ISSN 1119-9296

Natural and Applied Sciences Journal Vol. 11 No. 1
Available online at www.naasjournal-ng.org

LITHOFACIES ANALYSIS AND TEXTURAL CHARACTERISTICS OF EOCENE NANKA SAND, SOUTHEASTERN NIGERIA

Onuigbo, E.N., Ajaegwu, N.E., Obiadi, I.I., and Okolo, C.M.
Department of Geological Sciences, Nnamdi Azikiwe University, Awka.

Abstract

Granulometric and lithofacies analysis were employed in the study of Nanka Sand in order to determine the environment of deposition of the sediments. Granulometric analysis of the sands shows that the sands are predominantly fine skewed, leptokurtic and moderately sorted. The sands plot in the river compartments on the environmental discrimination diagrams of Stewart (1958), Friedman (1961) and Moiola and Weiser (1968). Three lithofacies were deduced: wave rippled fine sand facies, cross bedded fine sand facies and heterolithic facies. Sedimentary structures include mud flasers, planar and trough cross beds, wavy and parallel laminations, ripples, tidal bundles, mud drape, reactivation surfaces, concretions and burrows, indicative of tidally influenced environment. The plots of thickness vs serial positions of the planar cross beds suggest tidal fluctuation (rhythmic) while the rose diagram shows bimodal- bipolar paleocurrent flow which were from Westerly and Northeastern direction.

Introduction

Nanka Sand is part of the sediments deposited in the Anambra Basin of Southeastern Nigeria. The Anambra Basin is a Cretaceous sedimentary domain partly sandwiched between the southeastern Benue Trough below the Niger Delta Basin above. It evolved following the subsidence of a platform in the Southern Benue Trough, concurrent with the lateral translocation of the depocentres during the Santonian thermotectonic event that folded and elevated the Abakaliki region (Reyment, 1965; Murat, 1972; Wright et al, 1985 and Nwajide, 2005). Nanka Sand and its lateral equivalents formed the Ameki Group.

The formation consists of fine to coarse sandstones with abundant intercalations of calcareous shale and thin shally limestone below, and of loose cross bedded white or yellow sandstone with bands of fine grained sandstone and sandy clay on top. Nanka Sand is of Eocene age and was deposited in an inter- tidal relatively high energy marine environment (Nwajide and Hoque, 1979 and Nwajide, 1980).

ISSN 1119-9296

Natural and Applied Sciences Journal Vol. 11 No. 1
Available online at www.naasjournal-ng.org

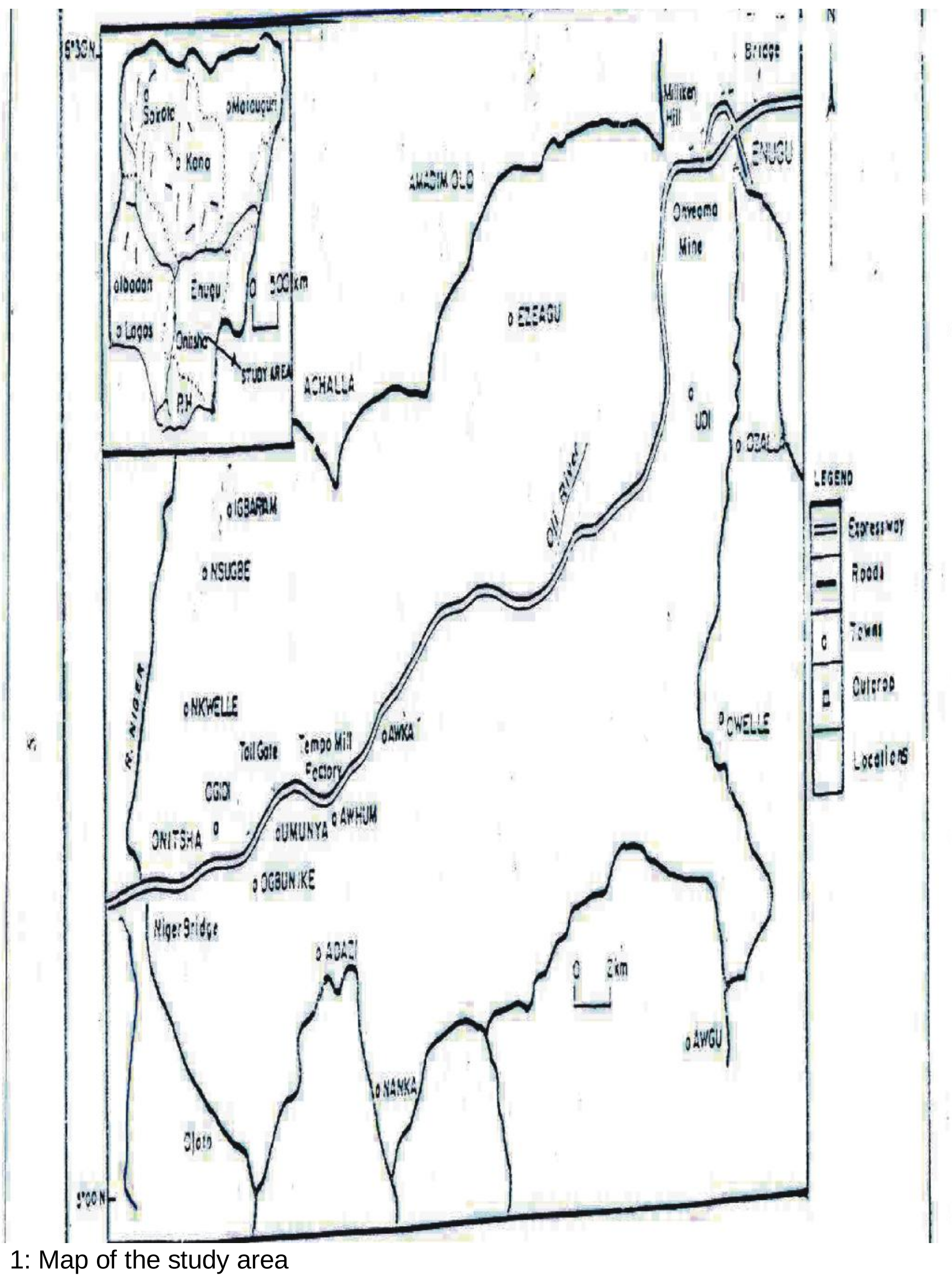

Fig. 1: Map of the study area

ISSN 1119-9296

ISSN 1119-9296

Natural and Applied Sciences Journal Vol. 11 No. 1
Available online at www.naasjournal-ng.org

Methodology

The sedimentological methods employed in this research work include the lithofacies, paleocurrent and grain size analyses. Syatematic description of the outcrops of the formation at Umunya and Ikenga Village, Awka was carried out. The lithology, sedimentary structures, fossils and paleocurrent pattern were properly studied. Textural features of the sand grains were checked using hand- lens and the graph log of the outcrop at Umunya was produced. Field sketches and photographs were useful in illustrating structures. Samples of sands were collected from exposures at both Umunya and Ikenga, Awka for sieve analysis.

Paleocurrent analysis involves using sedimentary structures to determine the direction of flow or orientation of flow. Many sedimentary structures yield directional data that show the direction ancient current flowed at the time of deposition. The paleocurrent data were gathered in the Umunya area by measuring the orientation of seventy- seven cross beds with the aid of compass clinometer (Table 2a) also the thickness and serial positions of one hundred and twenty- three cross beds were taken from the lower sandstone unit (tables 1a and b). The plots of the thickness vs serial positions for the cross beds 1 & 2 (figs.4a and b) as well as the rose diagram of the azimuth of the seventy- seven cross beds (fig.5) were very useful in making environmental interpretations.

Eight sand samples from the formation were sieved according to the technique of Friedman (1979). The nest of sieve were arranged with the coarsest at the top and the finest (pan) at the bottom. The disaggregated and weighed samples of the sand were each poured into the uppermost part of the sieve and shaken for fifteen minutes. The frequency curves of the samples were plotted and the critical percentiles (Φ_5, Φ_{16}, Φ_{25}, Φ_{50}, Φ_{75}, Φ_{84} and Φ_{95}) were obtained and the textural parameters of the sand which include the graphic mean, median, graphic standard deviation, inclusive graphic skewness and graphic kurtosis were calculated (Table 3a). the bivariate plots of skewness vs standard deviation (Friedman, 1961), mean diameter vs standard deviation (Moiola and Weiser, 1968) and skewness vs mean size were used for environmental discrimination.

Lithostratigraphic Description

Nanka Sand at Umunya

The exposure of about 6m thick consists of basal planar cross bedded fine, wave rippled sand, heteroliths, ironstone and pebbly sand almost at the topmost part of the outcrop.

The basal sand unit is planar cross bedded with a lot of horizontal cylindrical burrows of *Ophiomorpha* and *Telchnicus.* Reactivation surfaces, mud drape and associated tidal bundle, flaser and lenticular bedding characterize this lower fine sand unit. Overling the basal sand is wave rippled laminated sand which was overlain by heteroliths consisting of rapid alternation of claystone and sandstone. The horizontal burrows of *Thalassinoides* are associated with the unit and commonly occur in between the sand and claystone. Also present in this unit are concretions, product of diagenesis. The base of the heteroliths is erosional (unconformity). The pebbly sandstone almost at the topmost part of the exposure is interbedded with lensoid claystone. Trough cross bed also occur. The area documented soft sediment deformation in form of convolute bedding (recumbent fold) at the topmost unit.

Nanka Sand opposite Ikenga hotel, Awka

The outcrop comprises of planar cross bedded sand with clay drape and wave rippled laminated heteroliths consisting of interlaminated clay and sand. The sands are moderately to poorly sorted, dominantly medium grained, clayey and mica free. The sands display colour banding of yellowish brown due to iron oxide stains on the grain. Burrows of *Ophiomorpha* are common. The exposure is about 7.6m thick.

Lithofacies

Wave rippled fine sand facies

This unit comprises of wave ripple and parallel laminated whitish very fine sand of about 1.4m thick. The unit is at the lower part of the outcrop.

Cross Bedded Fine Sand Facies

The unit is about 1.65m thick and consists of planar cross bedded fine sandstone. Each cross bed has clay drape (1mm thick) which were deposited on top of each sand. For the cross bed sets, the thicker cross beds cut off the thinner ones giving rise to reactivation surfaces. The unit also contain the cylindrical burrows of *Ophiomorpha.*

ISSN 1119-9296

Natural and Applied Sciences Journal Vol. 11 No. 1
Available online at www.naasjournal-ng.org

Heterolith Facies

It comprises of the alternation of beds of wave ripple laminated fine sandstone and claystone. This unit was found at the topmost part of the outcrop and has an erosional base. Associated with this are burrows of *Thalassinoides* and concretions.

Other Lithofacies

These include wave ripple laminated clayey sand and coarse sandstone interbedded with lensoid claystone.

Sedimentary Structures

These include planar cross bedding, wave ripples, parallel lamination, flaser and lenticular bedding, reactivation surfaces, mud drape, tidal bundles, concretions and a lot of burrows of *Ophiomorpha.* However, burrows of *Thalassinoides* and *Telchincus* also occur

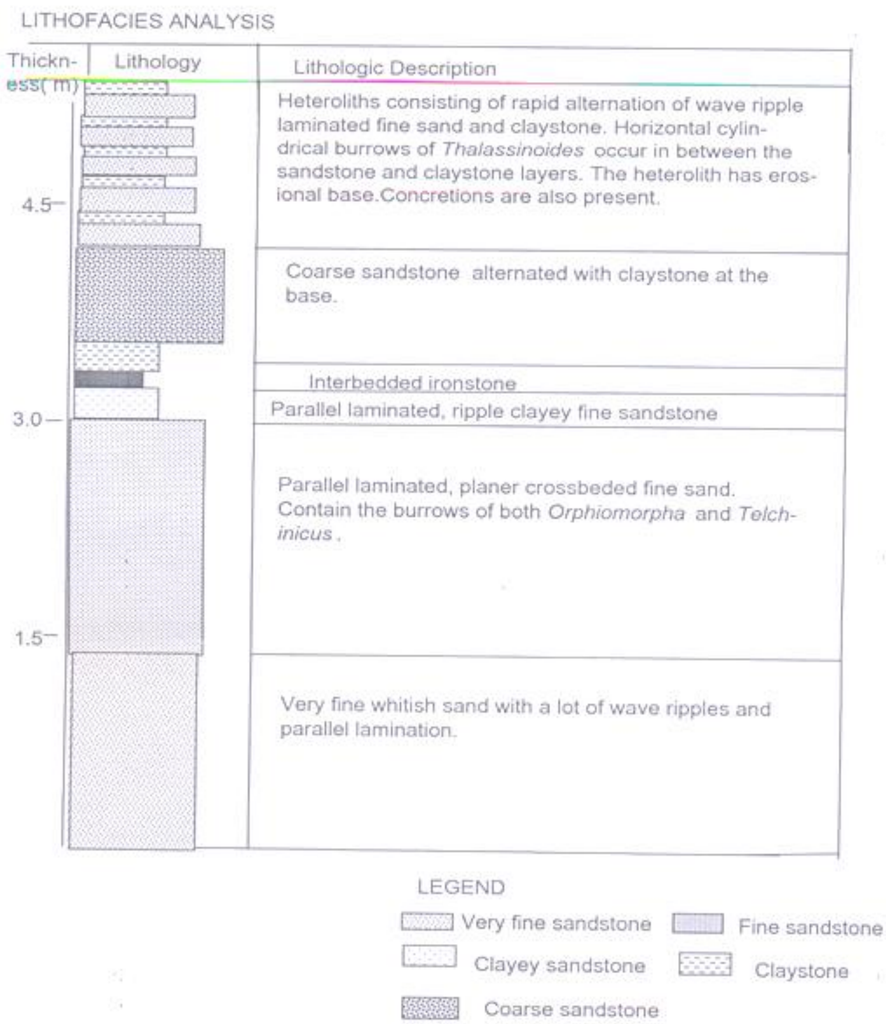

Fig.2: Lithologic Section of Nanka Sand at Umunya.

ISSN 1119-9296

Natural and Applied Sciences Journal Vol. 11 No. 1
Available online at www.naasjournal-ng.org

Paleocurrent Analysis

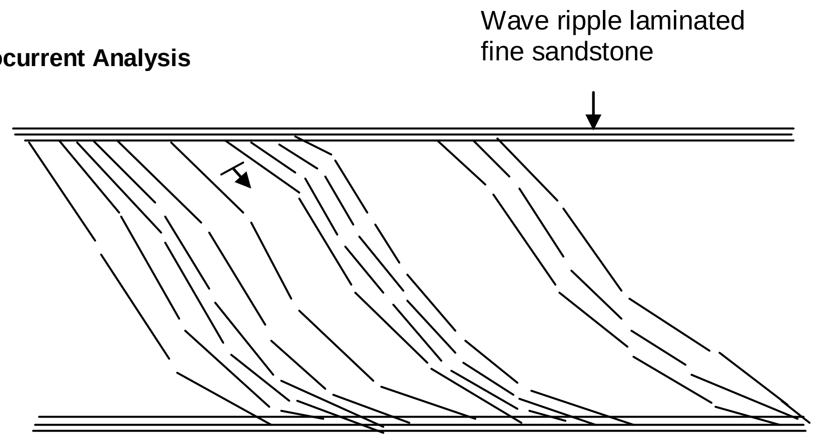

Fig.3: Schematic Diagram of the planar cross beds and associated tidal bundle on Nanka Sand exposed at Umunya.

Each cross bed has clay drape which are deposited on top of each sand. For the cross bed sets, thicker ones cut off the thinner ones and thus giving rise to reactivation surfaces.

Table 1a: Cross beds data 1

Serial position	Thickness (cm)	Serial position	Thickness (cm)	Serial position	Thickness (cm)	Serial position	Thickness (cm)
1	2.00	21	1.50	41	3.50	61	2.50
2	2.00	22	2.50	42	3.00	62	2.00
3	2.00	23	3.00	43	4.00	63	1.50
4	1.50	24	2.00	44	3.00	64	2.50
5	2.00	25	5.00	45	5.00	65	1.80
6	2.00	26	2.00	46	2.00	66	2.00
7	2.00	27	2.00	47	2.80	67	2.50
8	1.50	28	5.00	48	2.90	68	3.00
9	4.00	29	2.50	49	1.80	69	4.50
10	2.00	30	2.00	50	2.00	70	4.00
11	3.00	31	5.00	51	1.50		
12	2.80	32	3.00	52	1.80		
13	3.00	33	2.50	53	1.00		
14	3.00	34	3.50	54	1.50		
15	2.00	35	2.50	55	1.00		
16	1.60	36	1.50	56	0.50		
17	2.50	37	2.00	57	1.50		
18	2.00	38	2.00	58	2.00		

ISSN 1119-9296

Natural and Applied Sciences Journal Vol. 11 No. 1
Available online at www.naasjournal-ng.org

19	3.80	39	3.00	59	2.00		
20	1.50	40	3.00	60	1.50		

Table 1b: Cross beds data 2

Serial position	Thickness (cm)	Serial position	Thickness (cm)	Serial position	Thickness (cm)
1	1.80	21	2.00	41	2.80
2	1.50	22	2.00	42	5.00
3	2.80	23	2.00	43	4.00
4	1.50	24	2.00	44	3.50
5	1.80	25	3.00	45	2.00
6	4.20	26	5.00	46	4.00
7	3.00	27	2.00	47	3.50
8	4.00	28	2.80	48	4.00
9	3.00	29	4.80	49	2.00
10	3.00	30	5.00	50	2.00
11	4.80	31	4.80	51	2.00
12	2.00	32	3.00	52	2.00
13	2.80	33	2.80	53	3.00
14	2.00	34	1.80		
15	3.00	35	1.80		
16	3.00	36	1.80		
17	2.00	37	2.00		
18	3.50	38	2.80		
19	1.80	39	2.80		
20	3.00	40	3.00		

Table 2a: The orientation of the cross beds measured in the field

S/N0	Azimuth (°)	S/N0	Azimuth (°)	S/N0	Azimuth (°)
1	318	28	16	55	286
2	288	29	50	56	261
3	297	30	22	57	276
4	308	31	38	58	286
5	266	32	32	59	268
6	265	33	80	60	266
7	267	34	28	61	270
8	270	35	70	62	264
9	276	36	42	63	268
10	262	37	46	64	48
11	283	38	40	65	64
12	280	39	32	66	72
13	308	40	258	67	44
14	307	41	263	68	56
15	276	42	270	69	82

ISSN 1119-9296

Natural and Applied Sciences Journal Vol. 11 No. 1
Available online at www.naasjournal-ng.org

16	300	43	267	70	38
17	266	44	268	71	36
18	266	45	268	72	56
19	262	46	277	73	46
20	266	47	274	74	78
21	262	48	270	75	72
22	270	49	266	76	54
23	292	50	270	77	80
24	278	51	264		
25	76	52	260		
26	40	53	292		
27	62	54	286		

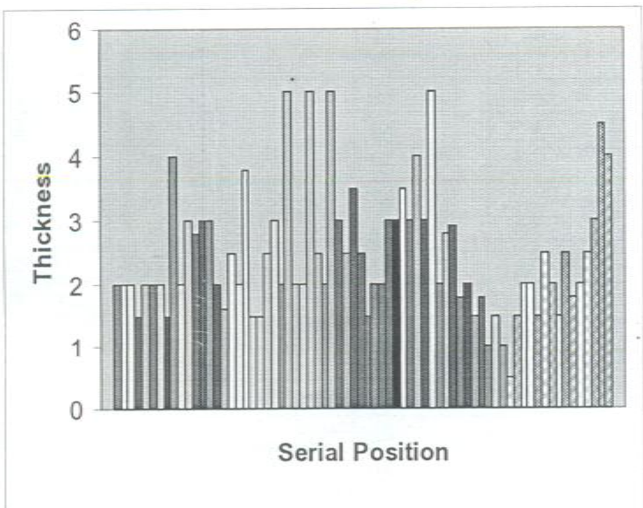

Fig.4a: Plot of Thickness vs Serial Positions of cross beds Data 1

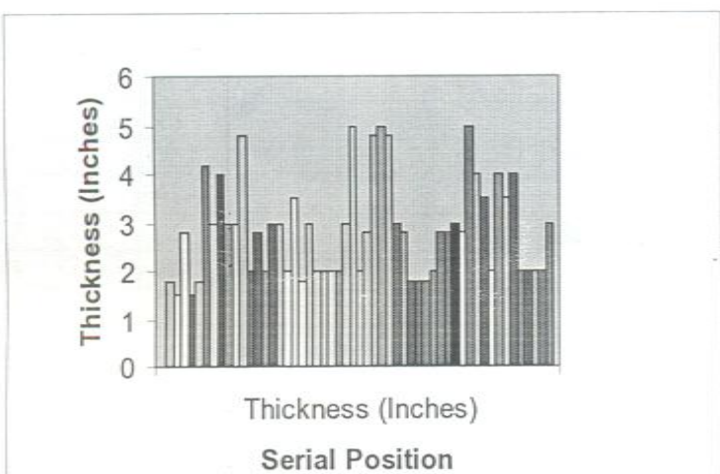

Fig.4b: Plot of Thickness vs Serial Position of Cross Beds data 2.

ISSN 1119-9296

Table 2b: Analysis of the cross beds

S/N0	Azimuth (Range)	Frequency	Total (%)
1	0- 15	-	-
2	15- 30	3	3.9
3	30- 45	9	11.69
4	45- 60	7	9.09
5	60- 75	5	6.49
6	75- 90	5	6.49
7	90- 105	-	-
8	105- 120	-	-
9	120- 135	-	-
10	135- 150	-	-
11	150- 165	-	-
12	165- 180	-	-
13	180- 195	-	-
14	195- 210	-	-
15	2I0- 225	-	-
16	225- 240	-	-
17	240- 255	-	-
18	255- 270	29	37.66
19	270-285	8	10.39
20	285- 300	7	9.09
21	300- 315	3	3.9
22	315- 330	1	1.3
23	330- 345	-	-
24	345- 360	-	-

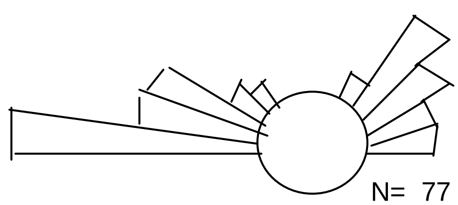

Fig.5: Rose diagram of the direction of currents for the outcrop at Umunya.

ISSN 1119-9296

Natural and Applied Sciences Journal Vol. 11 No. 1
Available online at www.naasjournal-ng.org

Sieve Analysis

Table 3a: Statistical Parameters for the sieve analysis

Sample No	Mean	Std. Deviation	Skewness	Kurtosis
IS_1	1.0 Medium	1.09 Poorly sorted	-0.21 Negatively skewed	0.89 Platykurtic
IS_2	1.20 Medium	0.96 Moderately sorted	-0.2 Negatively skewed	1.26 Leptokurtic
IS_3	1.62 Medium	0.95 Moderately sorted	-0.36 Strongly negatively skewed	2.33 Very leptokurtic
IS_4	1.55 Medium	1.01 Poorly sorted	-0.71 Strongly negatively skewed	1.60 Very leptokurtic
IS_5	1.23 Medium	1.00 Poorly sorted	-0.16 negatively skewed	1.68 Very leptokurtic
US_1	1.95 Medium	0.48 Well sorted	0.68 Strongly positively skewed	1.74 Very leptokurtic
US_2	1.97 Medium	0.54 Moderately sorted	-0.08 Near symmetrical	0.97 Mesokurtic
	1.37 Medium	0.75 Moderately sorted	-0.13 Negative skewed	0.90 Mesokurtic

Table 3b: Average values for the parameters

Mean	1.49 Medium sand
Standard Deviation	0.85 Moderately sorted
Skewness	-0.15 Negatively skewed
Kurtosis	1.42 leptokurtic

Nanka Sand is strongly positively skewed through near symmetrical to strongly negatively skewed with the average being negatively skewed. Average sorting is moderately sorted and kurtosis is leptokurtic. According to Friedman (1961), beach sands are generally negatively skewed and well sorted while river sands are positively skewed and poorly sorted. The frequency histograms showed that the grain size distribution indicated unimodal and bimodal characters with shifting modes. Both symmetrical and asymmetrical forms occur (figs.6a- e). The unimodal nature is an indication of sorting of a particular fraction with respect to others by the transported medium. The shift in the modal class entails the deposition under fluctuating energy condition. The sand plot in the river compartment of Moiola and Weiser (1968) and Friedman (1961). However, the combined plots of Stewart (1958), Friedman (1961) and Moiola and Weiser (1968) indicated river process as a dominant process in the transportation and deposition of the sands with minor wave action.

Discussion and Conclusion

According to Zimmerle and Zimmerle (1995), ancient tidal processes are recognized on sedimentary rocks by these following criteria: (1) Presence of paleocurrent patterns indicating bi-directional flow. (2) The abundance of reactivated surfaces and clay drapes (3) Presence of sedimentary features indicating repeated, small scale alternations in sediment transport. The recognition of ancient tidal flat deposits is based on the sedimentary structures association and sediments considered to indicate tidal processes and on the presence of fining- upward sequences reflecting tidal-flat progradation. Ancient tidal flat channels comprise an erosive based conglomeratic lag overlain by coarse grained sandstones with planar, trough, sigmoidal and complx low angle sets of cross- bedding. The overlying tidal flat deposits fine to medium grained, ripple laminated sandstone and thin tidal current and storm generated units interlaminated with silty claystone interbeds.Trace fossils showing escape structures and the presence of symmetrical ripple marks draped by clays, and causing flaser, wavy and lenticular bedding may be additional evidence.

Tucker (1982) noted that paleocurrent pattern in shallow marine shelf can be bimodal through tidal current reversals, can be unimodal if one tidal current dominates. Polymodal and random pattern also occur. However, paleocurrent interpretation need to be combined with the studies and interpretation of the facies for maximum information. The lithofacies of Nanka Sand in the study which comprises of the lithologies as well as the associated sedimentary structures which include flaser and lenticular bedding, mud drape, reactivation surfaces, tidal bundles, planar and trough cross beds and wave ripple laminations are suggestive of tidal sedimentation.

ISSN 1119-9296

Natural and Applied Sciences Journal Vol. 11 No. 1
Available online at www.naasjournal-ng.org

Wave ripples are associated with storm dominated processes and are common in shallow water affected by wave oscillation (Reineck and Singh, 1980). The rose diagram (fig.5) indicated bimodal-bipolar paleocurrent pattern. The bi- directional paleo- flow is in the Northeastern and Westerly directions. The plots of the thickness of the cross beds versus their serial positions (figs.4a and b) indicated rhythmicity or sinuosity pattern which can be attributed to tidal fluctuation. The thicker and the thinner cross beds were formed during the spring and neap tide respectively. The sands are moderately sorted and negatively skewed on the average. River sands are generally positively skewed and poorly sorted while beach sands are well sorted and negatively skewed (Friedman, 1961). The scatter plots of Friedman (1961) and Moiola and Weiser (1968) showed that river process was dominant in the deposition of the sands with minor wave action. The negative skewness and good sorting exhibited by the sands could be as a result of winnowing by wave action. The average kurtosis is leptokurtic (excessively peaked) indicating that the center is better sorted than ends. The symmetrical and asymmetrical unimodal current pattern with shifting modes (fig.6a-e) indicate fluctuating energy condition while the bimodal pattern could suggest nearby source.

Ophiomorpha belong to *Skolithos* ichnofacies. Its occurrence is an indication of deposition in a high energy, intertidal flat environment (Nwajide and Hoque, 1979; Nwajide, 1980; Amajor, 1984 and Mode, 1991). However, Mbuk et al (1985) attributed it to tide dominated shallow marine. Okoro (1986) in his work at Leru (Nkporo Shale) noted the occurrence of both *Ophiomorpha* and *Thalassinoides* belonging to both Skolithos and Cruziana ichnofacies respectively. He therefore attributed it to wave and storm dominated delta front marine environment.

The work supported Nwajide and Hoque (1979) and Nwajide (1980) based on the bimodal- bipolar paleocurrent pattern, lithofacies and sedimentary structures that Nanka Sand was deposited in an inter- tidal relatively high energy environment.

References

Amajor, L.C., 1984. Sedimentary Facies Analysis of the Ajali Sandstone (Upper Cretaceous), Southern Benue Trough. J. Min. Geol., 28, PP.7- 17.

Friedman, G.M., 1961. Distinction between dune, beach and river sands from their textural characteristics. Journ. Sed. Petrol. 31, 514-b529.

Friedman, G.M., 1979. Differences in size distributions of populations of particles among sands of various origins. Sedimentology, 26, 3- 32.

Mbuk, I.N., Rao, V.R., and Kumaran, K.P.N., 1985. The Upper Cretaceous- Paleocene boundary in the Ohiafia- Ozu Abam area, Imo State, Nigeria. Jour. of Min. Geol.,22, pp.105- 119.

Mode, A.W., 1991. Assemblage zones, age, and paleoenvironment of the Nkporo Shale, Akanu area, Ohafia, Southeastern Nigeria. In: A.W. Mode (1997), Ichnostratigraphy and paleoenvironments of the Benue Trough, Nigeria. Jour. Of Min. and Geol., Vol.33, No 2, pp.115- 126.

Moiola, R.J., and Weiser, D., 1968. Textural parameters: an evaluation. Journ. Sed. Petrol. 38, 45-53.

Murat, R.C., 1972. Stratigraphy and Paleogeography of the Cretaceous and Lower Tertiary in Southern Nigeria. In: T.F.J. Dessauvagie and A.J. Whiteman (eds.). African Geology, University of Ibadan press, Nigeria. Pp.251- 266.

Nfor, B.N., 2003. Sedimentary facies and the diagnostic characteristics of the Campanian- Eocene deposits of the Anambra Basin Southeastern Nigeria. Unpublished Ph.D Thesis, Nnamdi Azikiwe University, Awka.

Nwajide, C.S., 1980. Eocene tidal sedimentation in the Anambra Basin, Southern Nigeria. Sedimentary Geology. 25, 189- 207.

Nwajide,C.S., 2005. Anambra Basin of Nigeria: Synoptic Basin Analysis as a basis for

ISSN 1119-9296

Natural and Applied Sciences Journal Vol. 11 No. 1
Available online at www.naasjournal-ng.org

hydrocarbon prospectivity. In: C.O. Okogbue (ed.). hydrocarbon potential of the Anambra Basin. Great AP Express, Nigeria. Pp.1- 46.

Nwajide, C.S., and Hoque, M., 1979. Trace fossils from the Nanka Formation, Southeastern Nigeria. Geologie en Mijnbouw. 58, pp.85-88.

Okoro, A.U., 1986. Stratigraphic study of Nkporo Shale at Lokpaukwu and Environs, Imo State. In: A.U. Mode (1997), Ichnostratigraphy and paleoenvironments of the Benue Trough, Nigeria. J. Min. and Geol., vol.33, no.2, pp.115- 126.

Reineck,H.E., and Singh, E.B., 1980. Depositional sedimentary environments, 2nd ed. Springer Verlag, New York.

Reyment, R.A., 1965. Aspects of the Geology of Nigeria. Univ. Ibadan, Nigeria.

Stewart, H.B., 1958. Sedimentary reflections of depositional environments in San

Miguel Lagoon. Baja California, Mexico. Bull. Amr. Assoc. Petrol. Geol. 42, 2567- 2618.

Tucker, M.E., 1982. Sedimentary petrology: An introduction (vol.3). Blackwell Scientific Publications, London. 40- 42.

Wright, J.B., Hastings, D.A., and Williams, H.R., 1985. Geology and Mineral Resources of West Africa. George Allen and Unwin, London. 40-42.

Zimmerle, W., and Zimmerle, H., 1995. Petroleum Sedimentology. Sci. 413

ISSN 1119-9296

Natural and Applied Sciences Journal Vol. 11 No. 1
Available online at www.naasjournal-ng.org