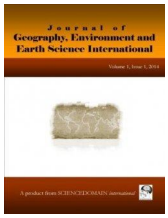

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Palynological Characteristic of Dark Gray Clays in the Ivorian Onshore Basin at Southern Bingerville

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Authors' contributions

This work was carried out in collaboration among all authors. Author GJMK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors BGR and YNJP managed the analyses of the study. Author DZB managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Samples from two wells implanted at the level of the dark gray clay outcrop of Bingerville were the subject of this palynological study. The main objective of this work is to inventory all the palynomorphs encountered, to propose a local palynostratigraphy and to reconstitute the paleobotany of our study area during the Tertiary formations north of the lagoon fault. The samples were processed according to the classical procedure of extraction and concentration of palynomorphs.
The high populations of dinocysts of the genus *Lejeunecysta lata*, *Opreculodinium centrocarpum* and *Selenopemphix quanta* as well as those of spores and pollens of the genre *Magnastriatites howardii, Perfotricolpites digitatus, Pachydermites diederixi, Bombacacidites bombax,*

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Retitricolporites irregularis, Retitriporites sp. Verrucatosporites usmensis are tributary to Oligocene. At the palaeobotanical and palaeoecological level, the highlighted palynoflora made it possible to characterize three environments, including mangroves, coastal plain, and rainforests.

Keywords: Dinocyst; spore; pollen; Oligocene; onshore; Côte d'Ivoire.

1. INTRODUCTION

Long remained unknown in the ivorian sedimentary basin, the Oligocene age formations were described for the first time by [1] southeast of the city of Bingerville. These results indicated lithologically that this stage is mainly composed of gray clays interspersed with thin joints of stratifications (hardground). The palynology data highlight the presence of characteristic dinocysts such as *Lejeunecysta communis*, *Lejeunecysta lata*, *Lejeunecysta pulchra, Lejeunecysta* sp., *Lejeunecysta granosa,. Lejeunecysta globosa, Lejeunecysta beninensis, Pheolodinium magnificum, Pheolodinium africanum, Selenopemphix nephroïdes* et *Cordosphaeridium inodes*. These dinocysts are associated with spores and pollen grains as *Magnastriatites howardii*, *Spirosyncolpites spiralis*, *Perfotricolpites digitatus, Retitricoporites irregularis, Retimonocolpites irregularis, Pachydermites diederixii*, *Psilatricolporites operculatus* et *Punctodiporites harrisii*.

Beside these studies, no results exist on the mapping of Oligocene age formations in the ivorian sedimentary basin and in particular in the northern part of the lagoon fault.

Recently, as a result of the amenagement work, gray but darker clays located beneath the variegated clays of known Mio-Pliocene age have been exposed at the southwestern entrance to Bingerville. This study was undertaken to date these levels in order to contribute to the paleogeographic reconstruction of deposits.

2. MATERIALS AND METHODS

2.1 Introduction of the Study Area

Bingerville area is located east of the city of Abidjan. This region is part of the onshore sedimentary basin of Côte d'Ivoire. There are generally clay formation unconformity on Meso-Cenozoic schist and granite.

This very narrow onshore basin is crossed from west to east by a fault "Lagoon Fault" of a rejection of several thousand meters separating two distinct zones [2] in [3]:

- South of this fault, a deep basin in which the base sinks at 4000 or 5000 m on the vertical of the coast;

- north of this fault is the shallower basin where the sedimentary cover rarely reaches 300 m thick. This onshore basin belongs to the lagoons region and covers an area of approximately 664 km^2.

This is the northern part of the Bingerville area. Sedimentation is dominated by clays and sands or ferruginous sandstones. Two wells P1 (5°38'54" N and 03°55'32"W) and P2 (5°34'24" N and 03°52'41" W), of depth 5,5 m and 18,5 m respectively were made in this study. From a physical geography, the Bingerville area has relatively rugged terrain. It has numerous lagoon water plans (the Ebrié South Lagoon and the Potou Lagoon in the North) around which a mangrove forest has developed.

2.2 Methods

The material used consists of ten (10) cuttings samples (Table 1) from two wells made in the Bingerville area east of Abidjan (Côte d'Ivoire).

Table 1. Number of samples and well depth

Well	Number of sample	Well depth (m)
Well P1	4	5,5
Well P2	6	18,5

Each sample cuttings collected underwent a palynological preparation. This preparation consists in destroying all the mineral phases of the sediment by the strong acids (HCl 30% and HF 70%) in order to preserve only the organic phase generally consisting of sporopollinic or palynomorphic materials. After this attack with strong acids, each sample is washed on a 10 micron canvas and the sporopollenic residue obtained is mounted between the blade and the lamella using a special resin to glue the coverslip. For each sample, a pair of slides was made and observed under a biological

microscope. This observation aimed to identify the palynomorphs present in the samples, to make a palynostratigraphy and to determine the depositional environment.

3. RESULTS

3.1 Analysis of the Wells

3.1.1 Lithology of well P1

The lithology indicates sedimentation as the presence of ferruginous sandstones surmounted by dark gray clays interspersed with past ferruginous cuirasses. These clay formations have an average thickness of 3 m. They are surmounted by variegated clays with some pasts of ferruginous cuirasses on 1 m thick (Fig. 2). At the top, sandstone (0,7 m) and lateritic clays (0,3 m) intersect.

3.1.2 Lithology of the P2 well

This well P2 is distant from the well P1 of 5 Km. It reached a depth of 18,5 m. Sedimentation shows from the bottom to the top dark pyritic and micromicassed gray clays capped by silty dark gray clays (1 m). Above this set are dark gray clays interspersed with ferruginous cuirasses on 9,5 m of power (Fig. 3).

Above, ocher yellow clays (1 m) are in contact with variegated clays interspersed with past ferruginous cuirasses over 4 m. At the summit clay sands (1 m) and sands (0,3 m) intersect.

3.2 Qualitative Palynological Analysis of the Studied Wells

A total of 629 spores and pollen grains, 292 dinocysts and 43 foraminifera basals have been counted (Table 2).

In Tables 3 and 4 are listed palynomorphs. The analysis of these tables shows a poverty of samples in dinocysts and an exceptional richness in spores and pollen grains. These spores and pollen grains are numerous and varied.

3.3 Palynostratigraphy

The taxonomic determination of palynomorphs adopted in this study is that of [4] for spores and pollen grains and [5] for the dinocyst.

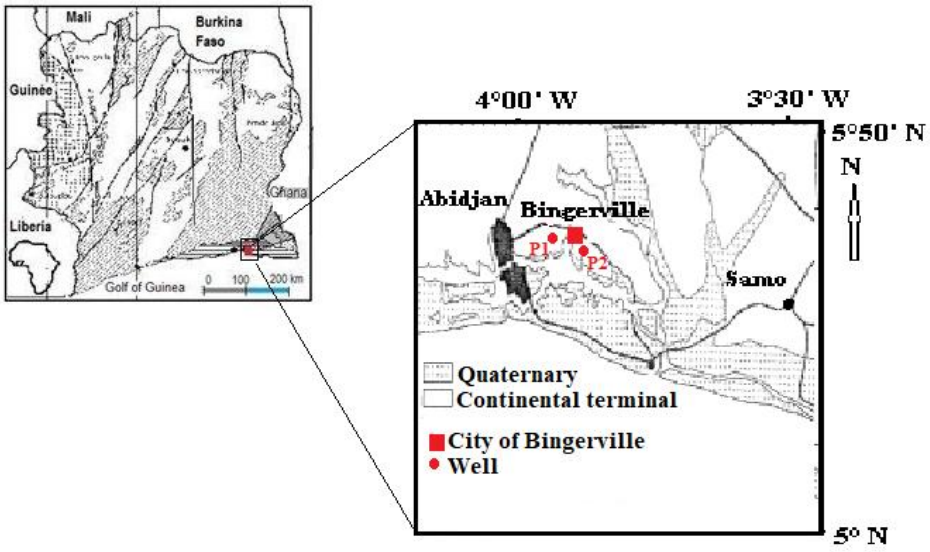

Fig. 1. Location of the study area

Table 2. Number of palynomorphs per well

Well	Dinocysts	Spores and pollen grains	Foraminifera basals
Well P1	54	153	4
Well P2	238	476	39
Total	292	629	43

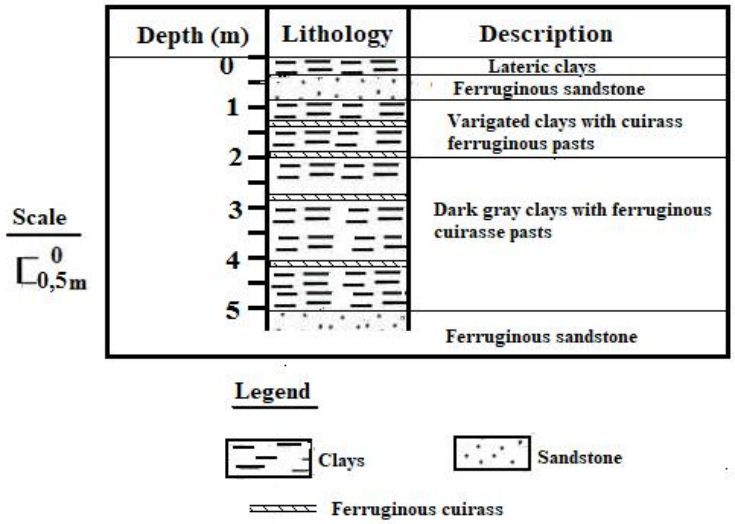

Fig. 2. Lithological synthesis of the well P1

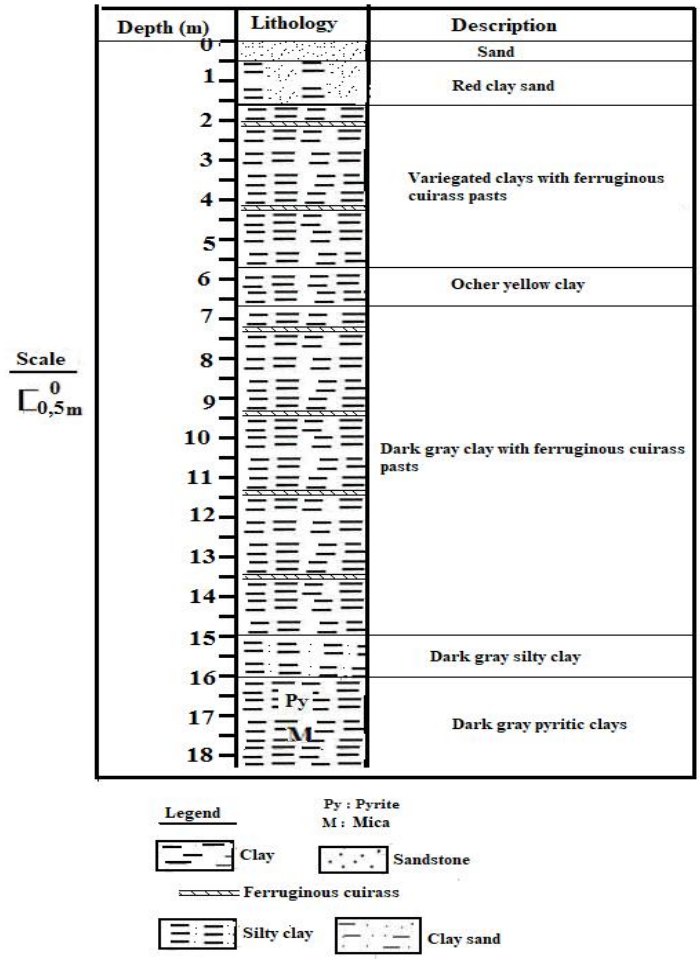

Fig. 3. Lithological synthesis of the well P2

Table 3. Palynomorphs count sheet in well P1

EPOCH	DEPTH (m)	TOTAL DINOCYSTS	TOTAL SPORE AND POLLEN	DINOCYSTS						SPORE AND POLLEN GRAINS																						
				Operculodinium centrocarpum	*Lejeunecysta lata*	*Batiacasphaera sp.*	*Lejeunecysta globosa*	*Spiniferites ramosus*	*Foraminifères*	*Polypoliadopollenites vancampoi*	*Occulapollis magnopoues*	*Retitricolporites irregularis*	*Verrucatosporites usmensis*	*Laevigatosporites ovatus*	*Triorites sp.*	*Striatopollis bellus*	*Deltoidospora minor*	*Psilastephanocolporites punctatus*	*Pachydermites diederixi*	*Retitriporites sp.*	*Monocolpites marginatus*	*Psilatricolporites laevigatus*	*Leiotriletes adriensis*	*Inaperturopollenites sp.*	*Trichome epidermique*	*Tricolpites americana*	*Echiperiporites icacinoides*	*Retitricoporites crassus*	*Monocolpopollenites sp.*	*Polypodiaceiosporites regularis*
OLIGOCENE	3	17	26	2	5	7	1		2		1	3	3	4			2	1	1	1	2	1	3				2		1	1
	4	14	59	1	1	7	2	2	1	1	3	5	14	7	1	1	9	1	1	1	1		2	3		2	1	3	1	2
	6	17	28	2	2	11	1	1		6	2	3	1		2	2	2	2	2	2						2			1	1
	10	10	40	3		5	1		1	3	1	1	6	6	1	2	6	1		1	2	2	3	3	1	1				
TOTALS				8	8	30	5	3	4	10	7	12	24	17	4	5	19	5	4	5	5	3	8	6	1	5	3	3	3	4

Table 4. Palynomorphs count sheet in well P2

EPOCH	DEPTH (m)	TOTALS DINOCYSTS	TOTALS SPORE AND POLLEN GRAINS	DINOCYSTS								SPORE AND POLLEN GRAINS																														
				Lejeuncysta sp.	*Operculodinium centrocarpum*	*Spiniferites ramosus*	*Lejeuncysta lata*	*Batiacasphaera sp.*	*Lejeuncysta globosa*	*Selenopemphix nephroides*	*Basales de foraminifères*	*Retitriporites sp.*	*Deltoidospora minor*	*Verrucatosporites usmensis*	*Psilatricolporites crassus*	*Retitricolporites irregularis*	*Laevigatosporites ovatus*	*Tetracolporites sp.*	*Momipites sp.*	*Psilastephanocolporites perforatus*	*Triorites sp.*	*Monocolpopollenites sp*	*Margocolporites vanwijhei*	*Monocolpites marginatus*	*Ocolopollis magnoporus*	*Psilatriporites sp.*	*Periporopollenites sp.*	*Polypodiaceoisporites regularis*	*Striatopollis bellus*	*Psilatricolporites operculatus*	*Margocolporites rauwolfii*	*Crototricolporites densus*	*Polypoliadopollenites van campoi*	*Racemonocolpites hians*	*Leiotriletes adriensis*	*Monocolpites sp.*	*Psilatricolporites laevigatus*	*Retitricolporites verrucatus*	*Laevigatosporites Hardii*	*Pachydermites diederixi*	*Heterocolpites verrucatus*	*Tricolpites americana*
OLIGOCENE	11	40	136		40	12		13	3	2	4	1	3	28	4	3	1	1	4	1	10	3	1		4			1	2		5	1	13	1	1	1	21	1	20	3		2
	11.5	57	88	1	37	1	2	9	3		4	2		4	1	3			1	2		3	1	2	3	1		2		1	4	1	10	1		2	9	3	9	1	21	1
	12.0	30	42	10	8			8		1	3	1	1	1	1	3	1	2		2	1	3					1	1	1	4		3				1	2	3	2	2	2	2	2
	13.5	26	54		14			2			10	1	4	1	6	4	2	1	1	3	4			1	5		1	1	1	1	1						8	1	5	1			
	15	55	69	1	20	3	2	14	1	2	12	3	1	4	3	10	4		5		1	3		1	5	2	1	1			3				1	5	10				5	1
	18	35	87	2	14	4	3	2	1	3	6	5	3	11	13	2	5	1	2	1	4	3	1	4	2	2					2				1	8	2	5	6	4	
TOTALS				14	133	20	7	48	8	8	39	13	12	49	28	25	13	5	13	9	20	15	3	8	19	6	3	6	7	2	18	3	23	2	3	11	59	9	41	13	32	6

The palynostratigraphic study of this well shows that the palynomorphs encountered extend over the Oligocene. The different characteristic palynomorphs of this stage are illustrated on Figs. 4, 5, 6 and 7.

Oligocene is characterized by the following dinocysts: *Operculodimium centrocarpum, Cordosphaeridium inodes, Spiniferites ramosus, Batiacasphaera sp., Lejeunecysta globosa and Leujenecysta lata*.

These dinocysts are associated with the following spores and pollen grains: *Verrucatosporites usmensus, Laevigatosporites ovatus, Perfotricolporites digitatus, Monocolpites sp., Deltoidospora minor, pachydermites diederixii, Leiotriletes adriensis, polypodiaceoisporites simplex, Monocolpopollenites sp., Psilatricolporites laevigatus, Monocolpites irregularis, Triorites sp., Momipites sp., Striatopollis bellus, Crototricolites densus, Retitricolpites americana, Retitricolporites irregularis* and *Occulopollis magnoporus*.

4. DISCUSSION

4.1 Palynostratigraphy

Oligocene has long been considered absent throughout the Ivorian sedimentary basin because it is strongly eroded. This erosion is highlighted in the Port-Bouet 1 sounding where the Miocene rests unconformably on the upper Cretaceous.

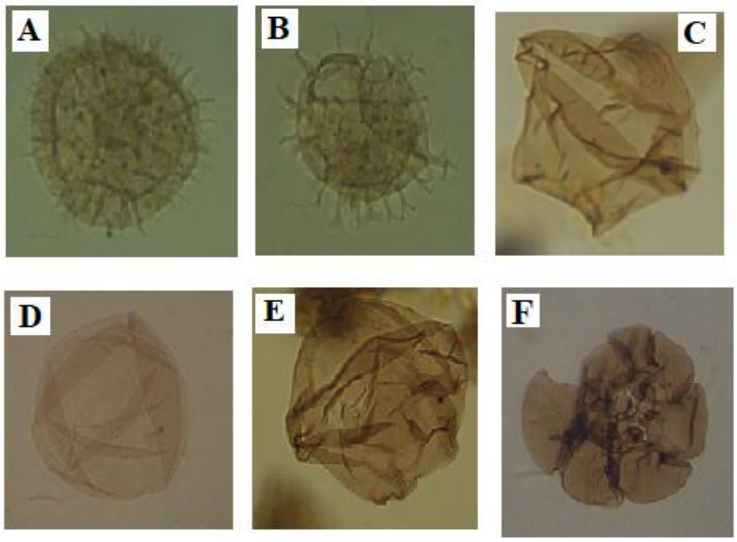

Fig. 4. Oligocene dinocysts of bingerville
A- Operculodinium centrocarpum; B- Spiniferites ramosus; C- Lejeunecysta lata; D- Batiacasphaera sp.; E- Lejeunecysta globosa; F- foraminifera basal

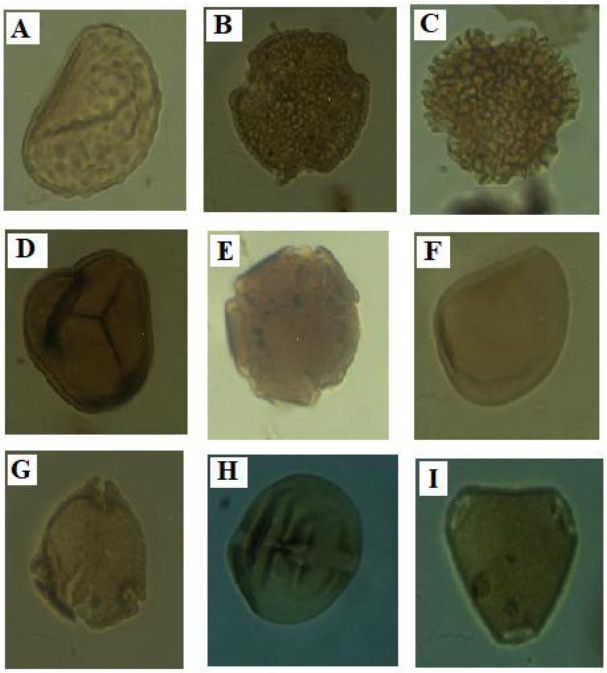

Fig. 5. Oligocene spore and pollen grains of bingerville
A-Verrucatosporites usmensis; B-Retitriporites sp.; C- Retitricolporites irregularis; D- Cyathidites minor; E- Pachydermites diederixii; F- Laevigatossporites ovatus; G- Occulopollis magnoporus; H- Psilastephanocolporites laevigatus; I- Momipites sp

However, the recent palynological work of [6,7] highlighted Oligocene in Bingerville east of Abidjan. This study continued by [8], has actually revealed a palynological association in the gray clays that overcome the variegated clays (Continental terminal). This palynological association consists of pollens *Spirosyncolpites spiralis, Perfotricolpites digitatus*.

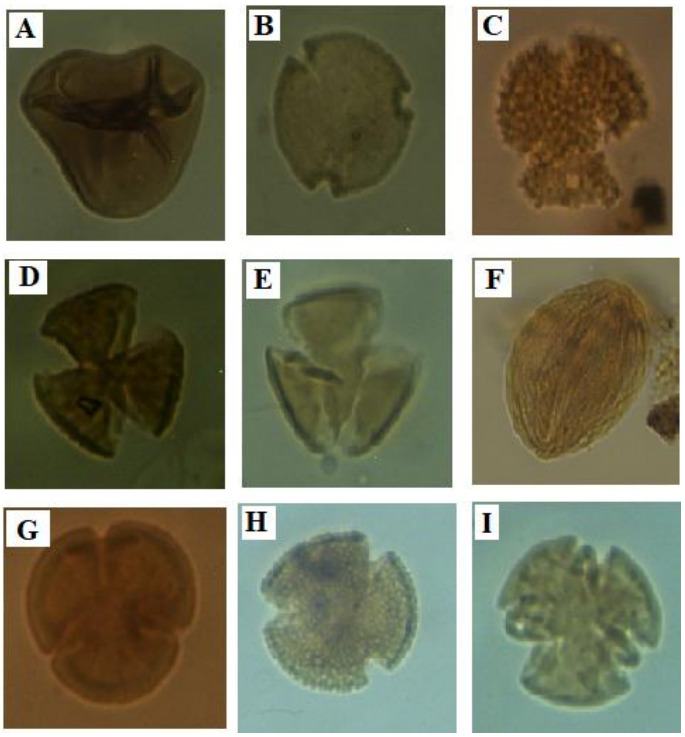

Fig. 6. Oligocene spore and pollen grains of Bingerville
A- Leiotriletes adriensis; B- Triporites sp.; C- Crototricolporites densus; D- Tricolpites sp.; E-Tricolpites americana; F -Striatopolis bellus; G- Margocolporites rauvolfii; H - Psilatricolporites crassus; I - Psilatricolporites operculatus

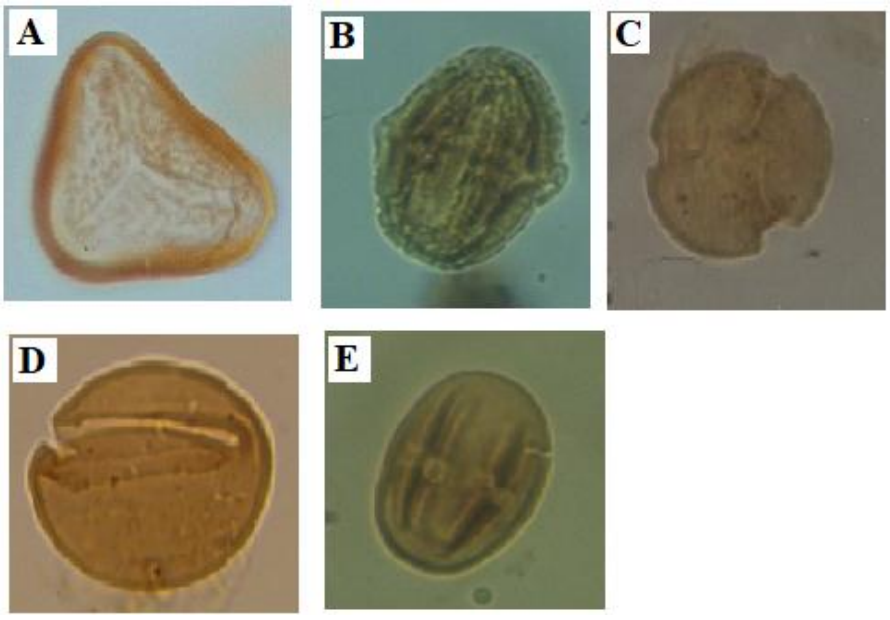

Fig. 7. Oligocene spore and pollen grains of Bingerville
A- Polypodiaceiosporites simplex; B - Psilastephanocolporites punctatus; C - Margocolporites rauvolfii; D - Monocolpites marginatus; E - Retitricolporites verrucatus

The work of [9] in the same area, allowed definition of two associations of palynomorphs: *Crassoretitriletes vanraadshooveni, Verrucatosporites usmensis* encountered in gray clays and *Verrutricolporites laevigatus* encountered in peats are characteristic associations of the lower Miocene.

This work has highlighted most of the species cited by these authors. These are spore species and pollen grains such as *Perfotricolpites digitatus, Verrucatosporites usmensus, Laevigatosporites ovatus, Pachydermites diederixii, Polypodiaceoisporites simplex, Psilatricolporites laevigatus, Monocolpites irregularis, Triporites sp., Momipites* sp., *Striatopollis bellus, Striatopollis catatumbus, Spinizonocolpites echinatus* and *Occulopollis magnoporus.*

These species are associated with dinocysts such as *Lejeunecysta pulchra, Lejeunecysta lata, Lejeunecysta globosa* and *Selenopemphix nephroides characteristic* of the Oligocene in most West African countries.

Uderico and Dario [10] have shown that the association of dinocysts consisting of *Lejeunecysta pulchra, Lejeunecysta lata, Lejeunecysta globosa, lejeunecysta* sp. *Selenopemphix nephroids, Operculodinium centrocarpum, Selenopemphix quanta* and *Cordosphaeridium inodes* characterizes the Oligocene in Nigeria.

Salard-Cheboldaeff [11] showed in Gabon that the association of spores and pollen grains such as *Perfotricolpites digitatus, Magnastriatites howardii, Praedapollis africanus, Psilatricolporites operculatus, Pachydermites diederixii, Verrucatosporites usmensis, Striatopollis bellus, Retitricolporites irregularis* and *Occulopollis magnoporus* characterizes the Oligocene.

Eisawi and Schrank [12] indicate that the species *Bombacacidites bombax, Psilastephanocolporites perforatus. Psilatricolporites operculatus, Magnastriatites howardii, Pachydermites diederixi, Perfotricolpites digitatus, Praedapollis africanus, Retitriporites sp*. and *Verrucatosporites usmensis* characterize the upper Oligocene-lower Miocene passage in most African sedimentary basins.

Most of these palynomorphs cited by these authors have been highlighted in this work. The Oligocene was retained and confirmed in view of the presence of *Lejeunecysta lata* and *Lejeunecysta globosa* in the studied wells.

4.2 Paleobotany and Paleoecology

The paleobotanical study of the wells shows the presence of the pollen grains of the Arecaceae (*Retitricolporites irregularis, Monocolpopollenites sp.*), Nypa (*Monocolpites marginatus, Racemonocolpites hians*), Meliaceae (*Psilastephanocolporites punctatus*), Moraceae (*Momipites sp.*), Polygalacaes (*Psilastephanocolporites perforatus*), Caesalpiniaceae (*Striatopollis bellus*), Alchorneas (*Psitricolporites operculatus*), Apocynaceae (*Margocolporites rauvolfii, Psilatricolporites crassus*) and Fabaceae (*Crototricolporites densus*). These pollen grains are associated with spores of Polypodiaceae (*Laevigatosporites ovatus, verrucatosporites usmensis*) and Cyatheaceae (*Deltoidospora minor*).

These different botanical groups can be divided into three paleoecological groups that are all mangroves group, rainforest group and Coastal plain group (including Swamp Species).

4.2.1 Mangrove group

The main mangrove elements identified in this study are *Psilatricolporites crassus* (Apocynaceae), *Psilatricolporites laevigatus, Cyathidites minor* and *polypodiaceiosporites regularis*.

Psilatricolporites crassus and *Psilatricolporites laevigatus* are important elements of mangrove widespread throughout tropical Africa and South America [13,14,15,16].

The *Psilatricolporites crassus* pollen is believed to be derived from the mangrove plant Pelliceria [15,17].

Ferns of the genus *Cyathidites minor* and *polypodiaceiosporites regularis* present in this group are typical of the dense forests of the coastal plains and are also found in mangrove areas [16,18,19].

4.2.2 Coastal plain group (including Swamp Species)

This groupe is represented by an assemblage consisting of *Pachydermites diederixi, Retitricolporites irregularis, Verrucatosporites usmensis, Laevigatosporites ovatus,*

Monocolpopollenites sp., Polypodiaceoisporites regularis, Momipites sp. and *Cyathidites minor.*

The genus *Pachydermites diederixi* shows a constant occurrence in both wells studied and associated with the pteridophyte of the genus *Polypodiaceoisporites regularis*. This fern spore inhabits coastal wetlands and wetlands [20].

The species *Pachydermites diederixi*, which belongs to the family *Symphonia globulifera*, is known to be a dominant species in the coastal marshes of Africa [13]. The species *Retitricolporites irregularis* has been identified as a taxon present in coastal swamp environments [13].

Armentrout et al. [21] attribute this same pollen to freshwater swamp forests. Tree ferns such as *cyathidites minor* (cyatheacea) and *Polypodiaceoisporites regularis* (Pteridaceae) inhabit thick tropical forests [18,19].

The association of *Pachydermites diederixi, Verrucatosporites usmensis* and *Laevigosporites ovatus* indicate a freshwater or brackish swamp environments [22]. This could probably happen in the freshwater marsh behind the mangrove.

4.2.3 Rainforest group

This group consists of *Psilastephanocolporites punctatus, Striatopollis bellus, Psilatricolporites operculatus, Margocolporites rauvolfii, Racemonocolpites hians, and Psilatricolporites laevigatus.* [16] have shown that *Psilastephanocolporites punctatus, Racemonocolpites hians,* and *Psilatricolporites laevigatus* are indicative of dense moist forest. [23] attribute the species *Striatopollis bellus and Racemonocolpites hians* to rainforest.

Cécile [24] confirms that *Striatopollis bellus* is a characteristic species of rainforest. Rull [15] also indicates that the species *Psilatricolporites laevigatus* is a characteristic species of rainforest.

5. CONCLUSION

The biostratigraphic analysis of Tertiary deposits in the Bingerville region through two wells P1 and P2 allowed the study to carry out the lithostratigraphic description of the formations present and their contents in palynomorphs.

Sedimentologically, the sediments are mainly composed of lateritic clays, variegated, dark gray with pasts of ferruginous cuirasses. There are also ferruginous sandstones, sands and reddish clay sands.

From the stratigraphic point of view the study revealed a palynoflora attributable tot he Oligocene it is characterized by the following dinocysts: *Lejeunecysta pulchra, Lejeunecysta lata, Lejeunecysta globosa. Selenopemphix nephroids, Selenopemphix quanta, Operculodinium centrocarpum* and *Cordosphaeridium inodes.*

These dinocysts are associated with the following spores and pollen grains: *Magnastriatites howardii, Perfotricolpites digitatus, Pachydermites diederixi, Bombacacidites bombax, Retitricolporites irregularis, Retitriporites sp. Verrucatosporites usmensis etc.*

At the paleobotanical and paleoecological level, the highlighted palynoflora made it possible to characterize three environments, including mangroves, coastal plain, and rainforests.

Overall, the identifiable pollen assemblage of pollen reflects a mangrove environment with a low-lying, partly marshy wet forest in a tidal estuarine coastal environment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Dinoflagellate cysts

Cordosphaeridium inodes (Klumpp) Eisenack, 1963b
Lejeunecysta globosa Biffi and Grignani, 1983
Lejeunecysta lata Biffi and Grignani, 1983
Operculodinium centrocarpum (O. Wetzel, 1933a) Deflandre and Cookson, 1955
Spiniferites ramosus (Ehrenberg, 1838) Mantell, 1854

Pteridophyte and bryophyte spores

Laevigatosporites ovatus Wilson & Webster, 1947
Leiotriletes andriensis Krutzsch, 1959
Polypodiaceoisporites simplex Sah,1967
Verrucatosporites usmensis (Van der Hammen, 1956) Germeraad et *al*., 1968
Deltoidospora minor (Couper, 1953) Pocock, 1970

Angiosperm pollen

Crototricolpites densus Salard-Cheboldaeff, 1978
Echitriporites trianguliformis Van Hoeken-Klinkenberg, 1964
Margocolporites rauvolfii Salard, 1978
Monocolpites marginatus Van der Hammen, 1954
Oculopollis magnoporus Zaklinskaya, 1963
Pachydermites diederixi Germeraad et *al*., 1968
Perfotricolpites digitatus Gonzàlez Guzmàn, 1967
Praedapollis africanus Boltenhagen & Salard, 1973
Psilastephanocolporites perforatus Salard-Cheboldaeff, 1978
Psilastephanocolporites punctatus Salard-Cheboldaeff, 1978
Psilatrcolporites operculatus Van Der Hammen and Wijmstra, 1964
Psilatricolporites crassus Van der Hammen and Wijmstra, 1964
Psilatricolporites laevigatus Van der Hammen and Wijmstra, 1964
Retitricolpites americana Wymstra, 1964
Retitricolporites irregularis Van Der Hammen and Wijmstra, 1964
Spinizonocolpites cf. *baculatus* Müller 1968
Spinizonocolpites echinatus Müller 1968
Striatopollis bellus Sah, 1967
Triorites festatus Müller,1968

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