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Sequential Analysis in the Identification of 3rd Order System Tract in the Abidjan Margin

Blandine Akissi Egoran[1], N'guessan Donald Ahoure[2], Fori Yao Paul Assalé[3], Sylvain Mondé[3], Loukou Victor N'da[4]

[1]UFR Marine Sciences, San Pedro University, San Pedro, Côte d'Ivoire
[2]UFR of Sciences and Technologies, Alassane Ouattara Bouaké, Laboratory of Plant Biology and Earth Sciences, Bouaké, Côte d'Ivoire
[3]UFR/STRM, Félix Houphouët Boigny de Cocody, Abidjan, Côte d'Ivoire
[4]PETROCI, Consultant at the Center for Analysis and Research, Department of Sequential Stratigraphy, Abidjan, Côte d'Ivoire
Email: blandineegoran@gmail.com

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Abstract

The use of sequential stratigraphy concept, based on well logs, sedimentology, and biostratigraphy, has shed light on the complex mechanisms controlling sedimentary accumulations. Consequently, identifying these mechanisms allows us to predict the hydrocarbon generation potential of source rocks. In the Ivorian offshore sedimentary basin, certain studies have contributed to understanding and characterizing the petroleum system. However, these previous works did not integrate biostratigraphic data to highlight sedimentary facies. This study, conducted on two wells in the Abidjan margin, is crucial as it helps us comprehend the geometry of fossil sediments in relation to sea level variations. It will also aid in reconstructing the basin-filling history and predicting the distribution of rocks capable of trapping oil, determining lowstand systems tracts (reservoir rocks), transgressive systems tracts, and highstand systems tracts (cap rocks). Lithological analysis revealed predominantly clayey sedimentation with sandy layers. Well log data facilitated the delineation of formation boundaries and highlighted reservoirs consisting of sands, sandstones, limestones, and occasionally intercalated shales. Integrating these analysis results with biostratigraphic interpretations based on foraminifera and palynomorphs revealed that the traversed formations were deposited in a transitional environment ranging from Coniacian to Maastrichtian ages. Applying sequential stratigraphy concept from well logging resolved dating issues encountered in microfossil-poor or microfossil-free zones. The results of the Coniacian-Maastrichtian age sequential subdivision were aligned with the chart.

Keywords

Sequence Stratigraphy, Systems Tracts, Senonian, Côte d'Ivoire

1. Introduction

Sequential stratigraphy emerged in the petroleum industry in the 1970s to 1980s, although some of its conceptual foundations date back to ancient Greece. Applying stratigraphic concepts allows for reconstructing the history of sedimentary basin filling, studying the factors influencing sedimentation, and predicting the distribution of reservoirs, covers, geometry, and continuity of associated reservoir and cover rocks. Sequential stratigraphy has become indispensable in sedimentary geology and has evolved significantly since the publication of the "Exxon" [1] report. The sediment geometry in the Senonian at the Abidjan margin remains poorly understood because few synthetic studies have been completed so far.

In Côte d'Ivoire, the sedimentary basin has been the subject of several research programs. However, most studies conducted both onshore and offshore, especially the work carried out by [2] [3] [4], have focused on the sedimentology and biostratigraphy characterization of the Ivorian sedimentary basin. These research efforts have shed light on the basin's stratigraphy and depositional environments. Nevertheless, previous investigations into the Ivorian sedimentary basin have not integrated sequential stratigraphy.

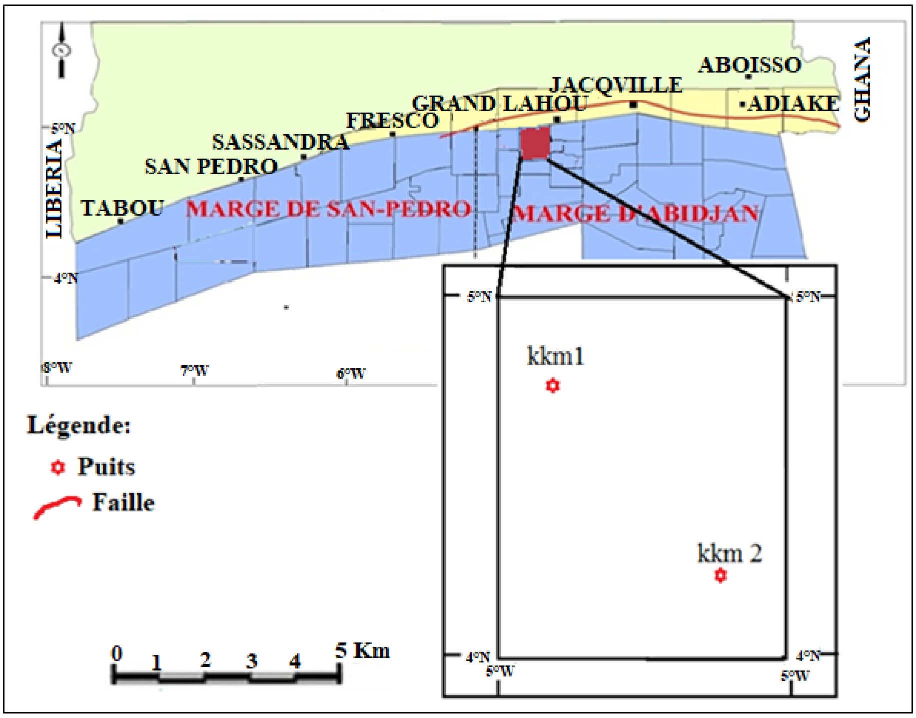

Figure 1. Geographic location of the studied boreholes.

As a result, this methodology, primarily focused on layer arrangement correlating with cyclic sea-level variations, deserves detailed examination. This would facilitate understanding the spatial arrangement of reservoir formations, covers, and source rocks, aiming to enhance knowledge in petroleum geology.

This study aims to sequentially divide the geological stages identified in boreholes based on biological, diagraphic, and sedimentological data to highlight sequence boundaries, transgressive surfaces, and maximum flooding surfaces. This sequential approach relies on the study of two boreholes located in the same block within the Abidjan margin (**Figure 1**).

2. Method

In this study, biostratigraphic, sedimentological, and diagraphic data constituted the main material. The method described for sequential division involves the inventory of bio-events, followed by the analysis of diagraphic and lithological data. Subsequently, we will align faunal and microfloral data with electrofacies and lithological data. The final step involves the sequential division of geological stages highlighted by biostratigraphy. Afterwards, deposition assemblages are identified within the sequences, notably in relation to geometries, facies, and the platform edge. Determination of the maximum flooding surface was carried out in the clay formation using gamma-ray, density, and neutron diagraphies. Defined sequence boundaries will be determined based on geometric relationships of markers (biostratigraphies), truncation, or erosion. All of this is harmonized with the sea level variation chart [5] (internal report of Petroci) (**Figure 2**).

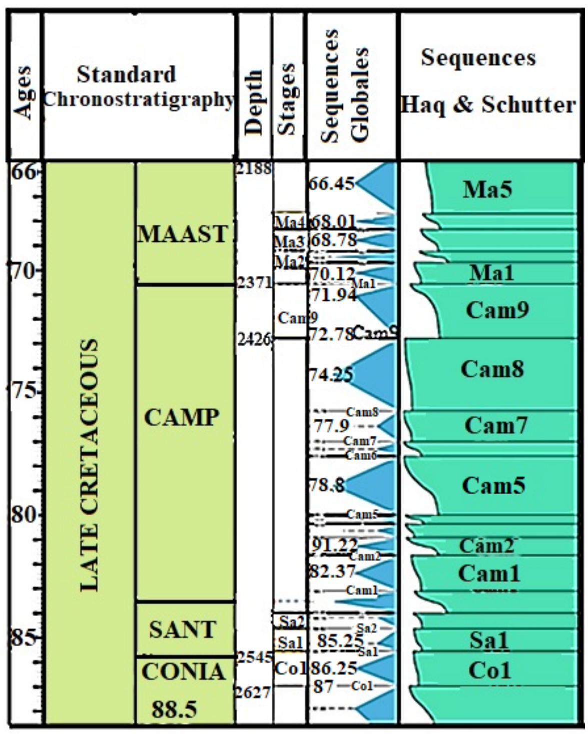

Figure 2. Chronostratigraphic chart.

3. Results

The deposit sequences were defined based on diagnostic microfossil species, gamma ray logs, and microfossil distribution curves. The sequence chart used is from [6] (Petroci internal report).

3.1. Sequential Division of Sedimentary Deposits kkm 1

Coniacian depositionalsequence: 2608 m - 2552 m

The terms of the sequence:

The faunal assemblage identified consists of species belonging to the Coniacian (Co1). Within this interval, the top of the Coniacian is fixed at 2552 m by the first appearance during drilling of *Whiteinella archaeocretacea*. This Co1 sequence is confirmed by drilling direction appearances (FDO) of *Marginotruncana sinuosa* at 2580 m, *Tricolpites Sp Sci* 217 at 2590 m, and *Whiteinella britonensis* at 2598 m (**Figure 3**).

In the Co1 sequence, the lowstand system tract extending from 2542 m to 2608 m, shows an increasing trend in gamma ray curve values. This assemblage consists of argillites with the presence of sand beds. Planktonic foraminifera are abundant, compared to agglutinated foraminifera (in small quantities) and calcareous foraminifera (in small quantities). Palynomorphs are absent, suggesting a mid-neritic to inner neritic environment. The transgressive system tract, located between 2582 m and 2592 m, reaches its maximum flooding surface (MFS) and is characterized by a peak in the gamma ray curve.

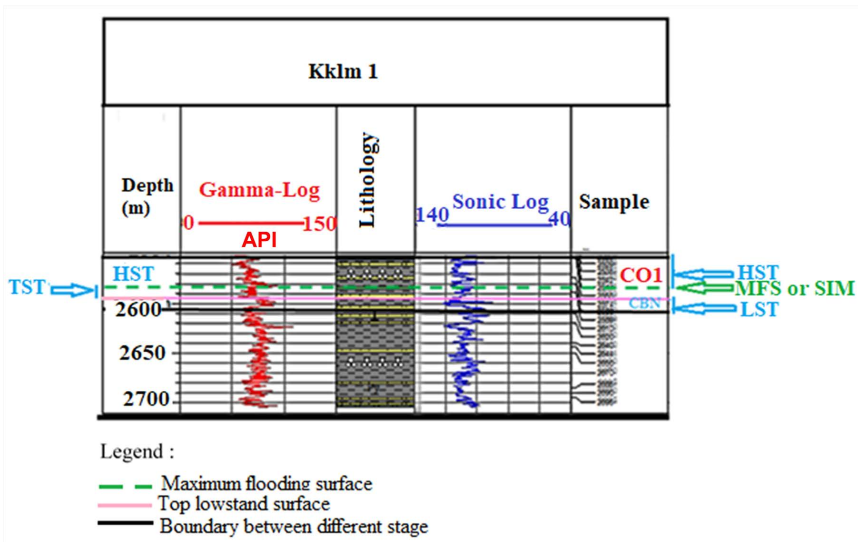

Figure 3. Sequential interpretation coupled with sedimentological, well-logs, and biostratigraphic data of the Coniacian stage from borehole kkm 1.

This is followed by a progradational trend, reflecting a highstand system tract (2555 m - 2582 m). These two assemblages are characterized by clayey levels with the presence of sand and marls. Lithological analysis reveals that these units contain a considerable abundance of planktonic foraminifera, as well as calcareous foraminifera, agglutinated foraminifera (present in number), and an abundance of miospores. Micropaleontological data suggest a mid-platform to inner platform environment.

Santonian depositionalsequence: 2552 m - 2480 m

The Santonian interval is confined to its single sequence, Sa1 (Figure 4).

The terms of the sequence:

The appearance during drilling of *Hedbergella delrioensis* at a depth of 2420 m indicates that this stratigraphic series can be attributed to the Santonian (Sa1). This identification of Sa1 is reinforced by the presence of species such as *Bulimina crasa* at 2440 m, *Crybelosporites pannuceus* at 2540 m, *Whiteinella baltica* at 2448 m, *Gleicheniidites senonicus* at 2450 m, *Heterohelix reussi* at 2450 m, and *Neobulimina subregularis* at 2450 m.

The progradational base is observed between 2469 m - 2552 m, reminiscent of the well logssignature of a lowstand system tract. This lowstand system tractis characterized by clayey levels with sandy intercalations. Additionally, there is a presence of pyrite, absence of dinocysts, and abundance of miospores, calcareous foraminifera, planktonic foraminifera, and rare occurrence of agglutinated foraminifera. Paleobathymetric data indicate a transition from an outer neritic to inner neritic environment.

A retrogradational trend, a typical signature of a transgressive system tract (TST), is located between 2452 m - 2469 m. A maximum flooding surface (MFS) characterized by a significant gamma-ray peak is present.

Within this clayey layer, there is an abundance of miospores, infrequent occurrence of agglutinated foraminifera and planktonic foraminifera, as well as dinocysts, while calcareous foraminifera are absent.

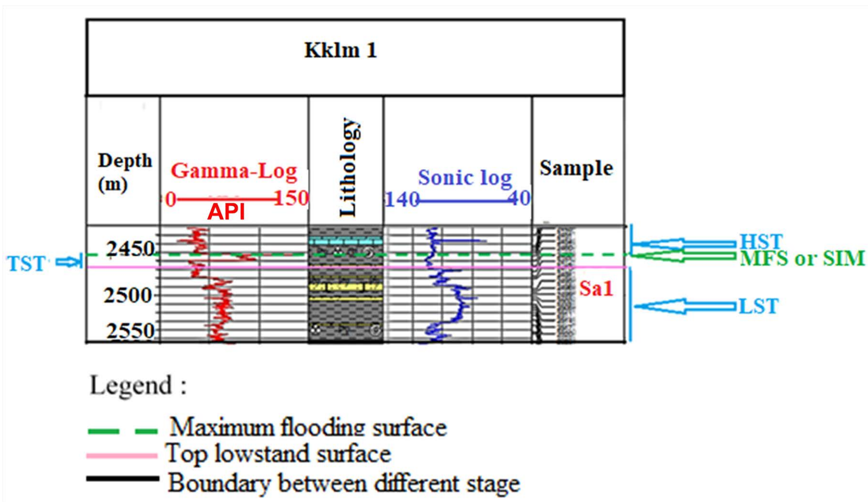

Figure 4. Sequential interpretation coupled with sedimentological, well-logs, and biostratigraphic data of the Santonian stage from borehole kkm 1.

A progradational trend reflecting a highstand system tract (HST) concludes this sequence. This highstand system tract consists of clay with intercalations of limestone beds at depths of 2435 m - 2445 m and contains numerous to very numerous microfossils.

According to micropaleontological data, the transgressive system tract (TST) and highstand system tract (HST) were deposited in an inner neritic environment.

Campanian depositionalsequences: 2357 m - 2340 m

The analysis of well logging expressions within the clayey interval, with the presence of Campanian-age glauconite, distinguishes two (2) deposit sequences. Each begins with a lowstand system tract (aggradational trend), followed by a transgressive system tract (retrogradational trend), and ends with a highstand system tract (progradational trend) (Figure 5).

Terms of sequence:

In this Cam9 sequence, the upper boundary is marked by the appearance (drilling direction) of *Gaudryina cretacea* at 2340 m. This sequence is confirmed by the presence of the species *Gaudryina rugosa* at 2350 m.

The clay is situated between (2353 m - 2357 m), with a slight expression in well logging indicated by an aggradational trend in gamma ray.

A retrogradational trend between 2350 m - 2352 m emphasizes the response of a transgressive system tract, which is capped at its top by a flooding surface at 2350 m.

The highstand system tract located between 2340 m and 2350 m exhibits an abundance of glauconite. These layer assemblages consist mainly of clayey sediments containing microfossils ranging from relatively numerous to rare. The depositional context corresponds to an outer continental shelf.

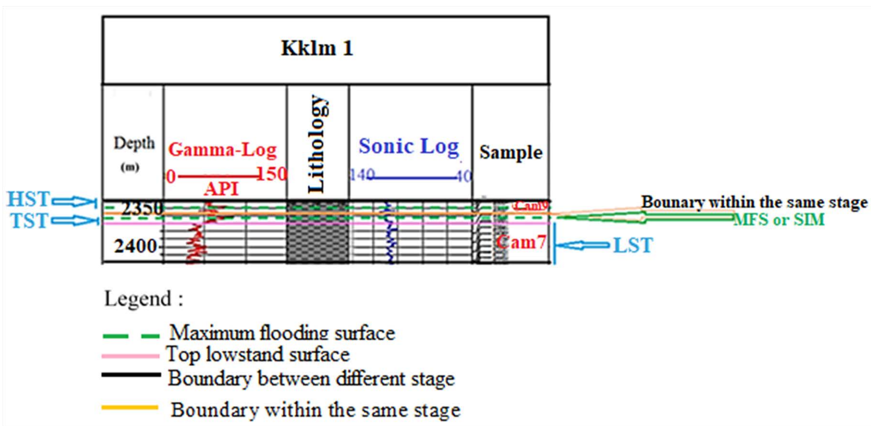

Figure 5. Sequential interpretation coupled with sedimentological, well-logs, and biostratigraphic data of the Campanian stage from borehole kkm 1.

Cam7 sequence (2357 m - 2420 m)

Terms of sequence:

The top of the Campanian sequence (Cam7) is indicated by the first appearance in drilling direction of the species *Trichodinium castanea* at depth 2359 m.

The lowstand system tract of the Cam7 sequence extends from depth 2370 m to depth 2420 m.

It consists of clayey strata containing a notable abundance of dinocysts, a considerable quantity of agglutinated foraminifera, as well as miospores. Calcareous foraminifera, on the other hand, are found in low numbers.

Planktonic foraminifera are absent. Micropaleontological data indicate that the Cam7 sequence was deposited in an outer continental shelf environment.

The transgressive system tract (2370 m - 2357 m) follows, reaching its maximum flooding at depth 2362 m (a mean sea level, which is bathymetric), dated to 76.37 Ma (according to [5]).

The highstand system tract is very slight and extends from depth 2362 m to 2357 m. All these layer assemblages consist of clayey sediments hosting dinocysts in low numbers, as well as agglutinated foraminifera also in small quantities. Other types of microfossils are rare or absent.

The depositional environment is of an outer neritic type. The Campanian-Santonian transition is marked by a regional unconformity of 3.63 Ma.

Maastrichtian depositionalsequences: 1900 m - 2340 m

The K/T boundary is fixed at 1900 m with the first downhole occurrences (FDO) of species such as *Cerodinium granulostriatum* and *Spiroplectammina navarroana*. The Maastrichtian interval is subdivided into three sequences: Ma5, Ma4, Ma3, Ma2, and Ma1 (Figure 6).

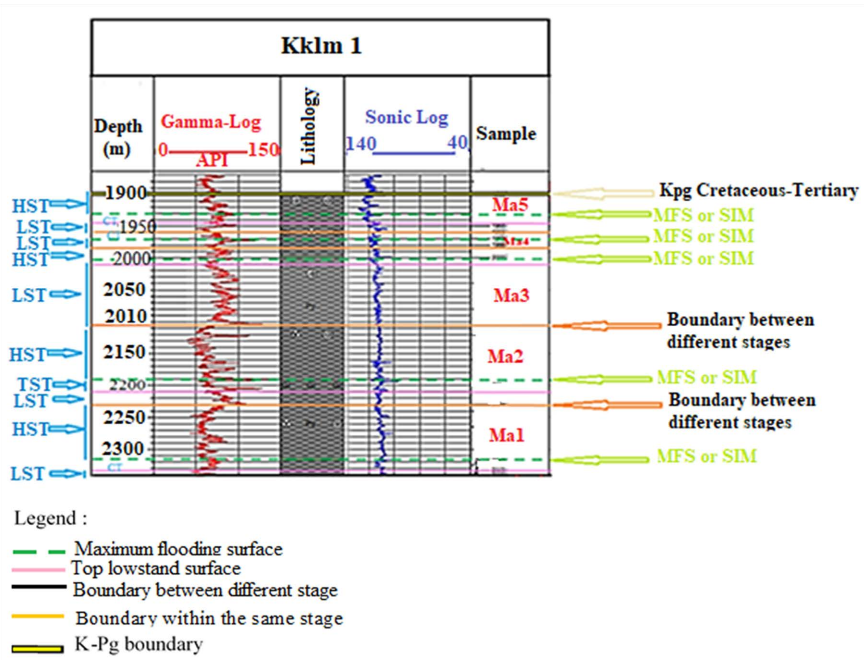

Figure 6. Sequential interpretation coupled with sedimentological, diagraphic, and biostratigraphic data of the Maastrichtian stage of well kkm 1.

Ma5 sequence: 1900 m - 1949 m

Terms of sequence:

The first downhole appearances of *Cerodinium granulostriatum* and *Spirop-*

lectammina navarroana at depth 1900 m indicate a Ma5 deposit sequence.

These clay strata consist of an abundance of dinocysts, a small quantity of agglutinated foraminifera, and a rare presence of planktonic foraminifera. Miospores, on the other hand, are absent.

The gamma-ray curve trend in the interval (1900 m - 1949 m) seems easy to interpret. Indeed, an aggradational trend is observed between 1960 m - 1945 m, resembling the signature of a lowstand system tractexpressed lithologically by clays. The peak of this aggradational trend is marked at 1945 m by a drop in gamma-ray.

This is followed by a retrogradational trend between 1945 m - 1931 m, emphasizing the response of a transgressive system tract, limited at the top by the maximum flooding surface at 1931 m; this clayey transgressive system tractcontains numerous to few microfossils. Then, a progradational trend (decreasing gamma-ray values after the significant peak moving towards higher levels) follows. This assemblage marks the Cretaceous-Tertiary (K/T) boundary.

Ma4 Sequence: 1985 m - 1960 m

Terms of Sequence:

The penetration of the Ma4 sequence interval is indicated by the downhole appearances (drilling direction) of species *Senegalinium microspinosum*, *Plectina lenis*, *Andalusiella gabonensis*, *Rugoglobigerina macrocephala*, *Rugoglobigerina rugosa*, and *Bulimina bantu* at depth 1960 m, marking the top of the Ma4 sequence. In this Ma4 sequence (1960 m - 1985 m), we have three assemblages from bottom to top.

The lowstand system tractis very slight, extending from 1985 m to 1980 m. The variations in gamma-ray radiation in this the lowstand system tractevolve towards lower values, with rare presence of dinoflagellates and foraminifera.

The transgressive system tract (1972 m - 1980 m), following its maximum flooding surface (MFS) at 1972 m, where a significant gamma-ray peak is observed towards higher values.

The highstand system tract, which is well pronounced on the well logging curve. These assemblages contain microfaunas ranging from few to numerous.

The analysis of foraminiferal assemblages indicates an outer to middle neritic environment in which this sequence was deposited.

Ma3 sequence: 1985 m - 2108 m

Terms of sequence:

At 1985 m, *Gaudryina Laevigata* and *Reophax duplex* appear (drilling direction). In this interval, certain species confirming their presence in this sequence are *Hormosina trinitatensis* at 2040 m, *Andalusiella ivoirensis* at 2108 m, and *Andalusiella mauthei aegyptica* at 2108 m.

This sequence begins with an aggradational trend (vertical stacking of successive units) from 2010 m to 2101 m. It consists of clayey levels (with pyrite presence) containing dinocysts (numerous), agglutinated foraminifera (very numerous), calcareous foraminifera (numerous), and rare planktonic foraminifera. Miospores are absent. Furthermore, faunal data indicate that the lowstand system tractwas established in environments ranging from upper outer neritic (100 m - 200 m) to middle neritic (50 m - 100 m).

The evolution of the gamma-ray curve towards higher values (transgressive trend) indicates a transgressive system tract. The deposit sequence in such environments consists mainly of clay. In this transgressive system tract, ranging from 2002 m to 2010 m, there are rare occurrences of dinocysts and an absence of miospores, as well as foraminifera. The retrogradational trend-progradational trend transition is interspersed with a maximum flooding surface (bathymetric SIM) at 2002 m, where an increase in gamma-ray values associated with a dinocyst abundance peak is observed.

A progradational trend follows, reflecting a highstand system tract. In this highstand system tract, a clay formation with the presence of siltstone, numerous agglutinated foraminifera, and rare occurrences of calcareous foraminifera and planktonic foraminifera are observed. Dinocysts and miospores are absent. All these assemblages consist of clayey sediments containing numerous to very numerous microfossils.

According to micropaleontological data, the transgressive system tract (TST) and highstand system tracts (HLA) were deposited in a middle outer neritic environment.

Ma2 and Ma1 sequences

The Ma2 and Ma1 sequences were delineated based on clear breaks in gamma-ray data and faunal species distributions.

Sequence terms:

The lowstand system tract, ranging from 2230 m to 2210 m, consists of clay containing few dinoflagellates, rare agglutinated foraminifera and calcareous foraminifera, with an absence of miospores and planktonic foraminifera. In this interval, the gamma-ray curve trend evolves towards lower values (aggradation).

Subsequently, a retrogradational trend is observed, a typical signature of a transgressive system tract (TST). In this transgressive interval, there is a clay formation with abundant dinocysts, numerous calcareous and planktonic foraminifera, but few agglutinated foraminifera. Miospores are absent. A bathymetric maximum flooding surface at 2190 m, dated to 69.23 million years ago (according to [7], is characterized by a significant gamma-ray peak associated with an abundance of dinoflagellates.

This retrogradational trend is followed by a progradational trend, indicating a highstand system tract. In this high-level marine interval, the lithology is predominantly argillaceous and contains numerous dinoflagellates and calcareous foraminifera, with few agglutinated and planktonic foraminifera. Miospores are absent. All these assemblages consist of clayey sediments containing numerous to very numerous microfossils.

Ma1 sequence (2340 m - 2230 m)

Sequence terms:

Variations in gamma-ray radiation in the clayey interval (2340 m - 2230 m), with silty intercalations, show characteristic diagraphic responses of a very slight lowstand system tract. The top of this lowstand system tract is fixed at 2335 m.

A retrogradational trend follows, with a maximum flooding surface at 2315 m materialized on the diagraphic log by a significant gamma-ray peak. The transgressive interval (2335 m - 2315 m) consists of argillite with a siltstone bed. This formation contains numerous to very numerous microfossils.

This is followed by a progradational trend, leading to the highstand system tract that terminates the sequence. Paleontological data indicate that we are in a middle continental shelf environment. The Maastrichtian-Campanian boundary is marked by an average discordance of 0.14 Ma.

3.2. Sequential Division of Sedimentary Deposits in Well Kkm 2

Terms of the Coniacian depositional sequence.

The Coniacian interval comprises a single deposit sequence, sequence Co1 (Figure 7).

The Coniacian depositional sequence 2344 - 2267 m

The first appearance datum (FDO) of *Marginotruncana sinuosa* at 2267 m indicates the penetration of sediments dated to sequence Co1.

The lowstand system tract (2344 - 2325 m) is suggested by a phase of aggradation on the gamma-ray log. This interval is relatively narrow.

The transgressive system tract (2325 - 2313 m) is also quite limited and reaches its maximum flooding surface at 2313 m.

The highstand system tract (2344 - 2313 m) is relatively well developed on the log diagraphic. The terms of this sequence conform to deposits laid down in a neritic marine environment according to the model of *Vail et al.* (1987, 1991 m).

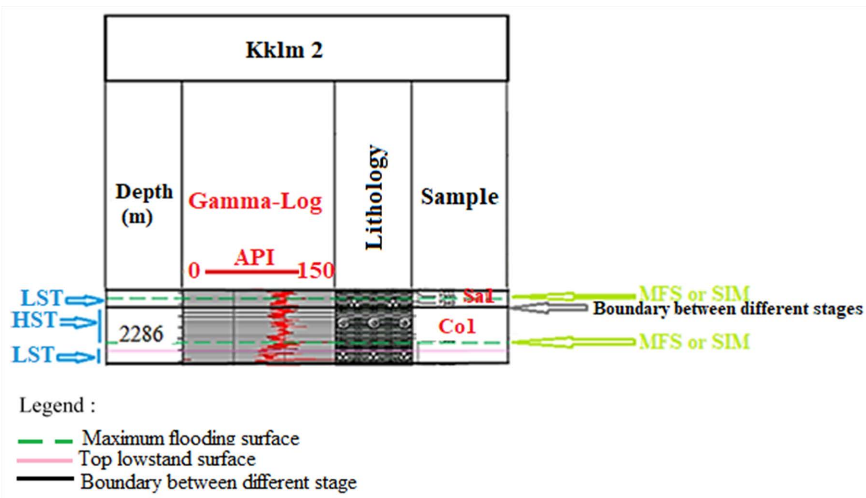

Figure 7. Sequential interpretation coupled with sedimentological, diagraphic, and biostratigraphic data of the Coniacian and Santonian stages from well Kkm 2.

The Santonian depositional sequence: (2267 - 2242 m)

The Santonian interval is reduced to the single sequence Sa1. It is essentially clayey with intercalations of small marly levels.

Terms of the Sa1 depositional sequence

The Sa1 sequence is reduced to its lowstand package due to the generally aggradational trend of the gamma-ray. The top of the sequence placed at 2242 m can be estimated to be no younger than 85.25 Ma, Sa1 MFS. This sequence is exclusively composed of clayey sediments with marly intercalations and contains rare palynomorphs and fairly to very numerous foraminifera.

Depositionalsequence of the Campanian: 2242 - 2165 m

The Campanian interval is confined to the single sequence Cam9. It exhibits a lowstand systems tract, a transgressive systems tract, and terminates with a highstand systems tract (Figure 8).

Sequence Terms

Sequence Cam9 (2242 - 2165 m) was defined based on the First Downhole Occurrence (FDO) of the planktonic foraminifera species *Gaudryina rugosa* at 2143 m and *Gaudryina sp*.4 at 2171 m. The gamma-ray curve distinguishes a lowstand systems tract, a transgressive systems tract, and a highstand systems tract.

The lowstand systems tract (2242 - 2211 m) is characterized by an aggradational phase in the gamma-ray log.

The transgressive systems tract (2211 - 2199 m) reaches its maximum flooding at 2199 m, where a peak in the gamma-ray values is observed. The highstand systems tract is relatively well-developed on the log diagram. These tracts consist of clayey formations containing abundant dinoflagellates, sporadic miospores, and abundant agglutinated foraminifera. Planktonic and benthic calcareous foraminifera are absent.

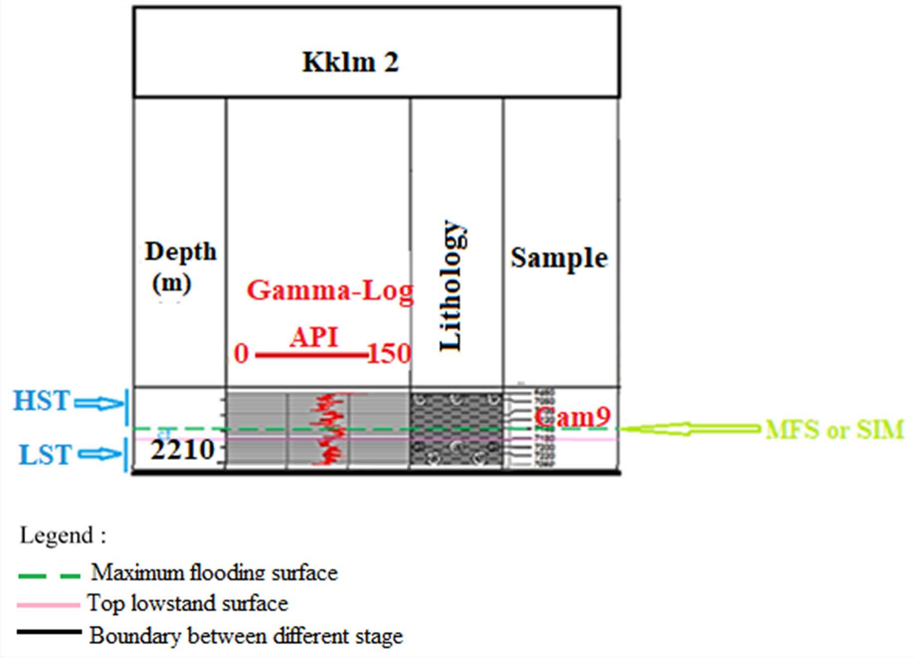

Figure 8. Sequential interpretation combined with sedimentological, well-log, and biostratigraphic data of the Campanian stage in well Kkm 2.

Depositionalsequences of the Maastrichtian: 2164 - 2051 m

The K/T boundary is set at 2051 m based on the FDO of the diagnostic Maastrichtian foraminifera species *Gaudryina pyramidata*. The Maastrichtian interval is divided into two sequences: Ma4 sequence, Ma3 sequence (**Figure 9**).

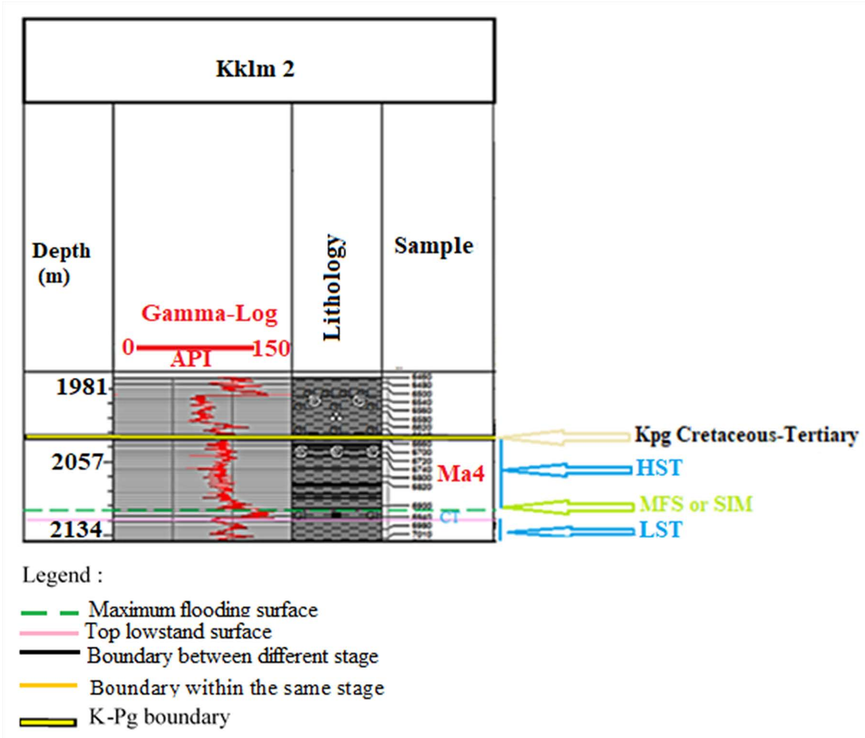

Figure 9. Sequential interpretation coupled with sedimentological, diagraphic, and biostratigraphic data of the Maastrichtian stage of borehole Kkm 2.

Ma4 sequence : 2051 m - 2104 m

Sequence terms

Ma4 sequence : 2104 - 2051 m

The interval 2104 - 2051 m—has been assigned to the Ma4 sequence with the FDO at 2051 m of *Gaudryina pyramidata* and *Rzehakina epigona fissistomata* at 2104 The lowstand system tract extending from 2104 - 2088 m consists of clayey levels, including dinocysts (quite numerous), miospores (rare), foraminifera (quite numerous), and a total absence of calcareous and planktonic foraminifera. In this assemblage, the gamma-ray shows an aggradational trend.

The transgressive system tractoccupies the interval 2088 - 2070 m marked by a retrogradational gamma ray. The high marine level extends from 2070 – 2051 m and is characterized by a generally progradational trend of the gamma ray. This assemblage contains abundant dinocysts and agglutinated foraminifera.

Ma3 Sequence: 2165 - 2104 m

Sequence terms

The overall appearance of the gamma-ray suggests the existence of a lowstand system tract, a very limited transgressive system tract, and a highstand system tract. The Ma3 sequence is essentially composed of glauconitic and pyritic clayey sediments with intercalations of small limestone levels in the high marine assemblage. The lowstand system tract (2165 - 2142 m) is moderately developed and represented by an aggradation on the gamma-ray log.

The transgressive system tract is almost nonexistent and is surmounted by a well-marked maximum flooding surface (MFS) on the gamma-ray at 1860 m.

The highstand system tract (2138 - 2104 m) is moderately developed and represented by a progradational phase on the gamma-ray. This assemblage contains quite numerous dinocysts. The terms of this sequence indicate that the low-level and highstand system tracts are moderately developed, suggesting that they were deposited in an environment ranging from upper slope to neritic according to the model of [6] [7].

4. Lateral Variation of Depositional Assemblages

The lateral variations of sequences and chronostratigraphic surfaces identified within the two sets of deposits reveal the presence of argillite alternating with sands or grits and limestones distributed in five deposition sequences. The strong coincidence of diagraphic data minimizes the possibilities of error. (**Figure 10**).

4.1. Coniacian Sequence

Correlations show a single CO1 sequence identified in the sedimentary deposits of drillings Kkm1 and Kkm2. The CO1 sequence comprises a low-level assemblage, a transgressive assemblage, and a high-level marine assemblage.

4.2. Santonian Sequence

The Sa1 sequence was identified in the sedimentary deposits of drillings Kkm1 and Kkm2 in the continental shelf to slope domain. In drilling Kkm1, the sequence comprises a low-level assemblage, a transgressive assemblage, and a high-level marine assemblage. The sequence in Kkm2 is reduced to a low-level marine assemblage.

4.3. Campanian Sequence

The Cam9 sequence is present in both drillings, while the Cam7 sequence is only present in drilling Kkm1. The absence of this sequence in drilling Kkm2 may be due to regression or non-deposition.

4.4. Maastrichtian Sequence

The Maastrichtian shows 5 sequences Ma1 to Ma5. The upper boundary of Ma5 is located at the Maastrichtian-Paleocene boundary. The Ma5 sequence is represented in drilling Kkm1. The Ma4 sequence is represented in both drillings Kkm1 and Kkm2. The Ma3 sequence is present in drilling Kkm1 and absent in drilling Kkm2. The Ma1 and Ma2 sequences are known in drilling Kkm1.

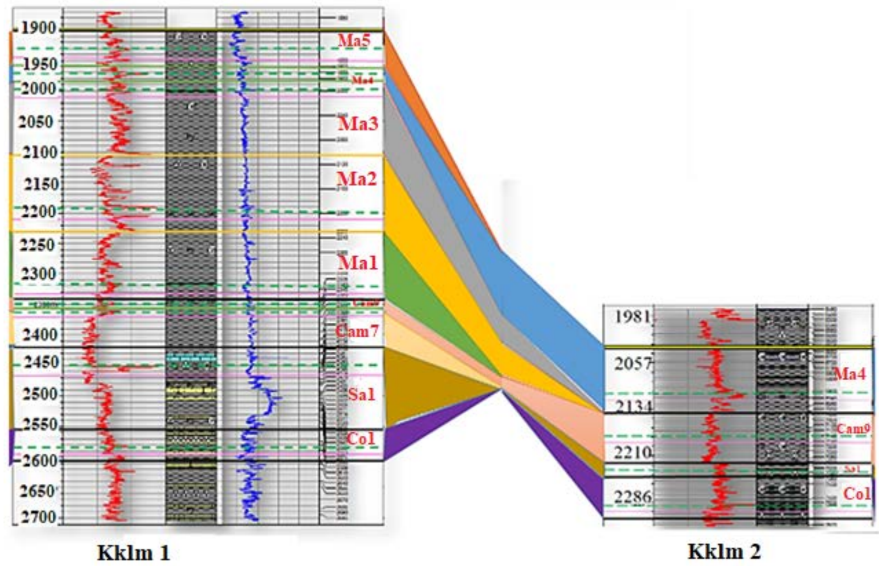

Figure 10. Depositional sequence correlation.

5. Discussion

The expressions of the sequences vary significantly depending on the sequences considered. Overall, the facies of the two boreholes have shown little variation. These slight variations suggest a depositional profile with very monotonic and low slopes [8]. The sequential stratigraphy method in both boreholes has allowed for the identification of lowstand systems tracts (LST), transgressive systems tracts (TST), and highstand systems tracts (HST). According to [6] [7] [9], previous studies, complete sequences determined during a cycle are generally genetically related strata. In our study interval, we identified 3 LST and 7 TST in borehole kkm1, and 4 LST and 4 TST in borehole kkm2. In the Paris Basin [8] [10], previous studies have determined the lowstand systems tracts from the Cenomanian to the Coniacian. The deposits in these two boreholes are characterized by siliciclastic sedimentation and are generally deposited in parasequences, as indicated by our study interval, which is consistent with previous findings [11]. The transgressive and highstand systems tracts identified decompose into 9 for the former and 8 for the latter in zone kkm1, and into 4 each in zone kkm2. In accordance with [12], previous research, considering the evolution of depth (indicating a transgressive trend) and in agreement with the terminology of previous studies [12], the depositional sequences in such environments mainly consist of transgressive sets and highstand sets. The deposits observed in the study interval suggest an environment ranging from upper slope to neritic.

6. Conclusions

The sequential approach using well logging, biostratigraphy, and sedimentology has allowed us to refine the depositional sequences in these boreholes, within which we have identified lowstand systems tracts (LST), transgressive systems tracts (TST), and highstand systems tracts (HST).

Thirty-five depositional sequences have been identified in this third-order megasequence of the Senonian. Within these sequences, 3 and 7 LST, 4 and 9 TST, and 4 and 8 HST were respectively encountered in boreholes kkm1 and Kkm2. The beginning and end of each transgressive tract are marked by a transgressive surface and a maximum flooding surface.

Lowstand systems tracts are the locations for predicting reservoir rocks, and their lithology is dominated by sandstones and conglomerates. Transgressive and highstand systems tracts are rich in mudstone or sometimes silty clay. The depositional environment is of the slope to middle neritic type.

This work opens up numerous perspectives, including the study of other cores from the study area to shed light on unresolved issues. This could lead to resolving the uncertainties noted in this work. A better understanding of the sequential stratigraphy of the Ivorian basin could enable a more precise synthesis of sediment geometry through the integration of high-resolution seismic data. Cyclostratigraphy study should be conducted to determine deposition sequences in deep sea and to correlate inaccessible paleogeographic domains.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Payton, C.E. (1977) Seismic Stratigraphy: Application to Hydrocarbon Exploration. American Association of Petroleum Geologists, p. 516.

[2] Yao, N.J.-P. (2012) Caractérisation Sédimentologique, minéralogique, géochimique et biostratigraphique des falaises vives de Fresco: Région de Grand-Lahou (Côte d'Ivoire). Thèse de Doctorat, Université Félix Houphouët-Boigny, p. 187.

[3] Assale, F.Y.P. (2013) Caractérisation sédimentologique, palynologique, géochimique et paléoenvironnementale des formations sédimentaires connexes à la faille des lagunes (Est du bassin onshore de Côte d'Ivoire). Thèse de Doctorat, Université Félix Houphouët-Boigny, p. 361.

[4] Kouassi, K.A. (2014) Episode anoxique à la limite Cénomanien/Turonien dans le bassin sédimentaire de Côte d'Ivoire: Intérêt pétrolier des black shales. Doctorat Thèse unique, Université Félix Houphouët-Boigny, p. 275.

[5] Haq, B.U. and Schutter, S.R. (2008) A Chronology of Paleozoic Sea-Level Changes. *Science*, **322**, 64-68. https://doi.org/10.1126/science.1161648

[6] Vail, P.R., Haq, B.U. and Hardenbol, J. (1987) Chronology of Fluctuating Sea Levels Since the Triassic (250 Million Years Ago to Present). *Science*, 235, 1156-1167. https://doi.org/10.1126/science.235.4793.1156

[7] Hardenbol, J., Vail, P.R. and Ferrer, J. (1981) Interpreting Paleoenvironments, Subsidence History, and Sea-Level Changes Onpassive Margins from Seismic Biostratigraphy. 26*th International Geological Congress*, *Geology of Continental Margins*: *Oceanologica Acta*, *Supplement*, **4**, 33-44.

[8] Lasseur, E. (2007) La craie du Bassin de Paris (Cénomanien-Campanien, Crétacé supérieur). Sédimentologie de faciès, stratigraphie séquentielle et géométrie 3D. Thèse de Doctorat, Université de Rennes, 173-184.

[9] Van Wagoner, J.C., Posamentier, H.W., Mitchum, R.M., Vail, P.R., Sarg, J.F., Loutit, T.S. and Hardenbol, J. (1988) An Overview of the Fundamentals of Sequence Stratigraphy and Key Definitions. In Wilgus, C., et al., Eds., *Sea-Level Change*, *an Integrated Approach*, Society of Economic Paleontologists and Mineralogists, 39-45.

[10] Haq, B.U., Hardenbol, J. and Vail, P.R. (1988) Mesozoic and Cenozoic Chronostratigraphy and Cycles of Sealevel Change. In Wilgus, C.K., Hastings, B.S., Ross, C.A., et al., Eds., *Sea-Level Changes—An Integrated Approach: SEPM Special Publication* no. 42, The Society of Economic Paleontologists and Mineralogists, 71-108.

[11] Arnaud, H., Arnaud, V.A., Bulot, L.G., Beck, C., Macsotay, O., Stephan, J.-F. and Victor, V.V. (2000) Crétacé inférieur du Venezuela oriental: Stratigraphie séquentielle des carbonates sur la transversale Casanay-Maturin (États de Anzoátegui, Monagas et Sucre). Géologie Alpine, 2000, 76, 29 p.

[12] Vail, P.R., *et al*. (1991) The Stratigraphic Signatures of Tectonics, Eustasyand Sedimentology: An Overview. In Einsele, G., Ricken, W., Seilacher, A., Eds., *Cycles and Events in Stratigraphy*, Springer-Verlag, 617-659.