Australian Journal of Basic and Applied Sciences, 4(3): 498-501, 2010
ISSN 1991-8178

Grain-size and Heavy Mineral Analysis of River Osun Sediments

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Abstract: In river sediments the whole range of known minerals can be found: salt minerals in very restricted areas, carbonates, heavy minerals; feldspars, quartz and clay minerals. In this paper we report the grain size and heavy minerals analysis of Osun River sediments. The heavy mineral analysis involved separation of sand grains into different sizes; density separation of heavy minerals using heavy liquid and counting the number of grains of each mineral using transmitted light microscope. Results show that the sediments with 250µm grain size dominate in all the samples. The average graphic mean, inclusive graphic skewness and measure of kurtosis determined from the grain size data are 1.14, 1.69 and -2.61 respectively. The heavy mineral assemblage indicates the presence of opaque and non-opaque minerals. The non-opaque minerals fall into three groups: Ultra stable (Zircon, Tourmaline, Rutile), Stable (Staurolite, Garnet) and moderately stable (Sillimanite, Epidote). The most abundance is Staurolite with 43.92%. The calculated Zircon, Tourmaline and Rutile (ZTR)% values varied between 21.1% in Ekiti to 56.7% in Lagos State**.** The maximum ZTR index of 56.7% obtained shows that the sediments are mineralogically immature.

Key words: Grain-size analysis, Heavy minerals, River Sediments, Provenance, ZTR index and River Osun

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 the surface layers. Additional sources of river sediments are soils which inherited their mineral content (with some alternation) from bedrock or which in the tropic may consist completely of newly formed minerals. In river sediments the whole range of known minerals can be found: salt minerals in very restricted areas, carbonates, heavy minerals; feldspars, quartz and clay minerals. In addition, amorphous particles of volcanic origin and of skeletons and shells from organisms contribute to the river sediments. Organic matter is generally present in a range 1% and 15%. In commercial terminology, the term 'ore minerals' refers to the metallic minerals containing relatively high percentage of metallic elements such as copper, silver, iron and aluminum. The term "Industrial mineral" means, the minerals used to manufacture the nonmetallic materials such as electrical and thermal appliances, ceramics, glasses, cement, fertilizer etc. Clay minerals form the basic materials for manufacture of bricks, tiles, potteries and ceramic ware.

Provenance analysis of sediments is aimed at reconstructing the parent-rock assemblages of sediments and the climatic physiographic conditions under which sediments formed.

Little is known about the composition of heavy minerals and concentration of primodial radionuclides in Osun river sediments in Nigeria. Osun River is one of the major rivers in Nigeria well known for economic activities such as irrigation, fishing and Mining of sand and gravel from the river bed for construction purposes.

The present paper deals with grain size and heavy minerals analysis of Osun River sediments. Osun River which rises in the Oke-Mesi ridge, about 5 km North of Efon Alaiye in Ekiti State is underlain by metamorphic rocks of the Precambrian basement complex, the great majority of which are very ancient in age. These basement complex rocks show great variations in grain size and in mineral composition.

MATERIALS AND METHODS

One Hundred and six (106) samples of Sediments from Osun River were collected at twenty five (25)

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different locations spanning the length of the river. In each location, samples were collected at a minimum of four different spots. The number of locations per state is partly due to accessibility, the distance traversed by the River in each state and largely the level of human activities along the River basin. Both the Granulometric and the Heavy mineral separation analyses were carried out at the Geology Department laboratory, University of Ibadan.

Granulometric Analysis:

In order to carry out granulometric and heavy minerals analyses on the sediment samples, small quantities were taken from each sample in a particular location. For example in Ekiti state where sixteen samples were collected at four different locations (with four samples per location) small quantities taken from each sample in a given location were mixed together. Hence in Ekiti state we have four samples for granulometric and heavy minerals analyses. Electric Rotap machine was used to agitate and activate the sieving process for fifteen minutes after which the fraction in each sieve and the pan was weighed and recorded, representing that fraction of a distinct grain size present in the samples. The sieves were arranged such that the screen with the smallest opening (212µm) was at the base and the largest (2.80mm) at the top. The pan was placed bellow the 212µm sieve.

Textural parameters such as Gravel, coarse sand, medium sand, fine sand, were determined from the distribution graphs and d_{10}, d_{30}, d_{60} respectively. The grain size data obtained was used to determine the graphic mean (M), standard deviation (sorting) (SD), Graphic Kurtosis (K) and Graphic Skewness (SK) based on Folk and Ward (1957) method as shown below:

(M) Mean = $\dfrac{\phi 16 + \phi 84 + \phi 50}{3}$

(SD) standard deviation (sorting) = $\dfrac{\phi 84 - \phi 16}{4} + \dfrac{\phi 95 - \phi 5}{6.6}$

(K) Graphic Kurtosis = $\dfrac{\phi 95 - \phi 5}{2.44(\phi 75 - \phi 25}$

(SK) Graphic Skewness = $\dfrac{\phi 16 + \phi 84 - 2\phi 50}{2(\phi 84 - \phi 16)} + \dfrac{\phi 5 + \phi 95 - 2\phi 50}{2(\phi 95 - \phi 5)}$

Heavy mineral analysis (Density liquid method):

For the purpose of this mineral separation analysis and granulometric analysis, the twenty-five samples were coded. The codes are HEK, HOS, HOY, HOG and HLA. for Ekiti, Osun, Oyo, Ogun and Lagos state respectively. We followed the procedure that has proved to be a rapid and accurate means of heavy minerals separation (Suzuki, 1975, Mange and Heinz, 1992). The fine sand with grain size 250µm in each of the 25 representative samples was used for the heavy mineral analysis.

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

$$ZTR\%INDEX = \frac{Zircon + Tourmaline + Rutile}{\sum non-opaque} \times 100$$

The ZTR index expressed as a percentage was calculated for the samples to ascertain the mineralogical maturity index.

RESULTS AND DISCUSSION

As shown in figure 1, sediments with grain size 250µm dominates. Sediments with grain size 2.80mm (gravel) is virtually absent. This shows that the sediments from Osun River are sands with clay/silt content.

Results of the grain size statistical analysis indicates overall average mean 1.14, and the average (standard deviation) sorting 0.84 which shows that the sediments are moderately sorted. The sediments have an average skewness of –2.61(which indicates an appreciable energy environment). The average kurtosis is 1.69 (very leptokutic) implying that the sediments are from the same source. Textural maturity, which is a measure of distance/time from the source area to the depositional site, of sediments is gauged largely in terms of grain size, sorting and roundedness. The sediments investigated in this study, can be said to be mature.

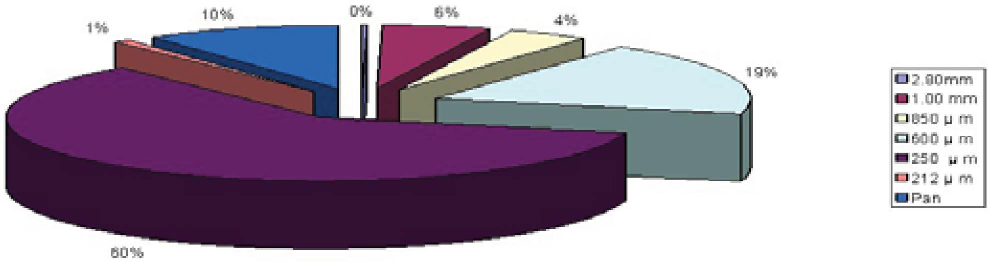

Fig. 1: Overall % proportion of each grain size in the sediment samples.

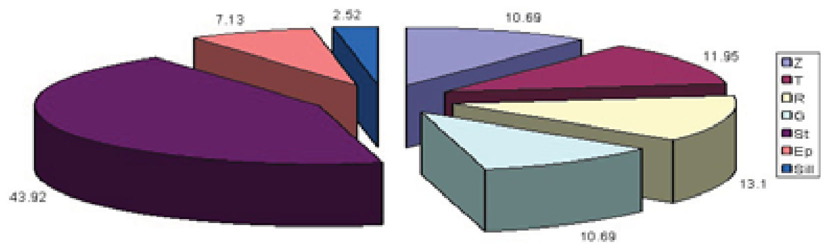

Fig. 2: Overall % proportion of each heavy mineral

The heavy mineral separation carried out on the twenty five (25) representative sediment samples show that the heavy mineral assemblage includes Zircon, Tourmaline, Rutile (ultrastable); Garnet, Staurolite (Stable); Epidote and Sillimanite (moderately stable) and opaque minerals. Percentages of opaque minerals in all simples are generally very high relative to the non-opaque 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.

Staurolite which has the highest individual mineral percentage of 43.92% is a red brown to black, mostly opaque, nesosilicate mineral with a white streak. 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 Steurolite recorded in all the sediment samples show regionally metamorphosed rocks such as iron – rich peliters, which may also have high Fe^{3+}, Fe^{2+} ratios at medium grades of metamorphisms. The mineral often occur along side garnet and kyanite Rutile is the second most abundant individual mineral (13.1%) Rutile is a heavy mineral compound primarily of titanium dioxide TiO_2. It is primarily extracted for use in factory manufacture or as a base paints. Rutile is also widely used as a welding electrode covering. It is a common accessory mineral in high temperature and high pressure metamorphic and igneous rocks. Rutile is a non - silicate mineral occurring as an accessory constituent of igneous rocks and many granites, diorites and their metamorphic derivatives such as gneisses and amphibolites. Rutile is used as a source of titanium. Titanium dioxide is by far the most important intermediate product of the world titanium industry. The whites of titanium oxide and light scattering effect makes it as the only suitable pigment for paint, paper and rubber industries (Gujar *et al.,* 2007).

Tourmaline comes next with 11.95% abundance. Tourmaline occurs in granite pegmatites. It is usually brown in colour (sometimes greenish) or brownish yellow. Its shape is commonly euhedral. It is a common detrital heavy mineral in sedimentary rocks. Some varieties of tourmaline are used as gemstones. Garnet and Zircon come next to tourmaline with 10.69% each. Zircons appear commonly colorless. Zircon is a common and widespread accessory mineral in all types of igneous rocks and detrital deposits derived from these rocks. Garnite is a key mineral in interpreting the genesis of many igneous and metamorphic rocks. Garnet sand is a good abrasive and can be used in sand blasting. Epidote which comes next with 7.13% abundance occurs in crystalline limestone and schistose rocks of metamorphic origin. Sillimanite, 2.52% the least in abundance is an index mineral indicating high degree of metamorphism.

The ZTR percentage index calculated range from 21.1 to 56.7%. According to Hubert (1962), the non-opaque or transparent non-micaceous heavy mineral assemblage of the quartz are predominantly zircon, tourmaline and rutile and these grains are ultimately concentrated in sandstones by prolonged abrasion. The chemically stable minerals are normally provided in sufficient quantities by most granitic and low rank metamorphic source interdependent. Thus the ZTR index is of modification or maturity of entire heavy minerals assembles of river sediment. According to modification of heavy mineral association and provenance by Feo-codecido (1956) the presence of zircon, Rutile and tourmaline indicates an acid igneous rock source of the sediments. The possibility of the source rock being basic igneous rock is very low because augite, diopside, hypersthene or olivine are largely absent from the heavy mineral assemblage. Instead staurolite, Rutile and garnet occur in relatively fairly large quantities with respect to Epidote and Sillimanite, which are indicative of dynamo thermal metamorphic rock source.The highest value of ZTR (56.7%) is recorded in Lagos state end 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

The textural study indicates sediments of fine to medium grained moderately sorted. All the samples have (0.00%) of Gravel while the sands ranges between (75.12% - 99.695%) and fine ranges between (0.31% - 24.88%) with uniformity co-efficient ranging between (0.71 – 1.00) indicating moderately sorted sediment.

Heavy mineral assemblages indicate the presence of opaque and non-opaque minerals. The non-opaque include zircon, Tourmaline, rutile, Staurolite while hornblende Haematite limonite, magnetite are the opaque. Heavy mineral studies indicate that Osun river sediment is mineralogical immature. The presence of all this non-opaque minerals such as zircon, tourmaline and rutile (ZTR), which are mainly igneous and metamorphic minerals is an indication of igneous and metamorphic provenance for the sediments.

ACKNOWLEDGEMENT

The authors wish to thank the Senate Research Grant Management of the University of Ibadan, Ibadan, Nigeria for making fund available to carry out this project.

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