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The Stratigraphic Significances of Lignite Deposits in Parts of Orlu, Southeastern Nigeria

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ABSTRACT

Utilizing Lithofacies, and biostratigraphic approach, formed the basis for the investigation of the lignite deposits of Ogwashi Formation around Orlu area, Southeastern Nigeria. It was expected to provide a more articulated stratigraphic significance, geochronological age and paleogeographic history of the lignite deposits associated with the Formation. Outcrop sections exposed along streams at Ekwe and Ekpe Ezizi were studied. Three Lithofacies comprising Mudstone Facies A, Lignite Facies B, and clayey sand Facies C were identified from field studies. Observed stacking pattern, lithology and palynomorph assemblages indicate continental to parallic conditions. A delta plain to mud flat and overflood bank environment of deposition was suggested for the studied sections. The absence of foraminifera from analysed mudstone samples could depict a non-marine setting. Age determination of the studied lignite and associated sediments was based on the abundant occurrence of some index palynomorphs including *Doulaidites laevigatus, Grimsdalea polygonalis, Monocolpites marginatus Proxapertites cursus* and *Periretipollisspinosus* which are Eocene index marker species. Also supporting this age interpretation are the presence of *Ctenolophonidtes costatus Retimonocolpites spp., Longapertites marginatus, Mauritidites crassiexnius* and *Retibrevitricolporites triangulatus*. The palynofloral assemblage observed in some other samples which supported this Eocene and probably younger age are the occurrences of *Pachydermite sdiederixi, Spirosyncolpites bruni and* the common occurrences of *Scrabratricolpites simpliformis,* abundant occurrences of *Retitriporites heterobrochatti* and *Retitricolporitesirregularis*. The palynomorph assemblages from the study indicate predominance of Phytoclasts and terrestrially derived pollen and spores. This suggests a fresh water swamp forest. The sediments were assigned a upper Eocene to younger ages based on the identified age maker species in the samples. The geologic controls on lignite deposition were related to changes in base level, tectonic movements and global sea level changes. Thus it follows that variations in the thickness and extent of lignite seam in the Tertiary strata of the Ogwashi Formation and elsewhere might be usefully related to the major subdivision (system tracts) of depositional sequences that form the basis for sequence stratigraphy.

Keywords: Lignite, Biostratigraphy, Lithofacies, Palynomorphs, Foraminiferal

INTRODUCTION

Lignite is one of the four fossil fuel resources found in substantial quantities in southeastern Nigeria. The others are sub-bituminous, bituminous coal, oil and natural gas. Lignite is regarded as a low rank coal (immature) (Akande et al., 2007; Ahiarakwem & Opara, 2012). Although Nigeria is blessed with abundant lignite deposits and largest in Africa, only few studies have been carried out on these deposits (Simpson, 1954; Reyment, 1965; Short & Stauble, 1967, Okezie & Onuogu, 1985; Akande et al., 1992, Nwadinigwe, 1992; Ahiarakwem & Opara, 2012., Ofuebe 2015). The Lignite unit under investigation probably falls under the Ogwashi Asaba Formation. The Ogwashi Formation consists of white-pinkish clay, cross bedded sandstones, carbonaceous black shales, lignites and coal. It extends eastwards beyond the River Niger to the east of Calabar and Cameroon frontiers (Okezie & Onuogu, 1985).

The Ogwashi Formation is a boundary Formation which is mappable in the subsurface from the top of the Agbada at its base to the base of the Benin Formation at its top. It does not outcrop, because it is covered by the Benin Formation. Its exposures are only along stream sections and quarries. The Benin Formation is the uppermost unit in the Niger Delta. It consists of the Late Miocene to Recent alluvial and upper coastal plain deposits that are up to 2000 m (6600 feet) thick (Avbovbo, 1978). It overlies the Ogwashi Formation whose topmost unit is regarded as the base of the formation. In the onshore and some coastal regions, the Benin Formation overlies the Agbada Formation.

The source potential of lignites has been reviewed by several workers. Nwadinigwe (1992) studied the wax and resin characteristics of Nigeria's lignites and subbituminous coals and concluded that the lower the coal rank the higher the total amount of wax and resin extracted from it. Goddard et al. (1992) studied the significance of lignites in Paleocene middle Wilcox stratigraphy in East central Lousiana and observed based on chemical analyses, as well as organic and petrographic geochemistry. The lignites are thermally Immature. At adequate thermal maturity, however,, are capable of generating crude oil and can therefore be considered as a good potential source rocks. Ogala (2011) classified the tertiary lignite series in the Ogwashi-Asaba Formation, Southern Nigeria as thermally immature with regards to petroleum generation. Okeke & Umeji (2016) studied the palynofacies, organic thermal maturation and source rock evaluation of Nanka and Ogwashi Formations in updip Niger Delta Basin, SE Nigeria. The study reveals that the Nanka Formation reflects type II/III kerogen typical of gas/oil prone source rock while the palynofacies assemblage is typical of terrestrial and non-marine forms. The present study characterized the lignite deposits around Orlu, Southeastern Nigeria from Lithofacies to biostratigraphic study.

Location and Geology of the Study Area

The study area is located between Latitude 5^{o} 26'N to 05^{o} 50'N and Longitudes 6^{o} 58'E to 07^{o} 39'E (Figure 1). The study area includes the following villages: Ekwe, and Ekpe ezize Ihioma in Orlu.

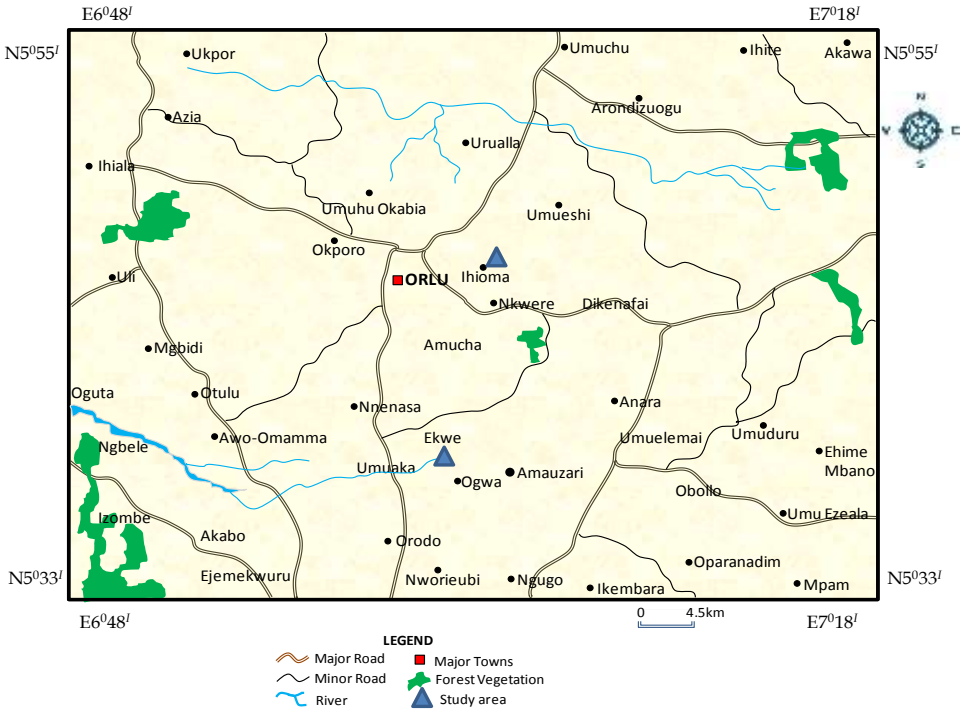

Figure 1: Location map of the study area, showing the sampling points, vegetation and accessibility

Stratigraphic Setting

The stratigraphic history of the Niger Delta started alongside the stratigraphic history of the Southeastern Nigerian sedimentary basins. The Tertiary Niger Delta basin is a sedimentary structure formed as a complex regressive off lap sequence of clastic sediments ranging in thickness from 9000– 12000m. The

basin has been divided into three major facies units based on the dominant environmental influences by Short & Stauble (1967). Three depositional lithofacies are readily identified despite local facies variations, as three regional and diachronous formations ranging from Eocene to Recent. The three major formations from the oldest to youngest are Akata Formation, Agbada Formation and Benin Formation. The basal Akata Formation and the Agbada Formation are only encountered in the subsurface. The contemporaneous outcrop equivalent of the Akata Formation is the Imo Formation; while that of the Agbada Formation is the Ameki Group and the younger overlying Ogwashi-Asaba Formation (Reyment, 1965; Maron, 1969).

Local Geology

The study area is within Ekwe, Ekpe-ezizie Ihioma in Orlu area of Imo State, Southeastern Nigeria. Ekwe, Ekpe-ezizie Ihioma are underlain by the Ogwashi-Asaba Formation (the Lignite Series) which is Upper Eocene in age. The Formation consists of variable sequence of clay, sandstones and thick seams of lignite. The thickness of the lignite seams is more than 6m in some areas (Reyment, 1965). The Ogwasi-Asaba Formation is only known from isolated outcrops and in boreholes (Reyment, 1965). The local geology of the study area is shown in Figure 2.

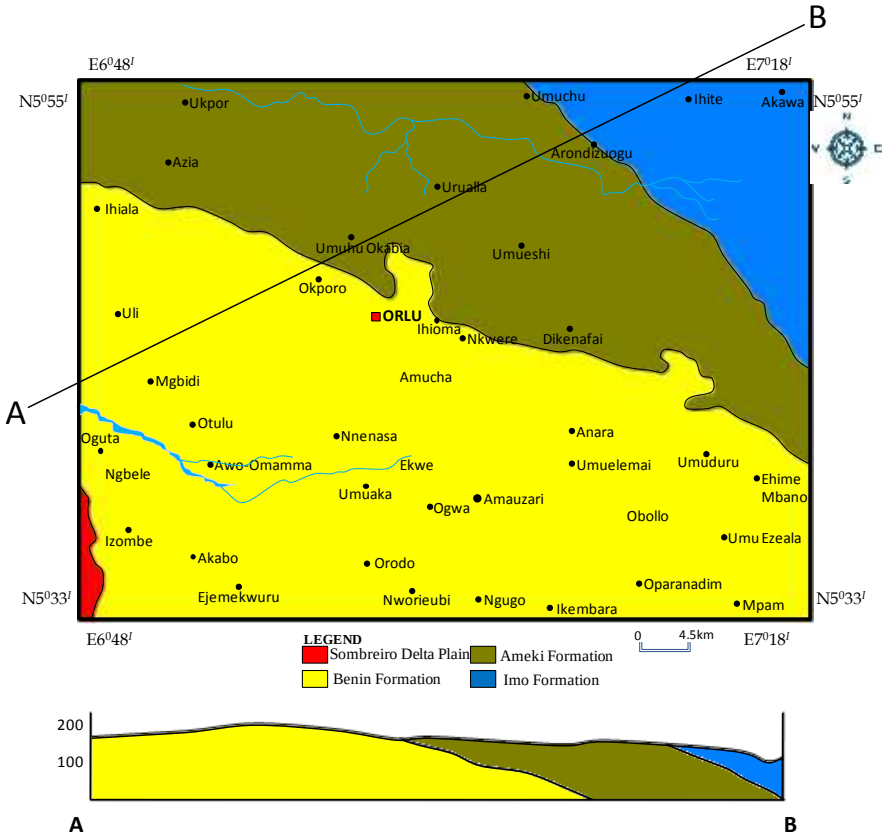

Figure 2: Geologic map of the study area showing cross section

MATERIALS AND METHODS

Field studies

Two outcrops were studied situated at Ekwe and Ihioma. Each outcrop was studied, logged from bottom to top. Each unit was described based on lithology, sedimentary structure, bedding contact and fossil content. The thickness of each unit was noted and measured using a measuring tape. The dip amount and direction of the beds was measured using compass clinometers. Litholog of section was sketched to mimic the grain size and sedimentary structures. Fresh samples of representative rock was collected using

a geologic hammer and appropriately packaged, labelled and sealed using sample bags and masking tapes. Each location was georeferenced using the Global Positioning System (GPS)

Laboratory Analysis

Biostratigraphic Analysis

Foraminiferal and palynological analyses were the two biostratigraphic analysis carried out on the lignite samples. These analysis yielded relative ages of the formation or sedimentary unit and were also useful in the interpretation of depositional environments of the sediments. These samples were subjected to standard paleontological processing procedures as described by Okoro (1995). The Palynological analysis was done by studying the prepared slides under transmitted light from an *Optika* biological microscope which was also used for the photomicrography. The labelled slides were subjected to species identification using relevant published manuals and the palynomorphs were counted and recorded quantitatively as actual counts where necessary. The age interpretation was attempted based on the identified index marker species and palynofloral assemblages using Evamy et al. (1978).

RESULTS AND DISCUSSION

Description of Lithostratigraphic Sections

Lithostratigraphic Description of Outcrop at Ekwe

The location is situated at Latitude N5^{o} 22' and Longitude 6^{o} 59' at an elevation of 137m. The section i**s** along Miri Ekwe, behind Ekwe secondary school. It has a total thickness of about 3.1m (Figure 3). It has a lateral extent of about 10m. The lower part of the section begins with the mottle bedded yellowish brown clay with pinkish stains. This was followed by 0.4m thick, greyish Silty clay. This is overlain by a 0.3m thick dark grey-black lignites (seam one) with fossilized wood branches. It has a sharp contact with the underlying clay unit. The lignite grades into a 0.4m thick silty clay with streaks of lignite and having a gradational contact. The overlying section is a lignite unit (seam two), with a thickness of about 0.3m, dark grey-black in colour with suspected fossilized branches of wood or tree. It is overlain by a 1.1m thick mudstone with suspected fossils. However, it has less abundance of flakes or streaks of lignite. This in turn is overlain by a 0.4m thick of fine grained mottle coloured yellowish brown clay with pinkish stains.

Lithostratigraphic Description of the section in Ekpe Ezize Ihioma

The location is situated at Latitude N5^{o} 41’ and Longitude 7^{o} 02’. The section is exposed at Ekpe Ezize Ihioma(Ihioma gully erosion site). It has an elevation of 360ft. Total logged section is about 3.5m (Figure 3). The lowermost with light grey carbonaceous shale about 1.5m thick. Which is overlain with a 2m thick mottle bedded sandy clay. Spring water was coming out from the contact between the sandy clay and the carbonaceous shale. The section is capped with overlying a lateritic overburden.

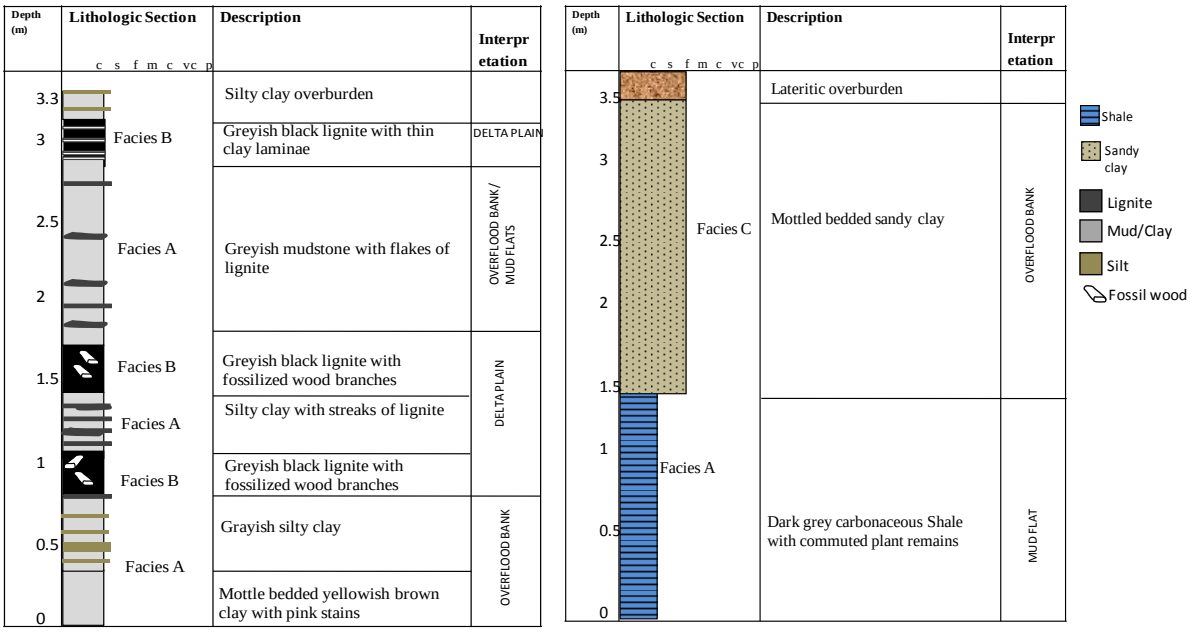

Figure 3: Lithostratigraphic section of outcrops in the study area

Lithofacies Study

Three lithofacies were identified in the studied sections namely:

- Mudstone Facies A
- Lignite Facies B
- Sandy Clay Facies C

Mudstone Facies A

The Facies was recognized in association with the lignite units in all the locations exhibiting a sharp contact with the overlying or underlying lignite seam. At Ekwe, this Facies lacks fissility occurring as pinkish to mottled clay at the base of the section. The lack of fissility or layering in the mudstone may be due to either original texture or the disruption of layering by burrowing organisms in the sediment prior to lithification. Upsection, this facies occur as grayish mudstone with flakes of lignite embedded in it probably suggesting intermittent flooding. This Facies account for more than 70% of all Facies recognized in the section. At Ekpe Ezizi, the Facies occur as highly weathered grayish shale at the base of the section with a thickness of about 1.5m. The Facies lack any form of Bioturbation however, it is highly carbonaceous with recognized wood particles.

Lignite Facies B

This Facies was observed at Ekwe. It occurred as dark grey slightly indurated seams with thickness of <1m. The Facies lies sandwiched between mudstone Facies A in all occurrence. Fossilized wood particles were also recovered from this Facies.

Lignite begins as an accumulation of partially decayed plant material, or peat. Burial by other sediments results in increasing temperature, depending on the local geothermal gradient and tectonic setting, and increasing pressure. This causes compaction of the material and loss of some of the water and volatile matter (primarily methane and carbon dioxide). This process, called coalification, concentrates the carbon content, and thus the heat content, of the material. Deeper burial and the passage of time result in further expulsion of moisture and volatile matter, eventually transforming the material into higher-rank coals such as bituminous and anthracite coal.

Sandy Clay Facies C

This Facies is fine grained and mottled coloured. It occurred only at the section at Ekpe Ezizi. The contact between this Facies and underlying Mudstone Facies B is sharp showing an abrupt transition in energy regime. Diagenetic processes probably accounts for the mottle appearance of this Facies.

Pinkish claystone facies A at Ekwe

Dark grey shale facies A at Ezizi

Dark grey lignite facies B at Ekwe (yellow arrow shows fossilized wood branch)

Lignite seams (1 and 2) at Ekwe

Fine grained Silty sandtone facies C at Ezizi

Figure 4: Described Facies in the study area

Result of Micropalentological Analysis

Foraminifera

All the mudstone samples from the Lignite outcrop subjected to foraminiferal analysis were all barren.

Palynological analysis

Palynological contents of the studied samples showed five types of palynomorphs namely: spores, pollen, fungal spores, freshwater algae, archritarch, including structured and unstructured phytoclasts (wood, cuticles, parenchyma). Table 1 and 2 shows the palynomorphs counts of sediments in the study area while photomicrographs of identified forms are shown in Figure 5. Identification of forms was based on Sratigraphic Committee of Niger Delta (2000).

Table 1: Index Pollen Count in the Study Area

POLLENS/LOCATIONS	L1U1	L1U2	L1U3	L1U4	L1U5	L1U6	L1U7	L2U1	L2U2	Total Count
Doualaidites laevigatus,						2		16		18
Gemmatricolpites spp.,	3	1								4
Grimsdalaepolygonalis,						1				1
Longapertites marginatus,								1		1
Magnastriatites howardi,						2				2
Mauritidites crassiexinus,								1		1
Monocolpites marginatus,		2						1		3
Pachydermites diederixi	,							3		3
Peregrinipollis nigericus,			1					1		2
Perfotricolpites digitatus	.						1			1
Periretipollisspinosus.						1				1
Praedopollis flexibilis,			1							1
Proxapertites cursus,				1			2			3
Psilastephanocolporites laevigatus,		11		102	7	99				219
Psilatricolporites crassus	,			24						24
Retibrevitricolpitestriangulatus,								31		31
Retimonocolpites spp,								1		1
Retitricolporites irregularis,	7	64	300	1	2	17	3	1	1	396
Retitriporites heterobrochatti ,		56				1				57
Scabratriporites simpliformis,						1		9		10
Spirosyncolpites bruni,						4				4
Striamonocolpites rectostriatus	,	1	2							3
Striatricolporites catatumbus		8	1			1		1		11
Verrustephanocolporites complanatus,	9	92	28	2	1					132
Verrutricolporites rotundiporis,			2							2

Table 2: Sporomorph Count in the Study Area

SPOROMORPHS/LOCATIONS	L1U1	L1U2	L1U3	L1U4	L1U5	L1U6	L1U7	L2U1	L2U2	Total Count
Cyathidites spp		2								2
Cingulatisporites spp,							7	1		8
Fusiformisporites spp.				19	1					20
Fungal hyphae			1							1
Fungal spores	3	1	7			11	5	2	1	30
Fusiformisporitescrabbii,				22		9	2	2		35
Magnastriatites horwardi						2				2
Glomus spp.									1	1
Pluricellaesporites spp				1		1				2
Polypodiaceisporites spp.,			1	1				1		3
Polyporisporites spp.,				1						1
Pteri spp							12			12
Psilatriletes spp.								1	1	2
Smooth monolete spore,		270	96	4				6		370
Smooth trilete spore,	12		36					24	1	72
Verrucatosporitesalienus,	9		8			1			1	19

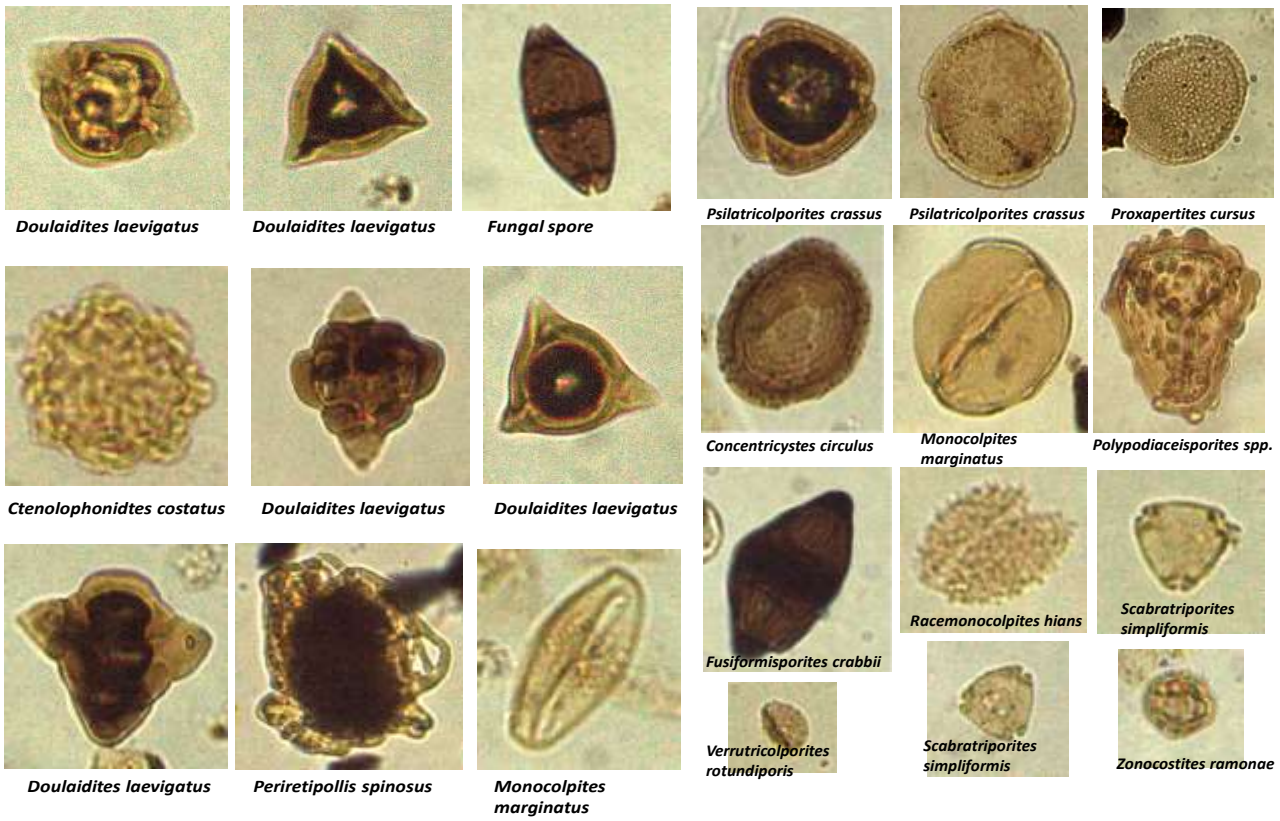

Figure 5: Recognized Palynomorphs in the Studied Samples

Depositional Environment

Five Lithofacies were recognized comprising Mudstone Facies, Lignite Facies, Lignite/Mudstone Facies, Shale Facies and clayey sand Facies. Generally, the lignite seams in the study area is fissile (splits easily) and the colour varies from brown to black. The average thickness of the lignite (as observed in the outcrop at Ekwe) is about 0.3m. It is occasionally interrupted by claystone and mixed claystone-lignite streaks intervals showing sharp to gradational contacts. Observed stacking pattern, lithology and palynomorph assemblages indicates continental to parallic conditions. A delta plain to mud flat and overflood bank environment of deposition has been suggested for the studied sections.

Transgressions and regressions in the Niger delta area during the Paleocene and their associated deltaic depositional systems (Fisher & McGowen, 1967), created favorable conditions for the accumulation of vegetation that formed the lignites. Past studies of the modern Delta Plain (Coleman & Gagliano, 1964), together with more recent investigations (Penland et al., 1991), have been very helpful in understanding the cyclic depositional framework observed in the Paleocene Ogwashi Formation.

The cyclic repetition of lignites is the characteristic of the Ogwashi formation and is the result of relative sea level fluctuations caused by rates of subsidence, type of depositional facies, quantity of sediment supplied to the area, and global influences. Controls on lignite distribution in the Paleocene Ogwashi formation are considered to be similar to controls on cyclic Upper Cretaceous coals of the Mamu formation (Ryer, 1981; Levey, 1985). In the study area, the upper surfaces of the lignites on top of the vertically stacked aggradational deposits of the lower delta plain represent marine flooding surfaces or parasequence boundaries. The lignites are almost always overlain by transgressive shales that may indicate either the occurrence of sea level rises or the dominance of basin and/or compactional subsidence. It is difficult to ascertain which of the processes prevailed, and likely at some time all were acting simultaneously. Evidence for more pronounced sea level variations would support fluctuations of sea level positions during specific time intervals, thus providing data for a refined sea-level curve for the Paleocene Ogwashi formation (Echols & Goddard, 1992). In addition, peat accumulations resulting in lignites, appear to represent only minor hiatuses between underlying aggradational distributary channel/overbank bayfill sands and overlying interdistributary bay/marine shales.

The non-occurrence of foraminifera from the two sample locations depicts a Non-marine setting. This inference is affirmed by the non-occurrence of marine-indicator palynomorphs such as dinoflagellate cysts, or foraminiferal lining. Acritarchs were minor occurrence. Identified algae were of fresh water affinity.

Age and Stratigraphic Significance of Lignite

Age determination of the studied lignite and associated sediments was based on the abundant occurrence of some index palynomorphs including *Doulaidites laevigatus, Grimsdalea polygonalis, Monocolpites marginatu,s Proxapertites cursus* and *Periretipollisspinosus* which are Eocene index marker species. Also supporting this age interpretation are the presence of *Ctenolophonidtes costatus Retimonocolpites spp., Longapertites marginatus, Mauritidites crassiexnius* and *Retibrevitricolporites triangulates* (Gemeraad et al., 1968).

The palynofloral assemblage observed in some other samples which supported this Eocene and probably younger age are the occurrences of *Pachydermite sdiederixi, Spirosyncolpites bruni and* the common occurrences of *Scrabratricolpites simpliformis,* abundant occurrences of *Retitriporites heterobrochatti* and *Retitricolporitesirregularis* The presence of *Psilatricolporites crassus, Striatricolporites catatumbus, Polypodiaceoisporites spp., Bombacacidites spp., Verrustephanocolporites complanatus.* However, this age interpretation was made probable because of the non occurrence of any index marker species. The palynomorphs were all long ranging from Eocene to Miocene and also due to the location of the samples, Eocene was inferred (Jansonius & Kalgutkar, 2000; Jarzaen & Elsik, 1986).

The stratigraphy of the entire Ogwashi formation in Niger delta basin has been described as consisting of sands, shales, and lignites seam of Pliocene-Eocene age deposited on top of the Paleocene Ameki Group. The geologic controls on lignite deposition were related to changes in base level, tectonic movements and global sea level changes. Tectonism and Eustasy taken together and along with changes in sediment

supply and sediment compaction, manifest themselves in the sedimentary record as relative changes in sea level (Coe, 2002.)

Thus it follows that variations in the thickness and extent of lignite seam in the Tertiary strata of the Ogwashi formation and elsewhere might be usefully related to the major subdivision (system tracts) of depositional sequences that form the basis for sequence stratigraphy (Evamy et al., 1978).

As with Cretaceous coals described by Levey (1985), the major occurrence of these Upper Paleocene lignìtes is associated with vertically stacked progradational events deposited during transgressive and regressive maxima.

CONCLUSION

The study utilized an integrated Lithofacies study and biostratigraphic tools to study the outcropping sections belonging to the Ogwashi Formation. From Lithofacies description including stacking pattern, a delta plain to mudflat and overflood bank environment was inferred. The absence of foraminifera in the analysed mudstone sample suggests a non-marine environment. The samples showed a rich abundance and diversity of palynomorphs dominated by pollen and spores. Identified index marker palynomorphs suggest age range of Eocene to Miocene.

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