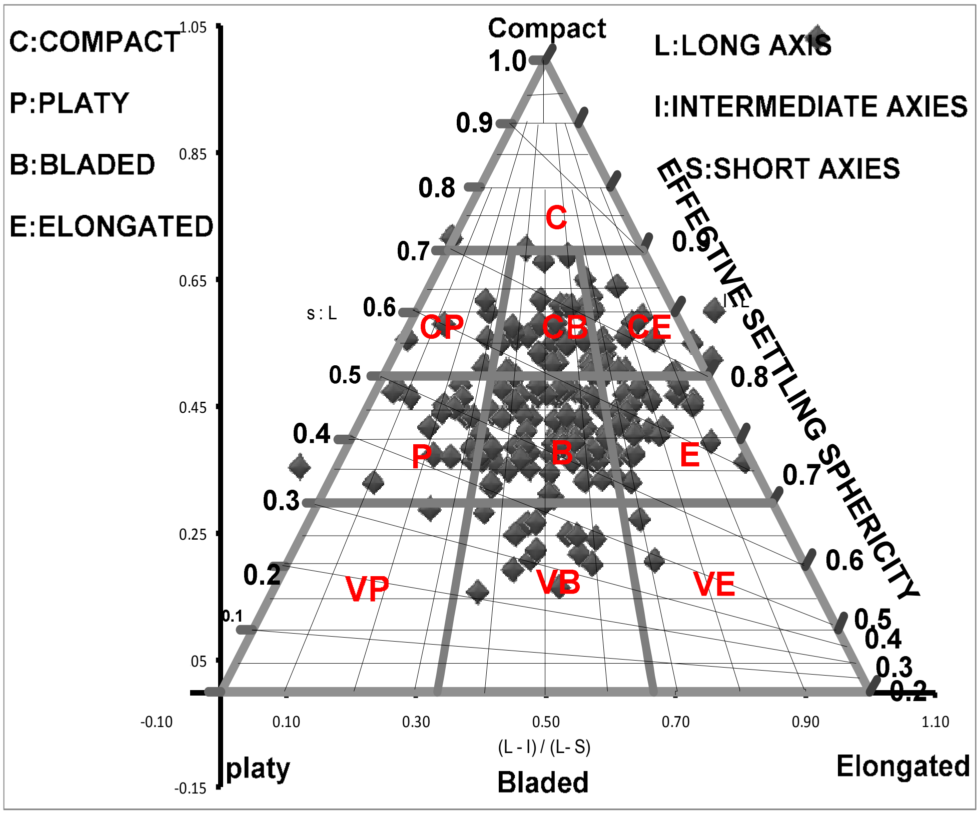

Figure 3: Form shape diagram (after Sneed and Folks, 1958)

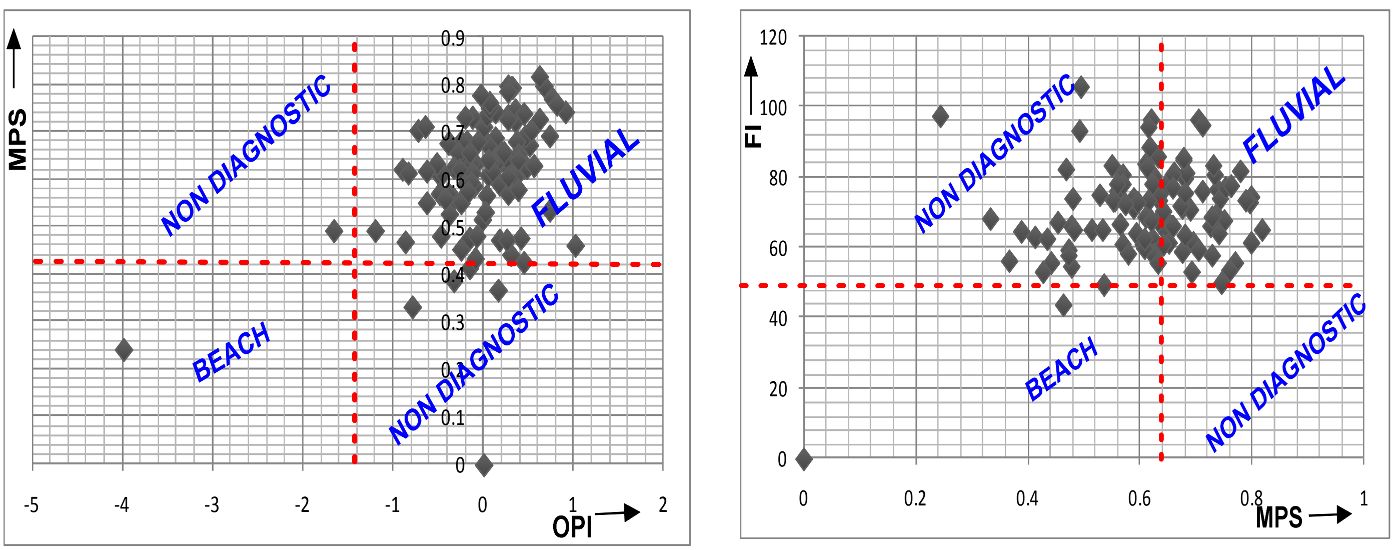

Figure 4: Bivariate plot of MPS vs. OPI.

Table 5: Statistical parameters with their descriptive terminologies for the analyzed samples (after Folk and Ward, 1957)

	SAMPLE IDENTITY:	Unit 1	Unit 2	Unit 3	Unit 4
Folk and ward method (O):	**Mean (M_Z):**	0.608	0.606	0.856	0.786
	Sorting ($\bar{O}_1$):	0.818	0.996	0.953	0.947
	Skewness (SK_I):	-0.005	0.293	0.093	-0.080
	Kurtosis(k_G):	1.034	1.197	0.988	0.769
Folk and ward method (Description)	**Mean:**	Coarse sand	Coarse sand	Coarse sand	Coarse sand
	Sorting:	Moderately sorted	Moderately sorted	Moderately sorted	Moderately sorted
	Skewness:	Symmetrical skewed	Fine- skewed	Symmetrical skewed	Symmetrical skewed
	Kurtosis:	Mesokortic	Leptokortic	Mesokortic	Platykortic

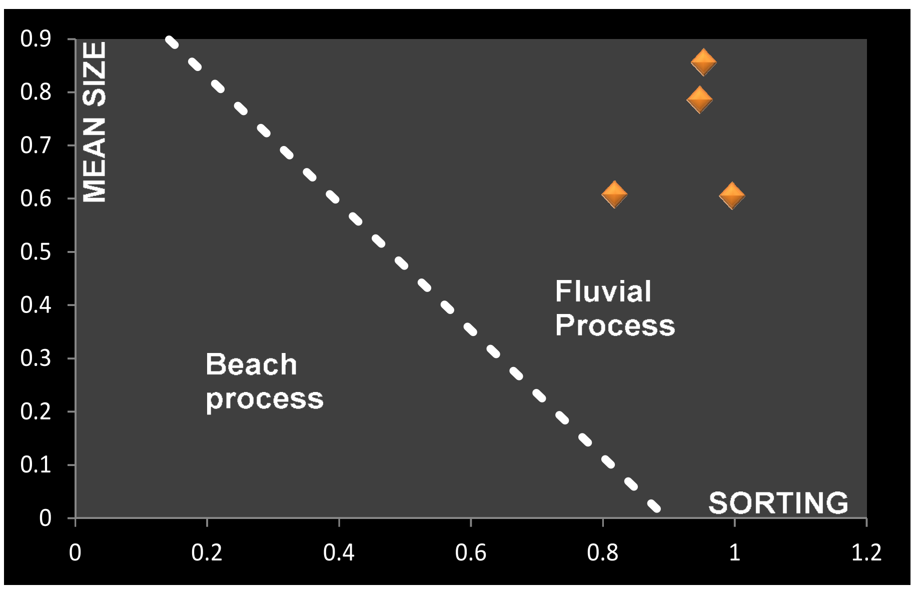

Figure 5: Plot of mean size against standard deviation

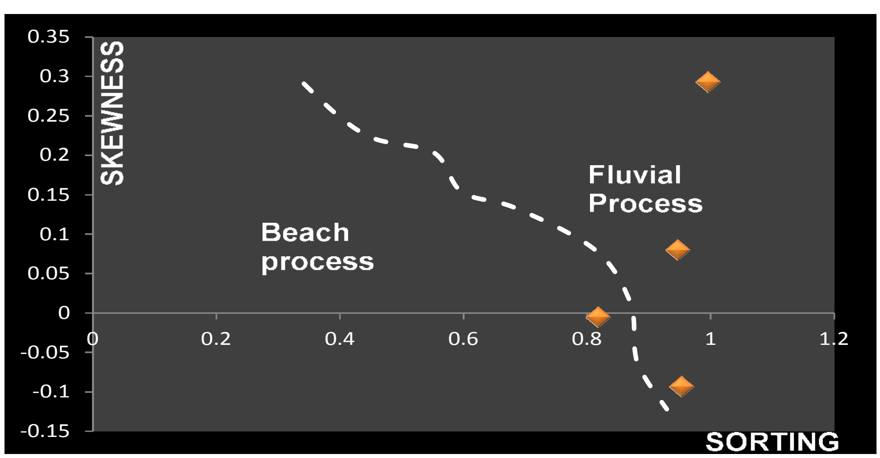

Figure 6: Plot of skewness against standard deviation

SUMMARY AND CONCLUSION

On the basis of pebble form indices, it is evident that the pebbles were shaped in fluvial environment.

Results from sieve analysis show that the sediments is predominated by coarse size sands, moderately sorted, symmetrical skewness and ranges from platykortic-mesokortic-leptokortic kurtosis. These data were used for bivariate plots of skewness against sorting/standard deviation and mean size against standard deviation. All the graphs depict fluvial depositional environment for the sediments.

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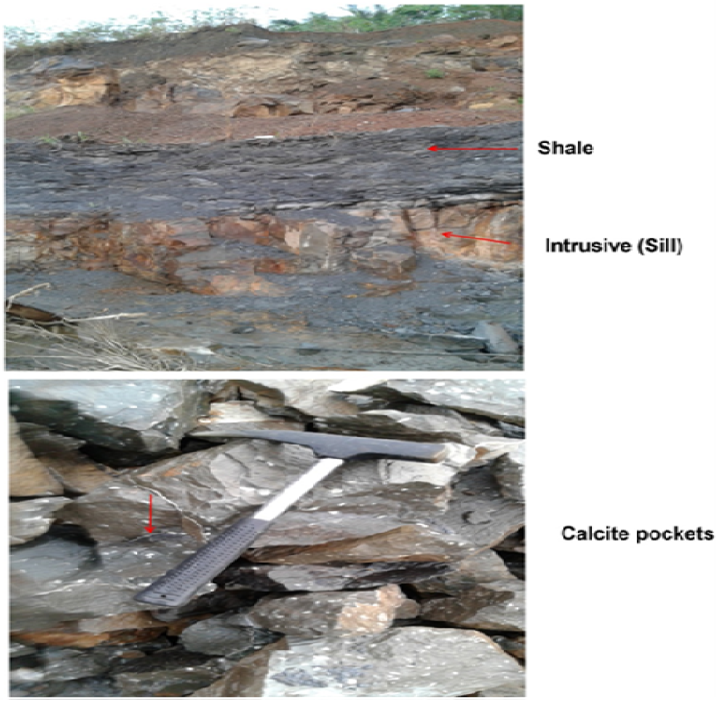

Plate 1: Dark gray baked shale and dolerite intrusion

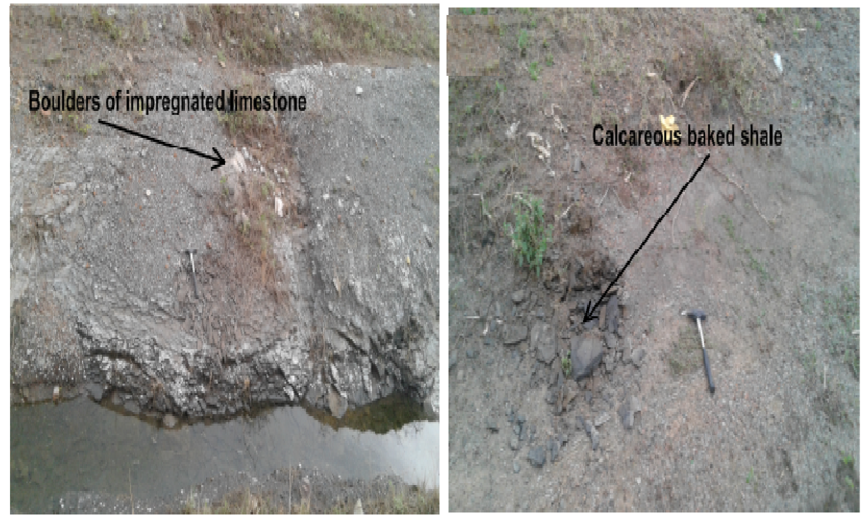

Plate 2: Light gray flaky shale

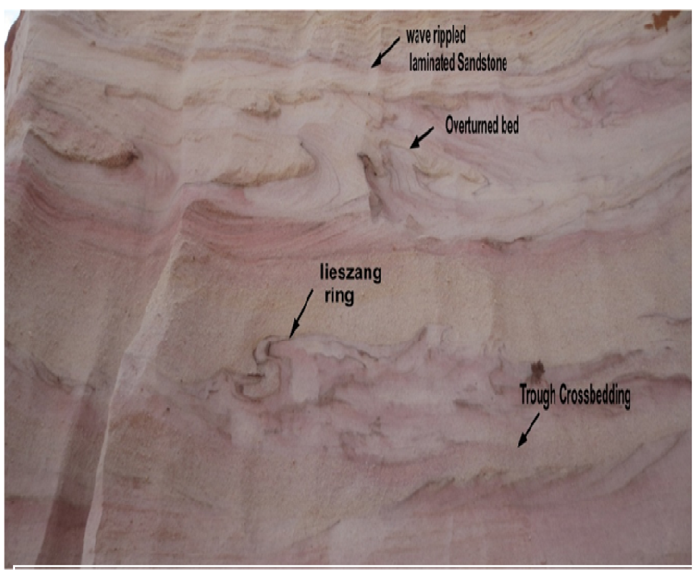

Plate 3: Cross bedded sandstone

Plate 4: Dark bluish shale and mudstone