Osun River Basin Sediments Heavy Mineral Distribution.

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ABSTRACT

Heavy mineral assemblage of sediments in Osun River basin has been studied in five states in Southwestern Nigeria to determine their concentrations and provenance. Twenty-five sediment samples were analyzed for heavy mineral assemblage determinations. The separation of these minerals was carried out using bromoform (specific gravity 2.85) and slide examination under the petrographic microscope. The heavy minerals assemblages of Zircon, Tourmaline, Rutile, Silimatate, Garnet, Epidote, and Staurolite indicated its derivation from mixed sources of acid igneous rock to medium and high grade metamorphic rocks. The calculated ZTR % values varied between 21.1% in Ekiti to 56.7% in Lagos State and the mean ZTR (Zircon, Tourmaline, Rutile) percentage indices was 36.4%. The two most abundant were Staurolite and Rutile with 43.92% and 11.95%, respectively. We found that their concentrations and sizes increase from Ekiti state in the upper section of the Osun basin to Lagos in the Southern part of the basin according to coastal drift.

(Keywords: heavy minerals, river sediments, activity concentration, provenance, mineralogical component, Osun River, zircon, tourmaline, rutile, silimatate, garnet, epidote, staurolite)

INTRODUCTION

River sediments originate from the near surface, exposed igneous, volcanic, and sedimentary rocks. Some of these are easily eroded, whereas others, especially the crystalline and metamorphic rocks, are affected by streams only when altered in surface layers. Additional sources of river sediments are soils which inherited their mineral content (with some alteration) from bedrock or which in the tropic may consist completely of newly formed minerals (Irion 1987).

The drainage system of Osun River rises in Oke-Mesi ridge, about 5 km North of Effon Alaiye on the border between Oyo and Ondo States of Nigeria, and flows North through the Itawure gap to latitude 7^0 53^1 before winding its way Westwards through Osogbo and Ede and Southwards to enter Lagos lagoon about 8 km east of Epe (Figure 1) is underlain by metamorphic rocks of Precambrian basement complex, the great majority of which are very ancient in age. This basement complex showed great variations in grain size and in mineral composition. The rocks are quartz geniuses and schist consisting essential of quartz with small amounts of white micaceous minerals (Tahal 1976).

According to Akande (2006), in grain size and structure, the rocks vary from coarse grained pegmatite to medium grained geniuses. The rocks are strongly foliated and they occur as outcrops especially in Efon alaiye and Ikere Ekiti area.

Sedimentary rocks of cretaceous and latter deposits are found in the southern sections of the Osun basin. The remaining sections are composed of crystalline rocks of the basement complex, consisting mainly of folded gneiss, schist and quartzite complexes, which belong to the older intrusive series. Although in many places outcrops are plainly visible, large areas are overlain by layers of laterite soil formed by weathering and decomposition of the prevent rock material. Along the river basin the provenance of the minerals have been dealt with, based on heavy minerals studies.

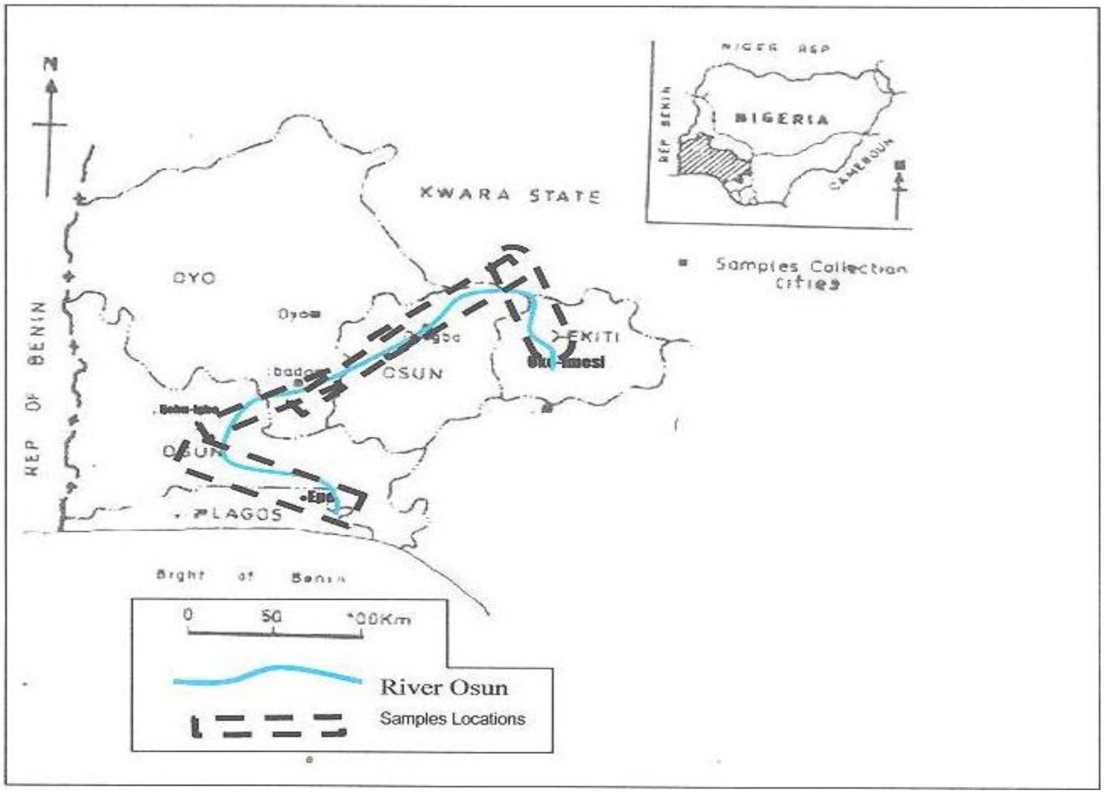

Figure 1: South Western Nigerian Map showing the States along the Osun River Basin where the Samples were Collected.

However, characterization of opaque is not yet attempted from the present study region. The present work highlights the distribution of non-opaque minerals with emphasis of possible source and concentration for exploitation.

MATERIALS AND METHODS

Field Measurements

One hundred and six (106) samples of River Sediments were collected at twenty five (25) different locations. As shown in Figure 2, the locations span the length of the river. In each location, samples were collected at a minimum of four different sports. The number of location per state is partly due to accessibility, the distance transverse by the River in each state, and largely the level of human activities along the river basin.

At each samples location, about 200g of the samples were collected. Each sample was packed in cellophane bags, tied, and labeled accordingly and taken to the laboratory for further investigation. Both the Granulometric and the heavy mineral separation analyses were carried out at the Geology Department Laboratory, University of Ibadan. Nigeria.

Experimental

A total of 25 bed load representative samples have been selected, between the months of February and March 2006, across South Western Nigeria, taking 4 samples each in Ekiti and Osun States, 3 samples each in Oyo and Lagos States, and 11 samples in Ogun State, respectively, ranging form North to South. Samples were sieved with a Ro-tap machine and statistical parameters were obtained (Folk and Ward 1957).

A total of 5g of each dried samples was released into a separating funnel using the dense-liquid technique, with bromoform (specific gravity $2.8g/cm^3$).

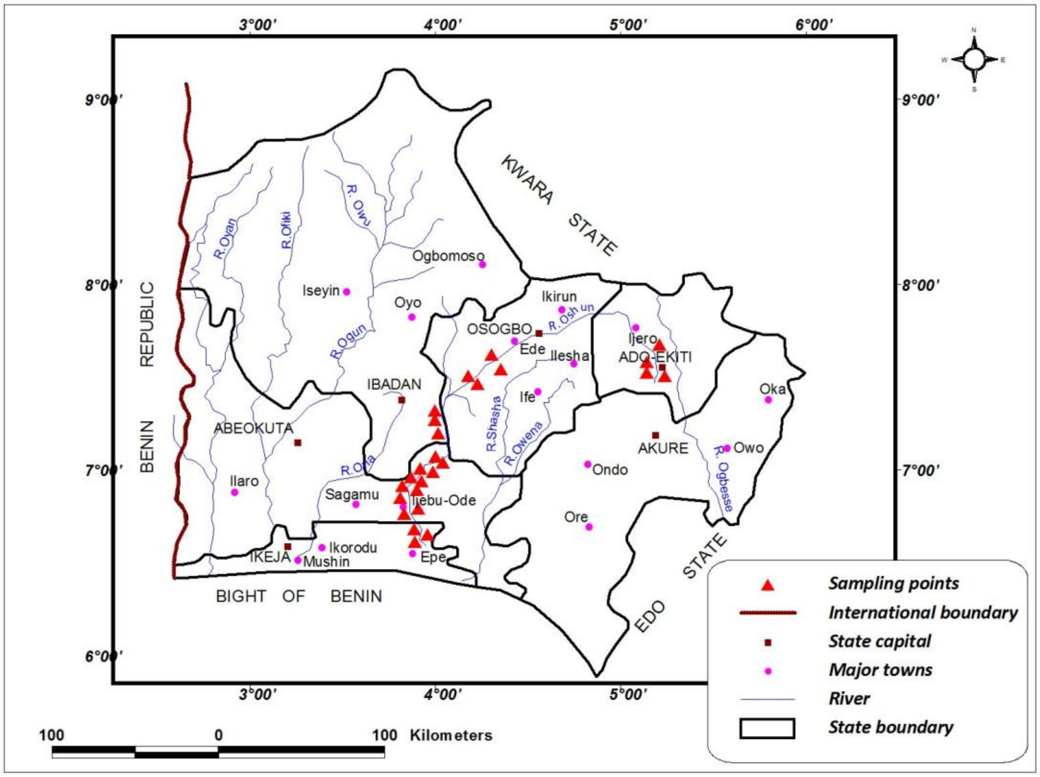

Figure 2: Map Showing the Sampling Points in Five States along Osun River Basin in Southwestern Nigeria.

Samples were boiled in 10% Hydrochloric acid for two minutes in order to disintegrate the samples. Boiled samples were rinsed with water to remove the hydrochloric acid and dried in an oven in order to separate the fine sand fraction.

The mixture was vigorously stirred and left for 5 minutes. The heavy minerals present in the sample with specific gravity > $2.85 g/cm^3$ were allowed to settle to the bottom of the separating funnel or after which the filtrate (heavy mineral) were thoroughly washed with acetone to move any trace of bromoform and also dry. The heavy minerals were mounted on slides with the aid of Canada balsam (Sato, 1996) and the opaque mineral was identified based on (Maria and Heinz, 1992) color guide as shown in (Figure 3).

The non-opaque minerals were studied under a transmission light microscope (Suzuki, 1975). The results obtained are shown in Table 2.

The "ZTR" index, which is a quantitative definition of mineral assemblage, was calculated using the percentage of combined Zircon, Tourmaline, and Rutile grains for each sample.

RESULTS AND DISCUSSION

Results of grain size statistics (Table1) indicate the average mean is 1.14, and the average (standard deviation) sorting is 0.84 which shows that it is moderately sorted and therefore indicative of sub-mature sediments. Statistical parameters such as average grain size and sorting normally reflect the energetic condition of the environment (Anfuso et al., 1999). The sediments have an average skewness of -2.61 which indicates an appreciable energy environment. The average kurtosis is 1.69 (very leptokurtic) which shows that the sediments could be from a single source. The sediments characteristics are medium to fine grained, moderately to well sorted (0.45 – 0.67) and negatively to symmetrically skewed.

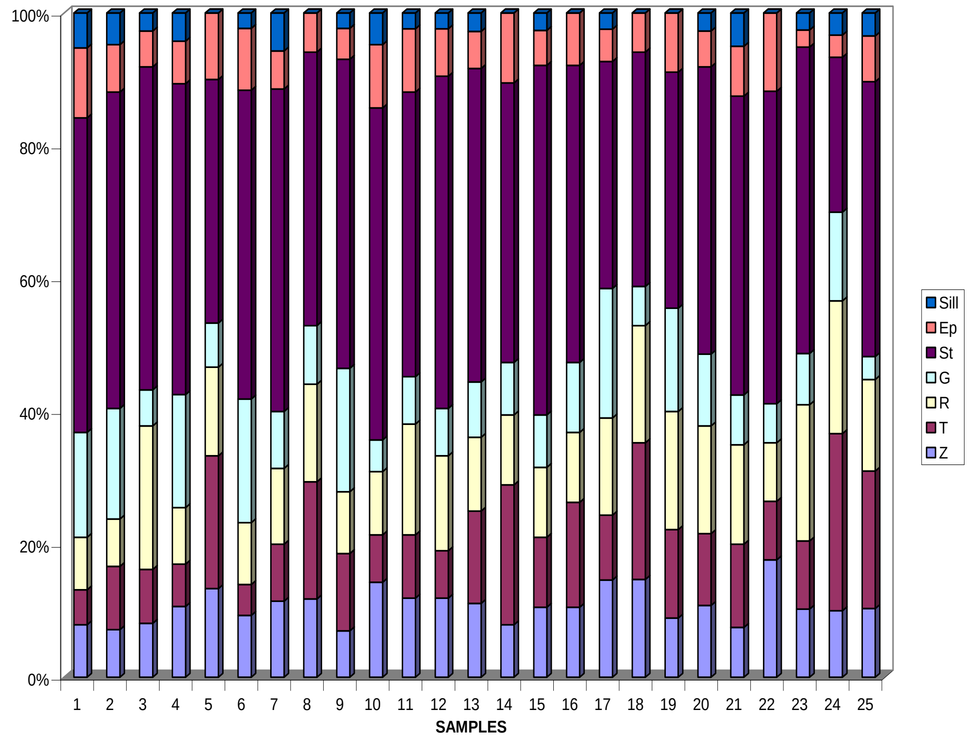

Figure 3: Proportion of Non-Opaque Heavy Minerals in the Sediment Samples.

Table 1: Calculated Grain Size Parameters for Osun River Sediments.

State	Sample Code	Mean	Sorting	Kurtosis	Skewness
Ekiti	HEK1	1.08	0.78	2.11	-2.46
	HEK2	1.13	0.81	1.79	-2.63
	HEK3	1.2	0.98	2.4	-1.79
	HEK4	1.31	0.92	1.68	-2.88
	HEK5	1.1	0.98	1.41	-4.35
Osun	HOS1	1.26	0.27	0	-0.31
	HOS2	1.08	1.06	1.37	-3.81
	HOS3	1.01	0.84	2.26	-2.27
	HOS4	1.05	0.97	1.24	-4.1
	HOS5	1.2	0.81	1.36	-2.71
Oyo	HOY1	1.3	0.55	0.43	-2.18
	HOY2	1.11	0.98	1.31	-3.51
	HOY3	1.17	0.77	1.51	-3.52
	HOY4	1.2	0.81	1.36	-2.71
	HOY5	1.01	0.8	2.53	-1.46
Ogun	HOG1	1.12	0.98	1.31	-3.51
	HOG2	0	0	0	0
	HOG3	1.08	0.78	2.11	-2.09
	HOG4	1.21	91	2.75	-2.09
	HOG5	1.15	0.84	1.29	-2.54
Lagos	HLA1	1.08	0.77	3.01	-0.09
	HLA2	1.15	0.93	2.45	-2.54
	HLA3	1.16	0.93	2.45	-2.68
	HLA4	0	0	0	0
	HLA5	1.13	0.89	1.24	-3.23
AVERAGE		1.14	0.84	1.69	-2.61

The heavy mineral analysis carried out on the twenty five (25) representatives samples revealed the presence of Zircon, Tourmaline, Rutile, Silimanite, Staurolite, Epidote, garnet and opaque minerals (Table 2). Percentage of opaque minerals in all samples are generally very high relative to the heavy minerals they are generally referred to as iron–stained minerals and because of the coating; illumination in a petrographic microscope cannot penetrate them, and hence their study will require chemical analytical approaches.

Table 2 shows the proportion of each mineral in each sample. The Zircon, Tourmaline, Rutile (ZTR) percentage index calculated for each sample is included in Table 3.

Staurolite which has the highest individual mineral percentage of 43.932% is a red brown to black, mostly opaque, neosilitate minerals with a white streak. It has a complex chemical formula (Fe, Mg, $Zn)_2Ag(Si, Al)_4O_{22}(OH)_2$. The iron magnesium and zinc usually occur in variable ratios. Staurolite is one of the index minerals that are used to estimate the temperature, depth and pressure of which a rock undergoes metamorphism. Staurolite is a regional metamorphic mineral of intermediate high grade.

The highest proportion of the Staurolite obtained recorded in all the states shows regionally metamorphosed rocks such as iron – rich peliters, which may also have high Fe^{3+}, Fe^{2+} ratios at medium grades of metamorphisms.

Table 2: Proportion of Heavy Minerals Concentrations in the Sediment Samples.

CODE	SERIAL NO.	Z	T	R	G	St	Ep	Sill	Op
HEK1	1	3	2	3	6	18	4	2	117
HEK2	2	3	4	3	7	20	3	2	128
HEK3	3	3	3	8	2	18	2	1	119
HEK4	4	5	3	4	8	22	3	2	106
HOS1	5	4	6	4	2	11	3	0	118
HOS2	6	4	2	4	8	20	4	1	122
HOS3	7	4	3	4	3	17	2	2	116
HOS4	8	4	6	5	3	14	2	0	122
HOY1	9	3	5	4	8	20	2	1	128
HOY2	10	6	3	4	2	21	4	2	178
HOY3	11	5	4	7	3	18	4	1	167
HOG1	12	5	3	6	3	21	3	1	158
HOG2	13	4	5	4	3	17	2	1	164
HOG3	14	3	8	4	3	16	4	0	109
HOG4	15	4	4	4	3	20	2	1	138
HOG5	16	4	6	4	4	17	3	0	136
HOG6	17	6	4	6	8	14	2	1	154
HOG7	18	5	7	6	2	12	2	0	159
HOG8	19	4	6	8	7	16	4	0	173
HOG9	20	4	4	6	4	16	2	1	168
HOG10	21	3	5	6	3	18	3	2	170
HOG11	22	6	3	3	2	16	4	0	68
HLA1	23	4	4	8	3	18	1	1	121
HLA2	24	3	8	6	4	7	1	1	144
HLA3	25	3	6	4	1	12	2	1	119

Table 3: ZTR Maturity Index and Individual Percentage Mineral of the Osun River Sediments Samples.

SERIAL NO.	Z	T	R	G	St	Ep	Sill	Total	Z+T+R	ZTR%index
1	3	2	3	6	18	4	2	38	8	21.1
2	3	4	3	7	20	3	2	42	10	23.8
3	3	3	8	2	18	2	1	37	14	37.8
4	5	3	4	8	22	3	2	47	12	25.5
5	4	6	4	2	11	3	0	30	14	46.7
6	4	2	4	8	20	4	1	43	10	23.3
7	4	3	4	3	17	2	2	35	11	31.4
8	4	6	5	3	14	2	0	34	15	44.1
9	3	5	4	8	20	2	1	43	12	27.9
10	6	3	4	2	21	4	2	42	13	31
11	5	4	7	3	18	4	1	42	16	38.1
12	5	3	6	3	21	3	1	42	14	33.3
13	4	5	4	3	17	2	1	36	13	36.1
14	3	8	4	3	16	4	0	38	15	39.5
15	4	4	4	3	20	2	1	38	12	31.6
16	4	6	4	4	17	3	0	38	14	36.8
17	6	4	6	8	14	2	1	41	16	39
18	5	7	6	2	12	2	0	34	18	52.9
19	4	6	8	7	16	4	0	45	18	40
20	4	4	6	4	16	2	1	37	14	37.8
21	3	5	6	3	18	3	2	40	14	35
22	6	3	3	2	16	4	0	34	12	35.3
23	4	4	8	3	18	1	1	39	16	41
24	3	8	6	4	7	1	1	30	17	56.7
25	3	6	4	1	12	2	1	29	13	44.8
Total	102	114	125	102	419	68	24	954		36.4
%	11	12	13	10.69	44	7.1	2.5	Individual mineral % abundance		
	Average ZTR% index= 36.4%.					Opaque = 3402			Non-opaque = 954	

The mineral often occurs alongside garnet and kyanite.

Rutile (13.1%) is next to Staurolite and relatively abundant in most samples, only the red colored variety was recognized. Epidote (7.13%) and silimanite (2.52%) are equally in small proportion. Rutile is a common accessory mineral in high temperature and high pressure metamorphic and igneous rocks. According to Pellant and Phillips (1990), Rutile is a non-silicate mineral occurring as an accessory constituent of igneous rocks and many types of granite, diorites and their metamorphic derivatives such as gneisses and amphibolites. Rutile is used as a source of titanium.

Tourmaline comes next with 11.95% abundance. Tourmaline occurs on granite pegmatites. It is usually brown in color (sometimes greenish) or brownish yellow. Its shape is commonly euhedral. It is a common detrital heavy mineral in sedimentary rocks. So varieties of tourmaline are used gemstones.

The quantity of zircon (same proportion as garnet) being the next abundant non-opaque heavy minerals to tourmaline in the sediment shows that its shapes are only fairly mechanically altered, (commonly euhedral to subherdal) due to their stability and lack of good cleavage. They appear commonly colorless. Figure 4 shows the individual mineral percentage abundance in all

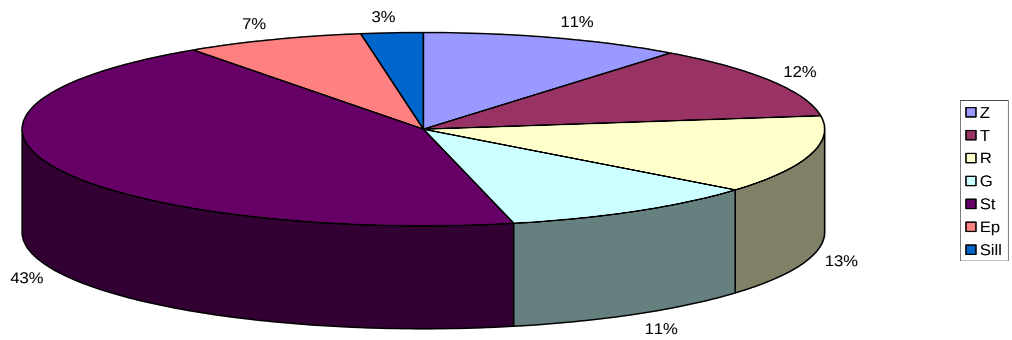

Figure 4: Overall Percentage (%) of Each Heavy Mineral.

samples put together. The ZIR percentage index calculated range from 21.1 to 56.7%. This is also depicted in the stacked column bar chart in figure 4 to show the proportion of the non-opaque minerals in sediment samples of the Osun River basin.

According to modifications of heavy mineral association and provenance by Feo–Codecido (1956), the presence of Zircon, Rutile, and Tourmaline an acid igneous rock source of the sediments. The possibility of the source rock being igneous rock is very low because Augite, Diopside, Hypersthenes, or Olivine are largely absent from the heavy mineral assemblage (Akinmosin et al., 2005). Instead Staurolite, Rutile and Garnet occur in relatively fairly large quantities with respect to Epidote and Silimanite, which are indicative of dynamo thermal metamorphic rock source.

Hubert (1962) stated that the non-opaque or transparent non-micaceous heavy mineral assemblage of the quartz heavy mineral assemblage of the quartz arenites are predominantly Zircon, Tourmaline, and Rutile and these grains are ultimately concentrated in sandstones by prolonged abrasion. The chemically stable minerals are normally provided insufficient quantities by most granitic and; low rank metamorphic source interdependent. Thus the ZTR index is of modification or maturity of entire heavy minerals assemblage of river sediments.

The highest value of ZTR (56.7%) is recorded in Lagos state and of the river while the lowest value (21.1%) is found in Ekiti State where the river originates. This shows that maturity increases with the distance traveled by the sediments.

CONCLUSION

Heavy mineral assemblages indicate the presence of opaque and non-opaque mineral. The non-opaque minerals include Zircon, Tourmaline, Rutile, Silimanite, Garnet, Epidote and Staurolite while opaque minerals which accounted for 52% dominated the assemblage. Heavy mineral studied that Osun River sediment is mineralogical immature.

From the heavy mineral analysis the presence of minerals such as Zircon, Tourmaline, and Rutile (ZTR), which are mainly igneous and metamorphic minerals coupled with dominant element of Staurolite have shown that the sediments of Osun River basin in southwestern Nigeria could have been derived principally from acid igneous rock with significant contribution from medium to high grade metamorphic rock.

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The authors have research interests in the areas of mineralogy, sediment assessment, and geological characterization.

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