Volume 3 No.1, January 2013 ISSN 2224-3577

International Journal of Science and Technology

http://www.ejournalofsciences.org

Sedimentological and Depositional Enviroment of the Mid-Maastritchtian Ajali Sandstone, Anambra Basin, Southern Nigeria

Odumoso, S.E [1]. Oloto, I.N [2]. Omoboriowo, A.O [3]

[1] Department of Geology, Delta State University, Abraka, Nigeria

[2, 3]Department of Geology, University of Port Harcourt, Port Harcourt, Nigeria

ABSTRACT

Outcrops of Mid-Maastrichtian strata belonging to the Ajali Sandstone in the Anambra Basin, Southeastern and Southern Nigeria were mapped and logged. Samples were studied and used to determine textural and mineralogical characteristics, chemical composition, and paleoccurrent direction, provenance, palaeoenvironment, palaeogeography and diagenesis so as to develop a depositional history for the rocks in the study area. On the basis of the lithologic and sedimentary characteristics, the rocks have been grouped into three facies from bottom to top; shale unit; cross-bedded, burrowed sandstone unit; and ferruginized sandstone unit. The sandstone units exposed in most part of the study area.. on the basis of Grain size analysis, it reveals that the sandstones are fine-grained to coarse-grained poorly sorted, leptokurtic, positively skewed, burrowed, planar and trough cross-bedded, but exhibit a fining-upwards texture gradient. The characteristics ichnofossils associated with the sandstones include dwelling burrows of Ophiomorpha and Palaeophycus which belong to the Skolithos ichnofacies. The sandstone generally lack both microfauna and macrofossils. On the basis of framework composition, the sandstones are grouped as quartz arenites but few are sublithic arenites. Heavy mineral analysis revealed a provenance of metamorphic and igneous rocks from Nigerian Basement complex and Oban Massif. Palaeocurrent analysis of the cross beds of the sandstones shows bimodal patterns indicating mainly SSW-NNE and as minor E-W directions of flow current as being responsible for their transportation. A continental (fluvio-deltaic) environment is proposed for the sandstones on the basis of grain size analysis, ichnofacies, geochemical and palaeocurrent analysis. A depositional history proposed for the sandstone is that ancient sands were derived from both igneous and metamorphic rocks of the Nigerian Basement Complex by two ancient rivers flowing n both SSW-NNE and E-W directions.

Keywords: *Ajali, Sandstone, Anambra, Sedimentology, Enviroment*

I. INTRODUCTION

the Anambra basin, it is generally characterized by sediments of Cretaceous and younger ages. Detrital rocks are formed by the sedimentation of minerals and rock fragments that were derived from mechanical breakdown of pre-existing rocks in the source area, and were transported to a depositional site (basin). These sediments could later form sedimentary rocks (shale, siltstones, sandstones, or conglomerates) after undergoing lithification, Often times, the rocks bear evidence of their depositional environment, transporting medium and original mineralogical composition. Such evidences can be reflected on the grain textures, sedimentary structures, and mineralogical composition. These indicators serve as tools for reconstructing ancient environments of deposition and provenance as well as establishing transportational, depositional and diagenetic histories of such rocks. This present study involves a systematic geological mapping of the study area to ascertain the rock types and their distributions based on field observations. It was found that the study area consists of two major rock types namely shale and sandstone. These rocks are exposed at gullies, road cuts and river channels with the sandstone overlying the shale. Common surface exposures are mainly sandstones, which occur in most parts of the study area and form the major objective of this study. Representative samples of these rocks were collected and were further subjected to various laboratory studies, which included grain size analysis, heavy mineral separation, geochemical analysis, and thin sectioning.

The field study also involved careful study of primary sedimentary structures (cross-beddings, ripple marks) in order to establish palaeocurrent direction for the sandstones. Combination of both field observations and interpretation of results obtained from the laboratory studies were used to establish the sedimentological properties; provenance, palaeoenviroment, diagenetic and depositional histories as well as palaeogeography of the study area,

Location and Accessibility

The study area lies within latitudes 5°38’N and 5°56°N and between longitudes 7°22’E and $7^0$31‘E. It falls within Southeastern and Southern part of Nigeria. The major roads such as the Enugu- Port Harcourt Expressway and Uselu-Ifon Expressway, enhanced accessibility to the outcrop locations. Within the study area are footpaths, which make accessibility within the areas easy. Also, the outcrop locations were linked by motorable earth road such as from Okigwe to Uturu and Uselu to Okokhuo.

International Journal of Science and Technology

http://www.ejournalofsciences.org

II. RESEARCH OBJECTIVES

This study is aimed at establishing the physical, biological and chemical characteristics of the rocks in the study area, in order to determine the following: Palaeocurrent direction of the sediments based on the sedimentary structures and Provenance of the Sandstones in the study area, the palaeogeography ,the diagenetic history of the sandstones and depositional environment of the study area

III. LITERATURE REVIEW

Several workers have carried out different studies on sandstones in different parts of the world. Arua [1,2] carried out an extensive textural study on both modern and ancient sands, which provided the basis for a genetic interpretation of sand texture. He inferred depositional environments based on the patterns displayed by plots of grain size against cumulative frequency on a log-probability paper. Other workers such as Friedman, Lancaster,Ojoh, and Wasken [7,9,10,20] used grain texture as a palaeoenvironmental tool. Crime [5] used trace fossils (Ichnofossils) as paleoenviromental tools. The use of primary sedimentary structures such as cross beddings and ripple marks as tools in establishing palaeocurrent direction and palaeogeography has been explained by Briggs and Friends (4,5). Provenance study of sandstones has been based on both maturity index (ZTR index) and elemental composition of the sandstones. The Anambra Basin, where the study area lies has attracted much attention particularly within the past three decades. Sedimentological studies of some sandstone units in the basin have been carried out by some workers. [13,14,18,]

Stratigraphy of Anambra Basin

The stratigraphy and lithostratigraphic studies of Anambra Basin are as follows:

Nkporo Formation: The Nkporo shale is the basal sedimentary unit that was deposited following the Santonian folding and inversion in Southeastern Nigeria and indicates a late Campanian age, based on the presence of Afrobolivina afra [18].The formation is generally poorly exposed but has been described as coarsening upward deltaic sequence of shale and interbed of sands and shale with occasional thin beds of limestone [18].

The Enugu shale: The Enugu shale is restricted to the central and northern parts of the Anambra Basin and consists of carbonaceous grey black shales and coals with interbeds of very fines and sandstone/siltstone deposited in lower flood plain and swampy environment. The bedding planes are poorly defined with early diagenetic minerals such as pyrite and siderites. The sediments have a poorly developed foreshore and shoreface with extensive coastal swamps he Enugu shale was assigned Campanian to Lower Maastrichtian, based on diagenetic species of palynomorphs such as Cingulatisporites ornatus and Tricolpites tienebaensis. [18]

The Owelli sandstone: The Owelli sandstone regarded as a facies of the Nkporo groups is a lateral equivalent of Enugu shale. It is an elongate shoestring sand body to the northwest defining a meander belt of fluvial channel system and a fluviatile point bar. The Enugu and Owelli sandstone were deposited in open marine shelf and alternatively storm and tide dominated. The Owelli sandstone is typically massive, hard and often ferruginous in some places and friable, it may be prominently cross bedded, medium-coarse grained with pebbles, sometimes aligned at the base of the cross beds.

Mamu Formation: The Mamu formation overlies the Enugu shale conformably and contains sandstone, shale mudstone, sandy-shale with coal seams in various horizons[18]. The sediment pile varies across the basin and ranges from 75m to over 1000m, its deposition are estuarine flood plain, Swamp and tidal flat flood plain [18].

Ajali sandstone: The Ajali sandstone overlies the Mamu Formation and has a diachronous age from South to North (Middle-upper Maastrichtian) and exhibits significant thickness variation from less than 300m to over 1000m at the centre of the basin. Depositional characteristics are uniform for most parts of the basin, made up with textually mature sand facies i.e. mature quartz arenite intercalated with kaolinite beds. Dominant sedimentary structures are cross bedding associated with reactivation surfaces, mud drapes, tidal bundles, backflow ripples, channel cut and fills and lateral accretion surface

IV. METHODOLOGY

(i) Field Study: Field study entailed carrying out a geological mapping of the rock types in the study area. The mapping exercise was basically aimed at identifying the rocks and establishing stratigraphic succession of the rocks on the basis of their field relationships. It also involved collection of spot rocks on the basis of their field relationships. It also involved collection of spot rock samples for laboratory studies. Field observations including grain texture, colour, grains orientation, mineralogical composition, measurements of dips and strikes of cross-beddings, in-situ measurements of length and breadth of ichnofossils, thickness and 25 lateral extent of beds, taking photographs of important sedimentary structures and logging of exposed vertical sections were done. Measurements of dips and strikes of the cross-beds were taken for palaeocurrent analysis .

(ii) Laboratory Techniques: The grain size analysis was aimed at determining grain size distribution of the sediments. The samples were first air-dried and twenty- three (23) samples were selected for the grain size analysis by sieving. Mechanical sieving method using sieve shaker was used. 100g of each sample were disaggregated using a mortar and pestle. The disaggregated samples were thoroughly mixed and a representative fraction of the sample was obtained by quartering. This was weighed in a dial spring balance and 50g of each sample were poured into a set of US mesh sieves comprising 3350,2000,1676,850,600,425,300,250,150,

Volume 3 No.1, January 2013 ISSN 2224-3577

International Journal of Science and Technology

http://www.ejournalofsciences.org

106,75,63 microns and a receiving pan were weighed in the dial spring balance, and their weights were recorded. The percentages of these weights, as well as their cumulative weights and cumulative weight percentages were determined, and tabulated. Statistical plots, which included frequently curves, cumulative frequency plots on both arithmetic paper and log probability paper were done. Grain sizes percentiles were obtained and were used to calculate the graphic mean, standard deviation (sorting), inclusive graphic skewness and graphic kurtosis for each sample.

V. PRESENTATION OF RESULT

(a) Lithostratigraphic Analysis The mapping exercise revealed that the study area consists of a lithostratigraphic sequence, which can be divided into three (3) distinct facies on the basis of lithological and sedimentary characteristics namely from bottom to top.

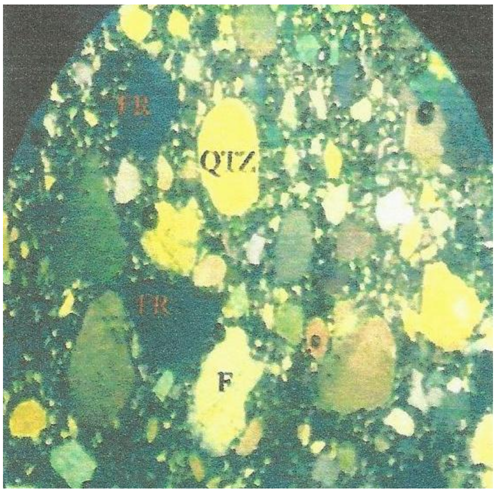
(i) Thick Shale Unit

(ii) Cross-Bedded, Burrowed Sandstone Unit

(iii) Ferruginized Sandstone Unit

The thick shale unit is made up of mainly alternating sequence of red, brown and grayish, fissile shaley beds in most parts where it is exposed, it often grades to grayish shale. It also consists of few intercalations of thin moderately well sorted., fine-grained, friable sandstones. The thickness of the thin sandstone beds ranges between 8 and 20cm and generally increases upwards. Comparatively, the lithological characteristics of the the Ajali Sandstone in Okigwe-Uturu area is similar to that found in Okokhuo along Uselu-.Ifon road of Edo State.

(b) Thin Section Twelve (12) thin sections were made for selected lithologic units **(See Plate A&B,)**. The thin section preparations were prepared. Both friable and consolidated samples were used. The friable sandstone samples were initially impregnated prior to cutting. The impregnation helped to harden the samples. The highly consolidated samples were thoroughly washed with water. The samples were each mounted with polished slide on a glass slide using Canada balsam. The mounted sample was again ground on a lap wheel with a coarse abrasive and was later washed with water. This was followed by manual grinding with sludge of fine abrasive on a glass plate until the slide was fine or thin enough for individual mineral identification. The slide was then thoroughly washed with water and was allowed to dry before covering with a cover slip.



PlateA

Photography of sandstone (Thin Section) of Ajali Sandstone at Ifon (Plate A)

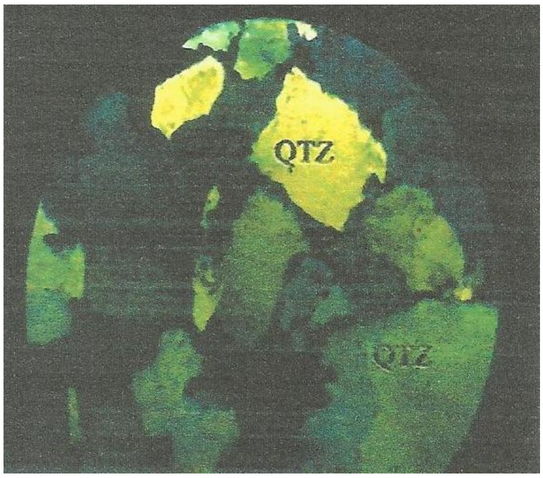


Plate B

Photography of sandstone (Thin Section) of Ajali Sandstone at Okigwe (Plate B)

The prepared thin sections were examined under a flat stage petrographic microscope for mineral identification and estimation of their relative abundance. Photomicrographs of diagnosis properties were also taken.

(c) Heavy Mineral Separation Fifteen (15) disaggregated samples were selected for heavy minerals separation. **(See Plate C& D**). Each sample was boiled with dilute hydrochloric acid for about 15 minutes to eliminate calcareous materials and to clean the grains. The boiled sample was thoroughly washed with water to remove the acid effects. The washed sample was then oven-dried and sieved through a 60-mesh seize, the fraction that passed through the sieve was thus used for the separation. Bromoform of specific gravity 2.85 was the heavy

Volume 3 No.1, January 2013 ISSN 2224-3577

International Journal of Science and Technology

http://www.ejournalofsciences.org

liquid used as the separating medium. 5g of each treated samples were taken and emptied into a separating funnel containing bromoform. The mixture was rigorously stirred and then allowed to settle. The separating funnel tap was opened to allow all heavy minerals that settle to its stern to be flushed out of it into a filter paper filled into a glass funnel in a conical flask. The separated heavy minerals were then washed with acetone (to remove the effects of the bromoform) and were later oven-dried and mounted on glass slides with Canada balsam. Examination and identification of the heavy minerals were carried out under a transmitted light flat stage petrographic microscope on the basis of their optical properties. The number, size and shape of the different opaque and non-opaque minerals were noted; the percentage of these minerals was also estimated. Maturity index or "ZTR index" was calculated.

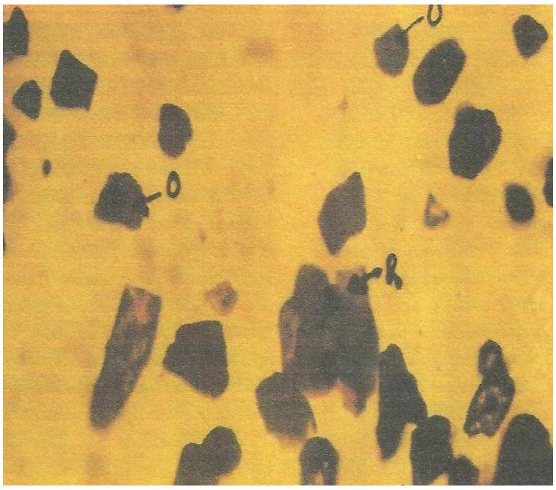


Plate C: Photomicrograph of some heavy the heavy mineral assemblages in the sandstone (plane polarized). O=Opaque minerals, R= Rutile

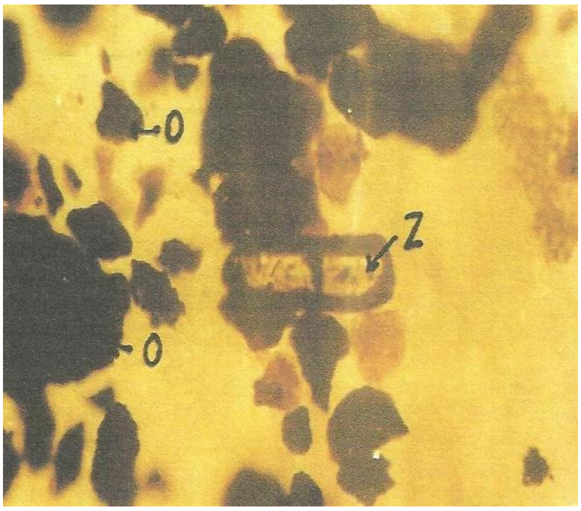


Plate D: Photomicrograph of some heavy the heavy mineral assemblages in the sandstone (plane polarized). O=Opaque minerals, Z= Zircon.

The ZTR index is used as a scale for the estimation of the degree of modification or maturity of the entire heavy mineral assemblages of the sandstone.

(d) Palaeocurrent Analysis The ancient current direction of the transporting medium for the sands in the study area was determined right on the field. This was achieved through measuring the azimuths and dips of cross beddings using a compass clinometer. Rose current diagram was also plotted for the overall strike measurements to obtain a regional palaeocurrent direction in the study area. These plots were used to construct the palaeocurrent map.

VI. DISCUSSION OF RESULT

Lithology The Ajali Sandstone as exposed in Okigwe and Ifon Areas consists of sedimentary rock which is mainly sandstone. These sandstones are massively bedded and they contain sedimentary structures (e.g. cross beddings) and deformational structures (e.g. folds and fractures), the sandstone range from fine to coarse grained with scattered pebbles and cobbles all over the outcrop, with the top layer being ferruginized. These scattered pebbles and cobbles are more concentrated along the bedding planes or at the base of successive layer. Sorting is generally poor. The stratigraphic sections are generally made up of successive alternation of planar cross beddings and horizontal beds. They are typically fining upward cycles. The sandstones generally occur as high ridges and they are chemically weathered, thereby resulting to the alteration of most of its feldspar content. The sandstone are grouped on the basis of colour, cementing materials and degree of consolidating into ferruginized and non ferruginized sandstones. The Ferruginized sandstone is reddish-brown in colour, this is as a result of the presence of probably hematite (Fe_20_3) acting as the cementing material of the sandstone [3]. Its gram size range from medium-coarse grained and it is moderately sorted. Grain shapes varies from sub-rounded to rounded. Thus indicating that the sediments traveled a relatively long distance from their parent rock to where they were finally deposited to form sandstone. The sandstones are well compacted and indurated. Sedimentary structures associated with the Ajali sandstones in Okigwe and Ifon areas have both primary and secondary structures . The primary sedimentary structures are those formed during deposition (**See Plate E)** (i.e. depositional structures) while the secondary structures are formed after deposition (hence they are otherwise known as post-depositional structures).

International Journal of Science and Technology

http://www.ejournalofsciences.org

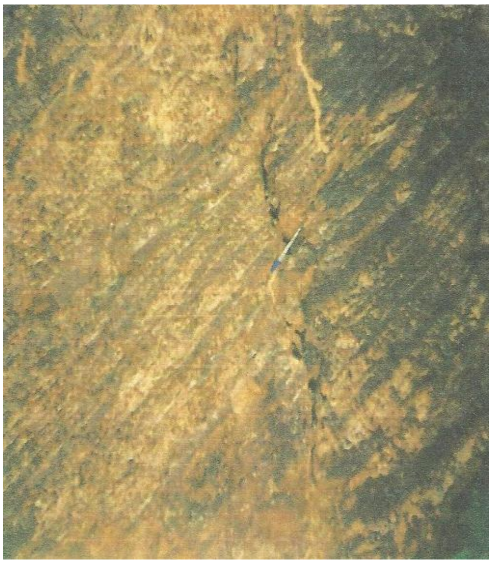


Plate E : Photograph of sandstone showing symmetrical ripples marks in Okokhuo

The primary structures associated with these sandstones are mainly plannar cross-beddings (plates and herring-bone cross beddings. Cross beddings are synsedimentary structures in which various layers lying one above another at an inclined angle. Such structures often result from deposition in a shallow water environment, with the streams suffering repeated changes in direction of flow or the current produced in the body of water and hence serve as paleocurrent tool. The secondary sedimentary structures (deformed structures) present on these sandstones are folds and Fractures which are evidences of tectonic activities in layered rock

Provenance The establishment of source area for the sandstones in the study area is achieved by considering grain texture, heavy mineral assemblages, palaeocurrent direction, geochemical and mineralogical compositions [4,13].The unimodal and fan-shaped palaeocurrent patterns of SSWNNE direction suggest sediment derivation from a source area lying in SSW parts of the study area. The unimodal pattern of grain size distribution also indicates a single source. The bimodal palaeocurrent pattern exhibited by few sandstone samples as well as the bimodal pattern of grain size distribution suggest sediment derivation from sources lying South South West (SSW) and easterly (E). These are similarly confirmed by the regional (overall) fan-shaped pattern exhibited by the sandstones in the study area [7,19]. The angular to subangular quartz grains and the opaque heavy minerals suggest a shorter distance of transportation. This similarly conforms with the presence of feldspar and rock fragments in some of the rocks of the sandstones since they (feldspar and rock fragments) may rarely survive long distant transportation due to their chemical instability. The sub-rounded quartz grains observed in some samples may indicate a relatively long distance of transportation [20].

The high ZTR index values and the high contents of quartz grains in the sandstones of the study area suggest that the sandstones of the study area are generally matured. The occurrence of staurolite, kyanite, hornbende rod polycrystalline quartz grains in the sandstones is excellent indicators of metamorphic source [7]. The framework composition of the sandstone shows very high quartz content and low feldspar and rock fragment contents. The rock fragments are predominantly igneous and metamorphic; this suggest a shorter distance transport. The presence of the igneous and metamorphic chips strongly suggests igneous and metamorphic sources. The result of the geochemical analysis shows that the sandstones of the study area consist of high Si_2O content, but relatively low in Al_20_3, MgO, Fe_20_3, 2O, Na_20 and CaO contents. These suggest that the source area is highly siliceous. Finally, the bulk of the sediments were originally derived from the igneous and metamorphic rocks of Nigerian Basement Complex and Oban Massif.

Palaeoevironment Reconstruction of an ancient depositional environment of sandstones was originally dependent on grain size distribution. The usefulness of statistical grain size parameters in characterizing sedimentary environment has become increasingly apparent over the past five (5) decades as previous studies revealed that, correlation actually exists between textural parameters based on grain size, frequently distribution of sands and their environments of deposition. Attempts have therefore been made to relate statistical parameters (obtained from grain size distribution) to different environments of deposition. These attempts have proved very fruitful in environmental interpretation especially when they are integrated with other parameters such as sedimentary structures and geological settings. Such integration is important since similar sedimentary processes may occur with a number of environments and the consequent textural response is similar [7,20]. Also, the problem of on log-probability paper shows that most of the sampled sandstones have 2-segment patterns (suspension and saltation population), thus suggesting a fluviatile environment. Few of the samples are characterized by 3-segment pattern of traction (rolling), saltation and suspension populations, which indicate a deltaic environment. The association of these processes shows that both high and low energy environments were prevalent during the period of deposition. The fining upwards sequence exhibited by the sandstones on the study area suggests deposition in a fluviatile environment. The tabular cross-stratification associated with sandstones of the study area suggests deposition by migrating sand waves. Sand waves and dunes are common on the beds of river and tidal channels. Similarly tabular sets of cross-strata with planar configuration are suggestive of fluvial settings [1].

Large amounts of heavy opaque minerals (average 76 6%) in the samples suggest an aerated environment of deposition while the predominance of quartz grains in the sandstones of the study area indicates an acidic environment. The absence of both marine fossils and carbonates mixed environments such as delta adjacent to a beach [7]. The sandstones in the study area range in grain size from fine coarse-grained (average medium-

International Journal of Science and Technology

http://www.ejournalofsciences.org

grained). it was suggested that such sediments were deposited by river system [7]. The poor sorted nature of the sandstones indicates that the sediments were deposited under variable current velocities and turbulence which led to the deposition of variable sand-sized sediments in the area.[11]. poorly sorted sandstones was being deposited in a river environment [7]. The skewness of the sandstones range from strongly coarse skewed to strongly fine skewed. This is characteristic of fluvial/glacial environment [9,10]. The different bivariant plots such as simple skewness measure versus sorting measure; inclusive graphic skewness against standard deviation, skewness against deviation and mean grain size versus standard deviation suggests that over 85% of the sandstone samples are mainly of river environment, while less than 15% are beach sediment [7]. Similarly, the bivariant plots of cumulative frequency against mean grain size show the prevalence of acidic conditions over alkaline envirorment.

The general local unimodal and regional fan-shaped palaeocurrent paterrns suggest sediments deposition in fluviatile environment [19]. The icinofossils of Ophiomorpha and Palaeophycus with some U- shaped burrows are grouped under the skolithos ichnofacies [12], which typifies moderate to high sediments influx that could produce moderately well-sorted, clean arenaceous subtrates. Such conditions are prevalent in foreshore and shoreface zones of beaches, bars and spits where physical sedimentary structures such as parallel to sub-parallel laminae and large-scale cross-beds predominate [15,16] .Ophiomorpha burrows have however, beer reported in inter tidal, fluvial, littoral and offshore marine environments. On the basis of ichnofacies, the sandstones in the study area are deposited in a fluviatile to shallow marine (sublittoral) environments. Considering all the above palaeoenvironment tools, a fluviatile environment is firmly established with a stretch into deltaic regime.

Palaeogeography Palaeogeographic history of the study area is established on the basis of grain size distribution pattern, field relation of the sandstones and palaeocurrent analysis. The palaeocurrent direction of the sandstones reveals that the study area was drained by both a major ancient river flowing in SSW-NNE direction and a minor steam flowing in E-W direction. These ancient rivers could have been responsible for the transportation of clastic sediments from the pre-Santonian igneous and metamorphic rocks of the Nigerian Basement Complex and Oban Massif. The grain size distribution of the sandstones in the study area reveals a general reduction in grain size along these directions of sediment transport because current velocity decreased as the distance from the source area increased. The presence of heamatite cements denotes an oxidizing environment thus suggesting that a humid climate prevailed in the area during the period of deposition.

Diagenetic Effects The sandstones in the study area show varying degrees of diagenetic changes such as compaction, authigenesis and cementation. Compaction refers to a decrease in the bulk volume of the sediments: due to a reduction in porosity and/or solid volume (Nwajide and Hoque 1984). Evidence of compaction is seen in the contacts between quartz grains, which are predominantly straight to concavo-convex. Pettijohn (1975) suggested that in an initial deposit, the contacts between grains ae basically point or tangential in nature overgrowth of quartz. grains (Plate 9) is a conspicuous and common evidence of authigenesis observed in the sandstones of the study area. The demarcation between the core and its overgrowth is often a line of dust particles. The source of the silica (quartz) overgrowth in the sandstone samples could be pressure solution as it is evidenced from concavo-convex and sutured contacts. Other sources of the dissolved silica include diagenetic changes in interbedded shalee and mixed-layer smectite-illite to pure in mudrocks [6]. Heamatite cement is present in some of the sandstones. The heamatite occurs as coatings on framework grains and as shapeless void fillers It shows varying degrees of adherence to detrital grains, often ranging from a loose, or no contact at all to a very close adherence along a clearly observable boundary.

Depositional History Depositional history of the ancient sands in the study area established on the basis of field relations; laboratory studies, particularly thin section and heavy mineral studies [11]. Thin section study carried out on the sandstones of the study area reveals that they are composed of both detrital (primary) and diagenetic (secondary) grains. The detrital grains consist mainly of quartz, few feldspar, rock fragments and detrital mica, which are all sand-sized. Other detrital grains include rutile, tourmaline, zircon, staurolite, hornblende, kyanite which occur as accessory minerals. These detrital grains are weathering products of igneous and metamorphic rocks. They are thought to have been transported by two ancient rivers flowing in SSW-NNE and E-W directions. The detrital grains survived excessive abrasion as evidence from their angularity. Depending on the current velocity of these rivers, detrital grains of variable sizes were transported, and coarse particles were first laid down as traction populations as the current velocity diminished. This was probably followed by medium-grained and fine-grained particles, which were respectively deposited as saltation and suspension populations at a relatively low current velocity. Saltation and suspension processes were the major prevailing processes responsible for the deposition of the bulk of the sandstones in the area. This kind of deposition of ancient sands in response to diminishing current velocity accounts for the fining-upward sequence characterizing the sandstones of the study area [7]. The diagenetic (secondary) minerals which are those minerals formed insitu [11], act as cenenting materials in the sandstones by binding the detrital grains together, thus reducing the porosity of the initially deposited unstable minerals (eg. Olivine, Pyroxene) may be dissolved by water at certain certain conditions of P^H and Eh; thus leading to the leaching out of highly mobile elements such as Ca^2, Na^+, K^+, Mg^{2+}, Fe^{2+} and Fe^{3+} which are carried in solution into depositional site. They may precipitate from solution to form secondary (diagenetic) minerals as a result of changes in the water chemistry (P^H and Eh). The secondary minerals in the sandstones of the study area are silica (quartz) overgrowths and heamatite cements which are thought to have formed in a

International Journal of Science and Technology

http://www.ejournalofsciences.org

similar way. Some burrowing organisms especially earthworms could have lived within or particularly on top of the deposited sediments, thus interrupting the sequence as a result of their activities. The ancient rivers responsible for sediment transport might have left evidences of their flow directions in the forms of planar and cross-stratification[17]. These structures (burrows and cross-beds) together with the sediments were preserved after lithification to give rise to the characteristic sandstones of the study area.

VII. CONCLUSION

The sedimentary rocks in the study area have been subdivided into (3) units or facies on the basis of lithological and sedimentary characteristics observed at outcrop sections sampled. Stratigraphically, the units include;

(i) Shale unit - **Base**

(ii) Cross-bedded, Burrowed Sandstone Unit- **Middle**

(iii) Ferruginized Sandstone Unit-**Top**

The basal shale unit is characterized by alternating sequence of red, brown, grey and dark grey, fissile shale with few intercalations of thin fine-grained sandstone beds. It lacks both fossils and microfauna, but consists of few worm burrows (trace fossils) .On the basis of its trace fossil contents, it is suggested to have been deposited in shallow marine environment .The middle cross-bedded, burrowed sandstone unit conformably overlies the shale unit. It has a variety of colours from white, pink, purple, red to grey. It consists of fine to coarse-grained, fining-upwards sequence of friable sandstone.it has a characteristic cross-beddings and burrows. Its enviroment of deposition is sublithoral.

The topmost ferruginized sandstone unit ranges from reddish brown to grey in colour and is fine to coarse-grained, poorly sorted sandstone. It consists of jointed and massive structures denoting transportation by strong current into shallow nearshore or continental environment. The sandstone outcrops in the study area exhibit a variety of colours ranging from white, pink, purple, grey to dark grey. They are fine to coarse grained, platykurtic to extremely leptokurtic, very poorly to well-sorted, friable to hard sandstone. A fining-upwards sequence often characterizes the sandstone, consisting of massive basal sandstones followed by medium grained, trough and flat cross-bedded sandstones and fine-grained rippled and burrowed sandstone. The sandstones in the study area lack body fossils but contain ichnofossils of Ophiornorpha and Palaeophycus burrows belonging to skokithos ichnofacies. Mineralogically, the sandstones are made up of 80% quartz; 3.4% feldspar, 2.5% rock fragments, 1.3% mica, 7.2% matrix and 5.7% cement. On the basis of framework composition of the sandstones, most of them in the study area are termed quartz arenites, while few are sublithic arenites. The mineralogical maturity index (MI) is respectively super-mature and sub-mature.

The heavy mineral analysis shows that the sandstones of the study area consist of rutile, tourmaline, zircon, staurolite, kyanite, hornblende and opaque minerals. ZTR index of 81% obtained indicates that they are matured. Geochemical analysis reveals that the sandstones are highly siliceous composing of 85.77% SiO_2, 3.4% Al_2o_3, 3.85% Fe_20_3, 1 .69% MgO, 1.55% CaO, 1.22% K_20 and 0.72% Na_20. A combination of grain texture, palaeocurrent, geochemical and heavy mineral analyses suggest that the source area for the sandstones is made up of acidic igneous and metamorphic rocks of Nigerian Basement Complex and Oban Massif. The environments of deposition for the sandstones were mainly continental (Fluviatile), although it might have extended to deltaic and sublittoral regimes as revealed by textural and ichnofacies attributes.

ACKNOWLEDGEMENT

The Authors acknowledged the effort of Ijeoma Adedayo for typesetting and proof reading the manuscript; Thank you very much, your Oil will never go dry.

REFERENCES

[1]. Arua, I. 1980: Paleocene macrofossils from the Imo Shale in Anambra Basin. Jour. Min. Geol. Vol.17 p 81-84.

[2]. Arua, I 1988: Episodic sedimentation. An example from the Nkporo shale (Campano -Maastrichtian) Nigeria. Jour. Africa Earth Science. Vol.7 p 759-762. 8.

[3]. Blatt, H., Berry, W.B.N. and Brande, S. 1991: Principles of stratigraphic ana1ysis Blackwell Sc. Pub. Boston. P 512

[4]. Briggs, G. 1963: Paleoccurrent study of the Brazos River Sandstone member. of the Carrier Formation, Palo-Pinto, County, Texas. Jour. Sed, Pet. Vol. 33, No. 1, p 97-104.

[5]. Crimes, T.P. and Crosley, J D). 1980: Interturbidite bottom current orientation from trace fossils with an example from the Silurian Flysch of Wales. Jour. Sed. Pet. Vol. 50, No. 3 p 821-842.

[6]. Crook, K.A. W. 1968: Weathering and roundness of quartz sand. grain. Sedimentology. Vol. 2 p 171-182.

[7]. Friedman, .J.M. 1961: Distribution between Dune, Beach and River sands from textural characteristic. Jour. Sed. Pet. Vol.31. No.4 p.529.

International Journal of Science and Technology

http://www.ejournalofsciences.org

[8]. Friend, P.F. 1965: Fluviatile Sedimentary Structures in the Wood Bay Series (Devonian) of spitsbergen. Sedimentology. Vol.5 p 39-68.

[9]. Lancaster, N. 1981: Grain size characteristics of the Namib Desert Linear Dunes. Sedinentology. Vol .28 p115-122.

[10]. Lancaster, N. 1986: grain size characteristics of Linear Dunes in the Southwestern Kalahari. Jour. Sed. Pet. Vol.56, No.3, p 395-400.

[11]. Mbulk, L N. Rao, V.R. and Kumarn, K.P.N. 1985: The Upper Cretaceous -Paleocence boundary in the Ohafia-Ozu Abarn area, Irno State, Nigeria. J. Mm. Geol. Vol.22, p 105-113.

[12]. Mode, A.W. 1993: Ethology and Palaeoenvironmental Significance of Trace Fossils from Cenomanian. Turonian sediments in the Upter Benue Trough, Nigeria. Jour. Min. Geol. Vol.2 1, No2 p 111-118.

[13]. Murat, R.C. 1972: Stratigraphy and Palaeogeography of the Cretaceous and Lower Tertiatiry in Southern Nigeria., African Geology Department, University of Ibadan, p 251-266.

[14]. Nwajide, C.S. and Reijers, T.J.A. 1996: Geology of Southern Anambra Basin. In: REUERS, T.J.A. (ed). Selected chapters on Geology. p 171-148.

[15]. Ojoh, KA. 1992: The Southern part of the Benue Trough (Nigeria) Cretaceous Stratigraphy, Basin Analysis, Palaeo-oceanography and Geodynamic Evolution of the Equatorial domain of the South Atlantic NAPE Bull. Vol.7 p 131-152.

[16]. Okoro, A.U. 1995: Petrology and Depositional history of the sandstone facie of the Nkooro Formation (Campano-Maastriebtian) in Leru Area, Southeastern Nigeria. Nig. J. Mm. Geol. P 105-112.

[17]. Oronsaye, N.J. 1987: Origin and Depositional environments of the Sandstones Deposits in Fugar Area, Bendel State. Nigeria. Nig. Jour. Mm. Geol. Vol 4 p. 96 - 102.

[18]. Reyrnent, RA. and Morner, N.A. 1977: Cretaceous Transgressions and Regression Exemplified by the South Atlantic Palcont. Soc.. Japan, Special papers, No.21, p 247- 261.

[19]. Selley, R.C. 1968: A Classification of Palaeocurrent Models. Jour. Geology l76 p 99-110.

[20]. Waskom, J.D. 1958: Roundness as an indicator of Environment along the coast of pan. Handle Florida. Jour. Sed. Pet. Vol. 28, p 35