Research Article

Palynostratigraphy of Early Cretaceous Sedimentary Deposits from the Rio del Rey Basin, S.W. Cameroon.

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Abstract

A Mid Albian-Cenomanian age has been assigned to the outcrop section along River Mesambi in the northeastern part of the Rio del Rey Basin on the basis of a palynofloral assemblage that include amongst others: *Ephedripites jansonii, E. montanaensis, E. subtilis, Steevesipollenites giganteus and S. binodosus*. This assemblage is comparable with previously established Early Cretaceous microflora from elsewhere. The total recovery is poor to only fair and could not be subjected to normal rigorous statistical analysis. Inference of the paleoenvironment of deposition was aided by the observed lithofacies. Important hydrocarbon source rocks have been described only from the Tertiary offshore portion of this basin. Recent discovery of oil and gas in some age equivalent onshore sediments in other West African Marginal basins; northern part of the Tano Basin in Ghana and Anambra Basin in Nigeria respectively has initiated investigations of the Cretaceous black shales onshore of the Rio del Rey Basin in Cameroon. Outcrops are generally very scarce however River Mesambi has unusually exposed a 32m sequence of dark gray to black, highly indurated shales, intercalated in places by thin limestone beds. The present study will contribute to the biostratigraphic data absolutely required towards the build up of the Cretaceous lithostratigraphy and the search for hydrocarbon in the Rio del Rey Basin.

Keywords: Assemblage, Early Cretaceous, Paleodepositional environment, Palynoflora, Rio del Rey.

Resumè

Sur la base d'un assemblage de palynoflore qui inclu entre autres: *Ephedripites jansonii, E. montanaensis, E. subtilis, Steevesipollenites giganteus* and *S. binodosus*, l'age Albien moyen à Cenomanien a eté attribué à l'affleurement situé le long de la riviére Mesambi au nord-est du Bassin du Rio del Rey. Ce type d'assemblage de microflore a anterieurement eté utilisé ailleur pour determiner l'age du Cretacé inférieur. L'essemble de microflore trouvé est faible et ne peut permettre d'etablir des statistiques fiables. Le paleoenvironment de depot a eté reconstruit par l'observation de lithofacies. D'importante roche mer d'hydrocarbure ont eté décrites seulement du coté offshore tertiare de ce bassin. Les decourvertes récentes de petrole et de gaz dans les sediments onshore de meme age dans certains bassins côtier de l'Afrique de l'Ouest tel que la partie nord du Bassin de Tano au Ghana et le Bassin Ananbra au Nigeria nous a motivé à faire les etudes sur les argiles noire Cretaces du côté onshore du Bassin de Rio del Rey au Cameroon. Generalement, les affleurements sont rares, neamoin, la riviere Mesambi a exposeé 32m de hauteur d'une sequence d'argiles gris-noires très dures et intercalés par les calcares peu-épais. La presente etude contribuera à l'acquisition des données biostratigraphiques necessaries pour la construction de la lithistratigrphie de la Crétacé et à la recherche d'hydrocarbure dans le Bassin de Rio del Rey.

Mots Clé: Assemblage, Crétacé inferieur, paleoenvironment de depot, palynoflore, Rio del Rey.

INTRODUCTION.

The Rio del Rey Basin (Belmonte, 1966 and Dumort, 1968, Reijers, 1996, Njoh and Petters, 2008) is one of the two Atlantic coastal basins lining the coast of Cameroon (Fig. 1) and 1a). It covers the extreme southwestern region of the country adjoining both the Niger Delta and the Calabar Flank basins in Nigeria while the Cameroon Volcanic Line delimits it from the Douala Basin to the east. It is part of the northern extension of a series of continental marginal sag basins seen along the Southern Atlantic coast of Africa (Gulf of Guinea) from Angola through Congo, Gabon and Cameroon to Nigeria (Fig. 2).

A veneer of Cretaceous sediments occur and outcrop as continuous deposits from the Douala and Rio del Rey Basins in Cameroon to the east of the study area, through the Calabar Flank, Afikpo Syncline and the Anambra Basin in Nigeria to the west. The Rio del Rey Basin has both off- and onshore portions. Cretaceous sediments are exposed onshore while the Tertiary occurs and overlies the Cretaceous offshore. The offshore portion of this basin is contemporaneous with, and forms the upper eastern flank of the Niger Delta that extends into Cameroon. The Rio del Rey Basin is very petroliferous and as such it has attracted several studies by multinational petroleum companies, unfortunately, results from such studies are restricted and classified. The studies have focused on the Tertiary productive interval while the Cretaceous sediments have hitherto not been studied, reason why the Rio del Rey Basin is erroneously thought of as entirely Tertiary in age. Except for a few synoptic notes (Reyment, 1965; Belmonte, 1966; Dumort, 1968; Regnoult, 1986 and Njoh and Petters, 2008), very little geologic information has been published on the Cretaceous units of this basin. Apart from the concerns above, there is also a general paucity of sedimentary outcrops in this typical Tropical Equatorial Rain Forest characterized by mangrove swamps and thick overburden that resulted from rapid weathering. The outcrop on which this work is focused occurs on the downstream, left hand side of the Mesambi River with a height of 32m and so it is very significant as it has exposed an exceptionally thick sequence of black to dark-grey shales that are very indurated, sometimes calcareous and intercalated in places by thin limestone beds. Several outcrops were encountered and studied but the section on which this work is focused is seen to be most representative.

Oil and gas has recently been discovered and plans to drill are on the way in Aptian/Albian sediments in the north Tano concession onshore the Tano Basin in Ghana. The search for oil and gas is also in progress in the onshore Cretaceous Anambra Basin of Nigeria. These two basins and the Rio del Rey Basin are all West African marine basins with a common regional geologic evolution that is linked to the opening of the South Atlantic and the formation of the Gulf of Guinea. Although each has been developed under different local tectonic controls, the present study is aimed at investigating the Cretaceous black shales onshore of the Rio del Rey Basin. The present work has for the first time identified and dated these sediments which though, very marginal in character, are thought to be the result of the first marine transgression in the basin. The work will contribute to the build up of the biostratigraphic data and the erection of a viable lithostratigraphy for the Cretaceous sedimentary pile in the basin which does not exist as yet.

Belmonte (1966), used the name Rio del Rey Basin for the first time while outlining the sequence of Tertiary sediments offshore of this basin and noted that Recent deltaic sands are widespread on the onshore. The first Geologic map of the region (Carte Geologique du Douala Ouest) was established by Dumort, 1968. Reyment (1965) had earlier described some Cretaceous sediments from a locality Kita which is now included in recent maps of this area. Njoh (2007) and Njoh and Petters (2008) established two Upper Cretaceous units which have not been named; the Turonian-Coniacian and Campanian-Maastrichtian, based on foraminifera microfossils recovered from outcrops samples in the basin.

Synthesis from studies of Deep Sea Drilling Project sites and from continental marginal basins have shown that the Cretaceous sea level history of the South Atlantic had several episodes of eustatic transgressions that occurred during the Mid-Late Albian, Late Cenomanian, Late Turonian-Coniacian, and Campanian-Maastrichtian (Reyment, 1980; Kogbe, 1976; Nyong and Ramanathan, 1985; Ramanathan and Fayose, 1990) These authors have established these major transgressive episodes in the Benue Trough and the neighboring Calabar Flank.

GEOLOGIC SETTING

The Rio del Rey Basin is one of the Equatorial Atlantic Marginal Basins found along the coast of Cameroon, in West Africa, Gulf of Guinea. The tectonic and stratigraphic development of this basin is closely related to the rifting of the Gondwanaland, the opening of the South Atlantic and the separation of South America from the African continent. It occupies the extreme southwestern portion of Cameroon, on- and offshore, extending westwards into the Niger Delta of Nigeria. The Rio del Rey Basin is sometimes described as the eastward extension of the Niger Delta. However, the

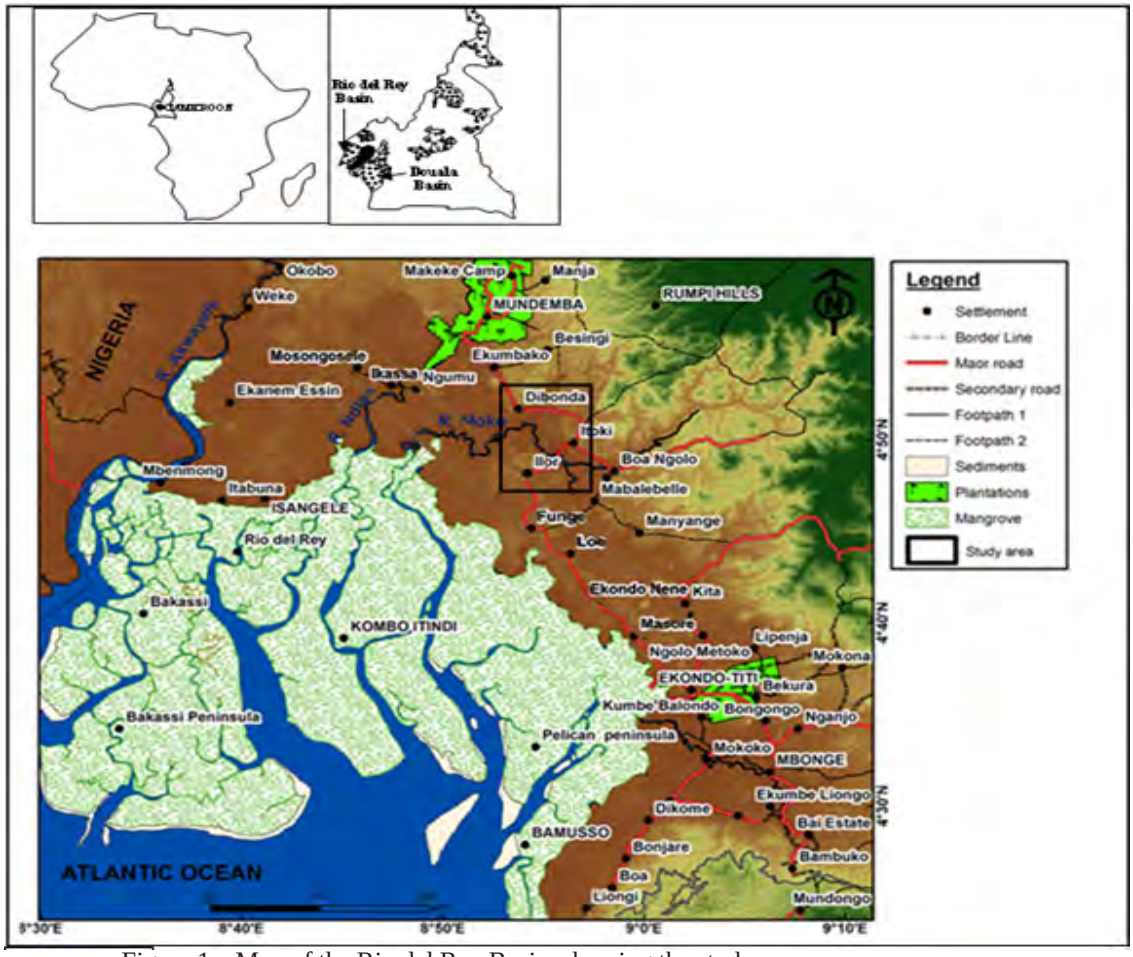


Figure 1a: Map of the Rio del Rey Basin, showing the study area.

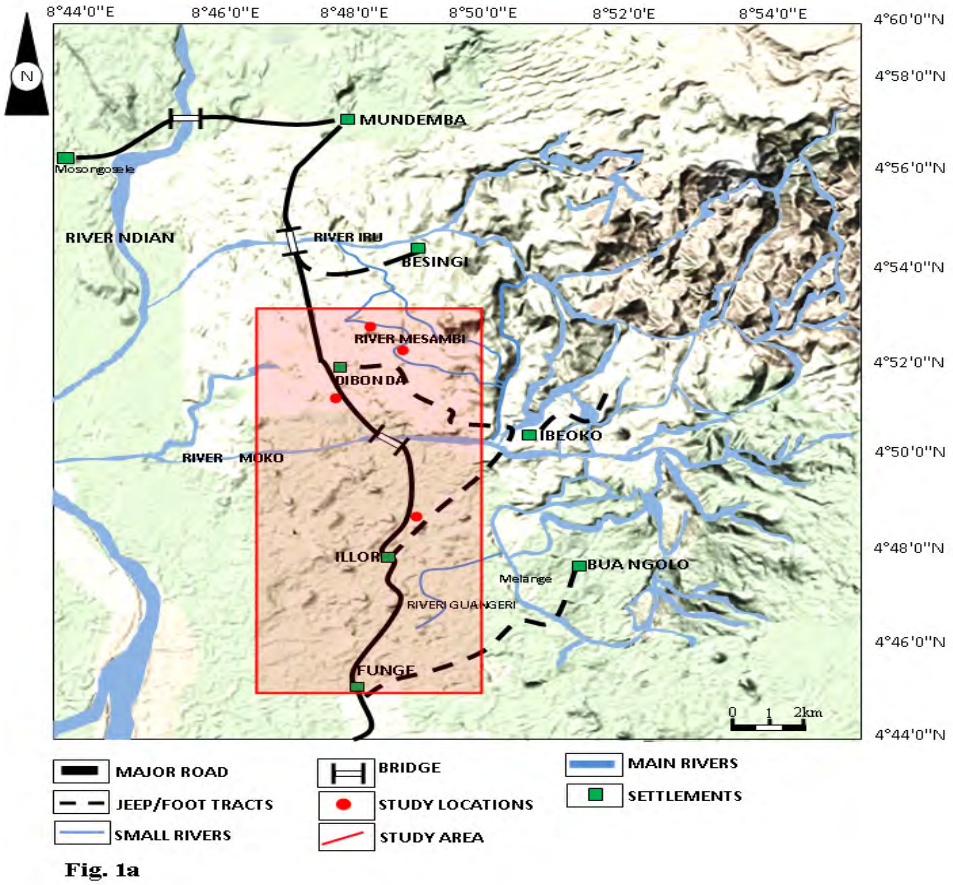


Fig. 1a

Figure 1b: Map of the northeastern part of the Rio del Rey Basin showing the area of study and sample locations.

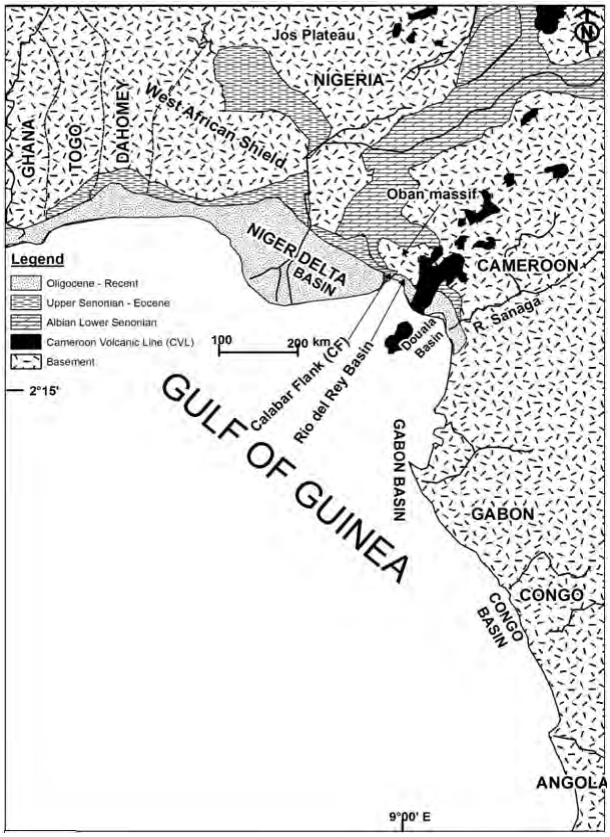


Figure 2: Regional geologic map of the Gulf of Guinea, showing the Rio del Rey Basin among other basins . Modified from Murat, 1972.

Cretaceous sediments that crop out along its northern flanks are seen to be an eastern continuation of the Calabar Flank which itself defines the eastern limits of the Benue Trough. The Tertiary sediments occupy the marginal coastal and ocean-ward portion of the basin.

The basin has accumulated well over 6000m thick of marine and non-marine clastic sediments ranging from Neocomian to Recent. Sedimentation in the basin started with the Cretaceous and the sequences were related to sedimentation in the Benue Trough and other basins of southeastern Nigeria and the Douala Basin (Nair *et al.*, 1981; Reijers and Petters, 1987; Nguene *et al.*, 1992; Petters *et al.*, 1995; Nwajide and Reijers, 1996; Njoh and Nkeme, 2008; Njoh *et al.*, 2010). Tertiary sedimentation preceeded with major progradational pulses with the upper deltaic deposits advancing over the parallic delta front and the later in turn gets over the distal offshore pro-delta which also advanced (Reijers, 1996).

The stratigraphy of the basin is still very incomplete particularly as the Cretaceous sequences have not been studied in detail. However, overlying the basement is the so called "*Gres des Base*" (basal sandstone) unit of Neocomian-Albian continental, fluvio-lacustrine sandstones and conglomerates. The name "Bafaka Sandstones" is an informal name used only for the purpose of this work. This unit was distinguished from the overlying Albian-Maastrichtian? sediments (Dumort, 1968). Njoh and Petters, 2008, dated Upper Cretaceous sediments in this basin in which Turonian-Coniacian and Campanian-Maastrichtian sedimentary units were recognized and the name Kita Shales has equally been adopted as an informal name. The Paleocene-Eocene to Recent Isongo Formation is a pro-deltaic marine shale unit overlying the Cretaceous and is overlain by the Oligocene-Miocene to Recent alternating sands and shale unit, the parallic Agbada Formation. The Pliocene-Recent Benin Sandstone Formation is the uppermost unit made of continental to coastal plain sandstones in this basin (Fig. 3).

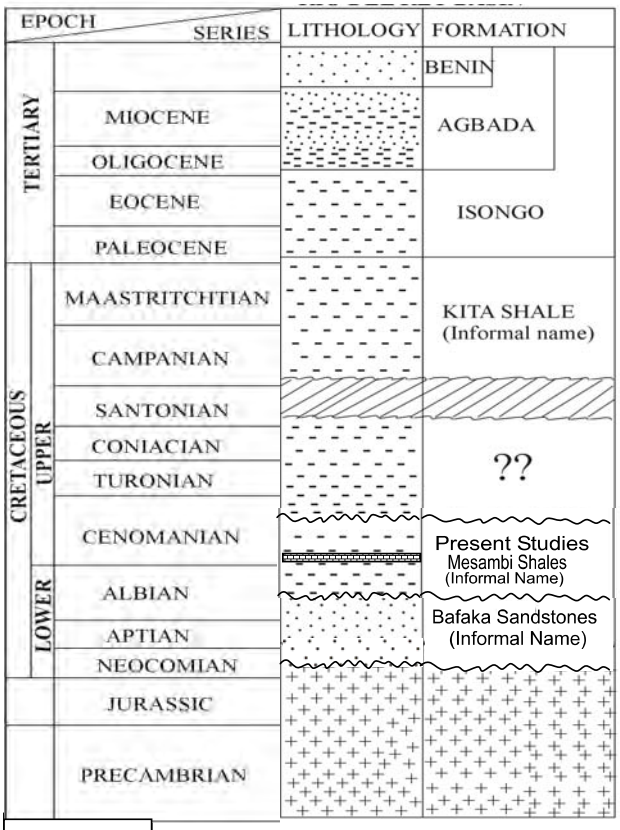


Figure 3

Lithostratigraphy of the Rio del Rey Basin, showing both the named and unnamed Units. Adopted from Njoh and Petters, 2008.

MATERIALS AND METHODS

Standard procedures for outcrop description were used guided by the approach employed in the oil industry (Reijers, 1996). The palynological laboratory technique for digesting sediments using hydrochloric acid (HCl) and Hydrofluoric acid (HF) as outlined by Traverse,

1988; Fægri and Iversen, 1992; Jansonius and McGregor, 1996; Wood *et al.*, 1997 and Oboh-ikuenebe, 2005, were followed.

Outcrops in this region are generally described as very scarce, highly weathered and small. As such, the section under study is exceptionally prominent and most representative. Although the outcrop was densely forested, with a thick overburden, it was first observed in its natural state. It was thereafter cleaned up and the weathered surfaces dug to expose relatively fresh sediments. During its logging, particular note was taken of the various rock types, bed thicknesses, sedimentary structures and mega-fossils. The spot sampling method was used and samples collected from bottom to top.

Each sample collected was placed in a well labelled sample bag. Because the principal aim of this study was to date this outcrop section and infer a depositional environment, ten (10) samples were selectively collected, dried, and 50g each weighed and processed for their palynological content. Standard palynological laboratory techniques for digesting sediments involved the use of hydrochloric acid (HCl), hydrofluoric acid (HF), followed by centrifuging and the use of Zinc bromide (ZnBr) with specific gravity 2.2. The samples were thereafter oxidized using conc. Nitric acid (HNO3) for a short while before neutralizing with Potassium Hydroxide (KOH). After thoroughly washing with distilled water, the residues were preserved by adding a drop of glycerin to each of well-labelled phials.

The samples were then placed on slides and examined under a Zeiss Photomicroscope with a standard stage and at 400X magnification. Photomicrographs were taken with a digital camera attached to the microscope.

RESULTS

Lithologic description

The outcrop, Messambi downstream, is located about 7km NE of Dibonda village. A steep and long descend along a hunting track reaches River Messambi and the outcrop is about 600m on the left bank downstream.

From the river bed, the outcrop (Fig. 4) measures up to 32m to the top along a spring channel that runs downhill. The exposure is composed of dark-grey to black well laminated calcareous shales which are highly indurated and occasionally intercalated by thin limestone beds. Fissility is well exhibited while some intervals show ripples and unidentifiable macro-fossils probably bivalves, with moulds seen in places (Fig. 5, photo. 7-8). Bedding planes are generally sharp and dipping at an angle of 18° to the SW.

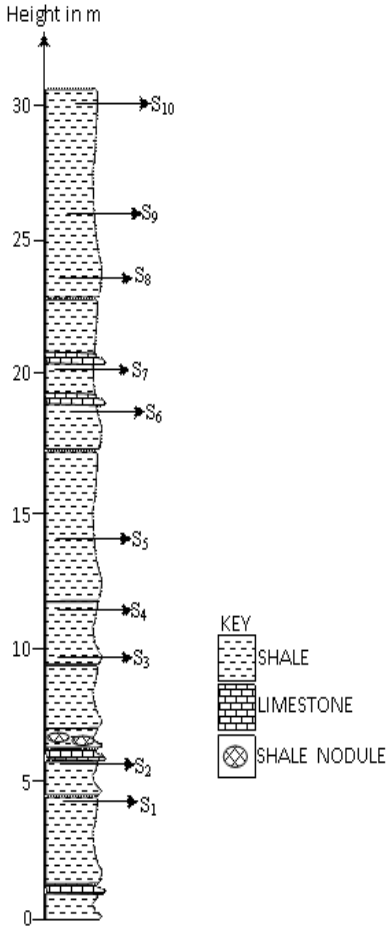


FIGURE 4

Log section of the outcrop at the Messambi downstream, showing sample Intervals.

The base of this outcrop is on the river bed, the shale beds here are dark in colour and two limestone beds occur at the interval between 5 and 6m, freshly chipped samples show that they are generally whitish in color and vary between 15 and 22cm in thickness. Limestone beds are again encountered between 18 and 22m. A thinly laminated shale bed, black in colour indurated and calcareous, is continuous from 7m to 18m interval. Wave ripples could be seen on the upper part of this interval together with macro-fossils. Above 22m towards the top, is another black shale that is interbeded by a limestone. The upper part of the outcrop is covered by boulders of columnar basalts and regolith (Fig. 4).

The topography of this part of the basin is generally hilly, in sharp contrast with the rest of the basin that is flat and marshy. These hills are thought to be the result of post depositional folding of the Cretaceous sediments. This particular outcrop occurs on one side of a deeply incised river valley downstream away from a waterfall. Plugs of columnar basalts are very regular features that intrude the sediments with scattered boulders in some places (Fig. 5).

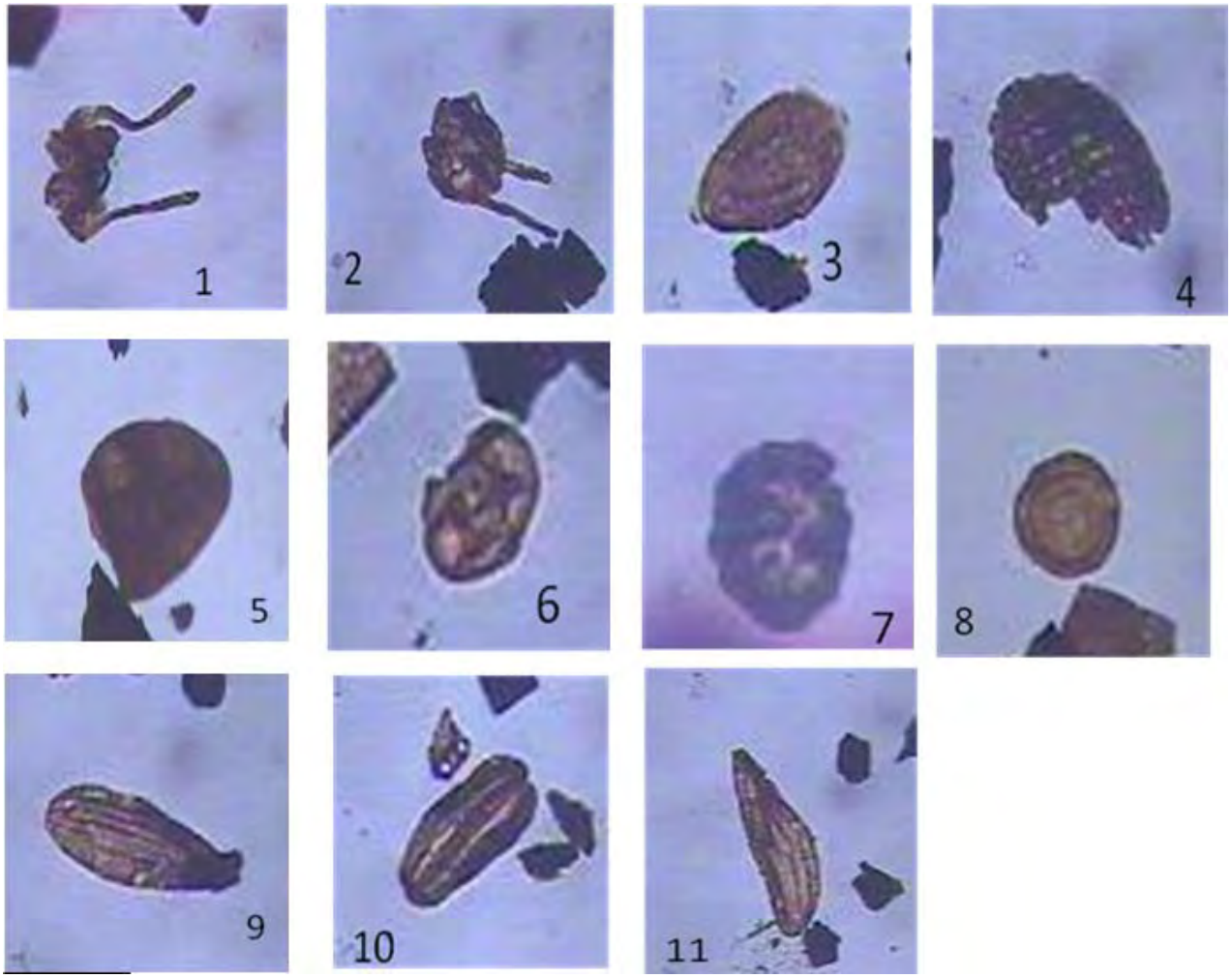
FIGURE 5 Photographs; (1-6) composite sequence of sections of the outcrop under study, from Base to upper part. 7-8) Embedded macrofossils and moulds, probably bivalves.

Palynological Analysis.

Samples collected from this outcrop, have proven to be palynogically rich though the preservation of the palynomorphs is only poor to fair. The palynoflora include a high percentage of the miospores that include the gymnosperm and angiosperm pollen grains and only a small percentage of dinoflagellates that is composed of spiniferates and dinogmnoid cysts. It also comprises a few fungi cysts, organic lining of foraminifera, structured and unstructured phytoclasts.

Twenty one biofacies were identified excluding the rest of the organic debris that were generally considerable in quantity and were noted to be the same in all ten samples. Of these, 18 were palynoflora from which 12 were identified down to species level while the rest could only be identified to the genus. Most of the palynomorphs recovered are long ranging and only a few diagnostic forms are included in this assemblage, and it is on this basis that the age of the sedimentary outcrop was assigned. The diagnostic taxa are principally species of the two genera, the *Ephedripites* and *Steevesipollenites which include; Ephedripites jansonii, E. montanaensis, E. subtilis, Steevesipollenites giganteus, S. binodosus,* and *Elateroplicites africaensis* (Plate 1).

Due to the poor to fair state of the preservation of



(Plate 1). Photomicrographs of some diagnostic palynomorph taxa based on which the outcrop was dated

the palynomorphs as also seen in the low counts recovered, a simplified scheme that is adapted to this low recovery was employed and as such, the normal rigorous statistical analysis was not applied The entire recovery was divided into the following palynomorphs and dispersed organic matter groups: pollen and spores, fungi spores, marine palynomorphs (dinoflagellates and microforaminiferal inner linings), structured phytoclasts (wood and cuticles) and unstructured phytoclasts (resins and degraded fragments) and described below on Table 1.

Simple numerical counts and percentage distribution

Table 1: Description of palynomorph groups and dispersed organic matter identified .

Palynomorphs/Organic debris	**Description**
Sporomorphs	These include the embryonic pollen and spores that most probably have been derived from original land plants.
Marine palynomorphs/Organic walled microfossils	Among these are the chitinous inner lining of foraminifera and dinoflagellate cysts.
Fungal derivatives	These are fungal spores which are dark brown in color, filamentous hyphae and mycelia of fungal origin.
Structured phytclasts	Structured remains of land plants which may include woody particles and cuticle fragments.
Unstructured phytoclasts	These are highly degraded remains of plants that no longer possess any structure and the colors generally range from yellow to dark and brown

of these groups were made (Table 2) with the aim of achieving some basic useful statistical basis for recognizing any palynofacies. Both structured and unstructured phytoclasts were not considered here since they appeared monotonous in all the 10 samples.

TABLE 2

Sample number	Height/ m	Sporomorphs/ 100	Fungi/ 100	Marine Palynomorphs /100
10	30	100	0	0
9	26	95.8	0	4.2
8	23	94.9	3.8	1.3
7	20	60	40	0
6	18	100	0	0
5	14	93.5	2.6	3.9
4	12	95.3	4.7	0
3	9.5	98.5	1.5	0
2	6.5	93.9	6..1	0
1	4	98.7	0	1.3

The sporomorphs clearly pre-dominate the entire assemblage. Although they were not counted and so not included in this basic statistic, the dispersed organic debris (phytoclasts) were next in quantity to the sporomorphs. The marine palynomorphs on the other hand were not generally skewed to any particular segment of the section studied. Thus the entire assemblage could not be distinguished into separate palynofacies, rather it seemed proper to group it into one.

INTERPRETATION AND DISCUSSION

Age assignment

The utility of palynomorphs have demonstrated that they are valuable stratigraphic markers both in continental, marginal and marine settings as well as in correlating non-marine and marine strata. The palynomorphs assemblage recovered from these sediments show a high percentage for the miospores (gymnosperms and angiosperms). The gymnosperm pollens such as the Classopollis and Cycadopites that occur in this assemblage are known from plants that had flourished during the late Triassic to the Cretaceous period, Moustafa and Lashin (2012) and Sinanoglu (1984). The marker species included in this assemblage are: *Ephedripites jansonii, E. montanaensis, E. subtilis, Steevesipollenites giganteus, S. binodosus* and *Elateroplicites africaensis* (Fig. 6). The common species of the Ephedripites and Steevesipollenites genera form part of the palynofloral plexus used by Herngreen *et al.* (1996), to define the Albian-Cenomanian Elaterates African-South American (ASA) Province. The presence of the species *Elateroplicites africaensis* in this assemblage supports this interpretation. This species belongs to the elater-bearing taxa which is restricted in the Elaterate Province. The first Elaterates, Elateropollenites occurred in the Early Albian together with *Ephedripites irregularis*, while the first Elaterocolpites, Elateroplicites and Elaterosporites are approximately Middle Albian. The occurrence of the taxa of the latter without species of Elateropollenites may therefore infer an age not older than Mid-Albian for this section of the outcrop. While dating Cretaceous sediments from the Ocean Drilling Program, Leg 159 on the Cote D'Ivoire-Ghana marginal ridge, Eastern Equatorial Atlantic Moullade et al., (1998) supported the Late Albian-Earliest Cenomanian age assigned to Unit III at Site 962 and Unit V at Sites 959 and 960 based on the co-occurrence of species of the genera Triorites and Classopollis. Brenner (1976), introduced the concept of Berremian-Cenomanian floral provinces, the Northern Gondwana Province (NGP) which circumscribed Africa and South America was defined by an assemblage in which *Cycadopsites* and *Ephedripites* are important elements. In Sinanoglu (1984), Ephedripites were very common and diversified in the lowest Creataceous floral assemblage in Peru, Brazil, West Africa and Israel.

The palynofloral assemblage recovered in this study undoubtedly confirms a Lower Creataceous age most probably, Mid Albian- Cenomanian depositional period for the outcrop Messambi downstream in this northwestern part of the Rio del Rey Basin.

Paleodepositional environment.

The lithofacies interpretation here forms the primary tool for recognizing the depositional conditions under which these Mid Albian- Cenomanian sediments where deposited in this part of the basin. The lone palynofacies determined above from simple visual observation (Tables 1 and 2) has been used only as a secondary tool because the entire palynofloral assemblage is poor to fair and so the data did not permit any detail statistical processing. The sediments in most depositional settings will receive dispersed organic matter which might have been transported as clasts (phytoclasts) or produced in situ (Oboh-Ikuenebe et al. 2005). The dispersed matter and sporomorphs (Table 1) most probably have been transported from the continent into a near shore marine setting by run-offs. Their abundance however, is generally expected to decrease seaward (Traverse, 1984). On the other hand, marine palynomorphs could also be carried onshore by storms into very marginal or brackish environments like lagoons and estuaries but will not go as far as fluvial environments.

In this study, the low percentage of the marine palynomorphs is indicative of minor marine influence while the high percentages of the sporomorphs (Tables

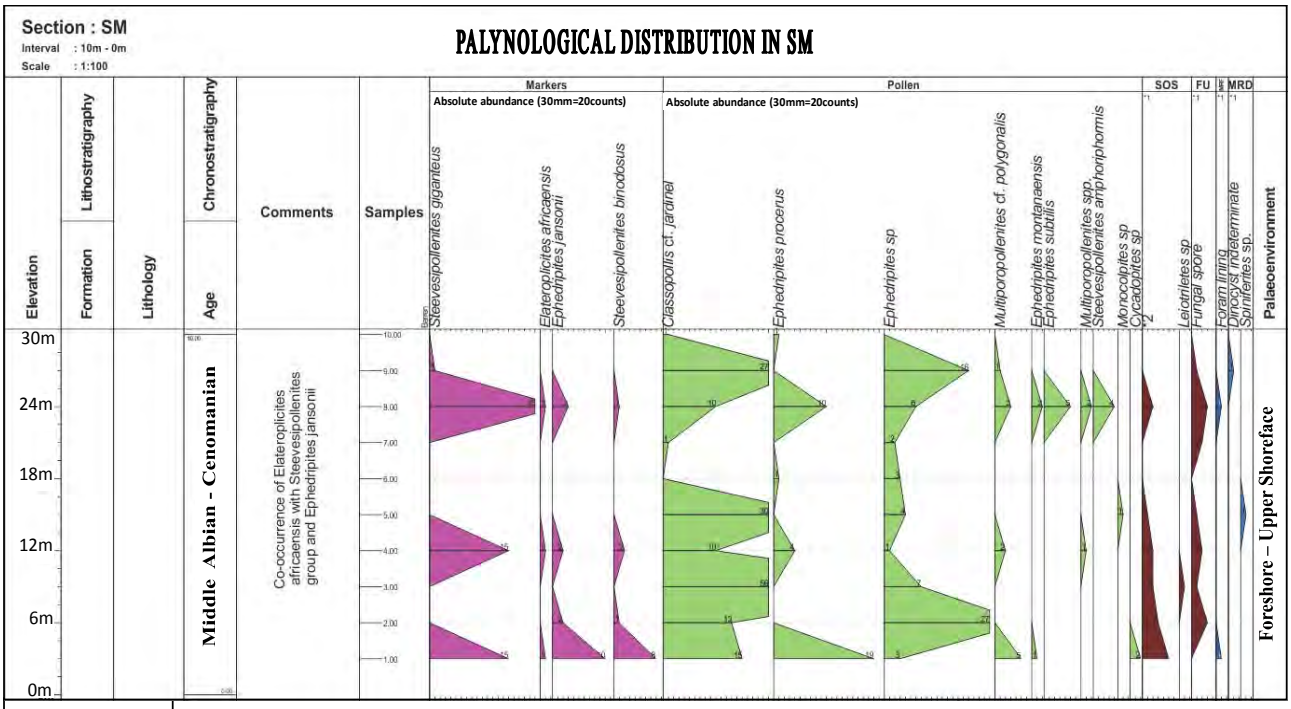


FIGURE 6 **Figure 6**: Biostratigraphic Chart of the studied section

1 and 2) equally signify stronger continental influence. It is on the basis of this assumption that this palynofacies and the lithofacies of the section under study can be intergrated to infer the depositional environments.

This sedimentary exposure can be divided into four portions (two of which are dark-grey shales intercalated by limestone beds, that is, the intervals 0 to 6m and 18 to 22m) and two of which comprise of black organic rich shales (the intervals between 6 and 18m and that from 22m and above). If the dark-grey to black shales and limestones are two lithofacies, the shales with high organic content must have been deposited under conditions of bottom anoxia, probably resulting from bottom water stagnation due to poor circulation or density stratification caused by high influx of terrugenous matter. The presence of original, thin laminations also indicate the absence of bioturbations by benthonic mud filters. The limestone beds on the other hand must have been deposited in a shallow, clear, warm and open marine setting in which there was a bloom of calcareous marine organisms.

Where the alternations of black shales and limestones were observed may point to a periodic sea level fluctuation thus shallowing and creating marginal but low energy inner neritic environments into which the shales were deposited and deepening, thus creating a shallow marine environment in which the limestones where deposited. The indication of both continental and marine influence as shown by the presence of high percentages of the pollen grains and equally high amounts of dispersed organic matter together with marine palynormorphs in these sediments, points to a shallow to marginal marine depositional setting. Therefore, the sediments studied here most probably have been deposited during the first marine incursion into the Equatorial Africa, during the opening of the South Atlantic.

CONCLUSION

The samples of sedimentary rocks collected and analyzed from the outcrop section "Messambi downstream" have proven to be palynologically productive. Although, the entire palynofloral assemblage recovered was only poor to fair both in abundance and diversity, some diagnostic species were present. These species have provided the basis on which the present study has not only re-iterated the occurrence of Cretaceous sediments in this area of the Rio del Rey Basin, but have been used to identify and assign a Mid Albian-Early Cenomanian age to the sediments. The entire assemblage showed high percentages of the pollen grains and high amounts of dispersed organic matter which were probably derived from continental sources and their occurrence with low percentages of marine palynomorphs is indicative of a very shallow marine depositional environment.

From the analysis, the samples are characterised by sparse palynofloral which have for the first time been used to date the sediments as being of Mid-Albian -Early Cenomanian age. Furthermore, the percentage of the marine indicators was less than 20% implying that these

samples could have been deposited in an upper shoreface. Thus the environment can be interpreted as from a foreshore to an upper shore face environment which falls within the inner neritic paleo - depth.
The history of the various episodes of transgressions in the South Atlantic is recorded in the sedimentary rocks along the West African coast, Gulf of Guinea. The earliest transgression occurred during the Mid Albian-Early Cenomanian (Reyment and Morner, 1977; Reyment, 1980; Kogbe, 1976; Nyong and Ramanathan, 1985; Ramanathan and Fayose, 1990).

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