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Facies analysis and depositional environment of conglomeritic deposits in the northeastern part of the Niger Delta Basin, Nigeria

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Abstract: *The Niger Delta Basin is an extensional rift basin located in the Niger Delta and the Gulf of Guinea on the passive continental margin near the western coast of Nigeria. Lithofacies analysis was carried out in order to ascertain the environment of deposition of the conglomeritic deposits. Ten lithofacies were delineated in the northeastern part of the Niger Delta Basin and grouped into three facies associations: facies association 1 comprising matrix-supported conglomerate (Cm), clast-supported conglomerate (Cc), massive sandstone (Sm), planar cross-stratified sandstone (Sc), trough cross-stratified sandstone (Tc) and horizontally stratified sandstone (Sp); facies association 2 comprising claystone (Ct) and variegated mudstone (M); facies association 3 comprising grey-green shale (Sh) and black shale (Sb). Facies association 1 was deposited in a braided fluvial channel because of the presence of unimodal paleocurrent pattern, organic matter, fining upward succession, subrounded to rounded and poorly sorted clasts ranging from granules to boulders. Facies association 2 represents braided fluvial floodplain deposit due to the presence of claystone and mudstone with organic matter. Facies association 3 is characterized by the following dinoflagellates cysts: Andalusiella sp., Paleocystodinium sp., Deflandra sp., Apectodiniumhomomorphum and pollen such as Spinizonocolpitesehinatus, Spinizonocolpitesbaculatus, Psilatricolporitescrassus, Proxapertitesoperculatus and Proxapertites cursus suggesting that it was deposited in estuarine environment. The occurrence of fluvial conglomerate on top of marginal marine grey green shale was triggered by a gradual progradation of a river over the shale as the sea level fell during the Eocene period.*

Keywords*: Facies analysis, conglomerate, depositional environment, Niger Delta, progradation*

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I. Introduction

The Niger Delta Basin is a progradational depositional complex within the Cenozoic era. It is located in the southern part of Nigeria and covers an area of about 75,000 square kilometers. It is among the World's largest petroleum Provinces and has been rated as the sixth largest oil producer and twelfth giant hydrocarbon Province. The origin of the Niger Delta Basin is traced to the the separation of the Afro-Brazilian plate during Early Cretaceous. The Niger Delta is the failed arm of a Y-shaped triple junction that initiated the opening of the south Atlantic Ocean and is thus regarded as an aulacogen (Olade, 1975; Hoque and Nwajide, 1984). Conglomeritic deposits abound in the northeastern part of the Niger Delta Basin (figure 1, 2) where they are being quarried for construction purposes.In the past, inadequate access routes and poor exposure related to thick subequatorial vegetation prevented previous researchers from thorough and sustained investigation of the rocks. Consequently, little is known about the conglomeritic deposits. Recently, extensive road construction and quarring have provided excellent exposures of the deposits. Hence, the need for a thorough research works to be carried out in the area in order to characterize the deposits. The aim of this research work is to undertake a detailed lithofacies analysis of the conglomeritic deposits in order to reconstruct the depositional environment of the deposits.

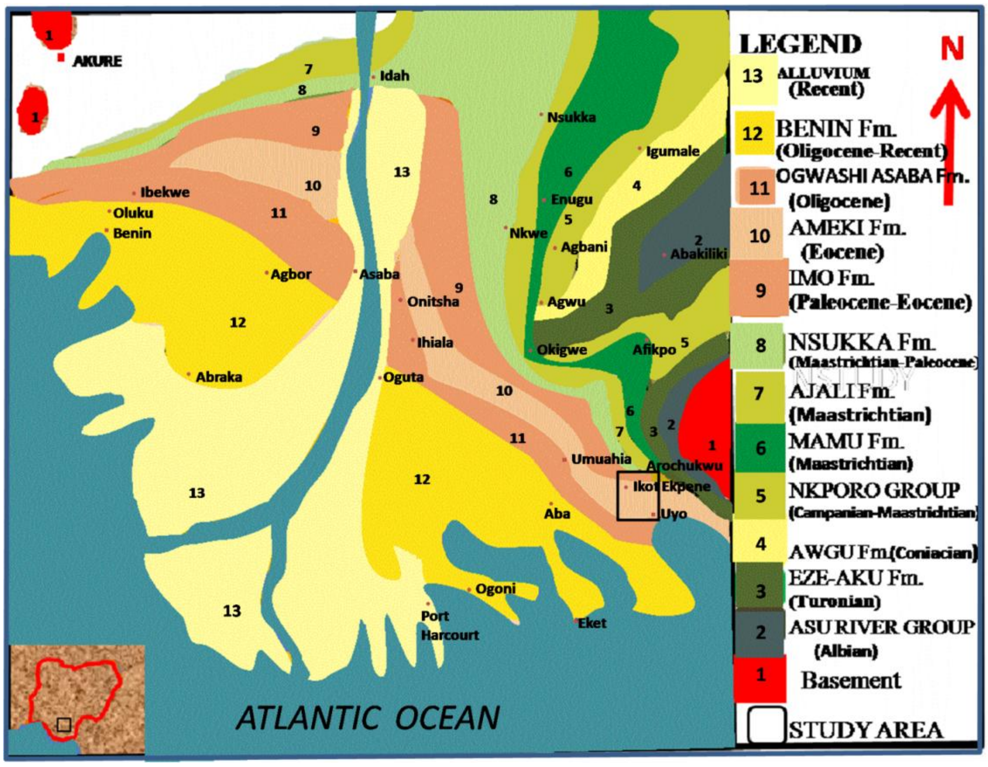

Figure 1: Geological map of southern part of Nigeria showing the study area.

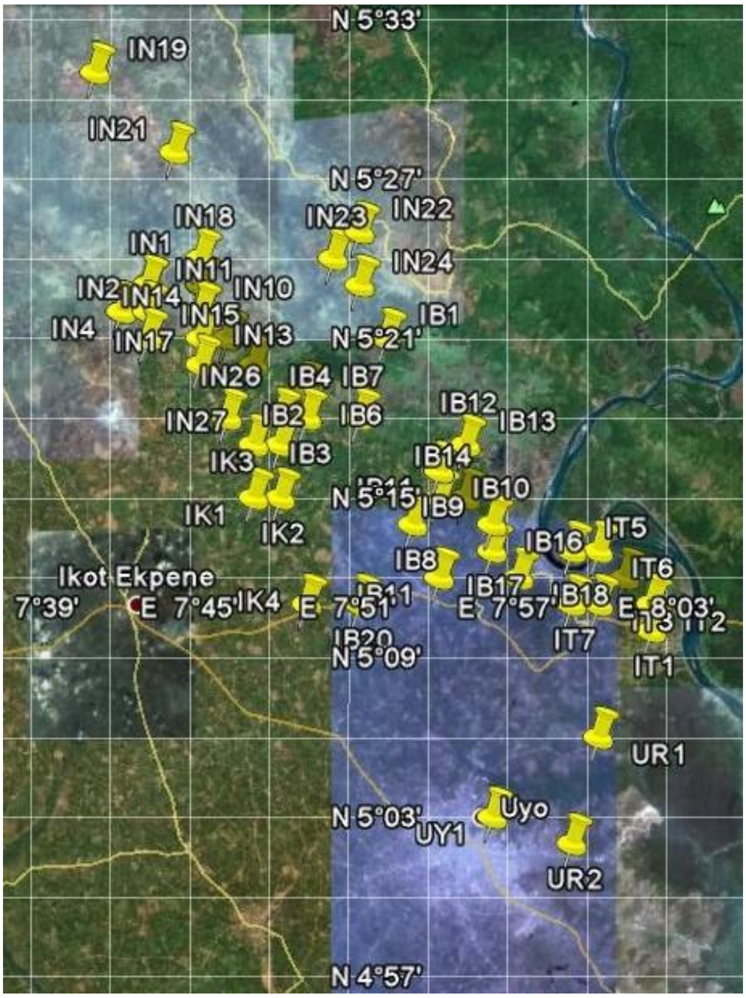

Figure 2: Sample location map

Tectonostratigraphic setting

The origin of the Niger Delta Basin and other southern Nigeria sedimentary Basins is linked to the evolution of the Benue Trough. The Benue Trough evolved as a result of the separation of the Afro-Brazilian plate during Early Cretaceous. The separation of the Aro-Brazilian plate initiated the opening of the south Atlantic during the Late Jurassic to Early Cretaceous times and reached Nigeria by Mid-Cretaceous (Fitton, 1980), resulting to the evolution of the Benue Trough (Murat, 1972; Hoque and Nwajide, 1984; Reyment, 1965; Nwachukwu, 1972; Olade, 1975; Kogbe, 1976; Petters, 1978; Wright, 1981; Benkhelil, 1982, 1989; Hoque and Nwajide, 1984). The Benue Trough is a continental scale intraplate tectonic megastructure which constitutes part of the Mid-African Rift system (Maluski*et al*., 1995). The tectonics of the Benue Trough is controlled by transcurrent faulting (sinistralwrenging) (Benkhelil, 1989). Genik, 1993 suggested that the Benue Trough is part of the West and Central African Rift System that opened as a sinistral wrench complex. The Benue Trough is the failed arm of a Y-shaped triple junction that initiated the opening of the south Atlantic Ocean and is thus regarded as an aulacogen (Hoffman et al., 1974; Olade, 1975; Hoque and Nwajide, 1984). The Benue Trough occurs as a NE-SW trending linear depression with about 4500m thick Cretaceous sediments (Olade, 1975). Hoque, 1984 and Benkhelil, 1989 suggested magmatic activity during the opening and closing of the Benue Trough which led to the deposition of Abakalikipyroclastics. Contact metamorphism occurs around the intrusive bodies while low grade metamorphism affected most deformed areas in Abakaliki (Benkhelil, 1989). The Niger delta complex is a regressive off lap sequence which prograded across the southern Benue Trough and spread out onto cooling and subsiding oceanic crust which was formed as Africa and south America separated.

The southern Nigeria sedimentary basins have been the scene of three depositional cycles. The first began with a marine incursion in the middle Cretaceous and was terminated by a mild folding phase in the Santonian time. The second included the growth of a proto-Niger delta during the Late Cretaceous and ended in a major Paleocene marine transgression. The third cycle, from Eocene to Recent, marked the continuous growth of the main Niger Delta (Short and Stauble, 1967).

The oldest sediments found in southern Nigeria are non-fossiliferous, arkosic, gravelly, and in general, ill-sorted, commonly cross-bedded sand and quartzitic sandstone. They form the weathering products of the nearby and underlying crystalline and metamorphic basement complex. The first marine incursion from the Gulf of Guinea in the Middle Cretaceous covered southern Nigeria and reached the Middle Benue Trough depositing Asu River Group in the Albian, Odukpani Formation in Cenomanian, Eze -Aku Shale in Turonian and Awgu Shale in the Coniacian time. This ended with the onset of a phase of folding, faulting and uplift in early Santonian time, resulting in erosion of Coniacian, Turonian, Cenomanian and even Albian deposits of the uplifted Abakaliki anticlinorium and simultaneous subsidence of Anambra Platform to form Anambra Basin and Ikpe Platform to form the Afikpo Sub Basin.

The Santonian folding phase was followed by subsidence which initiated a new marine transgression, resulting in the deposition of the Nkporo Shale of Campanian-Maestrichtian age, and its lateral equivalents, the Owelli Sandstone and the Enugu Shale. West of the River Niger, the marine Nkporo Shale ranges in age from Campanian to Maestrichtian. In the east, the Maestrichtian is represented by deltaic deposits (regressive phase) – the Mamu Formation, the Ajali Formation, and the Nsukka Formation. This regressive period, with the formation of a proto-Niger delta, continued throughout the end of Cretaceous and ended in a major Paleocene marine transgression.

The Palaeocene transgression also referred to as the Sokoto transgression resulted in the deposition of the Imo shale in the Anambra Basin to the northeast and the Akata shale in the Niger Delta Basin area to the southeast.

The main rock-stratigraphic unit of Paleocene age is the Imo Shale. The Imo Shale ranges into the early Eocene (Stolk, 1963) and is overlain by the sandy Ameki Formation (figure 3) which marks the onset of a regression and the formation of the modern Niger delta. East of the Niger, the Ameki Formation is very heterogeneous, consisting of alternating sandstone and shale, sandy or calcareous shale, marl, and a few fossiliferous shale and limestone beds. These abrupt, irregular alternations indicate deposition in a shallow marine environment with sediment supply from the nearby coast. During the Middle and Late Eocene, the sedimentary rocks became increasingly sandy, marking the onset of a general regression and of deltaic deposition.

In the Middle Eocene, major depocenters initiated in the Paleocene to Eocene in the Anambra Basin, Afikpo Syncline, and the Ikang Trough were the sites of deltaic outbuilding with the Niger-Benue and the Cross River drainage systems accounting for the bulk of the sediment supply. Both drainage systems merged at the end of the Oligocene and formed the present day Niger delta. Simple growth faults were initiated in the Oligocene (Whiteman,1982).

During the Miocene, uplift of the Cameroon mountains provided a new and dorminant sediment supply through the Cross River, thus constructing the Cross River Delta. The shoreline progressively migrated seaward during deltaic progradation. This was greatly accelerated in Miocene to Pliocene times with attendant increase in growth faulting and large scale diapiric movement of the Akata Shale. Deltaic growth declined in the Late

Pliocene to Pleistocene during a major drop in sea level, with sediments by- passing into deep sea fans. A Late Pleistocene transgression flooded the Plio-Pleistocene upper and lower deltaic plains. As sea level stabilized, a new regressive sequence developed.

Surface evidence of Oligicene and Miocene deposits is limited and much of the evidence for the age determination is inferred. The main rock-stratigraphic unit is the continental Ogwashi-Asaba Formation and its equivalent, the IjebuFormation in the Lagos area, which contains some sparse marine faunas. Both Formations are predominantly sandy, the sand alternating with lignite seams and a few beds of clay in the Ogwashi-Asaba Formation, or with a few thin clay beds with scarce marine faunas as in the Ijebu Formation (Reyment, 1965).

The youngest rock stratigraphic unit is the Benin Formation of possible Miocene to Recent age. The unit consists predominantly of yellow and white continental sand, alternating with pebbly layers and a few clay beds (Reyment, 1965)

The oldest Formation (Paleocene to Eocene) in the Niger Delta Basin form an accurate exposure belt along the delta frame. These are the Paleocene Imo Shale (fossiliferous blue-grey shales with thin sandstone, marl, limeston and locally thick nearshore sandstone); the Eocene Ameki Formation (fossiliferous calcareous clays, coastal sandstone); the late Eocene- Early Oligocene lignite clays and sandstones of Ogwashi-Asaba Formation and the Miocene-Recent Benin Formation (coastal plain sands). These Formations are highly diachronous and extended into the subsurface where they are assigned different formation names. The Akata, Agbada and Benin Formations are interfingeringfacies equivalent representing prodelta, delta front and delta top environments respectively. Unconformities, large clay fills of ancient submarine canyons and deep sea fans occur in the eastern and western delta. These formed mainly during the Early Oligocene and Tertiary low stand of sea level.

Short and Stauble (1967) divided the subsurface Niger delta Basin into three lithostratigraphic units, namely: Benin, Agbada and Akata Formations (table 1).

BENIN FORMATION

The Benin Formation has been described as “coastal plain sands” which outcrops in so many places in the Niger delta. It consists mainly of sands and gravels with thickness ranging from 1 to 2,100 meters. The sands and sandstones are coarse grained to very fine grained, pebbly, poorly sorted and unconsolidated to consolidated. The grains are subangular to well rounded. The sand and sandstone are white and yellowish brown in colour. Lignite occurs in thin streaks or finely dispersed fragments. Hematite grains and feldspars are common. Shale are few and thin. The shale is grayish brown, sandy to silty and contains some plant remains and dispersed lignite. Composition, structure, and grain size of the sediments indicate deposition in a continental, probably upper deltaic environment. The shale may be interpreted as backswamp deposits and oxbow fills.

In the eastern part of the Niger delta, the Benin Formation is interrupted by the Afam Clay Member. However, the Formation lacks faunal content and this makes it uneasy to date although an Oligocene-Recent age is generally accepted. Weber and Daukoru (1976) observed that the Benin Formation consists of fluviatile gravels and sands. The surface Benin Formation has been variously described as yellow and white, sometimes cross bedded sands, clays and sandy clays occurring in lenses (Whiteman, 1982). The formation is the main source of portable groundwater in the Niger Delta.

AGBADA FORMATION

The Agbada Formation underlies the Benin Formation and is the second of the three strongly diachronous Niger delta complex formations. It is characterized by intercalation of sandstones, sands and shale layers. The sands and sandstones are very coarse to very fine grained, predominantly unconsolidated, or slightly consolidated with a calcareous matrix. Lignite streaks and limonite grains are common. However, lignite-coated grains and feldspars which characterize the overlying Benin Formation are very scarce. Some fine-grained sand and sandstone units contain shell fragments and glauconite.

The microfossil assemblages range from littoral-estuarine-marsh types to faunas developed at water depth of approximately 300feet. The Agbada Formation is the subsurface equivalent of Ameki Formation.

AKATA FORMATION

Akata Formation is the basal major time transgressive lithologic unit in the Niger delta complex. It is characterized by a uniform shale development. The shale is dark gray, sandy or silty and contains plant remains and mica in the upper part. Benthonic foraminifera assemblages indicate that the shale was deposited in a shallow marine environment. The age of the formation is Paleocene to Holocene.

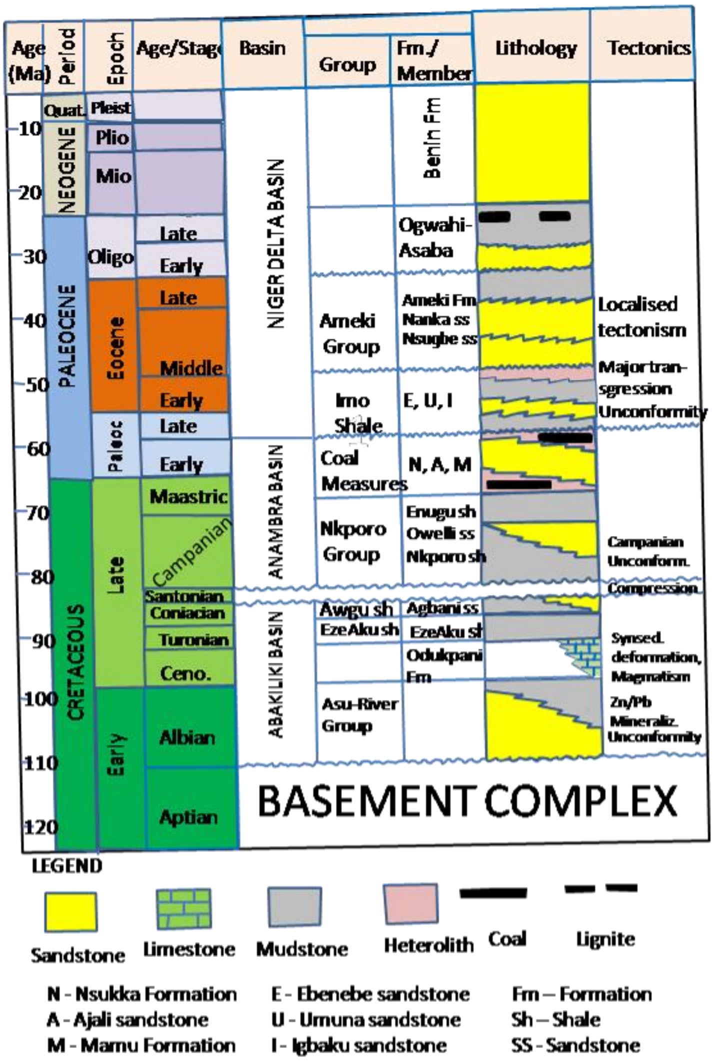

Figure 3: The stratigraphic succession in the Anambra Basin and outcropping Paleogene Niger Delta (after Ekwenye et al., 2014)

Table 1: Stratigraphic correlation of Tertiary Formation in the Niger Delta (modified after Reyment, 1965)

Age	**Surface Formation**	**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 Formation	Agbada Formation	Paralic
Paleocene-Recent	Imo Formation	Akata Formation	Marine

II. Methodology

Detailed field mapping was carried out in the northeastern part of the Niger Delta Basin using a topographic map, sheet 322 as the base map. Outcrops were accessed through road cuts and quarries. All rock exposures within the study area were sedimentologically logged and described. Attitude of the beds and azimuths of crossbeds were measured using a compass clinometer. The studied lithologic sections were systematically sampled and important features photographed.Shale samples obtained from the field were subjected to palynological analysis in order to ascertain the environment of deposition. The field observations were used to ascertain the lithofacies units and facies assemblages, which gave information on the depositional environments.

III. Results

Lithofacies description

The conglomeritic deposits in the northeastern part of the Niger Delta consist of ten sedimentary facies (figure 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 and table 2), defined on the basis of textural attributes, lithology and sedimentary structures. These lithofacies were further grouped into three facies associations.

Facies association 1 (fluvial channel deposit)

1. Mud supported conglomerate (cm)

Paraconglomeratefacies (figure 4) consists of reddish brown or white, massive, poorly consolidated matrix supported conglomerate. Maximum bed thickness is 15.4 meters. Clasts range from 0.5 to 8cm in diameter, subrounded to rounded, poorly sorted and made up of granules, pebbles and cobbles set in a matrix of clayey sand. There is paucity of imbricate structure and fossils. The base of this lithofacies is irregular and scoured. The presence of irregular bases gives a channel appearance to this facies. This facies forms about 5% of the conglomeritic deposits and it is underlain by shale. The facies is similar to faciesGms of Miall, 1977.

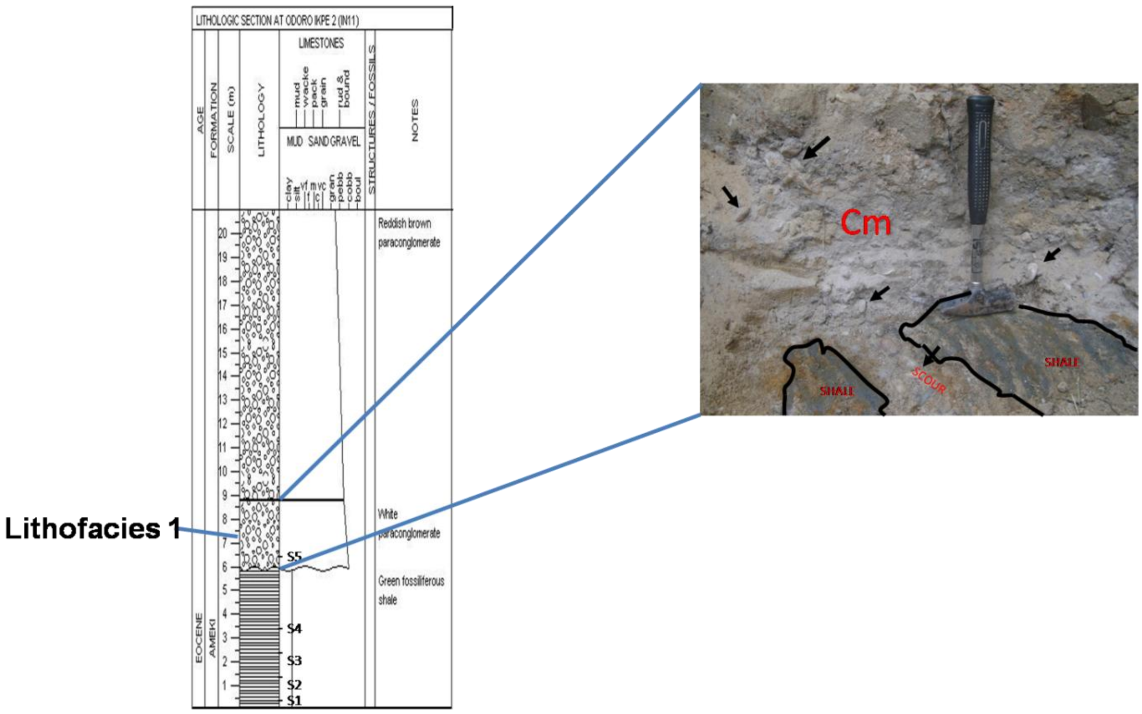

Figure 4: Sharp and scoured contact between matrix-supported conglomerate and shale.

2. Clast supported conglomerate (Cc)

Orthoconglomeratefacies (figure 5) is made up of reddish brown or white, clast supported, normally graded, structureless, nonfossiliferous and poorly consolidated conglomerate with thickness ranging from 0.5 to 12.4 meters. The conglomerate shows a graduation from cobbles as basal lag deposits to pebble size clasts and granules. The fabric is highly unordered, hence there is no clasts imbrications and stratification. Clasts range from 0.4 to 8cm in diameter, poorly sorted, subrounded to rounded and consists of quartz. The matrix is fine to very coarse grained sand and pebbles with some amount of plant fragments. The conglomerate is interbedded with sandstones at some locations. The sandstone interbeds range in thickness from 10 to 50cm and consists of very coarse grained pebbly sandstone which is either massive, cross or horizontally stratified. The grain size of the sandstone is identical to that of the matrix of the underlying conglomerate. Occasionally, there is gradation from conglomerate to sandstone beds, but in most cases the contact is sharp. The base of this facies is irregular and erosional. A thin ferruginized band marks the lower contact at some places where the facies overlies shale bed. The band is probably formed as a result permeability barrier between the two lithologies which traps the percolating rain water from where iron precipitates out. This facies is underlain by shale, and overlain by sandstone and clay. It forms about 70% of the conglomerate deposits. This facies is similar to facies A of Amajor, 1986 and facies Gm of Miall, 1977.

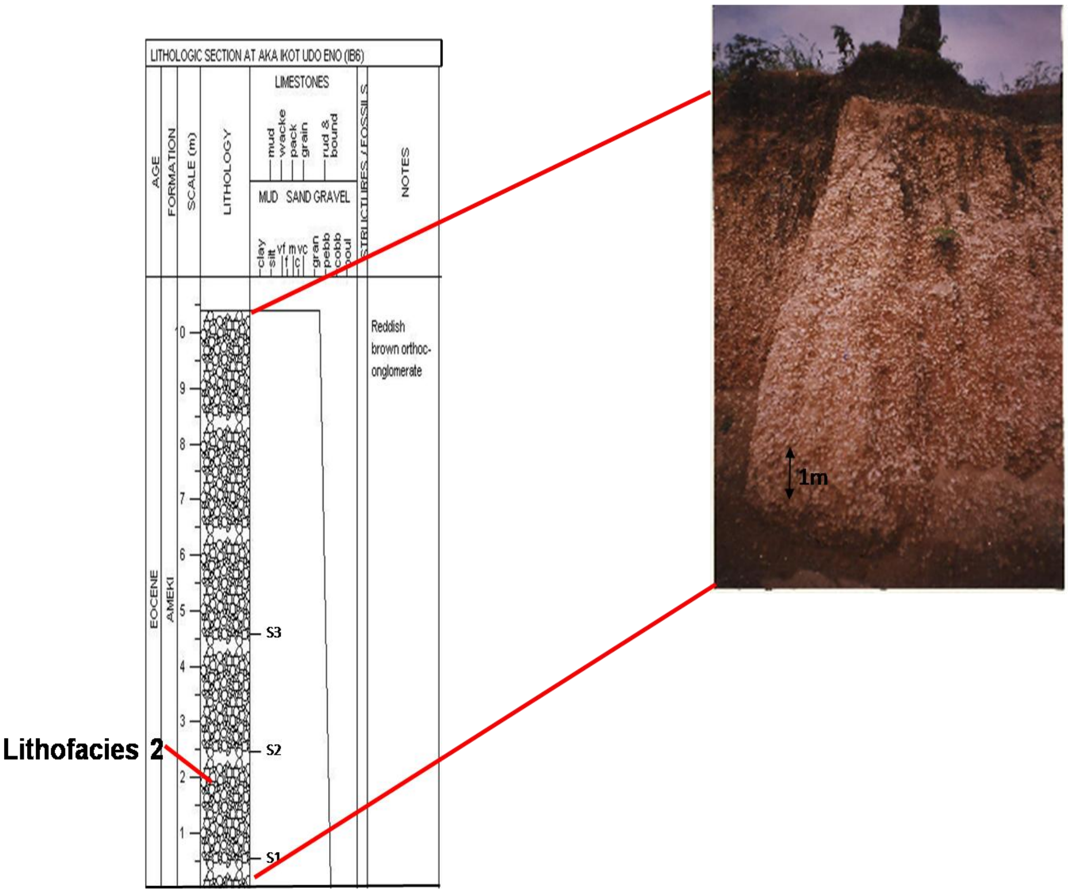

Figure 5: Orthoconglomeratefacies exposed in a quarry

3. Massive sandstone (Sm)

Massive sandstone facies (figure 6) consists of white or reddish brown, fine to coarse grained, pebbly, poorly to moderately sorted, friable and angular to subroundedstructureless sands. Plants fragments are ubiquitous. There is complete absence of fossils. The base of this facies is abrupt. This facies constitute about 10% of the conglomeritic deposits. It is similar to facies B of Amajor, 1986.

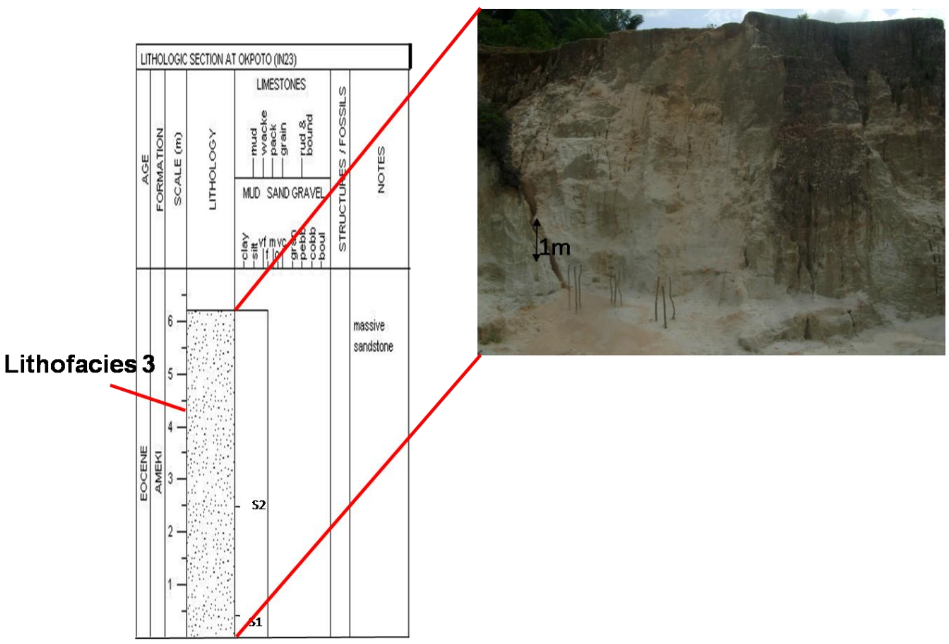

Figure 6: Massive sandstone facies

4. Planar cross-stratified sandstone (Sc)

Planar cross-stratified sandstone facies (figure 7) consists of mottled (yellow, red, brown, white), medium to coarse grained, poorly sorted, pebbly, angular to subrounded, friable planar cross-stratified sands with granules concentrated in some forsets. Set thicknesses range from 30 to 100 centimeters. Paleocurrents analysis indicate a unimodal pattern showing a southwest trend. The base of this facies is sharp. This facies forms about 5% of the conglomerate deposits. It is similar to faciesSp of Miall, 1977.

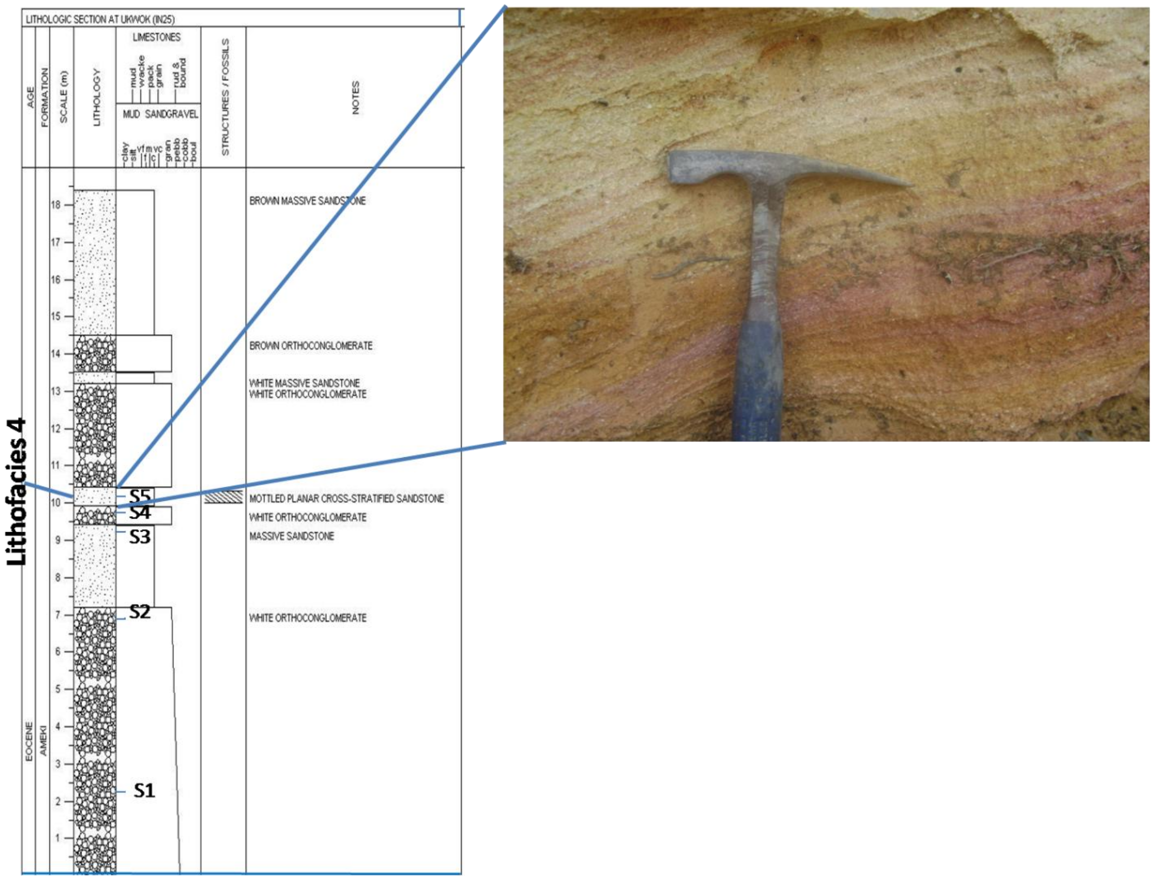

Figure 7: Planar cross-stratified sandstone

5. Trough cross-stratified sandstone (Tc):

Trough coss-stratified sandstone facies (figure 8) consists of medium to coarse grained, reddish brown or white trough cross-stratified sandstone in beds a few meters to centimeters thick. The sandstone is poorly sorted, angular to subrounded, and friable. It is pebbly at some locations. As in the case of faciesSc, this facies shows textural variations, where coarse sands and granules tend to concentrate in forests. The sandstone generally has a scooped erosional base. It is similar to facies St of Miall, 1977.

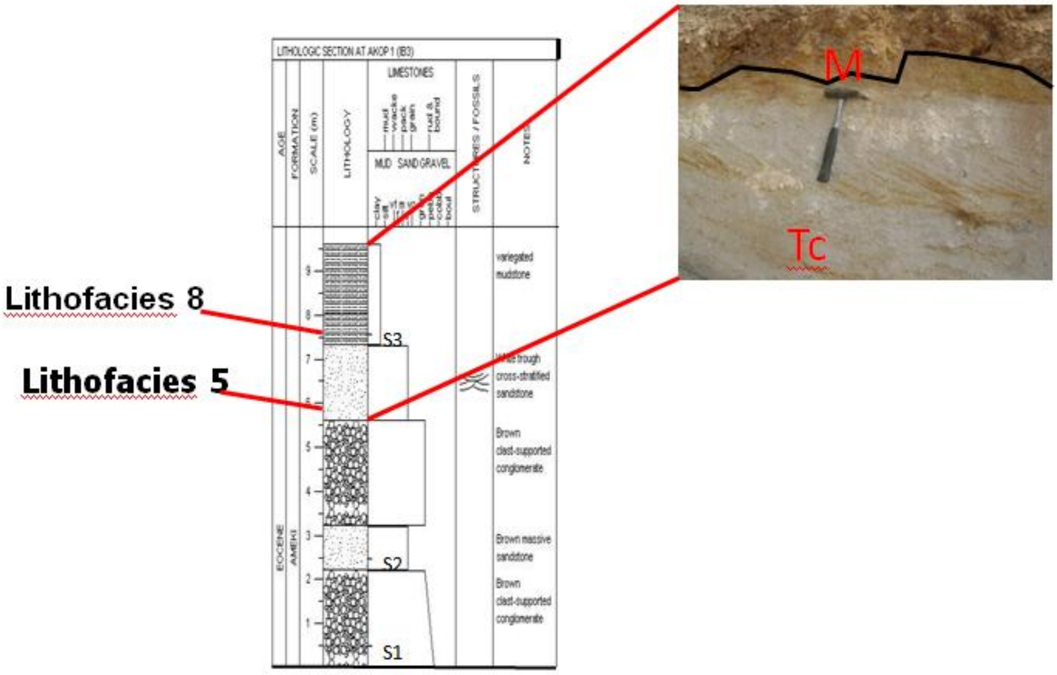

Figure. 8: Trough coss-stratified sandstone

6. Horizontally stratified sandstone (Sp)

Horizontally stratified sandstone facies (figure 9) is made up of white, fine to coarse grained, subangular to subrounded, poorly sorted, friable sands with horizontal stratifications. The stratifications appear as changes in grain size and by the presence of very thin fine grained siliciclastic laminae. The facies has a sharp contact with the underlying facies. This facies makes up about 5% of the conglomerate deposits and either overlies the conglomerate or occurs as interbeds. It is similar to faciesSh of Miall, 1977.

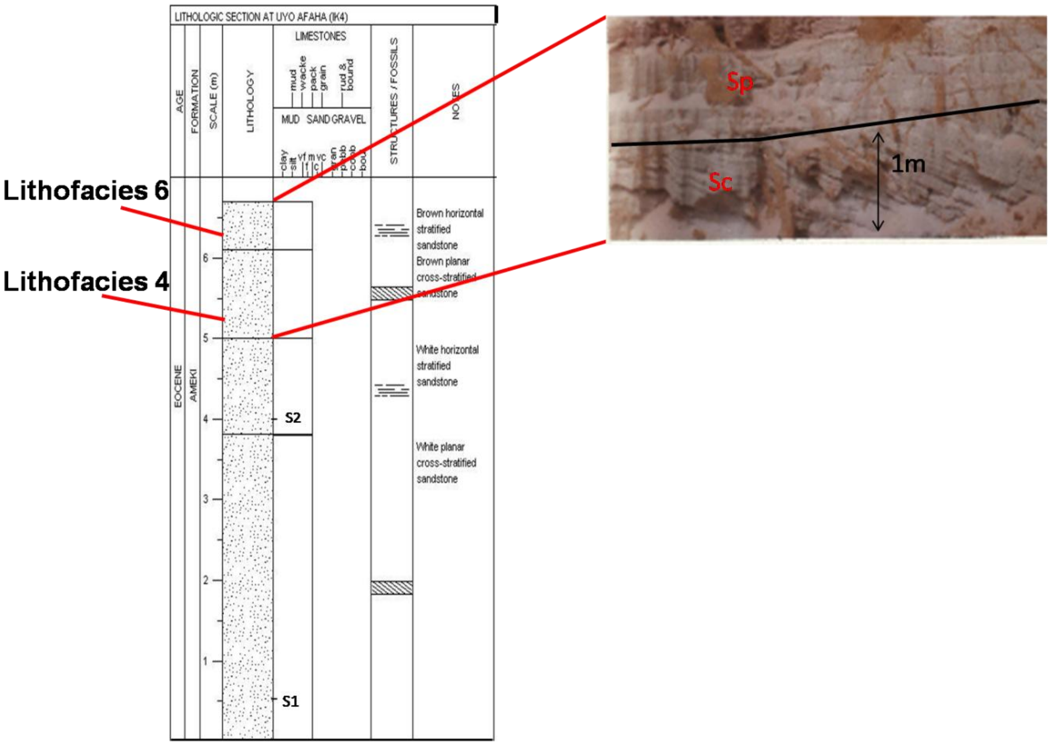

Figure 9: Horizontally stratified sandstone

Facies association 2 (floodplain of the braided fluvial deposit)

7. Claystone (Ct)

Claysonefacies (figure 10) consists of massive claystone that lack any observable sedimentary structure. This fine grained facies is light grey, white and pink in colour. The facies is soft to medium hard. This facies overlies the conglomerate and sandstone facies.

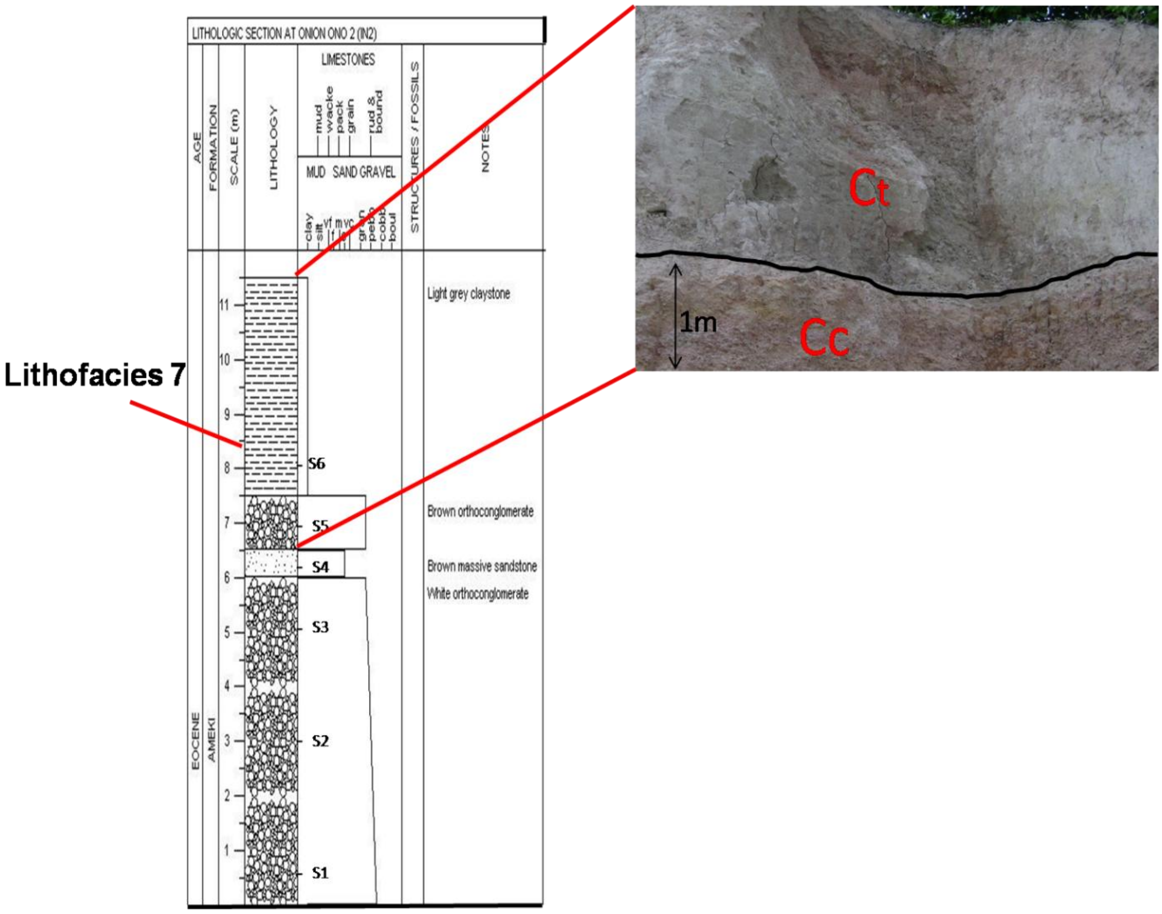

Figure 10: Claystone facies

8. Variegated mudstone facies (M)

Variegated mudstone facies (figure 11) is characterized by mottled structureless sandy mudstone. Organic fragments are apparent. The base of this facies is flat or irregular but not erosional. This facies makes up about 5% of the conglomerate deposits and overlies the conglomerate and sandstone facies. It is similar to faciesFm of Miall, 1977.

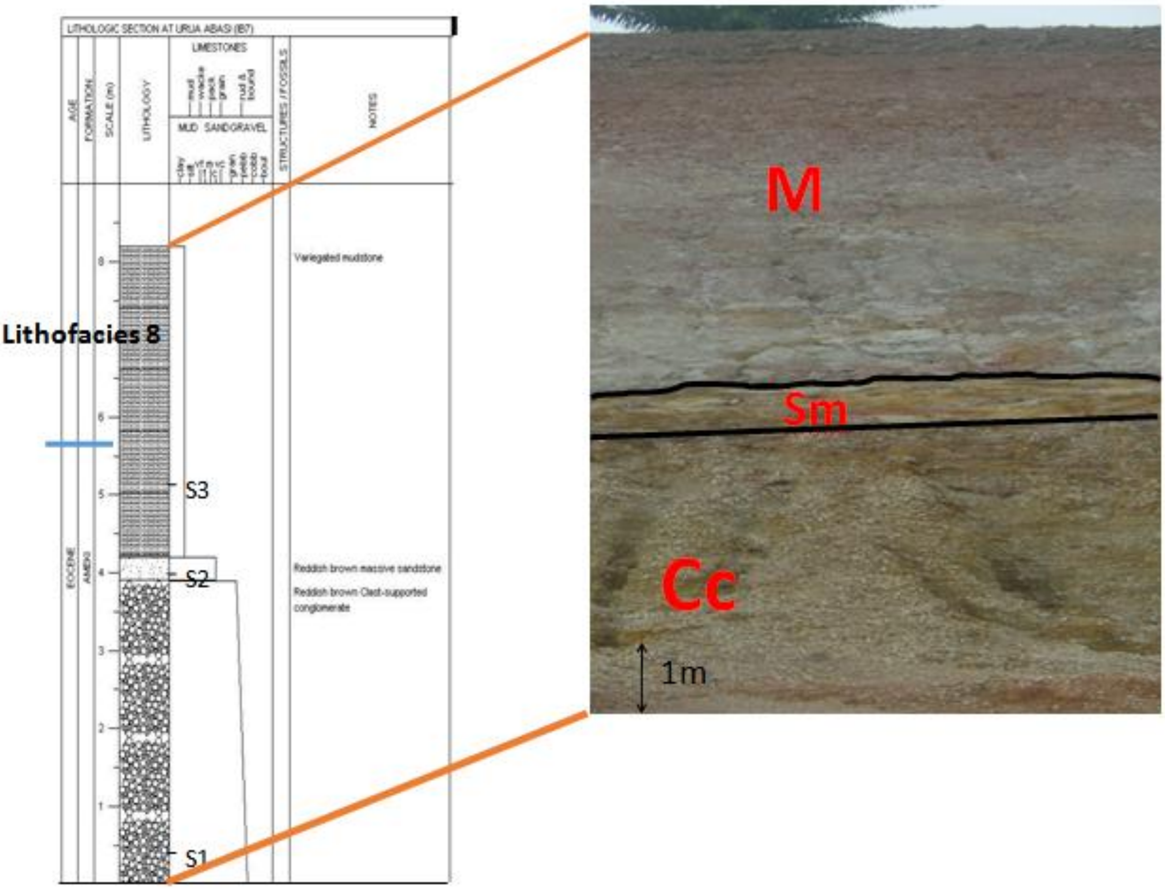

Figure 11: Orthoconglomerate (Cc), massive sandstone Sm) and variegated mudstone (M)

Facies association 3 (estuarine deposit)

9. Grey-green shale (Sh)

Gey-green shale facies (figure 12) consists of grey- green calcareous sandy shale with intercalations of shelly limestone. The shale is rich in mollusk, ostracode, foraminifera and palynomorphs. (table 3, 4 and figure 16) This facies underlies the conglomerate deposits.

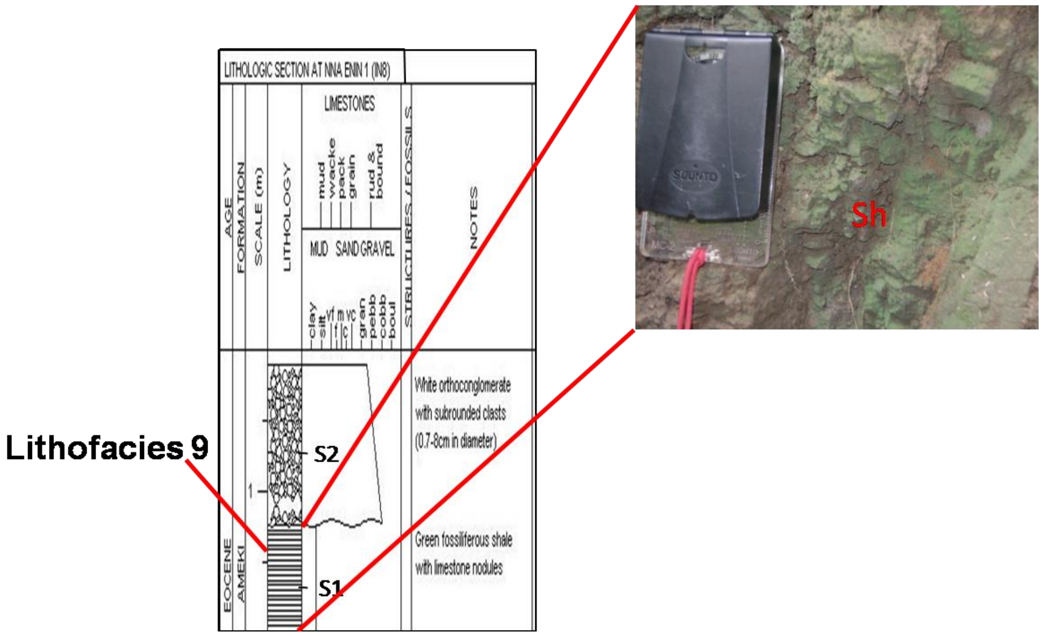

Figure 12: Grey-green shale facies

10. Black shale (Sb)

Black shale facies (figure 13) consists of black non-calcareous shale rich in ostracode, mollusk, foraminifera and palynomorphs (table 3, 4 and figure 17). This facies underlies the grey-green shale.

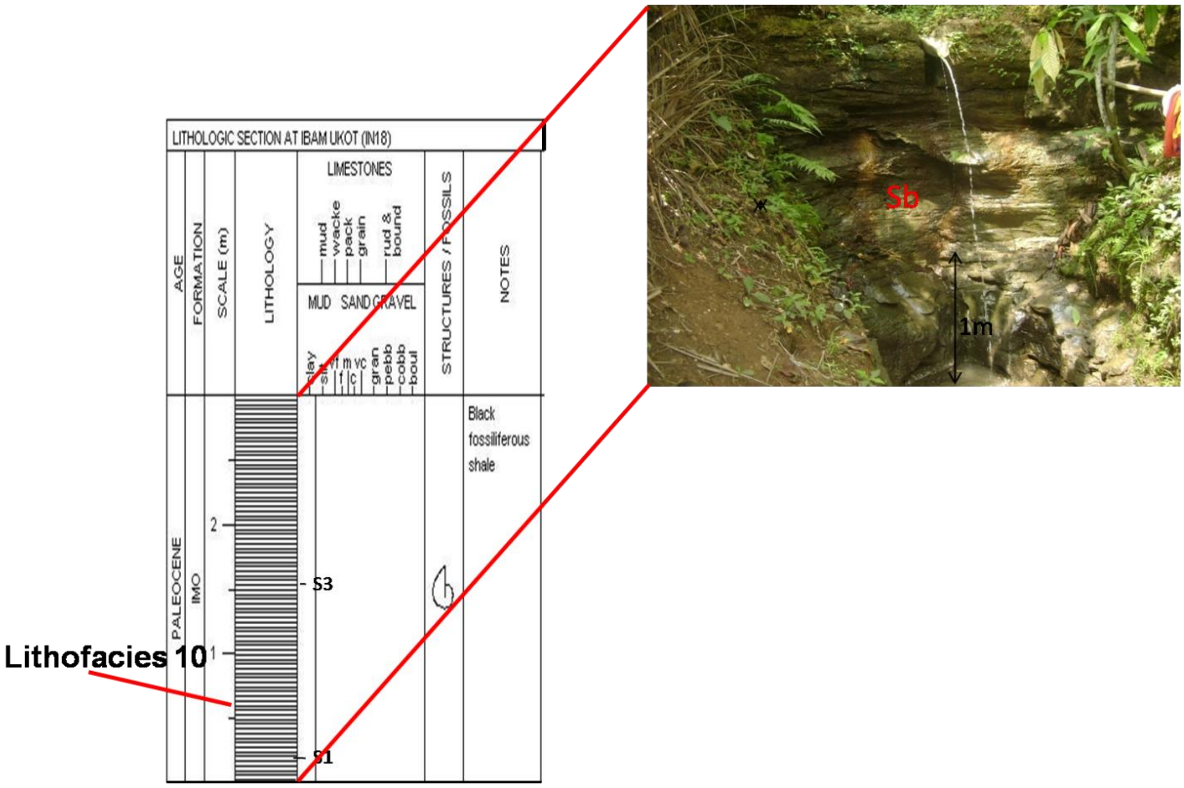

Figure 13: Black shale facies

Facies relationship

The vertical facies sequence (figure 14) begins with black shale followed by grey-green shale. This is succeeded by the gravelly facies resting on scoured erosional surfaces, sandy facies and mudstone facies in ascending order.

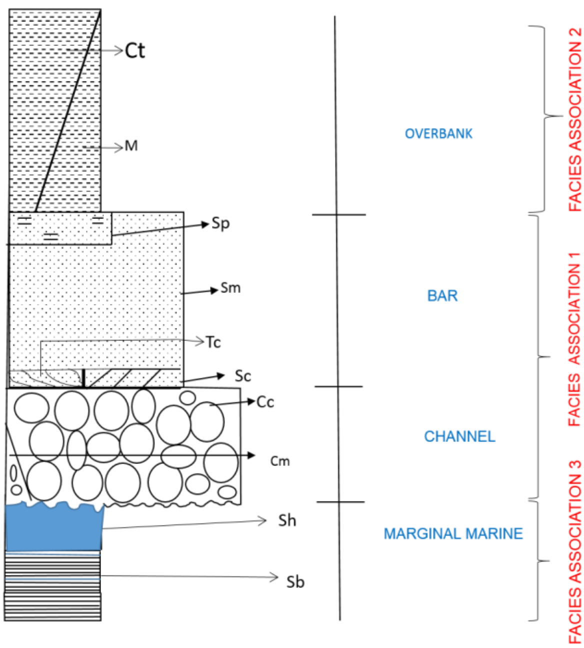

Figure 14: Vertical sedimentary facies model

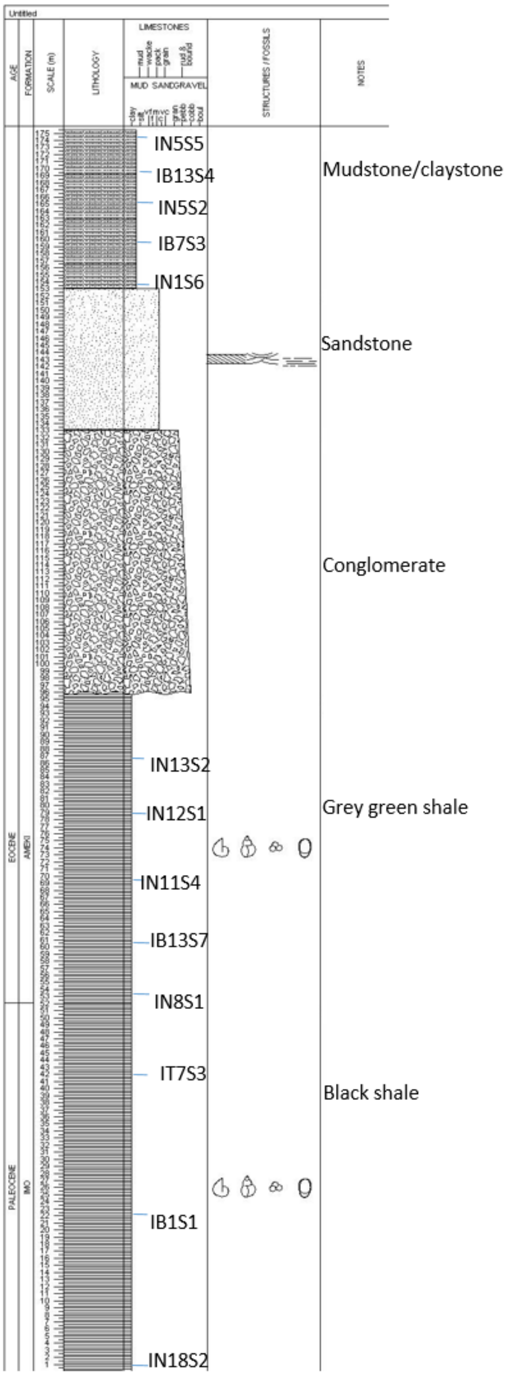

Figure 15: Composite stratigraphic section

Table 2: Summary of the description and interpretation of lithofacies occurring in the study area

Facies code	Lithofacies	Textures	Sedimentary structures	Fossils	Depositional process	Depositional environment
Cm	Matrix-supported conglomerate	Matrix supported, poorly sorted, clasts are subrounded to rounded,	Bed is structureless and shows normal grading but no clasts imbrications	None	Cohesive debris flow in a subaqueous setting	Braided fluvial channel
Cc	Clast-supported conglomerate	Clast-supported, poorly sorted orthoconglomerates, clasts are subrounded to rounded	Structureless beds with granules to cobbles range in clast sizes, Clasts show no imbrications	None	Longitudinal bars, channel lag deposits, sieve deposits	
Sm	Massive sandstone	Fine to coarse grained, non-fossiliferous structureless or massive sandstone	None	None	Gradual aggradation of sediments beneath steady flow or rapid deposition	
Sc	Planar cross-stratified sandstone	Medium to coarse grained, poorly sorted sandstone	Large scale planar cross-stratification (<45cm thick), forsets are angular, coarse sands and granules concentrate in some forsets	None	Migration of straight-crested bedform	
Tc	Trough cross-stratified sandstone	Medium to coarse grained, poorly sorted sandstone	Trough cross-stratification	None	Migration of lunate or sinuous- crested bedform	
Sp	Horizontally stratified sandstone	Fine to coarse grained, poorly sorted sandstone	Parallel bedding	None	Upper flow regime plane bed produced by decelerating current	
Ct	Claystone	Fine grained claystone	Structureless	None	Continuous and rapid deposition from suspension	Braided fluvial floodplain
M	Variegated mudstone	Variegated coloured, sandy, massive mudstone	None	None	Poorly drained palaeosol	
Sh	Grey green shale	Fine grained	Limestone nodules	Ostracode, mollusk, palynomorphs, foraminifera	Sediment fallout in low energy environment	Estuary
Sb	Black shale	Fine grained	Fissility	Ostracode, mollusk, palynomorphs, foraminifera	Sediment fallout in low energy environment	

Table 3: The absolute counts of the palynomorphs species encountered from the given analysed samples

SAMPLE NO / PALYNOMORPHS	IB1S1	IN11S4	IN12S1	IN13S2	IN5S2	IN8S1	IN18S2	IN1S6	IN5S6	IT7S3	IB13S7	IB7S3	IB13S4
Laevigatosporitesovatus	28	23	25	37	40	50	20	5	0	36	50	35	0
Cyathidites minor	6	0	1	0	0	0	0	0	0	4	6	3	0
Polypodiaceoisporites sp.	18	0	0	1	10	0	0	0	0	0	38	15	0
Cycadopitesovatus	0	0	0	0	1	6	2	0	0	0	0	0	0
Leiotriletesadriennis	0	0	2	0	3	0	2	0	0	18	2	1	0
Spinizonocolpitesbaculatus	0	2	0	1	0	2	0	0	0	0	0	0	0
Proxapertitesoperculatus	24	8	5	3	2	6	6	0	0	0	8	2	0
Tricolpiteshians	0	1	2	0	0	0	0	0	0	0	0	0	0
Proxapertites cursus	6	10	13	7	15	10	0	0	0	8	38	15	0
Monoporitesannulatus	2	2	4	6	3	0	0	0	0	0	4	6	0
Psilatricolporitescrassus	0	6	10	7	4	8	0	0	0	0	0	2	0
Retistephanocolpiteswilliamsi	0	4	3	2	1	0	0	0	0	0	0	4	0
Racemonocolpiteshians	0	2	0	0	0	0	0	0	0	2	0	0	0
Liliaciditesnigeriensis	4	2	1	3	0	0	0	2	0	0	0	2	0
Spinizonocolpitesechinatus	0	2	3	1	0	2	0	0	0	4	0	1	0
Retitricolporitesirregularis	0	4	2	5	10	2	0	0	0	0	0	4	0
Momipites sp.	0	2	0	0	0	0	0	0	0	0	0	0	0
Longapertitesmarginatus	6	2	0	2	6	4	0	0	0	4	18	2	0
Mauritiiditescrassibaculatus	0	2	1	3	0	2	0	0	0	0	0	1	0
Retidiporitesmagdalenensis	2	0	0	1	0	2	0	0	0	0	2	0	0
Scabratriporitessimpliformis	2	0	0	0	0	0	0	0	0	0	0	0	0
Psilatriporitesrotundus	0	0	1	1	0	0	0	0	0	0	2	1	0
Psilatricolporitesminutus	0	0	0	2	1	0	0	0	0	0	2	0	0
Spiniferitesramosus	0	46	20	10	0	2	0	0	0	0	0	0	0
Achilleodiniumbiformoides	0	16	10	7	0	0	0	0	0	8	0	0	0
Operculodiniumcentrocarpum	0	6	4	10	0	0	72	0	0	50	0	0	0
Kallosphaeridium cf. brevibarbatum	0	6	2	0	0	0	0	0	0	0	0	0	0
Impegidinium sp.	0	16	5	0	0	0	0	0	0	0	0	0	0
Polysphaeridium sp.	0	4	2	1	0	0	0	0	0	0	0	0	0
Areoligerasenoniensis	0	2	3	4	0	0	8	0	0	8	0	0	0
Homotrybliumtenuispinosum	0	2	0	0	0	0	0	0	0	4	0	0	0
Apectodiniumhomomorphum	0	0	0	0	0	0	0	0	0	12	0	0	0
Cyclonepheliumdeckoninckii	2	2	0	3	0	2	2	0	0	4	0	0	0
Adnatosphaeridiummultispinosum	0	0	1	3	0	0	0	0	0	14	0	0	0
Andalusiella sp.	2	0	0	0	0	0	0	0	0	0	0	0	0
Leoisphaeridia spp.	0	4	1	5	0	32	14	0	0	0	0	0	0
Paleocystodinium sp.	2	0	0	0	0	0	0	0	0	0	0	0	0
Deflandrea sp.	0	0	0	0	0	0	2	0	0	0	0	0	0
Glaphyrocysta ordinate	0	0	1	3	0	0	10	0	0	4	0	0	0
Cordosphaeridiumfibrospinosum	0	0	0	1	0	0	2	0	0	0	0	0	0
Hystrichosphaeridiumtubiferum	0		0	0	0	0	0	0	0	4	0	0	0
Lingulodiniummachaerophorum	0	0	1	2	0	0	0	0	0	14	0	0	0

Table 4: The occurrence and distributions of palynomorphs species present in the given analysedsamples

SAMPLE NO / PALYNOMORPHS	IB1S1	IN11S4	IN12S1	IN13S2	IN5S2	IN8S1	IN18S2	IN1S6	IN5S5	IT7S3	IB13S7	IB7S3	IB13S4
SPORES													
Laevigatosporitesovatus	X	X	X	X	X	X	X	X	0	X	X	X	0
Cyathidites minor	X	0	X	0	0	0	0	0	0	X	X	X	0
Polypodiaceoisporites sp.	X	0	0	X	X	0	0	0	0	0	X	X	0
Cycadopitesovatus	0	0	0	0	X	X	X	0	0	0	0	0	0
Leiotriletesadriennis	0	0	X	0	X	0	X	0	0	X	X	0	0
POLLEN													
Spinizonocolpitesbaculatus	0	X	0	X	0	X	0	0	0	0	0	0	0
Proxapertitesoperculatus	X	X	X	X	X	X	X	0	0	0	X	X	0
Tricolpiteshians	0	X	X	0	0	0	0	0	0	0	0	0	0
Proxapertites cursus	X	X	X	X	X	X	0	0	0	X	X	X	0
Monoporitesannulatus	X	X	X	X	X	0	0	0	0	0	X	X	0
Psilatricolporitescrassus	0	X	X	X	X	X	0	0	0	0	0	X	0
Retistephanocolpiteswilliamsi	0	X	X	X	X	0	0	0	0	0	0	0	0
Racemonocolpiteshians	0	X	0	0	0	0	0	0	0	X	0	0	0
Liliacidites nigeriensis	X	X	X	X	0	0	0	X	0	0	0	X	0
Spinizonocolpitesechinatus	0	X	X	X	0	X	0	0	0	X	0	0	0
Retitricolporitesirregularis	0	X	X	X	X	X	0	0	0	0	0	X	0
Momipites sp.	0	X	0	0	0	0	0	0	0	0	0	0	0
Longapertitesmarginatus	X	X	0	X	X	X	0	0	0	X	X	0	0
Mauritiiditescrassibaculatus	0	X	X	X	0	X	0	0	0	0	0	0	0
Retidiporitesmagdalenensis	X	0	0	X	0	X	0	0	0	0	X	0	0
Scabratriporitessimpliformis	X	0	0	0	0	0	0	0	0	0	0	0	0
Psilatriporitesrotundus	0	0	X	X	0	0	0	0	0	0	X	X	0
Psilatricolporitesminutus	0	0	0	X	X	0	0	0	0	0	X	0	0
DINOFLAGELLATE CYSTS													
Spiniferitesramosus	0	X	X	X	0	X	0	0	0	0	0	0	0
Achilleodiniumbiformoides	0	X	X	X	0	0	0	0	0	X	0	0	0
Operculodiniumcentrocarpum	0	X	X	X	0	0	X	0	0	X	0	0	0
Kallosphaeridium cf. brevibarbatum	0	X	X	0	0	0	0	0	0	0	0	0	0
Impegidinium sp.	0	X	X	0	0	0	0	0	0	0	0	0	0
Polysphaeridium sp.	0	X	X	X	0	0	0	0	0	0	0	0	0
Areoligerasenoniensis	0	X	X	X	0	0	X	0	0	X	0	0	0
Homotrybliumtenuispinosum	0	X	0	0	0	0	0	0	0	X	0	0	0
Apectodiniumhomomorphum	0	0	0	0	0	0	0	0	0	X	0	0	0
Cyclonepheliumdeckoninckii	X	X	0	X	0	X	X	0	0	X	0	0	0
Adnatosphaeridiummultispinosum	0	0	X	X	0	0	0	0	0	X	0	0	0
Andalusiella sp.	X	0	0	0	0	0	0	0	0	0	0	0	0
Paleocystodinium sp.	X	0	0	0	0	0	0	0	0	0	0	0	0
Deflandrea sp.	0	0	0	0	0	0	X	0	0	0	0	0	0
Glaphyrocystaordinate	0	0	X	X	0	0	X	0	0	X	0	0	0
Cordosphaeridiumfibrospinosum	0	0	0	X	0	0	X	0	0	0	0	0	0
Hystrichosphaeridiumtubiferum	0		0	0	0	0	0	0	0	X	0	0	0
Lingulodiniummachaerophorum	0	0	X	X	0	0	0	0	0	X	0	0	0
ACHRITARCH													
Leoisphaeridia spp.	0	X	X	X	0	X	X	0	0	0	0	0	0

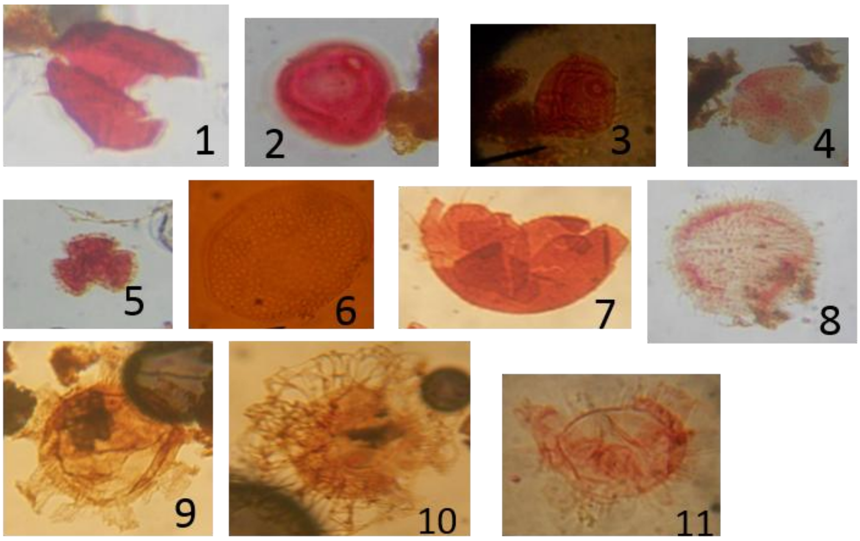

Figure 16: Photomicrographs of some key Eocene Palynomorphs from the analysed samples (x40)
1. Spinizonocolpites echinatus
2. Monoporites annulatus
3. Monoporites annulatus
4. Retistephanocolpites williamsi
5. Retitricolporites irregularis
6. Proxapertites cursus
7. Kallosphaeridium cf. brevibarbatum
8. Operculodinium centrocarpum
9. Cordospaeridium fibrospinosum
10. Adnatosphaeridium multispinosum
11. Achilleodinium biformoides

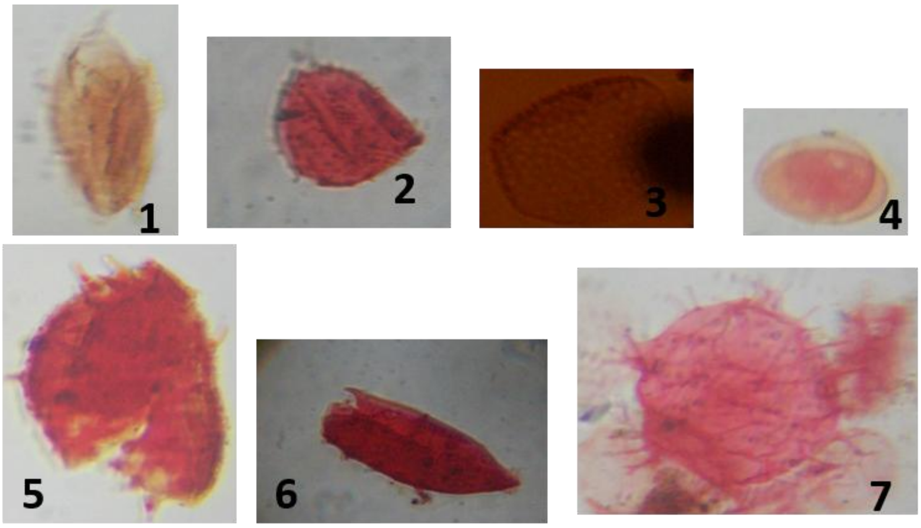

Figure 17: Photomicrographs of some key Paleocene palynomorphs from the analysed samples (x40)
1. Mauritiidites crassibaculatus
2. Scabratriporites simpliformis
3. Retidiporites magdalenensis
4. Proxapertites operculatus
5. Spinizonocolpites baculatus
6. Spinizonocolpites baculatus
7. Apectodinium homomorphum

IV. Discussion

Processes responsible for the deposition of thick conglomerates include:

(1) Debris-flow, in the sense of Middleton and Hampton, 1973, in which clasts are transported by a viscous matrix with strength,

(2) Grain-flow, in the sense of Middleton and Hampton, 1973, in which clasts are transported by dispersive pressure set up by grain interactions in the inertial regime,

(3) Traction, in which clasts are rolled as bed load by streams or sheet flood. Combinations of all of these processes are possible (Allen,1981).

Lithofacies Cm is interpreted as deposits from hyper-concentrated debris flows due to their lack of internal organization and matrix-supported framework (Rust, 1978; Schultz, 1984; Hubert and Filipov, 1989; Miall, 1996). The absence of preferred fabric means that the clasts were restricted in movement relative to each other. These deposits occupied pre-existing topography within channels ((Miall,1996).

Lithofacies Cc is interpreted as bed load gravel that was deposited from clast by clast accretion and rolling of clasts during higher discharges. Characteristic that support this interpretation is a clast-supported framework with no internal organization (Smith, 1974; Hein and Walker, 1977; Miall, 1977; Rust, 1978; Karpeta, 1993). The massive nature of this conglomerate is commonly attributed to deposition by a longitudinal bar in straight shallow reaches with high rates of sediment discharge (Ore, 1964; Williams and Rust, 1969; Smith, 1974; Hein and Walker, 1977; Rust, 1978; Ramos and Sapena, 1983; Miall, 1996). The matrix of very coarse sandstone is thought to have been transported in suspension simultaneously with bedload rolling of the large clasts. The essentially unstratified nature of the conglomerates or paucity of imbricated fabric indicates that bedload rolling of clasts in equilibrium with ambient flow conditions was limited.

The graded bedding of this facies (Cc) indicates deposition from a single current as the energy and flow strength diminished. The erosional base of this facies represents channel scour that was formed by avulsion at relatively high water stage (William and Rust, 1969; Miall, 1977; Yagishita, 1997). It may also imply that lithofacies Cc was deposited following a flood that eroded the strata below this facies.

The pebbly sandstone beds of lithofacies Cc could have been transported in suspension by the same flow which was transporting the gravels of the underlying conglomerate as bedload (Walker,1975a). The sandstone beds may therefore represent the upper part of a conglomerate sandstone couplet, deposited towards the end of the discharge cycle after flow velocities had waned slightly. The generally abrupt contact between orthoconglomerate and overlying sandstone bed reflects the change from bedload rolling to suspension as the main transport mechanisms, and need not reflect sudden or large decrease in flow strengths. Based on the aforementioned interpretations, it is likely that the gravelly facies suggests deposition in channels. Lithofacies Cc is overlain by sandy and fine lithofacies Sm, Sp, Sc, Ct and M.

Sedimentation in a given channel or channel complex results in aggradation above the surrounding area and a progressive loss of stream competency in response to the reduction in slope. These processes are reflected in the gross fining upward sequence. Probably during a flood event, the channel wall is breached and flow is diverted into topographically lower areas. The old channel or channel system is abandoned and the last sediment formed are fine grained deposit (Miall, 1977; Dyer,1970).

The lack of sedimentary structures indicates that lithofacies Sm may have been deposited by sediment gravity flows, or by rapid deposition during falling flow conditions (Todds, 1989; Maizels, 1989; Miall, 1996; Jo et al., 1997). This lithofacies may also result from post-depositional modification, such as dewatering or bioturbation (Miall, 1996). In the present interpretation, deformation is considered as irrelevant based on the absence of its indicators in any bed associated with facies Sm.

LithofaciesSc was deposited by the migration of straight crested dunes or ripples, as indicated by the cross-stratifications in the sandstone (Harm et al., 1982; Allen, 1984; Miall, 1996). Textural variations, where the coarse sands and granules tend to concentrate in foresets, were formed because sand is typically sorted by the process of ripple migration up to the stoss side of the dune or bars (Miall,1996). Lithofacies Tc was deposited by the migration of sinuous, linguoid or lunate crested bedforms. Their lee faces were the likely sites of avalanching of coarse sands and granules.The horizontal stratification exhibited by faciesSp is probably due to upper flow regime plane bed conditions.

Considering the nature of lithofacies Sm, Sc, Tc and Sp and their close relationship with facies Cc, Ct and M, these sandy facies are interpreted as channel to bar deposits. They are overlain by lithofacies M and Ct.

The massive nature of lithofacies Ct may be due to a very homogeneous and possibly rapid deposition from suspension or to lack of platy grains (Collinson and Thompson, 1982). Facies M is interpreted as poorly drained palaeosol. Both represent floodplain deposit.

Based on the aforementioned interpretations, it is clearly indicated that the overall fining upward association represents a succession of channel-bar-over bank deposits of a braided fluvial system.

Lithofacies Sb and Sh represent estuarine deposits because of the presence of brackish water dinoflagellates cysts such as *Andalusiella sp., Paleocystodinium sp., Deflandrea sp.,* *Apectodiniumhomomorphum and* pollen such as*Spinizonocolpitesechinatus, Spinizonocolpites. baculatus, Psilatricolporitescrassus, Proxapertitesoperculatus, and Proxapertites cursus.* The occurrence of fluvial conglomerate on top of estuarine grey green shale was triggered by a gradual progradation of a river over the shale as the sea level fell during the Eocene period.

The lithofacies identified in the study area were further grouped into facies associations in order to interpret the environments of deposition. Three facies associations have been identified in the study area based on lithology, primary sedimentary structures, fossil content, geometry, lateral and vertical succession of beds and the nature of bedding contacts. These facies associations are interpreted as sediments deposited in the following environment of deposition: braided fluvial channels, braided fluvial floodplain and estuary.

V. Conclusion

In conclusion, the study reveals that the conglomeratic deposits in northeastern part of the Niger Delta Basin consists of ten sedimentary faciesgrouped into three facies associations: facies association 1 comprising matrix-supported conglomerate (Cm), clast-supported conglomerate (Cc), massive sandstone (Sm), planar cross-stratified sandstone (Sc), trough cross-stratified sandstone (Tc) and horizontally stratified sandstone (Sp); facies association 2 comprising claystone (Ct) and variegated mudstone (M); facies association 3 comprising grey-green shale (Sh) and black shale (Sb). Facies association 1 was deposited in a braided fluvial channel, facies association 2 represents braided fluvial floodplain deposit while facies association 3 suggests estuarineenvironment..The conglomeritic deposits were therefore deposited in a braided fluvial system running over marginal marine deposits.

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