International Journal of Geology, Earth & Environmental Sciences ISSN: 2277-2081 (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jgee.htm
2014 Vol. 4 (3) September-December, pp. 149-159/Odumodu and Isreal
Research Article

PEBBLE FORM INDICES AS PALEOENVIRONMENTAL RE-CONSTRUCTION TOOLS FOR THE OGWASHI – ASABA FORMATION, SOUTHEASTERN NIGERIA

*** Chukwuemeka Frank Raluchukwu Odumodu[1] and Hope Onyechigoziri Isreal[2]**
[1]*Department of Geology, Anambra State University, Uli*
[2]*Department of Geosciences, Federal University of Technology, Owerri*
**Author for Correspondence*

ABSTRACT
Lithofacies analysis, sand textural analysis and pebble morphometric analysis were carried out so as to decipher the paleodepositional environment of the Ogwashi – Asaba Formation. The lithofacies analysis suggests that the Ogwashi-Asaba Formation consists of two facies association; the lignite facies association and the sandstone facies association. Results of pebble form indices suggest that the pebbles were formed in a fluvial environment. Pebble form indices for the formation have mean values of coefficient of flatness (FR %), sphericity, and oblate – prolate index which ranges from 65.60 to 71.75, 0.788 to 0.834 and – 1.869 to - 0.877 respectively. The mean values of coefficient of flatness, the mean sphericity values and most of the mean oblate – prolate index values support the fluvial origin for the pebbles. Scatter plots of coefficient of flatness against sphericity and sphericity against oblate-prolate index suggests that the pebbles were formed in a fluvial environment. Bivariate plots of sand-textural parameters such as simple skewness against simple standard deviation and second moment skewness against second moment standard deviation also support the fluvial origin of the sandstones. The lithofacies analysis suggests a braided fluvial system characterized by fluvial channel bars, swamps and lagoons, estuaries and floodplain.

Keywords: *Ogwashi-Asaba Formation, Coefficient of Flatness, Oblate-prolate Index, Roundness, Sphericity, Skewness*

INTRODUCTION
The Ogwashi-Asaba Formation (Reyment, 1965) was formerly known as the Lignite Series (Parkinson, 1907 and Simpson, 1954) or Lignite Group (Wilson, 1925; Wilson and Bain, 1928; Du Preez, 1946; Okezie and Onuogu, 1985). The Ogwashi-Asaba Formation consists of sandstones, shales, carbonaceous shales and lignites (Umeji, 2003). The Ogwashi-Asaba Formation has been interpreted as a swamp deposit, mainly on the basis of palynological studies of lignites, shales and clay samples (Jan Du Chene, 1978). Very little attention has been given to the sandstone facies of the Ogwashi-Asaba Formation. The sandstones of the Ogwashi-Asaba Formation contain an abundant quantity of pebbles. The study of pebble form indices such as maximum projection sphericity, coefficient of flatness, oblate prolate index and roundness have continued to be relied upon for the diagnosis of paleodepositional environments of several sedimentary basins of the world (Sames, 1966; Stratten, 1974; Nwajide and Hoque, 1982 and Els, 1988). The Ogwashi-Asaba Formation is very rich in lignites which are potential sources of energy that can be used in providing power to some industries. Consequently knowledge of the depositional environment and lithofacies distribution will be useful in this regard. This study is therefore focused on the reconstruction of the paleodepositional environment of the Ogwashi-Asaba Formation in Oraifite, Nnewi and Ozubulu areas, using pebble morphometric data. The results are corroborated with other evidence from sand textural parameters and sedimentary facies studies.

Study Area and Geologic Background
The study area is delimited by latitudes 5°54'N and 6°10'N and longitudes 6°47'E and 7°00'E (Figure 1).
The Ogwashi-Asaba Formation outcrops in a belt that stretches from Oba, Nnewi, Oraifite, Ozubulu, Ukpor, and Ihiala through Orlu to Umuahia in Southeastern Nigeria. The Ogwashi – Asaba Formation unconformably overlies the Ameki Group. Its age is approximately Oligocene to Miocene (Reyment,

1965). The Ogwashi-Asaba Formation consists of clays, sands, grits and seams of lignite alternating with grit clays (Du Preez, 1946).

MATERIALS AND METHODS

Several lithologic sections of the Ogwashi-Asaba Formation were logged systematically in the study area so as to collect sedimentological, ichnological and paleocurrent data.Quartzose pebbles collected from the outcrops were washed and numbered. Broken pebbles were excluded. The selection was based on its isotropic constitution and high resistivity to wear. The three (Long, L; Intermediate, I; and Short, S) axis of the pebbles were measured using the vernier calipers, based on (Krumbein, 1941; Sneed and Folk; 1958 and Dobkins and Folk, 1970) method. Roundness of each set of pebbles was estimated using Sames (1966) image set. This method were also used by (Sneed and Folk, 1958; Nwajide and Hoque, 1982; Odumodu and Ephraim, 2007a, 2007b) in some pebble morphometric studies. The morphometric parameters were calculated using values obtained from the measurements of three axes. The measured values were loaded into an excel spreadsheet. The following form indices were calculated using the following formulas (Table 1).

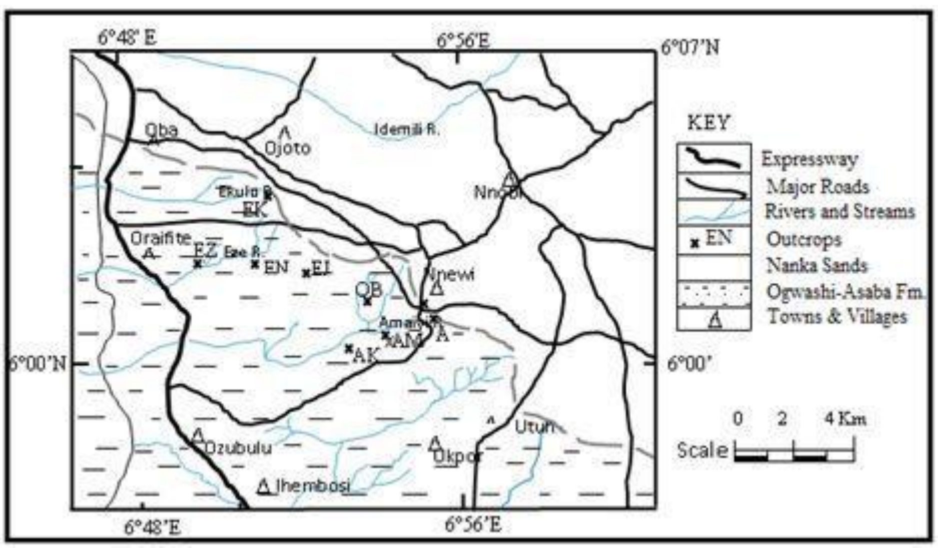

Figure 1: Geological map of the study area showing the studied outcrop locations

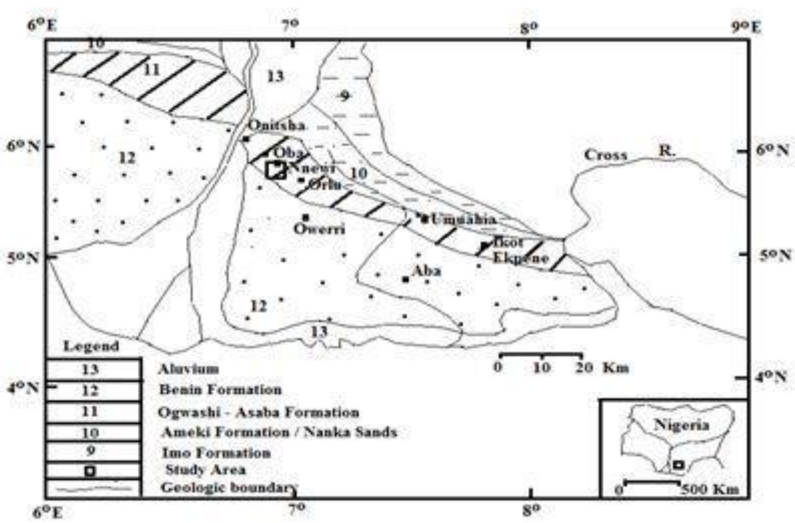

Figure 2: Geological map of the Tertiary Anambra Basin

Table 1: Pebble Morphometric Indices used for the study

Morphometric Indices	Formula	Author
Flatness ratio	S/L	
Coefficient of flatness	S/L * 100	Lutig (1962)
Elongation ratio	I/L	Lutig (1962)
Maximum projection sphericity	$\left(\frac{S^2}{LI}\right)^{1/3}$	Sneed and Folk (1958)
Oblate – prolate index	$10\left[\frac{L-I}{L-S}-0.50\right]S/L$	Dobkins and Folk (1970)
Roundness (%)	Visual Estimation	Sames (1966)

Table 2: Statistical parameters of sandstones used in this study

Statistical parameters	Formula	Author
Mean (1st Moment)	$x = \sum fm\varphi / 100$	Friedman (1967, 1979)
Standard Deviation or sorting (2nd Moment	$\sigma = \sqrt{\sum f(m\varphi - x)^2 / 100}$	"
Skewness (3rd Moment)	$\alpha_3 = \sum f(m\varphi - x)^3 / 100\sigma^3$	"
Kurtosis (4th Moment)	$\sum f(m\varphi - x)^4 / 100\sigma^4$	"
Graphic Mean	$1/3(\varphi16 + \varphi50 + \varphi84)$	Folk, 1974
Inclusive (graphic) skewness	$\frac{1}{2}\frac{\phi16+\phi84-2\phi50}{\phi84-\phi16} + \frac{\phi5+\phi95-2\phi50}{\phi95-\phi5}$	"
Inclusive (graphic) standard deviation	$\sigma_1 = \varphi84 - \varphi16 / 4 + \varphi95 - \varphi5 / 6.6$	"

Means and standard deviations of morphometric indices were calculated for each set of pebbles, using known statistical formula as given below

$$Mean = \bar{x} = \frac{\sum x}{n} \quad (1)$$

$$S.D. = \sigma(n-1) = \frac{\sum x^2 - \frac{(\sum x)^2}{n}}{n-1} \quad (2)$$

Where,
x = the deviations of each of the numbers *Xj* from the mean,
n = the number of samples in a population and
σ = the standard deviation of a population

Textural Parameters

Textural parameters of sand-size samples from the Ogwashi – Asaba Formation were calculated from sieve data obtained by using Folk (1974) conventional sieving procedure. After carefully disaggregating the samples, 50 grams of each sample was sieved using one phi sieve interval. The sieving time used is 15 minutes. The critical percentiles (5φ, 16 φ, 25 φ, 50 φ, 84 φ and 95 φ) were determined using the plotted cumulative probability curves. Textural parameters calculated include graphic mean (M_z), inclusive graphic skewness (S_k), and inclusive graphic standard deviation (σ_o). The following formulae (see Table 2) were used in the calculation. These parameters were used in bivariate plots for paleoenvironmental inferences.

RESULTS AND DISCUSSION

Sedimentary Facies

Several sections of the Ogwashi – Asaba Formation were systematically logged at Ekulo stream (Lat.: N6°02′34.16″ Long.: E6°50′45.78″), Eze stream, Enem spring (Lat.: N6°02′02.64″; Long.: E6°50′28.38″) and Ejighioku spring (Lat.: N6°00′02.75″; Long.: E6°53′ 38.44″) all in Oraifite town, and at Amaiyi spring (Lat.: N6°00′55.65″; Long.: E6°53′47.60″) , Obiakoloma spring (Lat.: N6°00′54.77; Long.:

International Journal of Geology, Earth & Environmental Sciences ISSN: 2277-2081 (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jgee.htm
2014 Vol. 4 (3) September-December, pp. 149-159/Odumodu and Isreal
Research Article

E6°53.43) , Mkpazi spring (Lat.: N 6°00′26; Long.: E 6°53′43, Ezeakamiri Umudim, and behind Anthill block industry (Lat.: N6°00′03.25″; Long.: E6°55′14.60″), all in Nnewi (Figures 3 & 4). In the study area, the lithology consists mainly of coarsening upward successions of clays, lignite seams, carbonaceous shales, sandstone shale heteroliths, fine grained sandstone and coarse grained pebbly sandstones (Figures 3 & 4). The lithologic logs shows that the formation is made up of seven recurring sedimentary facies which can be grouped together to form two facies association. The two facies associations are thus;

Lignite Facies Association: This is the basal facies association in the study area. It consists of light gray to reddish brown clays, dark brown lignites, bluish to grayish colored carbonaceous shales and heteroliths of fine sandstone and shales. A maximum of two subfacies are exposed at each of the studied sections (Figure 3). Sedimentary structures present include the thin parallel lamination observed in the carbonaceous shales and heterolithic units of fine sandstone and shales. The clays are interpreted as floodplain deposits, while the carbonaceous shales and lignites are suggestive of swampy and marshy environments.

Sandstone Facies Association: This facies association consists of fine, medium and coarse grained sandstones. The fine grained sandstones overlie the lignite facies association. The fine – medium grained sandstones are whitish to yellowish in color and have very few pebbles scattered in the matrix. The coarse grained sandstones consist of coarse and pebbly sandstones. The sandstones facies association is massive and planar cross-bedded in places. The fine – medium grained sandstones are suggestive of fluvial channel bars.

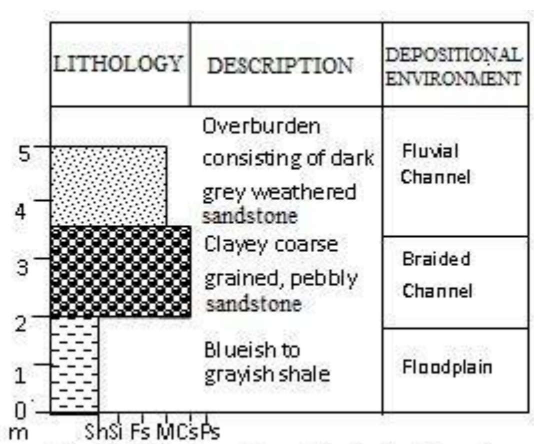

Figure 3A: Litholog of Ogwashi-Asaba formation at Ekulo stream in oraifite

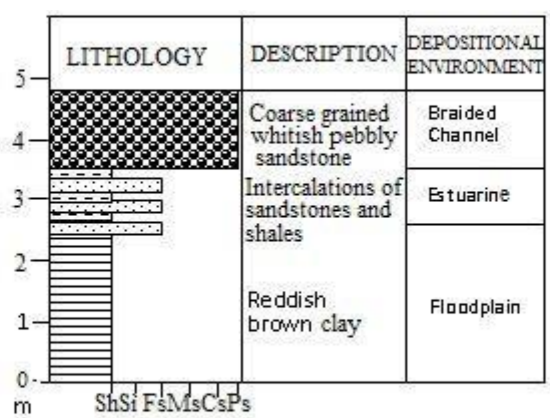

Figure 3B: Litholog of Ogwashi-Asaba formation at Eze stream in oraifite

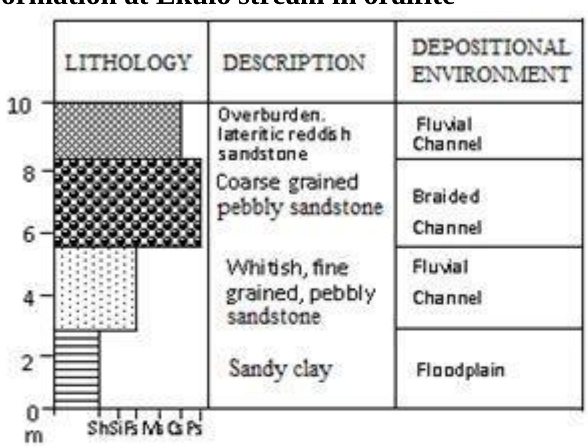

Figure 3C: Litholog of Ogwashi-Asaba formation at Ezeaka Umudim Nnewi

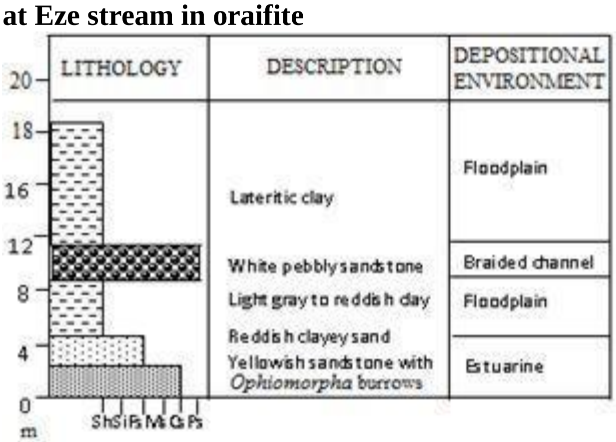

Figure 3D: Litholog of Ogwashi-Asaba formation at a gully site at oraifite

Research Article

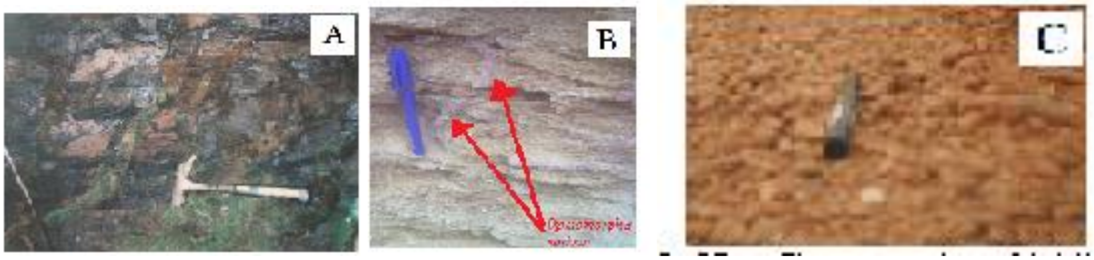

Figure 3E: Photographs of (a) lignite, (b) Ophiomorphaissp (c) pebbles from the Ogwashi-Asaba Formation

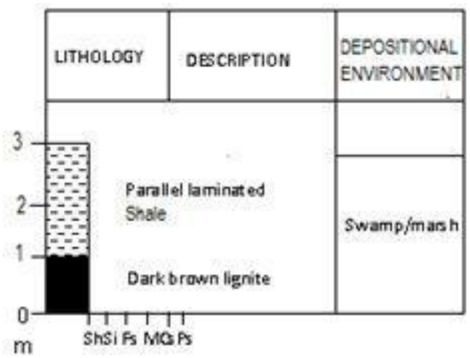

Figure 4A: Lithology of Ogwashi-Asaba Formation at Ejighioku stream, at Amakom lfite-Oraifite

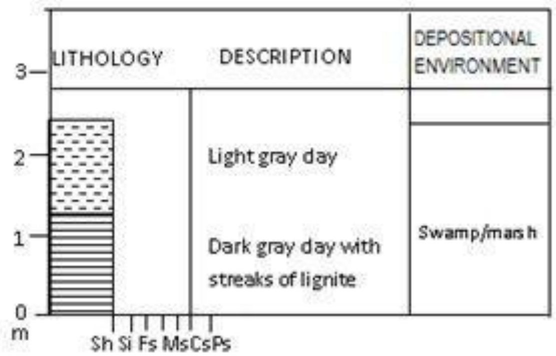

Figure 4B: Lithology of Ogwashi- Asaba Formation at Mkpazi Akamiri, Umudim Nnewi

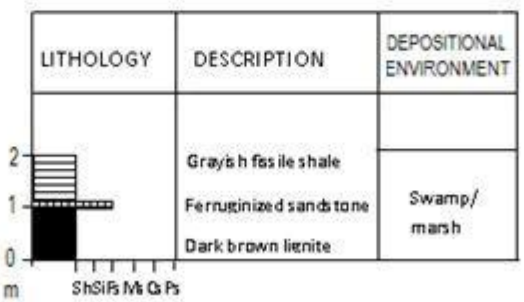

Figure 4C: Litholog of Ogwashi – Asaba formation at Amaiyi spring, Umudim Nnewi

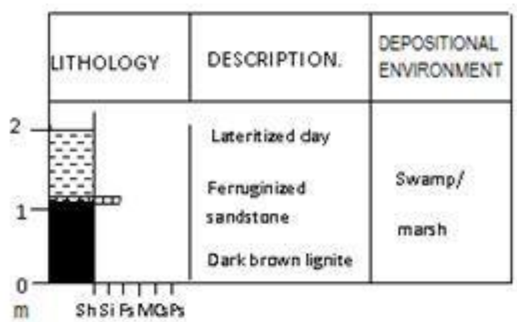

Figure 4D: Litholog of Ogwashi – Asaba formation at Obiakoloma stream, Okpunoeze Umudim Nnewi

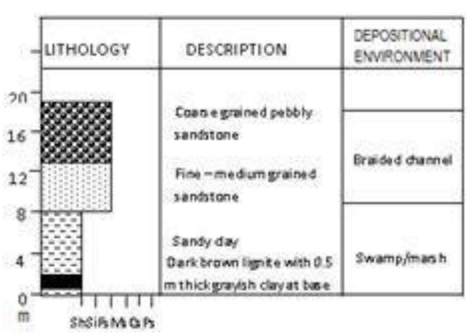

Figure 4E: Litholog of Ogwashi – Asaba formation at Enem stream Amawom lfite-oraifite

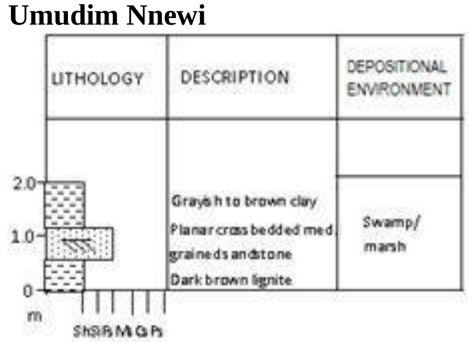

Figure 4F: Litholog of Ogwashi – Asaba formation behind Anthill block industry along Okigwe road

Table 3 : Pebble Form Indices for the Ogwashi - Asaba Formation pebbles

		Coefficient of flatness		Sphericity		Oblate -Prolate Index	
	n	×	**s**	×	**s**	×	**s**
(A) Combined form Data for pebbles larger than – 2.0 phi							
Locality							
1. Ekulo	30	67.59	8.79	0.605	0.066	- 1.492	3.166
2. Eze	30	68.25	8.55	0.808	0.070	- 1.469	2.946
3. Umudim	30	71.75	9.97	0.834	0.072	- 0.877	2.715
4 Amaiyi	30	65.60	13.05	0.788	0.100	- 1.869	4.029
(B) Form Data for Ekulo Stream							
Size (Phi Units)							
> - 3.0	1	71.43	-	0.870	-	4.000	-
> - 3.5	6	68.21	10.25	0.835	0.049	1.427	3.282
> - 4.0	16	69.17	8.51	0.812	0.066	-1.954	2.430
> - 4.5	7	64.11	8.80	0.768	0.068	-3.467	1.794
(C) Form Data for Eze Stream							
> - 3.5	1	75.28	-	0.865	-	0.029	-
> - 4.0	19	68.21	8.28	0.810	0.063	- 1.344	2.539
> - 4.5	10	67.62	9.62	0.802	0.085	- 1.853	3.659
(D) Form Data for Umudim Nnewi							
> - 4.0	19	72.23	10.39	0.843	0.070	- 0.142	2.237
> - 4.5	10	71.87	9.61	0.829	0.073	- 1.720	2.793
> - 5.0	1	67.62	-	0.733	-	- 6.424	-
(E) Form Data for Amaiyi Stream, Nnewi							
> - 3.5	1	39.78	-	0.687	-	8.846	-
> - 4.0	11	69.49	9.66	0.828	0.068	0.049	3.402
> - 4.5	17	64.07	13.81	0.765	0.113	- 3.685	2.945
> - 5.0	1	74.58	-	0.844	-	- 2.831	-

Pebble Morphometric Study

The computed form data and roundness data are given in Tables 3 and 4 respectively. Pebble morphometric results (Table 3) shows that the mean values of maximum projection sphericity range from 0.605 to 0.834 and mean values of oblate – prolate index range from -1.869 to – 0.877. The mean values of the coefficient of flatness range from 65.60 to 71.75. The form indices are represented graphically by plots of coefficient of flatness against sphericity (Figure 4) (Stratten, 1974), and plots of sphericity versus oblate – prolate index (Figure 5) (Dobkins and Folk, 1970).

Sieve Analysis

The results of the textural study of the sandstone samples are given in Table 5. Sand textural parameters such as graphic mean, inclusive graphic skewness and inclusive standard deviation, moment mean grain size, moment standard deviation and moment skewness were obtained so as to use the standard plots of (Friedman, 1967 and 1979) to decipher the paleodepositional environment of the Ogwashi-Asaba Formation.

Table 4 : Roundness indices for the pebbles from the Ogwashi – Asaba Formation

(A) Combined roundness indices for pebbles of different sizes for the five locations studied

Roundness			
Location	**n**	×	**s**
1	30	0.830	0.136
2	30	0.757	0.155
3	30	0.808	0.134
4	30	0.780	0.150

(B) Roundness indices for different fractions at the five locations studied

	1			2			3			4		
Phi Class	n	×	s	n	×	s	n	×	s	n	×	s
> - 3.0	1	0.960	-	-	-	-				-	-	-
> - 3.5	6	0.960	0.013	1	0.690	-				1	0.840	-
> - 4.0	16	0.783	0.145	19	0.761	0.145	19	0.784	0.122	11	0.772	0.156
> - 4.5	7	0.818	0.101	10	0.758	0.185	10	0.840	0.151	17	0.784	0.158
> - 5.0	-	-	-	-	-	-	1	0.960	-	1	0.740	-

(C) Combined roundness indices of all pebbles for the different size fractions

Roundness			
Phi Class	n	×	s
> - 3.0	1	0.960	-
> - 3.5	8	0.911	0.013
> - 4.0	65	0.775	0.140
> - 4.5	44	0.796	0.153
> - 5.0	2	0.850	-

× *is ths mean roundness; s is the standard deviation of the observations, n = number of samples;*

Research Article

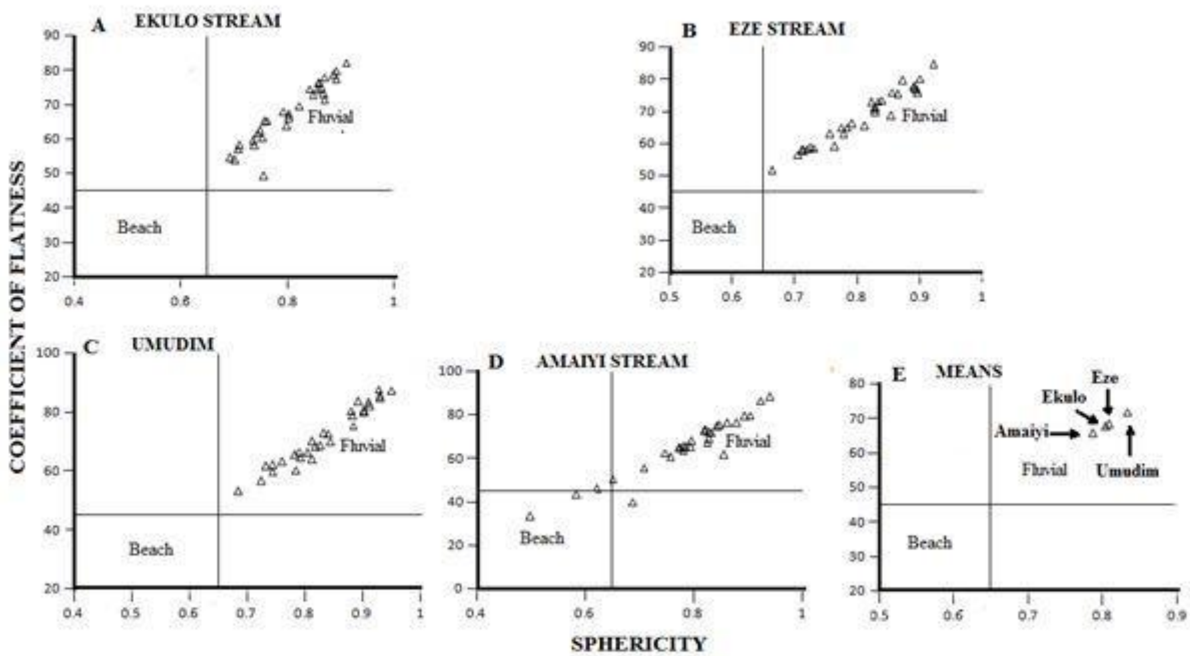

Figure 5: Graphical plots of coefficients of flatness and sphericity for individual pebbles for the locations studied (A to D) and the means of these (E). Broken lines on the diagrams indicate the empirical lower limits of 0.65 for sphericity and 45 for coefficient of flatness of fluvial pebbles, determined by Stratten (1974)

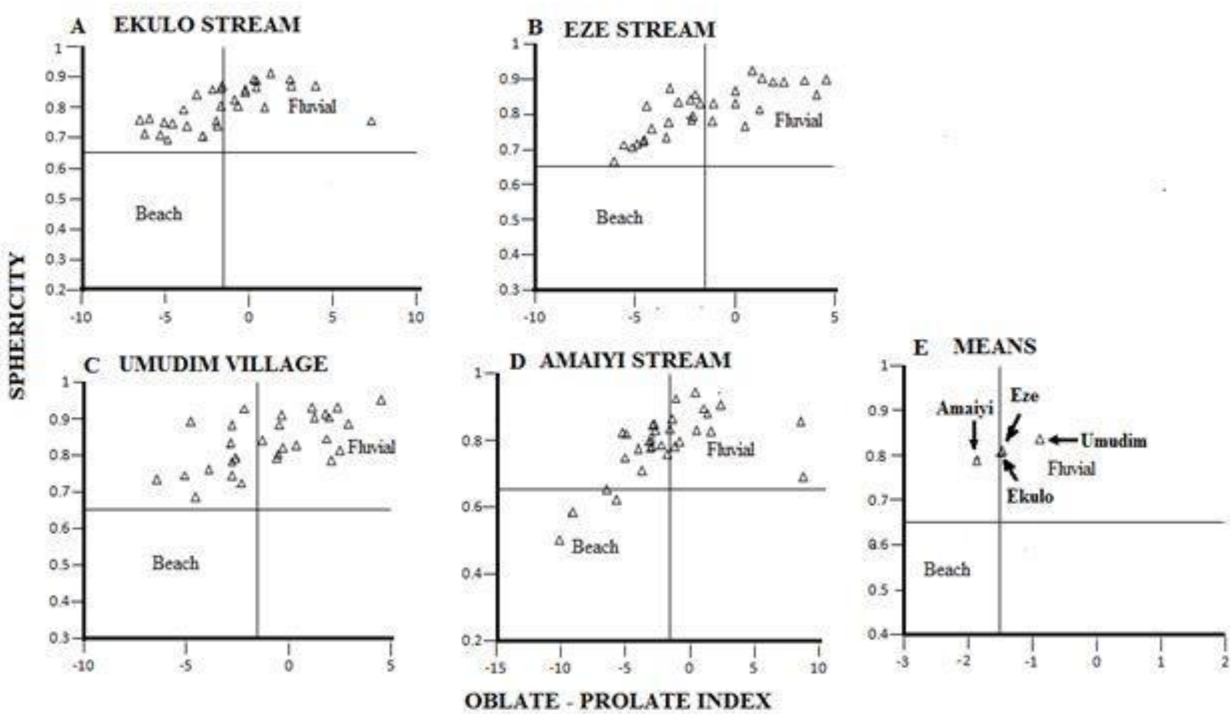

Figure 6: Graphical plots of Sphericity against oblate-prolate index for individual pebbles for the four locations studied (A to D) and the means of these (E). Broken lines on the diagrams indicate the empirical lower limits of – 1.5 for oblate-prolate index and 0.65 for for sphericity of fluvial pebbles, determined by Strattem (1974)

Research Article

Table 5a: Seive Analysis Result (Graphic method) for the Ogwashi – Asaba Formation

Sandstone Sample No	Mean (Mz)	Standard Deviation (σ_o)	Skewness (S_K)	Kurtosis (K_G)	INTERPRETATION / REMARKS
01	1.10	0.85	- 0.03	- 1.23	m,ms, ns,L.
02	1.25	0.74	0.19	0.96	m, ms, fs, M.
03	1.37	0.70	0.14	0.94	m , mws, fs, M.
04	1.37	1.20	0.09	1.04	m, ps, ns, M.
05	0.73	0.77	3.84	0.36	C, mws, vps, VP
06	0.19	1.59	3.68	0.94	C, ps, vps, M
07	0.45	0.73	- 0.54	0.68	C, ms, vns. P
08	1.37	0.70	0.14	0.94	m, ms, ps, M

Table 5b: Seive Analysis Result (Moment Measures) for the Ogwashi – Asaba Formation

Sandstone Sample No	Mean Grain Size 1st Moment	Standard Deviation or Sorting 2nd Moment	Skewness 3rd Moment	Mean Cubed Deviation	Interpretation /remarks
01	0.63	0.54	1.02	1.91	c, mws, vfs.
02	0.52	0.27	0.13	0.03	c, vws, fs.
03	0.52	0.33	0.35	0.13	c, vws, vfs.
04	0.57	0.48	0.48	0.45	c, ws, vfs.
05	0.54	0.87	0.71	2.21	C, ms, vfs
06	0.97	0.26	0.02	0.01	C, ms,ns
07	0.54	0.37	0.92	0.57	C, ws, vfs
08	1.29	0.71	0.32	0.70	C, ms, fs

Key: *m = medium grained, c = coarse grained, ws = well sorted, vws = very well sorted, mws = moderately well sorted, vfs = very fine skewed, fs = fine skewed.*

Form Indices

Pebble morphometric parameters have shown to be very useful in paleoenvironmental interpretation (Sames, 1966; Els, 1988). Some limits have been established to distinguish different depositional environments, using pebble form indices. The lower index limits of 45 and 0.65 for coefficient of flatness index and mean sphericity respectively were established by Sames (1966) for fluvial pebbles. However the maximum index limits for beach pebbles do not exceed these values. A lower index limit of 0.66 for the mean sphericity of river pebbles was also suggested by Dobkins and Folk (1970). Dobkins and Folk (1970) also indicated that the mean oblate – prolate index for fluvial pebbles are above – 1.5, while beach pebbles show lower values. Thus, the lower index limits for fluvial pebbles are; sphericity = 0.65 / 0.66, coefficient of flatness = 45, and oblate – prolate index = -1.5.

The calculated form indices are listed in Table 3 while the roundness data is in Table 4. Table 3a shows that the means of two of the three indices (sphericity and coefficient of flatness) are above the lower limits for fluvial pebbles, for all the locations studied. Table 3a also shows that the means for the oblate – prolate index are above the limits for fluvial pebbles for three locations, while one of the means is below the value. Plots of coefficient of flatness against sphericity show that pebbles from all locations studied, lie in the fluvial field of (Stratten, 1974) (Figure 5a – e). All the means, too, plot likewise (Figure 5f). The mean values of maximum sphericity of the pebbles range from 0.605 to 0.834. The mean values of coefficient of flatness obtained for the pebbles in this study range from 65.60 to 71.75. These values are within the limits suggested by Stratten (1974) as required for river pebbles. Plots of sphericity against oblate – prolate index (Figure 6), following Dobkins and Folk (1970) method show that most of the pebbles lie in the fluvial field. The oblate – prolate index calculated for pebbles in this study range from –

1.869 to - 0.877. One of the values fall below the minimum threshold value of – 1.5 required for pebbles formed in fluvial environments, while the other three values fall above the threshold value.
Dobkins and Folk (1970) suggested the values of 0.375 and 0.508 as the mean value of roundness for river and beach environments. In this study, the Krumbein (1941) visual method was used in estimating roundness. Thus results of roundness from this study were not compared with that of Dobkins and Folk (1970). The roundness values from this result ranges from 0.757 ± 0.155 to 0.830 ± 0.136. Lutig (1962) suggested that roundness increases in a downstream direction from a mean value of 0.542 upstream, 0.618 midstream and 0.633 in the downstream reaches. Thus, the roundness values of pebbles in this study suggest a very long provenance source.

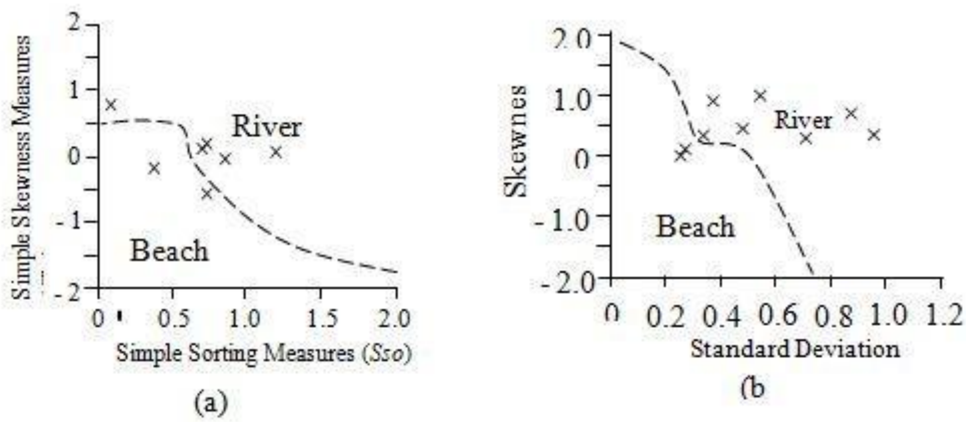

Figure 7: Bivariate plot of skewness against standard Deviation (After Friedman 1967 & Moiola and Weiser, 1968 and (b) Bivariate plot of 3rd moment skewness against Standard Deviation (After Moiola and Weiser, 1968

Textural Parameters
Bivariate plots of Simple Skewness measures (S_k) against Simple Standard Deviation or sorting (S_o) (Figure 7a) and 3rd moment skewness versus 2nd moment standard deviation (sorting) (Figure 7b) for sandstones of the Ogwashi-Asaba Formation supports a fluvial origin for the sandstones. An evaluation of the sieve analysis results in Table 5a shows that the sandstones of the Ogwashi-Asaba Formation have grain sizes ranging from 0.19ϕ to 1.37ϕ with a total average of 1.03ϕ (medium sand). The result of standard deviation for the sandstones of the Ogwashi-Asaba Formation ranges from 0.10 – 1.20 which suggests that the sands are well sorted to poorly sorted.

Conclusion
On the basis of the mean sphericities and coefficient of flatness obtained for the five sets of pebbles of the Ogwashi-Asaba Formation, it is evident that the pebbles were shaped in fluvial environment. This finding complements an already convincing set of criteria indicating a fluvial depositional environment for the formation. Plots of coefficient of flatness against sphericity, and sphericity against oblate – prolate index indicate that the pebbles were formed in a fluvial setting. Mean roundness indices computed for the pebbles are suggestive of a long distance of transport. The sedimentary facies analysis is indicative of a braided fluvial system characterized by channel bars, swamps and marshlands, estuaries and floodplain.

ACKNOWLEDGMENT
This study has been carried out in the Department of Geology of Anambra State University and Department of Geosciences of Federal University of Technology, Owerri. The authors wish to thank some anonymous reviewers for reviewing this work and for their constructive criticisms which greatly improved this paper.

REFERENCES

Dobkins JE and Folk RL (1970). Shape development of Tahiti- Nui: *Journal of Sedimentary Petrology* **40** 1167 – 1203.

Du Preez JW (1946). A further investigation on the lignites of Onitsha Province. *Annals of Reproductive Geological Society of Nigeria* 25 – 26.

Els BG (1988). Pebble Morphology of an ancient conglomerate: The Middelvlei Gold Placer, Witwatersrand, South Africa. *Journal of Sedimentary Petrology* **58**(5) 894 – 901.

Folk RL (1974). *Petrology of Sedimentary rocks.* Hemphil Publishing Company, Austin Texas 182.

Friedman GM (1967). Dynamic processes and statistical parameters compared for size frequency distribution of beach and river sands. *Journal of Sedimentary Petrology* **37** 327 – 354.

Friedman GM (1979). Differences in size distributions of populations of particles among sands of various origins. *Sedimentology* **26** 3 – 32.

Jan Du Chene RE, Onyike MS and Sowumi MA (1978). Some new Eocene pollen of the Ogwashi-Asaba Formation, southeastern Nigeria. *Revista Espanola de Micropaleontologia* **10**(2) 285 – 322.

Krumbein, WC (1941). Measurements and geological significance of shape and roundness of sedimentary particles. *Journal of Sedimentary Petrology* **11** 64 – 72.

Lutig G (1962). The shape of pebbles in the continental, fluviatile and marine facies. *International Association of Scientific Hydrology Publication* **59** 253 – 258.

Moiola RJ and Weiser D (1968). Textural parameters; An Evaluation. *Journal of Sedimentary Petrology* **33** 45 – 53.

Nwajide CS and Hoque M (1982). Pebble Morphometry as an aid in environmental diagnosis: an example from the Middle Benue Trough, *Nigerian Journal of Mining and Geology* **19**(1) 114 – 120.

Odumodu CFR and Ephraim BE (2007a). Paleoenvironmental analysis of the Nsukka Formation, using pebble morphology. *Natural and Applied Sciences Journal* **8**(1) 73 – 84.

Odumodu CFR and Ephraim BE (2007b). Pebble Morphometry as an indicator of the depositional environment of the Ajali Sandstone. *Natural and Applied Sciences Journal* **8**(2) 132 – 143.

Okezie CN and Onuogu SA (1985). The lignite's of Southeastern Nigeria. *Geological Survey of Nigeria Occupation Paper* **10** 28.

Parkinson (1907). The post-Cretaceous stratigraphy of Southern Nigeria. *Quarterly Journal of the Geological Society of London* **63** 311 – 320.

Reyment, R.A (1965). *Aspects of the Geology of Nigeria* (Ibadan University Press) Nigeria 145.

Sames CW (1966). Morphometric data of some recent pebble associations and their application to ancient deposits. *Journal of Sedimentary Petrology* **36** 126 – 142.

Simpson (1954). The Nigerian coalfield; the geology of parts of Onitsha, Owerri, and Benue provinces. *Geological Survey of Nigeria Bulletin* **24** 1 – 85.

Sneed ED and Folk RE (1958). Pebbles in the lower Colorado River, Texas: a study of particle morphogenesis. *Journal of Geology* **66** 114 – 150.

Stratten T (1974). Notes on the application of shape parameters to differentiate between beach and river deposits in Southern Africa. *Transactions of Geological Society of South Africa* **77** 59 – 64.

Umeji, OP (2003). Palynological data from the road section at Ogbunike toll gate, Onitsha, Southeastern *Nigerian Journal of Mining and Geology* **39**(2) 95 – 102.

Wilson RC (1925). The Geology of the Eastern railway. *Geological Survey of Nigeria Bulletin* **1** 1 – 95.

Wilson RC and Bain ADN (1928). The Nigerian coalfield (section II) parts of Onitsha and Owerri provinces. *Geological Survey of Nigeria Bulletin* **12** 1 – 5.