

## Sedimentary Deposits and Paleoenvironmental Changes in the Cenomanian–Turonian and Coniacian–Santonian Formations of the Ivorian Offshore Basin (Southeastern Abidjan Offshore Margin): The Case of the C1 Borehole

Larissa Chiayé KOFFI Epse COULIBALY <sup>1, \*</sup>, Léger Kouamé DJEYA <sup>2</sup>, César Yao AMANI <sup>1</sup>, Jolie –Wanesse Danielle Douzo <sup>2</sup> and Sylvain MONDE <sup>2</sup>

<sup>1</sup> Training and Research Unit of Geological Sciences and Mining, University of Man, BP 20 Man, Ivory Coast.

<sup>2</sup> Training and Research Unit of Earth and Resources Science Mining, University Félix Houphouët Boigny, 22 BP. 582 Abidjan 22, Ivory Coast.

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### Abstract

This geological study, conducted on a borehole located in the southeastern part of the offshore margin of Abidjan, Côte d'Ivoire, aims to reconstruct the sedimentary history and past environmental conditions of this area. This work. Following a lithological description, the 6 samples analyzed were washed, dried, sorted, and examined under a binocular microscope. The lithological analysis identified two major sedimentary units between depths of 3,420 m and 3,750 m: Unit I (Base): An alternation of clay and glauconite-rich sandstone beds (p. 3). Unit II (Top): A strong clay dominance with some intercalations of sandstone, containing pyrite and glauconite. The micropaleontological analysis revealed a microfauna dominated 82.77% by agglutinated benthic foraminifera (living on the seafloor), while planktonic foraminifera account for only 17.23%. Calcareous benthic foraminifera are completely absent. Biostratigraphy identified two age intervals based on Cenomanian–Turonian fossils (3,755 m–3,700 m), characterized by the species *Caudammina ovuloides* and *Caudammina ovulum* which are exclusively agglutinated benthic formaminifera. The Coniacian–Santonian (3,700 m–3,420 m) is identified by species such as *Dicarinella hagni* and *Archaeoglobigerina bosquensis*. The paleoenvironmental reconstruction concludes that the depositional environment evolved within a deep marine setting: Outer shelf near the slope: For the earliest period (Cenomanian–Turonian). Middle to outer shelf: For the more recent period (Coniacian-Santonian), with evidence of a low-oxygen (anoxic) environment explaining the rarity of calcareous forms.

**Keywords:** Micropaleontology; Biostratigraphy; Offshore Basin; Paleoenvironment

### 1. Introduction

The Ivory Coast sedimentary basin, located along the Atlantic Ocean in the northern Gulf of Guinea, is an area of major interest for the exploitation of natural resources and for understanding the region's geological history. This basin, which covers a narrow coastal strip representing 2.5% of Côte d'Ivoire's territory, is the result of several phases of structural and sedimentary evolution, ranging from rifting in the Lower Cretaceous to complete oceanization at the end of the Tertiary [1 ;2]

The study of sedimentary basins is essential for understanding the geological, biostratigraphic, and paleoenvironmental evolution of coastal basins. Sedimentary deposits, true natural archives, record the climatic variations, marine dynamics, and biological changes that have occurred over time. Thus, the study of microfossils, particularly foraminifera and palynomorphs, becomes crucial because it allows us to date different geological formations, determine depositional

\* Corresponding author: Larissa Chiayé KOFFI Epse COULIBALY

environments, and reconstruct the paleogeographic history of the basin. Recent studies conducted in the Ivorian sedimentary basin, both onshore and offshore, using various micropaleontological and sedimentological methods—including the work of [3,4,5;6] and many others—have shed light on the depositional environment. However, biostratigraphic data from the southeastern offshore portion of the basin are difficult to access, posing a major challenge for biostratigraphic studies and thus limiting our understanding of the depositional environments in this area. This data gap raises significant issues for understanding past ecological dynamics and geological evolution in this region. Thus, the C1 borehole, located in the eastern part of this basin, offers an opportunity to reconstruct the stratigraphic and paleoenvironmental history of this area. The combined approach of biostratigraphy and lithostratigraphy contributes to a better understanding of the geological processes and environmental dynamics that have shaped the Ivorian offshore basin.

The aim of this study is to determine the paleoenvironmental implications based on the microfauna and stratigraphic units of the sediments from borehole C1. Located southeast of the Abidjan margin, specifically between latitudes 4°17'N and 5°20'N and longitudes 4°17'W and 3°20'W, the C1 well has a depth of 3,750 m. (Figure 1).

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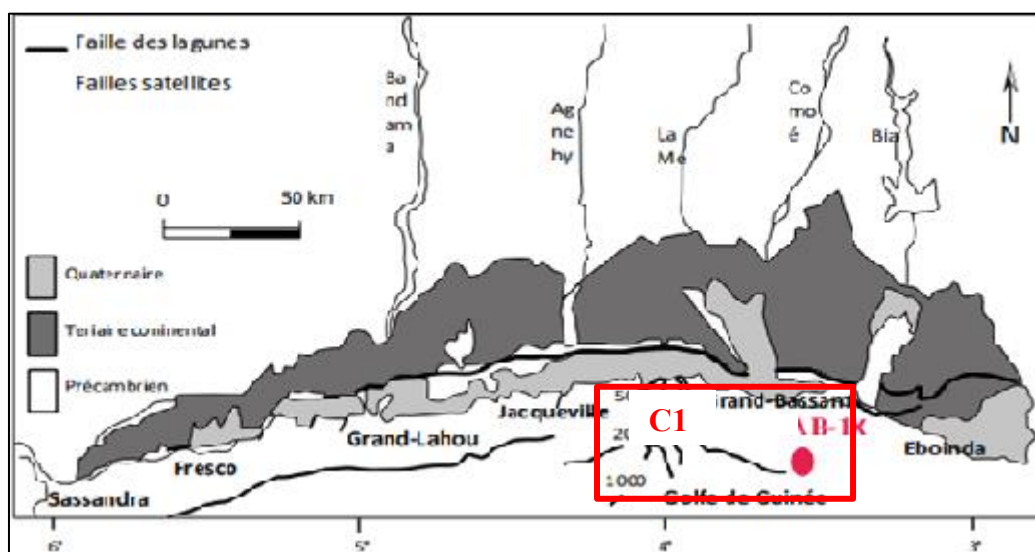


Figure 1 Location of the C1 borehole C1

## 2. Materials and Methods

Six samples of soil from Test Pit C1 were collected and described for this study. These samples were washed with soapy water using sieves with progressively finer mesh sizes (250, 100, and 63  $\mu\text{m}$ ). The residue from each sieve was then dried and sorted under a binocular magnifying glass to extract and describe all identified populations. Taxonomic identification of the microfossils involved identifying and naming the described faunas, then comparing them to faunas described in the species descriptions of known species in micropaleontological works, notably MIKROTAX; Foraminifera.eu, and the Atlas of Agglutinated Benthic Foraminifera by [7]. This allowed for a point count of the recovered microfossil forms and the proposal of a biostratigraphy for the studied interval. The determination of depositional environments is based on the Elf-Aquitaine depositional environment nomenclature [8] (1977), modified and adapted by [9] Goua (1997).

## 3. Results

### 3.1. Lithological Summary of Borehole C1

Analysis of the cuttings from borehole C1, at depths ranging from 3,420 m to 3,750 m, identified two units (Figure 2). Thus, in the direction of sedimentation:

- Unit I (3,750 m – 3,650 m):

This interval, with a total thickness of 100 m, is characterized by alternating layers of clay and numerous sandstone beds. The sandstones consist of fine to medium-grained material, and glauconite is present.

. Unit II (3,420 m – 3,650 m) A significant quantity of clay is observed, with interbedded sandstone layers (3,480 m). Accessory minerals include pyrite and glauconite.

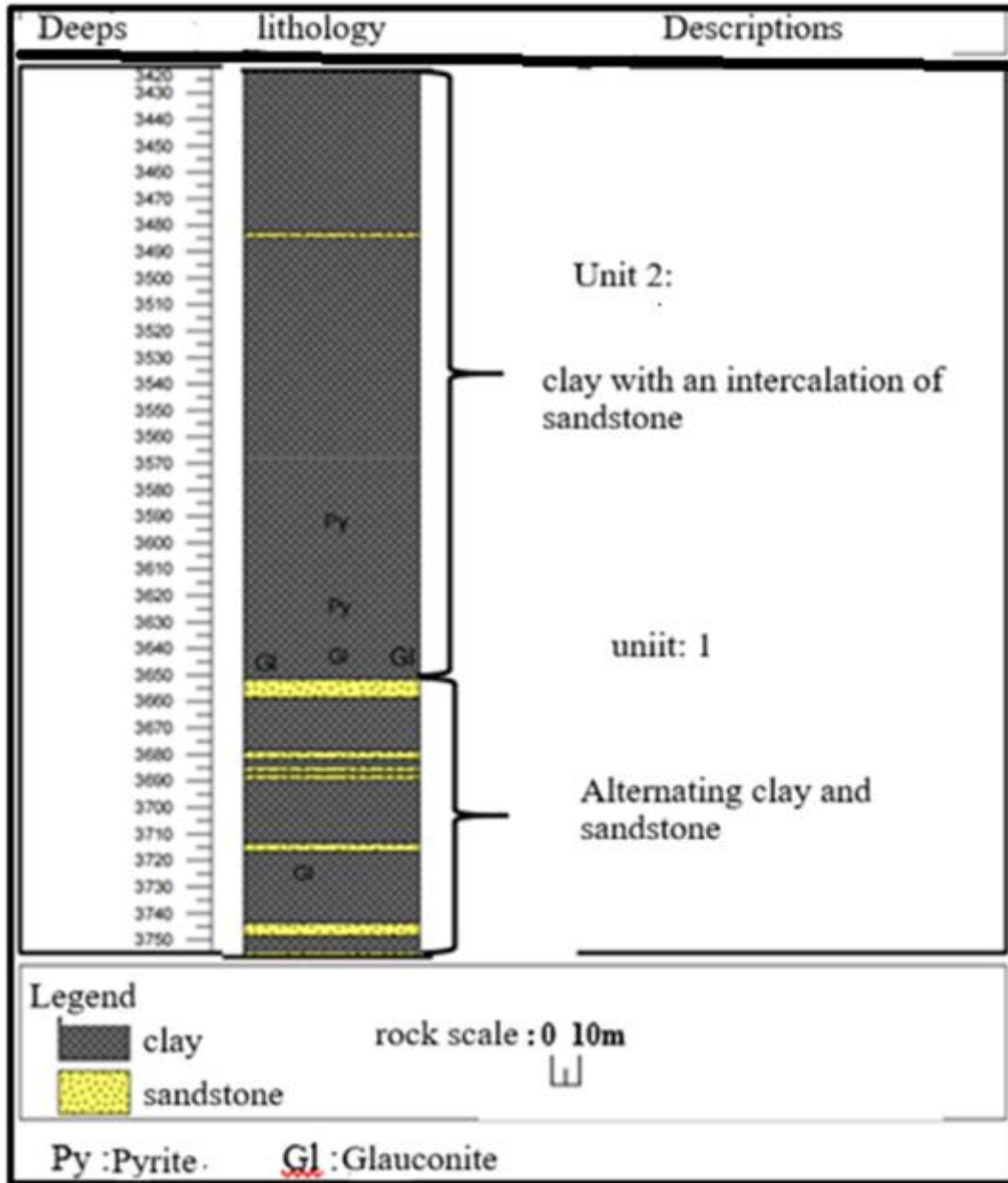
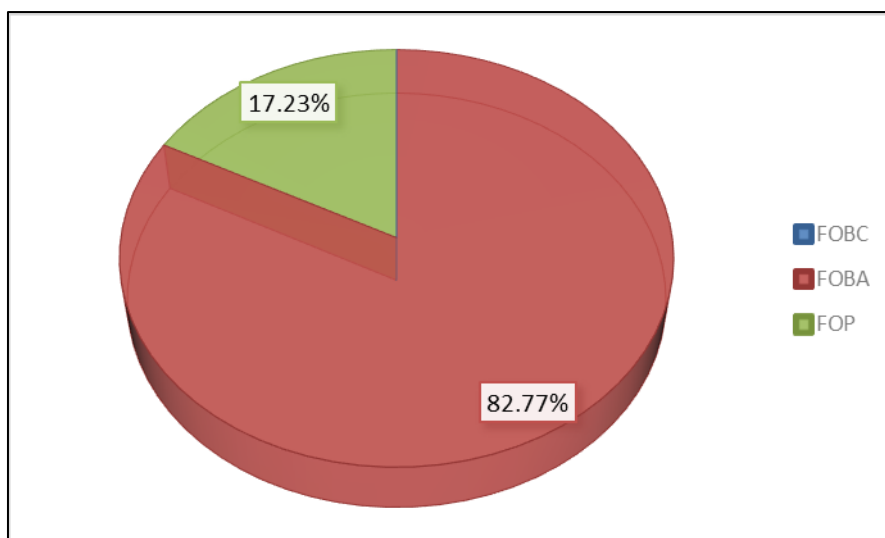


Figure 2 Lithological log of borehole C1

### 3.2. Micropaleontological study of borehole C1

Six samples were subjected to micropaleontological analysis. These samples provided a rich and diverse microfauna. There was a massive presence of agglutinated benthic foraminifera, with 615 individuals (82.77% of the total foraminifera population) distributed across 10 genera and 19 species, and 128 planktonic individuals (17.23%) distributed between 2 genera and 4 species (Figure 3).



**Figure 3** Representation of foraminifera by group based on their mode of life in borehole C1 (FOBC: Calcareous Benthic Foraminifera, FOBA: Agglutinous Benthic Foraminifera, and FOP: Planktonic Foraminifera)

### 3.2.1. Biostratigraphy of Borehole C1

The biostratigraphic divisions established in chronostratigraphic order of sedimentation have identified two (2) distinct levels based on microfaunal assemblages (Table 1).

Cenomanian – Turonian (3755 m – 3700 m)

The association of benthic (agglutinates and limestones) *Caudamina ovuloides* and *Caudamina ovulum* in the sense of sedimentation, combined with the absence of planktonic foraminifera, characterizes this level.

Coniacian –Santonian (3700 m – 3420 m)

Based on the sedimentary sequence, planktonic foraminifera such as *Dicarinella hagni*, characteristic of the Coniacian—and the presence of the species *Archaeoglobigerina bosquensis*, which is typical of the Santonian, allow this interval to be assigned to the Coniacian–Santonian age.

The presence of associated planktonic foraminifera such as *Archaeoglobigerina blowi* and *Archaeoglobigerina Cretacea* confirms that this interval is of coniacian-Santonian age.

**Table 1** Micropaléontological synthesis of berehole C1(Figure4 et 5)

DEPTH INTERVALS (m)	LEVELS	CHARACTERISTICS SPECIES		
		Planktonic Foraminifera	Benthic Calcareous Foraminifera and	Benthic Agglutinates Foraminifera
3700 – 3420	Coniacian-Santonian	<i>Archaeoglobigerina Cretacea</i> , <i>A. bosquensis</i> , <i>A. blowi</i> <i>Dicarinella hagni</i> ,	<i>Rzehakina épigona lata</i> <i>R. minima</i>	<i>Ammodiscus peruvianus</i> <i>Spiroplectamina navarrona</i> <i>S. spectabilis</i> <i>Reophax duplex</i>
3755– 3700	Cénomanian–Turonian	None	<i>Caudamina ovuloides</i> , <i>C. ovulum</i>	<i>Dorothia indatata</i> , <i>Haplophragmoides bulloides</i>

**Table 2** Composition of the microfauna in the study interval

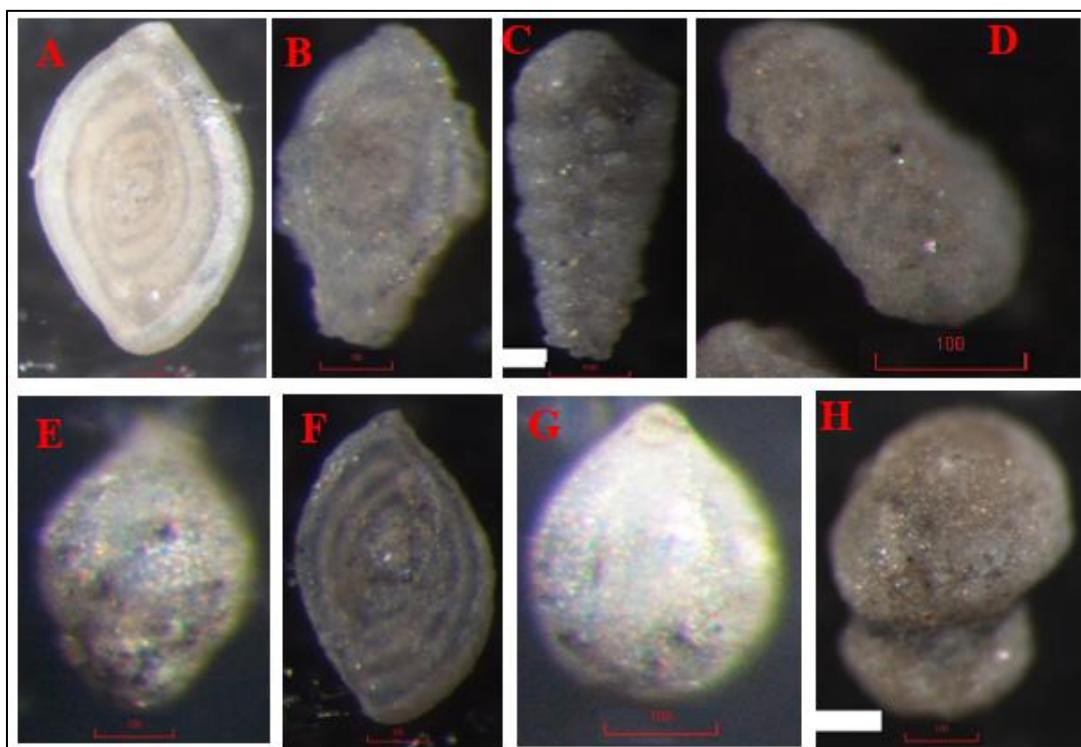
DEPTH(m)	FORAMINIFERA			
	FOBC	FOBA	FOP	Total foraminifera
3420 m-3510 m	0	128	40	168
3510 m - 3520 m	0	284	3	287
3530 m -3540 m	0	118	84	202
3560 m -3570 m	0	51	0	51
3630 m -3655 m	0	32	1	33
3720 m - 3755 m	0	2	0	2
TOTAL	0	487	88	575
PERCENTAGE	0	82.77%	17.23%	

### 3.3. Paléoenvironment of berehole C1 (Tableau 2)

#### 3.3.1. Distribution Analysis:

Agglutinated Benthic Foraminifera (FOBA) are the most consistent. They are present throughout the entire sedimentary column, with a maximum abundance (50–200 individuals) during the Coniacian and Santonian (between 3,700 and 3,420 m); in contrast, calcareous benthic foraminifera (CBF) are very limited and appear only between 3,755 and 3,700 m, during the Cenomanian and Turonian, with low abundance (1–10 individuals). They disappear completely at the top of the Turonian. Planktonic foraminifera (FOP) are present intermittently. They are absent at the beginning of the Coniacian, then show variations in abundance (up to 10–50 individuals) during the Coniacian and Santonian.

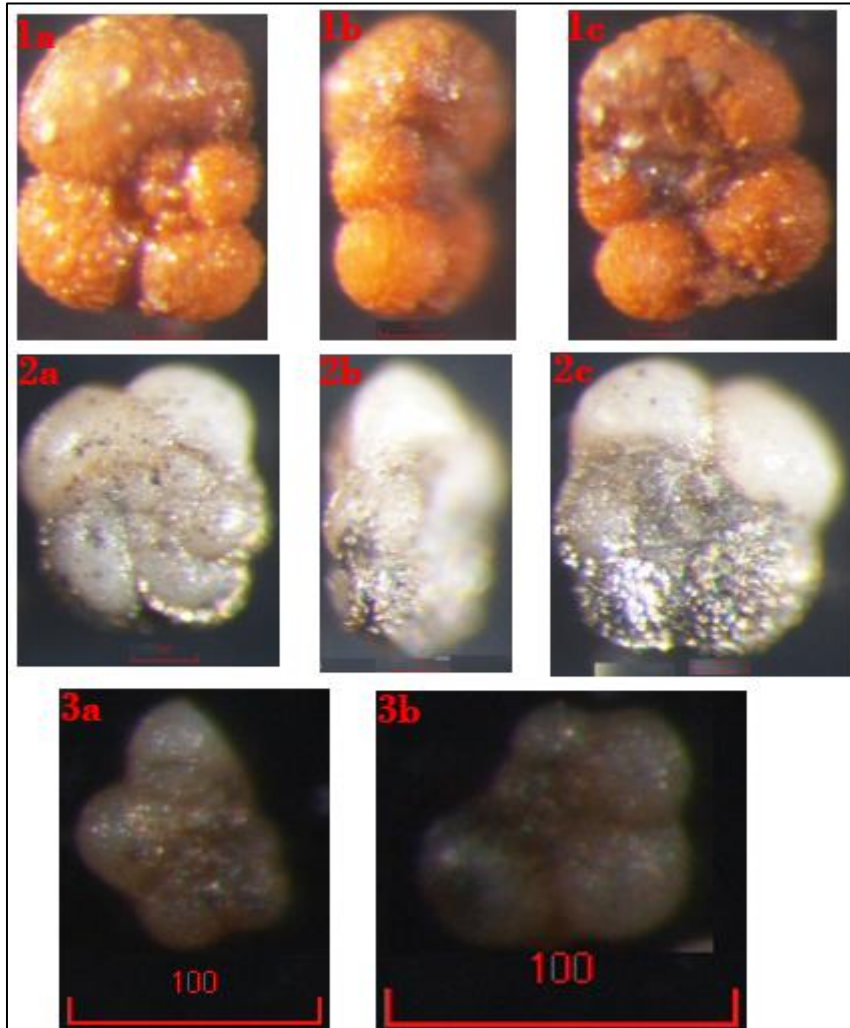
#### 3.3.2. Evolution of the paleoenvironment



**Figure 4** Agglutinated and calcareous benthic foraminifera  
**A:** *Rzehakina épigona lata* (Cushman & Jarvis, 1928); **B:** *Ammodiscus peruvianus* (Berry, 1928); **C:** *Spiroplectamina navarrona* (Cushman, 1932); **D:** *Spiroplectamina spectabilis* (Grzybowski, 1898 corrigés par Kaminski, 1984); **E:** *Caudamina ovuloides* (Grzybowski, 1901); **F:** *Rzehakina minima* (Cushman & Renz, 1946); **G:** *Caudamina ovulum* (Grzybowski, 1896) corrigé. Geroch, 1960; **H:** *Reophax duplex* (Grzybowski, 1896)

**Figure 4** Agglutinated and calcareous benthic foraminifera

The evolution of these microfossils allows us to infer significant environmental changes. The predominance of Agglutinated benthic foraminifera (FOBA) suggests a depositional environment on the seafloor at great depths of more than 3,400 m. Indeed, the disappearance of calcareous forms and the exclusive persistence of agglutinated forms starting at 3,700 m during the Coniacian-Santonian could indicate that the environment was located near or below the CCD, where limestone is dissolved. At this depth, calcium carbonate dissolves, preventing the survival or preservation of calcareous shells, favoring agglutinated shells instead. The increase in planktonic foraminifera toward the Santonian indicates a better connection with the environment, favoring the development of organisms living in the water column. These key findings suggest a phase of marine transgression or deepening of the basin, leading to a deep environment located below the carbonate stability zone.



1 : *Archaeoglobigerina blowi* ; (1a : face ombilicale ; 1b : vue de profil ; 1c : face spirale) ; 2 : *Dicarinella hagni* ; (2a : face ombilicale ; 2b : vue de profil ; 2c : face spirale) ; 3 : *Archaeoglobigerina cretacea* ; (3a : face spirale ; 3b : face ombilicale)

**Figure 5** Planktonic foraminifera

#### 4. Discussion

From a lithological perspective, the analysis identified four types of facies: predominantly clays, sandstone beds, marls, and layers of limestone, pyrite, carbonaceous debris, and micas. Studies conducted by [10, 11] on borehole D1-1X in the Ivorian basin, highlighting a similar lithology—primarily detrital, composed of black pyritic clays and sandstone—are consistent with our work carried out in the same basin. Indeed, the presence of carbonaceous debris in certain sections indicates the proximity of the continent to the sedimentation zone. The identified limestone levels result from deposits associated with lateral accumulations formed during the stabilization of the basin [12]. These formations occur within a context of marine transgression characterized by a reduced supply of detrital sediments, thereby allowing the development of platform carbonates in a low-depth environment.

From a biostratigraphic and paleoenvironmental perspective, the analyzed microfauna consists mainly of agglutinated benthic foraminifera such as *Haplophragmoides*, *Spiroplectammina*, and *Trochammina*, which are characteristic of deep-sea environments. These results were observed by [11], who states that all these species are characteristic of deep-water environments and exhibit specific ecological preferences. They are generally epifaunal or endofaunal species found in the middle to outer shelf zone near the shelf slope. The abundance of agglutinated benthic foraminifera indicates an anoxic environment on the bottom, which would explain the absence of calcareous benthic foraminifera. These results are consistent with the work of [13], which suggests that the formation of an oxygen-depleted water layer at the seafloor would explain the total absence of calcareous benthic foraminifera.

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## 5. Conclusion

The analysis of six soil samples from the eastern part of the Ivorian Basin has enabled characterization in three areas: lithological, biostratigraphic, and paleoenvironmental. Indeed, the deposits studied consist mainly of clays interbedded with limestone, sandstone, and marl; the accessory minerals identified are glauconite, pyrite, and carbonaceous debris. These sediments contain a relatively diverse microfauna dominated by agglutinated benthic foraminifera compared to calcareous and planktonic benthic forms. The use of these agglutinated benthic forms has revealed two stages in each borehole:

- The Cenomanian–Turonian, characterized by an association of species composed of *Reophax* and *Caudammina*.
- The Coniacian–Santonian, revealed by species such as *Dicarinella hagni* and *Archaeoglobigerina bosquensis*

From a paleoenvironment perspective, the associations of calcareous planktonic and benthic foraminifera, on the one hand, and the ecological preferences of agglutinated benthic foraminifera (epifauna to endofauna), on the other, have revealed that the Cenomanian-Turonian clay sediments were deposited in an environment above the CCD (presence of FOBC). As the basin deepened, the absence of calcareous benthic foraminifera and the explosion of agglutinated benthic foraminifera confirm an abyssal plain or trench environment.

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## Compliance with ethical standards

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### *Disclosure of conflict of interest*

The authors declare that they have no conflicts of interest. Compliance with ethical standards.

### *Statement of informed consent*

The authors declare that they participated in the drafting and compilation of the article and give their consent for publication in your journal.

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