***Original Research Article***

# Palynological and paleobotanic characterization of upper Eocene-lower Miocene deposits of the southeastern part of the onshore sedimentary basin of Côte d'Ivoire


## ABSTRACT

Samples from two boreholes in Bingerville and Assinie were the subject of this study. The main objective of this work is to make an inventory of the plant species that existed at the time of the establishment of these formations on both sides of the lagoon fault. The samples were processed according to the classical procedure of extraction and concentration of palynomorphs.
The palynostratigraphic analyzes revealed a palynoflora characterizing the upper Eocene and the lower Miocene. The lithology consists of sands and clays for the Bingerville well and sands, green clays and limestones for the Assinie well.
These green clays contain glauconites and remains of marine organisms, evidence of a transgressive sea at this time. Paleovegetation consists of freshwater species such as *Verrucatosporites usmensis, Laevigatosporites ovatus, Polypodiaceiosporites regularis, and Deltoidospora delicata,* which develop in a coastal wetland environment under a tropical climate with alternating warm and humid periods.


Comment [H1]: Not in italic


*Keywords: palynomorphs; paleobotanic; Miocene; Eocene; Bingerville: Assinie.*



UNDER PEER REVIEW


## 1. INTRODUCTION

The basin of Côte d’Ivoire in which this study is located, is part of a large set of coastal basins bordering the west Atlantic coast from southern Morocco to beyond Angola [1].
Palynological studies on the ivorian sedimentary basin began in 1960 with the work of [2], devoted to Cretaceous deposits.
Also, other contributions from the palynological study to the knowledge of the stratigraphy of the ivorian basin have been made, sometimes on Tertiary deposits [3, 4, 5, 6], sometimes Cretaceous [7, 8].
Many unpublished dissertation studies (DEA) dissertations have also provided data on the biostratigraphy of Tertiary age deposits [9, 10, 11] and upper Cretaceous age [12, 13, 14].
The present study was undertaken to date the formations of these two wells made in the ivorian onshore basin on both sides of the Lagoons fault in order to contribute to the paleobotanic reconstruction of the region which remains enigmatic.

## 2. PRESENTATION OF THE STUDY AREA

The study area (Fig. 1) is located south east of the ivorian sedimentary basin on both sides of the lagoon fault. Two wells made at Bingerville (P1) and Assinie (P2), the geographical coordinates and depths of which are given in Table 1 below are concerned to this study.
The geological history of the sedimentary basin of Côte d'Ivoire is linked to the opening of the south Atlantic, the consequence of which is the dislocation of Gondwana, which intimately united south America and Africa. This story recently recalled by [15] indicates that this basin is characterized by two distinct domains.

a) a continental domain or onshore basin area affected by a major "lagoon fault" along the coast from west to east. This accident has a vertical discharge of several thousand meters (4000 - 5000 m).
(b) a marine domain or offshore basin known only through oil drilling. This offshore basin is subdivided into two margins including the margin of Abidjan and that of San-pedro.

**Table 1. Coordinates of the wells**

| Site | Désignation | Longitude (w) | Latitude (N) | Depth in meter |
|---|---|---|---|---|
| **Bingerville** | P1 | 03° 52' 53,8" | 05° 20' 06,8" | 120 |
| **Assinie** | P2 | 03° 24' 02,3" | 05° 08' 54,8" | 180 |

**Comment [H2]:** southeast

**Comment [H3]:** South

**Comment [H4]:** Pedro

**Comment [H5]:** Designation

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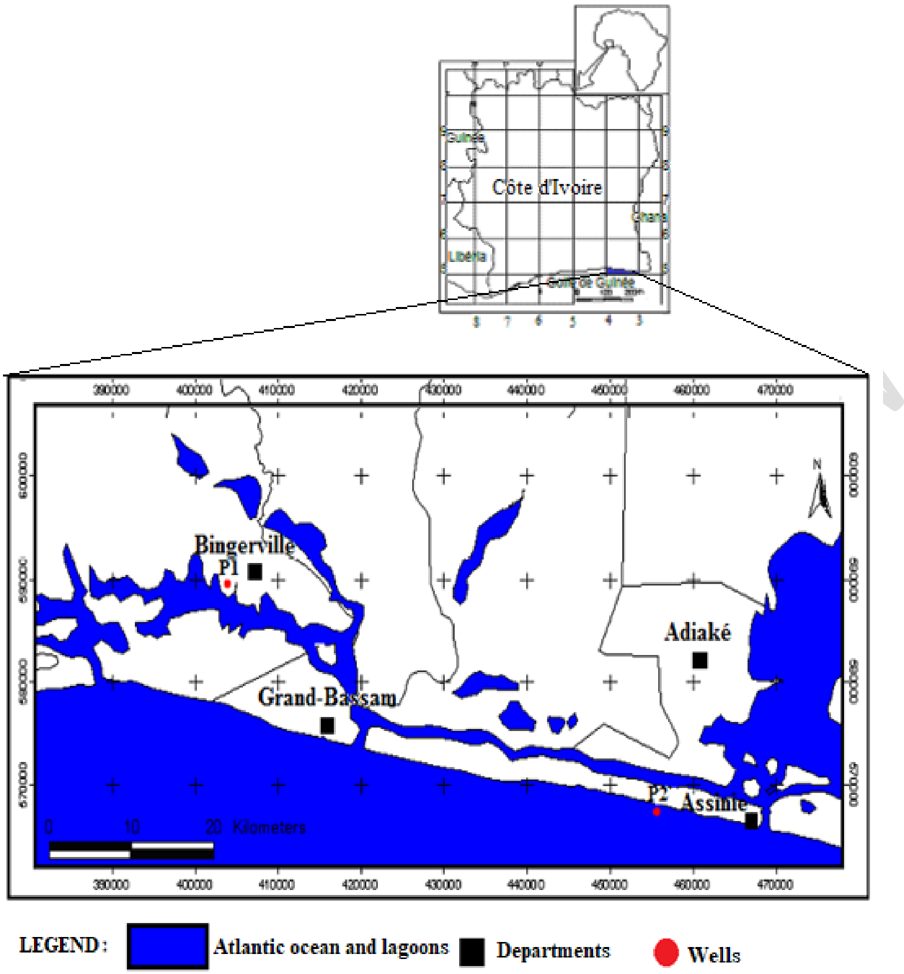


**Fig. 1. Location of wells**

## 3. MATERIALS AND METHODS

The material used consisted of twenty-five (25) samples of cuttings from two water wells located at Bingerville (10 samples) and Assinie (15 samples). Each cuttings sample was palynologically prepared as practiced in paleobotany laboratories [3].

It consists of destroying all the mineral phases of the sediment with strong acids (30% HCl and 70% HF) and preserving the organic phase generally consisting of sporopollinic materials.

A final attack with nitric acid (HNO3) 68% cold whose purpose is to clear the palynological material and organic matter content. After this last attack, the residue is sieved on a 10 µm single-use cloth and then the sporopollenic residue obtained is mounted between the blade and the coverslip using a special resin.

Using a biological microscope, observations are made to identify the palynomorphs contained in the slides. These palynomorphs made it possible to date the formations studied and to characterize the paleoenvironment of the region. The resulting paleobotany analysis is based on the ecological importance and the different botanical affinities of sporomorphs.

## 4. RESULTS

### 4.1 Lithological analysis of the wells

### 4.1.1 Lithology of the Bingerville well

The lithology of cuttings from the well (P1) located in Bingerville shows in the direction of sedimentation (Fig. 2): coarse white sand (120 - 97m); sandy variegated clays (97 - 92m); coarse sands (92 - 86 m); compact variegated clays and dark clays (86-44 m); reddish-brown sands (44 - 39 m) testifying to a strong presence of ferric oxide; very compacted dark clays (39 -25 m) and yellow-orange laterite clays (25-2 m).

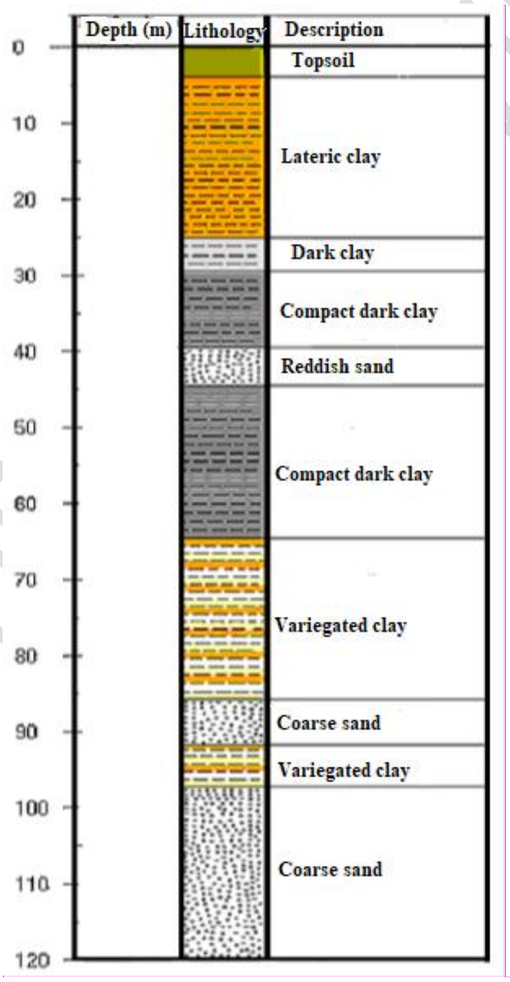


**Fig. 2. Lithological synthesis of the P1 well**

Comment [H6]: Top soil

### 4.1.2 Lithology of the Assinie well

The lithological analysis of the cuttings of the Assinie well (P2) shows in the direction of sedimentation (Fig. 3): glauconious limestones of greenish gray color with shell debris (180-164 m); very green clays, past calcareous plastics, rich in glauconites (164 - 65 m), sandy clays (65-47m); coarse orange-yellow sands, with rare shelly debris (47 - 23 m); medium to fine shellfish sands, of a light yellow color rich in shellfish debris of bivalves (23 - 2 m).

Comment [H7]: glauconitic

Comment [H8]: add a hyphen

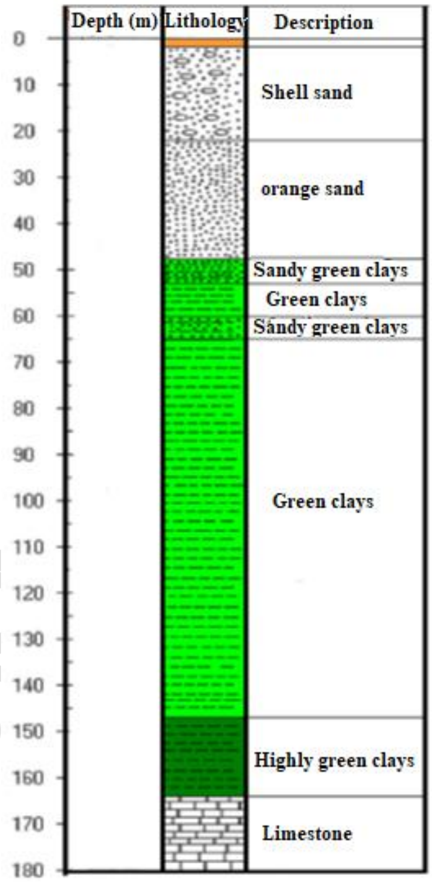


**Fig. 3. Lithological synthesis of the P2 well**

UNDER REVIEW

## 4.2 Quantitative analysis of P1 and P2 wells

The palynomorphs of the well P1 are composed mainly of spores and pollen grains (85%) and scarce dinocysts (15%). The state of conservation of these palynomorphs is excellent.
The palynological material of the well P2 is composed of spores and pollen grains (73%) as well as dinocysts (27%). This quantitative study has made it possible to observe many fossil palynomorphs, some of which are of stratigraphic interest.

**Table 2. Palynomorph Count Sheet in well P1**

| STAGE | DEPTH IN METER | TOTAL DINOCYSTS | TOTAL SPORE AND POLLEN | DINOCYSTS | | | | | SPORE AND POLLEN GRAIN | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *Batiacasphaera sp.* | *Lingulodinium machaerophorum* | *Selenopemphix quanta* | *Operculodinium centrocarpum* | | *Cupressacites hiatipites* | *Verrucatosporites usmensis* | *Retitricolporites irregularis* | *Polyadopollenites microreticulatus* | *Striatopollis catatumbus* | *Retitriporites sp.* | *Psilatricolporites crassus* | *Verrustephanocolporites complanatus* | *Psilatricolporites laevigatus* | *Monocolpopollenites sp.* | *Inaperturopollenites sp.* | *Magnaperiporites spinosus* | *Monosulcites sp.* | *Retimonocolpites irregularis* | *Laevigatosporites ovatus* |
| Lower Miocene | 30 | | 15 | | | | | | 2 | 6 | 1 | 1 | | 1 | | | 2 | 1 | | | | | 1 |
| | 34 | | 12 | | | | | | 1 | 3 | 2 | 2 | | 1 | | | 1 | 1 | | | | | 1 |
| | 42 | | 23 | | | | | | | 13 | 1 | 2 | 1 | 2 | | | 1 | 1 | | | | | 2 |
| | 47 | 1 | 17 | | | 1 | | | | 5 | 1 | 1 | 3 | 3 | | | 1 | 2 | | | | | 1 |
| Upper Eocene | 53 | 2 | 20 | | | 2 | | | | 6 | 2 | | | 2 | 2 | 1 | 3 | 2 | 1 | | | | 1 |
| | 59 | 1 | 16 | | | 1 | | | | 3 | 2 | | | 1 | 1 | 2 | 1 | 2 | 1 | | | | 3 |
| | 64 | 4 | 16 | 2 | | 2 | | | | 4 | 3 | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 2 |
| | 70 | 6 | 20 | 5 | | 1 | | | | 2 | 3 | | | 3 | 2 | 1 | 1 | 2 | 2 | 2 | | | 2 |
| | 75 | 7 | 18 | 3 | 1 | 3 | | | | 3 | 1 | | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 2 |
| | 94 | 11 | 23 | 6 | 1 | 2 | 2 | | | 4 | 1 | | | 4 | 1 | 3 | 2 | 1 | 1 | 2 | 1 | 1 | 2 |
| TOTALS | | | | 16 | 2 | 12 | 2 | | 3 | 49 | 17 | 6 | 4 | 19 | 9 | 9 | 15 | 14 | 8 | 6 | 2 | 2 | 17 |

**Table 3. Palynomorph Count Sheet in well P2**

| STAGE | DEPTH IN METER | TOTAL DINOCYSTS | TOTAL SPORE AND POLLEN | DINOCYSTS | | | | | | | | SPORE AND POLLEN GRAIN | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *Batiacasphaera sp.* | *Spiniferites ramosus* | *Cordosphaeridium inodes* | *Cometodinium obscurum* | *Operculodiliium centrocarpum* | *Isbelidium sp.* | *Lingulodinium machaerophorum* | | *Brevicolporites molinae* | *Laevigatosporites ovatus* | *Margotricolporites rauvolfii* | *Deltoidospora delicata* | *Cingulatisporites sp.* | *Tricolpites sp.* | *Leiotriletes adriennis* | *Baculatisporites sp.* | *Retitriporites sp.* | *Verrucatosporites usmensis* | *Pachydermites diederixii* | *Retitricolporites irregularis* | *Spinizonocolpites echinatus* | *Cicatricososporites dorogensis* | *Polypodiaceoisporites regularis* | *Momipites sp.* | *Retitricolporites sp.* |
| Lower Miocene | 52 | | 13 | | | | | | | | | 1 | | 1 | | 2 | | 1 | 1 | 1 | 5 | | | | | 1 | | |
| | 60 | | 12 | | | | | | | | | 1 | | 2 | | 1 | | 1 | 1 | 2 | 1 | | | | | 3 | | |
| | 64 | | 20 | | | | | | | | | 2 | 2 | 3 | | 1 | | 2 | 3 | 2 | 4 | | | | | 1 | | |
| | 71 | 2 | 22 | 2 | | | | | | | | 2 | 3 | 2 | | 1 | | 1 | 3 | 1 | 8 | | | | | 1 | | |
| | 76 | 1 | 14 | 1 | | | | | | | | 1 | 1 | 1 | | 1 | | 1 | 2 | 3 | 3 | | | | | 1 | | |
| | 82 | 1 | 13 | 1 | | | | | | | | 1 | 2 | 1 | | 1 | | 1 | 2 | 1 | 2 | | | | | 2 | | |
| Upper Eocene | 94 | 8 | 12 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | | | 1 | 1 | | | 1 | | 2 | | 1 | 2 | 1 | 1 | 1 | 1 | | |
| | 103 | 9 | 17 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | | | 1 | 2 | | | 1 | | 1 | | 4 | 1 | 2 | 2 | 1 | 2 | | |
| | 112 | 8 | 17 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | | | 3 | 3 | | | 1 | | 1 | | 2 | 1 | 1 | 1 | 2 | 2 | | |
| | 121 | 10 | 20 | 1 | 1 | 2 | 2 | 1 | 2 | 1 | | | 1 | 2 | 2 | | 3 | | 1 | | 3 | 1 | 2 | 2 | 1 | 1 | | 1 |
| | 130 | 12 | 25 | 2 | 3 | 1 | 2 | 2 | 1 | 1 | | | 2 | 1 | 1 | | 1 | | 1 | | 11 | 1 | 1 | 2 | 1 | 1 | 1 | 1 |
| | 139 | 11 | 18 | 1 | 1 | 1 | 3 | 3 | 1 | 1 | | | 1 | 1 | 1 | | 1 | | 2 | | 5 | 1 | 1 | | 1 | 2 | 1 | 1 |
| | 144 | 11 | 16 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | | | 2 | 3 | 2 | | 1 | | 1 | | 1 | 1 | 1 | | 1 | 1 | 1 | 1 |
| | 152 | 12 | 17 | 2 | 3 | 2 | 2 | 1 | 1 | 1 | | | | 1 | 2 | | 2 | | 2 | | 2 | 1 | 1 | | 1 | 2 | | 3 |
| | 165 | 7 | 15 | | 2 | 1 | 1 | 1 | 1 | 1 | | | | 4 | 1 | | 2 | | 1 | | 2 | 1 | 2 | | 1 | | | 1 |
| TOTALS | | | | 15 | 15 | 12 | 15 | 14 | 11 | 10 | | 8 | 19 | 26 | 9 | 7 | 13 | 10 | 24 | 10 | 54 | 10 | 12 | 8 | 10 | 21 | 3 | 8 |

### 4.3 Palynostratigraphy

- **Well P1**

Palynological analysis of the Bingerville well (P1) revealed two stages (Fig. 4), defined by associations composed mainly of spores and pollen grains and rare dinocysts.

- **The lower Miocene** ranges from 25 m to 51 m and is characterized by the following spores and pollen grains: *Hiatipites Cupressacites*, *Laevigatosporites ovatus*, *Polyadopollenites microreticulatus*, *Psilatricolporites laevigatus*, *Striatopollis catatumbus*, *Retitricolporites irregularis*, *Verrucatosporites usmensis*, *Retitriporites sp.* and *Monocolpopollenites sp*.

- **The upper Eocene** ranges from 51 m to 120 m is marked by species of spores and pollen grains such as: *Psilatricolporites crassus*, *Verrustephanocolporites complanatus*, *Retitricolporites irregularis*, *Verrucatosporites usmensis*, *Retimonocolpites irregularis.* These spores and pollen grains are associated with the following dinocysts: *Selenopemphix quanta*, *Batiacasphaera sp.*, *Spiniferites ramosus* and *Cleistosphaeridium flexuosum.*

- **Well P2**

Palynological analysis of the P2 well also highlighted two stages as well (Fig. 5).

- **The lower Miocene** range from 47 to 85 m is revealed by the palynological association composed of spores and pollen grains such as *Laevigatosporites ovatus*, *Leiotriletes adriennis*, *Polypodiaceoisporites regularis*, *Polypodiisporites speciosus*, *Cingulatisporites sp.*
- **The upper Eocene** extends from 85 to 180 m and is marked by spores and pollen grains characteristic of the upper Eocene such as *Pachydermites diederixii*, *Retitricolporites irregularis*, *Spinizonocolpites echinatus*, *Cicatricosporites dorogensis*, *Margotricolporites rauvolfii*, *Verrucatosporites usmensis.* To these spores and grains of pollen are associated dinocysts such as *Cometodinium obscurum*, *Spiniferites ramosus*, *Operculodilium centrocarpum*, *Batiacasphaera sp.*, *Cordosphaeridium inodes*, *Isabelidium sp.* and *Lingulodinium machaerophorum*.

**Comment [H9]:** ??Genera. sp.??

**Comment [H10]:** *Cupressacites hiatipites*

**Comment [H11]:** sp. ??

**Comment [H12]:** Not in italic

UNDER PEER REVIEW

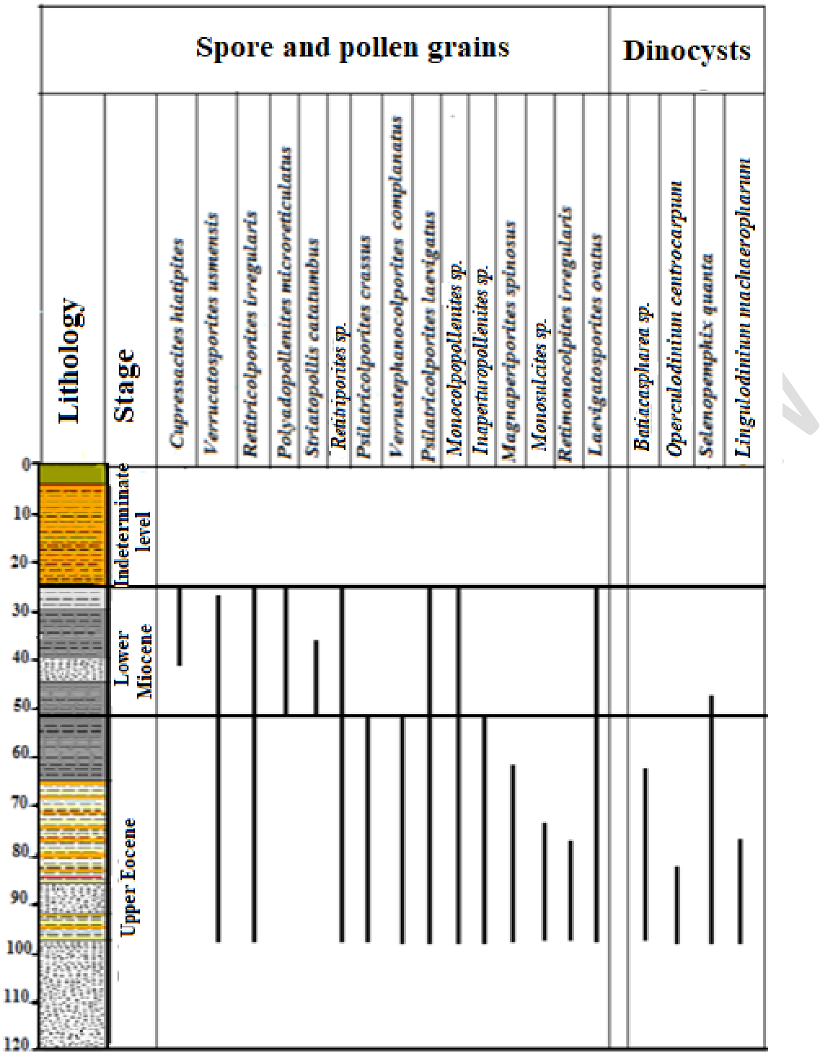


**Fig. 4. Vertical distribution of the main Bingerville palynomorphs (P1)**

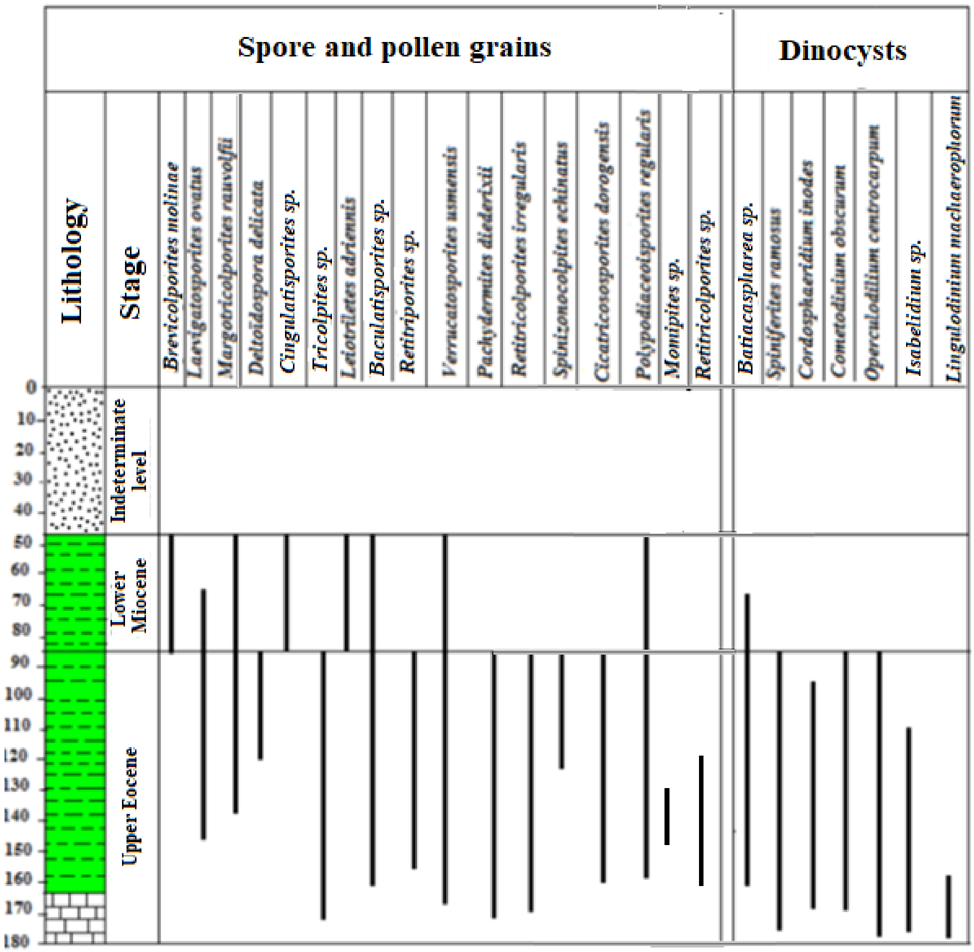


**Fig. 5. Vertical distribution of the main Assinie palynomorphs (P2)**

### 4.4 Paleobotanical characterization

The paleobotanical study of these 2 wells shows the presence of pollen grains from the Arecaceae (*Retitricolporites Irregularis*, *Monocolpopollenites sp.*), Fabaceae (*Striatopollis catatumbus*), Schizeaceae (*Inaperturopollenites sp.*), Pelliceria (*Psilatricolporites crassus)*, Nypa (*Spinizonocolpites echinatus*, *retimonocolpites irregularis*), Apocynaceae (*Margotricolporites rauvolfii*, *Brevitricolporites molinae*). These pollen grains are associated with spores of Polypodiaceae (*Laevigatosporites ovatus*, *Verrucatosporites usmensis*, *Polypodiaceiosporites regularis*), Schizeaceae (*Cicatricososporites dorogensis*, *Leiotriletes adriennis*), to Cyatheaceae (*Deltoidospora delicata*) and to Lygodium (*Crassoretitriletes vanraadshooveni*).

Palynoflora consists of angiosperm pollen grains from tropical rainforests and coastal swamps (*Pachidermites diederixii*, *Retitricolporites irregularis* and *Stritapollis catatumbus*), ancestors of the present-day palm trees of the genus Nypa (*Spinizonocolpites echinatus*, *retimonocolpites irregularis*), fern spores basically hygrophilous freshwaters that develop in moist, swampy areas (*Laevigatosporites ovatus*, *Verrucatosporites usmensis*, *Polypodiaceiosporites regularis*).

**Comment [H13]:** *irregularis*

**Comment [H14]:** *Striatopollis*

**Comment [H15]:** *Retimonocolpites*

This palynoflora indicates a tropical paleoclimate with alternating warm and humid periods. The association of coastal marine ecosystems (*Cordosphaeridium inodes, Spiniferites ramosus*) with this paleovegetation indicates a coastal marine ecosystem in this area.

## 5. DISCUSSION

**Palynostratigraphically**

Palynological analysis revealed lower Miocene and upper Eocene. Lower Miocene has been identified through associations of *Cupressacites hiatipites, Laevigatosporites ovatus, Polyadopollenites microreticulatus, Psilatricolporites laevigatus, Striatopollis catatumbus, Retitricolporites irregularis, Verrucatosporites usmensis, Leiotriletes adriennis, Polypodiaceoisporites regularis, Retitriporites sp.*
Our results are consistent with those of [16, 17, 18], who used some of these sporomorphs respectively in Soudan and Côte d'Ivoire to characterize the lower Miocene.
The species *Crassoretitriletes vanraadshooveni* extends from Miocene to Pliocene in Nigeria [19] and middle Miocene to Pleistocene in Venezuela [20]. As for *Verrucatosporites usmensis*, it characterizes the Eocene-Pleistocene interval in Nigeria and Borneo [19, 21].
*Laevigatosporites ovatus* is known in the Neogene in Burundi [22] and Paleogene in Nigeria [23].
*Striatopollis catatumbus* characterizes the Paleocene-Pleistocene interval in Nigeria [19] and the Pleistocene Eocene in Venezuela [20].
*Brevicolporites molinae* marks Oligocene and lower Miocene in Cameroon [21] and Miocene in Soudan [16].
The species *Retitriporites sp.* is a good marker of upper Oligocene and lower Miocene in Soudan [16]. However, the absence of *Lejeunecysta* (good marker of the Oligocene in Côte d'Ivoire) [7] in this interval restricts this age to the lower Miocene.
The Upper Eocene was highlighted thanks to the associations of *Psilatricolporites crassus, Verrustephanocolporites complanatus, Retitricolporites irregularis, Verrucatosporites usmensis, Retimonocolpites irregularis, Pachydermites diederixii, Spinizonocolpites echinatus, Cicatricosporites dorogensis, Margotricolporites rauvolfii.*
Indeed [24, 25, 26, 27] with its same palynomorphs has evidenced the upper Eocene in the Cameroun Basin. To these spores and grains of pollen are associated dinocysts such as *Cometodinium obscurum, Spiniferites ramosus, Operculodilium centrocarpum, Batiacasphaera sp, Cordosphaeridium inodes*. [28], considers the species *Cordosphaeridium inodes* as an indicator of the Eocene in Germany, while [29] attributes it to the middle Oligocene in Australia.
The species *Spinizonocolpites echinatus* makes its last appearance in the upper Eocene in many works [19, 26, 30, 31, 32] in Nigeria, Cameroun, Soudan and Ghana.
*Psilatricolporites crassus* characterizes the upper Paleocene and lower Eocene. In Cameroun, [26] identified it in the lower Eocene and middle Eocene. In Nigeria this species has been used by [19] to characterize the late Pleocene-Pleistocene interval. In South America, this species characterizes the lower Eocene-Middle Eocene [30, 33].
The species *Pachydermites diederixi* present in this stage characterizes the Eocene and Miocene in Cameroon [26], Oligocene and Miocene in Soudan [16].
However, the presence in this stage of *Lingulodinium machaerophorum*, an Eocene marker in Egypt [34] and *Cordosphaeridium inodes* known from Maastrichtian to upper Eocene [7, 23, 31, 35, 36] restricts this age to the upper Eocene.

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**Paleobotanically**

Paleobotanically, our work in agreement with those [18] showed that the assemblage composed of *Verrucatosporites usmensis, Retitricolporites irregularis, Laevigatosporites ovatus, Leiotriletes adriennis, Pachydermites diederixii, Polypodiaceoisporites regularis* is characteristic of tropical climates hot and humid.

The presence of the pollen grain *Brevitricolporites molinae* (Apocynaceae) typical of tropical forests [21] is confirmed in our work.

In addition, the results of [37] in conformity with ours reveal that fern spores such as *Laevigatosporites ovatus, Leiotriletes adriennis*, and *Verrucatosporites usmensis* indicate a humid tropical climate. This author also states that the species *Psilatricolporites crassus* is a pollen grain from mangrove vegetation which has been verified by our work.

The results of [38] reported by [39] indicate, as in our work, that Polypodiaceae (*Polypodiaceoisporites regularis*) are derived from tree ferns that indicate a thick and closed tropical forest.

For [39, 40], the genus *Striatopollis catatumbus* encountered in our formations is a species of freshwater and coastal swamps. These results are verified by our work. These authors also claim that they can be found in the coastal plains and also in tree savannas.

Similarly, our work is verified by those of [41]. They claim that dinocysts such as *Operculodinium centrocarpum, Spiniferites ramosus, Cordosphaeridium inodes* and *Batiacasphaera sp.* indicate a marine deposit environment near the coast.

## 6. CONCLUSION

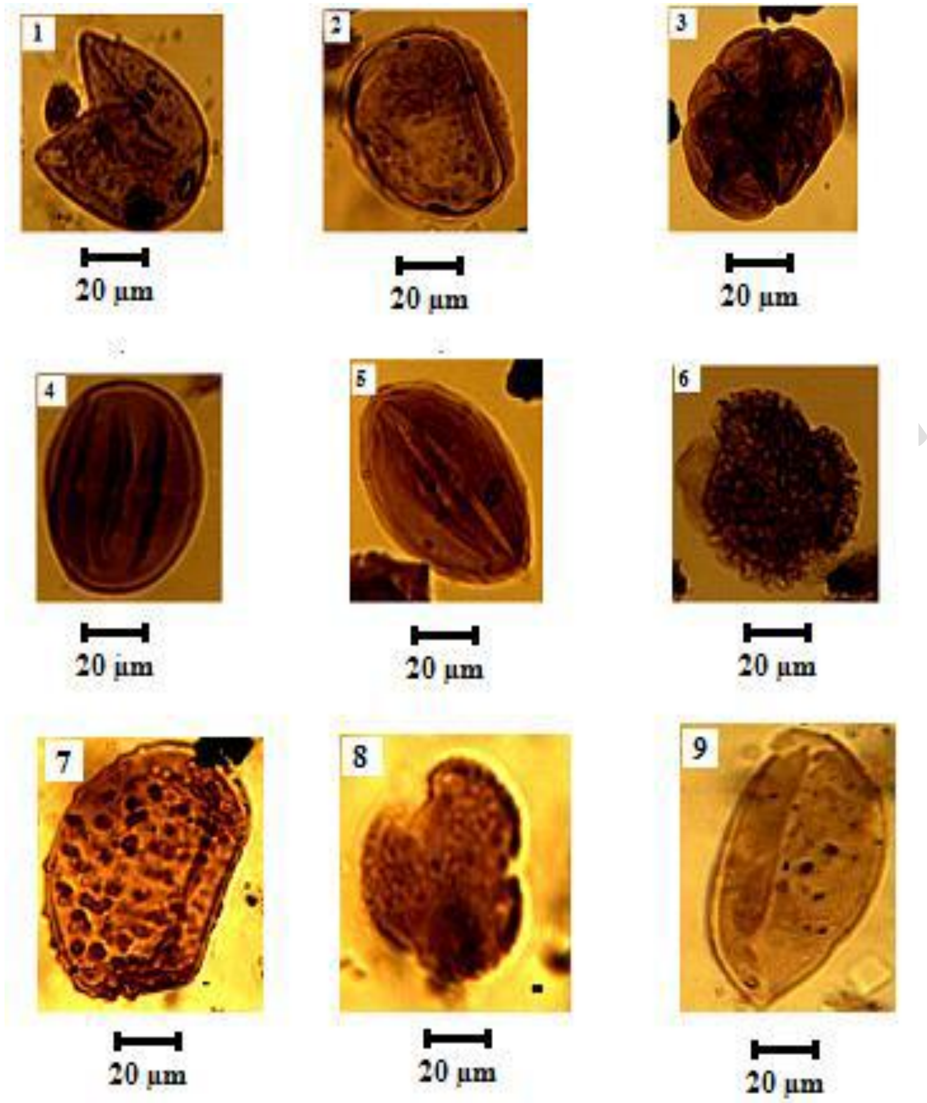
The palynostratigraphic and paleobotanical study of the sedimentary deposits of the 2 wells of Bingerville and Assinie revealed some characteristics

The lithology indicates the presence of dark, variegated sand and clays in the Bingerville well

The presence of shell sands, glauconious green clays and limestone in the Assinie well

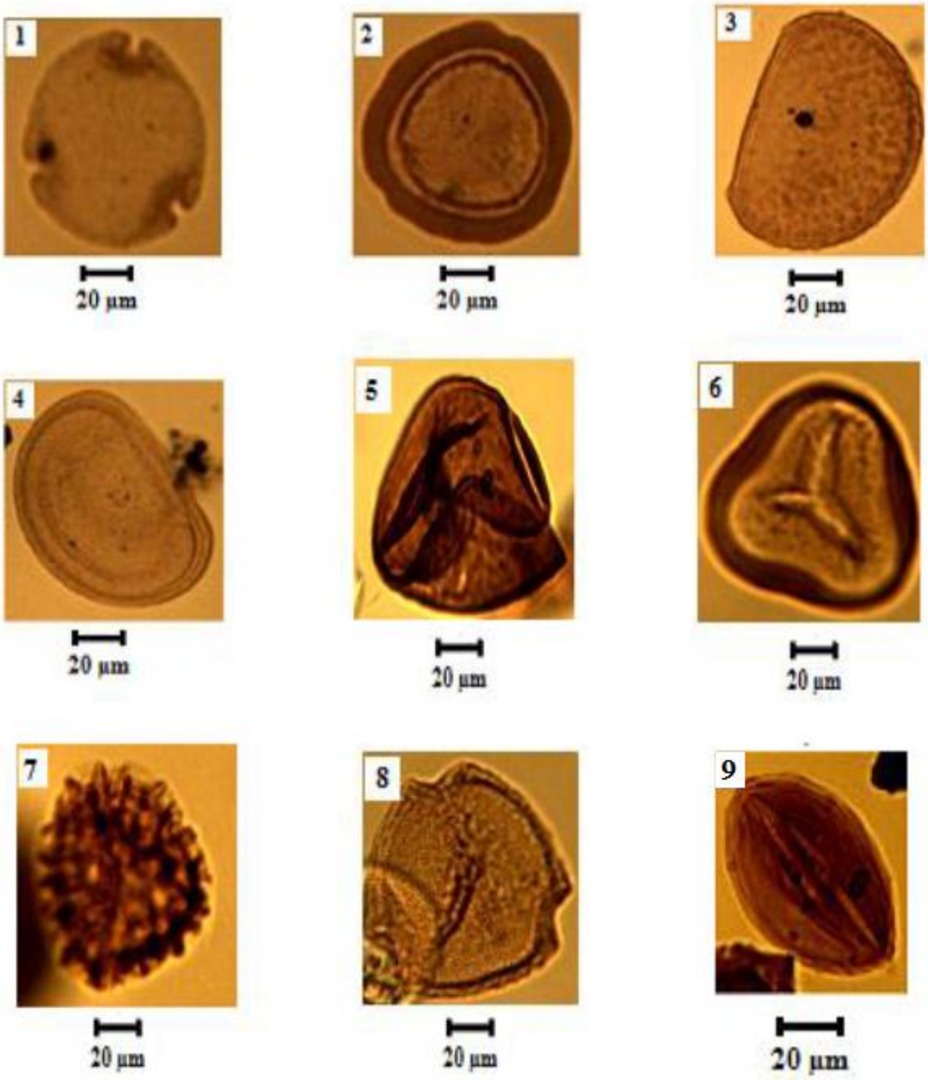
These green clays contain remains of marine organisms, evidence of a transgressive sea at this time.The palynostratigraphic analyzes revealed a palynoflora characterizing the upper Eocene and the lower Miocene. Paleovegetation reveals the presence of species that develop in a mangrove environment with moist, lowland, partly marshy forest in a tidal estuarine coastal environment.

UNDER PEER REVIEW



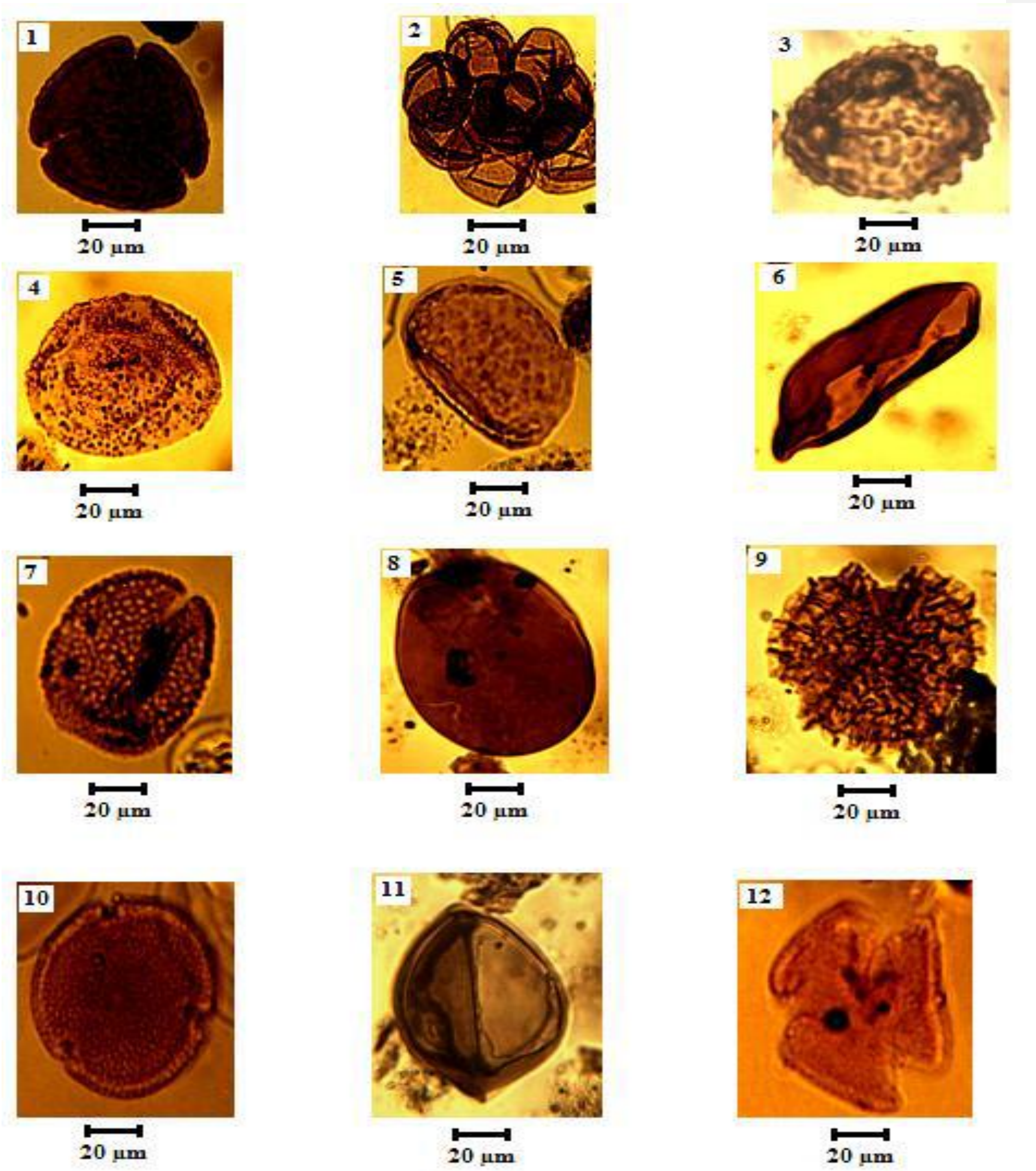

*1.Cupressacites hiatipites; 2.Laevigatosporites ovatus ;3.Polyadopollenites microreticulatus ; 4. Psilatricolporites laevigatus ;5. Striatopollis catatumbus ;6. Retitricolporites irregularis; 7. Verrucatosporites usmensis ;8. Retitriporites sp. ; 9. Monocolpolleniites sp.*

**Fig. 6. Spores and pollen grains from the lower Miocene of Bingerville**



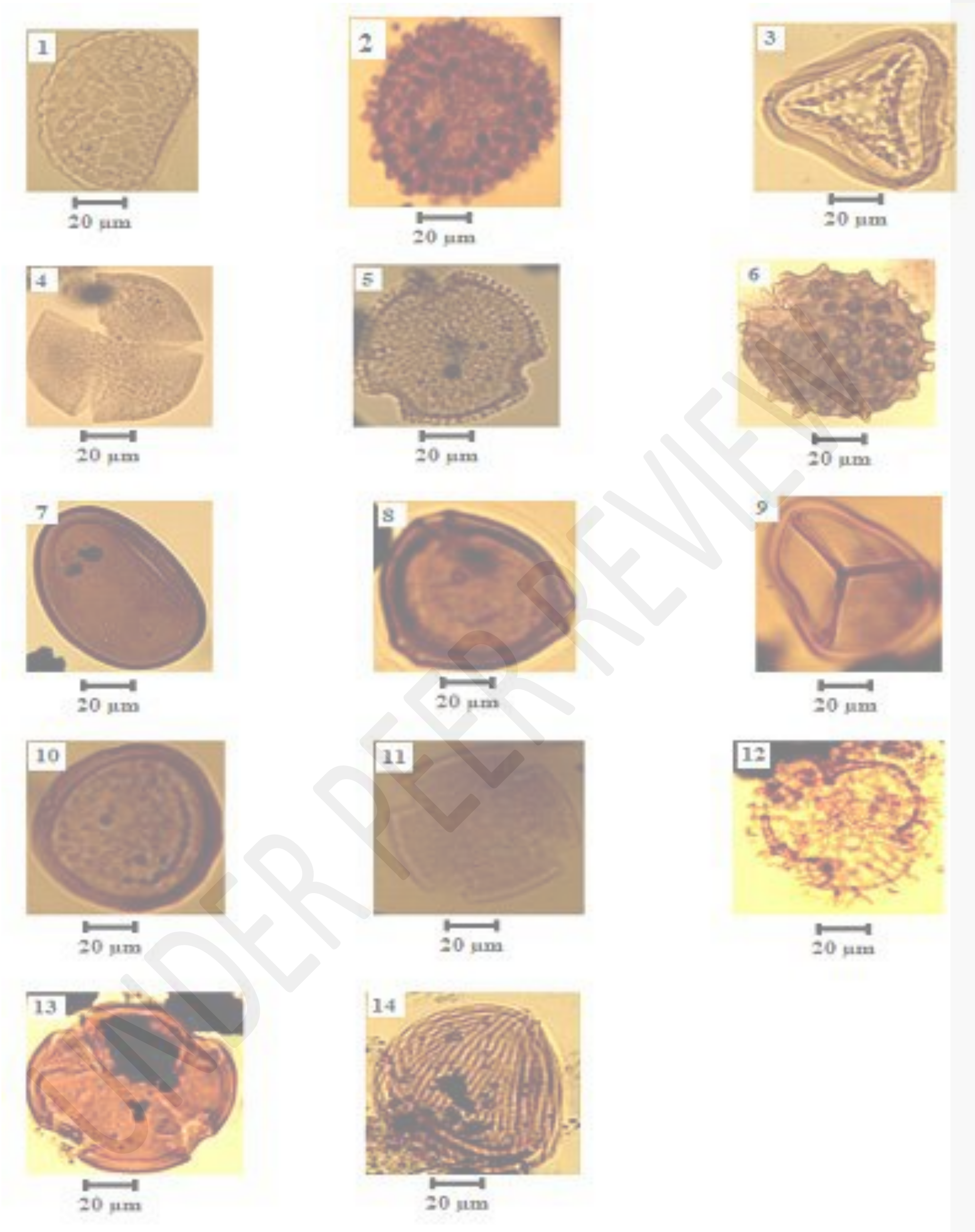

*1. Brevicolporites molinae ; 2. Cingulatisporites sp. ; 3. Verrucatosporites usmensis ; 4. Laevigatosporites ovatus ; 5. Leiotriletes adriennis ; 6. Polypodiaceoisporites regularis ; 7. Baculatisporites sp.; 8. Margotricolporites rauvolfii ; 9. Striatopollis catatumbus*

**Fig. 7. Spores and pollen grains from the lower Miocene of Assinie**




*1. Psilatricolporites crassus ; 2. Inaperturopollenites sp. ; 3. Verrustephanocolporites complanatus ; 4. Magnaperiporites spinosus ; 5. Verrucatosporites usmensis ; 6. Monosulcites ; 7. Retimonocolpites irregularis ; 8. Laevigatosporites ovatus ; 9. Retitricolporites irregularis ;10. Retitriporites sp.; 11. Monocolpopollenites ; 12. Retitricolpites sp.*

**Fig. 8. Spores and pollen grains from the upper Eocene of Bingerville**

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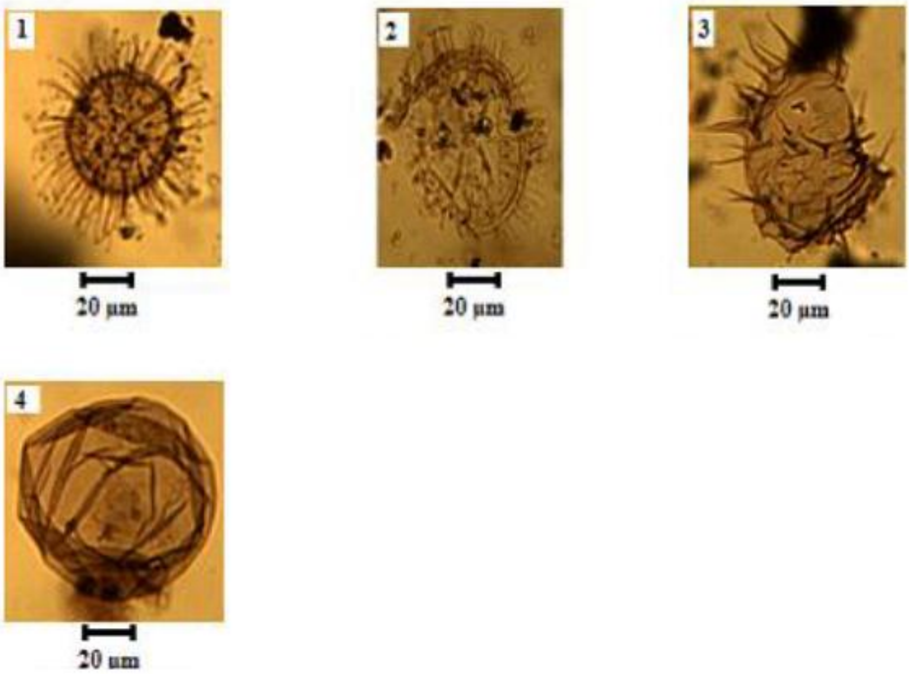
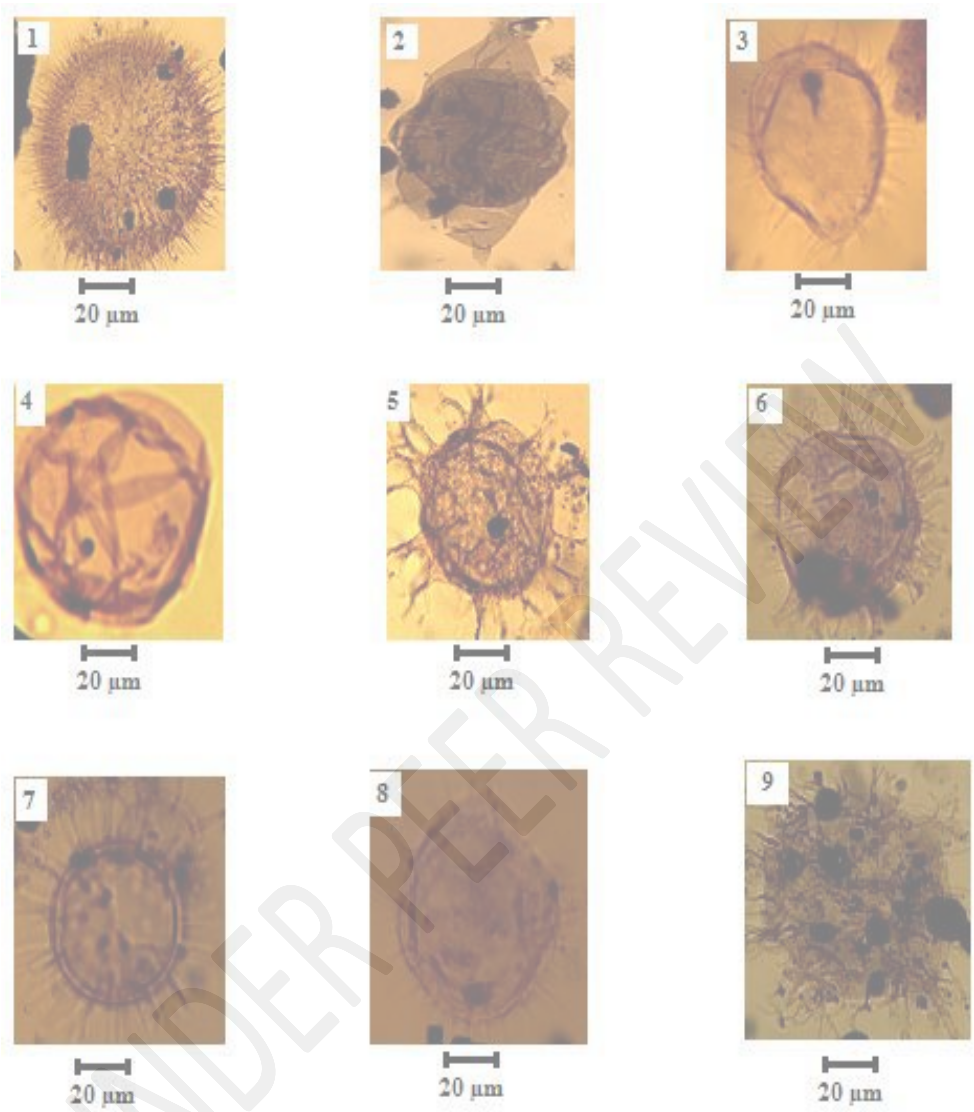
*1. Verrucatosporites usmensis ; 2. Baculatisporites ; 3. Polypodiaceoisporites regularis ;4. Tricolpites ; 5. Retitriporite sp. ; 6. Spinizonocolpites echitanus ; 7. Laevigatosporites ovatus ; 8. Momipites sp. ; 9. Deltoidospora delicata ; 10. Cingulatisporites ; 11-13. Pachydermites diederixii ; 12. Retitricolporites irregularis ; 14. Cicatricososporites dorogensis.*

**Fig. 9. Spores and pollen grains of the upper Eocene of Assinie**




*1. Lingulodinium machaerophorum ; 2. Operculodinium centrocarpum ;3. Selenopemphix quanta ; 4 Batiacasphaera sp.;*

**Fig. 10. Dinocysts of the upper Eocene of Bingerville**

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*1. Comotodinium obscurum; 2. Isabelidinium sp.; 3-8. Operculodilium centrocarpum; 4. Batiacasphaera sp.; 5-9. Spiniferites ramosus; 6. Cordosphaeridium inodes; 7. Lingulodinium machaerophorum*

**Fig. 11. Dinocysts of the upper Eocene of Assinie**

# APPENDIX

**Spore and pollen grains**

*Baculatisporites* *sp.* (Jaramillo & Dilcher, 2001)
*Brevicolporites molinae* (Schuler & Doubinger 1970) Salard-Cheboldaeff 1978
*Cicatricosisporites dorogensis* (Potonié&Gelletich, 1933)
*Cingulatisporites* *sp.*
*Cupressacites hiatipites* (Wodehouse,1933) Krutzsch, 1971
*Deltoidospora delicata* (Sah, 1967)
*Inaperturopollenites* *sp.*
*Laevigatosporites ovatus* (Wilson & Webster, 1947)
*Leiotriletes adriennis* (Krutzsch, 1959)
*Magnaperiporites spinosus* (Gonzalez, 1967)
*Margotricolporites rauvolfii* (Salard-Cheboldaeff, 1978)
*Monocolpollenites* *sp.*
*Monosulcites* *sp.*
*Pachydermites diederixii* (Germeraad, & Muller, 1968)
*Polyadopollenites microreticulatus* (Salard, 1974)
*Polypodiaceoisporites regularis (*Zhang, 1981)
*Psilatriporites* *sp.*
*Psilatricolporites crassus* (Van der Hammen & Wijmstra 1964)
*Psilatricolporites laevigatus* (Van der Hammen and Wijmstra, 1964)
*Retimonocolpites irregularis* (Van der hammen & Wijmstra 1964)
*Retitricolpites* *sp.*
*Retitricolporites irregularis* (Van de Hammen & Wijmstra, 1964)
*Retitriporites* *sp.*
*Spinizonocolpites echinatus* (Muller, 1968)
*Striatopollis catatumbus* (Gonzàlez Guzmàn, 1967) Ward, 1986
*Tricolpites* *sp.*
*Verrucatosporites usmensis* (Van der Hammen, 1956) Germeraad et al., 1968
*Verrustephanocolporites complanatus* (Salard-Cheboldaeff, 1978)

**Dinocyst**

*Batiacasphaera* *sp.* (Jaramillo & Dilcher, 2001)
*Cometodinium obscurum* (Deflandre & Courteville, 1959) Monteil, 1991
*Cordosphaeridium inodes* (Klumpp, 1953) Eisenack, 1963
*Isabelidinium* *sp.*
*Lingulodinium machaeropharum* (Deflandre and Cookson, 1955) Wall, 1967
*Operculodinium centrocarpum* (Deflandre & Cookson, 1955) Wall, 1967
*Selenopemphix quanta* (Bradford, 1975) Harland, 1981
*Spiniferites ramosus* (Ehrenberg, 1838) Mantell, 1854

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