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Research Article

PROVENANCE STUDIES AND SEDIMENTOLOGY OF OGWASHI-ASABA FORMATION, ANAMBRA BASIN, NIGERIA

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ABSTRACT

Sedimentology and stratigraphic architecture of the outcropping Tertiary Facies of the Anambra basin were carried out using twenty lithologic outcrop units. The lithostratigraphic unitsof Ogwashi-Asaba Formation were studied: The univariate, bivariate, multivariate, pebble morphometry and sedimentary structures indicate that the sandstones were deposited in a variety of depositional settings such as fluvial, lagoonal, tidal and shallow marine environments. Petrographic and palaeocurrent results show that the sediments are derived from two sources namely the basement area and from pre-existing sedimentary terrain which exist east and northeast of the study area. The stratigraphic architecture shows various facies associations such as the tidally influenced channels, braided fluvial channels, flood plains and fluvial channels.

INTRODUCTION

The Anambra Basin was formed following the Santonian tectonic pulse on a sub-basin formed by the differential subsidence of the fault block in the southern Benue Trough. It was a deltaic complex filled with a lithostratigraphic unit akin to those of the Cenozoic Niger Delta (Reijers, 1996).

The Niger Delta Basin was formed in the early Tertiary due to continued subsidence below the Anambra Basin was then filled with transgressive-regressive cycles between, in the Tertiary. The deposits are characterized by a series of Mega units referred to as depobelts which strike NW-SE and subparallel to the present day shoreline.

Several workers have studied the Anambra Basin and Niger Delta in terms of sedimentology, stratigraphy and sequence stratigraphic concepts (Nwajide and Reijers 1996; Obi, 2000). This author studied the depositional model of the outcrops along Isele Azagba-Onitsha-Akwa areas of the northern Niger Delta and Anambra Basins. The analysis and interpretation of the data sets allow the reconstruction of sedimentary facies parameters, diagenetic histories, dominant controls on sequence development, and allow an added interpretation of the sediments of the northern Niger Delta and Anambra Basin reservoir qualities.

Aim/objectives of the study: The aim of this research was to carry out a detailed study of the sedimentological and stratigraphic architecture of outcropping Tertiary facies of the Anambra and northern Niger Delta Basins, with a view to delineate the depositional model and to evaluate the outcropping units hydrocarbon potential.

Location of study: Area lies within latitudes 6^0 0’ N and 6^0 30′ N and longitudes 5^0 30’ E and 7^0 30’ E. The area delineated for the present study stretches through Onitsha, Umunya, Akwa, Nanka, Ekwulobia all in Anambra State. (Figure 1)

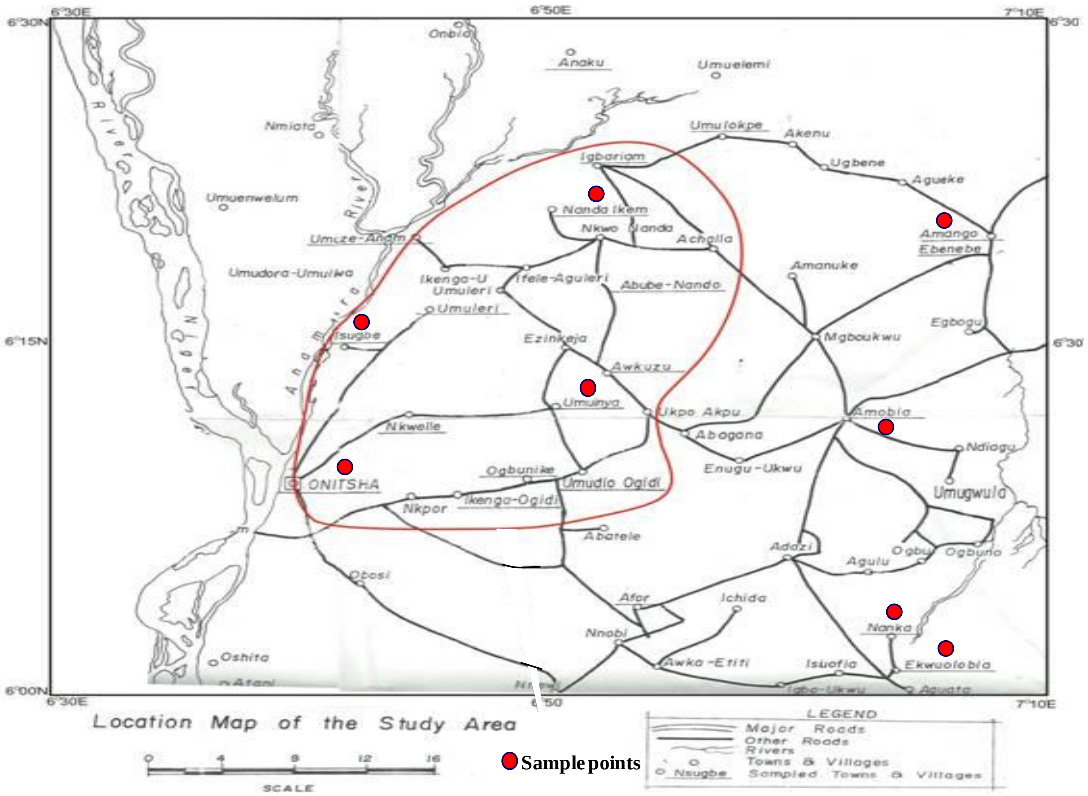

Figure 1: Location of the Study Area

Geology of Anambra and Niger Delta Basin: Deltaic sedimentation in the Anambra Basin was controlled by the morphologic proximity of sediment sources, sea movements during the Campanian to Eocene times, and the circulation system leading to a gradual reshaping of the coastline. Therefore the stratigraphic succession documents transgressive-regressive cycles and the coastline arrangement which relates to variations in sediment deposition.

The Tertiary succession in the Northern Niger Delta basin includes: the Imo shales, the Ameki Group, Ogwashi-Asaba and the Benin Formation (Table 1).

The oldest Formations (Palaeocene-Eocene) in the Niger Delta form an arcuate exposure belt along the delta frame. These are the Palaeocene Imo Shale (fossiliferous blue-grey shales with thin sandstones); the Eocene Ameki Group-fossiliferous, calcareous clays, sandstone and shales; the late Eocene-Early-Oligocene lignitic clays and sandstone of the Ogwashi-Asaba Formation and the Miocene-Recent Benin Formation (Coastal Plains Sands). These formations are diachronous and extend into the subsurface where they have been assigned different formational names. The Akata, Agbada and Benin Formations document prodelta, delta front and delta top environments respectively.

Age	Anambra Basin Surface Formation	Niger Delta Subsurface Equivalent	Broad Depositional Environment
Pliocene-Recent	Coastal Plain Sands	Benin Formation, Afam and Qua Iboe clay member	Continental
Miocene-Recent	Ogwashi-Asaba Formation		
Eocene- Recent	Ameki Group-Ameki Nsugbe, Nanka, Ebenebe	Agbada Formation	Parallic
Palaeocene-Recent	Imo Formation	Akata Formation	Marine

Table 1: Stratigraphic Correlation of Tertiary Formations in the Anambra and Niger Delta Basins (Modified after Reyment, 1965)

The Ogwashi-Asaba Formation: The Ogwashi-Asaba Formation consists of alternating coarse grained sandstones, lignite steaks and light clays. The formation is assigned the late Eocene-Oligocene age (Kogbe, 1976; Jan du Chene *et al.,* (1978).

METHODOLOGY

FIELD WORK: The study of sedimentary rocks in the field is best done by observing, measuring and recording as appropriate. The ultimate aim of the study of sedimentary rocks/outcrops is the interpretation or reconstruction of ancient depositional environments, stratigraphic correlation all leading to palaeogeographic reconstruction. (Tucker, 1988; Miall, 1990).

During the field work, which involved first the reconnaissance and then the actual mapping exercise, several tools and aids were used: topographic/base maps, hammer, chisels, dilute acid, hand lens, penknife, tape for measurement, camera, field notebook, safety coverings, binoculars, masking tape, logging template, compass/ clinometer, sample bags.

The aspects of the sedimentary rocks usually recorded include bed thickness, texture, composition, diagenetic features, sedimentary structures.

Sampling: In this study, the spot sampling method was employed whereby the outcrops were sampled as they were encountered, ensuring that all the lithologies were duly represented. One hundred samples were collected from the various locations studied.

Graphic Logging: Graphic logs were generated by measuring and recording data through vertical section: rock type, bed thicknesses/bed contacts, grain size, colour, sedimentary structures, palaeocurrent direction, thicknesses. The detailing used the following procedures:

- Lithology identification and description: The visual establishment of rock type and minerlogy composition.
- Texture: Colour, grain size, grain shape (roundness and sphericitcty), sorting, and fabric (preferred grain orientation and grain -matrix relations).
- Beds: Thickness, lateral persistence, shape (geometry), bedding planes (scoured, transitional, sharp) and erosional surfaces.
- Sedimentary structures: (a) Physical — Bedforms, channels and stratification, reactivation surfaces, tidal bundles, and deformation structures e.g. growth faults, water escape, overburden crossbeds, etc.
- Chemical – Nodules, concretions, colour bands/liesegang rings, stylolites.
- Biogenic Structures – Trails, tracks, burrows, faecal pellets.
- Fractures – Joints and faults.
- Paleocurrent direction – Dips and dips azimuths of cross-beds, lee azimuths of ripples and pebble imprication.

SIEVE ANALYSIS: Sieve analysis is a widely accepted form of mechanical analysis to determine grain size parameters of sand size sediments. (Krumbein and Pettijohn, 1961; Folk, 1974; Buller and McManus, 1979).

In this work, sieve analysis is particularly used for deriving the textural parameters since most of the samples are friable and would not yield suitable thin sections. The procedure of Friedman (1979) was employed for dry sieving. After a very careful disagregation, about 200 gm of each of the 100 samples was sieved at a mesh interval of $\frac{1}{2}$ and a time of 15 minutes using a Ro-Tap sieve shaker. Each sieve fraction was weighed and recorded. The silt and clay pan fractions were separated by sedimentation where the sample was oven dried at about 110°C and then immersed in water containing a dispersant (sodium hexametaphosphate) to prevent flocculation of clay minerals. From the results obtained, frequency and smoothed curves were plotted from which textural parameters were calculated. These include, mean grain size, standard deviation or sorting, skewness and kurtosis. These parameters are necessary for the construction of scatter plots needed for environmental interpretation because size frequency distribution among sands may sometimes correlate with their various origin and terminal environment of deposition

(Nwajide, 1997). The important textural parameters which were determined in this work are briefly discussed below:

RESULT AND DISCUSSION

OUTCROP DESCRIPTION: The outcrop exposure labeled OGI is located at km 13, Ogbunike along the Onitsha – Enugu express way. It is a road cut which exposes the formation although some section of the upper part has been eroded. The outcrop is about 24m thick from top to bottom. Four distinct lithofacies were distinguished from the outcrop.(figure 2)

Lithofacies Description:

Coarse grained-conglomeritic unit (5m thick):

The unit consists of planar coarse grained sandstone which are friable coarsering upwards into pebbly sandstone with flat beddings. The coarse grained sandstone unit is about 4m thick while the conglomerate unit is about 1m thick. The alternation of these units continues throughout the section.\

Fossiliferous Sandstone Unit (5m thick):

This unit consists of fine grained massive sandstone, friable, white to yellowish in colour. The sandstones grade from fine grained to medium sandstone and highly fossiliferous. It makes sharp contact with the overlying shale – siltstone unit.

Siltstone – Shale Unit (8m thick):

The unit begins with a 2cm thick siltstone layer which is hard and brownish. A shale sub unit overlies the siltstone that is grayish to greenish in colour containing some carbonaceous materials which makes the shale look pearl. On top if the shale sub unit is a siltstone layer about 1.5m thick ferruginized and fossiliferous. This unit terminates with a coarse grain massive sandstone sub unit of about 15cm thick.

Claystone – Lateritic Cover (6m thick):

This unit overlies the 15cm coarse grain massive sandstone unit. It is whitish to reddish due to the presence of laterite.

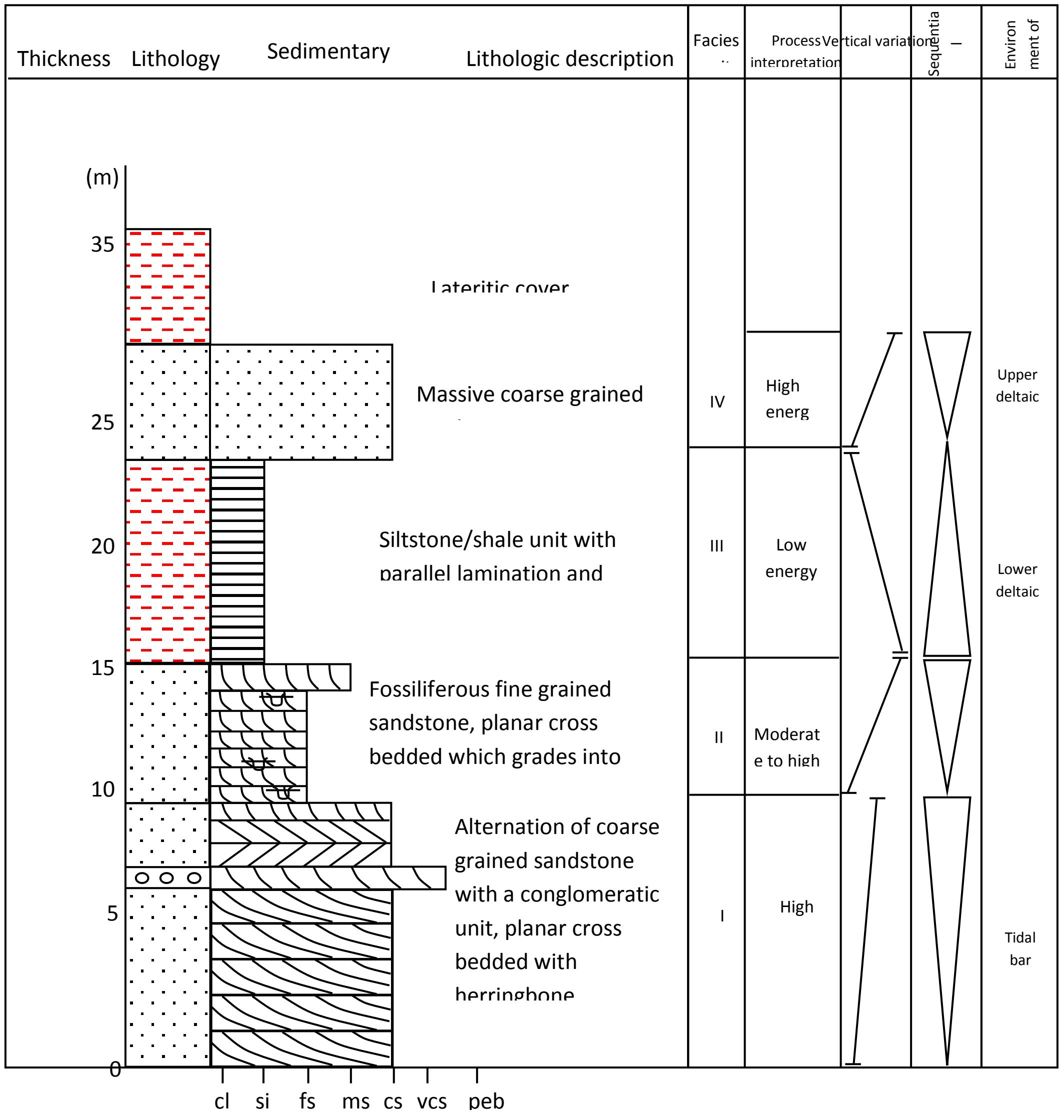

Figure 2: Lithologic Log of Ogwashi-Asaba Formation

GRAIN SIZE ANALYSIS/PROCESS INTERPRETATION:

Selected samples were used as representatives of the entire area for grain size analysis.

Univarite Grain Size Results:

Graphic Mean (GMϕ):

A measure of the average diameter of grains in the sediment. The interpretation was based on Folk and Ward Equation (1957).

Gmz	Interpretation
-1.0 – 0.00	very coarse sand
0.0 – 1.0	coarse sand
1.0 – 2.0	medium sand
2.0 – 3.0	fine sand
3.0 – 5.0	very fine sand
4.0 – 5.0	coarse silt

From the above scale, the sediments of the Ogwashi-Asaba Formation ranges from 0.80ϕ to 2.20ϕ with an average of 1.7ϕ which indicates medium grained sand. The result suggests deposition in a dominantly moderate to high energy environment fluctuated with a low energy depositional environment.

Graphic standard deviation (GSϕ): This parameter measures the spread of the distribution around the mean and gives clues to the sediment sorting; based on Folk and Ward (1957), equation below.

GSϕ	Interpretation
Less than 0.35	Very well sorted
0.35 – 0.50	Well sorted
0.51 – 0.71	Moderately well sorted
1.00 – 2.00	Poorly sorted
Greater than 4.00	Extremely poorly sorted

The analyzed results show a range from 0.74Ø (moderately well sorted) through 2.50Ø (poorly sorted) with an average of 1.33Ø (poorly sorted).

Graphic Skewness (GSKϕ):

This parameter shows the degree of asymmetry of the distribution curves. The interpretation of values is based on Folk and Ward (1957), equation shown below:

GSKϕ	**Interpretation**
+1.00 - +0.30	Very positively skewed
+0.30 - +0.10	Positively skewed
+0.10 - - 0.10	Nearly symmetrical
-0.10 - - 0.30	Coarsely or negatively skewed
-0.30 – 1.0	Very coarsely skewed (-0.134)

The analyzed samples range from -0.13ϕ (coarse skewed) through 0.02ϕ (nearly symmetrical) to +0.39Ø (positively skewed) with an average -0.01Ø (nearly symmetrical). The result suggest that the fine admixture exceeds the coarse components.

Graphic Kurtosis (KGϕ):

This is a measure of the peakedness of the distribution curves, that is, describes the departure of the distribution from normality. The interpretation is also based on the equation of Folk and Ward, (1957).

KGϕ	Interpretation
Less than 0.67	Very platy kurtic
0.66 – 0.90	Platy kurtic
0.90 – 1.11	Meso kurtic
1.11 – 1.50	Lepto kurtic
1.50 3.00	Very lepto kurtic
Greater than 3.00	Extremely lepto kurtic

All the analyzed samples show a range of values from 0.67Ø (Platykurtic) through Ø.91Ø (mesokurtic) to 1.28Ø (leptokurtic) with an average value of 1.15Ø leptokurtic. The results suggest a generally better sorting at the tail. Summary of the results is presented in Table below.

Summary of sieve analysis of the Ogwashi-Asaba Formation (method based on Folk and Ward 1957)

Size Parameter	Average value	Interpretation
Median	1.7ϕ	
Mean	1.7ϕ	Medium
Sorting	1.33ϕ	Poorly sorted
Skewness	-0.01ϕ	Nearly symmetrical
Kurtosis	1.28ϕ	Leptokurtic

The histograms for the sandstone of the Ogwashi-Asaba Formation shows that the sandstone members have a wide range covering all ϕ (phi) diameter values that is, all grain sizes (fine - coarse) are represented. The majority of the analyzed samples have their maximum ϕ values in the 1 2ϕ indicating medium grained. The analysed samples show unimodal and bimodal distribution suggesting more than one phase of deposition and probably a reworking or redeposition of the sediments.

The cumulative results show that all modes of transport of sediments are involved. The segment show a moderately sorted traction sediment load of about 25%, a moderately sorted saltation load making up of about 25 – 80% and a well sorted suspension load of about 45% of the total population. These curves suggest that a moderate energy takes place probably from fluvial to tidal currents in the environment of deposition.

Bivariate Grain Size Parameters: Plots of mean grain size (GM) against standard deviation (GD); skewness against (SKI) standard deviation and median against standard deviation were plotted for the sandstone of the Ogwashi – Asaba Formation (Figure 3). The results were interpreted based on the approach of Stewart, (1958); Friedman, (1961, 1967); Tucker, (1991). The plot of mean grain size against sorting shows that deposition occurs in the fluvial field. Plot of skewness against standard deviation shows that fluvial process was dominant. The plot of median against skewness shows that deposition was dominant in the fluvial region with an influence by tidal incursions in the beach region.

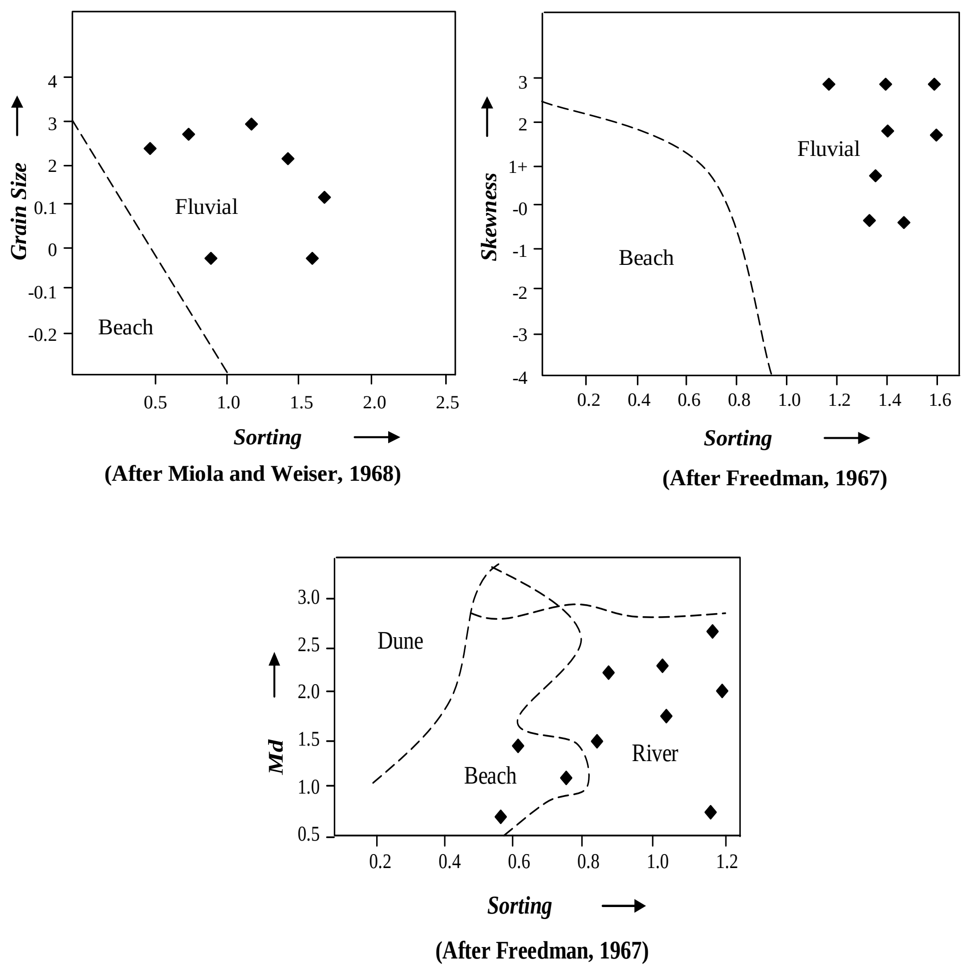

Figure 3: Bivanate Plots for the Ogwashi-Asaba

Formation at Km 13 Ogbunike to Tollgate:

Petrographic Analysis for Ogwashi Formation:

Petrographic analysis for the Ogwashi-Asaba Formation includes the light mineral microscopy and heavy mineral analysis. The results for the light minerals are presented in.

Light Minerals: The analysed samples shows that quartz consist of about 94-99% of the framework grains. Quartz overgrowths are absent to rare, water droplets also present. The quartz also show distinct straight boundaries and this suggest that there are less or no overburden pressure high enough to cause pressure solution or tectonic stress, Ehrenberg (1997); Hart Kamp *et al.,* (1993). The quartz grains show dominance of monocrystalline nature over polycrystalline types with undulose extinction although sharp and non-undulose types also exist. The high predominance of monocrystalline, unstrained grains suggest selective destruction of less stable polycrystalline and strained monocrystalline forms during transport and recycling, Boggs, (1995). This led credence to a multicycle origin of the sediments, Suttner *et al.,* (1981); Amajor, (1986).

Thin Section Analysis for Light Mineral of the Ogwashi-Asaba Formation at Km 13, Onitsha Enugu Expressway

Sample No	Mineralogical composition	Texture	Type of Quartz	Type of Extriction	Type of Contact	Maturity
OG1	Quartz- 98% clay matrix	Subangular to subrounded poorly sorted	monocrystallire	Unduloze	Point	Matured
OG2	Quartz – 97% clay matrix	Subrounded poorly sorted	Monocrystllire 75% polycrystallire 25%	Non-unduloze	Point	Matured
OG3	Quartz – 99% silicacerent clay matrix	Subrounded moderately sorted	Monocrystallire	Sharp	Point	Matured
OG4	Quartz – 97% silica cerent	Subangular to subrounded moderately sorted	Monocrystallire	Unduloze	Point	Matured
OG5	Quartz – 98% clay matrix	Subrounded poorly sorted	Monocrystallire 88% polycrystallire 12&	Sharp	Point	Matured
OG6	Quartz – 99% clay matrix	Subangular to subrounded poorly sorted	Monocrystallire	Undulose	Point	Matured
OG7	Quartz – 94% clay matix	Subangular to subrounded poorly sorted	Monocrystallire	Unduloze	Point	Matured
OG8	Quartz – 99% clay matrix 0.08%	Subrounded poorly sorted.	Monocrystallire	unduloze	Point	Matured

Roundness/Sphericity: Roundness indicates the extent of abrasion grain have undergone. Roundness as Wadell (1930) in Tucker (1988) defined as the average radius of curvature of all corners of a grain, divided by the radius of the largest inscribed circle, hence a property of grain corners.

Roundness = $\sum \left(\frac{r/R}{N} \right)$

Where r is radius of curvature of grain corners

R is the radius of inscribed circle

N is the number of corners.

A total of 100 grains were counted in this work using the counting method of Pettijohn et al, 1987. The mean roundness ranges from 0.25mm (sub angular) – 0.50m (rounded) with an average of 0.38mm. The result show that the relatively high roundness value tend to confirm that the sediments must have traveled a long distance.

The sphericity results show that the samples range from 0.54mm – 0.68m with an average of 0.60mm. From the work of Petfijohn et al, 1987, the grain are subsequent to equant. The relatively high sphericity values tend to suggest that there has been some appreciable amount of reworking of the sediments from pre-existing sediment, most like that the grains are multicycle sediments. This agrees with the work of Suttner, *et al,* (1981).

Maturity of Outcropping Units in the Study Area: The maturity of a terrigenous clastic sediment of sedimentary rock is referred to as the extent to which the material has changed when compared to the starting material of the bedrock from which it is derived, Pettijohn (1975); Nicols (1999). Maturity can be measured in two ways: Textural and compositional or mineralogical.

Textural Maturity: Textural maturity of a clastic sediment refers to the degree of sorting, degree of rounding, and shape of the grains which also are dependent on the physical processes acting on the grains. The textural maturity criteria of a sediment according to Folk (1951) are marked by three distinct stages.

i. The removal of clay materials

ii. The attainment of good sorting and

iii. The rounding of the quartz grains.

The sand of the study area has a relatively low clay content, less than 5%, the standard deviation (sorting measure) in phi scale is averagely 0.80 (moderately sorted); and the mean roundness of 0.39 (subrounded). These attributes when judged against the criteria stated above, indicate that the outcropping sands are texturally submature. The data also indicate that a moderate to high energy condition occurred within the depositional environment. At low energy level, the processes fail to operate; while at too high energy, the processes are self-destructive and become responsible for textural inversions such as rounded but poorly sorted sediments.

Mineralogical (Compositional) Maturity: The mineralogical maturity of clastic sediment is a measure of the proportion of resistant or stable minerals present in the sediment. Quartz being the most stable and durable light mineral is usually used as a measure of mineralogical maturity. Analytical evidence from the mineralogical composition study shows that quartz is the most abundant light mineral in the study area with a total average of 95% - 99%, thus forming the entire framework. This criterion infers that the outcropping units are mineralogically mature. Evidence from the heavy mineral study shows that the ultral stable heavy mineral suite of zircon, tourmaline and rutile are more abundant. These indicate that the ultrastable minerals have survived many chemical and mechanical reworkings, hence suggesting a mineralogical maturity to the outcropping units, Pettijohn and Potter, (1972); Pettijohn, (1975).

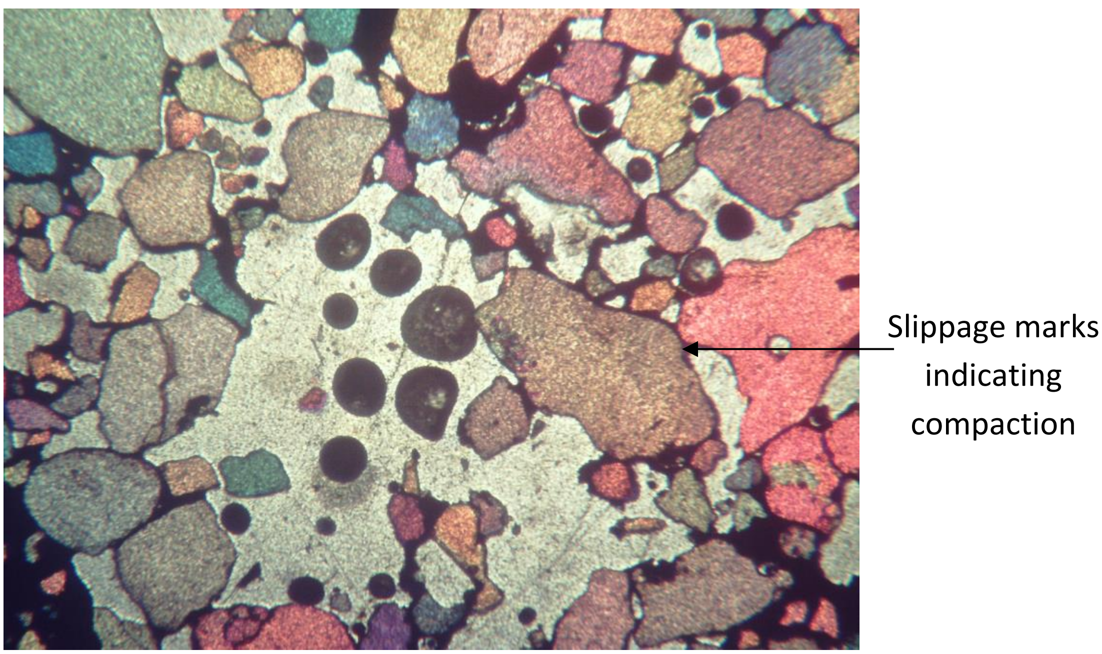

Figure 4: Photomicrograph showing compaction of the sediment, from the study area

Cementation: The sandstones in the study area are almost completely absent with cement except the ferruginized sandstones found within the area. The common sandstone cements such as silica and calcite are absent although iron oxides are common. The complete absence of the cements may be due to the non availability of cementing materials, that is, silica, calcite, authigenic feldspars. The absence of silica may be due to the fact that the overburden pressure was not high enough to cause high pressure solution or due to absence of intense tectonic stress.

Quartz overgrowths are common in the study area as a result of interstitial reactions recupalizing the quartz at grain contacts. They acts as primary cement as they fill the original void without replacing other materials and developing on detrital grains parent grains.

The ferruginized sandstones are cemented by brownish yellow cement of iron oxides refer to as limonite as it appears by its opaque nature. This cement may have been formed by precipitation around the sediments due to weathering, transportation and deposition of amorphous iron compounds. It might also have arisen through a purely diagenetic origin whereby iron is supplied by intrastatal solution of phyllosilicates. In the sands under study, it acts as a void filling materials and as a coating on framework grains. The iron oxide cement shows varying degree of adherence to the separate defrital grains either as loose or without contact to a close adherence to the contact along their boundaries. Dapples (1972), regard such cements here having a sharp and discordant contacts with the framework grains.

Provenance Studies: Provenance studies of sandstone sequences are made possible by the use of modal composition and maturity indicators, Valloni and Myanard, (1981); Dickson, (1985) and Valloni, 1985 in Zuffa, (1985). Provenance studies may be single and comprise of only one dominant rock type or it may be complex where there is more than one source area, and/or sediments which are recycled from other sediments. Lateral changes in composition within a sedimentary unit usually reflect different source rocks or source areas, Mack, (1977). However vertical changes in a sequence of rock usually reflects either a change in dominant source area supplying the basin or a change in the source rock character in the same source area due to tectonic uplift and progressive removal of basement rocks. A change in climate or the depositional environment can also cause vertical changes due to differences in erosion of source rocks as climate changes.

The most informative components of arenites for provenance interpretation are rock fragments, heavy minerals and feldspars. Quartz however has little value in determining provenance because quartz grains in sandstone may be derived from grainitic bedrock, a range of different metamorphic rocks or reworked from older sandstone beds. The textural characteristics of the quartz grains can however be useful. Therefore, in this study, as rock fragments and feldspars are absent, quartz and heavy mineral content are used for provenance reconstruction.

Quartz: Petrographic studies of the samples show that quartz grains predominate other detrital fragments. This makes the determination of the provenance of the sandstones rest almost entirely on the quartz grain attributes, Kryrine (1940, 1946) in Tucker (1988). Quartz grains may be single (monocrystalline) showing either straight or undulose extinction or composite (polycrystalline) with straight or undulose extinction within the individual subcrystal and may or may not show elongation of the subcrystals. The attributes of quartz used for provenance studies include, monocrystallinity, polycrystalinity, undulosity, non undolusity, straight extinction, colour, roundness, inclusions (solid or liquid), size, multiple overgrowth etc, Pettijohn, (1975). The type of quartz is a guide to the nature of the source rock. A metamorphic origin for quartz is characterized by mineral inclusions, wavy extinction, elongate form and other strain properties. An igneous origin contains no inclusion or only liquid and gas inclusions and is relatively strain free and more equidimensional.

Four varieties of quartz were recongnized in the studied sandstones and these are monocrystalline quartz, polycrystalline quartz, non undulose quartz and undulose quartz. The undulosity of monocrystalline quartz has been used for the provenance of quartz grains. Undulosity greater than 5^0 has been ascribed a metamorphic origin while those grains with less than 5^0 are attributed to a plutonic origin (Basu et al, 1975). The polycrystalline quartz is a better indicator of provenance, Basu *et al.,* (1975); Blatt, (1967); Blatt *et al.,* (1972); Young, (1976). Blatt (1967) advocated that a polycrystalline quartz and preferred orientation of the c-axis of the individual crystals in the quartz fragment indicates a metamorphic origin. Hence the presence of multi-crystal quartz grains in the study area indicates that at least some of the polycrystalline quartz grains show bimodality of more than six sub grains indicating also a metamorphic source, Basu *et al*., (1975); Blatt *et al*., (1972). However some show sub grains less than six, which indicate a plutonic origin for these ones. Young (1976), advocates a progressive regional metamorphic source for polycrystalline quartz grains whose bimodality in crystal sizes are due to the growth of large ones at the expense of smaller ones. Blatt and Chistie, (1963); Blatt, (1967) in their studies of quartz grains in igneous and metamorphic rocks concluded that there are no real differences in the degree of undulosity in quartz grains among the igneous and metamorphic rocks but that grains with undulosity greater than 5^0 appear in such a way due to the relationship between the plane of thin sectioning and plane containing the optic axis of the quartz grains. This is why undulosity is not a definitive criterion in distinguishing between quartz grains from plutonic or metamorphic origins.

The degree of undulosity in monocrystalline and polystalline quartz grains indicate strain which occur due to progressive disorientation of the various parts of a quartz grain during metamorphism hence an increase in metamorphism leads to the formation of small crystals, a process referred to as polygonisation, Blatt, (1967); Pettijohn, (1972). Small inclusions which are subparallel and Boehm lamellae are products of intense strain which must have occurred in the quartz lattice before or after incorporation in the sediment. In the study type section, this property is common and they are planes of dislocation leading the formation of deformation bands, which also indicate a metamorphic source, Young (1976).. Medium to high-grade metamorphic quartz grains also occur showing non-undulose extinction, polyhedral crystals and straight boundaries. The metamorphic terrain of sediment provenance as deduced has to be taken with a caution because post depositional changes can also cause undulosity of quartz grains. The percentage of monocrystalline quartz, which are majorly subrounded, rare microcline and overgrowths, which are not interlock with other overgrowths suggest that the sediments were in suspension and therefore underwent reworking. Therefore a minor part of the sands in the study area is a reworked sediment.

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