SEDIMENTOLOGICAL CHARACTERISTICS OF AJALI SANDSTONE IN THE BENIN FLANK OF ANAMBRA BASIN, NIGERIA

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(Received: 16th June, 2011; Revision Accepted: 29th September, 2011)

ABSTRACT

Outcrop mapping as well as textural, mineralogical and structural studies of sandstone in the Auchi locality were carried out in order to interpret depositional environment of Ajali Sandstone in the Benin flank of Anambra Basin. Two major lithologic units were identified: the lower bioturbated shale and overlying sandstone units. The bioturbated lower shale beds contain burrows of *Ophiomorpha* and *Paleophycus* spp. which belong to skolithos ichnofacies that typifies littoral environment. The upper sandstone unit is tabular cross-bedded with NNE-SSW paleocurrent direction. The grains are fine to coarse, poorly sorted and leptokurtic with a fining upward sequence motif. The major framework composition is $Q_{95.6}$ $F_{3.2}$ $L_{1.2}$ which classifies the sandstone as Quartz arenite. Non-opaque heavy minerals constitute 13% of the entire heavy mineral suite of which ZTR index is 87%. The grains are texturally immature as depicted by their subangular edges but mineralogically mature in terms of quantities of quartz and high value of ZTR index. Dominance of Fe_2O_3 (3.85%) in the uppermost bed renders it as ferruginous sandstone. The texture as well as the various bivariate plots of the sandstone indicate fluvial sedimentation probably in a meandering channel that builds up point-bar and overbank deposits. The two litho-units therefore provide three different facies namely the bioturbated shale, the cross bedded sandstone and ferruginous sandstone facies.

Keywords: Sedimentology, Ajali Sandstone, Benin Flank, Quartz Arenite, Littoral, Fluvial.

INTRODUCTION

Sandstone beds within Auchi locality are the western extension of the post-Santonian Ajali Sandstone of the Anambra Basin. Much as the lithostratigraphic units of Anambra Basin were well known and documented (Umeji and Nwajide, 2007; Shell-BP and GSN., 1957; Hoque, 1977; Nwajide and Reijers, 1996), little attention has been drawn to the extension of the Maastrichtian Ajali Sandstone in the Auchi locality probably on account of its occurrence as terminal wedge on the basement of West African massif (Fig. 1). .

The Ajali Sandstone is an extensive stratigraphic unit conformably overlying the Lower coal measure (Mamu Formation) and underlying the Upper coal measure (Nsukka Formation) in the Maastrichtian. The environment of deposition has been discussed by various authors especially Simpson (1954), Reyment (1965), Hoque and Ezepue (1977) and Ladipo (1986). Simpson (1954), in the Nigerian Geological Survey report described the lithostratigraphic unit as False bedded Sandstone. Reyment (1965), associating it with its type locality, formally named it Ajali Sandstone. Hoque and Ezepue (1977) evaluated its textural characteristics and inferred a fluvio-deltaic depositional setting while Ladipo (1986) on the contrary argued for a tidally influenced regime in a shelf/shoreline environment. The present study which is focused on the sedimentological characteristics, intends to provide detailed information on the lithologies, textures and mineralogical compositions in order to establish the depositional history in the extreme western margin of the formation.

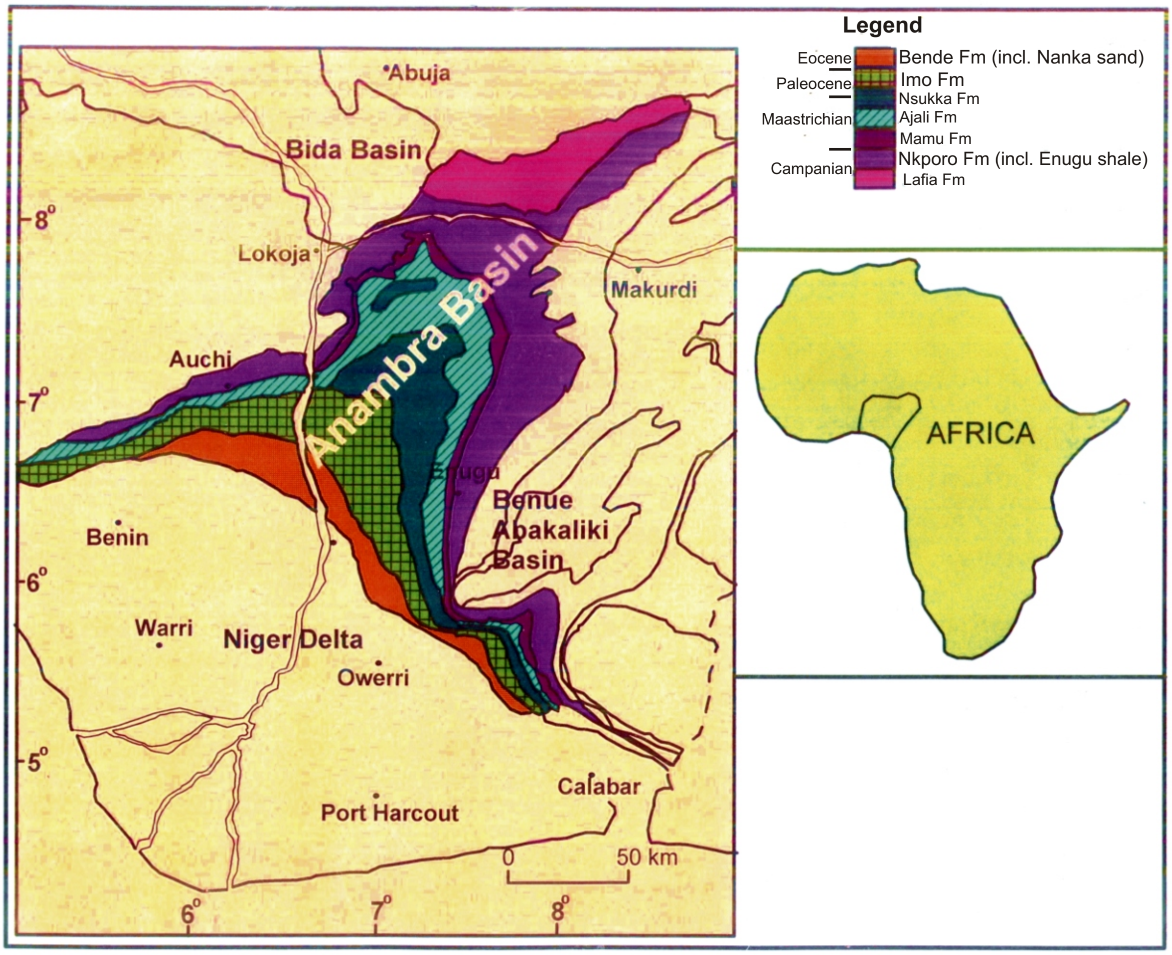


Fig 1: Anambra Basin Showing the Extension of Ajali Sandstone within Auchi Environs (Drawn from Geological Map of Nigeria, GSN1994).

GEOLOGICAL SETTING

Lower Benue Trough is the southern section of the NE-SW aulacogen that developed as a failed arm of the triple radial rift system (Grant, 1971; Burke et al., 1971 Olade, 1975 and Hoque, 1977). Stages of sedimentations in the trough were in three cycles (Table 1). The first cycle was the pre-Cenomanian deposits of Asu River Group followed by the second cycle Cenomanian-Santonian sedimentation. Consequent upon inversion tectonics of the Abakaliki anticlinorium which led to evolution of both Anambra Basin and Afikpo syncline, the third cycle of sedimentation produced the incipient Nkporo Group on Anambra Basin which is composed of the Nkporo Shale, Enugu Shale and Owelli Sandstone. The Nkporo Group is overlain conformably by the Coal Measure Group consisting of the Mamu, Ajali and Nsukka Formations that form the terminal units of the Cretaceous series. The Maastrichtian Coal Measure Group is succeeded by the Paleocene Imo Shale and the Eocene Nanka and Ameki Formations (Umeji and Nwajide, 2007).

Previous works on Ajali Sandstone indicate that its thickest section is in the Udi Plateau where it attains over 350m and extends continuously in thin outcrops to the southeast of Okigwi (Reyment, 1965). Texturally, the formation is mainly composed of unconsolidated medium to coarse grained sub-angular to sub-rounded quartz arenite laterally laid in a sheet-like geometry (Ladipo 1986). Its most conspicuous feature is its cross stratification having its foreset beds alternating between coarse and fine grained sands (Hoque and Ezepue, 1977).

MATERIALS AND METHODS

Methods of investigation involved both field study and laboratory analyses. Intensive field study covered a total of 23 localities from where samples were taken (Fig. 2). Bedding characteristics in terms of structure, texture, attitude and lithology were studied and described. Laboratory studies of the samples were based on grain size analysis, petrography, heavy mineral separation, paleontology and geochemical analysis.

Grain size distribution in the study area was achieved through mechanical sieving of a total number of 23 samples derived from various sections of the study area by employing a Ro-tap shaker for 15 minutes in agitating a 50g sample. The sample was put

Table 1: Stratigraphy of Southern Benue Trough/Anambra Basin

AGE		SOUTHERN BENUE/ANAMBRA BASIN	CYCLE OF SEDIMENTATION
TERTIA RY	EOCENE	AMEKI/NANKA FORMATION	3RD CYCLE OF SEDIMENTATION
	PALEOCENE	IMO SHALE	
UPPER CRETACEOUS	MAASTRICHTIAN	NSUKKA FORMATION	
		AJALI FORMATION	
		MAMU SHALE	
	CAMPANIAN	ENUGU/NKPORO FORMATION	
	SANTONIAN-CONIACIAN	AWGU FORMATION	2ND CYCLE OF SEDIMENTATION
	TURONIAN	EZE-AKU GROUP. (KEANA, MAKURDI, AGALA AND AMASERI FORMATIONS)	
	CENOMANIAN	ODUKPANI FORMATION	
LOWER CRETACEOUS	ALBIAN	ASU RIVER GROUP	1ST CYCLE OF SEDIMENTATION
	APTIAN		
PRECAMBRIAN		BASEMENT COMPLEX	

on top of the sieve set with the following order of mesh sizes; 3350, 2000, 1676, 850, 600, 425, 300, 250, 150, 106, 75 and 63. The fraction of each mesh size was weighed for statistical analysis based on the procedure of Folk and Ward (1957) as well as Friedman (1961).

Heavy minerals were investigated in five sandstone beds in order to assess the maturity and provenance of the grains. Bromoform (SG=2.85) was used as a separating medium. The heavy minerals were mounted for petrographic studies after rinsing off the bromoform with acetone.

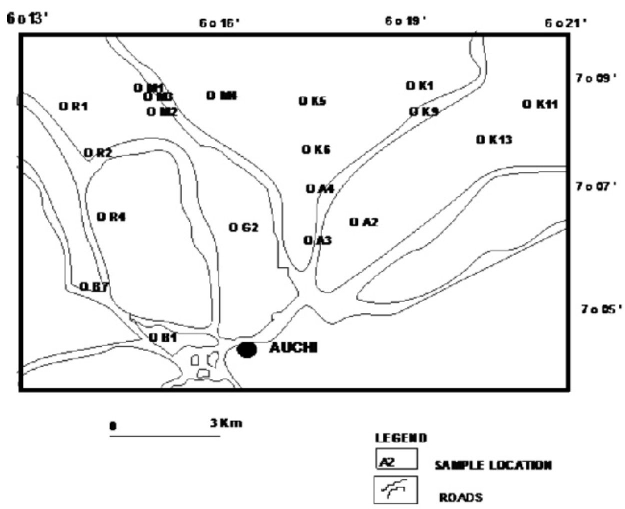


Fig. 2 Map of Study area showing sample locations

Thin sections of representative samples of indurated sandstone were prepared for petrographic study of the minerals and textures of the grains using a polarising microscope. Individual percentage of minerals was computed for classification of sandstone using Folk (1974) method.

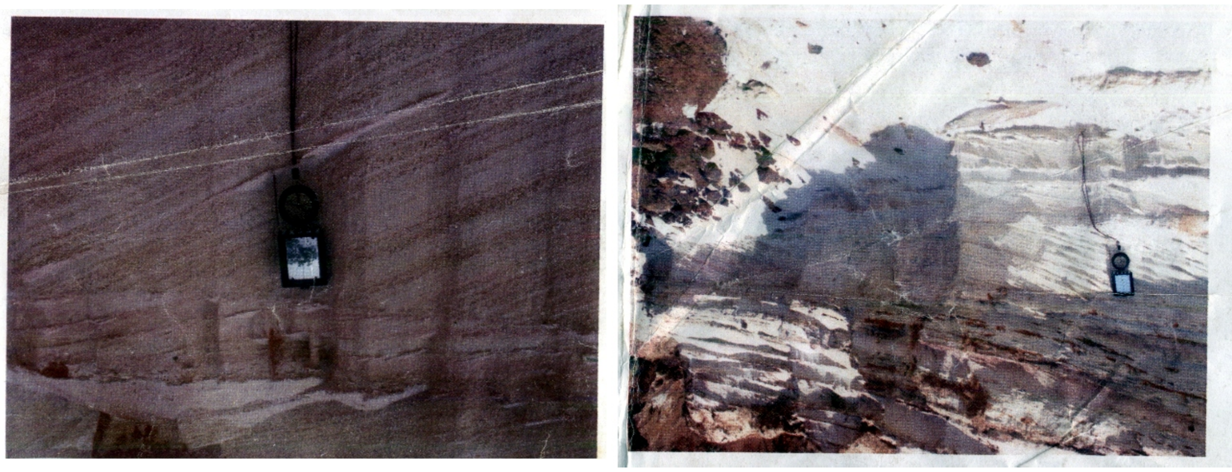
Paleontological studies include biogenic and microfauna analyses. While trace fossils were studied on the field, foraminifera and ostracods were investigated in the laboratory. The procedure for investigation involved soaking of shale samples using anhydrous sodium carbonate and 10% concentrated hydrogen peroxide solution. The soaked sample was then washed through 63 micron mesh sieve and allowed to air-dry.
The residue was in portion spread over black paper under OLYMPUS binocular microscope for picking of the foraminifera and ostracods.

RESULTS AND INTERPRETATION

Field Characteristics

The entire investigated sediments in the outcrops of Auchi envrons consist of three main lithofacies, namely, the fissile bioturbated shale, tabular cross bedded sandstone as well as ferruginous sandstone facies. The thickness of the shale facies range from 30cm to 2m and it is prominent at Okabigbo section along Auchi Fugar road. The beds occur variously in form of alternating sequence of red, brown, and grayish colours. There are also few intercalations of thin fine grained friable sandstone whose contact with the shale bed is marked by load structures. Worm burrows were also found at the upper section of the shale beds and extend into the overlying sandstone unit.

The tabular cross bedded sandstone facies displays white, pink, yellow, purple and grey beds. These beds are poorly to moderately well sorted, fine to coarse grained in texture. They are marked with syn-depositional primary structures such as tabular cross bedding, planar bedding and trough cross bedding (Fig. 3). The trend of the cross beds is used in obtaining the paleocurrent direction of which azimuth is NNE-SSW. The foresets of the cross-beds range from 10 to 50cm in thickness. The basal bed of the sandstone is also marked with ball and pillow structures as well as load casts.



(a) (b)

Fig. 3: Tabular Cross Bedded Fine to Medium Grained Sandstone Facies Observed within a) Auchi Metropolis b) the Trough Cross Bedded Sandstone Observed at Okabigbo.

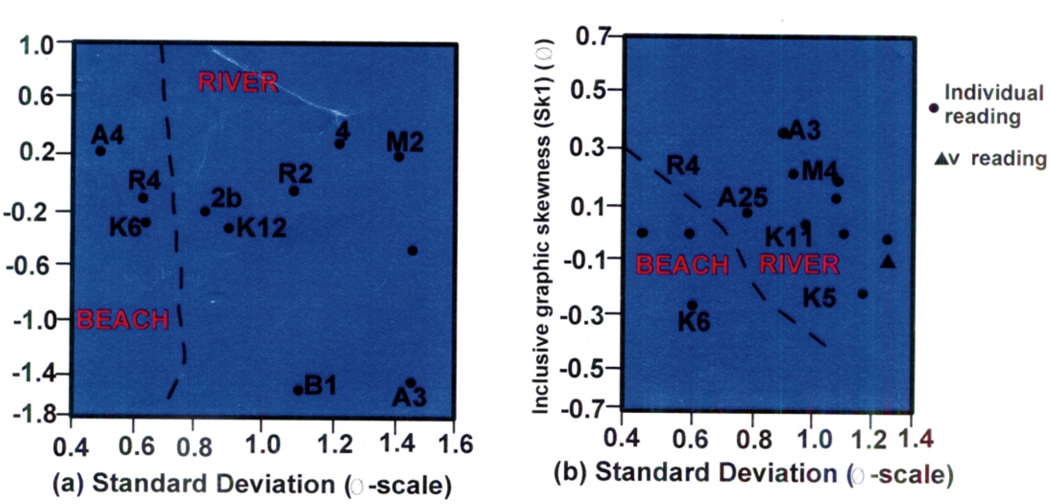
Grain size Analysis

The investigated particle sizes range from 0.14f to 2.3f which classifies them within the medium and coarse grained sizes. The average particle size of 1.4f generally puts the sandstone as medium grained. The standard deviation (measure of dispersion sorting) falling between 0.47 and 2.21 shows that the particles range from very poorly sorted to well sorted, but the average value of 1.28 generally indicates moderately sorted grains. Skewness values are between 0.67 and 0.34 with an average of 0.11 showing that the grain size distribution is near symmetrical. The grain size distribution is generally leptokurtic with an average of 1.40 (Table 2).

Table 2: Calculated Results of the Grain Size Analysis

S/N	SAMPLE NO	GRAPHIC MEAN (MZ)	STANDARD DEVIATION (1)	SIMPLE SORTING MEASURE (SO_S)	INCLUSIVE GRAPHIC SKEWNESS (Sk_i)	SIMPLE SKEWNESS (7s)	GRAPHIC KURTOSIS (KG)
1	A_2b	1.917	0.799	1.352	-0.069	-0.200	1.230
2	A_3	1.327	1.657	2.450	-0.367	-1.700	0.688
3	A_4	2.320	0.465	0.875	-0.009	0.23	1.434
4	B_1	1.100	1.177	2.150	-0.246	-1.500	1.356
5	B_1a	1.323	1.515	2.500	-0.576	-2.400	1.114
6	B_7	0.747	1.146	2.000	-0.037	0.000	1.271
7	G_2	1.553	0.593	1.050	-0.014	0.020	1.230
8	K_1	0.9533	1.023	1.925	-0.053	1.650	0.789
9	K_1b	0.5367	1.066	2.040	-0.073	1.320	1.563
10	K_5	0.600	1.087	3.300	-0.320	5.500	1109
11	K_6	0.140	0.620	2.030	-0.261	-0.30	1.047
12	K_9	1.100	1.165	1.750	-0.170	1.280	1.205
13	$K_{11}a$	1.233	1.126	1.900	-0.144	1.500	1.137
14	$K_{11}b$	1.407	1.538	2.600	-0.284	-0.220	1.122
15	$K_{13}a$	1.207	0.870	1.650	-0.110	-0.100	1.352
16	M_2	0.427	1.904	3.050	-0.066	-1.700	0.933
17	M_3	1.120	1.438	2.650	-0.011	0.260	1.671
18	M_1	1.180	0.962	1.820	-0.205	0.960	1.492
19	M_2	1.667	1.608	2.750	-0.667	2.900	4.508
20	M_2	0.640	2.214	3.510	-0.351	-1.82	0.943
21	R_1a	1.133	1.283	2.090	-0.036	4.820	0.952
22	R_2	1.133	0.292	2.200	-0.034	2.600	2.774
23	R_4	0.793	1.066	1.850	-0.190	0.100	1.167
AVERAGE		1.040	1.275	2.150	-0.111	0.574	1.395

Histogram and frequency distribution of the sandstone particles show strongly unimodal character while the plots of cumulative frequency against the particle diameter reveal more of suspension and saltation sedimentation processes. Discrimination charts using bivariate plots of Friedman (1961, 1967) were employed (Fig. 4). The plots are those of simple skewness vs standard deviation; inclusive graphic skewness vs standard deviation; mean grain size vs standard deviation as well as simple skewness vs simple sorting measure, which reveal the particles as fluvial sediments (Fig. 4a-d).



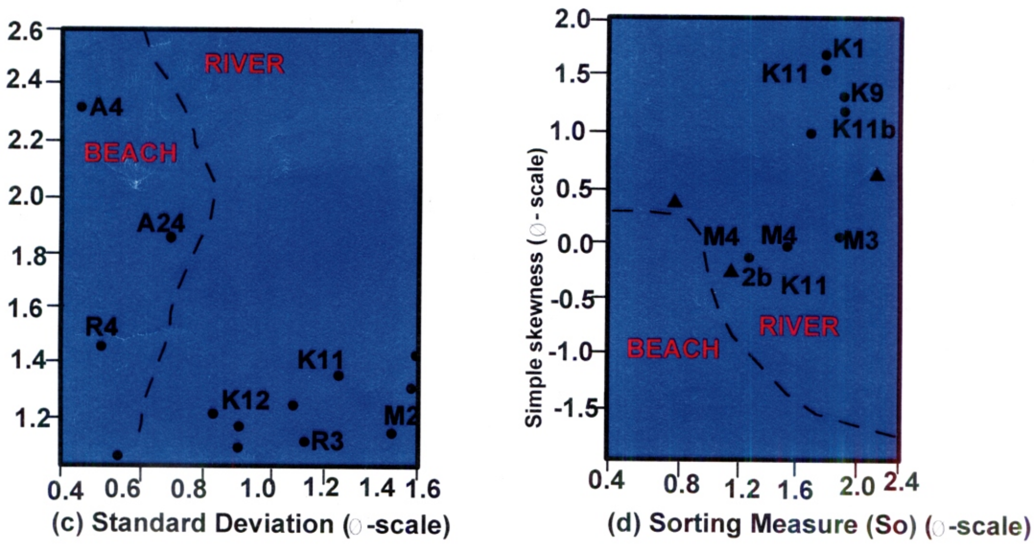


Fig 4: Bivariate Plots: a) Skewness vs Standard Deviation
b) Inclusive Graphic Skewness vs Standard Deviation
c) Mean Grain Sizes vs Standard Deviation
d) Simple Skewness vs Simple Sorting Measure

Thin Section Petrography

The grains of the sandstone range from angular to subangular. They are mostly monocrystalline quartz although some are polycrystalline. Most of the grains are not in contact but a few show straight, concavo-convex and sutured contacts. Cementing materials are mainly silica in form of authigenic quartz and iron-oxide coatings while porosity is between 18 and 35%. The mineralogical composition shows on the average 80% quartz, 3.4% feldspar, 2.5% rock fragment, 1.3% mica, 7.2% matrix and 5.7% cement (Table 3). A ternary diagram is plotted based on the framework composition of Quartz (Q), Feldspar (F) and Rock Fragment (L) of sandstone classification of Pettijohn (1975). The sandstone is classified as quartz arenite with composition $Q_{95.6}\,F_{3.2}\,L_{1.2}$ and sublithic arenite with composition $Q_{89.5}\,F_{4.9}\,L_{5.6}$ (Fig. 5).

Heavy Mineral Petrography

Heavy mineral suite consists of both opaque and non-opaque forms. The opaque minerals constitute 76.6% on the average while the non-opaques have the following composition: rutile (7.77%), tourmaline (5.50%), zircon (5.33%), staurolite (2.6%), kyanite (1.07%) and hornblende (1.13%). The calculated ZTR index is 78% with rutile as the most abundant of the ultra-stable mineral (Table 4)

S/N	Sample	Q (%)	F (%)	RF (%)
1	A1	96.5	1.2	2.3
2	A3	96.8	2.1	1.1
3	B1	96.4	1.2	2.4
4	B2	97.5	2.5	0.0
5	B6	97.6	1.2	1.2
6	G2	95.6	2.2	2.2
7	K1	96.5	2.4	1.2
8	K6	96.4	1.2	2.4
9	K14	97.6	2.4	0.0
10	M2	87.0	2.6	10.4
11	M5	86.5	2.7	10.8
12	R1	95.5	1.1	3.4

Geochemical Analysis

The result of the geochemcial analysis indicates that the sandstone exhibits high SiO_2 contents ranging from 77.45 to 91.30% with an average value of 85.77% while alumina (Al_2O_3) contents range between 2.10% and 4.98% with an average of 3.46%. The sandstone is therefore highly siliceous. Low alumina might be indicative of the dearth of alumino-silicate minerals in the provenance. Fe_2O_3 content is on the average 3.85%. Generally SiO_2 and Al_2O_3 constitute 93.08% of the entire composition (Table 5) indicating that the sandstone is chemically mature, probably as a result of its enriched chemically stable minerals.

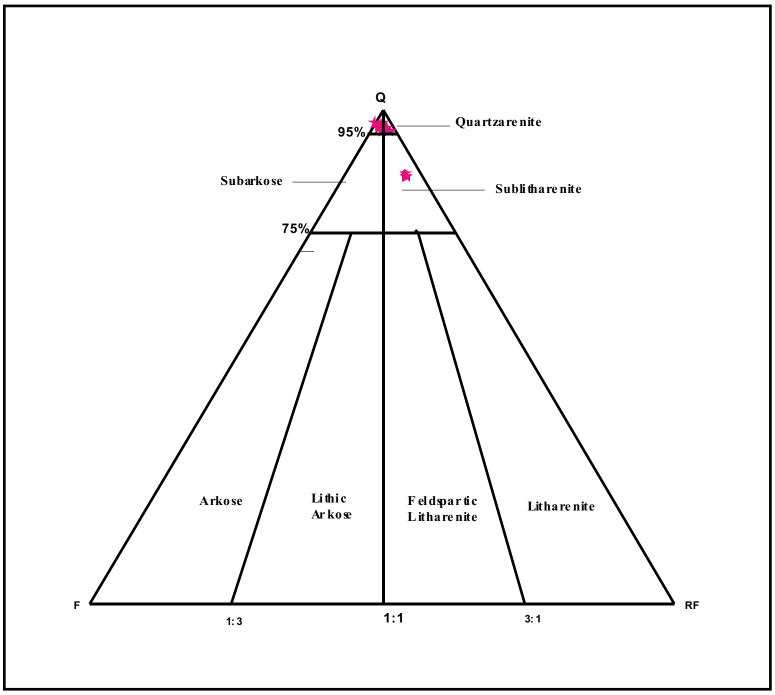


Fig 5: Modal Composition of the Sandstone in the Study Area.

Micropaleontology and Trace Fossils

Microfossils (either foraminifera or ostracods) were not recovered from the shale beds. Trace fossils were however identified in the field. The identified forms are cylindrical vertical burrow of length 5cm and diameters between 1 and 2cm. Some of them are identified as skolithos, ophiomorpha and paleophycus (Fig. 6).

Fig 6 : Vertical Section of Bioturbated Sandstone Lithofacies Showing Trace Fossils of Ophiomorpha and Skolithos.

DISCUSSION

The sediments around Auchi locality generally consist of three major lithofacies, namely, the lower bioturbated shale, the middle tabular cross-bedded bioturbated sandstone and the topmost ferruginous sandstone.

The lower shale unit possessing interlaminations of friable sandstone and colour variations is indicative of the fluctuating water depth which is believed to be in the littoral depositional environment on account of the skolithos ichnofacies particularly the presence of ophiomorpha and paleophycus. The texture, mineralogy and sedimentary structures of the dominating middle sandstone beds impart definitive attributes on the sedimentary sequence. Texturally, the sandstone consists of fine to coarse grained particles that are moderately sorted and near symmetrical in skewness. Mean grain size value of 1.04 indicates a prevalence of medium grain sizes. The presence of a wide range of grain sizes, ranging from fine to coarse is a reflection of variable current velocities and turbulence of the transporting medium (Amaral and Pryor, 1977) or it could suggest that the grains were from different sources. However, the prevalence of unimodal and leptokurtic distribution as well as dominance of NNE-SSW azimuth of the paleocurrent direction implies a single source. Sedimentation processes, dominated by saltation and suspension as revealed by graphical plots of cumulative frequency against grain sizes, is a reflection of dominant occurrence of fine to medium grained particles transported in a fluvial setting. Such grain population in the study area might have been a product of by-passing of relatively smaller size grains through coarse fractions. However, Hoque and Ezepue (1977) were of the opinion that the particles were derived from the fragmentation of polycrystalline quartz during fluvial transportation.

Table 3: Mineralogical Composition of the Sandstone from Thin Section Study

		QUARTZ (%)			FELDSPAR (%)			ROCK FRAGMENTS (%)			OTHERS (%)	
S/N	SAMPLE NO	MQ	PQ	TQ	KF	PF	TF	M	I	TR	MATRIX	CEMENT
1	A2	78	5	83	2	1	1	1	1	2	4	8
2	A3	83	8	91	2	2	2	-	1	1	-	2
3	B1	72	8	80	2	1	1	1	1	2	10	3
4	B2	68	10	78	1	2	2	-	-	-	7	9
5	B6	71	10	81	2	1	1	-	1	1	5	10
6	G2	74	12	86	-	2	2	1	1	2	10	-
7	K1	73	9	82	1	2	2	1	-	1	4	8
8	K6	71	9	80	1	1	1	-	2	2	6	10
9	K14	70	11	81	1	2	2	-	-	-	12	2
10	M2	60	7	67	3	2	2	5	3	8	11	7
11	M5	58	6	64	2	2	2	4	4	8	12	9
	R1	81	4	85	2	3	1	2	1	3	6	-
AVERAGE		71.6	8.3	79.9	1.7	1.7	1.7	1.25	1.25	2.5	7.2	5.7

MQ - Monocrystalline Quartz; PQ - Polycrystalline Quartz; TQ -Total Quartz; KF - Potassium Feldspar; PF - Plagioclase Feldspar; TF - Total Feldspar; M - Metamorphic fragment; I - Igneous fragment; TR - Total Rock fragment.

Table 4: Heavy Mineral Suites in the Sandstones of the Study Area

S/N	SAMPLE NO	RUTILE	TOURMALINE	ZIRCON	STAUROLITE	KYANITE	HORNBLEND	OPAQUES	ZTR INDEX
1	A2	10	15	5	-	-	2	67	91
2	A4	14	4	-	7	2	6	67	53
3	B1	2	6	12	1	-	-	79	94
4	B2	12	3	5	6	-	-	74	77
5	K1	8	5	8	4	-	-	75	84
6	K2	26	13	11	3	2	-	45	92
7	K11	-	4	1	1	1	1	92	62
8	K12	-	7	-	2	-	-	91	75
9	K13	3	9	9	3	3	6	67	65
10	M2	10	-	-	-	-	2	88	75
11	M3	4	-	-	-	-	-	96	10
12	M5	12	-	6	-	-	-	82	10
13	R1	3	3	7	2	3	-	82	52
14	R2	12	9	14	1	2	-	62	93
15	R3	3	4	2	3	3	-	85	54
AVERAGE		7.77	5.5	5.33	2.6	1.07	1.13	76.6	66

Each of the encountered beds has a fining upward sequence typical of the waning cycle of fluvial activities. The tabular cross stratification is a reflection of river deposition by migrating sand waves (Harms et al., 1975) and this corroborates the bivariate discrimination plots (Fig. 4).

The framework composition having quartz in abundance and ZTR index value of 78% shows that the sandstone is mineralogically mature. The low quantities of feldspar, rock fragment and matrix (15%) classify the sediment as quartz arenite ($Q_{95.6}$ $F_{3.2}$ $L_{1.2}$) and sublitharenite ($Q_{89.5}$ $F_{4.9}$ $L_{5.6}$). The compositions give the ratio Q/F+L (maturity index of Pettijohn, 1975) as 21.7 and 8.5 respectively meaning that the sediments are supermature and submature. The geochemical assay reflects high percentage of SiO_2/Al_2O_3 ratio (about 27.17) and considerable ratio of CaO/K_2O and Na_2O/K_2O (about 0.59). These values, according to Jenner et al. (1981), are indicative of enrichment of chemically stable minerals in sandstone.

Contact boundaries of the grains are mostly sutured and angular to subangular. These contact types as well as angular opaque minerals argue for a shorter distance of transportation from provenance (Folk, 1974); hence the grains are texturally immature despite the mineralogical maturity. Presence of staurolite, kyanite, hornblende and polycrystalline quartz as well as the composition of the rock fragments, bearing imprints of igneous and metamorphic rock chips, are good indicators of a basement terrain provenance (Suzuki, 1975).

Deposition in the studied area can, therefore, be said to have started with an intertidal sedimentation as marked by the skolithos ichnofacies of the lower shale beds. Subsequent deposition of sandstone must have been initiated by the structural inversion of Abakaliki Anticlinorium which converted the Anambra platform to a basin. The gradient created between

Table 5: Results of Geochemical Analysis Using XRF Method

LOCATION NO	A3	A4	B3	B6	B7	G1	K1	K5	K8	K9	K14	K15	M3	M5	R2	AVERAGE
$S1O_2$	91.30	90.84	88.05	89.90	83.02	90.54	84.75	86.40	88.14	86.43	83.45	84.24	78.01	77.45	74.05	85.77
Al_2O_3	2.14	2.48	3.40	2.10	4.90	2.12	3.25	3.75	2.86	4.01	4.98	3.82	4.32	3.98	3.80	3.46
Fe_2O_3	2.09	2.21	2.21	2.36	3.10	3.52	4.75	3.78	2.76	3.65	4.39	3.51	6.42	5.84	3.21	3.86
MgO	1.16	1.06	2.13	1.24	2.12	1.43	1.24	1.14	1.38	1.92	2.18	2.08	2.50	2.34	1.43	1.69
CaO	0.85	0.95	0.35	1.05	2.13	0.98	1.95	2.10	1.26	1.22	1.98	1.56	1.35	2.02	2.52	1.55
K_2O	0.82	0.75	1.10	0.94	1.55	0.92	1.60	1.06	1.10	1.13	1.03	1.05	1.83	1.95	1.52	1.22
Na_2O	0.45	0.45	0.62	0.84	0.93	0.44	0.92	0.68	0.50	0.69	0.61	0.72	1.05	0.98	0.95	0.22
Total	98.91	98.74	98.86	98.43	97.95	99.95	98.46	99.91	97.99	99.05	98.62	96.98	95.48	94.56	97.5	98.26
SiO_2/Al_2O_3	42.66	36.63	25.90	42.81	16.94	42.07	26.07	23.04	30.83	21.55	16.76	92.05	18.06	19.46	22.11	27.17
NaO/K_2O	0.55	0.60	0.56	0.89	0.60	0.48	0.57	0.64	0.45	0.59	0.59	0.69	0.57	0.50	0.62	0.59

the structural relief of the NNE and the basin in the SSW had accounted for the fluvial paleocurrent direction carrying sediments to the basin. Diagenesis on the laid sediments is reflected in the effects of compaction, authigenesis and cementations. The thin section revealed an average porosity of 18 to 38% which when compared with the average porosity of 40 to 45% for any freshly deposited sands (Pettijohn et al., 1987) suggests that considerable gravitational compaction or post depositional matrix and cementation development had taken place. The compaction is reflected in the sutured and concavo-convex contacts of the grains. Diagenetic dissolution of the silicate minerals as well as diagenetic changes in interbedded shale and mixed-layer smectite-illite to pure illite in mudrocks must have been the source of dissolved silica developing into quartz overgrowth (authigenesis) (Crook, 1968 and Pittman, 1972). Cementation is highly enhanced by the quartz overgrowth as well as by iron-oxide coatings (ferruginisation). The iron oxide (Fe^{2+} and Fe^{3+}) might have been leached out from chemically unstable minerals like olivine and pyroxene which might have probably derived from a basic rock in the close-by basement source. The precipitation of the Fe^{2+} consequent upon changes in pH and Eh of the interparticulate fluid led to iron oxide cementation. Such ferruginisation must have controlled to a large extent the cementation of the uppermost bed intepreted as overbank deposit.

The entire sequences of the Ajali Sandstone in Auchi locality therefore reflect deposition in shallow marine (littoral) environment as indicated by the shale facies as well as in fluvial environments as indicated in the attributes of the overlying tabular and ferruginous upper sandstone facies. The result of the investigation is however contrary to the fluvio-deltaic and tidal shelf environments as concluded by Hoque and Ezepue (1977) as well as Ladipo (1986) respectively. The different conclusions are obviously a reflection of lateral facies changes of the extensive stratigrahic unit.

SUMMARY AND CONCLUSION

The sediments of Auchi locality is made up of three major lithofacies, the basal bioturbated shale, the middle tabular sandstone and the overlying ferruginous sandstone facies. The facies are interpreted as representing two major paleoenvironments: the near shore littoral environment as well as fluvial environment. Mineralogically, the grains of the sandstone are mature as indicated by abundance of quartz and high value of ZTR index. However, the angular and sutured grain contacts are expression of textural immaturity of the sediments. Cementation is highly enhanced by the quartz overgrowth as well as by iron-oxide coatings (ferruginisation). Ferruginisation could have resulted from a precipitated Fe^{2+} and Fe^{3+} within the sediment particles as a result of changes in pH and Eh of the interparticulate fluid. Such process of ferruginisation controlled the cementation of the uppermost beds of the sequence interpreted as overbank deposits. Depositional history of the deposited sediments in Auchi environs therefore began with sedimentation in a near-shore littoral environment which was subsequently subjected to the influence of fluvial sedimentation owing to regressive lateral facies changes. Similar effect of the facies changes of Ajali Sandstone is reflected in the interpretations of the earlier workers notably Hoque and Ezepue (1977) as well as Ladipo (1986). The former inferred a continental fluvio-deltaic depositional setting while the latter referred to the depositional environment as tidal shelf. The different interpretations were consequent to the dominant sedimentological characteristics in the different localities of investigations as a result of lateral facies changes.

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Ife Journal of Science
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