Journal of Mining and Geology, Vol. 35(1), 1999, pp. 23 - 36 1116-2775
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SEDIMENTOLOGY AND DEPOSITIONAL ENVIRONMENT OF AWI FORMATION CALABAR FLANK, SOUTHEASTERN NIGERIA

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Received 9 June, 1995; Revision accepted 13 July, 1998

ABSTRACT

A sequence of conglomerates, sandstones, siltstones, claystones carbonaceous shales and mudstones which rims the Oban Massif in the Calabar Flank, constitutes the Early Cretaceous (probably Aptian) Awi Formation in the southeastern Nigeria. Field studies and laboratory analyses were conducted on these sediments to determine their provenance and depositional environment.

Field observations show that the sediments are gently dipping (.< 16°) in a southwesterly direction. They vary in thickness from thin to very thick beds and are laterally discontinuous. The pattern of sedimentation is cyclic with fining upward sequences. The sediments are textually immature with angular to subangular grains dominating, thus indicating short distance transportation.

The sandstones are medium to coarse-grained, poorly sorted, mostly leptokurtic, fine skewed and unimodal in distribution. They are subarkosic with more than 70% quartz which are of igneous and metamorphic origin while the associated claystones contain kaolinite.

Heavy mineral assemblages show the presence of predominantly zircon, tourmaline, rutile, garnet and staurolite with a range of 66.7 to 96%. This indicates mature to supermature sandstones and can be attributed to wet climatic conditions. The carbonaceous shales which grade into mudstone in some cases are non-fossiliferous, poorly laminated, pyritized and rich in lignitised wood.

All these indicate that sediments of Awi Formation were derived from the Oban Massif and deposited in environments ranging from channel lag and point bar to flood plain.

INTRODUCTION

The Calabar Flank, located at the easternmost part of the Gulf of Guinea is that part of the southern Nigerian continental margin between the Cameroon volcanic trend in the east, the Ikpe platform on the west, the Oban Massif and the Calabar hinge line to the north and south respectively (Fig. 1) (Nyong and Ramanathan, 1985).

The initial rifting of the southern Nigeria margin produced two principal sets of faults, trending, NE-SW and NW - SE. The former sets of faults bound the Benue depression while the later sets were present and active in the area of the Calabar Flank. After the initial rifting episode, the Calabar Flank underwent a somewhat different tectonic and stratigraphic development compared to the adjacent Anambra and Lower Benue Trough sedimentary basins (Murat, 1972).

The major tectonic elements of the Calabar Flank include the Ikang Trough, which was a mobile depression and the Ituk High that was a stable mobile submarine ridge. This is borne out of sedimentary facies distribution in the area (Murat, 1972).

Within the Calabar Flank, Reyment (1965) proposed the name Odukpani Formation to a sequence comprising of basal arkosic sandstones and conglomerates, limestones in the middle and calcareous sandstones and alternating limestones and shale in the top part. This formation rests unconformably on the basement complex.

Fayose (1978) noted that the lithologic and tectonic structures of the basal part of the Odukpani formation justify its subdivision into two distinct formations. Later, Adeleye and Fayose (1978) proposed the name Awi Formation to the basal arenaceous part of the Odukpani Formation. They delineated a type section and retained the name Odukpani Formation for the rest of the succession.

Adeleye and Fayose (1978) described the Awi Formation as fluviodeltaic, partly fossiliferous, folded and cyclothemic, comprising cross bedded sandstones, siltstones, mudstones, claystones, conglomerates and shales. They correlated it with the Early Cretaceous Mamfe Formation of the Cameroon.

Odebode (1982), using microflora dated the Awi Formation, Upper Albian - Lower Cenomanian. This age assignment is at variance with that of other workers on the overlying Mfamosing Limestone which has its age as Middle to Upper Albian (Petters, 1982; Nyong and Ramanathan, 1985).

This paper presents the sedimentology and depositional environment of Awi Formation from few outcrop locations encountered within the Calabar Flank (Fig. 2). Accessibility to most of the outcrop locations was hampered by thick vegetation that characterised this area. Some of the outcrops were poorly exposed due to extensive weathering and most of the sampling was affected to a certain extent by this. However, based on field evidence and laboratory studies which include textural, mineralogical, as well as micropalaeotological evaluations, the provenance and the depositional environment of the sediments were deduced.

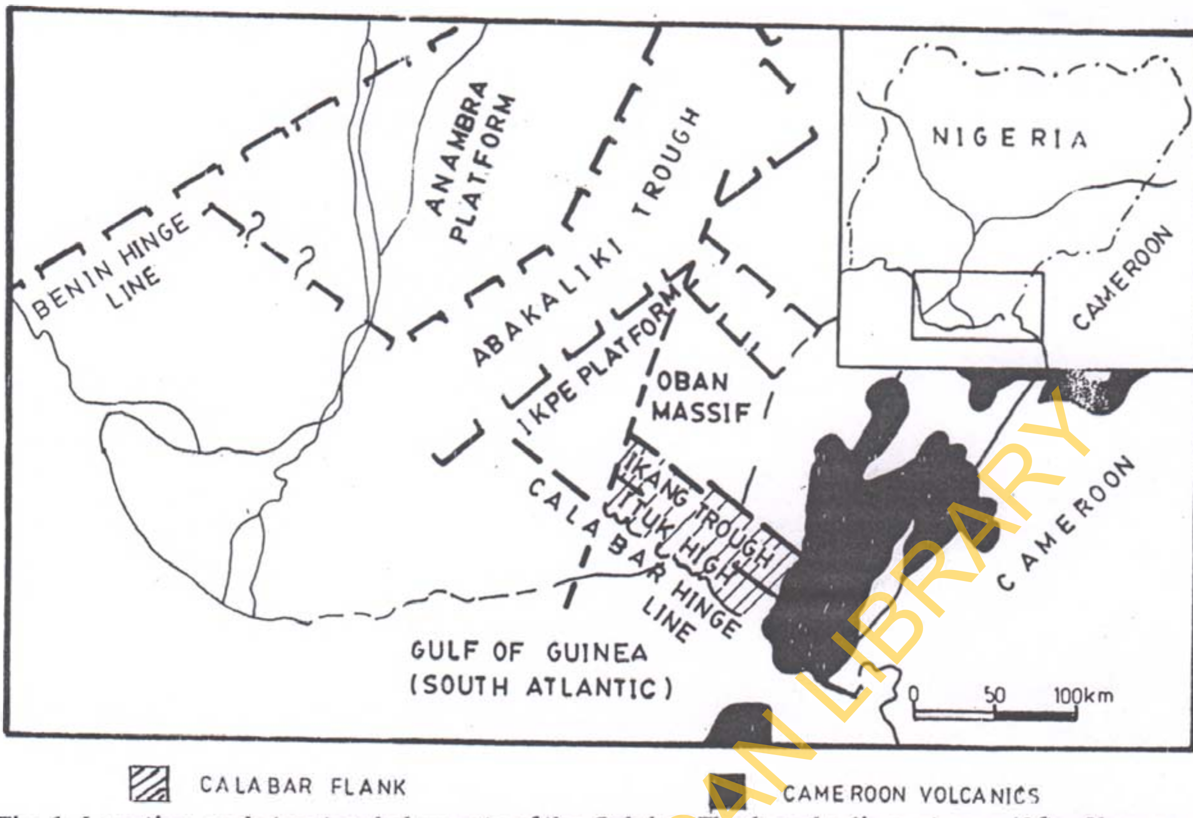


Fig. 1. Location and structural elements of the Calabar Flank and adjacent area (After Nyong and Ramanathan, 1985).

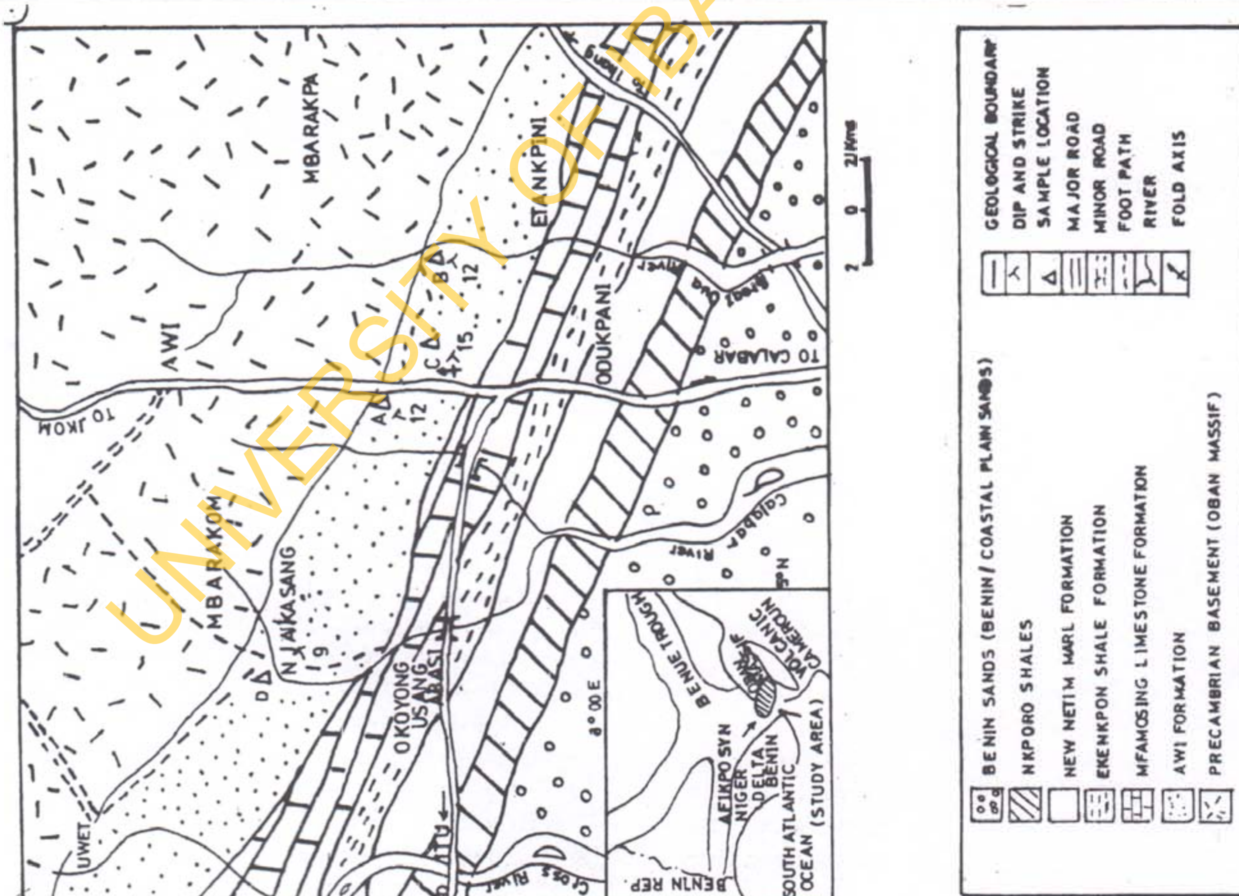


Fig. 2. Sketch geologic map of the Calabar Flank showing sample locations

STRATIGRAPHY

The lithostratigraphic development in the Calabar Flank was controlled by vertical movements of faulted blocks notably the Ituk High and the Ikang Trough and by associated transgression and regression (Nyong, 1995).

Different formation names have been proposed by several authors for sediments within the Calabar Flank (Reyment, 1965; Dessauvagie, 1974, Adeleye and Fayose, 1978; Petters, 1982; Petters et al. 1995). The sedimentary sequence of the Calabar Flank begins with continental clastics, consisting of a fluvio - deltaic sequence of cross - bedded sandstones, siltstones, mudstones, conglomerates, claystones and shales. This unit overlies the Precambrian Oban Massif unconformably and constitutes the basal part of the Odukpani Formation of Adeleye and Fayose (1978). These clastics (Awi Formation) belong to Early Cretaceous (probably Aptian) age.

Enhanced subsidence of the faulted blocks results in the initiation of a series of marine transgressions. The earliest of these transgressions in Middle Albian, resulted in the deposition of platform carbonates (Mfamosing Limestones, Petters 1982). A hardground exposed at the top of the limestone quarry at Mfamosing, marks the break in sedimentation and deposition and separates the Mfamosing Limestone from the thick sequence of black fissile shales with minor but frequent intercalation of marls, calcareous mudstones and shales above. Petters et al. (1995) have given a new name (Ekenkpon Shale formation) to this unit with a type section in Ekenkpon village along Calabar - Itu Road. This new name replaces Nkalagu/Eke - Aku Formations of earlier workers (Petters and Ekweozer, 1982). Deposition of these sediments resulted from a second phase of marine transgression which was initiated in Late Albian and continued through to Turonian times with a break towards the end of Cenomanian (Nyong and Ramanathan 1985).

A thick marl unit with thin dark shale intercalations overlies the Turonian in the Calabar Flank. This unit belongs to the New Netim Marl Formation (Petters et al., 1995). Santonian and Early Campanian sediments are not encountered and this interval is regarded as a period of non-deposition and/or erosion in the Calabar Flank. The Late Campanian to Maastrichtian sediments are characterized by dark-grey, carbonaceous, friable shales with occasional thin bands of marlstones and gypsum referred to as Nkporo Shales (Reyment, 1965). The Nkporo Shales are overlain by Tertiary - Recent sands of continental origin. These sands represent the Benin Formation (Fig. 2).

METHODS AND MATERIALS

The Awi Formation was sampled from four locations (A to D) within the area of study (Fig. 2.). Spot samples were collected from about two feet deep at different stratigraphic position in the respective outcrops. Most of the sedimentary structures have been obliterated by weathering and the few encountered were noted, described and photographed.

Field Observations

Locations A: (Km 27, Calabar - Ikom Road)
The stratigraphic sequence here is shown in Fig. 3. The overall thickness of the outcrops is 6 metres and the sedimentary unit unconformably overlies weathered basement made up of granite gneiss. The outcrop dips 12°SW and consists of basal conglo merate followed by sandstone, mudstone, siltstone and capped with highly weathered pebbly sandstone unit.

Generally, the sandstones are greenish to greyish, angular and poorly sorted with large mica flakes. Quartz grains are milky to colourless and occasionally smoky. The sandstones display graded bedding fining Upward from basal conglomerates (Fig. 4). Bedding is discontinuous and lenticular. The contact between the Awi Formation and the weathered granite gneiss is sharp (Fig. 5).

The mudstone bed is about 0.40m thick at this location. It is greenish to pinkish, fine grained, silty, plastic and flat bedded. The middle sandstone is capped by siltstone that is fine grained, rippled greyish and micaceous. Grains are angular to subangular.

Location B: This location is at a river channel accessible off km 26.5 on Calabar-Ikom road, which is half a kilometre south of location A (see Fig. 2). The thickness is about 2 metres (Fig. 6) and dips 12°SW. The lithology is made up of sandstones and claystones and the base is not exposed. The sandstones are milky to brown in colour, unconsolidated with angular grains. They are micaceous and poorly sorted. Poorly developed cross-bedding with azimuths 200° and 230 (Southerly and Westerly) have been measured in this location.

The claystones are greyish and plastic. Overlying this sequence is a pebbly, highly weathered sandstone, lateritic unit. From the sandstone unit to the claystone at the middle indicates a fining upward sequence.

Location C: (Type section - km 9 South of Awi village or km25 Calabar - Ikom Road)
This outcrop is well exposed at 9Km south of Awi village or 2Km south of location A (see Fig. 2). It is

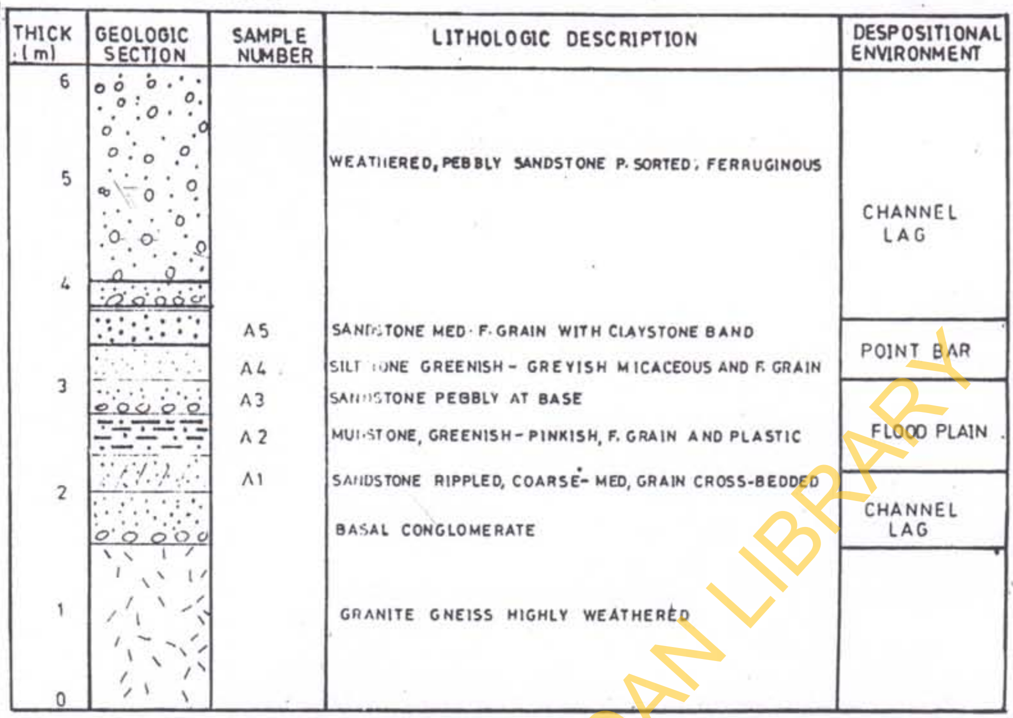


Fig. 3. Lithologic Succession of location A (Km 27 Calabar-Ikom Road)

Fig. 4. Field photograph of basal conglomerates indicating a finning upward sequence.

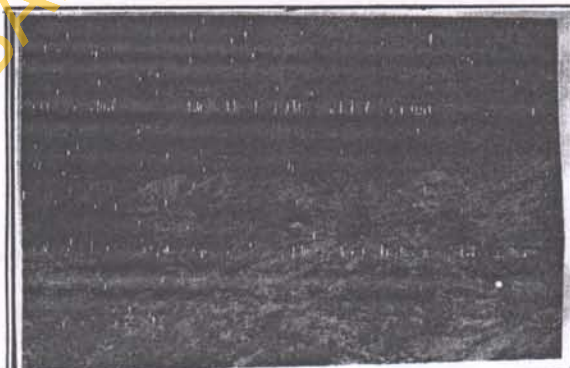


Fig. 5. Field photograph showing sharp contact between Awi Formation and weathered basement.

about 15m thick (Fig. 7) with lot of facies changes. It dips 15°SW and its base is not exposed. The lithology is made up of pebbly to very coarse-grained sandstones at the base, mudstones, siltstones, claystones and carbonaceous shales at the middle and upper parts, respectively. The whole sequence is cyclical and fines upward. It is folded with E-W fold axis (Fig. 8).

The sandstones are thickly bedded (Fig. 9), partly weathered, weakly cross-bedded, colour banded, poorly sorted and angular. Two sets of cross bedding with azimuths 205° and 208° (southerly) have been measured in this location. They are micaceous and the bedding is discontinuous and in some parts, it is iron stained. Some of the sandstone beds are indurated and concretionary. The sandstones were sampled at two levels - the lower and the middle portions.

The siltstones are greyish to milky, very fine - grained and poorly consolidated. They are plastic, micaceous and the beds are laterlly discontinuous. In some cases, the siltstone are sheet-like, rippled, with roots, mottled and colour banded. From the lower sandstone unit to the middle siltstone indi-

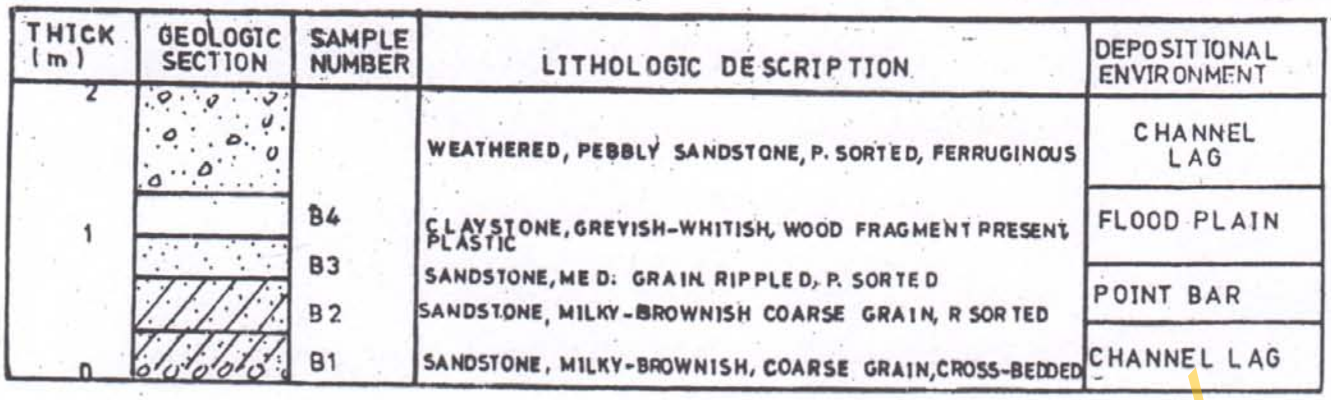


Fig. 6. Lithologic Succession of location B

cates a fining upward sequence.

The claystones are greenish to milky, well bedded, micaceous, fine grained and plastic. They are seen at the upper sequence of the outcrop. The shales are carbonaceous, pyritized and contain pieces of lignitised wood. They are weathered and poorly laminated. Within the shale units are siltstone and claystone interbeds (Fig. 10).

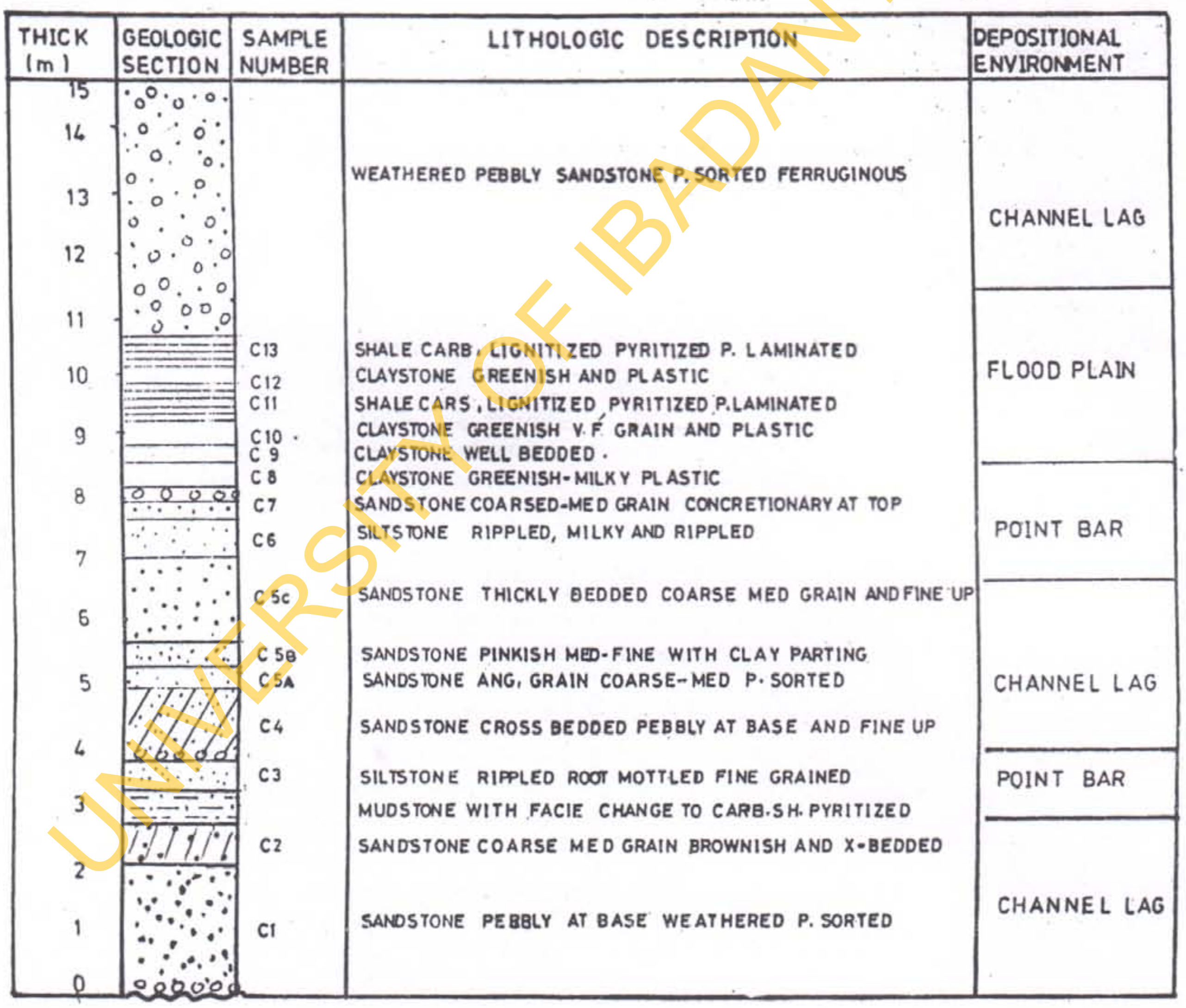


Fig. 7. Lithologic Succession of Awi Type Section (Location C)

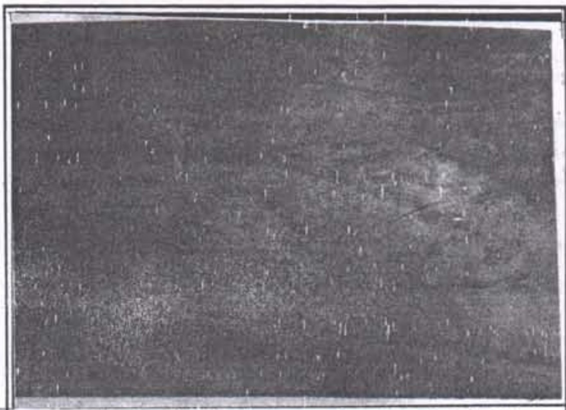


Fig. 8. Field photography showing fold with E-W axis.

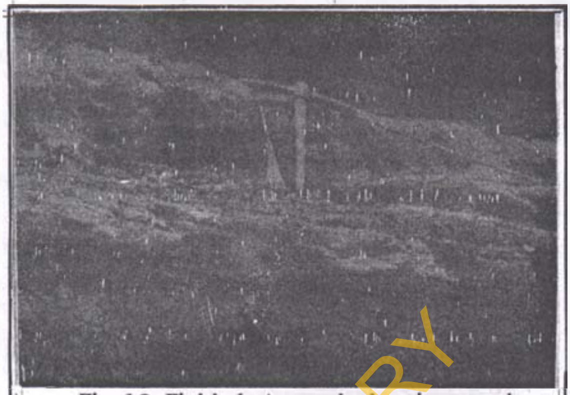


Fig. 10. Field photograph showing poorly laminated carbonaceous shales with claystones and siltstones interbeds.

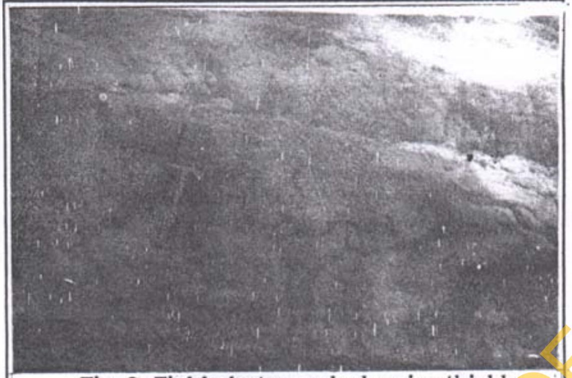


Fig. 9. Field photograph showing thickly bedded sandstones.

Location D: (Njakasang Village)
This location is assessible through Okoyong Usang Abasi - Mbarakom footpath off Calabar - Itu Road (see Fig. 2). The outcrop occurs along a stream channel as a 'boulder'. The valley wall reveals a sequence made up of highly weathered sandstones, claystones and carbonaceous shales (Fig. 11). The sandstone is dark, fine grained and micaceous. Apart from this sandstone unit, the remaining sequence was not sampled because of extensive weathering effect.

Laboratory Studies

Granulometric analysis: Standard method for grain size analysis was employed using a set of sieves at ½ phi intervals (ASTM) on a Ro-tap shaker for 15 minutes.

The statistical parameters calculated were based on Folk and Ward (1957).

Clay mineralogy: Physical analysis (Plastic Limit and Liquid Limit) of the claystones was used for their identification as the readily available means. The results were superimposed on Bain's (1971) chart for classification (Fig. 12). Further analytical studies using x-ray diffraction for detailed mineralogical assessment of the claystones and limestones within this areas is in preparation.

Heavy mineral studies: Siltstones and sandstones samples were analysed for their heavy minerals

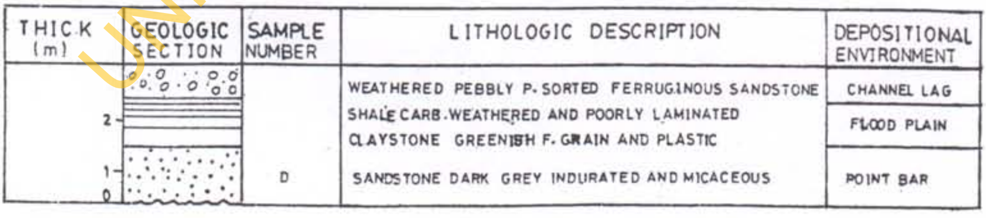


Fig. 11. Lithologic succession of location D.

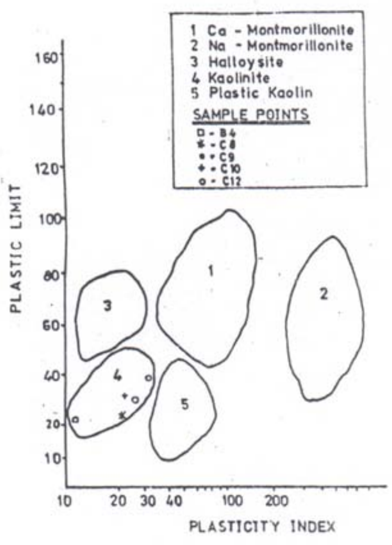


Fig. 12. Clay identification chart.

using bromoform (S.G.2.85) as the separating medium. The bromoform extracts were rinsed with acetone, mounted on slides and studied under a petrographic microscope. Their sizes, shapes as well as the percentages of the opaques and non opaques were estimated. Maturity index (ZTR) (Hubertt, 1962) was estimated for each sample.

Thin section petrography: About ten representative samples of sandstones and siltstones were selected for thin section petrography. The indurated samples were thin sectioned directly but the few loosely consolidated ones were impregnated with resin before cutting and mounting on slides with araldites and Canada balsam. They were examined under the flat stage of a petrological microscope. Point count method was used to count each mineral and based on this, individual percentages of the minerals were computed. Photomicrographs of features of interest were taken. Classification of the sandstones is based on Folk (1974).

Micropalaeotological Analysis: The shale samples were subjected to foraminiferal processing using anhydrous sodium carbonate and 10% concentrated hydrogen peroxide. The sample were washed, dried, sieved and then picked for foraminifera. In this study, no microforaminifera was recovered.

RESULTS AND INTERPRETATION

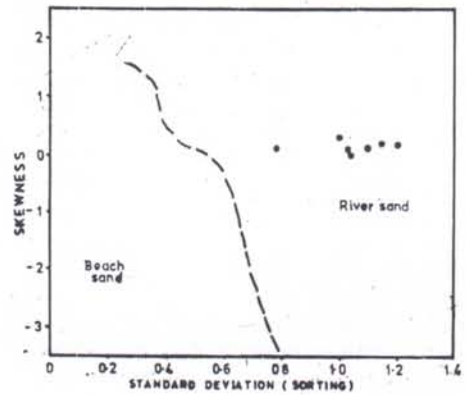
Grain Size Analysis

The Awi sandstones range from 0.32mm to 1.43mm and fall between medium to coarse sand. The standard deviation (dispersion sorting) values range between 0.79 and 1.20 and are predominantly poorly sorted. Skewness values are between 0.07 and 0.30 and are mostly in the fine skewed range with one population near symmetrical. Kurtosis values range between 0.74 and 1.69. Though leptokurtic type predominates, it however has very few mesokurtic and one platykurtic populations (Table 1).

Table 1. Calculated Grain size Statistical Parameters for Sandstones

Sample No.	First Percentile	Graphic Mean (Mz)		Dispersion Sorting (σ_1)		Incl. Graph. Skew (SK1)		Coefficient Kurtosis (KG)	
B_1	-1.70	0.32	(Coarse sand)	1.00	(Poorly sorted)	0.30	(fine skewed)	0.74	(Platykurtic)
B_2	-1.80	0.47	(Coarse sand)	1.10	(Poorly sorted)	0.16	(Fine skewed)	1.34	(Leptokurtic)
B_3	-1.70	0.87	(Coarse sand)	1.20	(Poorly sorted)	0.25	(Fine skewed)	1.03	(Mesokurtic)
C_2	-1.00	1.43	(Medium sand)	1.04	(Poorly sorted)	0.07	(Near symmetrical)	1.16	(Leptokurtic)
C_{5A}	-0.90	0.60	(Coarse sand)	0.79	(Moderately sorted)	0.16	(Fine skewed)	1.69	(Very Leptokurtic)
C_{5C}	-0.75	1.20	(Medium sand)	1.15	(Poorly sorted)	0.26	(Fine skewed)	1.01	(Mesokurtic)
C_7	-1.20	0.87	(Coarse sand)	1.06	(Poorly sorted)	0.17	(Fine skewed)	1.17	(Leptokurtic)

Histograms and frequency distributions of the sandstones show strongly unimodal character. Statistical plotting of the grain size data based on Friedman (1961) and Folk (1974) show that they fall within river sands and fluvial setting respectively (Figs. 13 and 14). The probability ordinate plot (Fig. 15) contain the upper two segments corresponding to suspension and saltation loads of Visher (1969).



Figs. 13. Plot of third moment (Skewness) and standard deviation for beach and riversands. After Friedman, 1961)

Thin Section Petrography: The result of petrographic analysis is shown in Table 2. From here, it can be seen that both metamorphic and common quartz are present with a total range of 70 to 80%. The common quartz show angular to subangular shapes (Fig. 16). Some of the quartz grains have equant grains with distinct straight boundaries (Fig. 17). In addition, some of the quartz grains are polycrystalline and show strains in different directions (Fig. 18).

The feldspars are not fresh and are mainly potassic type with little plagioclase embedded in the matrix. They range from 8 to 13.2%. Rock fragments comprise polycrystalline quartz, granite and mudclast. The igneous and metamorphic rock fragments are angular to subangular while the mudclasts are silty and clayey. The range of the rock fragments is 0.1 - 1.3%.

The matrix is between 2.8 - 7.1% and is composed of kaolinite clays and silt-size feldspars. Most of the matrix fill the pore spaces and reduce the porosity which range from 1 to 8.7%. Iron oxide and calcite constitute the cement which range from 0.3 to 7.4%.

From the recalculated framework composition of quartz, feldspars and rock fragments, the sandstone are therefore classified as subarkose (Folk, 1974) (Fig. 19). From the high matrix content (>5%), the poor sorting and angular to subangular grains, the Awi sandstones are texturally immature (Folk, 1951). From the quartz: Feldspar + Rock fragment ratio (Folk, 1974), the sandstones are mineralogically submature.

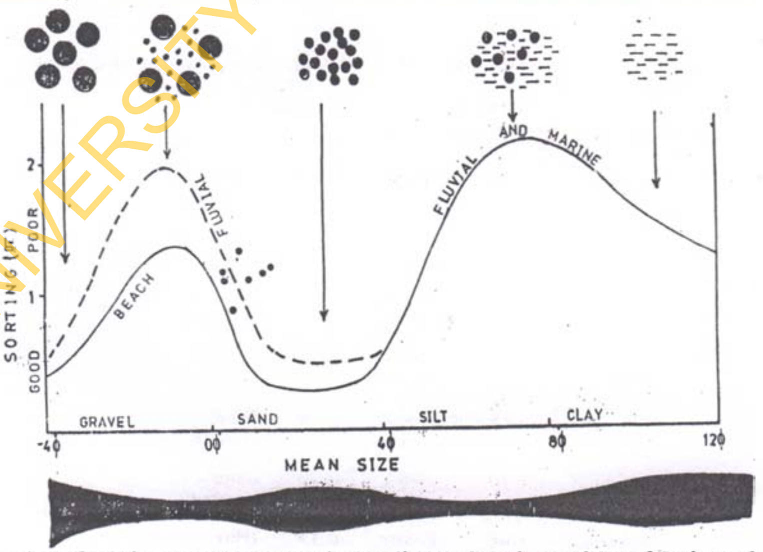


Fig. 14. Plot of sorting versus mean size; solid circles show plots of Awi sandstones (Modified after Folk 1974)

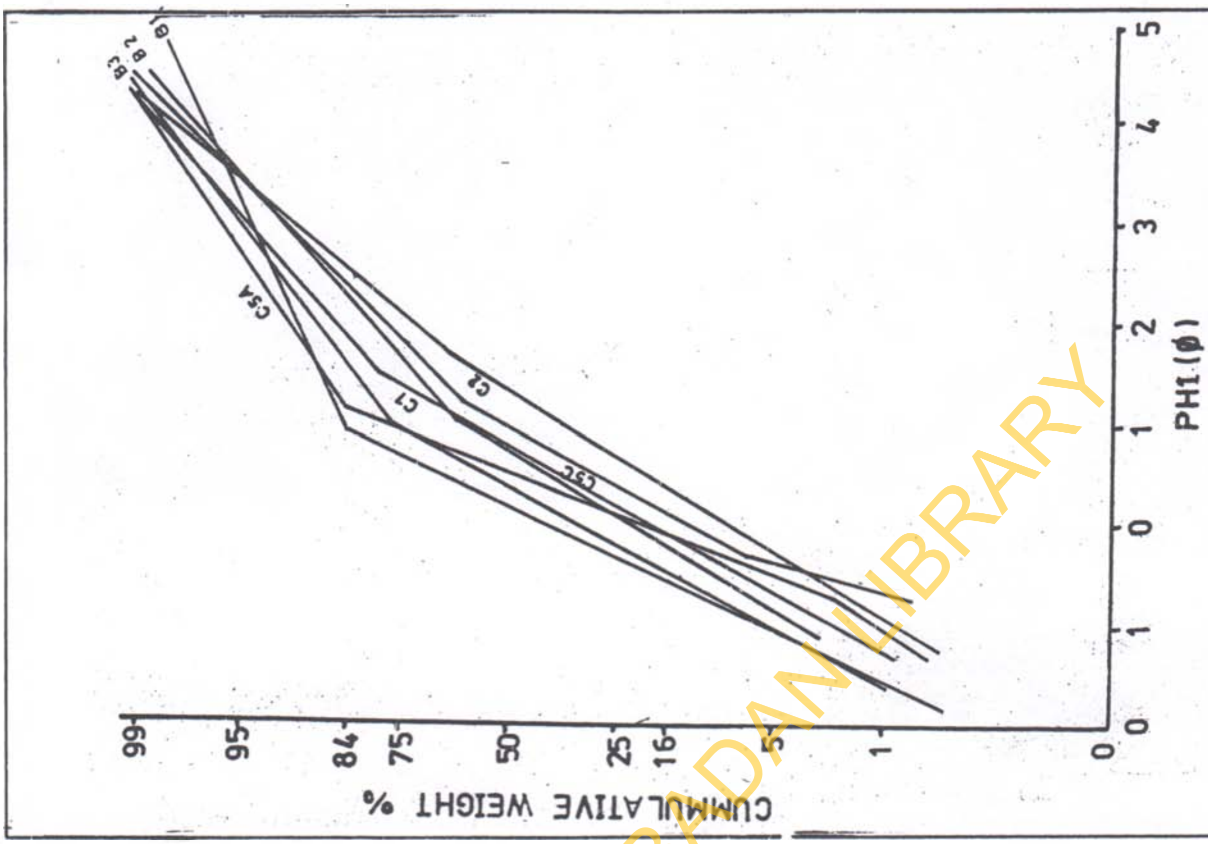


Fig. 15. Probability ordinate plot for samples

Table 2. Petrographic Analysis Data

Sample No	Grain size (μ)	% CQ	% MQ	% Feldspar	% R.F.	% Mica	% Matrix	% ϕ	% Cement
A1	>20	5	71	9.7	0.3	0.4	6	1	6.6
A3	>20	60	17	8	0.1	-	2.8	6	6.1
A4	>20	62	14	8.8	0.3	0.1	6.1	8.7	-
C1	>20	70	8	10	-	-	6	-	6.0
C5c	>20	15	55	13.2	0.7	1.1	5	3	7.0
C4	>20	64	12	12	-	0.4	7	4.3	0.3
C6	>20	13	63	9.6	0.2	0.4	-	6.4	7.4
C7	>20	14	66	10	0.5	0.3	5.7	4.3	-
C10	>20	66	10	8.6	0.1	0.4	3.6	5.2	6.1
D	>20	14	58	9	1.3	0.2	7.1	4.4	6.0

CQ = Common Quartz; MQ = Metamorphic Quartz; R.F. = Rock Fragment; ϕ = Porosity

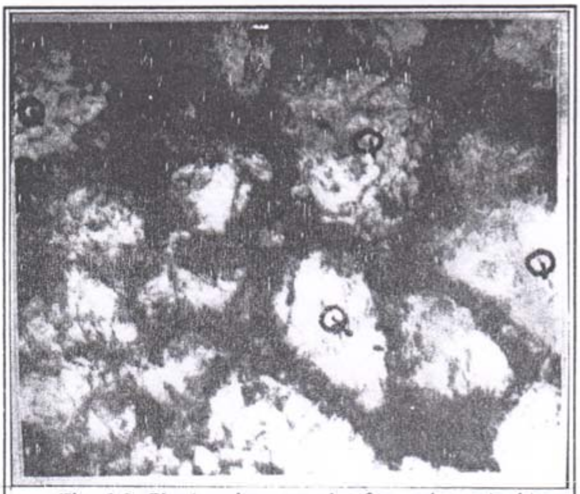


Fig. 16. Photomicrograph of poorly sorted to subangular common quartz grains (Q).

Fig. 17. Photomicrograph of equant grains with straight grain boundaries in different directions

Clay Mineralogy

Clay mineral studies in the Calabar Flank is still in progress. However, in this study, claystones sampled from two locations were identified as kaolinite by the superimposition of Atterberge limits (plastic limit and plasticity index) on Bain (1971) Chart (Fig. 12 and Table 3). This method of classification was used as the readily available means.

Several workers have pointed to the fact that weathering of feldspathic rocks in warm humid tropical climates tend to produce materials essentially rich in kaolinite (Adeleye, 1978; Ajayi and Agagu, 1981).

Fig. 18. Photomicrograph showing polycrystalline grains with strains in different directions.

Table 3. Data of Physical Analysis of Clay Samples

Samples Nos.	Liquid Limit	Plastic Limit	Plastic Index
B_4	30	21	10
C_8	45	20	25
C_9	70	36	34
C_{10}	55	32	23
C_{12}	55	29	25

Heavy Mineral Petrography

In decreasing order of abundance, the opaque minerals are hematite, leucoxene, ilmenite and pyrite. The non opaques are mainly zircon, tourmaline, rutile, garnet and staurolite (Table 4).

The ZTR index ranges from 66.7 to 96% with the ultra stable population increasing in the order of abundance, zircon tourmaline and rutile. The range indicates mature to supermature sandstones.

Pettijohn (1941) has explained that younger sediments generally contain a greater number of different heavy mineral species than the older ones. He observed that heavy minerals of many Palaeozoic sediments consist almost entirely of Zircon, tourmaline, rutile and garnet. This he attributed to intrastratal solution by underground water as older ones are more susceptible to this.

Hoque and Ezepue (1977) observed that sandstones attain higher mineralogical than textural maturity due to intense weathering both at the source and during transport.

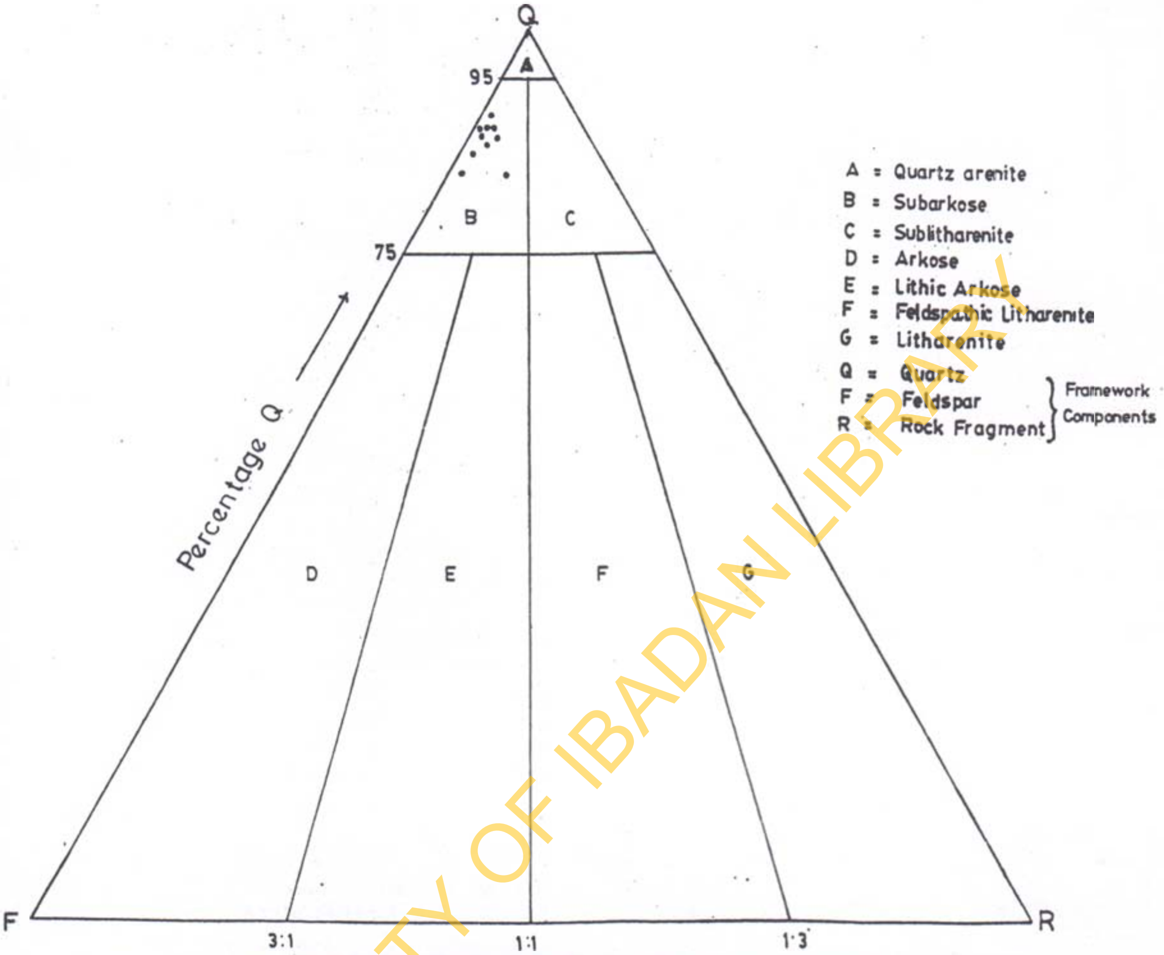


Fig. 19. Ternary classification of sandstones based on framework components.

Table 4. Results of Heavy Mineral Analysis (Point Count)

Sample No.	Opaque (%)	Non-Opaque (%)	Zircon (%)	Tourmaline (%)	Rutile (%)	Garnet (%)	Staurolite (%)	ZTR Index (%)
A3	50	50	30	30	36	2	2	96
B1	85	15	-	26.7	53.3	-	-	80
B3	85	15	6.7	26.7	53.3	13.3	-	86.7
C3	87	13	15.4	23.1	53.8	7.7	-	92.3
C5A	84	16	12.5	37.5	37.5	12.5	-	87.5
C5B	90	10	10	50	20	-	20	80.0
C5C	85	15	20	20	26.7	33.3	-	66.7
C7	95	5	-	40	40	20	-	80.0
D	95	5	-	40	40	20	-	80.0

DISCUSSION

Provenance

The Awi sandstones are poorly sorted and texturally immature. Such sediments according to Amaral and Pryor (1977) are deposited under variable current velocities. Folk (1974) has reported that these kind of sediments are usually deposited near to the source. The sandstone are generally leptokurtic and unimodal in distribution which indicate a single source.

The presence of both plutonic and metamorphic quartz point to a source in basement terrain. The angularity of the grains particularly among the coarsest fraction suggests nearness to source rocks which is igneous and/or metamorphic (Krumbein and Pettijohn, 1932). The maturity of the heavy minerals which is a variance with the angular nature of the grains can be associated with humid tropical conditions which have depleted the metastable components (Adeleye, 1978, Agagu, 1990, pers. comm). Blatt et al. (1980) have described zircon as the most ubiquitous, non-opaque minerals in silica-rich rocks. Rutile is unstable in low grade metamorphic rocks (Force, 1970). Tourmaline is known to occur in low grade metamorphic and acid igneous rocks. Garnet is found in pegmatites as well as in high grade metamorphic rocks and staurolite is highly diagnostic of metamorphic source (Folk, 1974). The Oban Massif which borders the Awi Formation to the north has several rock types such as granites, diorites, gneisses, quartzites, pegmatites etc. (Rahman et al. 1981) and could be the source of the Awi sediments. The predominant direction of sediment transport is southwards.

According to Adeleye (1978), Ajayi and Agagu (1981), kaolinite clays are formed as a result of weathering of feldspathic rocks in warm tropical in climate. A similar setting is envisaged for the formation of kaolinite found in the Awi Formation.

Whiteman (1981) has pointed out that sandy deltaic facies from Oboko merged with coarse sandy clastic of the Mamfe Embayment and extended southwards around the Oban Massif. From this study, the grains angularity together with the felspar and matrix content of > 5% has suggested near source. In essence, sandy deltaic facies from Oboko could not have come a longway with such features retained. The Oban Massif is therefore the closest and possible source of the Awi sediments.

Depositional Environment

The Awi sandstones which are texturally immature and mineralogically mature were deposited in fluvial setting. Inference from statistical size distribution and parameters of scatter plots corroborate this evidence. The mineralogical maturity was attained due to humid climatic conditions that characterised the area. (Adeleye 1978). Visher (1965) has described kaolinite as a clay mineral type more abundant in fluvial sands. This is consistent with this study.

The Awi sediments display a cyclical fining upward sequence which is characteristic of fluvial environment (Allen, 1965, Visher 1965; Adeleye, 1974). Okoro and Nwajide (1990) have associated cyclic sedimentation and fining upward sequence with climatic fluctuation, intermittent tectonic uplift, basin subsidence as well as eustatic sea level changes.

Beerbow (1964) discarded the invocation of such external processes as causes of cyclicity particularly if it is of a local extent. He rather pointed to the to and fro migration of a river channel across its flood plain coupled with isostatic adjustment of the basin as their causes.

In the area of study, the sequence beginning with pebbly conglomerates which contains mud chips and leaf fragments are indicative of channel lag deposits. Overlying this basal lag is cross bedded coarse to medium grain sandstones that fine upwards to siltstone and mudstone. This unit belongs to the point bar. The occurrence of lignite remains and pyrites in the carbonaceous shales and claystones are indicative of flood plain deposits.

With bank caving and accretion, there is bound to be migration in the channel resulting in the sequence becoming cyclical. In such a setting, conglomerates are deposited in the deeper part of the channel while the finer siltstones and claystones accumulate in flood plains as abandoned channels (Le Blanc, 1972). This view is envisaged in this study.

The porosity values of 1 to 8.7% are very low when viewed in line with the fact that a freshly deposited sand has porosity values between 40 and 45% (Manus and Cogan, 1974). However the low values could be attributable to slight compaction which results in the straining of the quartz. In addition, diagenetic alteration of feldspars results in clay matrix which also reduces the porosity.

The Awi sediments can thus be said to be cyclic sediments caused by channel switching and deposited in a meandering setting.

SUMMARY AND CONCLUSIONS

The Awi sediments, made up of conglomerates, sandstones, siltstones, mudstones, shales and claystones are cyclical with fining upward sequences.

The sandstones are texturally immature and indicate short distance of transportation. They are subarkosic with the quartz showing contributions from both igneous and metamorphic sources. The clay mineral is kaolinite and indicates weathering of feldspathic rocks under warm humid setting.

Heavy mineral assemblages point to super maturity attributed to wet climatic conditions.

The basal conglomerates containing mud chips and leaf fragments are indicative of channel lag deposit. The overlying cross bedded coarse - grained sandstones with fining upward sequence to siltstones and mudstones are point bar sediments. The shales and claystones that are ripped and contain lignites and pyrites are deposits of flood plains.

From the foregoing, the Awi Formation is riverborne sediments from the nearby Oban Massif and deposited in a meandering setting. It can be inferred that as the Awi clastics were prograding as non marine sediments, marine transgression deposited the Mfamosing Limestone. Formation on it thus altering the setting in the Calabar Flank. The depositional sequence is similar to the Early - Middle Cretaceous sequence of eastern North Atlantic continental margin described by Schlee and Jansa (1981).

ACKNOWLEDGEMENTS

I am greatly indebted to Dr. G.I. Unomah who supervised this work as part of my M.Sc. project. The anonymous reviewers are also acknowledged for their useful criticisms while Prof. A. A. Elueze cannot be forgotten for his encouragement.

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