ISSN: 2141 – 3290
www.wojast.com

SOURCE ROCK STUDIES OF OGUNNIYI SEDIMENTS AND PERCENTAGE OF ZTR MINERALS IN ITS ENVIRONS

ATAT [1]J., ADEDOYIN [2]A., UMOREN[3] E.
[1,3]*Department of Physics, University of Uyo, Uyo, Nigeria.*
[2]*Department of Geology and Mineral Sciences, University of Ilorin, Ilorin, Nigeria.*
Corresponding Author Email: josephatat@uniuyo.edu.ng.

ABSTRACT

Ogunniyi area had been studied to obtaininformation on the heavy mineral presence in the location using binocular microscope and sieving equipment for analysesand separated in funnel by means of bromoform with specific gravity of approximately 2.89. The heavy minerals present in lithologic sand units are mainly opaque and Zircon-Tourmaline-Rutile (ZTR) minerals and staurolite. Other heavy minerals like hornblende and topaz were also recorded but in little quantity. The most dominant non-opaque mineral is tourmaline with 32.73% of the total non-opaque minerals counted in the area. Tourmaline is very noticeable in locations OG11 and is present is five out of six examined locations.Other ZTR minerals like zircon and rutile contributed 25.45% and 18.18% respectively of the total sum of non-opaque heavy minerals. The mineralogical index has been determined to be 76.36% which indicates that the sediments are matured since the value is greater than 75.00%. The index is commonly high in beach or littoral zone depositional environment due to the long transport distances from the source and the high energy of the environment. Moreso, the sediments are sourced from porphyroblastic schists (which are foliated rocks) of medium grade regional metamorphic rock and granite (felsic) of acidic igneous rock.

INTRODUCTION

A placer deposit is the effect of flowing water (streams and rivers) causing the buildup of mechanically segregated minerals. The erosion of weathered rocks and minerals bring about the concentration of the more resistant and higher specific gravity (density) minerals (Gandhi and Raja, 2014). Minerals with density greater than 2.89 g/cm^3 are noted as heavy minerals which are both opaque and non-opaque in character (Singh, 2012). Heavy minerals are defined as high density with specific gravities greater or equal to 2.9 g/cm^3(Muller, 1997; Oladipo *et al.*, 2018). The heavy mineral assemblage in sediments can be used to trace their parent rocks as well as their source (Raiswell and Anderson, 2005). Factors which influence the accumulation of the heavy minerals are weathering at different stages between the original source rocks and sedimentary environments, mechanical abrasion during transportation, physical sorting and diagenetic processes during burial (Morton and Hallsworth, 1999).

Heavy minerals may be ultrastable (such as rutile, tourmaline and zircon). Rutile is extensively distributed as accessory mineral in metamorphic and felsic igneous rocks (Boggs, 1995). Zircon is resistant to damage during erosion and deposition and it is usually distributed in granites and syenites (Pettijohn, 1975).The round shape of zircon and tourmaline may be due to the long distance of their sediments transport (Mohemmed *et al.*, 2015). This heavy mineral may also be grouped as metastable if they are garnet, epidote and staurolite. Staurolite being one of the minerals detected during this study is a regional metamorphic rock. It is one of the index minerals used to measure the temperature, depth and pressure at which a rock metamorphosed (Mason and Berry, 1968). Heavy mineral can be unstable such as amphiboles group which include tremolite, hornblende and glaucophane. Hornblende is our interest since it is recorded as one of the heavy minerals in this area. It(Hornblende) is moderately stable but classified under unstable mineral; it is mostly found in igneous and metamorphic rocks. It is seen as medium-grade metamorphic rocks where hornblende and plagioclase are dominantcomponents. There are other groups like pyroxene and celestite detected by some researches like Mange and Morton (2007), and Mohemmed *et al.* (2015).

Heavy minerals are vital in understanding of diagenetic processes. Heavy minerals are less than 3% in sands when highly compressed by weathering. Its assemblages or accumulations depend on size, shape and density which are the physical properties that affect selective sorting due to hydraulic effects. Each assemblage comprisesvarious heavy minerals with distinctive grains that bear its paleo-history.

The aim of this study is to evaluate the heavy minerals present in sand units of Ogunniyi so as to infer its sediment provenance, diagenesis, weathering history and maturity of the sediments forming minerals. These heavy minerals physical evaluation and identification of the dominant mineral components of lithologic samples were done using binocular microscope. Petrographic analysis prevents us from losing valuable information conveyed by rock fragments and facilitates the assessment of heavy mineral concentration more accurately. Provenance interpretations can then be based on firm ground (Garzanti and Ando, 2019). However, they are of economic importance as non-metallic and metallic raw materials alike. Economic heavy mineral deposits are mainly located in tropical and sub-tropical countries. Heavy minerals are traded globally as bulk and bagged minerals.

Location and Geology

The study area (Ogunniyi) is one of the villages in Kwara State, Nigeria (Figure 1). The latitude is between $08^{0}27^{1}$N and $08^{0}30^{1}$N and longitudes $04^{0}55^{1}$E and $04^{0}59^{1}$E. It covers an area of nearly 46.98km^2. Most people in the area are farmers; planting mostly cereal crops such as guinea corn and maize.

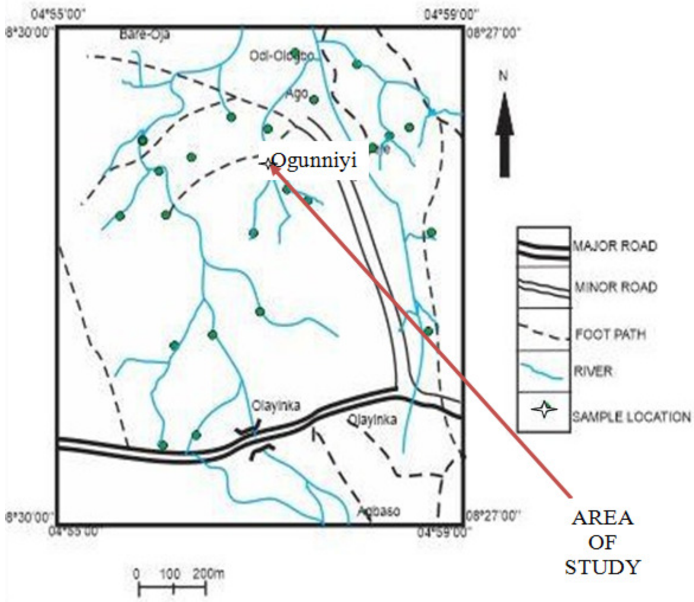


Figure 1: Oguniyi location in the Western part of Nigeria.

The average rainfall in the area is between 20-50 inches annually, average temperature is about 27^{0}C. The dry season always begin from November to March. The wet (or rainy) season is usually experienced between April and October (Kayode *et al*., 2016); the rainfall is approximately 1.3 x 10^3mm and its spreading is bimodal within hydrologic year.

Nigeria is made up of three main provinces: the basementcomplex, the younger Granite and the sedimentarybasins. The basement complex occurs in three areas (the North Central Segment, the Eastern Segment and the Western Segment) in Nigeria. The basement complex underlines the entire area (Yahaya *et al.*, 2014) and includes all rocks older than the late Proterozoic meta-sediments and lies within a zone of ancient African Craton. The vegetation is typical of tropical and guinea savannah. It is characterized by short grasses, scattered trees, vegetation and shrubs indicating vegetation of guinea savannah. The maximum altitude is about 4 x 10^2m above sea level; the lowest altitude is nearly 251m above sea level.

Theoretical Background

Igneous rocks are made when molten material from within the Earth termed magma, cools down and solidifies to form crystals. It may be acidic, intermediate or basic, due to the amount of silica (SiO_2) in them. Acidic rocks (like granite, microgranite and rhyolite) are rich in silica and comprise minerals such as: quartz, feldspar, biotite and others. Basic rocks (like gabbro, dolerite and basalt) are poor in silica; theycomprise minerals such as olivine, pyroxene, feldspar and/or quartz and others; they are also rich in the metals: magnesium, iron and are frequentlycalledmafic. The intermediate rocks are rocks like diorite, micro-diorite and andesite. Felsic describes igneous rock rich in elements that produces feldspar and quartz (Marshak, 2009). It is contrasted with mafic rocks which are richer in magnesium and iron.

Metamorphic rocks were once igneous or sedimentary rocks but have been transformed (metamorphosed) as a result of strong heat and pressure (or either) within the Earth's crust. They are crystalline and frequently have a compacted (that is foliated or banded) texture. There are two major types of metamorphic rocks which are those that are foliated (ones made in an environment with either directed pressure or shear stress) and those that are not foliated (that is, onesmolded in an environment without directed pressure or closeto the surface with very slight pressure). Some types of metamorphic rocks like quartzite and marble are also formed in directed pressure conditions but do notdisplay foliation since their minerals (quartz and calcite correspondingly) do not show alignment.The various types of foliated metamorphic rocks in order of the grade or intensity of metamorphism are slate, phyllite, schist, and gneiss (Figure 2).

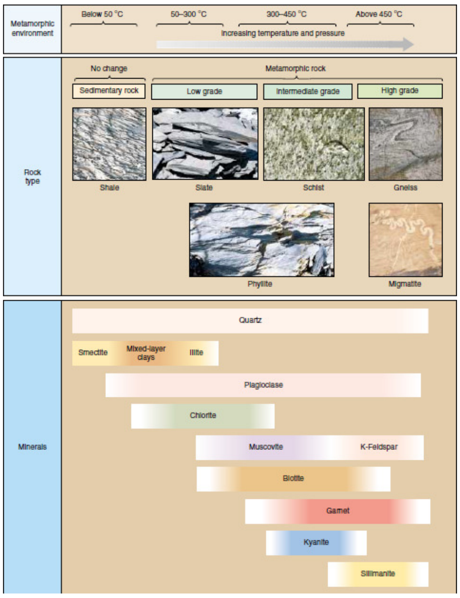


Figure 2: Different metamorphic grades (Thompson and Turk, 1997).

Metamorphic rocks formed by either low-pressure or confining pressure do not become foliated due to not being buried deeply.Marble is metamorphosed limestone. When it is formed, the calcite crystals grow larger and destroy any sedimentary texture and fossils that might have existed.Quartzite is metamorphosed sandstone. It is mostly quartz and in numerous cases, the original quartz grains of the sandstone are fused together with additional silica. Most sandstone comprises some clay minerals; it may also contain other minerals like feldspar or fragments of rock. This indicates that most quartzite has some impurities with the quartz. Hornfels is another non-foliated metamorphic rock that usually forms during contact metamorphism of fine-grained rocks [like mudstone or volcanic rock]. If the hornfels formed in a conditionwithout directed pressure, these minerals would be arbitrarilypositioned, not foliated as they would have been if formed with directed pressure (Earle, 2015).Even if made during regional metamorphism, quartzite will not be foliated since quartz crystals do not align with directional pressure.

However, any clay present in the original sandstone istransformed to mica during metamorphism and any such mica will align with the directional pressure. Regional metamorphism is caused by large geologic processes such as mountain-building and typically produces foliated rocks like gneiss and schist.

The nature of the parent rock controls the type of metamorphic rocks that aremade from it under differing metamorphic conditions. The kinds of rocks that can be predicted to form at different metamorphic grades from various parent rocks are recorded in Table 1. Rocks like granite do not change greatly at the lower metamorphic grades since their minerals are still stable up to several hundred degrees.

Table 1: Types of metamorphic rocks that are formed from different parent rocks at different grades of regional metamorphism

Grades of regional metamorphism		Very Low Grade	Low Grade	Medium Grade	High Grade
Temperature ranges		150°C to 300°C	300°C to 450°C	450°C to 550°C	Greater than 550°C
Parent rocks	Mudrock	Slate	phyllite	schist	gneiss
	Granite	no change	no change	no change	granite gneiss
	Basalt	chlorite schist	chlorite schist	amphibolite	amphibolite
	Sandstone	no change	little change	quartzite	quartzite
	Limestone	little change	marble	marble	marble

Sedimentary rocks are rocks that are made by the deposition of organic particles onthe Earth's surface leading to cementation.Sedimentation is the group name for processes that cause these particles to settle in place. The geological detritus made from weathering and erosion of existing rocks or from the solidification of molten lava drops erupted by volcanoes, they are moved to the place of deposition by water, wind, ice or mass movement. Biological detritus is made by bodies and parts (mostly shells) of dead aquatic organisms suspended in water and gently piling up on the floor of water bodies (marine snow). Sedimentation may also occur as dissolved minerals precipitate from water solution.

The sedimentary rock cover of the continents of the Earth's crust is wide (73% of the land surface of the Earth) (Wilkinson *et al*., 2008); it is assessed to be only 8% of the volume of the crust. Sedimentary rocks are only a thin layer over a crust comprising majorly of igneous and metamorphic rocks (Buchner and Grapes, 2011). They are vital sources of natural resources including coal, fossil fuels, drinking water and ores. The study of the sequence of sedimentary rock strata is the major source for an understanding of the Earth's and paleo history;also include paleoclimatology and the history of life.

ZTR minerals and source rocks

Heavy minerals may be opaque or non-opaque. Opaque ones often predominate in a heavy mineral suite (Friedman and Sanders, 1978). Non-opaque might be ultraor metastable. Suites of heavy minerals and their source rocks are presented in Tables 2 and 3. The heavy minerals present indicates provenance of igneous and metamorphic rocks (including granites, pegmatites,mica schists, gneisses), and presence of hydrothermally generatedminerals.

The ZTR index is a method of defining how weathered sediment might be (Prothero and Schwab, 1996); itsemphases is on minerals such as Zircon, Tourmaline and Rutile (ZTR). The index is to determine the mineralogical maturity so as to draw accurate conclusion on how mature, sub-mature, immature and no identification of these minerals in a sample. The index is commonly high in beach or littoral zone depositional environment due to the long transport distances from the source and the high energy of the environment.

$$ZTR\ Index = (Z + T + R) \times\ 100\% / \sum NO \quad (1)$$

Z is Zircon, T is Tourmaline, R is Rutile, NO is Non-opaque minerals; ZTR $<$ 75% implies immature to sub-mature. ZTR $>$ 75% indicates mineralogically matured sediments (Suleiman *et al*., 2015). High ZTR index and grain roundness indicates intense in-situ and deep weathering and dissolution of unstable heavy mineral components (Etimita and Beka, 2020).

Table 2: Major source rocks of the heavy mineral species (Cascalho and Fradique, 2007)

S/n	Heavy minerals	Source rocks
1	Biotite, tourmaline, apatite, zircon, rutile, amphibole and iron, titanium oxides, and occasionally garnet.	Granite
2	Biotite, garnet, sillimanite, apatite and zircon	Micaschists, gneisses and migmatites
3	Amphibole (abundant), apatite (accessory)	Amphibolites and amphibolitic schists
4	Garnet, staurolite and biotite(abundant), zircon, tourmaline, apatite, sillimanite and magnetite (accessories)	Porphyroblastic schists
5	Andalusite, garnet and staurolite (abundant in some schists and greywackes), kyanite occasionally present.	Schist-greywacke complex
6	Biotite, andalusite (chiastolite) in hornfels. Garnet and andalusite (chiastolite) in schists. Apatite, tourmaline, sillimanite, amphibole, pyrite, ilmenite and zircon are also present.	Schists, greywacke quartzites, hornfels and metasediments

Table 3: Heavy minerals and their source rocks (Feo-Codecido, 1956)

S/N	Minerals	Source rocks
1	Rutile, Topaz, Zircon, Apatile	Acid Igneous rocks
2	Garnet, Topaz, Tourmaline, Monzonite, Cassiterite	Granite, Pegmatite
3	Augite, Magnetite, Chronite, Hypersthene, Diopside	Basic Igneous rocks
4	Topaz, Garnet, Andalusite, Ziosite, Corundum	Contact Metamorphic rock
5	Epidote, Garnet, Kyanite, Silimanite, Staurolite	Regional Metamorphic rock
6	Zircon, Rutile, Tourmaline	Reworked Sediment

METHODOLOGY

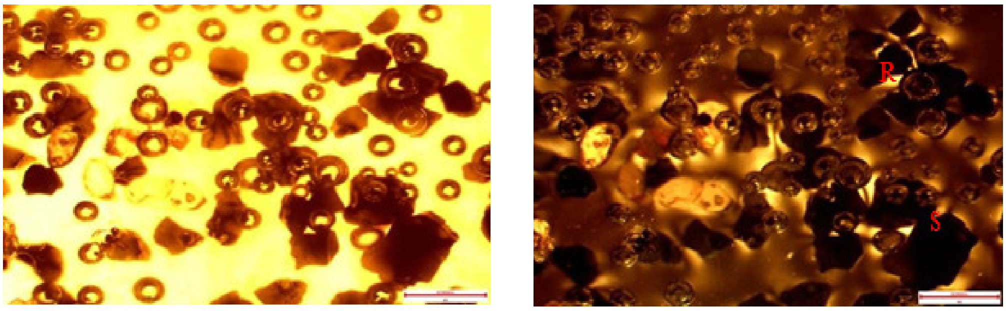
Lithology samples were collected from different locations in Ogunniyi with sample bags, measured using weighing balance and analysis made using separating funnel, heavy liquid, filter funnel with support and collecting bottle. They were analyzed using binocular microscope. Samples were disaggregated to allow only sand-size lithology as defined by Wentworth 1922. Minerals were separated in funnel using bromoform with specific gravity of approximately 2.89. Gravity method was adopted to separate heavy minerals from other minerals of lower density. Light density fractions float while high density ones sink after allowing for almost seven hours. The grains of the heavy mineral were placed on the microscope slide for further examination so as to identify and tally them accurately.

RESULTS AND DISCUSSION

The results of petrographic studies which show photomicrographs of few heavy minerals from different samples obtained from Ogunniyi are presented in Figures 3 to 8. The heavy minerals that are detected in the sand sediments are opaque, tourmaline, zircon, rutile and staurolite (both have the same amount), hornblende and topaz in descending order of magnitude (Table 4).These minerals are represented in Figure 9 with respect to sample locations. The percentage of the total heavy minerals available in the whole area of study is Figure 10.

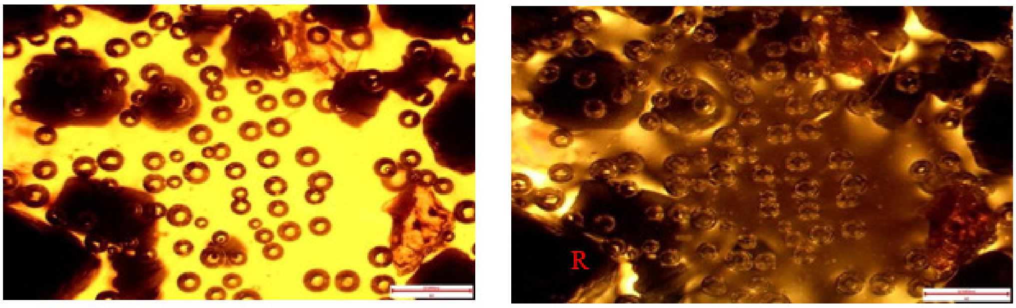
Table 4: Number of counts of heavy minerals viewed from themicroscope.

Sample	Zircon	Tourmaline	Rutile	Hornblende	Topaz	Staurolite	Opaque minerals
OG5	4	2	3	0	0	2	7
OG7	0	3	4	0	0	1	12
OG11	0	6	0	0	1	0	14
OG12	3	0	0	2	0	4	22
OG18	4	3	2	0	0	0	28
OG24	3	4	1	0	0	3	18
Total	14	18	10	2	1	10	101



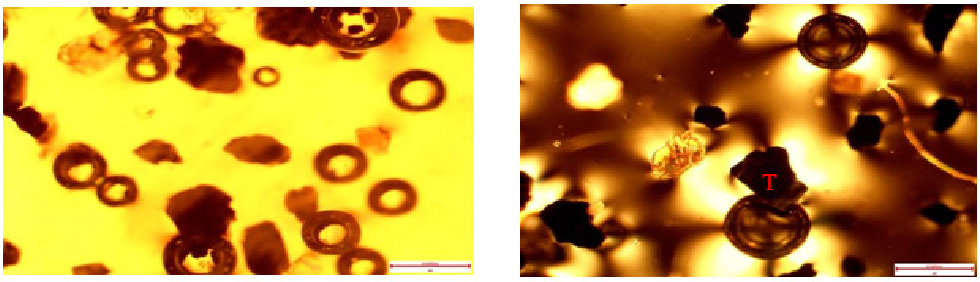
i **ii**

Figure 3: Photomicrograph of few heavy minerals from sample OG5 under (i) Cross Polarized Light (XPL) (ii) Plane Polarised Light (PPL); R = Rutile, S= Staurolite.



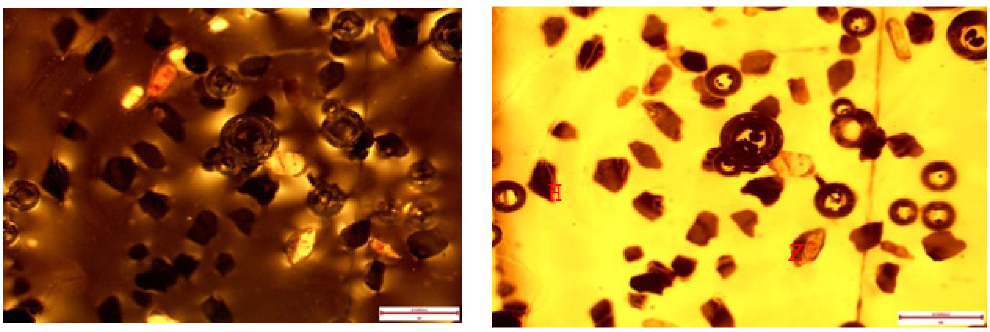
iii **iv**

Figure 4: Photomicrograph of few heavy minerals from sample OG7 under (iii) Cross Polarized Light (XPL) (iv) Plane Polarised Light (PPL); R = Rutile.



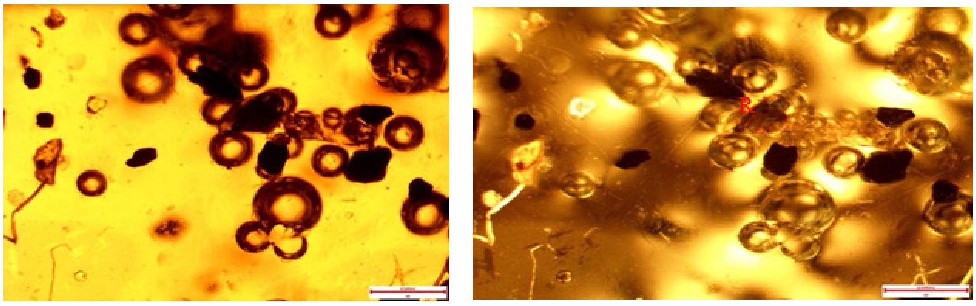
v **vi**

Figure 5: Photomicrograph of few heavy minerals from sample OG11 under (v) Cross Polarized Light (XPL) (vi) Plane Polarised Light (PPL); T = Tourmaline.



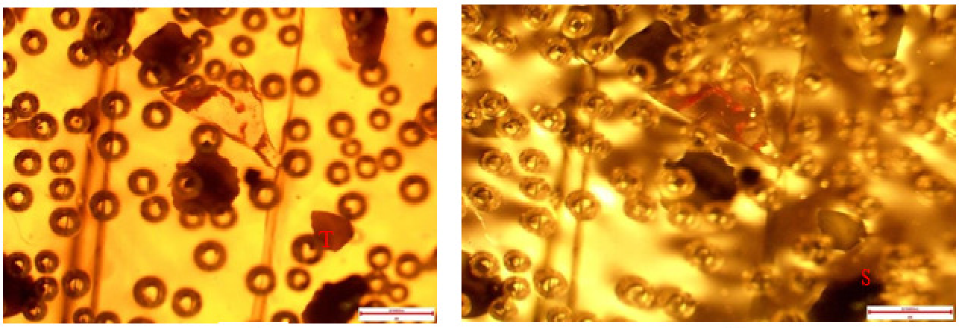
vii **viii**

Figure 6: Photomicrograph of few heavy minerals from sample OG12 under (vii) Cross Polarized Light (XPL) (viii) Plane Polarised Light (PPL); Z = Zircon, H = Hornblende.



ix **x**

Figure 7: Photomicrograph of few heavy minerals from sample OG18 under (ix) Cross Polarized Light (XPL) (x) Plane Polarised Light (PPL); R = Rutile.



xi **xii**

Figure 8: Photomicrograph of few heavy minerals from sample OG24 under (xi) Cross Polarized Light (XPL) (xii) Plane Polarised Light (PPL); S= Staurolite.

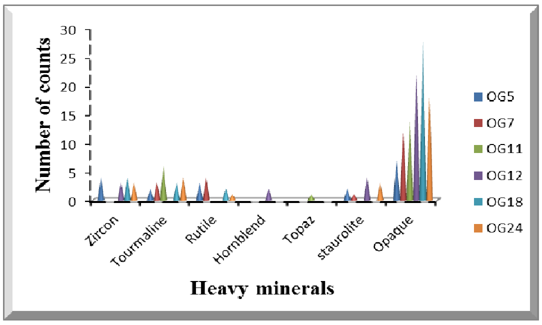


Figure 9: The presence of minerals in different locations

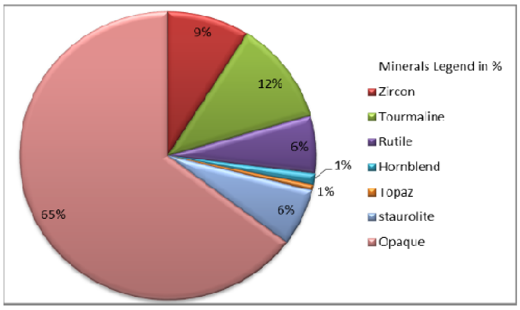


Figure 10: Pie chart of total heavy mineralconcentration.

DISCUSSION

We have considered Tables 2 and 3 in the discussion of our results. These Tables satisfied the choice of different source rocks of sediments.

First, location OG5 contains zircon, tourmaline, rutile, staurolite and opaqie minerals. Non-opaque minerals present suggest the source rock as granite and porphyroblastic schists. When the strength of these minerals were noted, more minerals were recorded in support of granite as the source rock. Therefore, with the presence of ZTR and staurolite non-opaque minerals, the predicted source rock is granite with some percentage of porphyroblastic schists.Location OG7 has tourmaline, rutile, staurolite and opaque minerals. From Table 4, the amount of Tourmaline (T) plus Rutile (R) is more than that of Tourmaline (T) plus Staurolite (S). Therefore, the source rock is granite with little intrusion of porphyroblastic schists.

In OG11, Tourmaline is appreciable with little Topaz heavy mineral (non-opaque); opaque mineral is high in this location. From Table 2, Tourmaline-Topaz combination indicates sediments source rock as granite and pegmatite (both are made from igneous rock).

OG12 reveals availability of zircon, hornblende (which is a dark-coloured amphibole) and staurolite. We are facing Zircon-Hornblende (which suggest the source rock as granite) and Zircon-Staurolite (which support porphyroblastic schists of metamorphic rock as the source rock) competition. The amount of Zircon-Staurolite is higher than that of Zircon-Hornblende and therefore predicts porphyroblastic schists of metamorphic rock as the source rock with little presence of granite of igneous rock.

OG18 has complete ZTR minerals as the only non-opaque minerals in the area. These sediments are sourced from reworked sediments which could originate initially from granite of igneous rock. We have also noted that opaque minerals are really dominating in this location (the highest when compared to other ones noted from other locations).

In OG24, tourmaline is available as well as zircon. Rutile is also seen in small quantity. Staurolite (S) is appreciable too with the presence of opaque minerals. Grouping these non-opaque heavy minerals as Z-T-R and Z-T-S, we observed that the later (Z-T-S) presence out number the counts of the previous. Therefore, the source rock is porphyroblastic schists of metamorphic rock as the source rock with few intrusions of granite of igneous rock.

In order to remark on the mineralogical maturity of sediments, we have determined the index of ZTR in the area of study. Equation 1 was considered for this finding. Zircon contributed 25.45% of the total sum of non-opaque heavy minerals; the percentage of tourmaline is 32.73% while that of rutile is 18.18%. This gives the same value (76.36%) we obtained, using Equation 1. Therefore, the mineralogical index indicates that the sediments are matured. The index is commonly high in beach or littoral zone depositional environment due to the long transport distances from the source and the high energy of the environment.

CONCLUSION

The heavy minerals present in Ogunniyi sand units have been identified and they show abundance of opaque and ZTR minerals and staurolite which have been influenced mainly by provenance, diagenetic dissolution and dominant mineral replacement by iron oxyhydroxides minerals with decreasing burial depth. The ultrastable minerals attribute observed infers granitic and metamorphic source rocks derivative which are probably from intensely weathered areas. The lithologic sediments are matured and they are sourced from porphyroblastic schists (which are foliated rocks) of medium grade regional metamorphic rock and granite of felsic igneous rock which is acidic.

REFERENCES

Boggs, S. Jr. (1995). *Principle of Sedimentology and Stratigraphy*. New Jersey: Prentice Hall. P. 774.

Buchner, K. and Grapes, R. (2011).Metamorphic rocks. *Petrogenesis of Metamorphic Rocks,* 8th Edition. Springer. Pp. 21 – 56.

Cascalho, J. and Fradique, C. (2007). The Sources and Hydraulic Sorting of Heavy Minerals on the Northern Portuguese Continental. *Developments in Sedimentology*, 58: 75 – 110.

Earle, S. (2015). *Physical Geology*, 2nd Edition. Gabriola Island: Victoria B. C.

Etimita, O. O. and Beka, F. T. (2020). Heavy Mineral Analysis of Eocene Sands and Sandstones of Nanka Formation, Cenozoic Niger Delta Petroleum Province. *Journal of Geology, Ecology and Landscapes*, 4(4): 251 – 256.

Feo-Codecido, G. (1956). Heavy Mineral Techniques and their Classification to Venezuelan Stratigraphy. *Bulletin of. American Association of Petroleum Geologists*, 40: 984 – 1000.

Friedman, G. M. and Sanders, J. E. (1978). *Principle of Sedimentology*. New York: John Wiley and Sons Incorporated.

Gandhi, M. S. and Raja, M. (2014). Heavy Mineral Distribution and Geochemical Studies of Coastal Sediments between Besant Nagar and Marakkanam, Tamil Nadu, India. *Journal of Radiation Research and Applied Sciences*, 7(3): 256 – 268.

Garzanti, E. and Ando, S. (2019). Heavy Minerals for Junior Woodchucks. *Minerals*, 9(148): 1 – 25.

Kayode, J., Amoo, J. O. and Ayeni, M. J. (2016). Barks Extravitism and Healthiness of Aboriginal Yoruba Populace in Kwara State, Nigeria. *Journal of Biomedical Papers*, 1: 13 – 20.

Mange, M. A. and Morton, A. C. (2007). Geochemistry of Heavy Minerals. *Developments in Sedimentology*, 58: 345 – 391.

Marshak, S. (2009). *Essentials of Geology*, 3rd ed. USA: W. W. Norton and Company.

Mange, M. A. and Wright, D. T. (2007). Heavy Minerals in use. *Developments in Sedimentology,* 58: 215 – 245.

Mason, B. and Berry, L.G. (1968).*Element of Mineralogy: A Series of Book in Geology*. San Francisco: W.H. Freeman and Company. P. 55.

Mohemmed, L. H., Al-Jaefir Thamir A. Al-shamari (2015). Provenance of Injana Formation in Selected Areas by Studying Heavy Minerals. *Journal of Babylon University/Pure and Applied Sciences*, 23(2): 726 – 738.

Morton, A. C. and Hallsworth, C. R. (2007). Stability of Detrital Heavy Minerals during Burial Diagenesis. In M. A. Mange and D. T. Wright (Eds), Heavy Minerals in use. *Developments in Sedimentology,* 58: 215 – 245.

Morton, A. C. and Hallsworth, C. R. (1999). Processes Controlling the Composition of Detrital Heavy Mineral Assemblages in Sandstones. *Sedimentary Geology*, 124 (1): 3 – 29.

Muller, L. D. (1997). Laboratory Methods of Mineral Separation. In: Zussman, J., *Physical Methods in Determination Mineralogy*, 2nd Edition. London: Academic Press.

Oladipo, V. O., Adedoyin, A. D. and Atat, J. G. (2018). The Geostatistical Investigation of Grain Size and Heavy Minerals of Stream Sediments from Agunjin Area, Kwara State. *World Journal of Applied Science and Technology*, 10(1B): 249 – 257.

Pettijohn, F. J. (1975).*Sedimentary Rocks*, 3rd Edition. New York: Horper and Row. P. 628.

Prothero, D. R. and Schwab, F. (1996). *Sedimentary Geology: An Introduction to Sedimentary Rock and Stratigraphy*, 3rd Edition. New York: W. H. Freeman and Company. P 460.

Raiswell, R. and Anderson, T. F. (2005). Reactive Iron Enrichment in Sediments Deposited Beneath Euxinic Bottom Waters: Constraints on Supply by Shelf Recycling. In: McDonald, I., Boyce, A. J., Butler, I., Herrington, R. J. and Polya, D. (Eds.), *Mineral Deposits and Earth Evolution*, Geological Society London Special Publications, 218: 179 – 194.

Singh, M. (2012). Heavy Mineral Assemblage of the Pinjor Formation of Northwestern Himalaya and its Significance in Deciphering the Provenance of the Sediments. *Geosciences*, 2(6): 157 – 163.

Suleiman, M. M., Ibrahim, I. S., Elfaki, J. T. and Dafa-Allah, M. S. (2015). Origin and Distribution of Heavy Minerals in the Surficial and Subsurficial Sediments of the Alluvial Nile River Terraces. *Open Journal of Soil Science*, 5: 299 – 310.

Thompson, G. R. and Turk, J. (1997). *Introduction to physical geology*, 2ND Edition. USA: Brook Cole.

Wentworth, C. K. (1922). A Scale of Grade and Class Terms for Clastic Sediments. *Journal of Geology*, 30: 377 – 392.

Wilkinson, B. H., McElroy, B. J., Kesler, S. E., Peters, S. E. and Rothman, E. D. (2008). Global Geologic Maps are Tectonic Speedometers – Rates of Rock Cycling from Area-Age Frequencies. *Geological Society of America Bulletin*, 121(5–6): 760 – 779.

Yahaya, O. Y., Adamu, G. K., Bamidele, O. I. and Moshood-Oniye, T. (2014). The Impact of Cropping Systems on Fertility Status of Soil in Babanla Rural Area, Nigeria. *Academic Research International*, 5(4): 181 – 188.