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Mineralogy and Textural Properties of Sandbar Deposits in River Forcados along Patani and Environs

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ABSTRACT

Sixteen samples were taken from the top and bottom of a mid-channel sandbar within the lower reaches of Forcados River along Patani and environs to determine the mineralogy and textural characteristics of the sediment. XRF was used for the bulk chemistry and grain size analysis was used to determine the statistical parameters. The grain size analysis shows the sediments are majorly fine grained sediments transported by suspension transport in a low energy regime. The mean ranges from 3.43 ϕ – 6.30 ϕ with an average of 5.93 ϕ, which is coarse silt size grade. The values of the median range from 5.60 ϕ – 6.40 ϕ with an average of 6.09 ϕ in the medium silt size grade. The modal class is >6 ϕ; the sediments are unimodal. They are moderately well sorted with average sorting value of 0.63 σ, negatively skewed with a value of -0.12 on the average and very leptokurtic with an average value of 1.69. These are a reflection of the maturity of the river and the distance and duration of travel of sediment from source. The proportion of coarse grains is very minimal and the sediment size indicates a down current decrease in grain size. The bulk chemistry shows enrichment in quartz (SiO_2); with average concentration value above 82% which indicates sediment maturity. Also, there is enrichment of MgO, Fe_2O_3, P_2O_5, CaO and TiO_2 in some of the locations, which may be related to localize formation of clay minerals and carbonates such as dolomite. SiO_2/Al_2O_3 ratio ranges from 14.550 to 20.914. This indicates SiO_2 enrichment, sediment maturity and also, infers intense weathering and long distance of travel that enabled the weathering. The sediment can therefore be further concentrated and mined for silica for industrial uses or dredged for high quality construction and engineering material.

Keywords: Sandbar, Grain size, Oxide analysis, Fluvial system, Maturity of sediment

INTRODUCTION

River Niger is one of the major rivers in Nigeria; it takes its course from Futa Jalon highlands of Guinea in the north and bifurcates into River Forcados and River Nun just after Aboh town down south. The River Forcados drains towards the west into the Atlantic Ocean, whereas, River Nun drains down south. Patani town and environs are along the course of River Forcados on its route to the Atlantic Ocean. There are a lot of sedimentary environments associated with River Forcados along Patani and environs which indicate the maturity of the river at the study area. Examples of such are the associated sandbars and floodplains which form an intricate network with the river. These environments derive their sediment load from the weathering and erosion of the various areas drained by the River Forcados as it moves from source down south to the Atlantic Ocean. The sediment load of a typical river is composed of the different grades of sediment: gravels, sands, silt, clay, organic matter and dissolved ions. The weathering, erosion and transportation of these sediments are affected by the climate, drainage, vegetation and basically the geology of the drained areas. Some of these sediments are deposited on channel beds, flood plains, sandbars and other depositional environments especially in the lower reaches of the river before some are carried through to the Ocean basin (Reineck & Singh, 1980).

Sandbars are ridges or topographic highs within a river channel. They may be partly exposed or completely submerged ridges. They have different forms and shapes depending on their position or location with respect to the river. Their formation is influenced by the river morphology, sediment supply and wave energy. They occur in rivers, estuaries, coastal sea environment, and marine environment: sub-tidal and inter-tidal zones (Sassa & Watabe, 2009). Several types of sandbars are observed in the study area: these include pointbars and linear (mid – channel) bars.

The study area is within latitudes N05º14'10.6" and N05º14'12.6" and longitude E006º12'32.4" and E006º12'38.4 (Figure 1). This study hopes to look at the mineralogy and texture of sediment in the mid channel sandbars that occur in River Forcados along Patani and environs. This is important for the river management and the suitability of sediment for mining of minerals and dredging of sediment for industrial, construction and engineering purposes.

GEOLOGY OF THE STUDY AREA

The study area is within the Niger Delta Basin. The surface geology of the study area is made up of Quaternary sediments composed of gravels, sands, silts and clays which occur in alluviums, swamps, meander belts, mangroves, beaches etc., these are prevalent in the Niger Delta basin, while, the subsurface geology is made up of three lithostratigraphic units from Palaeocene to Eocene. These are: The Akata Formation, Agbada Formation and the Benin Formation. The basal Akata Formation is basically shale, the Agbada consists of intercalations of shale and sand, it is sandier towards the top. The overlying Benin Formation is made up of Coastal medium sand with subordinate silt and clay lenses (Akpokodje, 1987; (Table 1)).

LITERATURE REVIEW

Rivers carry a wide range of particle sizes from the source: coarse grained sediments like gravels, pebbles that lag behind and sands which form the bed load accumulate at the channel bottom, while fine grained sediments like silt and clay form the suspension load (Reineck & Singh, 1980).

The fluvial system is made up of three geomorphologic zones, which are: the erosional zone, the transfer zone and the deposition zone. Sediments deposited in the depositional zone are in river channels and floodplains or on the surface of alluvial fans which constitute the zone (Nichol, 2009).

Figure 1: Map showing River Forcados along Patani and environs (Google map)

Table 1: Stratigraphic Column of the Niger Delta (Akpokodje, 1987)

Geologic Unit	Lithology	Age
Alluvium (General)	Gravel, sand, clay, silt	
Freshwater Backswamp, Meander Belt	Sand, clay, some silt gravel	
Mangrove and Salt Water/Backswamps	Medium fine sands, clay and some silt	Quaternary
Active /Abandoned Beach Ridges	Sand, clay, and some silt	
Sombreiro – Warri Deltaic Plain Sand	Sand, clay, and some silt	
Benin Formation Coastal Plain Sand	Coarse to medium sand with subordinate silt and clay lenses	Miocene
Agbada Formation	Mixture of sand, shale and silt	Eocene
Akata Formation	Shale	Palaeocene

Also, according to Nichols (2009), rivers are known as bedload rivers when their sediment load is massively made up of clastic materials that are transported by traction and saltation. The sediments are deposited in the channel floor as bars of sand and gravels. The bars are covered during high flow or flood, when sediments are mainly transported, but are exposed during low flow stages.

Pettijohn (2004) acknowledged that there is down current decrease in grain size and attributed it to several factors, which include the following: nature of bed material and abrasion during transport, size and nature of material, stream gradient and competence, duration and distance involved, size and proportion of associated materials, etc.

Rivers serve as medium for transporting weathered materials from source rock to where they are deposited. The fluvial system consists of the channel, sandbars and floodplain environments. Transported materials are deposited along these various sub-depositional environments en-route the ocean basin. These materials are made up of products of both physical and chemical weathering of source rock. The most stable products of chemical weathering are clay minerals, iron oxides and hydroxides and aluminium hydroxides (Misra, 2012).

Sandbars are depositional structures that form when current: water, waves or wind deposit sand, gravels and other granular sediments in specific patterns. Sandbars form in fluvial systems, coastal and shoreline environments. Several types of sandbars occur in rivers and other bodies of water, examples of fluvial bars are: longitudinal bars, transverse bars, mid-channel bars, pointbars, etc. (Reineck & Singh, 1980).

Sandbars are very common in beaches; they form part of beach morphology. They are formed when wave actions arrange unconsolidated sediments in patterns which may be parallel, rhythmic or irregular bodies of granular sediments in shallow waters at the shoreline (Plant et al., 1999).

MATERIALS AND METHODS

The study employed a combination of field work and laboratory analyses. Sixteen sediment samples were collected from various locations at the top and bottom of the mid – channel elongate sandbar in the axis of the meander of the Forcados River in Patani, using sampling bags, a pail and other appropriate equipment. For the laboratory analyses, eight of the samples collected from the top and bottom parts of the sandbar were used. The geo-references of sample points and physical description of samples are listed in Table 2.

The textural characterization of the sediment from the sandbars was done by mechanical sieving and graphical determination of statistical parameters after Folks and Wards, 1957, while, the mineralogical constituents were analysed by oxide analysis using XRF for the bulk chemistry.

PRESENTATION AND DISCUSSION OF DATA

Table 2 shows the geo –references of the sample points, grain sizes, colour and lithologies of the sediment collected from the sandbar at the middle of the river.

Table 2: Sampling Points for Sandbars

Location No.	Geo Reference	Grain sizes	Colour	Lithology
PAT4 Top	N05º14'10.7"	Fine	Brown	Fine Sand
PAT4 Bottom	E006º12'31.7"	Fine	Brown	Fine Sand
PAT5 Top	N05º14'10.6"	Fine	Brown	Fine Sand
PAT5 Bottom	E006º12'32.4"	Medium	Brown	Medium Sand
PAT6 Top	N05º14'11.0"	Fine	Brown	Fine Sand
PAT6 Bottom	E006º12'33.2"	Medium	Brown	Medium Sand
PAT7 Top	N05º14'11.1"	Fine	Brown	Fine Sand
PAT7 Bottom	E006º12'34.2"	Medium	Brown	Medium Sand
PAT8 Top	N05º14'10.7"	Silt	Dark Brown	Silt Sand
PAT8 Bottom	E006º12'35.0"	Fine	Brown	Fine sand
PAT9 Top	N05º14'10.9"	Very fine	Brown	Very fine sand
PAT9 Bottom	E006º12'36.9"	Medium	Brown	Medium Sand
PAT10 Top	N05º14'11.2"	Very fine	Brown	Very Fine Sand
PAT10 Bottom	E006º12'38.0"	Fine	Brown	Fine Sand
PAT11Top	N05º14'12.6"	Very Fine	Brown	Very fine Sand
PAT11 Bottom	E006º12'38.4"	Fine	Brown	Fine Sand

Grain Size Analysis

Samples were taken from the top and bottom areas of the sandbar and the statistical parameters determined from the grain size analysis included the mean, median, sorting, skewness and kurtosis according to Folks and Wards (1957). The values of the calculated statistical parameters and their average values are listed in Table 3. The average mean of the population of the sediment which is the average size grade is 5.93 ф, which is coarse silt size grade, the values range from 3.43 ф – 6.30 ф. The values of the median range from 5.60 ф – 6.40 ф with an average of 6.09 ф in the medium silt size grade. The modal class is > 6 ф. The sediments are moderately well sorted with average sorting value of 0.63σ. According to Tucker (1988), the grain size of the best sorted sediment usually approximate to a single size with low sorting (σ) values. The studied sediments are negatively skewed with a value of -0.12 on the average and very leptokurtic with an average value of 1.69 corroborating the sorting of the sediment.

Tables 4 and 5 show the weight % and cumulative weight % of sediment from the sandbar. Figures 2a and b are the plots of cumulative weight % versus grain size of the sediment from sample points on the top and bottom of the sandbar respectively. They indicate that the grain size of most of the sediment is >5 ф, and is fine grained sediment transported by suspension transport in a low current energy regime (Reineck & Singh, 1980). Sediments of other modes of transport are minimal in the studied population

The results show a predominance of grain size in the medium silt size grade and below >6 ф, with a very few occurrences in the coarse silt fraction (5 ф – 6 ф). The frequency histograms show the sediment is unimodal in the medium silt size grade at the top and bottom of the sandbar (Figures 3a and b).

The sediment size grades which are in the coarse to medium silt and below with an average mean size in the coarse silt fraction and averagely moderately well sorted is a reflection of the maturity of the river and the distance and duration of travel of sediment from source. The coarse granular grains in the sand and gravel class are very minimal in the sediment load; these may have been deposited along the channel route from the provenance point. The study area is in the far reaches of the Forcados River, the sediment size is likely indicating a down current decrease in grain size (Pettijohn, 2004).

Table 3: Grain size statistical parameters for sandbars sediments

Sample No.	Mean (M) ϕ	Median (Md) ϕ	Sorting (σ)	Graphic Skewness	Kurtosis
PAT4 Top	6.00	6.10	0.36	-0.23	1.64
PAT4 Bottom	6.06	6.00	0.32	-0.17	1.78
PAT5 Top	6.00	6.00	0.39	0.12	3.33
PAT5 Bottom	5.96	6.00	0.78	0.03	1.50
PAT6 Top	6.30	6.30	0.45	-0.14	1.39
PAT6 Bottom	6.13	6.30	0.32	0.07	1.03
PAT7 Top	6.26	6.10	0.49	-0.16	1.23
PAT7 Bottom	6.23	6.30	0.38	0.33	3.00
PAT8 Top	3.43	5.60	3.17	-0.81	0.50
PAT8 Bottom	6.16	6.20	0.47	0.25	1.16
PAT9 Top	6.30	6.30	0.33	0.43	0.90
PAT9 Bottom	6.26	6.40	0.46	-0.30	4.58
PAT10 Top	6.16	6.20	0.47	-0.25	0.87
PAT10 Bottom	5.86	5.90	0.60	0.16	0.97
PAT11Top	5.76	6.00	0.50	-1.02	2.26
PAT11 Bottom	5.96	5.80	0.55	-0.22	0.97
Average	5.93 (Coarse Silt)	6.09 (Medium Silt)	0.63 (Moderately well sorted)	- 0.12 (Negatively skewed)	1.69 (Very leptokurtic)

Table 4: Weight % of Sandbars

Class Interval	Weight % 4Top	Weight % 4Bot	Weight % 5Top	Weight % 5Bot	Weight % 6Top	Weight % 6Bot	Weight % 7Top	Weight % 7Bot	Weight % 8Top	Weight % 8Bot	Weight % 9Top	Weight % 9Bot	Weight % 10Top	Weight % 10Bot	Weight % 11Top	Weight % 11Bot
-1	0.22	0.19	0.39	0.83	0.42	0.7	0.35	0.49	28.81	0.79	0.49	0.28	0.38	0.35	0.49	0.76
0-1	0.22	0.19	0.39	0.51	0.42	0.56	0.35	0.49	1.29	0.5	0.49	0.28	0.38	0.35	0.63	0.76
1 – 2	0.22	0.19	0.39	0.51	0.42	0.7	0.47	0.64	1.68	0.5	0.49	0.28	0.38	0.47	0.34	0.91
2 – 3	0.33	0.27	0.39	0.51	0.42	0.56	0.35	0.64	1.29	0.5	0.49	0.28	0.51	0.47	0.63	0.91
3 – 4	0.22	0.19	0.39	0.67	0.3	0.56	0.47	0.64	1.1	0.65	0.49	0.28	0.38	0.58	0.77	0.91
4 – 5	0.44	0.73	0.39	0.51	0.3	0.7	0.47	0.78	1.1	0.65	0.49	0.39	0.51	0.7	0.92	1.37
5 – 6	0.99	5.78	2.08	4.76	0.54	3.01	1.69	1.23	3.2	2.91	2.79	1.42	7.04	17.73	12.47	13.3
>6	97.35	92.43	95.54	91.65	97.14	93.17	95.82	95.07	61.48	93.46	94.25	96.74	90.39	79.31	83.67	81.03

Table 5: Cumulative weight % of Sandbars

Class Interval	Cumulative Weight % 4Top	Cumulative Weight % 4Bot	Cumulative Weight % 5Top	Cumulative Weight % 5Bot	Cumulative Weight % 6Top	Cumulative Weight % 6Bot	Cumulative Weight % 7Top	Cumulative Weight % 7Bot	Cumulative Weight % 8Top	Cumulative Weight % 8Bot	Cumulative Weight % 9Top	Cumulative Weight % 9Bot	Cumulative Weight % 10Top	Cumulative Weight % 10Bot	Cumulative Weight % 11Top	Cumulative Weight % 11Bot
-1	0.22	0.19	0.39	0.83	0.42	0.7	0.35	0.49	28.81	0.79	0.49	0.28	0.38	0.35	0.49	0.76
0-1	0.44	0.38	0.78	1.34	0.84	1.26	0.7	0.98	30.1	1.29	0.98	0.56	0.76	0.7	1.12	1.56
1 – 2	0.66	0.57	1.17	1.85	1.26	1.7	1.17	1.62	30.78	1.79	1.47	0.84	1.14	1.17	1.46	2.43
2 – 3	0.99	0.84	1.56	2.36	1.68	2.52	1.52	2.26	33.07	2.29	1.96	1.12	1.65	1.64	2.09	3.34
3 – 4	1.21	1.03	1.95	3.03	1.98	3.08	1.99	2.9	34.17	2.94	2.45	1.4	2.03	2.22	2.86	4.25
4 – 5	1.65	1.76	2.34	3.51	2.28	3.78	2.46	3.68	35.27	3.59	2.94	1.79	2.54	2.92	3.78	5.62
5 – 6	2.64	7.54	4.42	8.3	2.82	6.79	4.15	4.91	38.47	6.5	5.73	3.12	9.58	20.65	16.25	18.92
>6	99.99	99.97	99.96	99.95	99.96	99.96	99.97	99.98	99.95	99.96	99.98	99.95	99.97	99.96	99.92	99.95

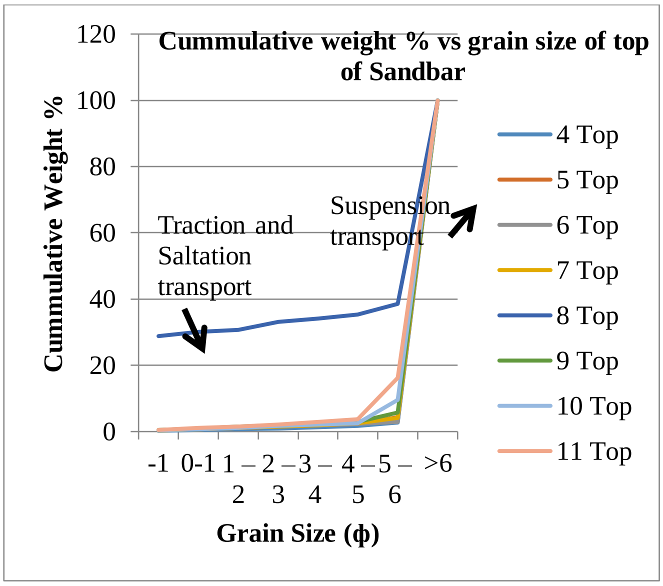

Figure 2a: Cumulative weight % vs grain size of top of sandbar

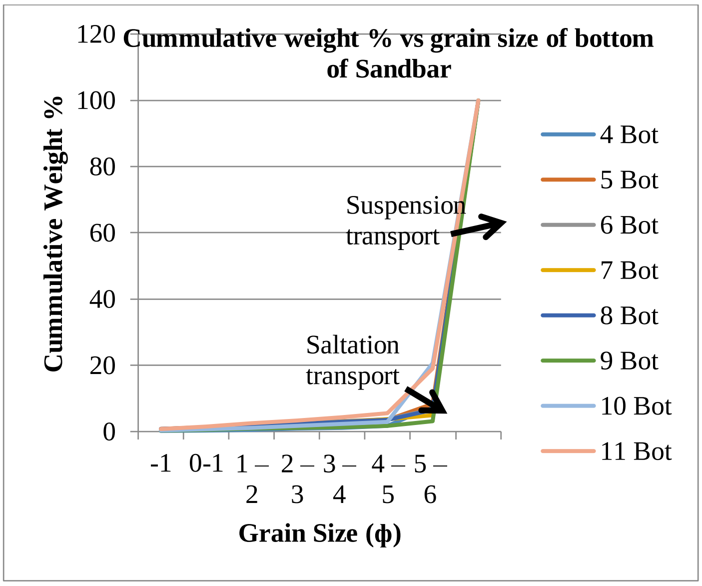

Figure 2b: Cumulative weight % vs grain size of bottom of sandbar

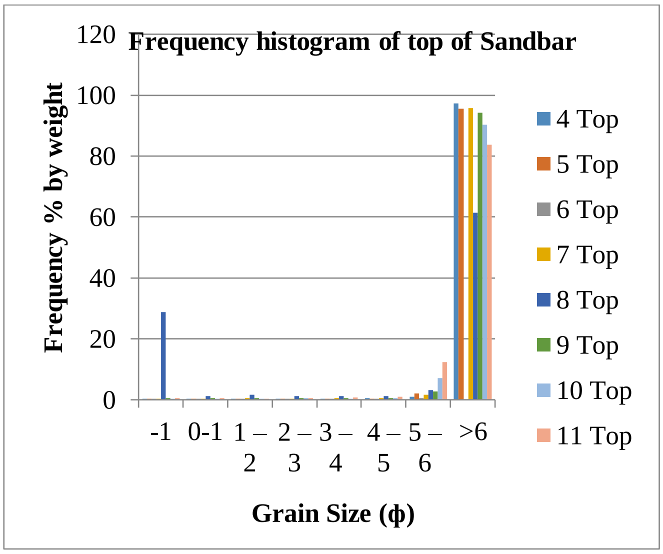

Figure 3a: Frequency histogram of top of sandbar

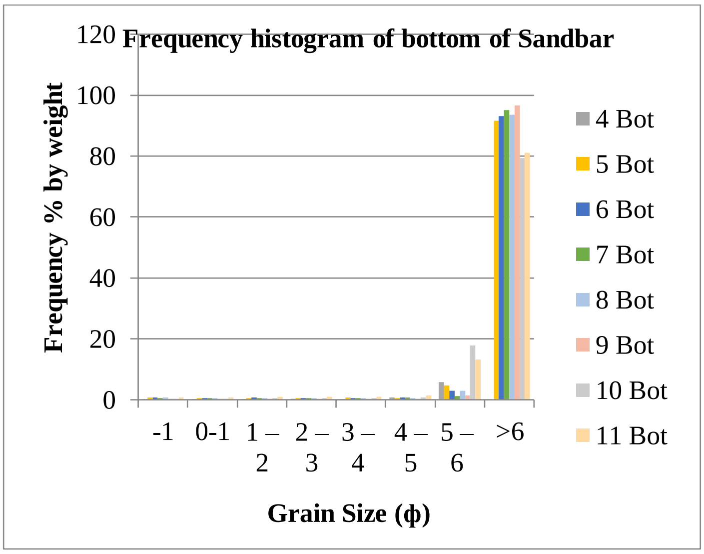

Figure 3b: Frequency histogram of bottom of sandbar

Mineralogy

Table 6a: MINERALOGY (OXIDE ANALYSIS) OF SANDBARS

	Oxide analysis of sediments (concentration in WT %)						Elemental constituents of sediments (concentration in WT %)					
		PAT4 Top	PAT4 Bottom	PAT6 Top	PAT6 Bottom	AVE		PAT4 Top	PAT4 Bottom	PAT6 Top	PAT6 Bottom	AVE
1	SiO_2	**88.325**	**87.722**	**89.911**	**89.732**	**88.923**	O	51.304	50.805	51.731	51.461	51.325
2	V_2O_5	0.012	0.020	0.025	0.037	0.024	Mg	0.000	0.000	0.000	0.000	0
3	Cr_2O_3	0.069	0.037	0.072	0.092	0.068	Al	3.141	3.190	2.275	2.399	2.751
4	MnO	0.049	0.060	0.000	0.006	0.029	Si	41.287	41.005	42.028	41.945	41.566
5	Fe_2O_3	0.831	**1.341**	0.696	0.959	0.957	P	0.000	0.021	0.630	0.032	0.171
6	Co_3O_4	0.017	0.032	0.041	0.004	0.024	S	0.368	0.000	0.201	0.381	0.238
7	NiO	0.001	0.001	0.005	0.006	0.004	Cl	0.796	0.851	0.793	0.799	0.810
8	CuO	0.015	0.084	0.059	0.045	0.051	K	1.722	2.111	1.025	1.353	1.553
9	Nb_2O_3	0.008	0.007	0.007	0.007	0.007	Ca	0.409	0.322	0.309	0.371	0.353
10	MoO_3	0.006	0.006	0.004	0.004	0.005	Ti	0.126	0.219	0.105	0.156	0.152
11	WO_3	0.006	0.004	0.000	0.021	0.008	V	0.007	0.011	0.014	0.021	0.013
12	P_2O_5	0.000	0.049	**1.444**	0.074	0.392	Cr	0.047	0.025	0.049	0.063	0.046
13	SO_3	0.918	0.000	0.501	0.951	0.593	Mn	0.038	0.046	0.000	0.005	0.022
14	CaO	0.572	0.450	0.432	0.519	0.493	Fe	0.581	0.938	0.487	0.671	0.670
15	MgO	0.000	0.000	0.000	0.000	0.000	Co	0.012	0.023	0.030	0.003	0.017
16	K_2O	**2.074**	**2.542**	**1.235**	**1.630**	**1.870**	Ni	0.001	0.001	0.004	0.005	0.003
17	BaO	0.057	0.278	0.207	0.179	0.180	Cu	0.012	0.067	0.047	0.036	0.041
18	Al_2O_3	**5.934**	**6.027**	**4.299**	**4.534**	**5.199**	Zn	0.002	0.001	0.011	0.000	0.004
19	Ta_2O_5	0.049	0.079	0.053	0.086	0.068	Sr	-	-	-	-	
20	TiO_2	0.210	0.365	0.176	0.261	0.253	Zr	0.016	0.013	0.009	0.025	0.016
21	ZnO	0.002	0.002	0.013	0.000	0.004	Nb	0.006	0.006	0.006	0.006	0.006
22	Ag_2O	0.028	0.025	0.015	0.018	0.022	Mo	0.004	0.004	0.003	0.003	0.004
23	Cl	0.796	0.851	0.793	0.799	0.810	Ag	0.026	0.024	0.014	0.017	0.020
24	ZrO_2	0.021	0.017	0.012	0.034	0.021	Sn	0.000	0.000	0.000	0.000	0.000
25	SnO_2	0.000	0.000	0.000	0.000	0.000	Ba	0.051	0.249	0.185	0.161	0.162
26	SrO	0.000	0.000	0.000	0.000	0.000	Ta	0.040	0.065	0.043	0.070	0.055
							W	0.005	0.004	0.000	0.017	0.007
	SiO_2/Al_2O_3	14.884	14.555	20.914	19.791	17.536						

Table 6b.: MINERALOGY (OXIDE ANALYSIS) OF SANDBARS (CONTD)

	Oxide analysis of sediments (concentration in WT %)						Elemental constituents of sediments (concentration in WT %)					
		PAT7 Top	PAT7 Bottom	PAT11 Top	PAT11 Bottom	AVE		PAT7 Top	PAT47 Bottom	PAT11 Top	PAT11 Bottom	AVE
1	SiO_2	**85.690**	**82.390**	**77.595**	**86.210**	**82.971**	O	51.078	50.729	49.633	50.623	**50.516**
2	V_2O_5	0.067	0.018	0.090	0.013	**0.047**	Mg	3.189	5.242	2.035	0.000	**2.617**
3	Cr_2O_3	0.147	0.054	0.056	0.073	**0.083**	Al	2.394	2.205	4.852	3.136	**3.147**
4	MnO	0.014	0.025	0.066	0.074	**0.045**	Si	40.055	39.249	36.272	40.299	**38.969**
5	Fe_2O_3	0.812	0.462	**2.172**	**1.482**	**1.232**	P	0.074	0,000	0.005	0.027	**0.035**
6	Co_3O_4	0.007	0.000	0.034	0.007	**0.012**	S	0.268	0.000	0.132	0.044	**0.111**
7	NiO	0.005	0.002	0.002	0.025	**0.009**	Cl	0.779	0.603	0.578	0.844	**0.701**
8	CuO	0.023	0.016	0.043	0.059	**0.035**	K	0.967	1.159	2.534	2.115	**1.694**
9	Nb_2O_3	0.004	0.005	0.005	0.010	**0.006**	Ca	0.184	0.079	0.839	0.586	**0.422**
10	MoO_3	0.006	0.004	0.003	0.002	**0.004**	Ti	0.140	0.071	1.204	0.897	**0.578**
11	WO_3	0.001	0.011	0.012	0.000	**0.006**	V	0.037	0.010	0.051	0.007	**0.026**
12	P_2O_5	0.170	0.000	0.011	0.061	**0.061**	Cr	0.101	0.037	0.038	0.050	**0.057**
13	SO_3	0.670	0.000	0.330	0.110	**0.278**	Mn	0.011	0.019	0.051	0.058	**0.035**
14	CaO	0.257	0.110	**1.174**	0.020	**0.390**	Fe	0.568	0.323	1.519	1.037	**0.862**
15	MgO	**5.288**	**8.692**	**3.374**	0.000	**4.339**	Co	0.005	0.000	0.025	0.005	**0.009**
16	K_2O	**1.165**	**1.396**	**3.052**	**2.547**	**2.04**	Ni	0.004	0.002	0.002	0.019	**0.007**

17	BaO	0.059	0.120	0.038	0.078	**0.074**	Cu	0.018	0.013	0.034	0.047	**0.028**
18	Al_2O_3	**4.524**	**4.355**	**9.168**	**5.925**	**5.993**	Zn	0.000	0.002	0.001	0.004	**0.002**
19	Ta_2O_5	0.045	0.011	0.045	0.063	**0.041**	Sr	-	-	-	-	**-**
20	TiO_2	0.233	0.119	**2.009**	**1.495**	**0.964**	Zr	0.011	0.010	0.085	0.062	**0.042**
21	ZnO	0.000	0.002	0.001	0.005	**0.002**	Nb	0.003	0.004	0.004	0.008	**0.005**
22	Ag_2O	0.018	0.017	0.022	0.010	**0.018**	Mo	0.004	0.002	0.002	0.001	**0.002**
23	Cl	0.779	0.603	0.578	0.844	**0.701**	Ag	0.017	0.016	0.021	0.010	**0.016**
24	ZrO_2	0.015	0.013	0.115	0.084	**0.057**	Sn	0.000	0.000	0.001	0.000	**0.0003**
25	SnO_2	0,000	0.000	0.002	0.000	**0.001**	Ba	0.053	0.107	0.034	0.070	**0.066**
26	SrO	-					Ta	0.037	0.009	0.037	0.51	**0.148**
							W	0.001	0.009	0.009	0.000	**0.005**
	SiO_2/Al_2O_3	18.941	18.918	8.464	14.550	15.218						

Table 6a and b show the oxide analysis and elemental concentration of minerals in the analysed sandbar. The sandbar sediments are enriched in SiO_2, K_2O, Al_2O_3 and all their associated elements in all the samples but enrichment in MgO, Fe_2O_3, P_2O_5, CaO and TiO_2 is only in some of the locations. The sediments are depleted in all the other analysed oxides and their associated elements. Sediments are said to be enriched in a particular oxide when its value is >1, it is depleted, when the values is <1, and no change in its relative abundance when it is = 1. Silica (SiO_2) is the most dominant mineral in the sediment, its concentration ranges from: 77.595 to 89.732. This is followed by Al_2O_3, with arrange of 4.299 to 9.168. K_2O ranges from 1.165 to 3.052. MgO occurs only in three of the samples and enrichment ranges from 3.374 to 8.692, also, there is enrichment of Fe_2O_3, P_2O_5, CaO and TiO_2 in some of locations, which may be related to localized formation of clay minerals and carbonates such as dolomite. NaO does not occur in the sediment. The abundance of silica (SiO_2) is attributed to its stability and resistance to weathering. The enrichment in K_2O and Al_2O_3 observed in the sediment can be alluded to the formation of clay minerals which are usually end products of weathering of silicate minerals (Misra, 2012). The complete non - occurrence of NaO could be as result of the intense weathering or non-occurrence in the source rock. The depletion of the other analysed minerals may be due to their instability and weathering during transport.

The maturity of sediment is related to the abundance of quartz in it. Quartz is a very stable mineral, the enrichment in quartz indicates that most of the unstable minerals have been weathered out. The studied sediments are very high in quartz content; they have an average value that is above 82%, which indicate that the sediments are very mature. SiO_2/Al_2O_3 ratio is another measure of maturity, high values of the ratio show that the sandstone is mature, while low values indicate immaturity (Roser & Korch, 1986; Roser et al., 1996). SiO_2/Al_2O_3 values of the sediment are very high. They range from 14.550 to 20.914. This indicates SiO_2 enrichment and infers intense weathering and long distance of travel that enabled the weathering (Roser et al., 1996; Pettijohn, 2004; Akpofure & Udeji, 2024).

Therefore, the sediments are very mature and are composed of high degree of silica with minimal impurities. The sediments can therefore be further concentrated and mined for silica for industrial uses or dredged for high quality construction and engineering material.

CONCLUSION

The study area is in the far reaches of the Forcados River which is a tributary of River Niger located in Patani and environs in the Niger Delta basin. The grain size of the sandbar shows predominance of the medium silt size grade and below (>6 ф), with very few occurrences in the coarse silt fraction (5 ф – 6 ф). The sediments are unimodal. They are moderately well sorted with average sorting value of 0.63 σ, negatively skewed with a value of -0.12 on the average and very leptokurtic with an average value of 1.69. This is a reflection of the maturity of the river and the distance and duration of travel of sediments from source. The coarse granular grains in the sand and gravel class are minimal in the sediment load, these may have been deposited along the channel route downstream. The sediment size indicates a low current energy regime and down current decrease in grain size.

The sediments are mature, they show enrichment in silica, ranging from 77.595 to 89.732, Al_2O_3 ranges from 4.299 to 9.168 and K_2O ranges from 1.165 to 3.052. Also, there is enrichment of MgO, Fe_2O_3, P_2O_5, CaO and TiO_2 in some of the locations, which may be related to localize formation of clay minerals and carbonates such as dolomite. NaO does not occur in the sediments. The SiO_2/Al_2O_3 ratio, also, corroborate the maturity of the sands. The high values of the ratio range from 14.550 to 20.914, indicates maturity which may have been derived from intense weathering and long distance of travel.

Therefore, the sediments are rich in silica and are moderately well sorted. The silica content can be mined and concentrated further for industrial uses and also, the sediment can be dredged as high quality material for construction and engineering purposes.

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