World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Check for updates

Lithological and geochemical characterisation (Rock-Eval pyrolysis) of the KOUM-1X and ABENA-1X wells on the western margin of the Côte d'Ivoire sedimentary basin

Kobenan Guy-Roland KOUMAN [1,*], N'Goran Jean-Paul YAO [2] and Kouakou Alphonse YAO [3]

[1] *Engineering Sciences and Techniques (IST), Institute National Polytechnique Félix Houphouët-Boigny (INP-HB), BP 1093 Yamoussoukro, Côte d'Ivoire.*
[2] *Laboratory of Geology, Mineral Resources, and Energy (LGRME), Earth Sciences and Mining Resources Training and Research Unit (UFR STRM), University Félix Houphouët-Boigny (UFHB), 28 BP 536 Abidjan, Côte d'Ivoire.*
[3] *School of Mines and Geology (ESMG), Institute National Polytechnique Félix Houphouët-Boigny (INP-HB), BP 1093 Yamoussoukro, Côte d'Ivoire.*

World Journal of Advanced Research and Reviews, 2026, 29(02), 1490-1504

Publication history: Received on 17 January 2026; revised on 25 February 2026; accepted on 27 February 2026

Article DOI: https://doi.org/10.30574/wjarr.2026.29.2.0467

Abstract

This study focuses on the lithological and geochemical analysis of 99 rock core samples from two boreholes (KOUM-1X and ABENA-1X) located on the western margin of the Ivorian sedimentary basin. It aims to reconstruct and characterize the formations to assess the petroleum potential of the various intervals in the Albian-Paleocene sequence crossed by each borehole. The results primarily show a succession of sands and clays with occasional limestone intercalations. Geochemical analysis using the Rock-Eval method indicates that the distribution of total organic matter content relative to depth in the KOUM-1X borehole ranges from poor to excellent. In contrast, the distribution in ABANA-1X ranges from poor to very good. These data, combined with the hydrogen index (HI) as a function of depth, highlight the presence of type II, III, and II/III hydrocarbons in the wells. Furthermore, the variation in oil potential (S2) with depth shows values ranging from poor to excellent in the KOUM-1X well and from poor to very good in the ABANA-1X well. Since the organic matter is immature in the formations within the study area, no potential source rock has been identified.

Keywords: Lithostratigraphy; Rock-Eval pyrolysis; Sedimentary basin; Côte d'Ivoire

1. Introduction

Since the 1950s (PETROCI and BEICIP, 1990), the sedimentary basin of Côte d'Ivoire has been regularly subjected to numerous investigations for both oil exploration and scientific research (Digbéhi, 1987; Yao, 2012; Bamba, 2019; Gbangbot, 2012; Kouassi, 2014; 2019; Fea, 2019; Doukouré, 2020; Ablé, 2021; Tahi, 2022). Despite encouraging results, which in most cases have revealed significant accumulations of hydrocarbons in its eastern part, the western margin of the Ivorian basin remains poorly understood to this day. This situation is reflected in the significant number of unsuccessful surveys in the area (PETROCI and BEICIP, 1990) and runs counter to the Ivorian government's desire to increase production. In this context, it is essential to deepen our knowledge of petroleum systems to reduce the risk of failure and better promote this region. Thus, the overall objective of this study is to evaluate the organic matter in terms of richness, type, and degree of thermal maturity, based on Rock-Eval pyrolysis parameters, of the potential source rocks of the formations crossed by the KOUM-1X and ABENA-1X wells. Specifically, the aim is first to determine the lithological characteristics of these wells and then to characterize the organic matter contained in their formations.

* Corresponding author: KOUMAN Kobenan Guy-Roland

1.1. Study Site

The surveys submitted for this study are located in the submerged part of the San Pedro margin (Figure 1). Structurally, the Côte d'Ivoire sedimentary basin is bisected from west to east by the main lagoon fault, which runs almost parallel to the coast. According to Tastet (1979), two zones of influence are identified: in the north, directions S1 (10-30°N) and S2 (140-150°N), while in the south, the direction is 80-100°N, derived from the Precambrian basement. The model reveals parallel and transverse satellite faults (30-40°N to the east, 170-180°N to the west), which form stepped sections. Bellion et al. (1988) associate the 90-100°N fractures with late events in the basement. Spengler and Delteil (1966) highlight a Neogene-granitic basement unconformity with a gap of 1,900 million years. According to Sombo (2002), the margin is segmented into three regions: west with perpendicular faults, transition at Trou Sans Fond, and east anastomosed, each with similarities and distinctive features.

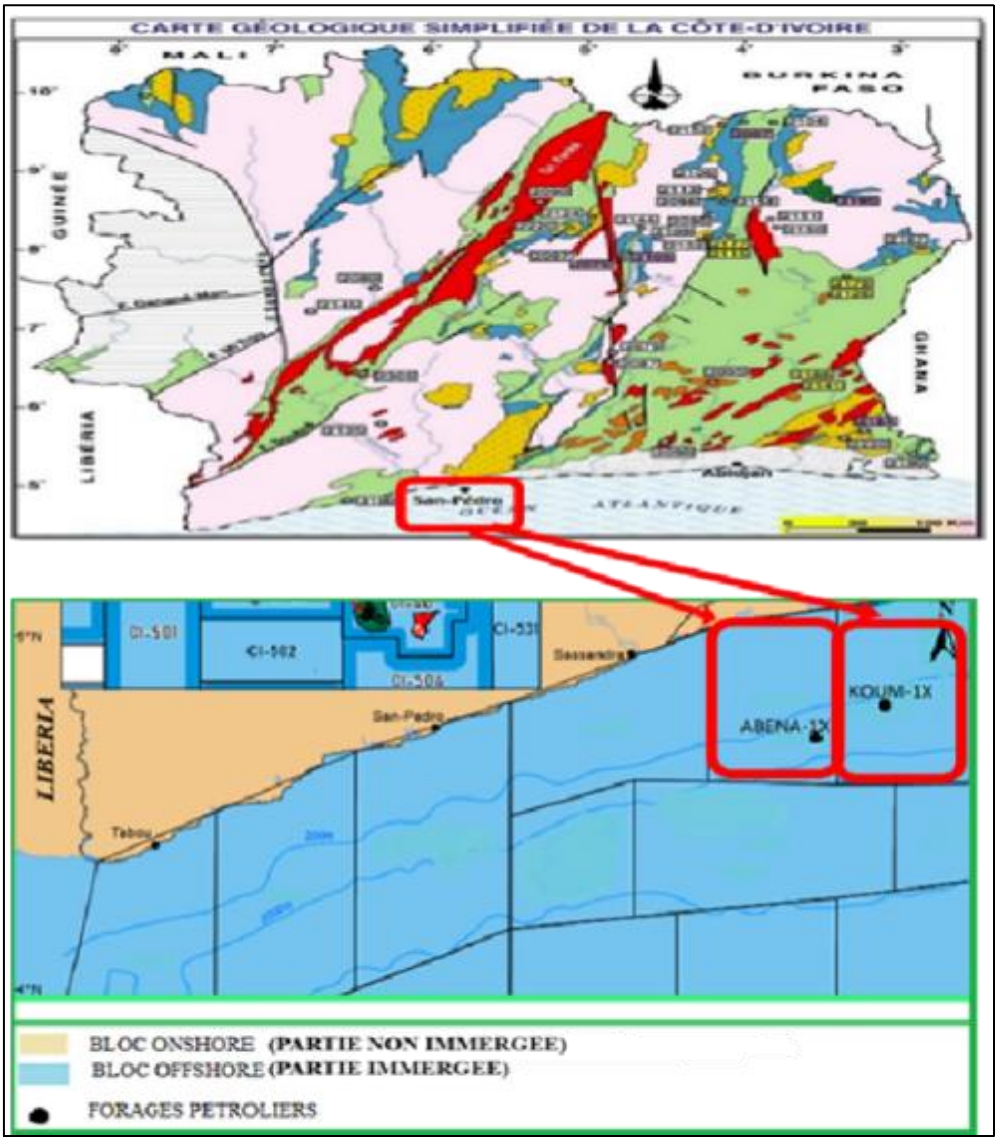


Figure 1 Location map of the ABENA-1X and KOUM-X wells

2. Materials and methods

The nature and quantity of excavated material studied varied according to the objectives.

In the case of the sedimentological study

Most of the study material consists of drill cuttings from two boreholes (KOUM-1X and ABENA-1X) and biostratigraphic data (floor of the stages) obtained from PETROCI's Analysis and Research Center (CAR). The samples selected from each stage were processed using standard methods for lithological and geochemical analysis. In the lithological study, the nature (clay, sand, limestone) and color of the sediments were assessed by direct observation, touch, and hydrochloric acid testing. Subsequently, a binocular magnifying glass was used to identify in detail grain shape and the presence (abundance) or absence of accessory elements (pyrite, glauconite, carbonaceous debris). Thus, 40 g of sediment samples (drilling spoil) were taken at each elevation in a beaker with liquid soap for 24 hours, and then washed through a column of four sieves with mesh sizes decreasing from 500 µm, 250 µm, 125 µm to 63 µm. After drying in an oven at a temperature of 60°C for 2 hours, the samples were sorted.

The morphoscopy of the sand grains was determined using the Petitjohn chart (Figure 2).

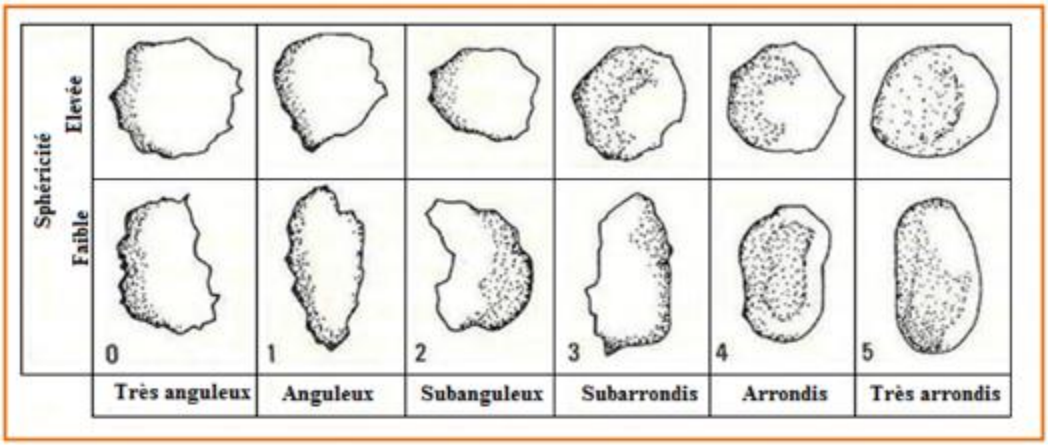


Figure 2 Visual chart for determining grain roundness and smoothness (Petitjohn, 1949 in Chamley, 1990)

The abundance of accessory elements (Table 1) allows for the characterization of the paleoenvironments during deposition. Using Strater 5 software, lithological logs of the boreholes were established and interpreted to understand the geographical extent of the identified formations.

Table 1 Abundance of accessory elements and deposit environment

Accessory items	Deposit environment
Pyrite	Anoxic sulfide environment
Glauconite	Marine environment
Carbonaceous debris	Environment with continental influences

2.1. Principle of the Rock-Eval 6 method

Analyses were based on Rock-Eval pyrolysis. This involved washing with water and soap on a column of two sieves (800 and 100 µm) to remove soluble pollutants from the sludge and then selecting debris smaller than 800 µm. Sorting under a magnifying glass removed solid and pasty pollutants, while drying 15 to 20 minutes in an 500 mg oven removed absorbed water. Subsequently, Soxhlet extraction was performed to remove any remaining impurities.

The method consists of subjecting a crushed raw rock sample (80-100 mg) to pyrolysis under helium then oxygen, using a rising temperature program (25°C min). The kerogen contained in this rock fraction then undergoes thermal cracking and the residual fraction after pyrolysis undergoes oxidation in air (Espitalié et al, 1977).

Depending on the temperature, pyrolysis analysis will simultaneously record S2 (oil potential), TOC (total organic carbon), HI (hydrogen index), and Tmax (maximum pyrolysis temperature), which are very important parameters for interpreting the results. They provide quick and efficient information on the petroleum potential of rocks, the quantity and quality of organic matter, the nature of kerogens, and their state of maturation. These recordings were interpreted according to Peters K. E.'s 1986 table (Table 2), which covers the four parameters and the intervals found therein. These four parameters made it possible to conclude whether or not bedrock was present, its maturity, and its capacity to generate hydrocarbons.

Table 2 Rock-Eval pyrolysis geochemical parameters (Peters K. E. 1986)

COT: % Weight	**Tmax (°C)**
Poor 0-0.5 Average 0,5-1 Good 1-2 Very Good 2-4 Excellent >4	Immature <435 Early maturity 435-445 Peak maturity 445-450 Advanced maturity 450-470 Overripe > 470
S2:(mg HC/g rock)	IH:(mgHC/gCOT
Poor 0-2,5 Average 2,5-5 Good 5-10 Very Good 10-20 Excellent > 20	I> 600 (Oil) II 300-600 (Oil) II/III 200-300 Oil and Gas Mixture III 50-200 Gas IV<435

3. Results

3.1. Lithology of the KOUM-1X well

The well, from 3070 m to 2000 m, was subdivided into three lithological units:

3.1.1. Unit 1 (3070 m–2760 m)

Characterized by alternating layers of claystone, sandstone, sandstone, and rare limestone. Between 3070 m and 2860 m, the sand is fine to medium, sometimes coarse, transparent, translucent, subangular to rounded, and moderately sorted. Claystones are light gray, firm, micromicaceous, and very low in limestone content. The siltstones are medium gray, blocky, and also firm and micromicaceous.

From 2860 m to 2760 m depth, fine sands become coarse and are sub-rounded. The claystones contain increasing amounts of limestone with a relative abundance of carbonaceous material and rare pyrite.

3.1.2. Unit 2 (2760 m–2000 m)

This unit, located at an elevation of 2760 m-2600 m, is characterized by the presence of claystone and limestone. The claystone is medium gray in color, blocky, firm, micromicaceous, slightly calcareous to calcareous. The limestone is very light gray, firm, blocky, crystalline. There are very fine to fine sands, rarely medium, transparent, translucent, sub-rounded and well sorted. Between 2710 m and 2600 m, the claystone is medium dark gray in color, blocky, firm, micromicaceous, non-calcareous to very calcareous. The limestone is very light gray and sometimes white, firm, blocky, and microcrystalline. Rare glauconite and pyrite. From 2600 m to 2000 m, there is a level of claystone, medium gray in color, sometimes light olive gray, calcareous, massive, sometimes firm, micromicaceous, pyrite-bearing, and glauconitic in places.

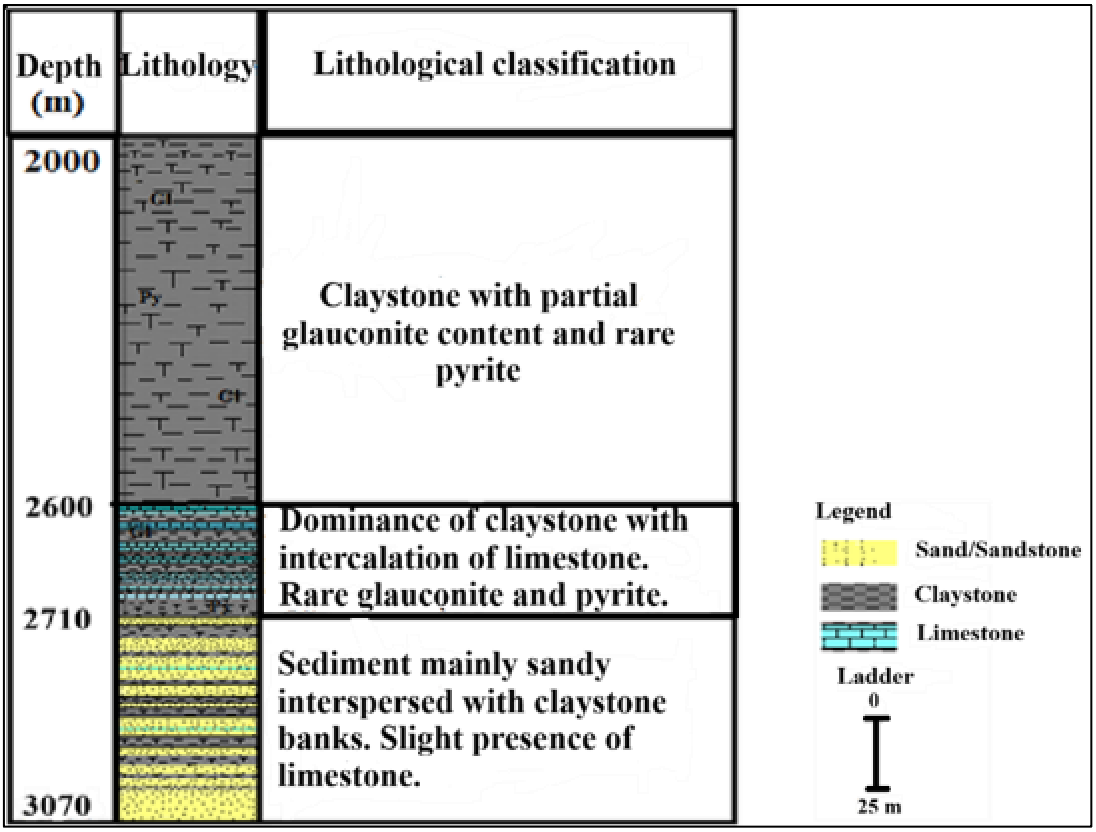


Figure 3 Lithological log of the KOUM-1X well

3.2. Lithology of the ABENA-1X well

The well was studied from elevation 4175 m to elevation 2775 m and was subdivided into two lithological intervals (Fig.4).

3.2.1. Unit 1 (4175 m–3550 m)

Unit 1 is characterized by predominantly sandy sediment with intercalations of claystone. The sand is white, smoky in places, translucent to transparent, very fine to very coarse, subangular and poorly sorted. The claystone is medium dark gray to dark gray, rarely brownish gray, in blocks, sometimes soft, micromicaceous, and calcareous in places. The limestone is white, sometimes light olive gray, in blocks, friable. Kaolinite is white to very light gray, sandy, friable, and very calcareous.

3.2.2. Unit 2 (3550 m–2775 m)

This unit is mainly characterized by alternating claystone and sand up to an elevation of 3,410 m. Above this elevation, the sediments are mainly claystone. The sand is light gray, sometimes off-white, translucent to transparent, sometimes opaque, very fine to very coarse, angular to subangular, poorly sorted. The clay is dark gray, firm, in blocks, slightly micromicaceous to micromicaceous, sometimes medium dark gray, in blocks to subfissile, firm, slightly micromicaceous, partly pyrite-bearing. Rare limestone is observable and is white, in blocks, hard, crystalline, friable.

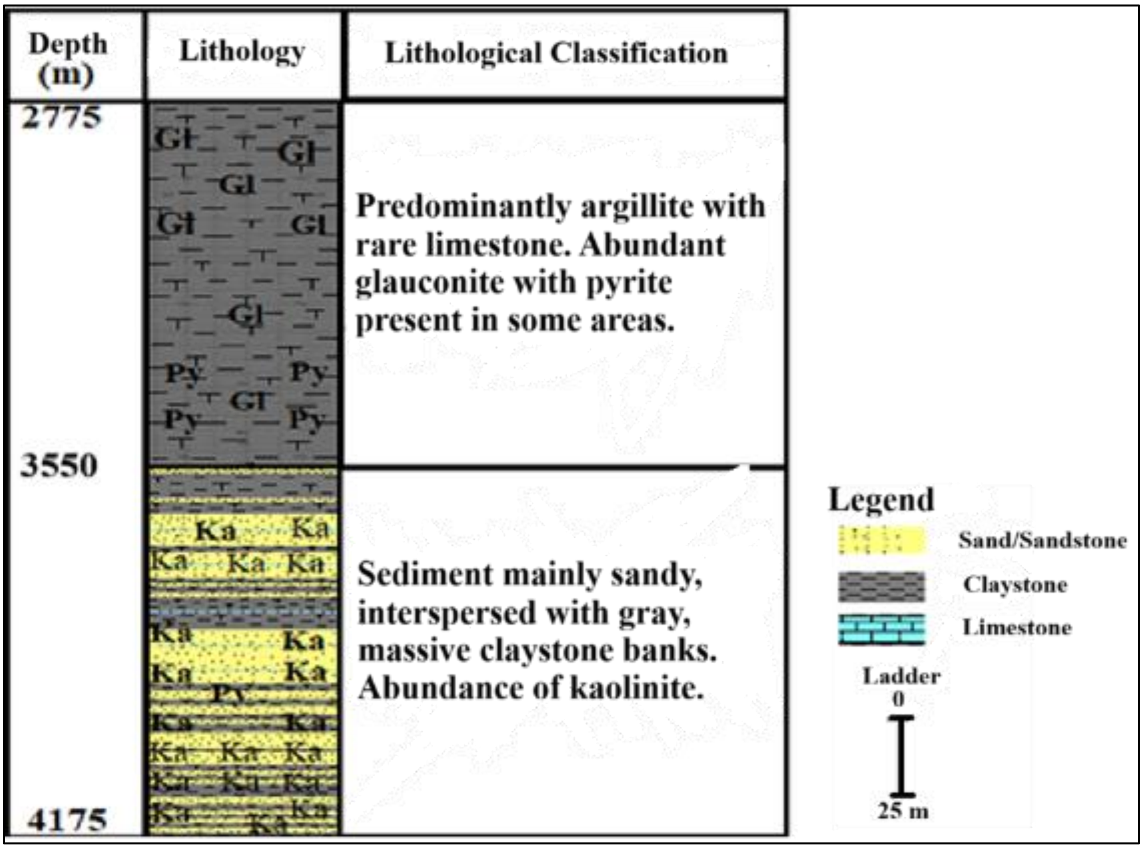


Figure 4 Lithological log of the ABANA-1X well

3.3. Geochemical characterization of sediments from the KOUM-1X well

3.3.1. The Albian (3058 m–2585 m)

The Albian is divided into four sequences.

3.3.2. A first section (a) from 3058 m to 3005 m

According to the samples, the total organic carbon content varies between 0.73 and 1.46% by weight, with an average of 1% by weight, indicating an average organic matter content (0.5 < TOC < 1% by weight). The oil potential varies from 1.07 to 2.08 mg HC/g rock, with an average of 1.48 mg HC/g rock, highlighting its low capacity to produce hydrocarbons (0 < S2 < 2.5 mg HC/g rock). Below 435°C, the Tmax value indicates that the organic matter is immature. The HI concentration ranging from 153 to 168 mg/g TOC (with an average of 145.43 mg/g TOC) suggests the presence of type III kerogen favorable for gas production. The OM is of continental origin; there is no rock in this sequence.

3.3.3. A second section (b) from 3005 m to 2875 m

According to the samples, the total organic carbon content varies between 0.73 and 1.46% by weight, with an average of 1% by weight, indicating an average organic matter content (0.5 < TOC < 1% by weight). The oil potential varies from 1.07 to 2.08 mg HC/g rock, with an average of 1.48 mg HC/g rock, highlighting its low capacity to produce hydrocarbons (0 < S2 < 2.5 mg HC/g rock). Below 435°C, the Tmax value indicates that the organic matter is immature. The HI concentration ranging from 153 to 168 mg/g TOC (with an average of 145.43 mg/g TOC) suggests the presence of type III kerogen favorable for gas production. The OM is of continental origin; there is no rock in this sequence.

3.3.4. The third (c) from 2855 m to 2725 m

The organic matter content of the samples in this section, which varies from 1.55 to 3.3% by weight, with an average of 2.6%, is very high (2 < TOC < 4% by weight). With an average content of 4.82 mg HC/g rock, the petroleum potential ranges from 3.76 to 5.75 mg HC/g rock (with an average of 4.82 mg HC/g rock). The fact that the maximum temperature is below 435°C indicates that the organic matter is still immature for producing hydrocarbons. The presence (IH) of type III kerogen favorable for gas production is indicated by a hydrogen index between 163 and 257 mg/g TOC (with an average of 191.33 mg/g TOC).

The average potential level indicates poor preservation of organic matter, which was very high during sedimentation. The origin of this OM is continental, and it is immature, as the Tmax values are below 435°C, with the exception of the 2725m coast, which reaches 440°C. This is an immature medium rock.

3.3.5. The fourth and final section (d) from 2690 m to 2580 m

These samples contain organic carbon. The total varies from 2.63 to 4.68% by weight, with an average of 3.54% by weight, indicating a very good concentration of organic matter (2< TOC < 4% by weight). The oil capacity ranges from 10.23 to 19.76 mg HC/g rock (with an average of 16 mg HC/g rock), suggesting that it is highly capable of producing hydrocarbons. Tmax values below 435°C indicate that the organic matter is not yet ready to produce hydrocarbons. The presence of Type II kerogens favorable to oil production is indicated by a hydrogen index between 389 and 476 mg/g TOC, with an average of 446.71 mg/g TOC. Based on this observation, an immature source rock can be observed.

3.3.6. The Cenomanian (with a single peak of 2570 m)

The sample in this section has a total organic carbon content of 2.21%, indicating a very good amount of organic matter (2 < TOC < 4% by weight). The oil content is 9.97 mg HC/g of rock, suggesting a good amount. The maximum temperature below 435°C indicates that the organic matter is still immature for producing hydrocarbons. The presence of type II kerogen, which promotes the production of liquid hydrocarbons, is indicated by the hydrogen index of 452 mg/g TOC.

The OM is of marine origin, indicating the presence of oil. It is immature, with a value below 435°C. These conditions show us that the clayey source rock is immature.

3.3.7. The Campanian (2560 m -2395 m)

The Total Organic Carbon (TOC) of the samples in this section varies from 1.73 to 2.82% by weight, with an average of 2.35% by weight. They are characterized by a very good organic matter content (2 < TOC < 4% by weight). The hydrocarbon production potential is very high, ranging from 7.68 to 13.87 mg HC/g rock (with an average of 11.23 mg HC/g rock). The fact that the maximum temperature is below 435°C indicates that the organic matter is still immature for producing hydrocarbons. The presence of type II kerogen, which is favorable for oil production, is indicated by a hydrogen index between 444 and 516 mg/g TOC (with an average of 476 mg/g TOC). This suggests that we have a clayey source rock because the mineral carbon value is less than 2%.

The Campanian is very rich in TOC, a very efficient S2 capable of producing hydrocarbons. The fact that the TOC and S2 values are high suggests that the preservation environment was oxygen-depleted. The fact that the organic matter (OM) is of marine origin encourages the formation of liquid hydrocarbons. The base of this rock is clayey and immature.

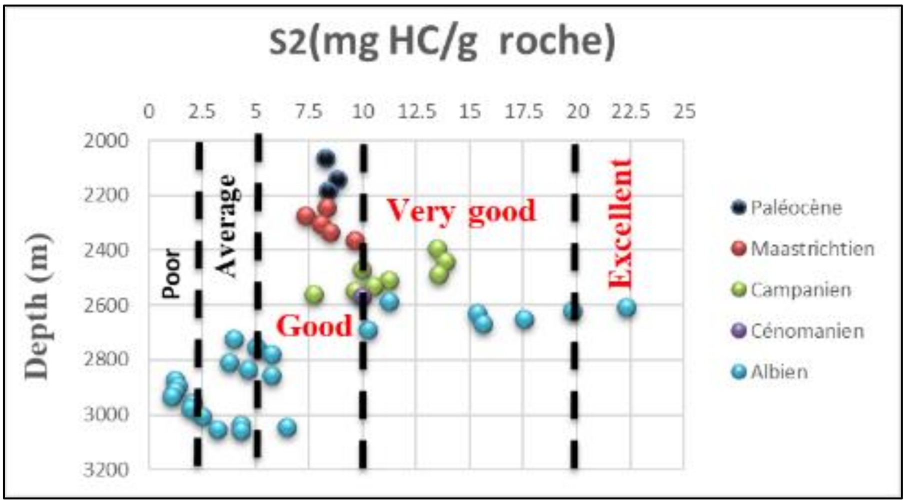
3.3.8. The Maastrichtian (2365 m-2245 m)

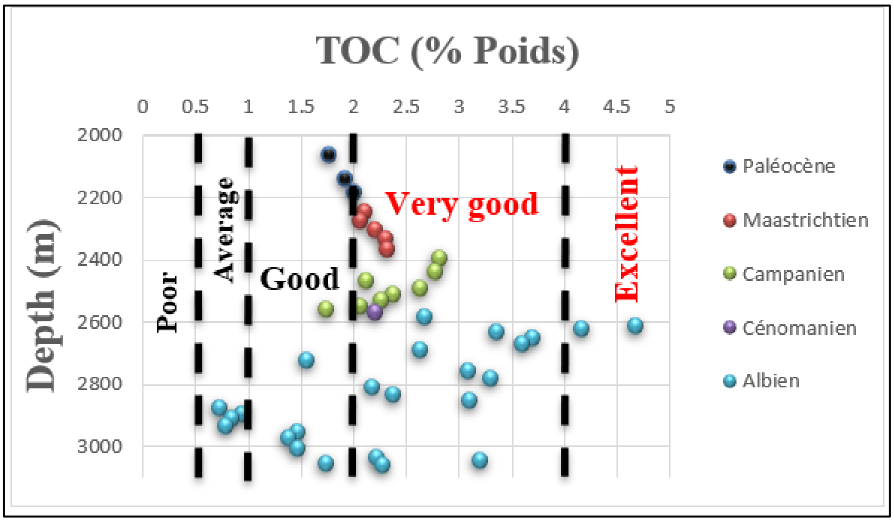
The weight percentage of total organic carbon in the samples ranges from 2.06 to 2.32% by weight, with an average of 2.20% by weight, indicating a very good organic matter content (2 < TOC < 4% by weight). The oil potential varies from 7.31 to 9.61 mg HC/g rock, with an average of 8.35 mg HC/g rock, demonstrating its capacity to produce hydrocarbons (10 < S2 < 20 mg HC/g rock). The Tmax value of less than 435°C indicates that the organic matter is still immature for producing hydrocarbons. The hydrogen index ranges from 355 to 414.6 mg/g TOC, with an average of 379.6 mg/g TOC, suggesting the presence of Type II kerogens favorable for oil production. This suggests that we have a clayey source rock because the mineral carbon value is less than 2%.

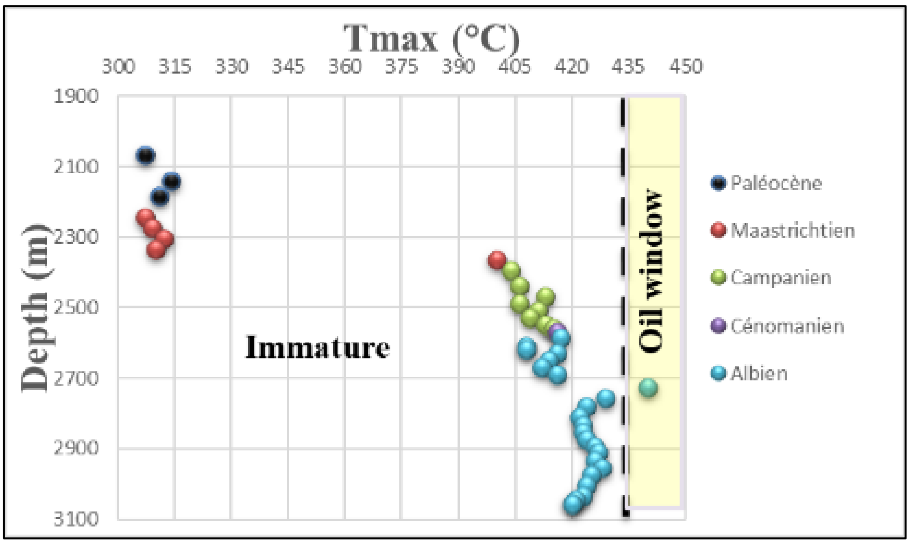
The Maastrichtian has a high TOC content (a high amount of OM during sedimentation and consistent quality), as well as high oil potential (S2) that can produce hydrocarbons. The preservation environment is therefore anoxic. The hydrogen index (HI) indicates the presence of Type II kerogen from the sea. It produces liquid hydrocarbons. This suggests that we are dealing with immature source rock.

3.3.9. The Paleocene (2185 m–2065 m)

In this section, samples with a total organic carbon content between 1.77 and 2% by weight, or an average of 1.90% by weight, are distinguished by a good amount of organic matter (1 < TOC < 2% by weight). The oil potential varies from 8.28 to 8.82 mg HC/g rock (8.48 mg HC/g rock on average). These values indicate that it is promising for hydrocarbon production. Tmax values below 435°C indicate that the organic matter is immature. The presence of type II kerogens favorable to oil production is indicated by a hydrogen index between 416 and 468 mg/g TOC (with an average of 448 mg/g TOC). The presence of total organic carbon (TOC) is significant in the Paleocene (the presence of OM during sedimentation and its preservation are evident) and high oil potential (S2), indicating that it can produce hydrocarbons. The OM is of marine origin and consists of amorphous plates and figured elements. This characteristic indicates immature source rock. (fig.5 and table 3)







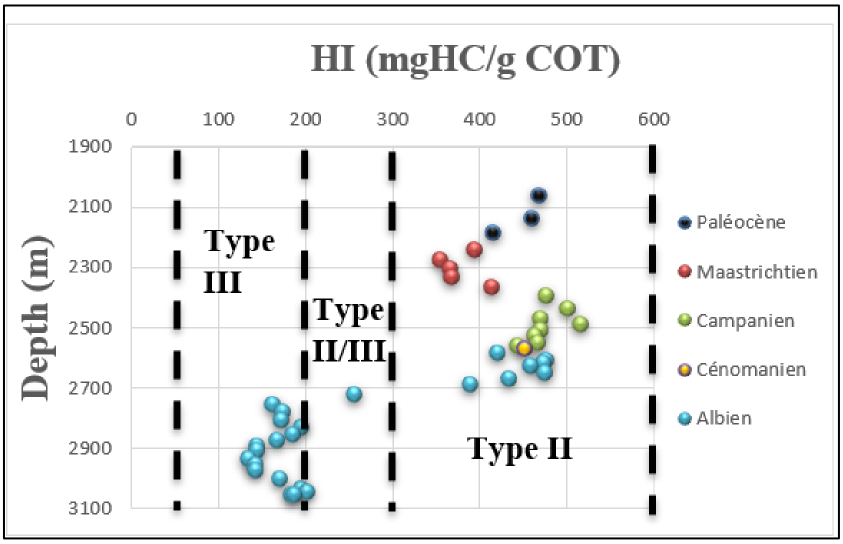


Figure 5 Variation in S2, TOC, Tmax, and IH in the sequence as a function of depth in the KOUM-1X well

Table 3 Summary of the KOUM-1X well

TOC % weight on average	S2 (mghc/g rock)	IH (mg HC/g TOC)	Tmax(°C)	FLOOR	Observations
V. Good	V. Good	Type II	Immature	Albian (d)	Immature bedrock
V. Good	Average	Type III	Immature	Albian (c, a)	Immature medium bedrock
Poor	Poor	Type III	Immature	Albian (b)	No bedrock
Good	Good	Type II	Immature	Cenomanian	Immature bedrock
V. Good	V. Good	Type II	Immature	Campanian	Immature bedrock
Good	Good	Type II	Immature	Maastrichtian	Immature bedrock
Good	Good	Type II	Immature	Paleocene	Immature bedrock

3.4. Rock Eval 6 pyrolysis of the ABENA-1X well

3.4.1. The Albian (4175 m to 3805 m)

In this section, the 17 samples have a total organic carbon content ranging from 0.26 to 0.65%, with an average of 0.40%. These samples have a low amount of organic matter (0 < TOC < 0.5% weight). The petroleum potential is low, ranging from 0.71 to 2.94 mg HC/g rock (with an average of 1.56 mg HC/g rock). The fact that the maximum temperature is below 435°C indicates that the organic matter is still immature for producing hydrocarbons. The presence of a hydrogen index ranging from 224 to 569 mg/g TOC (with an average of 386.35 mg/g TOC) suggests the presence of type II kerogen favorable for oil production.

The study of the 17 samples from this age range reveals a low TOC ET S2 content. The low quantity of organic matter present during sedimentation is responsible for this marked poverty. It is of marine origin and immature. From what has been said previously, there is no rock.

3.4.2. The Cenomanian and early Albian (3755 m to 3665 m)

The samples in this section have a total organic carbon content ranging from 1.65 to 1.94%, with an average of 1.78%, indicating a good concentration of organic matter (1 < TOC < 2% by weight). The oil potential is satisfactory, with values ranging from 5.99 to 6.56 mg HC/g rock (with an average of 6.28 mg HC/g rock). The fact that the maximum temperature is below 435°C indicates that the organic matter is still immature for producing hydrocarbons. From 314 to 397 mg/g TOC, with an average of 355.5 mg/g TOC, this suggests the presence of Type II kerogens favorable for oil production.

The TOC and oil potential of the Cenomanian and early Albian are quite high. The organic matter comes from the sea (Type II) and is not yet mature. The potential source rock is still immature.

3.4.3. The Turonian (3605 m to 3455 m)

The 10 samples have a total organic carbon content ranging from 0.35 to 2.06% by weight, with an average of 1.47%, suggesting a good amount of organic matter (1 < TOC < 2% by weight). S2, which varies from 1.58 to 6.06 mg HC/g rock, with an average of 3.57 mg HC/g rock, demonstrates its average capacity to produce hydrocarbons (2.5 < S2 < 5 mg HC/g rock). Based on a Tmax value of less than 435°C, it is clear that the organic matter is still immature for hydrocarbon production. The hydrogen ratio, which ranges from 141 to 493, with an average of 255.6 mg/g TOC, suggests the presence of Type II/III kerogens favorable for oil and gas production.

The total organic carbon of the 10 samples present at this age has an adequate content, while the oil potential is average. The average hydrogen index suggests mixed organic matter (marine and continental). This is immature organic matter. The average source rock is immature.

3.4.4. The Senonian beginning (3425 m to 3400 m)

The percentage by weight of total organic carbon in the samples, from an elevation of 3,410 m, ranges from 1.44 to 1.89%, with an average of 1.67%, indicating a good organic matter content (1 < TOC < 2% by weight). The S2, ranging from 3.17 to 5.41, with an average of 4.26 mg HC/g rock, is satisfactory (good). Tmax values below 435°C indicate that the organic matter is still immature for producing hydrocarbons. The HI ranging from 241 to 287 mg/g TOC (with an average of 251.5 mg/g TOC) indicates the presence of type II/III kerogen favorable for oil and gas production.

The early Senonian is characterized by high TOC and high S2 oil potential, which can produce hydrocarbons. The average hydrogen index suggests that the organic matter is type II/III, meaning it is mixed (marine and continental). The potential source rock is still immature.

3.4.5. Campanian/ Maastrichtian (3390 m to 3060 m)

It can be divided into three sequences.

A third section (e) from 3,390 m to 3,325 m

The Total Organic Carbon (TOC) of the nine samples in this section varies from 0.87 to 1.23% by weight, with an average of 1.10%. These samples are characterized by a good organic content (1 < TOC < 2% by weight). The petroleum potential is 1.12 to 3.43 mg HC/g rock (average of 1.90 mg HC/g rock), which suggests that it is not very suitable for producing hydrocarbons. The organic matter is immature, with a Tmax value below 435°C. The presence of type III kerogens favorable to gas production indicates an IH concentration between 110 and 230 mg/g TOC, with an average of 168.44 mg/g TOC.

The TOC and S2 averages mentioned above indicate a good amount of OM and a low amount of OM, respectively. The low S2 value indicates poor preservation of OM. The origin of this organic matter is continental (Type III) and it is immature at all temperatures below 435°C. This zone is not a potential source rock.

3.4.6. A second section (f) from 3300 m to 3150 m

The TOC of the three samples from this section ranges from 1.44 to 1.81% by weight, with an average of 1.66% by weight, which is characteristic of a good organic matter content (1 < TOC < 2% by weight). The petroleum potential (S2) varies from 4.57 to 7.73 mg HC/g rock (with an average of 6.6 mg HC/g rock), which is good. Tmax values below 435°C show that the organic matter is immature for hydrocarbon generation. The Hydrogen Index (HI) between 318 and 432 mg/g TOC (with an average of 392.33 mg/g TOC) indicates the presence of Type II kerogen suitable for oil generation.

In section (f) of this sequence, the amount of organic matter is adequate. S2 is well composed. The average hydrogen index indicates OM originating from the sea. The potential source rock is still immature.

3.4.7. A first section (g) from 3120 m to 3060 m

The TOC varies from 2.16 to 2.73% by weight, with an average of 2.44% by weight. This indicates a very good amount of organic matter (2 < TOC < 4% by weight). The S2 content ranges from 10.43 to 17.97 mg HC/g rock, with an average of 14.42 mg HC/g rock, indicating excellent quality. The fact that the maximum temperature is below 435°C indicates that the organic matter is still immature for producing hydrocarbons. With an average of 585.33 mg/g TOC, the IH ranges from 483 to 659 mg/g TOC, suggesting the presence of Type II kerogens favorable for oil production.

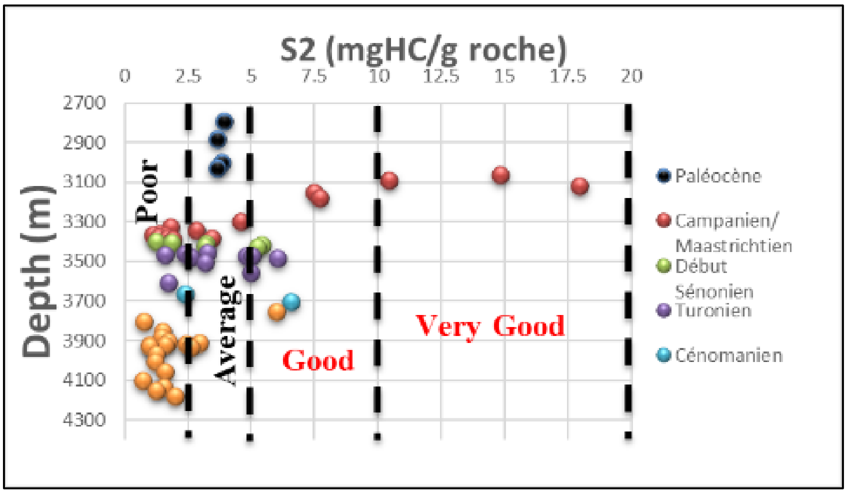
Section (a) The sequence is characterized by a high total organic carbon (TOC) content and high oil potential (S2). The presence of these two parameters is correlated with the adequate preservation of OM. This preservation was achieved in a non-harmful environment.

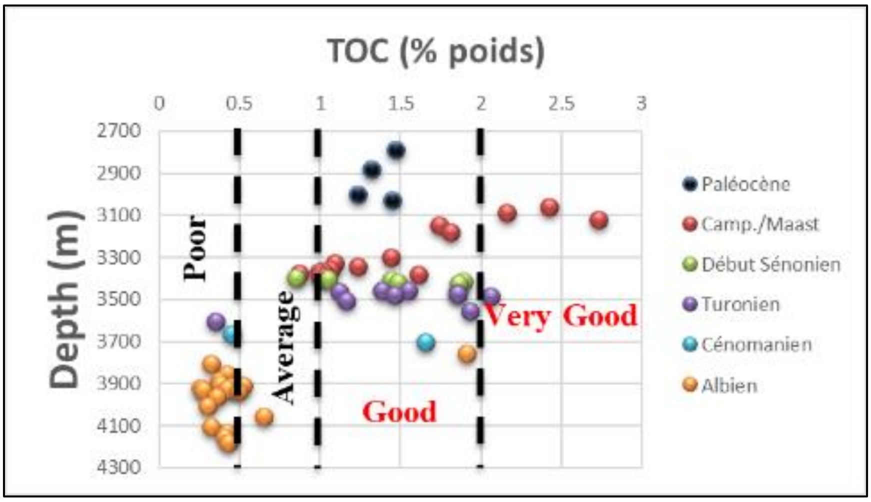
The index values (IH) indicate the existence of OM originating from the sea. Its composition consists of amorphous organic ranges and figured elements, and it generates mature liquid hydrocarbons. The potential source rock is still immature.

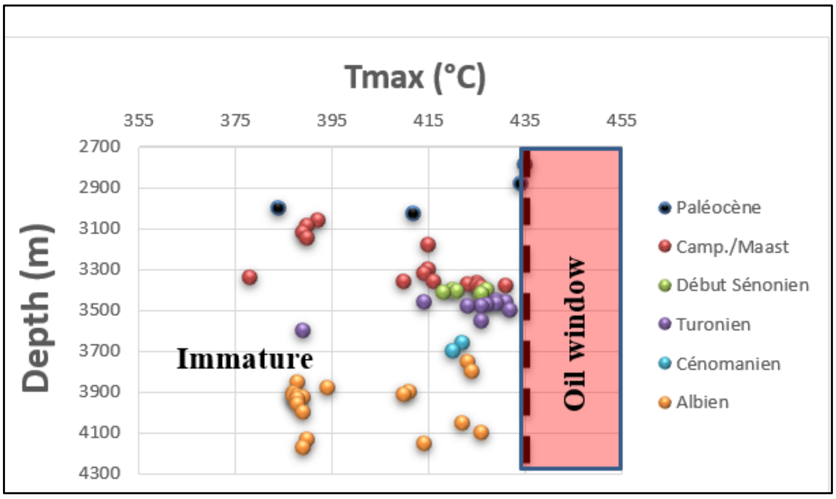
3.4.8. The Paleocene (3030 m to 2790 m)

In this section, samples with total organic carbon (TOC) levels ranging from 1.23 to 1.47% by weight, with an average of 1.37% by weight, indicate a good organic content (1 < TOC < 2% by weight). The average oil potential (S2) value is 3.65 to 3.95 mg HC/g rock (with an average of 3.78 mg HC/g rock). The fact that the maximum temperature is below 435°C indicates that the organic matter is still immature for producing hydrocarbons. The presence of type II/III kerogen, which promotes oil and gas production, is indicated by a hydrogen index between 254 and 311 mg/g TOC (with an average of 277.5 mg/g TOC). With an average of 0.71%.

The Paleocene has a high total organic carbon (TOC) content and S2 oil potential. The organic matter (OM) is both marine and continental, making it a mixed material. This mixed origin is attributed to the effect of transgression and regression. The cause of the continental OM lies in the decrease in sea level. The OM is considered immature, as the Tmax values are below 435°C. It is an immature bedrock average. (fig.6 and table 4).







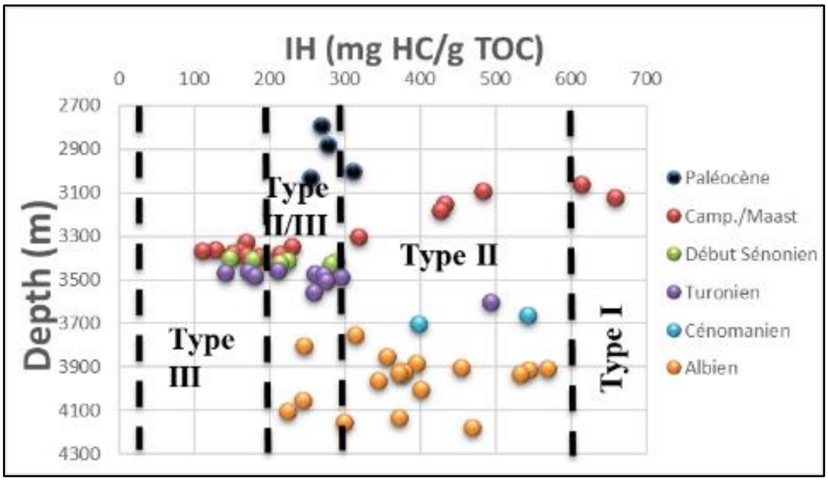


Figure 6 Variation in S2, TOC, Tmax, and IH in the sequence as a function of depth in the ABENA-1X well

Table 4 Summary of the ABENA-1X well

TOC % weight on average	S2 (mghc/g rock)	IH (mg HC/g TOC)	Tmax(°C)	FLOOR	Observations
Poor	Poor	Type II	Immature	Albian	No bedrock
Good	Good	Type II	Immature	Cenomanian /Early Albian	Immature bedrock
Good	Average	Type II/III	Immature	Turonian	Immature medium bedrock
Good	Average	Type II/III	Immature	Early Senonian	Immature medium bedrock
V. Good	V. Good	Type II	Immature	Campanian/ Maastrichtian (g)	Immature bedrock
Good	Good	Type II	Immature	Campanian/ Maastrichtian (f)	Immature bedrock
Good	Good	Type III	Immature	Campanian/ Maastrichtian (e)	Immature medium bedrock
Good	Average	Type II/III	Immature	Paleocene	Immature medium bedrock

4. Discussions

4.1. Lithostratigraphic Discussion

The alternation of clayey and sandy facies, distinguished by a high sand content observed in units 1, suggests a turbulent sedimentation environment and, consequently, intense hydrodynamics (Vigreux et al., 2011). The defined units are varied in color: dark gray, reddish brown, and gray. According to Chevillon (1992), the dark gray coloration is due to a significant reduction in dissolved oxygen, indicating a relatively reducing environment linked to depth, conducive to the accumulation of organic matter. Within this stratum, the detection of glauconite and pyrite suggests a shallow, hypoxic marine environment and a slow sedimentation rate (Yao et al., 2011). This dark gray color, linked to the concentration of organic matter, is confirmed by the abundant presence of plant remains found in most of the boreholes examined (Chevillon, 1992).

The formations in Unit 2 comprise carbonate layers interbedded with claystones and marls. These layers were identified in the KOUM-1X and ABENA-1X boreholes, and Sombo (2002) had already noted their presence in the western part of Abidjan. This stratum, characterized by a high claystone content, is mainly the product of sedimentation by decantation, indicating a depositional environment with a very low or even non-existent hydrodynamic regime (Yao, 2012).

4.2. Geochemical discussion (Rock Eval Pyrolysis)

Drillings 1 and 2 at Fresco revealed the exclusive presence of type II, III, or IV kerogens. These are generally associated with organic matter of continental or mixed origin, whose oil potential is limited (Yao, 2012; Assalé, 2013; and Ahouré, 2021). In contrast, the wells examined in our research show a greater diversity of kerogens – types I, II, II/III, and III – suggesting significant variability in sedimentary environments and higher hydrocarbon potential, particularly for types I and II.

In addition, Rock-Eval 6 analyses confirm the complete immaturity of the organic matter within our source rocks, which is in perfect agreement with the observations from the Fresco wells (Yao, 2012 and Assalé, 2013). This lack of maturation, observed in 99% of the samples from both wells, reveals a low geothermal gradient in the basin. This situation limits hydrocarbon generation, despite the quality of the kerogens. These findings highlight the importance of conducting additional exploration at greater depths to assess the potential for maturation.

5. Conclusion

5.1. Lithological

Unit 1 is dominated by sand (KOUM-1X and ABENA-1X wells), with intercalations of claystone beds and thin limestone bands in places; between 2,710 m and 2,600 m, the KOUM-1X well consists of moderately dark gray clay interbedded with limestone containing traces of pyrite and glauconite, while Unit 2 of the ABENA-1X and KOUM-1X wells is mainly clayey with a high presence of glauconite and pyrite.

5.2. Geochemistry

Oil potential (S2): for the KOUM-1X well, it is good for the Paleocene, Maastrichtian, and Cenomanian. It ranges from good to very good for the Campanian and from poor to excellent for the Albian. However, for the AENA-1X well, the Albian and early Senonian are poor, the middle Paleocene, Turonian, and early Senonian range from poor to average, and finally the Campanian/Maastrichtian range from poor to excellent.

The Tmax values for the two wells studied are below the norm, indicating immaturity of the organic matter. There is therefore no potential source rock.

5.3. Perspectives

The results obtained from lithostratigraphic and geochemical studies (Rock-Eval pyrolysis) of sediments from the western margin of the sedimentary basin have enabled important stratigraphic markers to be defined. The following should therefore be considered:

- Gamma ray analyses to confirm or refute the lithology
- Visual studies of kerogen to confirm or refute the maturity given by Rock-Eval 6 pyrolysis

- A chemostratigraphic study to characterize significant geological events in order to highlight other stratigraphic markers.

Compliance with ethical standards

Acknowledgments

The authors are grateful to mister Kalou Bi Hervé DOBO, Ingénieur Géochimiste, for his valuable support in my studies, to PETROCI Analysis and Research Center in Abidjan (Côte d'Ivoire), especially to Mrs Laure ATSE for the analysis of the samples. We also thank the General Director of Institut National Polytechnique Felix Houphouet-Boigny, Yamoussoukro (Côte d'Ivoire) and the African Centre of Excellence for Mining and Mining Environment (CEA-MEM).

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] ABLE. G. J. (2021). Evolution of sedimentary dynamics, mineralogy and geological history of the Albian-Maastrichtian formations of the eastern margin of Abidjan (Ivory Coast). Doctoral thesis, Félix Houphouët Boigny University, 86p.

[2] Ahouré N.D., (2021). Contribution of microfaunal and geochemical analyses to the sequential stratigraphy of Albian-Maastrichtian deposits in the eastern margin of the Ivory Coast sedimentary basin. Doctoral thesis, F.H.B University (Cocody/Abidjan), 161p.

[3] Assale F.Y. P. (2013). Sedimentological, palynological, geochemical, and paleoenvironmental characterization of formations related to the lagoon fault (eastern part of the onshore basin of Côte d'Ivoire). Single doctoral thesis. Félix Houphouët Boigny University, Cocody, Côte d'Ivoire, 361p.

[4] Bamba M. K. (2019). Contribution of micropalaeontology to the identification of Aptian-Albian deposits in the Ivorian sedimentary basin. Local biozonation, palaeoenvironment and palaeoceanographic reconstruction. Doctoral thesis, Felix Houphouët Boigny University, Earth and Mining Sciences, 198 p.

[5] Chevillon.C. (1992). Biosedimentology of the Great North Lagoon, Study &THESE, ORSTOM, Paris, 223p.

[6] Digbehi, Z. B. (1987). Comparative studies of sedimentation in the early stages of Atlantic – Gulf of Guinea – Bay of Biscay openings. Sedimentology, Biostratigraphy. Doctoral thesis, University of Pau, 366 p.

[7] Doukoure M. (2020). Depots d'age albien de la marge d'abidjan, côte d'ivoire : palynostratigraphie, palynofacies, paleoclimat, geochimie et paleoenvironnement. Thèse Doctorat, Univ. Félix Houphouët Boigny, pp.116-138.

[8] Espitalie J., Laporte J. L., Madec M., Marquis F., Leplat P., Paulet J. & Boutefeu A. (1977). Rapid method for characterizing source rocks, their petroleum potential, and their degree of evolution. Journal of the French Petroleum Institute, 32: pp. 23–42.

[9] Espitalié, J., Deroo, G., Marquis, F., 1985. Rock-Eval pyrolysis and its applications. Part I. Journal of the French Petroleum Institute, 40(5), pp. 563–579.

[10] Fea. I. (2019). Reconstruction of the dynamics of deposits in the offshore sedimentary basin of Côte d'Ivoire (northern Gulf of Guinea) and its impact on Albian-Cenomanian reservoir rocks. Single thesis, University. Cocody. 113p

[11] Gbangbot. (2012). Stratigraphic characterisation of aquifers in subsurface formations in the lagoon region of Côte d'Ivoire. Attempt to model Tertiary deposit environments. Doctoral thesis, Félix Houphouët Boigny University, 218 p.

[12] Kouassi, K. A. (2014): Anoxic episode at the Cenomanian/Turonian boundary in the offshore sedimentary basin of Côte d'Ivoire: petroleum interest of black shales. Doctoral thesis, Univ F H B Cocody, 251 p.

[13] Merrill, M. D. (2012). First principles of instruction: Identifying and designing effective, efficient, and engaging instruction. Association for Educational Communications and Technology (AECT).

[14] Pettijohn F. (1949). Sedimentary Rocks Happer Frères. Edit. New-York .1 vol – 526 p

[15] PETROCI & BEICIP (1990). Côte d'Ivoire Petroleum Evaluation. Ministry of Mines, Abidjan, Côte d'Ivoire. Promotional report, 99 p

[16] Peters, K.E. (1986). Guidelines for Evaluating Petroleum Source Rock Using Programmed Pyrolysis. AAPG Bulletin, pp. 70, 318-329.

[17] Sombo B. C. (2002). Study of the structural and seismostratigraphic evolution of the offshore sedimentary basin of Côte d'Ivoire, a passive margin cut by a canyon. Doctoral thesis in Earth Sciences. University of Abidjan (Côte d'Ivoire), 304p.

[18] Tahi. I. (2022). Palynologie et caractérisation de la matière organique des dépôts Albo/Aptien-Crétacé Supérieur du basin sédimentaire de Côte d'Ivoire. Sorbonne Université, France, pp. 101-103

[19] Tyson, R. V., 1995. Sedimentary Organic Matter: Organic Facies and Palynofacies. Chapman & Hall, London, 615 p

[20] Vigreux T., Aoustin D. et Flotte P. (2011). Sedimentary record and Holocene environment of the Giessen alluvial plain (Scherwiller, Bas-Rhin, Alsace). Quaternaire, 22, (2), 2011, pp. 129-145

[21] Yao N. J. P., Digbehi Z.B., Monde S., Kra A. C., Aka K., Bleoue N. Z., Tea Y.J., Kplohi Y.L.H., Duffi K. L. (2011). Sedimentological Study and Palaeoenvironmental Sketch of the Fresco Formations. Sciences & Nature, 8(1-2), pp. 73-84

[22] Yao N. J. P., (2012). Sedimentological, mineralogical, geochemical, and biostratigraphic characterization of the steep cliffs of Fresco: Grand-Lahou region (Ivory Coast). Doctoral thesis, F.H.B University (Cocody/Abidjan)

Authors short biography

KOUMAN Kobenan Guy-Roland is from Bondoukou (Côte d'Ivoire) born on March 6, 1990. He holds a Master's degree in Earth Sciences and Mining Resources, with a specialisation in Sedimentary Environment and Energy Geosciences, from Felix Houphouet Boigny University, Cocody, Côte d'Ivoire. He is currently a PhD student in petroleum geosciences at the World Bank's African Centre of Excellence for Mining and Mining Environment (CEA-MEM). He works as a petroleum geologist and research officer in charge of petroleum research at the Directorate General of Hydrocarbons of the Ministry of Mines, Petroleum and Energy in Côte d'Ivoire.