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Fossils Dinoflagellates from the Northern Border of the Douala Sedimentary Sub-Basin (South-West Cameroon): Age Assessment and Paleoecological Interpretations

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Abstract The deposits of the Douala sub-basin stand among the Gulf of guinea best-studies series. In spite of continuous oil prospecting production in the area, there is still a paucity of published information and data on the palynology of the Douala sub-basin. This study aimed at reconstructing the palaeoenvironments from dinoflagellates cysts identified in surface samples collected among deposits of the Nkappa formation. Ten surface samples from three different localities (Miang, Fiko and Bwapaki) were collected, studied and analyzed for their lithological and palynological contents. This essentially comprised the field description of lithological and textural characteristics of facies. The laboratory work was based on treatment and extraction of dinoflagellates cysts from shales samples selected for the study, using the standard palynological method applied in the laboratory of micropaleontology of PETROCI (Ivory Coast). Hence, four lithological units were delineated made up of dark to grayish shales, fine, medium and coarse sandstones. A total of sixteen dinoflagellates cysts were recovered and identified from the samples. They all belong to the class Dinophyceae but are subdivided into four families (Gonyaulacaceae, Peridiniaceae, Areoligeraceae and Protoperidiniaceae). The dominant dinocysts grains are those of Areoligera sp, glaphyrocysta sp, Paleocystodinium golzowense and Cerodinium sp. Correlation with other studies carried in the neighbouring basin and event over the world allow giving a Maastrichtian-Paleocene age to the formation studied. Palaeoecological interpretations from the above data suggest of shallow marine coastal environments where waters are warm and have a normal salinity.

Keywords Douala Sub-Basin, Dinoflagellate, Age, Paleoecologie

1. Introduction

The Cameroon Atlantic basin localized in the Gulf of Guinea is one of the West African coastal basins. It is divided into two major basins: The Douala-Kribi/Campo basin and the Rio Del Rey basin. However, these two sedimentary units separated in onshore by the volcanic massif of Mount Cameroon form only one sedimentary unit in their offshore. The Douala/Kribi-Campo basin is subdivided into two sub-basins: the Kribi-Campo sub-basin to the South and the Douala sub-basin to the North subject to the present study (figure 1). Owing to the economic potential of this area, several studies have been carried by scientist and petroleum industry, leading to the characterization and the stratigraphy of the deposits.(Amonst:[1],[2],[3],[4],[5],[6],[7],[8],[9],[10],[11], [12],[13],[14],[15],[16],[17],[18]).

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All those works for the most part were very globalizing ignoring the specificities of each part of the basin. However, the structural dynamics that led to the establishment of the Douala Kribi / Campo sedimentary basin like other basins of the West African coast has resulted in the sequence variability of deposits by sector considered. Moreover, many of the works are unpublished because of the known confidentiality characterizing the oil research domain.

Indeed, the establishment of sub-basin of Douala is linked to the gradual opening of the North-South South Atlantic, which resulted in the diachronism of deposits from South to North. Another consequence of this was a temporal and spatial variation of sedimentary environments along the West African coast. This situation do not permit to easily extrapolate the results obtain from one basin to another. Reason why Cameroonians sedimentary geologists and foreigners decided to conduct research program in each sector of the Cameroon Atlantic basin. It is in this context that, Ntamak et *al* since few years are developing an important scientific production in the Kribi-Campo sub-basin,[18] carried out a research topic on the palynostratigraphy of the Cretaceous facies in the eastern border of the Douala sedimentary sub-basin. Till now, very rare palynological investigations were conducted on sediments from the northern part of this basin except for unpublished reports of petroleum industries. Existant micropaleontological studies were concentrated of animals microfossils. But due to the azoic nature of the facies, palynology became the mean way to reconstruct the past environment of deposition. The rare palynofloral investigations recently engaged did not take into consideration the marine phytoplankton ([19]) in the reconstruction of the paleoenvironment. All this justifies the poverty of palynologic data especially dinoflagellates data of the Tertiairy in this basin. The present study aims at (i) investigating marine phytoplancton from surface samples cropping out in the northern part of the Douala sedimentary sub-basin (ii) determine the age of dinoflagellates cysts identified and (iii) deduced the past environment of deposition.

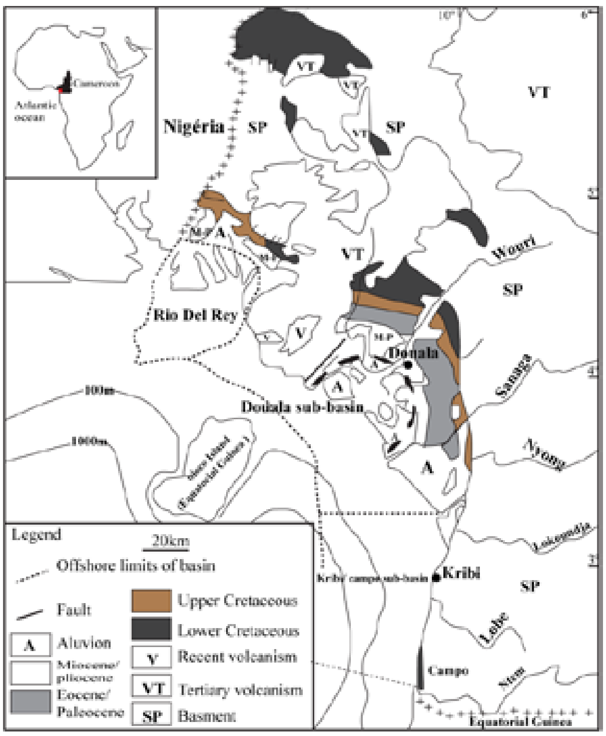

Figure 1. map showing the location of the Douala sub-basin

2. Regional Overview and Stratigraphic Evolution

The Douala sedimentary sub-basin lies on the South coast of Cameroon both onshore and offshore between latitude 3°03' and 4°06'N and longitude 9°00' and 10°00'E, covering a total surface area of 12805 km^2 (The onshore part of the Douala basin has a trapezoic shape and cover a total surface area of about 6955km^2 while the offshore part cover an area of about 5850km^2).

It has a crescent (half moon) shape starting from the south-eastern border of Mount Cameroon where the onshore part is about 70km wide (In the N20E direction) and extend throughout the atlantic coast with a gradual decrease in width of the onshore part toward the south up to Londji (North of Kribi). It is bordered by Precambrian basement to the east and northeast and by Mount Cameroon volcano of the Cameroon Volcanic Line (CVL) to the west and northwest.

2.1. Tectonic Setting

The Douala Basin developed during the Cretaceous break-up of Gondwana and the separation of Africa from South America. The initial rifting phase may have started during very Early Cretaceous time (Berriasian-Hauterivian) but the principal rifting episode in these areas occurred from late Barremian-Aptian time. The initial formation of oceanic crust as the continents separated is believed to have commenced during the late Aptian-late Albian interval.

It would appear that the rifting was asymmetrical, as many of the syn-rift features that would normally be expected are not apparent at depth in this area, but they are abundant in the corresponding South American segment. Several additional tectonic events occurred during the passive "drift" phase of the continental margin evolution at 84 Ma (Santonian), 65 Ma (K/T boundary) and 37 Ma (late Eocene). These events, resulting in uplift, deformation and erosion at the basin margins, are generally attributed to changes in plate motion and intraplate stress fields due to convergent and collision events between Africa and Europe. The Santonian uplift and possibly the late Eocene events also appear to have resulted in significant mass wasting of the continental margin by gravity sliding, contributing towards reservoir formation.

The final uplift event relates to the growth of the Cameroon Volcanic Line (CVL) and effectively lasts from 37 Ma through to present day on the northwest margin of the basin.

2.2. Stratigraphy

The basic stratigraphy of the Douala Basin is interpreted to comprise of pre-rift, rift, transition and drift megasequences related to the tectonic evolution over African cratonic basement and associated Atlantic margin. Regional stratigraphic and tectonics can be summarized in four main phases of evolution related to pre, syn and post-rift separation of Africa from South America:

Pre-rift phase

Prior to the rifting of the Afro-American plate, the atlantic margins extended over a wide Protérozoique-lower Paleozoic tectonic domain resulting from the Pan-africano-brésilian orogenesis[20]. The orogenesis was follow by intense erosion leading the creation of a vast sedimentary area. Jurassic continental sediments were then deposited in an Afro-Brasilian depression, an intracratonic sag basin that extended over the Gabon and Douala basins ([21]). Earlier interpretations of the Douala Basin place the transition between oceanic and continental crust approximately along the present coastline.

Syn-Rift Phase **:** *(Barrémien ?-Aptien)*

The Cretaceous break-up of Gondwana and the separation of Africa from South America began during Early

Cretaceous time (Berriasian-Hauterivian). But the principal rifting episode in Douala occurred from late Barremian-Aptian time.

During this period, the crustal thinning and extensional tectonic movements cause thermal anomalies that develop in the craton during thermotectonic events. The Consequent subsidence causes a series of normal faults with variable. Thus, a system of rifts of NS direction developed from the pole 19 ° N and 2 ° E with respect to Africa ([22],[23]). The tectonic activity, erosion and sedimentation occurring simultaneously, a series of grabens and horts set up throughout the Gulf of Guinea. e.g. horst of Lambaréné in Gabon, the Ise and Afowo graben in the Dahomey basin. Sedimentation is characterized by rapid lateral facies variation resulting from intense erosion of uplifted areas. The lithology is predominantly detrital made up of reworked sand and silt interbedded with clay (shales) deposited by a fluvial dynamics. This sedimentation is represented in the Douala basin by the formation named "Mundeck."

Rift-Drift transition phase (Aptien-Albien)

The initial formation of oceanic crust as the continents separated is believed to have commenced during the late Aptian-late Albian interval.

The rifting that separated Africa and South American cresulted in marginal basins with synthetic and antithetic boundary faults. This phase is marked by the beginning of intermittent marine incursions into the rift and characterized by evaporite deposits ([24]) dated Aptian in the Douala basin, Congo and Gabon. They were also dated Aptian in the basins of the north of Gulf of Guinea notably in Nigeria in the area of Afowo with comparison with equivalent saline basins of the Congo, Gabon and Brazil. But it should be noted that in Cameroon, the presence of these salt deposits was much highlighted in the Kribi / Campo sedimentary basin. The beginning of Albian oceanic accretion in equatorial Atlantic reactivates the rift faults and causes deformations on margins ([25]).

Phase post-rift

The post-rift phase (Albian – Present) comprises three stages of drift where the passive margin wedge was deposited and marked by a short compressive episode localised along the transfer faults ([26]). According to these authors, compressive deformation has also occurred in Cretaceous/Tertiary deposits in several places both along and near the African margin. Older structures, especially the cross-faults, were reactivated by transpressional stresses, resulting in a folding and faulting deformation.

The first drift stage (Albian–Coniacian, noted Drift I, is characterised by rotational fault blocks in the proximal part, salt movement ([27],[28],[29]), and gravity sliding. These structures are linked to the gravitational instability of the margin and the presence of salt.

The second drift stage (Santonian–Eocene, noted Drift II,is a discrete drift phase linked to a regional tectonic episode. Original rift-related roll-over structures were inverted and the platform sedimentary section was folded. The Santonian unconformity separating the first and second drift stages is recognised along the West African margin as a result of uplift during Cretaceous episode.

The third drift stage (Eocene Pleistocene, noted Drift III, has been linked to late gravity sliding caused by uplift in the Tertiary. The uplift and erosional unconformity are dated at about 30–40 Ma. Unlike the explanations provided by[27] , based on the deformation due to halokinesis,[26] believe that the origin of the deformation is related to the reactivation of the fossil extension of the Fracture Zone systems, comparable to that recognised in other parts of West African margins ([30],[31]).

3. Data Sets and Methods

The study whose results are presented here took place in two main phases marking the approach chosen to achieve the goal:

- Fieldwork: During this phase, lithostratigraphic investigations were carried throughout the Tertiary formations in the northern part of the Douala sedimentary basin. As a result of these prospective campaigns, five outcrops were chosen as representative and selected for the study. Thus, after detailed description of the different lithofacies constituting each outcrop, lithostratigraphic columns were performed. This description allows identifiying some basic characteristics of the depositional environments. This phase ended with the collection of samples for analysis.

-Laboratory analyses were essentially based on palynology using standard palynological method of In laboratory of micropaleontology at PETROCI:

About 20 g of material were diluted in 37% HCl to remove carbonates, nitrates and a part of chloride and silicates.

A treatment with 70% HF is then performed to dissolve silicates and a part of fluoride.

Finaly a treatment with warm HCl permit to dissolve fluosilicates formed during the previous treatment. Subsequent to each chemical preparation step, the material was sieved through a 10-20 mm nylon screen.

Material

Ten samples were collected from dark to grey shales strata of the area studied. They were taken from three natural outcrops A1, A2 and A3 located respectively at Kompina Miang and Fiko, three localities of the northern border of the Douala sub-basin (Figure 2). Out of ten samples studied, nine yielded a palynological content. These are K1, K2 (fgure 3), M1, M2, M3, M4, M5 (figure 4), F2 and F4 (figure 5). Only sample K3 was barren.

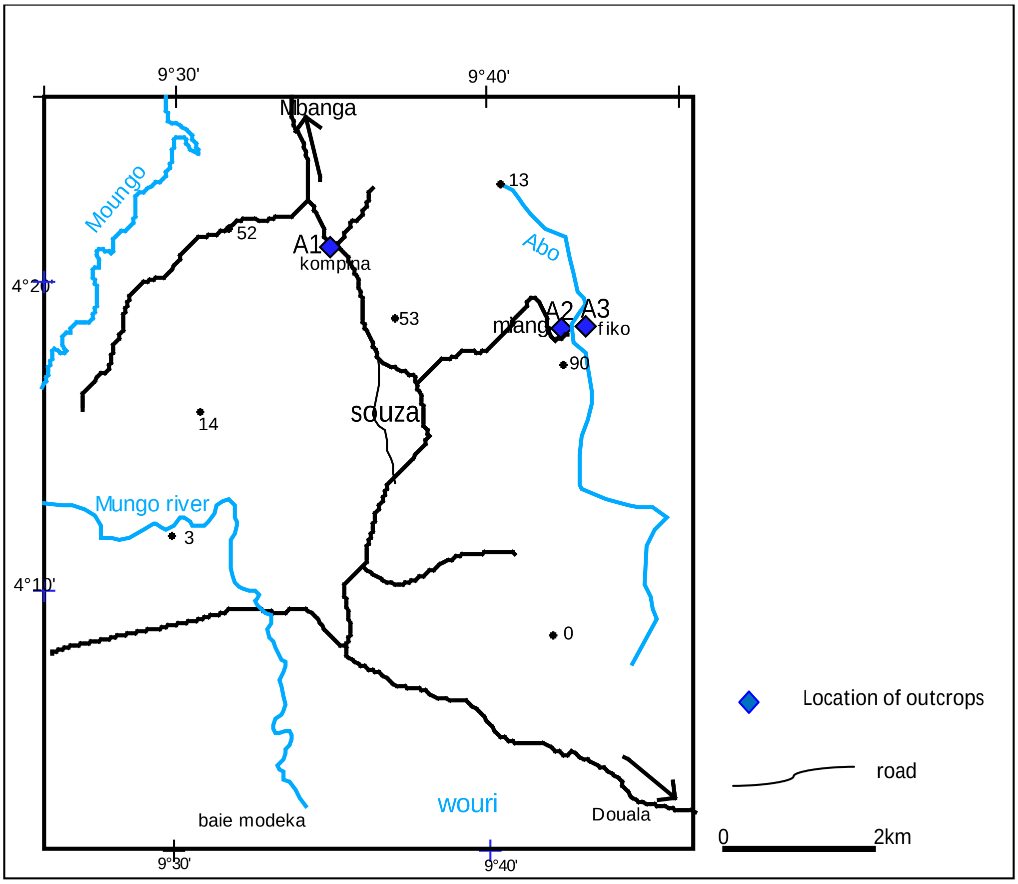

Figure 2. Map showing the location of the area studied, onshore northern Douala, and the studied outcrops

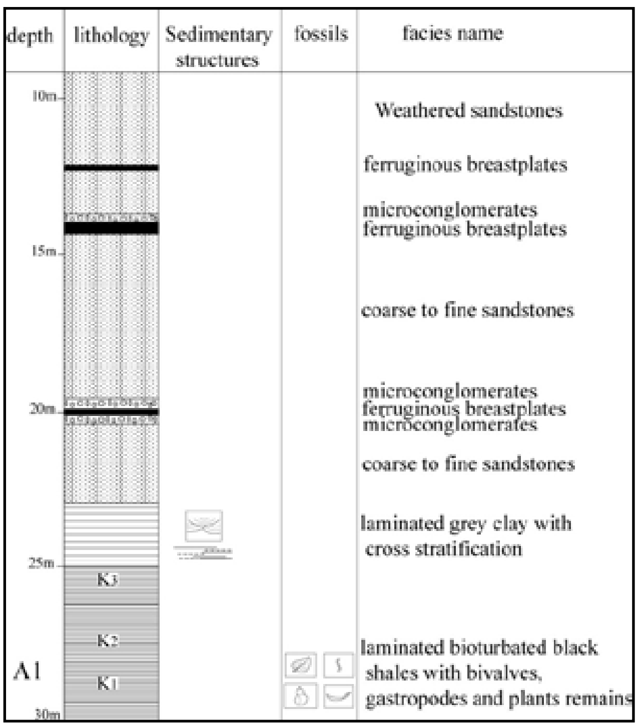

Figure 3. lithostratigraphic section of A1 showing the stratigraphic position of the dark to grey shales and the investigated sample

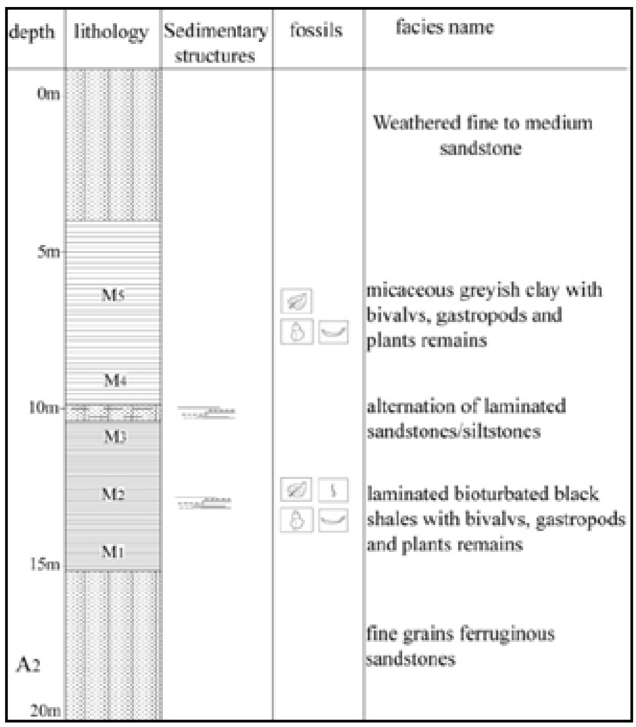

Figure 4. lithostratigraphic section of A2 showing the stratigraphic position of the dark to grey shales and the investigated samples

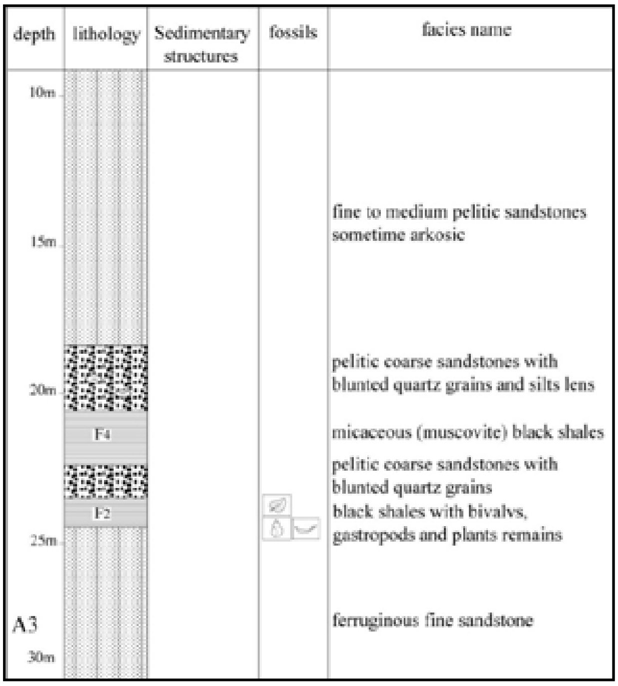

Figure 5. lithostratigraphic section of A3 showing the stratigraphic position of black shales and the investigated samples

4. Results

The investigated samples yielded a high percentage of of land–derived pollen and spores. The average percentage of dinoflagellates for all the grains counted reaches 18,34% against 81,66% for spores and pollen. The percentage of the recovered marine phytoplankton versus the land-derived micro flora in each sample is illustrated in figure 6.

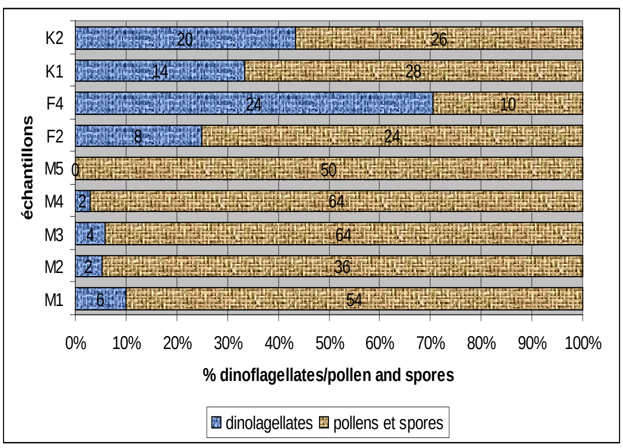

Figure 6. Diagram showing the percentage of dinoflagellates cysts versus spore and pollen for the studied samples

The dinoflagellates cysts are richly represented especially in dark shales samples of Fiko and Kompina where they sometimes dominate spores and pollen (F4, K1 and K2).

The following dinoflagellates cysts have been encountered in the shales deposits of the Nkappa formation. They are arranged in alphabetical order:

Adnatosphaeridium (Williams & Downie, 1966)
Andalusiella gabonensis (Stover & Evitt, 1978)
Areoligera spp (Lejeune-Carpentier, 1938)
Cerodinium granulostriatum (Ehrenberg, 1830)
Cerodinium sp. (Vozzhennikova, 1963).
Damassadinium mutabilis(Morgenroth, 1968)
Fibrocysta bipolaris (Cookson et Eisenack, 1965)
Fibrocysta radiata (Lindemann, 1928)
Glaphyrocysta spp. (Stover & Evitt, 1978)
Glaphyrocysta wilsonii (Kirsch, 1991)
Hafniasphaera septata (cookson et Eisenack, 1967)
Kallosphaeridium sp. (Coninck 1969)
Palaeocystodinium golsowense (Alberti, 1961)
Phelodinium africanum (Biffi et Grignagni, 1983)
Spiniferites ramosus (Ehrenberg, 1838) Mantell, 1854
Spiniferites spp. (Mantell, 1850)

All the marine phytoplankton assemblage is made of dinoflagellates of the class Dinophyceae. The families represented are Gonyaulacaceae (41,66%) Peridiniaceae (25%), Areoligeraceae (25%) and Protoperidiniaceae (8,33%). The recorded dinoflagellates are irregularly distributed throughout the studied samples. Samples F2, F4, K1 and K2 showing an exceptional richness in dinoflagellates cysts with respectively 25%, 70,58%, 33,33% and 43,47% of the palynoplanktonic content (figure 2)

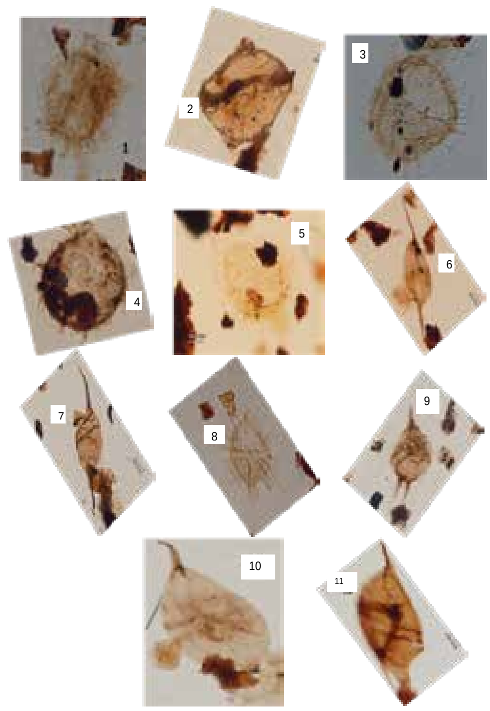

Figure 7. Illustrations of some dinoflagellates cysts identified in samples studied: (1): *Glaphyrocysta spp*. (Stover et Evitt, 1978), (2): *Phelodinium magnificum*. (Biffi et Grignagni, 1983) (3) *Spiniferites sp*. (Mantell, 1850). (4) *Hafniasphaera Septata* (cookson et Eisenack, 1967) (5) *Areoligera spp*. (Lejeune-Carpentier, 1938) (6et 7): *Palaeocystodinium golzowense*(Alberti, 1961) (8) *Damassadinium mutabilis*. (Morgenroth, 1968) (11) *Cerodinium sp* (Vozzhennikova, 1963) (10) *Andalusiella gabonensis* (Stover et Evitt, 1978) (11) *Cerodinium granulostriatum*(Ehrenberg, 1830)

5. Discussion

Most part if not all the palynological studies on the Cameroonians basin and event those of the West Africa coast are unfortunately directed towards investigating the pollen and spores and neglecting dinoflagellates and its stratigraphic significance. Thus, informations on the local distribution of index dinoflagellates in the Douala-subasin and those surrounding are rare if not non-inexistent. This could not facilitate the biostratigraphic correlation of the present association.

However, the works of ([18]) on the Cretaceous of the eastern part of the the Douala sub-basin constituted a beginning for solving this problem.

In spite of all these difficulties, the species identified in the present research work have been correlated with some associations described by ([18]) in the eastern border of the Douala-subasin and the others basin in Africa and around the world:

For example *Glaphyrocysta spp* have been described in the Scotish margin where it age is Eocène-Upper Paléocène ([32]).

Spiniferites spp have been identified in the Paleogene formations of the North atlantic ([33]), the Eocene formations of the Abidjan marginal basin ([34]) and the Lower Paleocene formations of the South of Caroline in USA ([35]).

Palaeocystodinium golzowense was reported from the Upper Campanian of Israel ([36]), the Campanian-Maastrichtian at the North of Alps in Itly ([37]) and the Upper Campanian-Lower Maastrichtien of the Godula formation ([38]).

Cerodinium granulostriatum was reported from the Danian in the marine section of Nuussuaq (Western Greenland) by ([39]), the Maastrichtian deposits of the Abidjan marginal basin ([34]) and the Upper Campanian-Lower Maastrichtien of the Godula formation ([38]).

Glaphyrocysta Wilsonii was date Eocène by ([40]) in the offshore formations of Keelung (North of Taiwan), Paléogène in the Podhale formation in Poland ([41]) and Upper Campanien in the Godula formation-Czech republic ([38]).

Spiniferites ramosus was discribed in the lower Aptian formations of Hurlands Farm Borehole-England ([42]), The Albien-Maastrichtien formations of the North-East Nigeria ([43]), The Albian-Turonian facies of the eastern part of the Douala sub-basin([18]), the Upper Campanian-Lower Maastrichtien of the Godula formation ([38]) and the Maastrichtian-Danian of the Denmark basins ([44]).

May ([45]) reported the presence of *Aeroligera spp* in the Upper Maastrichtian of “Monmouth” Group in New Jersey (USA). Njike Ngaha ([18]) gave it a Maastrichtian age in the facies of the eastern border of the Douala sub-basin

Fibrocysta Radiata was reported in the Upper Maastrichtian-Paleocene facies of the Godavari-Krishna basin in South India ([46]). It was also date lower Eocene in the basin of south Caroline in USA ([35]).

Damassadinium Mutabilis was identified from Selandian formations (Upper Paleocene) of the scotish coastal basins ([32]). It was also date Danian in deposits of Denmark basins ([44]).

Hafniasphaera septata was dated lower Eocene in South Caroline basin in USA ([35]) and Danian in deposits of Denmark basins ([44]).

It is to notice species of assemblage identified in the present study have been reported in other sedimentary basin all by other scientist all over the world (Africa, Asia, America, Europe...).

Although the ages of recovered species range in a wide time interval (lower Cretaceous–Eocene), the dominant species *(Areoligera sp, Glaphyrocysta sp, Cerodinium sp, Paleocystodinium Golzowense, Glaphyrocysta sp…)* are of Maastrichtian-Paleocene age. Accordindly, it could be possible to assign facies studied a Maastrichtian-Paleocene age.

Depositional environment

The presence of marine phytoplankton within the shales of Miang, Fiko and Kompina in the northern border of the Douala sedimentary basin suggests an ingression of sea during deposition. This hypothesis is confirmed by the domination of gonyaulacaceae cyst known as being abundant in the marine environments ([47]). In the other hand, the high percentage of land derived microflora especially in samples M1, M2, M3, M4 and M5 indicates deposition in shallow marine environment. The assemblage of dinocysts made of *cérodinium sp, Paleocystodinium golzowense, Cerodinium granulostriatum, Phelodinium africanum et areoligera sp* is indicative of shallow marine coastal environments where waters are warm and have a normal salinity ([48],[49]). The weak representation of the deep marine species such as *Spiniferites sp* confirms the shallow character of water. The environment can also be interpreted as being swampy with sporadic influence of the sea.

The changes in the distribution pattern of dinocyst within the samples are probably due to a local variation in the conditions of sedimentation or climate.

6. Conclusions

Dinoflagellates cysts are weakly represented in surface sediments of northern part of the Douala sub-basin (18,34% against 81,66% for spores and pollen). But they are relatively diverse in species and well preserved. The assemblage consists principally of Dinophyceae especially those of the families Gonyaulacaceae (41,66%) Peridiniaceae (25%), Areoligeraceae (25%) and Protoperidiniaceae (8,33%). Comparison with palynological results obtain in other basins indicates shallow marine or swampy environments during deposition of sediments but with sporadic influence of the sea. On the chronostratigraphical aspect, significant dinoflagellates cysts species indicated Maastrichtian to Paleocene age for the sediments. Additional palynological studies including study of pollen and spores in other sectors of the basin and on core samples will allow making correlations throughout the basin and help to establish a good synthetic lithostratigraphic column of the Cameroon atlantic basin.

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