PALYNOLOGICAL AND ENVIRONMENTAL STUDY OF SEDIMENTS IN THE EBRIE LAGOON, CASE OF ATTOUTOU BAY, CÔTE D'IVOIRE

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ABSTRACT

A biotratigraphic campaign was carried out in Attoutou Bay in south-eastern Côte d'Ivoire, during which 16 samples were taken. The samples were processed using the classic palynomorph extraction procedure, enabling the sediments to be dated and a palynofacies to be established. The palynomorphs encountered have a higher proportion of spores and pollen grains (65 %) than dinocysts (35 %). These are the following pollen grains: *Leotriletes adriennis, Inaperturopollenites sp, Pachydermites diederixii, Tricolporopollenites sp, Psilastephanocolporites sp, Monocolpollenites sp*, and for the spores of : *Deltoidospora minor, Foveotriletes margaritae, Verrucatosporites usmensis.* However, the dinocysts are essentially made up of gonyaulacoids. These species have been found in the Paleocene and Eocene. Three main environments were observed : - depositional environment rich in phytoclasts with a high oxygen content (oxidised environment); - depositional environment consisting of a mixture of amorphous organic matter and phytoclasts with an average oxygen content; - depositional environment rich in amorphous organic matter with an oxygen content of almost zero (reduced environment). The variation in dissolved oxygen content in Attoutou Bay is due to the proximity of the sea or the continent.

Keywords : *palynology, palynofacies, Attoutou Bay, Côte d'Ivoire.*

RÉSUMÉ

Étude palynologique et environnementale des sédiments de la lagune de l'Ebrié, cas de la baie d'Attoutou, Côte d'Ivoire

Une campagne biostratigraphique a été réalisée dans la baie d'Attoutou, au Sud-Est de la Côte d'Ivoire, au cours de laquelle 16 échantillons ont été prélevés. Les échantillons ont été traités selon la procédure classique d'extraction des palynomorphes en vue de dater les sédiments et d'établir un palynofaciès. Les palynomorphes observés présentent une majorité de spores et de grains de pollen (65 %) par rapport aux dinocystes (35 %). Il s'agit des grains de pollen suivants : *Leotriletes adriennis, Inaperturopollenites sp, Pachydermites diederixii, Tricolporopollenites sp, Psilastephanocolporites sp, Monocolpollenites sp,* et pour les spores de : *Deltoidospora minor, Foveotriletes margaritae, Verrucatosporites usmensis.* Cependant, les dinocystes sont essentiellement constitués de gonyaulacoïdes. Ces espèces ont été datées du Paléocène et de l'Eocène. Trois environnements principaux ont été observés : - milieu de dépôt riche en phytoclastes avec une teneur en oxygène élevée (milieu oxydé) ; - milieu de dépôt constitué d'un mélange de matière organique amorphe et de phytoclastes avec une teneur en oxygène moyenne ; - milieu de dépôt riche en matière organique amorphe avec une teneur en oxygène presque nulle (milieu réduit). La variation de la teneur en oxygène dissous dans la baie d'Attoutou est due à la proximité de la mer ou du continent.

Mots-clés : *palynologie, palynofaciès, baie d'Attoutou, Côte d'Ivoire.*

I - INTRODUCTION

The Côte d'Ivoire sedimentary basin consists of an onshore terrestrial part and an offshore marine part. The onshore basin is affected by a major east-west fault with a rejection of about 5000 m in which the Ebrié lagoon is located. Côte d'Ivoire's lagoon system, located in the southern coastal zone, covers an area of 1,200 km^2. It comprises three main lagoons stretching from west to east: the Grand-Lahou, Aby and Ebrié lagoons. The Ebrié lagoon in particular has fourteen bays that account for almost one-fifth of the surface area of the water body (99 km^2 out of 523 km^2), including Bingerville Bay, Abou-Abou Bay and Attoutou Bay [1]. Since the 2000s, several studies have been carried out on the lagoon system in Côte d'Ivoire. These include biological studies [2], hydrodynamic bathymetry [3] and geochemical studies [4]. Very few studies have been carried out in the field of palynology, which is the case for Attoutou Bay. In recent decades, the sedimentary basin has become of major importance with the identification of oil potential in the offshore zone, and the exploitation

of oil fields in blocks CI-11 'Lion, Panthère', CI-27 'Foxtrot' and CI-40 'Baobab' off Jacqueville testify to the importance of oil deposits in this area. It was against this backdrop that we initiated research to identify palynomorphs and characterise the depositional environment at the water-sediment interface in Attoutou Bay.

II - STUDY AREA PRESENTATION

Attoutou is a village in the south of Côte d'Ivoire ***(Figure 1)***, in the Jacqueville department of the Grands-Ponts area. It's located 62 km from Abidjan, to the west of the Vridi canal and 37 km from the department of Dabou by way of the coast and around 7 km from the sub-prefecture of Toupah. The geomorphology of the Attoutou Bay catchment is made up of low plateaux and sand plains. The lowlands occupy the northern half and are bordered by the main channel of the Ebrié lagoon. Their altitude varies between 10 and 12 m. They are made up of continental azo clayey sands laid down by spreading in sheets during the pre-Holocene regression [5]. There are two types of barrier beach in the southern half. The older ones are sandy, marine, bleached and arranged in parallel bands running in an east-west direction with an altitude varying from 2 to 6 metres, resting on the southern edge of the 'low plateaux' [6]. The recent strips are arranged in parallel ripples offred sand close to the current beach, with a few ripples of higher altitude created by longshore drift [7].

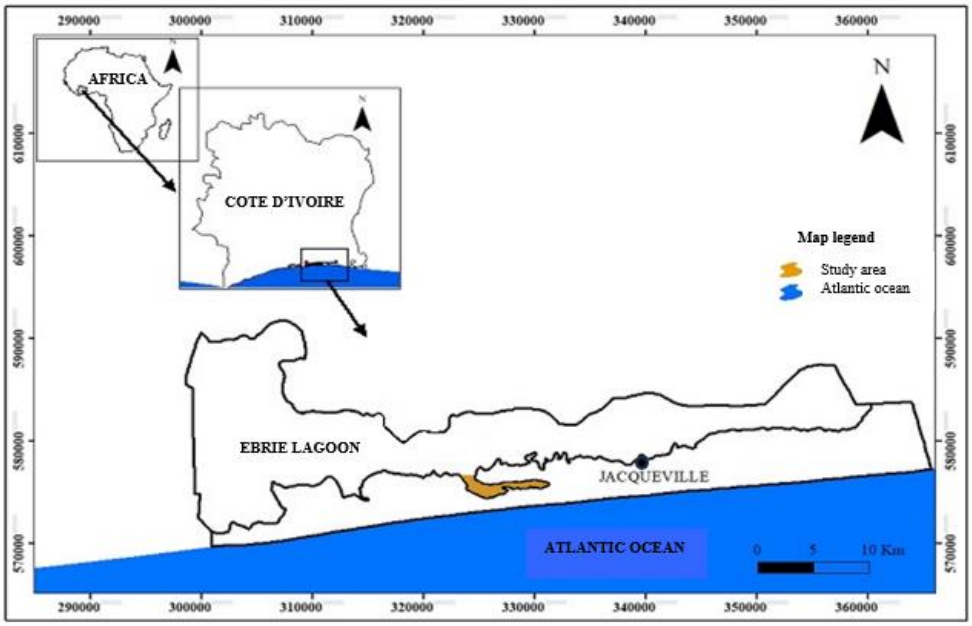

Figure 1 : *Location of the study area*

III - MATERIAL AND METHODS

The study material consisted of 16 samples of sandy and muddy sediment taken from various points in the bay as shown in ***Figure 2***. The samples underwent the classic palynological treatment using strong acids (HCl and HF), which consists of destroying all the mineral phases of the sediment, leaving only the organic phase, generally consisting of sporopollenic or palynomorphic material [8]. Attacking with 37 % cold hydrochloric acid (HCl) eliminates carbonates, nitrates and much of the saline rock. A second treatment with hydrofluoric acid (70 %) eliminates the silicates and produces a residue composed mainly of organic matter. A third hot hydrochloric acid treatment (37 %) dissolves the fluosilicates and fluorides formed during the previous treatments. The residue is then washed through a 10 or 20 µm nylon mesh. Two drops of sporopollen material are placed on the slide and then dried. The slide is then mounted on a slide labelled with a special resin. The palynological slides were studied using a transmitted light optical microscope.

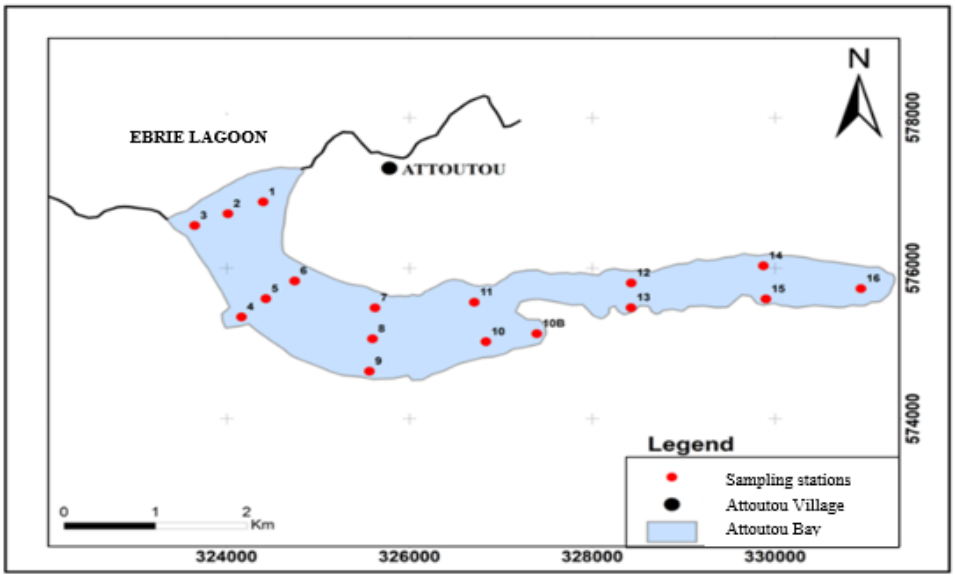

Figure 2 : *Sampling stations*

III-1. Palynological analysis

Palynological analysis involves studying all the palynomorphs present on the palynological slides. These palynomorphs are made up of marine microplankton including dinokysts, acritarchs and the organic (or basal) walls of foraminifera, and sporomorphs including spores and pollen grains of terrestrial origin [9]. The taxonomic determination of species is based on the morphographic work of Potonie (1974) for spores and pollen grains and the indexes of Lentin and Williams (1987 - 1993) for dinoflagellate cysts.

III-2. Study of organic matter and determination of palynofacies and study of palynofacies

Using a fluorescent light microscope, phytoclasts, amorphous organic matter and palynomorphs were counted. These organic matter constituents can be used to theoretically define 3 palynofacies [10]. The results obtained are projected in the ternary diagrams of Tyson (1993) in [11, 12], which make it possible to determine the type of palynofacies, the type of kerogen and the origin of the organic matter.

IV - RESULTS

This palynological study identified 224 palynomorphs. There were 144 spores and pollen grains and 80 dinocysts.

IV-1. Palynomorphs identified

- ***Dinokysts***

Dinocysts are less numerous and form a homogeneous population. This population is represented by the gonyaulacoid genus, of which we count eighty (80).

- ***Spores and pollen grains***

Spores and pollen grains are more numerous in the sediments observed ***(Plate 1)*** and make up a heterogeneous population. This population is represented by the genera: *Leotriletes adriennis* (36,11 %), *Deltoidospora minor* (22,22 %), *Inaperturopollenites sp* (29,17 %), *Monocolpollenites sp* (5.56 %), *Pachydermites diederixii* (1, 39 %), *Verrucatosporites usmensis* (1,39 %), *Tricolporopollenites sp* (1,39 %), *Psilastephanocolporites sp* (1,39 %), *Foveotriletes margaritae* (1,39 %).

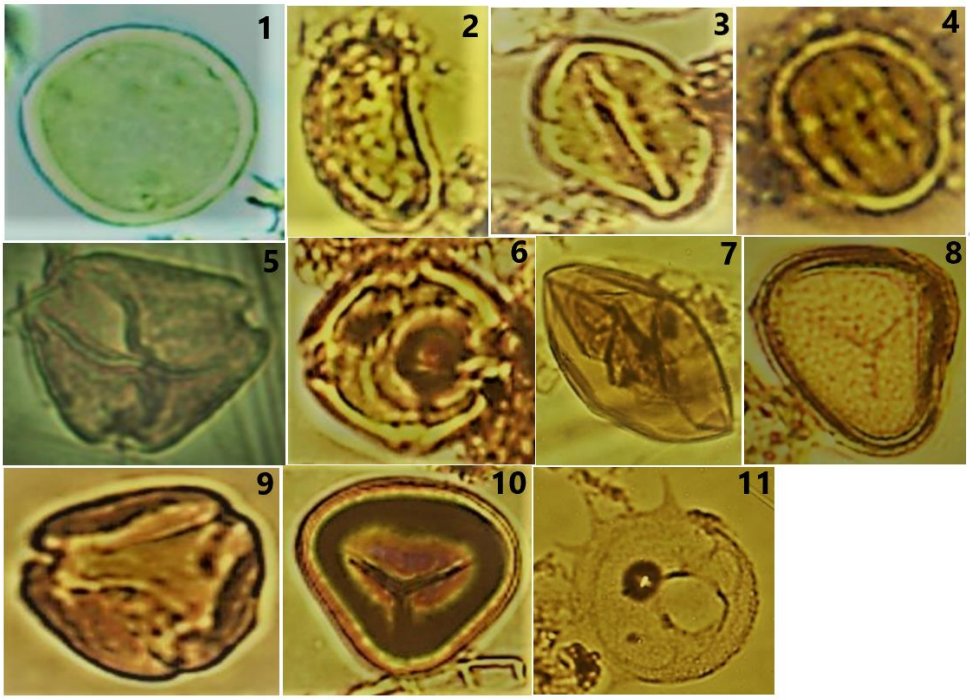

Plate 1 : *Spores, Pollen grains and gonyaulacoid*

1-Inaperturopollenites ; 2-Verrucatosporites sp. ; 3- Monocolpollenites sp. ; 4- Stephanocolporatae ; 5- Tricolpopollenites sp. ; 6- Pachydermites diederixii; 7- Leotriletes adriennis; 8- Foveotriletes margaritae; 9- Tricolpopollenites sp. ; 10- Genus Deltoidospora; 11- Gonyaulacoidae

IV-2. Palynofacies of sediment deposition environments

- ***Palynofacies***

The projection in the Phytoclasts-AOM-palynomorphs palynofacies diagram of Tyson (1993) ***(Figure 3)*** shows that the organic matter is dominated by the phytoclast fraction (figure 4) where it varies from 40 % to 95 %, then comes the amorphous organic matter (AOM) and finally the palynomorphs ***(Figure 3&4 and Table 1)***. Projection of the proportions of organic matter in Tyson's (1993) Phytoclasts-AOM-Palynomorphs Diagram indicates the existence of three (3) types of palynofacies :

- Palynofacies 1 dominated by phytoclasts (proportions greater than 90 %);
- Palynofacies 2, dominated by amorphous organic matter;
- Palynofacies 3 dominated by a mixture of amorphous organic matter and phytoclasts.

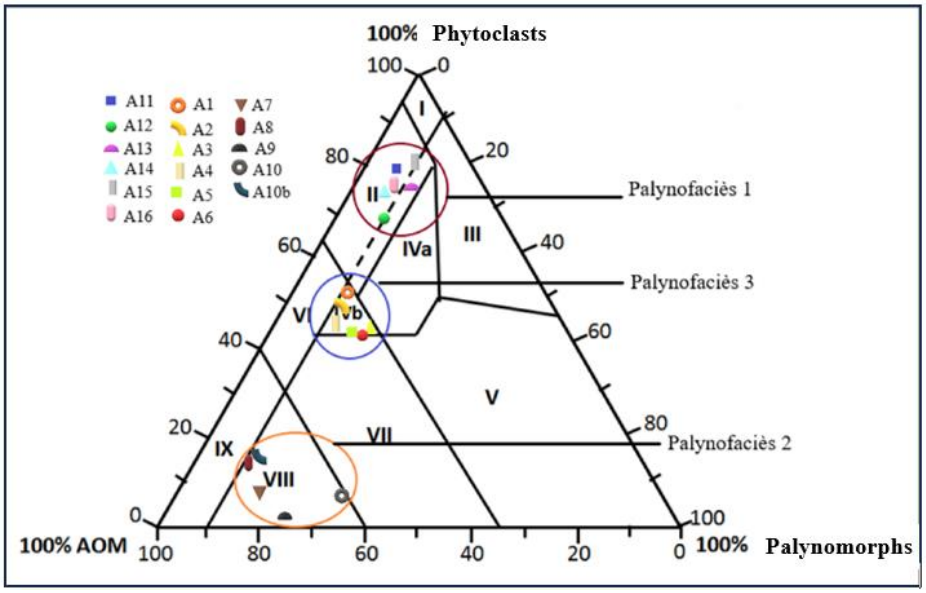

Figure 3 : *Projection in the Tyson diagram (1993)*

- ***Palynofacies 1***

In this palynological association, phytoclasts (epidermal flaps, stomata, cuticle debris and wood debris) predominate over all the components of organic matter. These phytoclasts are polygonal in shape, large, elongated and rarely rounded. There are also a few palynomorphs scattered between the phytoclasts. This palynofacies describes an anoxic to dysoxic marginal basin (depositional environment). The depositional environments are summaried in ***Table 1***.

- ***Palynofacies 2***

In this palynological association, amorphous organic matter predominates over all organic matter components. It takes the form of flattened elements with no internal structure, and palynomorphs are few in number. This palynofacies describes a transition zone between plateau and basin (depositional environment).

- ***Palynofacies 3***

In this palynological association, the mixture of phytoclasts and organic matter predominates over all the components of organic matter. There are also a few palynomorphs scattered between the phytoclasts and the amorphous organic matter. This palynofacies describes an oxic to dysoxic plateau.

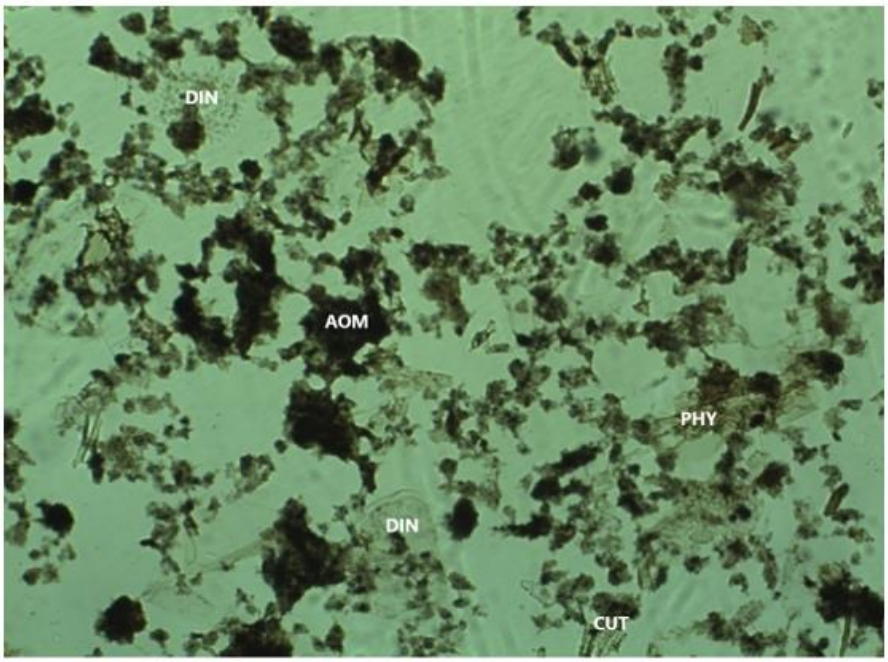

Figure 4 : *Example of a palynofacies DIN : Dinocyst ; AOM : Amorphous organic matter ; PHY : Phytoclast ; CUT : Cuticle*

Table 1 : *Summary of palynofacies associations with depositional environments*

Type of palynofacies association	Blades	Depositional environments
Palynofacies 1	A11, A12, A13, A114, A15, A16	Marginal anoxic to dysoxic basin
Palynofacies 2	A1, A2, A3, A4, A5, A6	Transition between continental shelf and basin
Palynofacies 3	A7, A8, A9, A10, A10B	Oxic to dysoxic plateau

The study of the palynofacies and the determination of the depositional environment make it possible to subdivide Attoutou Bay into three 3 zones DM1, DM2, DM3 according to the variation in dissolved oxygen content. The three zones are shown in ***Figure 5***.

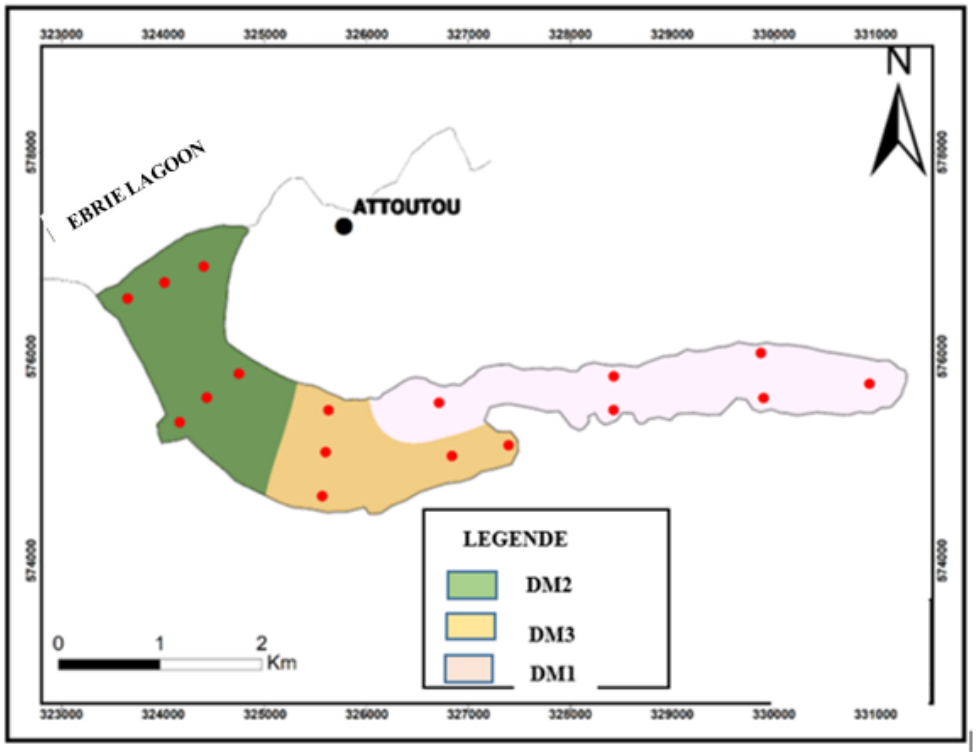

Figure 5 : *Map of Attoutou Bay divided into three areas*

- ***DM1 (P1-P6)***

This zone is essentially made up of phytoclasts. Their presence indicates an oxygenated environment close to the mainland. The presence of oxygen encourages the proliferation of animal and plant species.

- ***DM2 (P7-P10B)***

This zone is made up of amorphous organic matter of marine origin, which characterises a reducing (anoxic) environment. Anoxic conditions favour unfavourable conditions for life on the seabed.

- ***DM3 (P11-P16)***

DM3 is a mixed zone, made up of a mixture of phytoclasts and amorphous organic matter. The presence of these two components sometimes characterises an oxygenated and anoxic environment.

V - DISCUSSION

V-1. Palynomorphs found in Attoutou Bay

The palynological study of Attoutou Bay revealed the presence of various palynomorphs. These are : *Leotriletes adriennis, Deltoidospora minor, Inaperturopollenites sp, Pachydermites diederixii, Verrucatosporites usmensis, Tricolporopollenites sp, Psilastephanocolporites sp, Monocolpollenites sp, Foveotriletes margaritae*. These species come from sediments sampled at the water-sediment interface. We will not attempt to establish a statigraphic scale as a function of depth, but to determine the age range of the sediments. We found low species diversity in the sediments. The stratigraphic synthesis of the Ivorian onshore sedimentary basin described formations ranging from Maastrichtian to Quaternary [13]. The Cretaceous-Tertiary boundary is marked by a high fossil content in Maastrichtian sediments compared with the scarcity of palynomorphs that characterises the overlying Paleocene facies [14]. From the above, the palynomorph population obtained would characterise the Palaeocene. The biostratigraphic synthesis of spores and pollen grains from the Eocene-Aptian interval of the Ivorian Basin by [15] revealed that the last appearance of *Foveotriletes margaritae* was in the Lower Paleocene [16]. The same is true for the offshore sediments of the Ivorian Basin [17]. The presence of *Foveotriletes margaritae* would suggest a Lower Palaeocene age. The genera *Deltoïdospora sp* and *Monocolpopollenites sp* are among the microfossils identified in Tertiary sediments in the Cordillera Occidental and have been used to identify the Palaeocene in Colombia [18]. The Upper Palaeocene and Lower Eocene are marked by a global warming trend that peaks at the beginning of the Eocene. This is the warmest period of the Cenozoic [19]. The rise in sea surface temperature may have been associated with increased production of gonyaulacoid cysts [17]. This could explain the high population of gonyaulacoids found in this study. According to the work of [20] (Eisawi & Schrank 2008) the species *Verrucatosporites usmensis* appeared at the beginning of the Eocene. *Pachydermites diederixii*, marks the appearance of species characteristic of the Eocene in certain African basins (Cameroon, Nigeria) [17]. In the absence of species characteristic of the Oligocene such as *Lejeunecysta sp., L. pulchra, L. lata, Selenopemphix nephroides, Magnastriatites howardii* [21], we can affirm an absence of the Oligocene. From the above, we can say that the sediments date from the Paleocene, Eocene.

V-2. The depositional environments of Attoutou Bay

A study of the palynofacies in Attoutou Bay has revealed three depositional environments based on their dissolved oxygen content, divided into three zones known as DM1, DM2 and DM3. This variation in dissolved oxygen content in the different zones of Attoutou Bay is due to contact with the sea. During

periods of high water, the sea reaches the bay of Attoutou with a high concentration in the DM2 zone and significant deposits of amorphous organic matter, a medium concentration in the DM3 transition zone with less significant deposits of amorphous organic matter and phytoclasts and then a low concentration in the DM1 zone with significant deposits of phytoclasts originating from the continent, since this zone is close to the continent. According to our analyses, the variation in dissolved oxygen content in Attoutou Bay is due to proximity to the sea or the mainland. Similar results were found in Biétry Bay. According to [22], the average dissolved oxygen concentrations observed at the surface are 5.5 mg/L and 3.95 mg/L at depth. This low oxygenation (values) of the water may be linked to the confinement of the estuary and the presence of organic matter transported into the estuary by runoff and industrial discharges that endanger aquatic life. Similarly, according to [23], the low oxygen levels measured can be explained by the large quantities of organic matter brought into the estuary by domestic and industrial discharges, run-off and erosion. The low mixing of the water, the nitrification of minerals brought into the bays, the low level of sunlight, particularly during the rainy season, and the resuspension of sediments. On the other hand, the oxygen supersaturation observed is the result of the influx of marine water and the action of the tides, which dilute the water in the bays, as well as the photosynthetic activity of the algae and the atmospheric influx of oxygen by diffusion [24].

VI - CONCLUSION

The palynological analysis of the samples revealed palynomorphs with a proportion of 65 %, spores and pollen grains: *Leotriletes adriennis, Deltoidospora minor, Inaperturopollenites sp, Pachydermites diederixii, Verrucatosporites usmensis, Tricolporopollenites sp, Psilastephanocolporites sp, Monocolpollenites sp, Foveotriletes margaritae* and a proportion of 35% of dinocysts of the gonyaulacoid family. The different palynofacies analysed revealed three depositional environments : zone DM1 is rich in oxygen, indicating an environment favourable to life. The DM2 zone is low in oxygen, indicating an environment unfavourable to life. The DM3 zone is a transition zone, indicating environments that are sometimes oxygenated and anoxic.

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