Baseline Analysis of the Western Andoni Coastline Beaches in the Niger Delta Region

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Abstract

Gross geosciences parameters were used to evaluate the sensitivity attributes of the sandy beaches of the coastal zone of the western Andoni area of the Niger Delta region for sedimentological characteristics, micropaleontological attributes, and physiochemical parameters of the adjoining coastal water quality. Grain morphometry and composition are indicative of predominantly multicycle arenites, while spatial distribution model suggests dominant eastward flow of the depositing coastal currents. The heavy mineral assemblage is indicative of source derivation from continental terrains. Micropaleontological attributes are suggestive of non-marine to middle neritic depo-environemnt of Pliocene-Holocene age. Significant wave action on the beach sands at the intertidal channels and shoreline, and the wide spatial remains of flora relics confirm extensive beach erosion. Pollution index parameters, including biochemical oxygen demand and dissolved oxygen, show that the western Andoni coastal waters are highly polluted by anthropogenic activities. Gross pollution index parameters indicate that the study area requires purpose-driven environmental management plan towards sustainable protection of the coastal environment from degradation that may occasioned by current and up-coming interest in industry sector-related anthropogenic activities.

Keywords: Compositional, textural, heavy mineral, biogenic and sedimentary structures, water quality index

1. Introduction

Coasts, beaches and seashores are the most familiar parts of the ocean for most people. They are the land areas which boarder on and are affected by the ocean and sea water. They are areas where marine environment influences terrestrial environment and vice versa. A coast or coastline is a land along the sea or ocean describing its shape or appearance and is used to describe an area that is longer than a shoreline, adjoin or near the sea, or the boundary between the land and the ocean. The terms coast, coastal area, coastal zone and coastlines are used interchangeably to describe the areas where the land meets the sea.

Nigeria is a maritime state with a coastline of approximately 853 km which lies between latitude 4°10' to 6°20'N and longitude 2°45' to 8°5'E (FEPA 1997). The Nigerian coastline stretches from the eastern border with the Republic of Benin to the western border of the Cameroon Republic (FEPA 1997). The 853km long Nigeria coastline runs through seven of the Southern States of the Federation; Lagos, Ondo, Delta, Bayelsa, Rivers, Akwa Ibom and Cross Rivers and bordered by the Atlantic Ocean (Orupabo, 2004). The Nigerian coastal area lies within the Atlantic Ocean with its continental shelf, and the coastal fresh water and brackish wet lands ramified by an atomizing network of rivers and creeks. These water bodies are characterized by periodic tidal variations and changes along water channels and the differences depend on the hydrological properties and the slopes of the various channels.

Several studies have been carried out on the Nigerian coastal zone. However, data accumulated from these studies have not been comprehensively coordinated. Many studies carried out by oil and gas exploration companies are largely unpublished and consequently not available for dissemination. The present state of knowledge on the Nigerian coastal zone is chiefly based on studies carried out by scientists in Universities, Research Institutes and some Government Agencies such as: Center for Environment and Development in Africa (Ceda), European Union, FAO, NLNG, Federal Ministry of Environment, USAID, Nigerian Institute for Oceanography and Marine Research, etc. Works of the European Union-sponsored team that looked at management of the 800km-long Nigerian coastline (Orupabo, 2004), concluded that the coastal zone of Nigeria has in recent years been subjected to increasing economic activities, primarily driven by seaport activities and oil exploration and exploitation. These activities have reportedly resulted in accelerated shoreline erosion estimated at between 20-30m per annum. Historical data derived from aerial photographs for a section of the Nigerian coastline spanning the years 1900-2002 was used to estimate shoreline dynamics, which is now conservatively put at 1.7m per annum, corresponding to a net sediment loss of 7.3m^2 per annum (Orupabo, 2004). Allen (1964, 1965, and 1970) made reference to the eastern flank of the Niger Delta between brass and Andoni River in terms of the thick series of fine sands that grade seaward into clean coarse silt. He further noted that eastward from the Andoni River the coarse facies is restricted to the inner part of the platform. NADECO (1959) studied the longshore sand drift pattern along the Niger Delta coast and noted that the drift increase from the Delta nose to the east and west. These sands are derived from the successive distributaries that contribute about one million cubic, meters (1 x 10^6m^3 of sand per year to the delta NADECO (1959). Specific research on the western Andoni white beaches have been carried out by Amajor and Ngerebara (1990). This work was an attempt to determine the compositional and textural properties and probable source rocks of the Sands from the western Andoni beach and flanking rivers (Andoni and Imo). The results of the research showed that the two rivers and the beach are dominated by quartz arenites, moderately to well sorted, sub rounded to rounded, fine sands (greater than 96%) while the silt and clay fraction (less than 5%) is very minimal. However, the beach is richer in fine sand, best sorted and cleaner. The Imo River unlike the Andoni River, exhibits a more regular compositional maturity downstream, thus reflecting the sedimentary nature of the source and catchment areas of the Imo River. Kaolinit and ilite dominates the clay minerals in the silt/clay fraction. They also discovered that the average mean size of the beach sands decreased in an easterly direction as the silt and clay proportion increases, indicating a possible flow direction of the depositing coastal currents. Also, the shoreward increase in the average grain size of the beach sands is consistent with the intertidal setting of the beach. Combinations of some grain size statistics such as mean, standard deviation and skewness differentiated the river channel sands from those of the beach with only slight overlaps. The Imo river sands contain zircon, tourmaline and rutile, those of Andoni River and beach contain garnet, and staurolite in addition. This observation not only confirms the easterly direction of the sediments dispersal, but suggests that much of the beach sands are supplied by Andoni River, a distributary of the Niger Delta. The heavy mineral suit, however, suggests original derivation of sands from plutonic igneous and metamorphic rocks.

This research is a follow up of Amajor and Ngerebara (1990), aimed at examining the compositional, textural, bio stratigraphic and surface water index characteristics of the Western Andoni coastline.

The Study Area

The Western Andoni Coastline Beaches (about 33km long and 0.6km wide from Oyorokoto to Inyon-Okpon or Down below) is one of Nigeria's many barrier bar beaches along the Atlantic Ocean coastline. It lies in the east-central sector of the Niger Delta with latitudes 4° 25'17.03" to 4° 29'19.63" N and longitude 7°24'37.24" to 7°34'16.95" E. It is flanked by the Andoni and Imo Rivers respectively to the west and east (fig. 1). The semi-enclosed island is usually flooded during high tide, which is semidiurnal up to 50%.

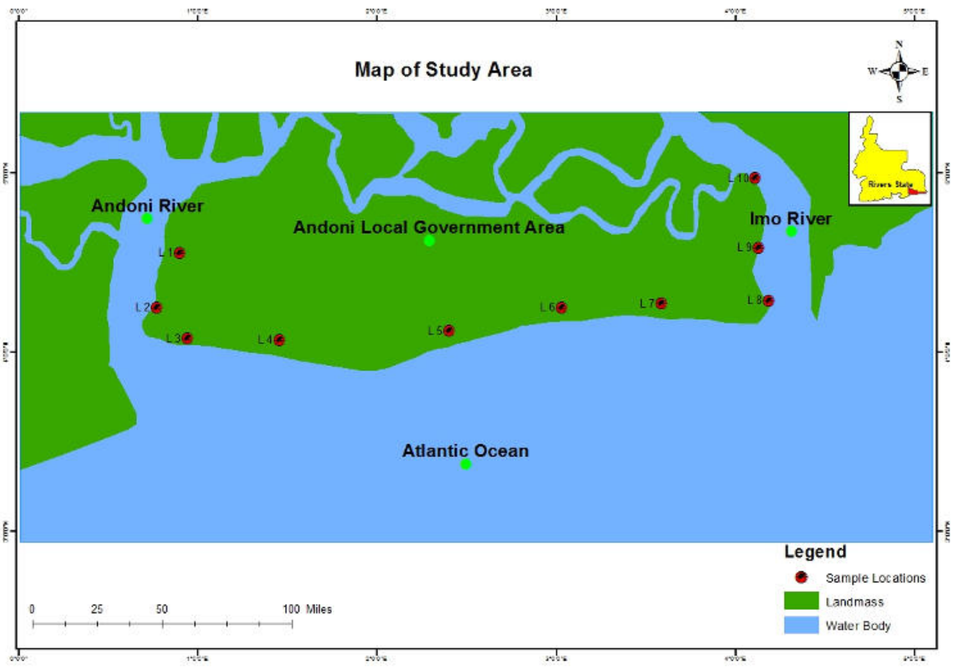

Fig. 1: Map of Study Area showing Sample Locations

2. Methods

Geologic mapping and field survey of the Western Andoni coastline beaches was carried out using compass (GPS) traverse method during low tide of 2008 and 2009. Soil and water samples along the coastline beach face about 3km sampling intervals were collected to a maximum depth of 2m using hand auger. The water samples were collected from the ocean along the coastline with the sample container completely submerged after rinsing with same water and discharged properly to avoid contamination of source. A total of forty (40) soil samples and 10 water samples were collected. Photographic snap shots of the entire area were taken for proper analysis of sedimentary structures. Laboratory analysis was done for Particle size determination (Folk 1974), Thin Sectioning using a Polarizing Microscope, Heavy minerals using gravity separation (Carver, 1971), Foraminifera and Palynomorph composition, at the Geology Laboratories, University of Port Harcourt and Water Quality test (UNEP/WHO 1996) at the Biochemistry Laboratory, University of Port Harcourt.

3. Results

The data obtained from the field and laboratory analysis are presented in this work in tabular forms for easy evaluation and are also presented in various graphical presentation forms, such as logs, Columns (2D clustered column), Scatter (only markers, smooth lines, straight lines), Radar, Line (3D, 2D stacked line), and Area (2 & 3D).

Table 1: Particle Size Distribution and Textural Analysis

LOCATIONS	MEAN Φ	SORTING Φ	SKEWNESS Φ	KURTOSIS Φ
L 1	2.81	0.31	-0.17	1.01
L 2	2.89	0.37	-0.39	1.22
L 3	2.61	0.44	-0.28	1.91
L 4	2.03	0.37	-0.19	1.71
L 5	2.58	0.31	0.22	1.43
L 6	2.91	0.43	-0.69	1.58
L 7	2.66	0.43	-0.14	1.03
L 8	2.81	0.53	-0.40	1.01
L 9	2.70	0.54	-0.42	1.04
L 10	2.78	0.46	-0.33	1.09

Thin Sections

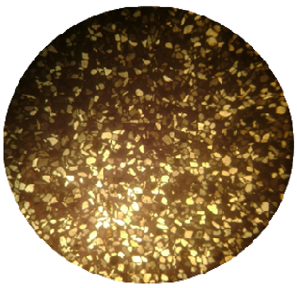

Plate 1

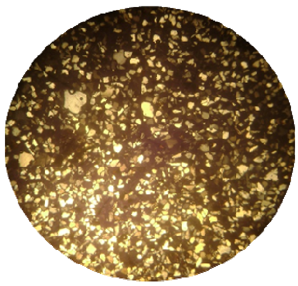

Plate 2

Heavy Mineral

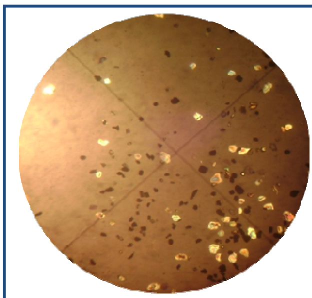

Plate 3

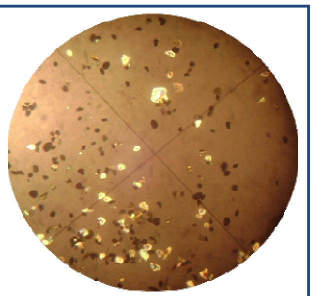

Plate 4

Trend Patterns

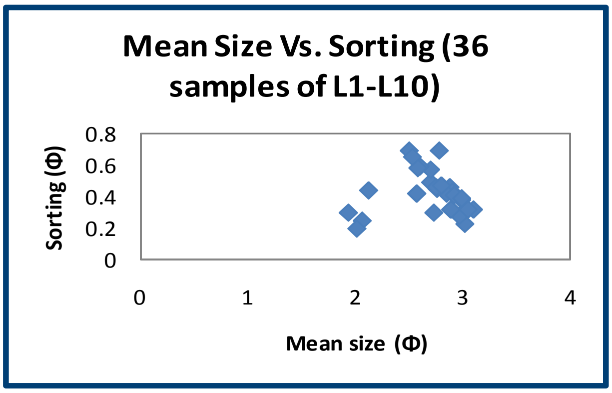

Fig. 2: Bivarite Plot of Mean Size Veresus Sorting

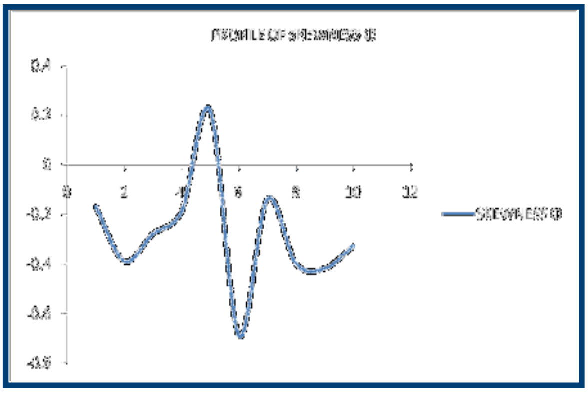

Fig. 3:Showing the Profile for the Skewness

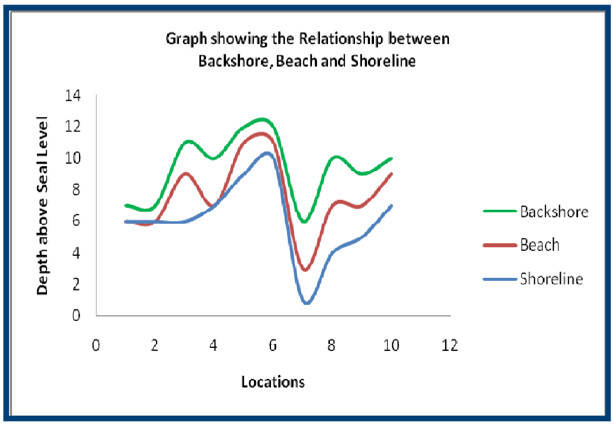

Fig. 4: Depth Profile for the Backshore, Beach and Shorelines above sea level.

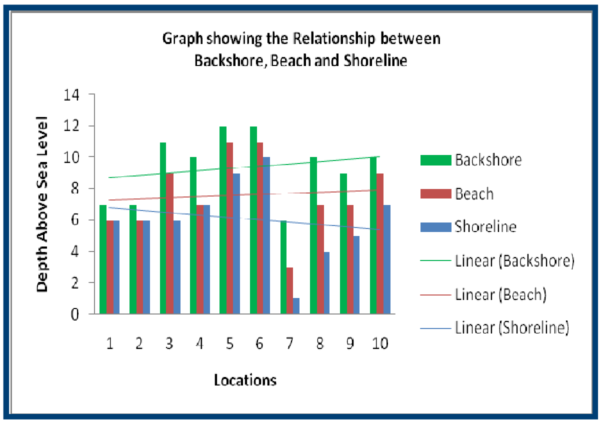

Fig. 5: Trend Directions for the Backshore, Beach and Shorelines above sea level.

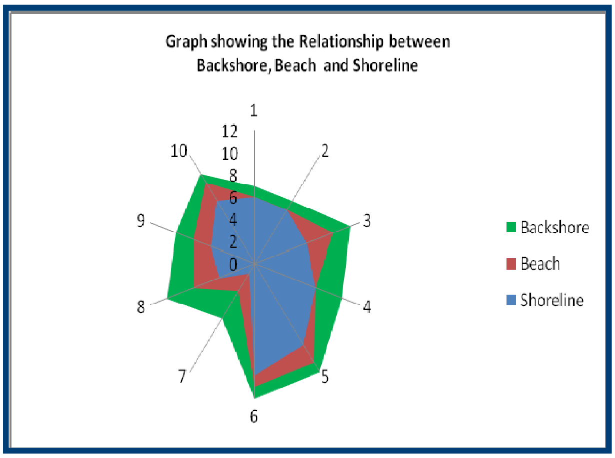

Fig. 6: Interaction between the Backshore, Beach and Shorelines above sea level.

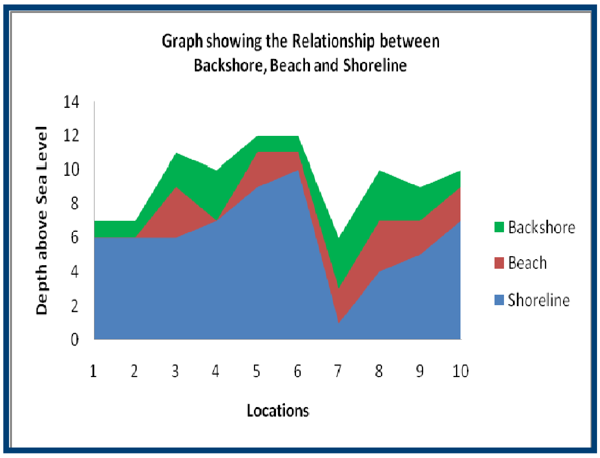

Fig. 7: Interaction between the Backshore, Beach and Shorelines above sea level.

Trend Patterns

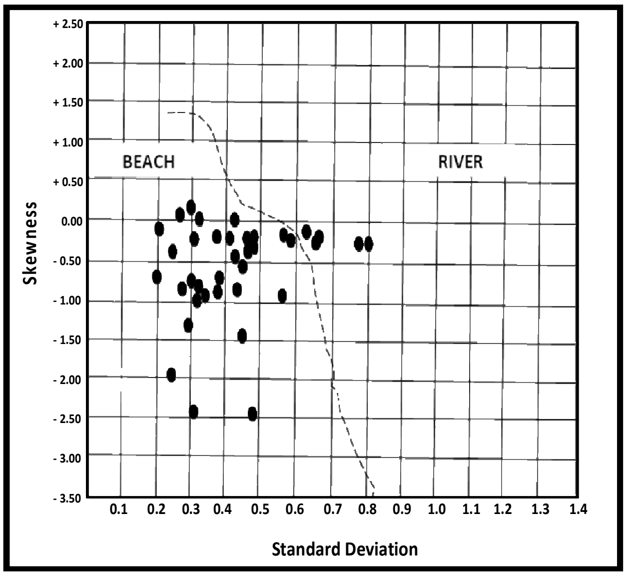

Fig. 8: Plot of Skewness against standard deviation for Andoni beach sands (After Friedman, 1967)

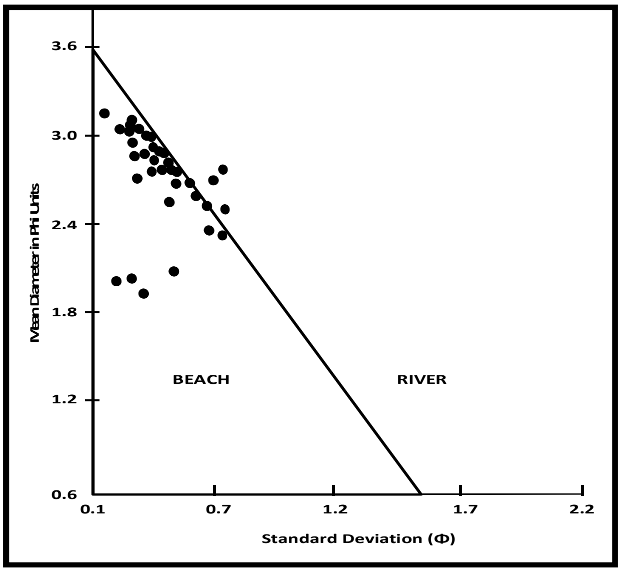

Fig. 9: Plot of Mean diameter versus Standard Deviation for Andoni Beach sands. (After Miola and Weiser, 1968)

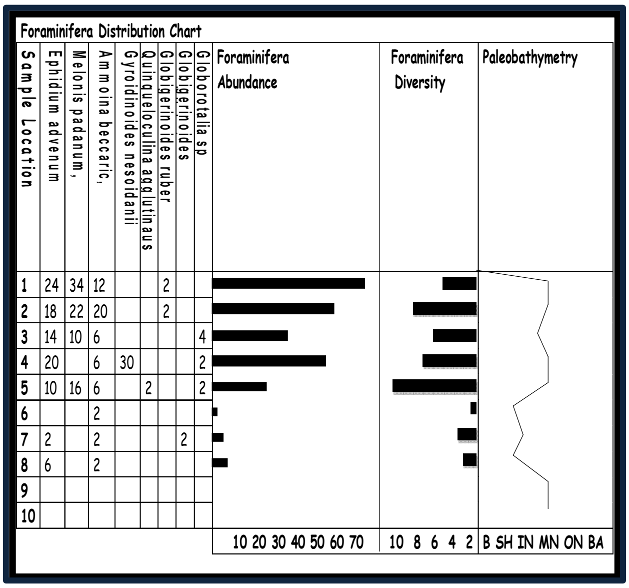

Fig. 10: Foraminifera Distribution Chart

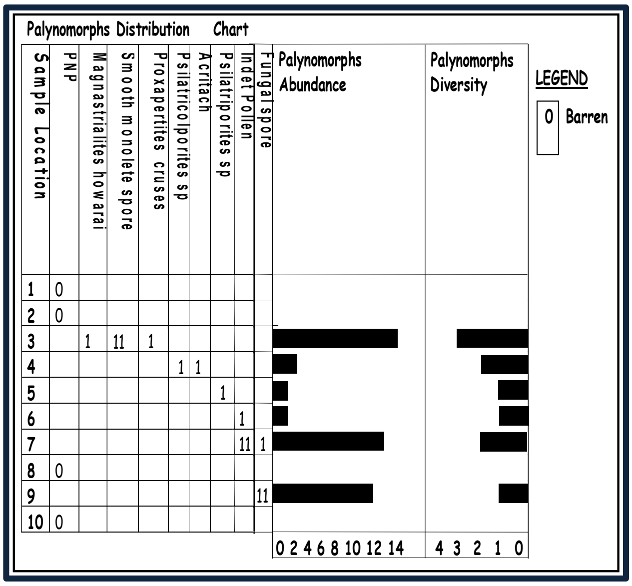

Fig. 11: Palynomorphs Distribution Chart

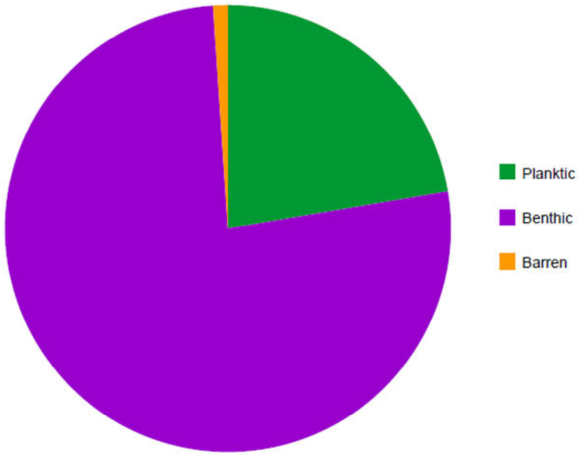

Fig. 12: Pie chart showing summary of benthic and planktic foraminifera taxa

Water Quality

Table 2: Surface water quality

Parameters	Unit	Range
CL- 1me	mg/l	14,000 - 26,100
Na+	(PPM)	5535.90 - 10471.00
S042- 1m / 50ml	mg/l	344.445 - 482.223
Mg2+	PPM	649.95 - 1042.70
Ca2+	(PPM)	401.90 - 615.57
K+	(PPM)	129.523 - 190.933
CO32-/HCO3-	mg/l	32.00 - 48.00
Cd2+(	PPM)	0.000 - 0.101
Pb2+(	PPM)	0.022 - 0.068
Hg2+(	PPM)	0.000* - ND
NO2- (Nitrite)	mg/l	Nil
NO3- (Nitrate)	mg/l	0.882 – 1.853
PO43- (Phosphate)	mg/l	0.008 - 0.0165
pH		8. 00 - 9. 60
Alkalinity	mg/l	32.00 - 48.00
Turbidity	NTU	0.04 - 0.72
TDS	mg/l	28,200 - 34,800
(DO)	mg/l	0.80 - 1.20
(BOD)	mg/l	240.00 - 280.00
(COD)	mg/l	400.00 - 420.00
Total Phosphate	mg/l	0.003 - 0.005
Total Nitrogen	mg/l	0.024- 0.04
Total Hardness	mg/l	3423.42 - 6306.30
Calcium Hardness	mg/l	3,400.00 - 6,300.00
Salinity	mg/l	25270.00 - 47110.50
Conductivity	µmhos/cm	21500 - 27050
(TS)	mg/l	29,000.00 - 45,500.00
(TSS)	mg/l	3100.00 - 6700.00
(TOC)	mg/l	0.36 - 1.44
(THC)	mg/l	0.00 - 1.00

Table 3: Calculation of Overall Water Quality Index (Brian 2014)

Factor	Weight	Quality Index
Dissolved oxygen	0.17	2
Fecal coliform	0.16	
pH	0.11	55
Biochemical oxygen demand	0.11	5
Temperature change	0.10	
Total phosphate	0.10	100
Nitrates	0.10	96
Turbidity	0.08	98
Total solids	0.07	20

Based on the 7 factors entered, the water quality index is 48. The 100-point index can be divided into several ranges corresponding to the general descriptive terms shown in the table below.

Water Quality Index Legend (after Brian 2014)

Range	Quality
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very bad

Sedimentary and Biogenic Structures

Fig. 13: Beddings and laminations

Fig. 14: Beach sand deposition layering

Fig. 15: Beddings and laminations

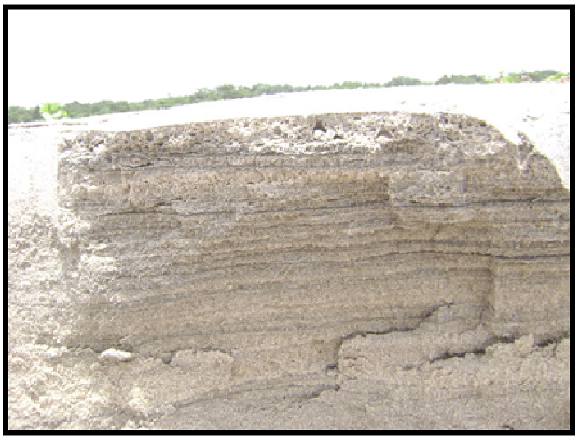

Fig. 16: Beddings and laminations

Fig. 17: Ripples

Fig. 18: Ripples

Fig. 19: Ophiomorpha and skolithos

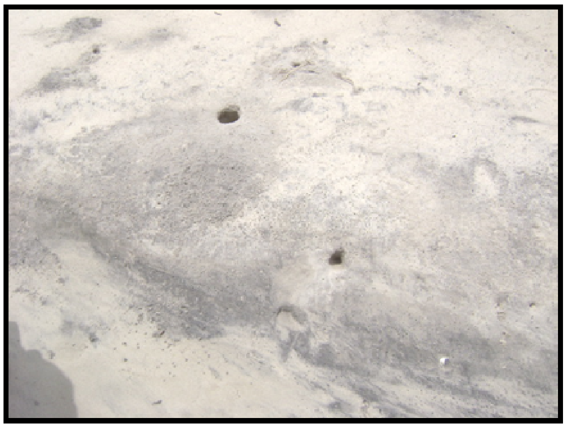

Fig. 20: Ophiomorpha and skolithos

Biofacies

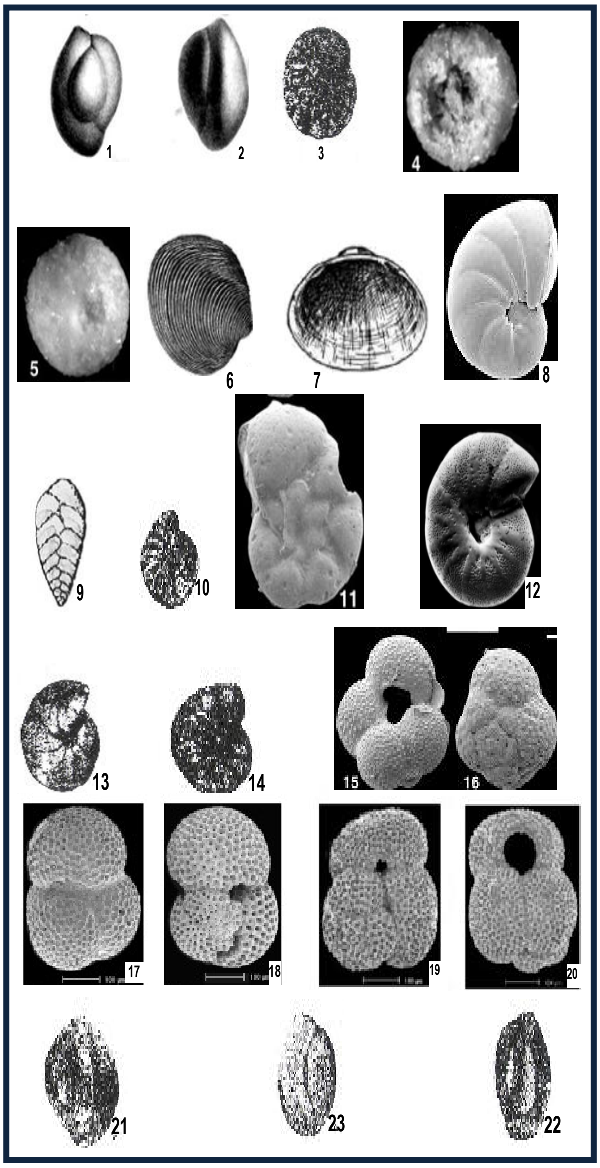

Plate 5.

1, 2: Triloculina austriaca, 3: Ammonia beccarii, 4, 5: Saccammina sp., 6, 7: Pelycepoda,
8: Nonionella auris, 9: Bolivina 10: Elphidium advenum, 11: Astrononion stelligerum,
12: Melonis padanum, 13: Gyroidinoides neosoldanii, 14: Astrononion stelligerum,
15, 16: Globigerina sp., 17, 18: Globigerinoides quadrilobatus, 19, 20: Globigerinoides ruber,
21: Quingueloculina bicarinata, 22: Quingueloculina agglutinans, 23: Quinqueloculina seminulum

4. Discussion

The study area is one of the numerous barrier bars along the Nigerian coastline, as shown in the map (fig 1). The lithology of the beach sands is mainly sands with little silt fraction. The mechanical analysis, reveals a wide range of unimodal distribution of medium to fine to very fine sands with average mean size of 2.73 (fine sand). This suggest that the sediment were probably deposited in a dominantly low energy environment with fluctuation to a high energy depositional environment at some periods. The standard deviation (sorting) values range from well sorted through moderately well sorted to very well sorted, with an average of 0.42 (well sorted grains). Scatter plot of mean size versus sorting (standard deviation), shows a master trend which reveals that the best sorted sediments are those with mean sizes of about 2 to 3Φ (fine sand) (Folk, 1974). (Fig.2). similarly, the skeweness values vary from positively skewed through negatively skewed through very negatively skewed with an average of -0.34 (very negatively skewed). This result implies that the fine admixture exceeds the coarse sediments in the distribution. A plot of skewness confirms the sinuous nature of the beach profile as seen in the depth profile above sea level (Figure 3 and 4). The kurtosis values range from platykurtic through mesokurtic through leptokurtic through very leptokurtic to extremely leptokurtic with an average of leptokurtic. This strongly indicates that there was a better sorting at the tails of the distribution (Mason and Folk, 1958).

The roundness ranges from 0.3 (sub angular) through 0.7 (rounded) with mean roundness of 0.5 (sub rounded class) based on Power's visual chart, indicating reworking of pre-existing sediments. Sphericity values, using Powers, (1982) and Pettijohn et al, (1957) visual comparators, ranges from 0.25 to 0.700 (low to high) with mean of 0.48 (moderate). This suggest reworking of the sediments based on the fact that some of the grains exhibit high sphericity, which is a very slow process and cannot be achieved in one cycle as also revealed by the presence of associated angular to rounded grains of the same size. (Plate 1, and 2). Mineralogical composition of the Western Andoni Beach Sands shows that quartz (98.9%) is the dominant mineral with feldspar (0.6%) and rock fragments (0.5%). The grains show point to tangential, long, floating and concavo-convex contacts. These indicate that the sands are loosed and unconsolidated (Plate 1, 2, 3, and 4). The heavy mineral suite of stable minerals like garnet, staurolite, rutile and the near rounded zircon and tourmali grains, in conjunction with the white to light gray colour of the sands as seen in lithology, support a probably igneous to metamorphic source origin of the sands as drained by the River Niger/Benue through its distributary the Andoni River (plate 3 and 4).

The sedimentary structures observed are beddings, laminations and ripple marks (symmetrical and asymmetrical). The asymmetric ripples indicate that the sediments are loose and unconsolidated (Reinck and Singh, 1980; Potter 1978) indicating unidirectional current flow (figure 16 to 21). The order of the development of the ripples from less complex to complex bedforms, conforms with the decreasing water depth of the coastline from location 1 to location 10 (Boggs, 2006) towards the spit landform. Biogenic structures such as trace fossils of ophiomorpha and skolithos, indicates soft ground sandy shore within the sub-lithoral zone high water energy, diagnostic of shallow marine barrier beach environment (figure 19 and 20). The numerous benthic foraminifera forms found in the beach sands such as *Ammonia beccaii, Elphidium advenum, Melonis padanum, gyroidinoides nesoldanii. Quinqueloculina agglutinans* and some planktics such as *Globigerinoides quadrilobatus, Globorotalli sp* and *Globigerinoides rubber* (Plate 5, figure 15), may suggest that the beach sands are late Pliocene to Recent in age. This is further supported by the presence of few palynomorphs, such as Magnastrialites howardi and Psilatricolporites sp. (figure 15). Foraminiferal abundance decreased towards the Imo river (location 10) while diversity increased towards location 5 (location near the tidal channel) from both locations 1 and 10, while palynomophs abundance increased eastward towards Imo River and diversity decreased in the same direction (figure 10 and 11).

The paleoenvironmental reconstruction of the Andoni beach sands, based on sedimentary facies, (a product of the depositional environment), indicates that the geometry of the Andoni beach sands can probably be classified as sheet sand bodies type with great horizontal extent and thickness. Sheet sands are typically quartz arenites. The mean size of (2.69Φ) indicates a low to high energy depositional medium, while combination plots of skewness and kurtosis indicate a fluctuating environment. The Andoni beach sands are compositionaly matured with a heavy mineral suite typical of beach environments. The combination of the different types of sedimentary structures such as asymmetric, symmetric ripples and burrows of trace fossils Ichnogenera ophiomorpha and skolithos, found in the area all confirm a barrier beach environment. Based on the composition (textural and mineralogical), sedimentary structures, foraminifera of the various locations studied, a transitional (Marginal-marine) depositional environment is proposed for the Andoni beach sands. The depositional environment consists of several sub environments based on process interpretation as Barrier Island and near shore environments, barrier beach. This conforms to the beach/river sands discriminatory diagrams of Miola and Weiser (1968), Friedman (1967) presented in figs. 8 and 9 showing that the sand samples taken from the Andoni beach site are indeed beach sands, with a little overlap. Erosion trends along the coastline were based on depth above mean sea level, showing decreasing shoreline elevation at low tide moving from location 1 to 10, with a corresponding increase in the beach and floodplain elevation, signifying the presence and action of erosion taking place subtly without significant notice (figure. 5, 6 and 7)

The physiochemical ocean water quality indicates that the water is saline as can be seen from results of salinity and TDS. The pH shows fair to poor indicating very alkaline water. Turbidity is normal while Dissolved oxygen is poor confirming the pH, and indicating micro invertebrate population decline under such conditions along the coastline. The biochemical oxygen demand shows that the water is very poor and polluted containing organic waste, which is also confirmed by the total organic content. The water is very hard as indicated by the calcium and total hardness concentration. The total suspended solids and total solids indicate inorganic inferior water. Phosphate and total phosphate indicates an excellent level of phosphate concentration. The water has an excellent level of nitrate concentration with no nitrite and medium concentration of chemical oxygen demand. Total nitrogen, conductivity, chloride, sodium, sulphate, magnesium, calcium, potassium, bicarbonate and alkalinity indicate the water as natural/sea/ocean water (table 2). The water quality index is 48, confirming the quality of the water as bad as shown by other physiochemical parameters (table 3).

5. Conclusion

From the results of the analysis carried in this work, it can be concluded that the beach sands are quartz arenites, well sorted sub angular to rounded medium to very fine sands, very negatively skewed, and leptokurtic thus suggesting that the sands were probably deposited in a low energy environment with fluctuations to high energy. The average mean size decreases in an easterly direction as indicated by the mean trends as well as the foraminifera taxa, while the palynomorps taxa increases. This is possibly a reflection of flow direction of the depositing coastal currents eastwards. The heavy minerals found include garnet, staurolite, zircon, tourmaline and rutile suggesting igneous and metamorphic source rocks as the original derivation of the sands from. Foraminifera and palynomorphs found points to a late Pliocene (Recent) age and beach sands deposition in a non-marine - middle neritic paleo-water depth. The water quality index is 48 strongly showing that the water is polluted (table 3). Figs. 7, 9 and 10 categorically show that the shoreline has encroached on the beach at locations 1, 2 and 4. If nothing is done quickly, there will soon be nothing left of the western Andoni coastline beaches.

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