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Oxide Analysis of River Bed Sediments from Lower Reaches of River Forcados along Patani and Environ

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Abstract: The river bed sediments of River Forcados along Patani and environs were sampled and taken to the laboratory for bulk analysis using XRD. It was observed that the sediments were silty clay to coarse sand. The sediment colour range from brown to grey. SiO_2 was observed to be the most abundant oxide with a concentration ranging from 58.660% to 84.258% with an average of 72.955%. The sediments are enriched in the following oxides: Sio_2, Al_2O_3, Fe_2O_3, K_2O, MgO, CaO and TiO_2. Whereas, the sands are depleted in the following oxides: V_2O_5, Cr_2O_3, MnO. Co_3O_4, NiO. CuO, Nb_2O_3, MoO_3, WO_3, P_2O_5, SO_3, BaO, Ta_2O_5, ZnO, Ag_2O, Cl, ZrO_2, SnO_2. Sodium in oxide form (NaO) or elemental form (Na) is not observed because its concentration is below detection limit of 0.01%. The SiO_2/Al_2O_3 ratio and the K_2O,/NaO ratios show that the sediments are mineralogically mature and have an acidic igneous rock source.

1. Introduction

River systems serve as one of the most prevalent means of transportation. They are the sediment travel path from the hinterlands or highland where weathering occurs to the different basins of deposition. Though, some sediments are preserved and deposited within and around the river channel with time depending on the channel shape, its sinuosity, braiding, anastomosing nature and associated floodplains, most are carried through to the terminal ocean, lake, or depositional basins. River bed sediments are bed loads transported by traction and saltation and deposited along the bottom of the river.

The study of mineral suite in sediment has given great insight into the source, climate and relief of area of formation of sediments. At the time of formation, most minerals are stable and at equilibrium with their environments. During weathering, erosion and transportation, the equilibrium and stability of these minerals are lost and they gradually begin to disintegrate, decompose or go into solution. Several evidences of stability and instability are observed on the remnant minerals. Some examples of instability are: corroded borders and etched surfaces, while, evidence of stability remain secondary growth or enlargement of minerals.

The River Niger is one of the major rivers that drain Nigeria. It flows from the north and bifurcates just below Abo into River Forcados and River Nun. River Nun with a length of about 160 km flows down south passing several communities in the south-south zone of Nigeria en-route to the Atlantic Ocean. Whereas, the Forcados with a length of about 198 km flows down west passing through several communities and empties into the Atlantic Ocean at the Bight of Benin in Delta State of Nigeria (Figure 1). Several sandbars, such as pointbars, meanders, linear bars and floodplains are some of the associated environments observed in River Forcados along Patani indicating a mature stage of the river. Patani community is one of the major communities on the river's path in the Niger Delta basin en-route to the Atlantic Ocean. Patani is the headquarters of Patani Local Government Area of Delta State, Nigeria. The area is low lying with an altitude of about 13.86m (45.48ft). The area is in the Tropical climate and has two seasons, which are: wet and dry seasons. The wet season is from April to October with a break of about two weeks in the month of August. The dry season starts in November to March. The harmattan wind is usually experienced within the dry season in the months of December and January [2]. The study area is within the Niger Delta Basin within latitudes N04^{O}58$^{'}$38.7$^{''}$ and N05^{O}14$^{'}$03.6$^{''}$ and longitudes E06^{O}06$^{'}$17.5$^{''}$ and E06^{O}11$^{'}$51.8$^{''}$. This study aims to look at the mineralogy of the river bed sediments of the River Forcados at Patani and environs with a view to evaluate the source rock.

Figure 1: Map showing River Forcados along Patani and environs.

2. Literature Review

Quaternary sands are found majorly in rivers, beaches, and to some extent as dunes in shallow near shore areas. Also, they occur as eolian dunes and marine sands on the shelf environment. .Alluvial sands are associated with fans, river channels and as sand splays on the floodplains. Today, most of the sites of accumulation of sands are linear, (in beaches and rivers), while extensive sheetlike strataforms existed in the past [4].

According to [4], the resultant sedimentary detrital residue is derived from the combined effect of the interaction of relief and climate on the source rock and also abrasion and sorting during transportation. He also observed that compositional changes occur in sediments downstream. The changes show rapid elimination of unstable minerals resulting to the enrichment of the more stable minerals.

Sediments of a wide range of particle sizes are carried by rivers. This range from coarser sediments like gravels and pebbles which lag behind; sands which are carried as bed loads and silt and clays which are carried faster in suspension. Accumulation of coarse grained sediments takes place at the channel bottom [5].

Alluvial sands are one of the most common categories of modern sands. The average modern sands are immature to submature sands texturally and compositionally, with exception to those derived from supermature sandstones [4]. Also, he opined that modern sands lack matrix making them remarkably deficient in CaO and CO_2, unlike, their ancient counterparts.

3. Stratigraphy

The stratigraphy of the Niger Delta basin is made up of the basal Akata Formation, overlain by the Agbada Formation and the topmost lithologic unit is the Benin Formation. The Akata Formation is Paleocene to Recent marine shales that serve as the major petroleum source rock of the basin. The Agbada Formation (Eocene to Recent), consists of intercalations of shale and sands and becomes sandier towards the top. It serves as the major petroleum reservoir of the basin. The Benin Formation contains the major aquifer of the region. The age is from Miocene to Recent. It is made up of medium to coarse grain sands with few clay lenses in places. Above the Benin Formation are Quaternary deposits – gravels, sand, silt and clays that have been described by [1], see Table 1.

Table 1: Stratigraphic Column of the Niger Delta [1].

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	Paleocene

4. Methodology

The methods employed were basically divided into field analysis and laboratory analysis. The field analysis involved the collection of river bed sediments by a diver using a pail and labeled accordingly. The sample locations were spaced about 100m apart on the course of the Forcados River along Patani and environs downstream. 12 locations were visited and 12 samples collected for analysis. Table 2 gives the sample points and their requisite information. The samples were then taken to the laboratory for oxide analysis. XRF was used for the bulk chemistry to determine the elemental constituents of the sediments.

5. Presentation Of Results

Table 2: Description of Sampled Sediments and Location

SAMPLE NO.	LOCATIONS	GEO. REFERENCE	GRAIN SIZE	COLOUR	ROCK TYPES/DESCRIPTION
RB1	1.	N04^{O}58΄38.7” E06^{O}06΄17.5”	Medium grain	Brown	Medium sand
RB2	2.	N05^{O}13΄43.1” E06^{O}11΄37.7”	Fine grain	Brown	Fine sand
RB3	3.	N05^{O}13΄46.1”	Coarse grain	Brown/Grey	Coarse sand

		E06^{O}11`39.6”			
RB4	4.	N05^{O}13`49.4”	Silty-clay/clayey silt	Dark	Silty clay
		E06^{O}11`41.5”			
RB5	5.	N05^{O}13`49.4”	Fine grain	brown	Fine sand
		E06^{O}11`41.6”			
RB6	6.	N05^{O}13`56.0”	Coarse grain	Brown	Coarse sand
		E06^{O}11`46.5”			
RB7	7.	N05^{O}13`57.5”	Coarse grain	Brown	Coarse sand
		E06^{O}11`47.2”			
RB8	8.	N05^{O}13`59.3”	Fine grain	Brown	Fine sand
		E06^{O}11`49.0”			
RB9	9.	N05^{O}13`59.3”	Medium grain	Pale Brown/Brown	Medium sand
		E06^{O}11`49.0”			
RB10	10.	N05^{O}14`01.5”	Coarse grain	Dark Grey	Coarse sand
		E06^{O}11`50.5”			
RB11	11.	N05^{O}14`02.3”	Silty clay	Dark Grey	Silty clay
		E06^{O}11`51.0”			
RB12	12.	N05^{O}14`03.6”	Silty clay	Dark Grey	Silty clay
		E06^{O}11`51.8”			

Table 3: Elemental Constituents of Sediments from River Forcados along Patani and Environs

	OXIDE ANALYSIS OF SEDIMENTS (CONCENTRATION IN WT %)						ELEMENTAL CONSTITUENTS OF SEDIMENTS (CONCENTRATION IN WT %)					
	RB1	RB1	RB3	RB8	RB11	AVE		RB1	RB3	RB8	RB11	AVE
1	SiO2	76.668	84.258	72.234	58.660	72.955	O	49.010	50.882	48.084	46.519	48.624
2	V2O5	0.051	0.000	0.090	0.104	0.061	Mg	0.000	0.000	2.985	2.437	1.356
3	Cr2O3	0.044	0.047	0.068	0.032	0.048	Al	5.664	4.120	4.069	9.415	5.817
4	MnO	0.089	0.026	0.098	0.259	0.118	Si	35.838	39.386	33.765	27.420	34.102
5	Fe2O3	2.952	1.590	3.093	9.697	4.243	P	0.000	0.547	0.233	0.071	0.213
6	Co3O4	0.011	0.029	0.014	0.036	0.023	S	0.160	0.174	0.150	0.085	0.142
7	NiO	0.002	0.004	0.002	0.000	0.002	Cl	0.854	0.652	1.351	0.738	0.899
8	CuO	0.060	0.066	0.051	0.054	0.058	K	3.720	1.966	3.515	3.473	3.169
9	Nb2O3	0.009	0.008	0.008	0.016	0.010	Ca	1.333	0.599	1.211	1.138	1.070
10	MoO3	0.001	0.005	0.002	0.006	0.004	Ti	0.877	0.273	1.624	1.162	0.984
11	WO3	0.013	0.004	0.005	0.000	0.006	V	0.029	0.000	0.050	0.058	0.034
12	P2O5	0.000	1.254	0.534	0.162	0.488	Cr	0.030	0.032	0.047	0.022	0.033
13	SO3	0.400	0.436	0.375	0.213	0.356	Mn	0.069	0.021	0.076	0.200	0.092
14	CaO	1.865	0.838	1.694	1.592	1.497	Fe	2.065	1.112	2.163	6.782	3.031
15	MgO	0.000	0.000	4.949	4.041	2.248	Co	0.008	0.021	0.011	0.027	0.017
16	K2O	4.481	2.368	4.235	4.184	3.817	Ni	0.002	0.003	0.001	0.000	0.002
17	BaO	0.122	0.055	0.076	0.188	0.110	Cu	0.048	0.053	0.041	0.043	0.046
18	Al2O3	10.701	7.785	7.688	17.788	10.991	Zn	0.000	0.003	0.002	0.009	0.004
19	Ta2O5	0.053	0.047	0.046	0.070	0.054	Zr	0.105	0.035	0.486	0.147	0.193
20	TiO2	1.462	0.456	2.708	1.938	1.641	Nb	0.007	0.007	0.006	0.012	0.008
21	ZnO	0.000	0.003	0.003	0.012	0.005	Mo	0.001	0.003	0.002	0.004	0.003
22	Ag2O	0.019	0.020	0.019	0.011	0.017	Ag	0.018	0.018	0.018	0.010	0.016
23	Cl	0.854	0.652	1.351	0.738	0.899	Sn	0.000	0.000	0.000	0.000	0
24	ZrO2	0.142	0.047	0.657	0.198	0.261	Ba	0.109	0.049	0.068	0.168	0.099
25	SnO2	0.000	0.000	0.000	0.000	0	Ta	0.044	0.039	0.038	0.057	0.045
							W	0.010	0.003	0.004	0.000	0.004
	SiO2/Al2O3	7.163	10.823	9.396	3.298	7.669						

6. Discussion

6.1 Field Analysis

12 samples were collected from 12 different locations which were about 100 km apart from the next. The grain sizes range from silty-clay to coarse sand sediments. Most of the sediments were light brown to brown with the last 3 samples downstream grey in colour (Table 2).

6.2 Oxide Analysis

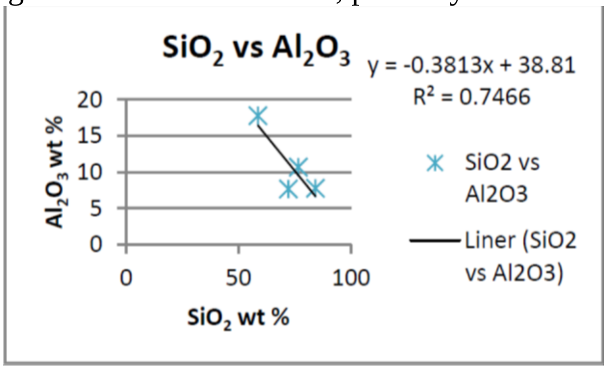
The concentration by weight percent of elemental constituent of the sediments is presented in Table 3 as oxides and in elemental form. Using the elemental ratio, values >1, means enrichment, <1 is indicative of depletion, and =1 shows that the relative abundance of the element did not change. It is observed that the sediments are enriched in the following oxides which occur with >1. They are; Sio_2, Al_2O_3, Fe_2O_3, K_2O, MgO, CaO and TiO_2. The values of SiO_2 range from 58.660% to 84.258% with an average of 72.955%, making it the most abundant oxide in the samples. This is expected because of the stability of silica. Alumina with values ranging of 7.688% to 17.788% is next highest. It has an average value of 10.991%. Fe_2O_3 ranges from 1.950% to 9.697%, with an average value of 4.243. The sediments are also observed to be enriched in K2O, MgO and CaO, with average values of 3.817%, 2.248% and 1.497% respectively. The sediments are depleted in the remaining oxides: V_2O_5, Cr_2O_3, MnO. Co_3O_4, NiO. CuO, Nb_2O_3, MoO_3, WO_3, P_2O_5, SO_3, BaO, Ta_2O_5, ZnO, Ag_2O, Cl, ZrO_2, SnO_2 listed in Table 3. Sodium in oxide form (NaO) or elemental form (Na) is not evident on the list because its concentration is below detection limit of 0.01%.

Despite the sediments enrichment in CaO, it is observed that the concentration of CaO in the samples is low. The concentration ranges from 0.838% to 1.865%. This can be attributed to the lack of matrix in the river bed sands analyzed. The enrichment in CaO and MgO may also be associated with the enrichment of carbonates especially dolomite within the Niger Delta Basin. The low concentration of MgO and Fe_2O_3 may be due to composition of the source rock or disintegration during weathering and transportation. The sediment is enriched with TiO_2 which occurs as a minor mineral.

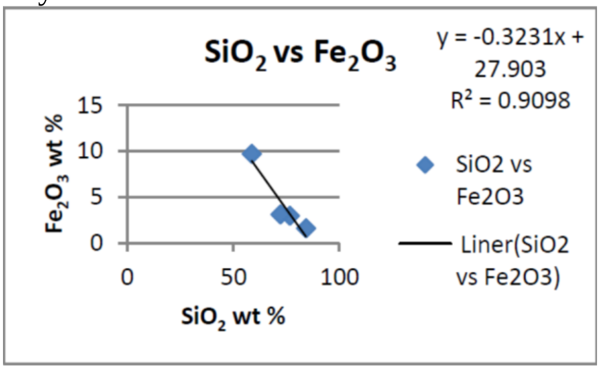
Mineralogical maturity of sediment can be ascertained using the ratio SiO_2/Al_2O_3. [6]. It gives a measure of silica enrichment. The high values of the ratio show maturity, 5.0 indicate progressive maturity which means more quartz content. The average ratio range is from ~ 3.0 (basic rocks) to ~ 5.0 in an unaltered igneous rock [7]. This is so because quartz is very stable and resistant to weathering. This ratio in the studied sediments ranges from 3.298 to 10.823, with an average of 7.669. This shows the mineralogical maturity of the sediments from River Forcados along Patani community and environs. It also infers that the sediments are most likely from an acidic igneous rock domain. This is corroborated by the feldspar content of the sediments. According to [3], provenance and diagenesis will determine the ratio of K_2O/NaO. Feldspars are very predominant minerals in igneous rocks and are very unstable minerals that disintegrate easily during weathering and transportation. From the analysis, the concentration of NaO in the sediment is below the detection limit, which makes it insignificant. The insignificant or non-occurrence of plagioclase may be from the source rock or its depletion with weathering and transportation. Therefore, the predominant feldspar in the samples is alkali feldspar with concentration ranging from 2.368% to 4.481%. The presence of alkali feldspar indicates an acidic igneous rock.

Figures 2 A – H show the negative linear correlation between SiO_2 and Al_2O_3, Fe_2O_3, K_2O, MgO, CaO, MnO, TiO_2 and Cl. As silica (SiO_2) increases, the other oxides decrease. Silica (quartz) is one of the most resistant and stable element to weathering and the most ubiquitous mineral of sand. Sand or sandstone is termed compositionally mature if its composition is enriched with stable mineral such as quartz. Some of the factors that influence this are: source rock chemistry, distance of travel, cycle of sedimentation, climate and relief, which affect the rate of weathering, time taken for the processes to occur and the intensity of the processes.

The sediments from River Forcados are enriched in silica depicting long distance of travel that would have allowed most of the unstable minerals to disintegrate or probably a supermature provenance source [4]. Alumina is the second most abundant oxide in the sediments. This can be attributed to the fact that alumina is one of the least mobile oxide/ and one of the major component in the formation of clay minerals which are alumino-silicates and are the main residual deposits of the weathering of unstable minerals. Sample 11 which is silty clay (Table 2) and downstream show a high enrichment in alumina, probably due to the clay content of the sediment.



A



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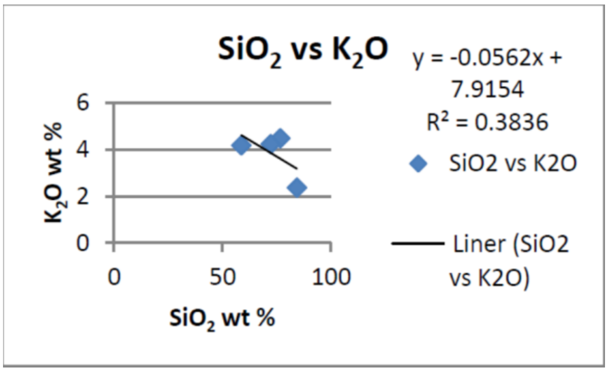

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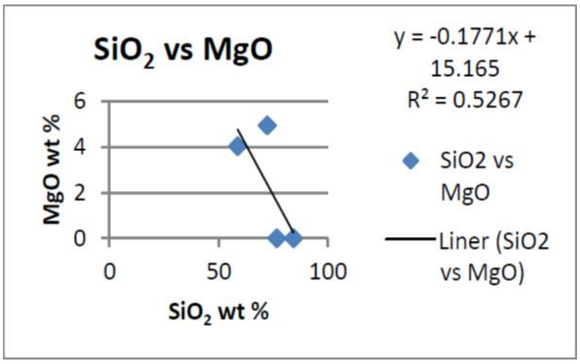

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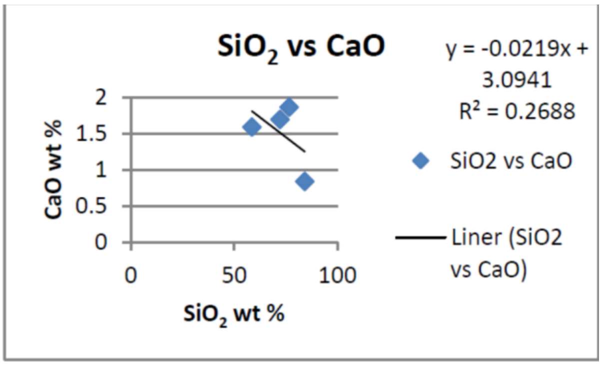

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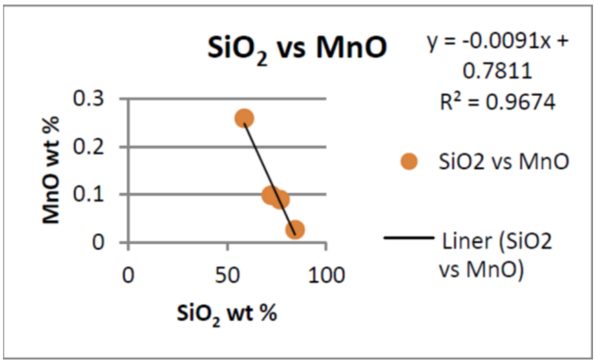

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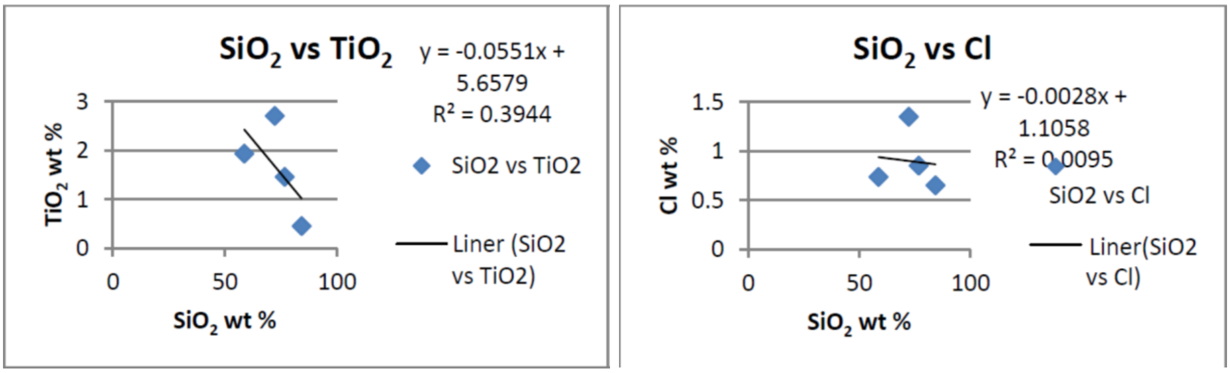

G H

Figures 2: A – H: Harker diagrams of SiO_2 versus Al_2O_3, Fe_2O_3, K_2O, MgO, CaO, MnO, TiO_2 and Cl

7. Conclusion

The river bed sediments from River Forcados along Patani and environs in the Niger Delta have grain size ranging from silty clay to coarse sands and their colour range from brown through dark brown to grey. The sediments are enriched in the following oxides: Sio_2, Al_2O_3, Fe_2O_3, K_2O, MgO, CaO and TiO_2. Whereas, the sands are depleted in the following oxides: V_2O_5, Cr_2O_3, MnO. Co_3O_4, NiO. CuO, Nb_2O_3, MoO_3, WO_3, P_2O_5, SO_3, BaO, Ta_2O_5, ZnO, Ag_2O, Cl, ZrO_2, SnO_2.

The concentration of SiO_2 ranges from 58.660% to 84.258% with an average of 72.955%, making it the most abundant oxide in the samples. SiO2 (Quartz) is very stable and resistant to weathering. The negative linear correlation that exist between SiO_2 and Al_2O_3, Fe_2O_3, K_2O, MgO, CaO, MnO, TiO_2 and Cl, which means that as SiO2 increases, these other sediments are decreasing.

The SiO_2/Al_2O_3 ratio and the K_2O,/NaO ratios show that the sediments are mineralogically mature and have an acidic igneous rock source. The insignificant or non -occurrence of NaO and Na also buttress this fact.

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