Biostratigraphy and paleoenvironment of the lower Cenomanian-Senonian interval in the KES-1 well of the Abidjan margin (Côte d’Ivoire)

T. M. Kesse¹, J. M. K. Gbangbot²*, Z. D. A. Behi³, N.J.P. Yao³, Z. B. Digbehì³

1Institute National Polytechnic of Yamoussoukro
2University Jean Lorougnon Guede of Daloa, UFR Environment BP 150, Laboratory of Environmental Sciences and Technologies
3University Félix Houphouët Boigny of Cocody, UFR Earth Sciences and Mining Resources, Laboratory of Marine Geosciences

Received 15 Jan 2019; Revised 29 Jan 2019, Accepted 12 Feb 2019

*Corresponding author:gbangbotjeanmichel@yahoo.fr

Keywords
Biostratigraphic Analysis, Paleoenvironment, Cenomanian, Turonian, Senonian

Abstract
Fifteen samples (13) of drill cuttings ranging from 2630 m to 2400 m were subjected to biostratigraphic analysis to determine the age and the sediment deposition environment from KES-1 drilling. KES-1 is located in the submerged (offshore) part of the sedimentary basin of Côte d’Ivoire. Sorting revealed the presence of 1003 individuals, of which 831 planktonic foraminifera represented 82.85%, 98 benthos forlengoinds agglutinated or 9.77% and 74 calcareous benthic foraminifers, or 7.38%. These foraminifers have been identified and used for dating formations traversed by drilling. Thus, on the basis of the first or the last appearances of planktonic foraminifers and microfaunistic associations, the determined ages are the Cenomanian, the Turonian and the Lower Senonian (Coniacian). The diversity of planktonic foraminifers and the presence of benthic foraminifers has allowed the paleoenvironmental reconstitution of the seabed from internal neritic to lower bathyal type.

1. Introduction

For many years, very thorough studies have been undertaken both in a scientific and economic framework at the level of the Ivorian sedimentary basin in order to know the conditions of its implementation, its components as well as its evolution. Especially:

-[1-4], provided details of the fauna of lamellibranchs, gastropods, and microfauna (foraminifers, ostracods) and the Cretaceous and Tertiary microflora;

-[5-10], from micropaleontological data, subdivided Paleocene and Upper Cretaceous into foraminifera biozones and provided insights into deposition environments;
-[11] undertook studies on Calcisphaerulidae from micropaleontological and sedimentological data syntheses in the Ivorian basin which resulted in a West-East correlation test carried out by [12];

-[13], from the analysis of sedimentary formations related to the fault of the lagoons, showed the presence of Burdigalian in the onshore basin Ivorian more precisely to the south of the fault.

These studies made it possible to define the geological and biostratigraphic context as well as the oil system of the Ivorian margin. But there is a need for in-depth knowledge, mainly from Cenomanian to Senonian.

The present study has the dual purpose of characterizing the biostratigraphy and palaeoenvironment of the Lower Cenomanian-Senonian interval of the KES-1 offshore oil well off the Abidjan margin. Its geographical coordinates are: 4 ° 49’20,24”N and 3 ° 15’19,44” W.

Fig.1. Geographical location of the KES-1 well

The geology of Côte d’Ivoire consists of a Precambrian basement that covers 97.5% of the country and a secondary and tertiary sedimentary basin that forms a thin littoral fringe [14-16]. The geochronological studies carried out on this base, distinguish an archean (3000 to 2300 m.a.) corresponding to the orogenic cycle said Liberian and a Proterozoic lower and middle or Birimian (2300 to 1500 m.a.) and corresponding to the orogenic cycle called Eburnean. Liberian formations are out in the west of the country; the Birimian occupies almost the entire territory. The coastal sedimentary basin represents only 2.5% of the territory. It is affected by a major tectonic accident called "Lagoon fault" which would be an extension in the continental domain of the oceanic fracture of Saint-Paul [17]. Its rejection can reach 5000 m.
The submerged part (offshore) represents the largest part of the basin and develops on the continental shelf 25 to 30 km wide [14,15,18]. This deep basin is delimited by two major transoceanic faults, notably the Romanche fault in the South-East and the Saint-Paul Fault in the North-West, which constitutes the major glacis accident.

2. Material and methods

The material in this study consists essentially of 13 samples of KES-1 well cuttings in the range 2630 m - 2400m. They served as a support for the biostratigraphic analysis. Indeed, each 40g sample was soaked and then washed with soapy water, sieved wet on a column of three sieves mesh downward decreasing (250 microns, 100 microns and 63 microns). The refusals are dried, sorted and observed under a binocular microscope for their taxonomic determination supported by micropaleontological works, particularly those of [10,19-31]. The dates of the formations have adopted the distribution scales of [21,28,32]. The reconstruction of the depositional environments was based on the models of [31,33] which propose a model of bathymetric distribution of planktonic foraminifers of higher Cretaceous age.

3. Results and interpretations

3.1. Quantitative study of the microfauna

The micropaleontological study provided a rich microfauna composed of foraminifera (1003). Planktonic foraminifers constitute a very important population in the studied interval. There were 831 individuals, representing 82.85% of the total population, divided into 11 genera and 32 species. Planktonic foraminifers consist of globular forms and carinated forms. In addition, benthic foraminifers are composed of agglutinated benthic forms and calcareous benthic forms. Agglutinated benthos foraminifera account for 98 individuals, or 9.77% of the population, divided into 9 genera and 12 species. The limestone benthic foraminifers include 74 individuals, or 7.38% of the population, divided into 7 genera and 10 species.

3.2. Biostratigraphie

The study interval was subdivided into three floors thanks to microfaunistic associations. These are Cenomanian, Turonian and Lower Senonian (Coniacian).

3.2.1. Cenomanian (2630 m-2600 m)

The Cenomanian in this interval is marked by a proliferation of individuals of the genus Hedbergella including Hedbergella delrioensis. This floor is also characterized by a relative abundance of species Whiteinella brittonensis, Hedbergella planispira and Whiteinella baltica. The roof of this stage was fixed mainly by the last appearance of the species Globigerinelloides bentonensis. This last occurrence confirms the Cenomanian age.

3.2.2. Turonian (2600m - 2470m)

This interval has been subdivided into lower or basal Turonian and medium to upper Turonian. It is marked by an abundance of the genera Whiteinella and Heterohelix.
• Lower or basal Turonian (2600 m-2580 m)

The lower Turonian is marked by the first appearances of the species *Whiteinella archaeocretacea*. This subinterval is marked by the presence of the genera *Heterohelix* and *Whiteinella* (*Whiteinella baltica* and *Heterohelix globulosa*) associated with some benthic forms. Note that the foraminiferal population is quite small.

• Turonian medium to upper (2580 m - 2470 m)

This subinterval is characterized by an explosion of the foraminiferal population dominated by the genus *Whiteinella* to the Middle Turonian, followed by the genus *Heterohelix* to the Upper Turonian. There is also an increase in number and diversity of benthic forms throughout this stage. The association of several species composed of *Heterohelix globulosa*, *Hedbergella delrioensis*, *Hedbergella flandrini*, *Whiteinella baltica*, *Whiteinella archaeocretacea* and *Heterohelix reussi*, indicates a middle to late Turonian age. This association made it possible to fix the roof of the Turonian.

3.2.3. Lower Senonian (Coniacian) (2470 m - 2400 m)

The associations of planktonic foraminifera *Dicarinella cf concavata*, *Heterohelix glabrans*, *Whiteinella paradubia*, *Heterohelix reussi*, *Heterohelix globulosa*, *Hedbergella delrioensis*, *Whiteinella baltica*, *Dicarinella hagni*, *Marginotruncanen renzi*, *Marginotruncanen sinuosa*, *Whiteinella archaeocretacea* and *Hastigerinoides sp*., argue in favor of Senonian age lower (Coniacian). The presence of benthic forms characterized by the following associations: *Neobulimina subregularis*, *Praebulimina robusta*, *Praebulimina fang*, *Praebulimina prolixa longa*, *Gyroidinoides subangulatus*, *Gyroidinoides spp.*, *Conorotalites michelinianus* and *Lenticulia spp*. They make it possible to confirm the belonging of this floor to the Lower Senonian (Coniacian).

4. Paleoenvironment

The assemblage of the microfauna of the study interval leads to the identification of the different deposition environments which are established as follows:

4.1. The Cenomanian (2630 m - 2600 m)

This range is marked by a small population of planktonic foraminifera but dominated by globular forms composed of the genus *Hedbergella* (40%) and the genus *Whiteinella* (29%). There is a relative abundance of the genus *Heterohelix* is 27%. However, the genera *Hedbergella* and *Whiteinella* are considered to be open sea taxa, which predominate when water depths are respectively low and intermediate or when the conditions are unfavorable greater depths (case of areas of minimum oxygen). The preferred areas of productivity (higher nutrient intakes) seem rather to result in a clear increase in the number of opportunistic globular forms such as the *Heterohelix*.Moreover, the analysis of the data reveals a significant importance of the genus *Heterohelix* (29%). These indications suggest that we are in a shallow area. The species belonging to the first genera cited live between 0 and 100 m of water, and those of the second genus between 0 and 50 m. Hence this level can be attributed to a internal neriticenvironment to medium neritic.
4.2. The lower or basal Turonian (2600 m - 2580 m)

This interval is marked by an abundance of the genus *Heterohelix*, 55%, followed by some *Whiteinella* (31%) and *Hedbergella* (14%). Note that the foraminiferal population is quite small in this interval, slightly dominated by the genus *Heterohelix*. Since the minimum water limit for species belonging to this genus is 50 m, this level can be attributed to an internal neritic zone.

4.2.1. The middle Turonian (2580 m - 2470 m)

Because of its thickness this interval will be subdivided into three units to know:
- unit 1, from 2580 m to 2560 m;
- unit 2, from 2560 m to 2520 m;
- unit 3, from 2520 m to 2430 m.

**Unit 1 (2580 m to 2560 m):** This unit is characterized by a dominance of globular forms composed by the genera *Hedbergella* and *Whiteinella* (80%) and a decrease of the genus *Heterohelix* is 20%. However, *Hedbergella* and *Whiteinella* are considered to be open sea taxa, which predominate when water depths are respectively low and intermediate or when conditions are unfavorable at greater depths [33]. So, this level can be attributed to neritic internal neritic means.

**Unit 2 (2560 m to 2520 m):** This unit is dominated by the genus *Whiteinella*. This genus alone accounts for nearly 90% of the planktonic microfauna and lives between 0 and 100 m of water. The genera *Hedbergella* and *Heterohelix* represent less than 10% of the planktonic population. This zone can so be attributed to a medium-to-internal neritic level because of its low *Heterohelix* genus rate.

**Unit 3 (2520 m to 2470 m):** This upper unit shows a sudden decrease in planktonic foraminifera. This observation doesn’t allow the exploitation of planktonic foraminiferal data. Nevertheless, the use of the benthics aggregated / total benthic report allowed to characterize this unit. Indeed this level contains:
- 42% agglutinated benthic foraminifera that resemble typical upper slope assemblages - average slope after [31]. They are: *Dorothia, Gaudryina, Tritaxia, Ammodiscus, Haplophragmoides, Subreophax, Trochammina, Nothia* and *Trochamminoides*;
- 35% of the limestone benthic limestone microfauna [28] in particular: *Gyroidinoides spp* and *lenticulina spp*. This level can be attributed to a medium bathyal medium to lower bathyal.

4.2.2. The Lower Senonian (Coniacian) (2470 m to 2400 m)

This range is marked by the presence of keeled (7 to 10%) dominated by species belonging to the genus *Dicarinella*, associated with the genus *Marginotruncana*. These genera, at the adult stage, only colonize deep waters of at least 100 m. In addition, in reference to the work of [34], the presence of the few planoconvex forms that are *Dicarinella* suggests an increase in depth. Therefore the lower Senonian (Coniacian) would correspond to the average outer neritic.

The different depositional environments that prevailed during the sedimentation period in the range studied are shown in Fig. 2.
Fig. 2. Foraminiferal evolution curve and palaeoenvironmental evolution of the Cenomanian-Lower Senonian (Coniacian) interval in the KES-1 well

Discussion

The different microfaunas studied, which made it possible to establish the biostratigraphy of our study interval, are for the most part known in the Phanerozoic basins bordering the Atlantic coast. Indeed, they have been studied in the Cretaceous sediments of Senegal [35], Gabon [36], Angola [19], Congo [31]. Although Rotalipora (markers of the Cenomanian, [19]) are absent in the sediments studied, we note in our work the presence of the species *Globigerinelloides bentonensis* used by [32] to characterize the Cenomanian superior in their studies on the Brazil Basin. These results were confirmed by [12] in the Ivorian offshore. The present study has highlighted the Cenomanian on the basis of associations composed of *Hedbergella planispira*, *Hedbergella delrioensis* and *Globigerinelloides bentonensis*. It has an abundance of the genus *Hedbergella*, according to the work of [8, 37]. These authors confirm the presence of the Cenomanian in our study interval. The Cenomanian-Turonian limit observed globally by the decline of the foraminiferal (planktonic and benthic) population was not observed in our work.
Some authors have specified that the Cenomanian-Turonian transition is characterized by the zone at *Whiteinella archaeocretacea* defined at its base by the last occurrence of *Rotalipora cushmani* and at its peak by the first occurrence of *Helvetoglobotruncana helvetica*. What could not be observed in our well.

The species *Whiteinella baltica* and *Heterohelix globulosa* are abundant in Turonian, this result is in line with those made in the Ivory Coast basin by [8, 38] and in the Senegalese basin by [39]. The basal Turonian was highlighted through this study by the first occurrences of the species *Whiteinella archaeocretacea*. This result is consistent with those of [40] which showed that the species *Whiteinella archaeocretacea* appears at the base of the Turonian.

The roof of the Turonian has been fixed on the basis of the last appearances of the species *Claviherbergella cf. amabilis* in association with the species *Hedbergella flandrini* and *Hasitgerinoides subdigitata*. The species *Heterohelix moremani* which has been used to fix the Turonian roof in most studies carried out on the sedimentary basin of Côte d’Ivoire, in particular those of [12] and [37] was not observed in our samples.

The last appearance of the species *Whiteinella paradubia* and *Hedbergella planispira* occurs in the Coniacian. These two species in association with *Dicarinella concavata* made it possible to characterize the lower Senonian (Coniacian). Benthic foraminifers are present: *Gavelinella sp*, *Buliminella sp*, *Siphogerinoides sp*, *Praebulimina sp*, *Neobulimina sp* and *Afrobolivina sp*.

According to the work carried out on the Ivory Coast-Ghana ridge by [27] in [37], the average Coniacian to Upper Santonian interval is marked by a diversity and an abundance of benthical foraminifers such as *Praebulimina sp*, *Buliminella sp*, *Neobulimina sp*, *Gyroidoids sp*, *Gavelinella sp* and *Lenticulina sp*. This information corroborates our results.

It should also be noted that the successive occurrences of planktonic organisms along the depth gradients are influenced by a number of ecological factors. These factors may include intensification and deepening of the minimum oxygen zones [41, 42, 43], fluctuations contribution nutrient [44] or salinity [43]. Thus, are *Hedbergella* and *Whiteinella* considered to be open sea taxa, which predominate when water depths are respectively low and intermediate, or where conditions are unfavorable at greater depths (case, areas of minimum oxygen) [41, 42, 43]. *Heterohelix* are interpreted as opportunistic taxa indicative of high (eutrophic) or unstable productivity conditions (salinity and / or oxygen)[44]. Keeled taxa are considered to be forms of equilibrium, open sea, which abound when the depths of water are large and the conditions favorable. Ultimately, the literature indicates that in oligotrophic zones, for example, the high percentage of planktonic foraminifers with frequent carinated specimens is the characteristic of deep water. While low percentages of foraminifera with frequent species not keeled (or without keeled forms) indicate low water depths. However the abundant supply of nutrients (in the eutrophic zones) can disturb this relation. [31].

**Conclusion**

The biostratigraphic and palaeoenvironmental characterization of the 2630 m - 2400 m interval of the KES-1 borehole was conducted in different stages. Micropaleontology revealed a microfauna dominated by planktonic foraminifera, followed by agglutinated benthical foraminifera, and calcareous benthical foraminifera.

The Cenomanian (2630 m - 2600 m) is characterized by the association of *Whiteinella brittonensis*, *Hedbergella planispira*, *Hedbergella delrioensis* and *Globigerinelloides bentonensis*. 

The Turonian (2600 m - 2470 m) is characterized by the association composed of the species *Heterohelix globulosa, Hedbergella delrioensis, Hedbergella simplex, Hedbergella flandrini, Whiteinella baltica, Whiteinella archaeocretacea* and *Heterohelix reussi*.

The Lower Senonian (Coniacian) (2470 m - 2400 m) is defined by the species *Hedbergella delrioensis, Hedbergella planispira, Whiteinella paradubia, Dicarinella hagni, Marginotruncana renzi, Whiteinella archaeocretacea, Praebulimina robusta, Praebulimina fang, Praebulimina prolixa longa, Gyroidinoides subangulatus* and *Conorotalites michelinianus*.

Finally, the bibliographic data associated with the foraminiferal study have been useful approaches in the estimation of palaeoenvironments ranging from internal neritic to talus (lower bathyal).

The following figures represent the main foraminifers observed in the sediments of the KES-1 well.

Fig 4: a: Umbilical Face ; b: Profile ; c: Spiral face

1- *Archaeoglobigerina cretacea*, 2-*Whiteinella baltica,*
**Fig. 5.** :a: Umbilical face ; b : Profile ; c : Spiral face

1- *Whiteinella brittonensis*,

**Fig 6:** a: Umbilic face ; b : Profile ; c : Spirale face

1-2 : *Globigerinelloides bentonensis*, 3- *Gavelinella sp,*
References


(2019) © JASES, USMBA Fez, Morocco