International Journal of Innovation and Scientific Research
ISSN 2351-8014 Vol. 71 No. 2 Mar. 2024, pp. 235-247

http://www.ijisr.issr-journals.org/

LITHOSTRATIGRAPHIC CHARACTERIZATION OF THE TURONIAN DEPOSITS OF THE ABIDJAN MARGIN (IVORY COAST)

***Lou Soholy Ange Claverie Lassey*[1], *Chia Marie Reine Kokoa*[2], *N'Guessan Donald Ahoure*[3], *and Affian Kouadio*[4]**

[1]University of San Pedro, Faculty of Marine Sciences, 01 BP V1800, San Pedro, Côte d'Ivoire

[2]University of Félix Houphouët Boigny, Faculty of Earth Sciences and Mining Resources, Marine Geology Department, 22 B.P. 801 Abidjan 22, Côte d'Ivoire

[3]University Alassane Ouattara, Faculty of Medical Sciences, Science and Technology Department, BP 1801, Bouake, Côte d'Ivoire

[4]University of Félix Houphouët Boigny, Faculty of Earth Sciences and Mining Resources, Marine Geology Department, 22 B.P. 801 Abidjan 22, Côte d'Ivoire

ABSTRACT: In order to gain a better understanding of the Ivorian sedimentary basin and optimize the exploitation of its resources, a number of researchers have begun work there, especially in the offshore part of the basin. However, the Turonian, having been severely eroded and presented as consisting of small thicknesses of rock, has long remained neglected. In order to fill the knowledge gap on the Turonian formations of the Abidjan margin, this study was carried out with the aim of determining the complete lithostratigraphy of the Turonian sedimentary rocks of the Abidjan margin. The work was carried out on 313 samples from five (5) wells on this margin. It involved lithological analysis and study of accessory elements (glauconites, carbonaceous debris and pyrites) using a binocular magnifying glass, as well as calcimetric study of the sediments using a Bernard calcimeter. Diagonal analysis was used to identify the lithology of the formations studied. The Turonian is characterized by dark argillites (for the most part), limestone, sands and sandstones. The sediments are essentially low in calcium carbonate. Pyrites, carbonaceous debris and abundant glauconites are found. The sediments were deposited in a shallow, semi-confined marine environment close to the mainland.

KEYWORDS: Sedimentology, lithology, calcimetry, logging, paleoenvironment.

1 INTRODUCTION

The Turonian is an upper-secondary stage that exists in rock fragments. It is practically absent or confused with the Cenomanian or Lower Senonian due to the strong erosion that has affected it. Numerous geologists and petroleum companies, such as [1], [2], [3], [4] and [5] of different specialties, have taken an interest in the deposits of the Cenomanian-Turonian (C-T) transition due to the contrasting nature of the underlying and overlying deposits. Turonian source rocks are rich in organic matter. During the Cenomanian-Turonian, the Tethys and the newly-formed Atlantic Ocean were characterized by poor water circulation and stagnation, due to both the ancient Strait of Gibraltar and the limited connection between the Atlantic Ocean and neighboring oceans [6]. These factors of isolation were decisive in the development of anoxia during this period ([7], [8], [9]), resulting in a strong conservation of organic matter in these areas. The Turonian was highlighted in a few areas of the sedimentary basin thanks to its biostratigraphic markers and was essentially marked by the presence of black-shales. Extremely hot climatic conditions, abnormally high carbon dioxide levels, a change in the geodynamic configuration of the continents and a rise in global mean sea level led to the installation of anoxic conditions in the oceanic domain during the Middle Cretaceous period, and the deposition of organic carbon-rich layers known worldwide as "black-shales" [10]. Researchers [11], [12], [13],

[14] and [15] have studied the Turonian sediments of the Ivorian offshore basin lithologically, micropalaeontologically, paleoenvironmentally and geochemically, and have established a succession of formations essentially made up of organic-rich black shales. According to [16], the black shales deposited during oceanic anoxic event II in the Abidjan margin are composed of alternating marls, dark gray laminated clays and rare limestone sequences. Despite all these studies, gaps in our knowledge remain, notably the complete lithostratigraphy of the Turonian formations and their spatial distribution in the Abidjan margin. This study was carried out to fill these gaps. To do this, we will establish the complete lithostratigraphy of the sediments from several Turonian wells, by studying lithology, calcimetry, accessory elements characteristic of the paleoenvironment and diagenetic analysis. A correlation of the various wells will enable us to assess the spatial distribution of the formations.

2 Materials And Methods

The material consists of 313 drill cuttings samples (Table I).

Table 1. Number of samples studied per well with their different study intervals

Wells	Surveyed interval (m)	Number of samples
L1	2643 -2759	35
L2	2353 - 2402	11
L3	2376 – 2617	74
L4	2372 - 2712	103
L5	2379 - 2676	90

***Source**: National Oil Company of Ivory Coast (PETROCI).*

These sediments come from five (5) PETROCI oil wells L1, L2, L3, L4 and L5 located along the Abidjan margin of Côte d'Ivoire (Figure 1).

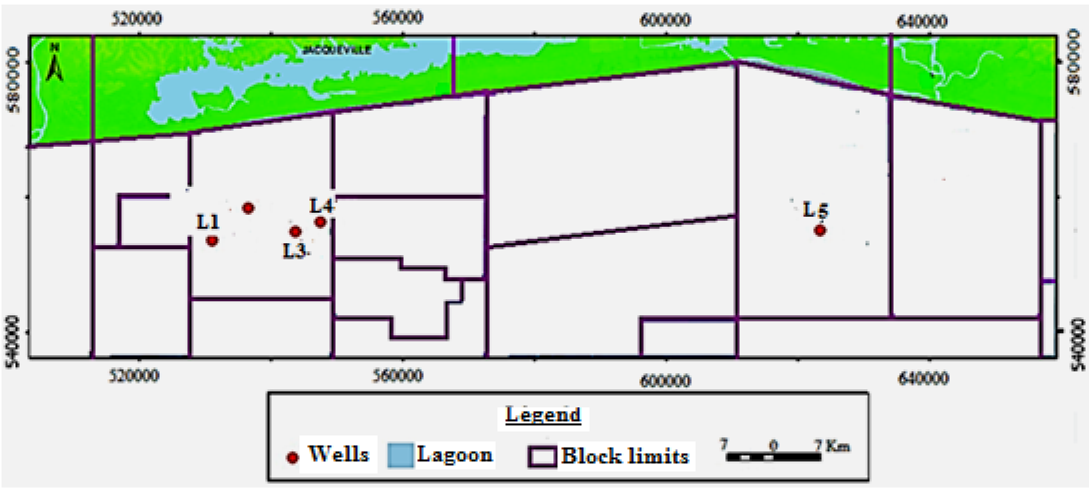

Fig. 1. Map showing the location of the wells studied on the Abidjan margin

As a preliminary step, 40 g of drill cuttings were collected and processed for better binocular analysis.

- **Lithological study**: used a binocular magnifying glass to determine the formations crossed by the borehole. using a binocular magnifying glass. Sediment descriptions were made using the color chart, size chart, morphoscopy chart and sand grain percentage chart.
- **Study of accessory elements**: consisted in identifying and quantifying in percentage under a binocular magnifying glass of the accessory elements (glauconites, pyrites and carbonaceous debris) present in the sediments. The nomenclature of sediment depositional environments defined by GOUA (1997) was used to determine the depositional environments of the sediments studied.
- **Calcimetric analysis:** a Bernard calcimeter was used to determine the calcium carbonate ($CaCO_3$) content of the sediments.
- **Gamma ray logging analysis:** consisted in interpreting the logging data to identify the lithology of the formations studied. Gamma Ray (GR) was analyzed in this work.

3 RÉSULTATS

This study was carried out on sediments systematically in the direction of drilling. Each analysis was interpreted to define the sediment deposition environment.

3.1 LITHOSTRATIGRAPHY OF WELLS

3.1.1 PUITS L1

The L1 well studied over the interval (2643 m -2759 m) consists solely of argillite (a single unit) as shown in Figure 2. This unit consists of dark grey and black argillite with traces of sandstone. The gray argillite is massive and often fissile, soft to firm, while the black argillite is massive. Accessory minerals include glauconites (5%), pyrites (4%) and carbonaceous debris (3%). This medium is very low in calcium carbonate ($CaCO_3$), with levels ranging from 0.85 to 9.26%. The gamma ray signature is generally low, while the lithology has clayey facies. The clays in this unit therefore contain fewer radioactive elements. The environment is marked by the presence of glauconites and carbonaceous grains at the base of the shaft, with a total absence of pyrites. However, at the roof, pyrites are frequent, with a decrease in carbonaceous debris. This would indicate the transition from an oxygenated marine environment, close to the continent with continental influence, to a marine environment with little continental influence, confined and anoxic. This would suggest a transition from a middle to an inner platform. The presence of argillites confirms that the sediments were deposited in a marine environment. This description of the sediments in the L2 well studied has enabled us to establish the lithostratigraphic column shown in Figure 2.

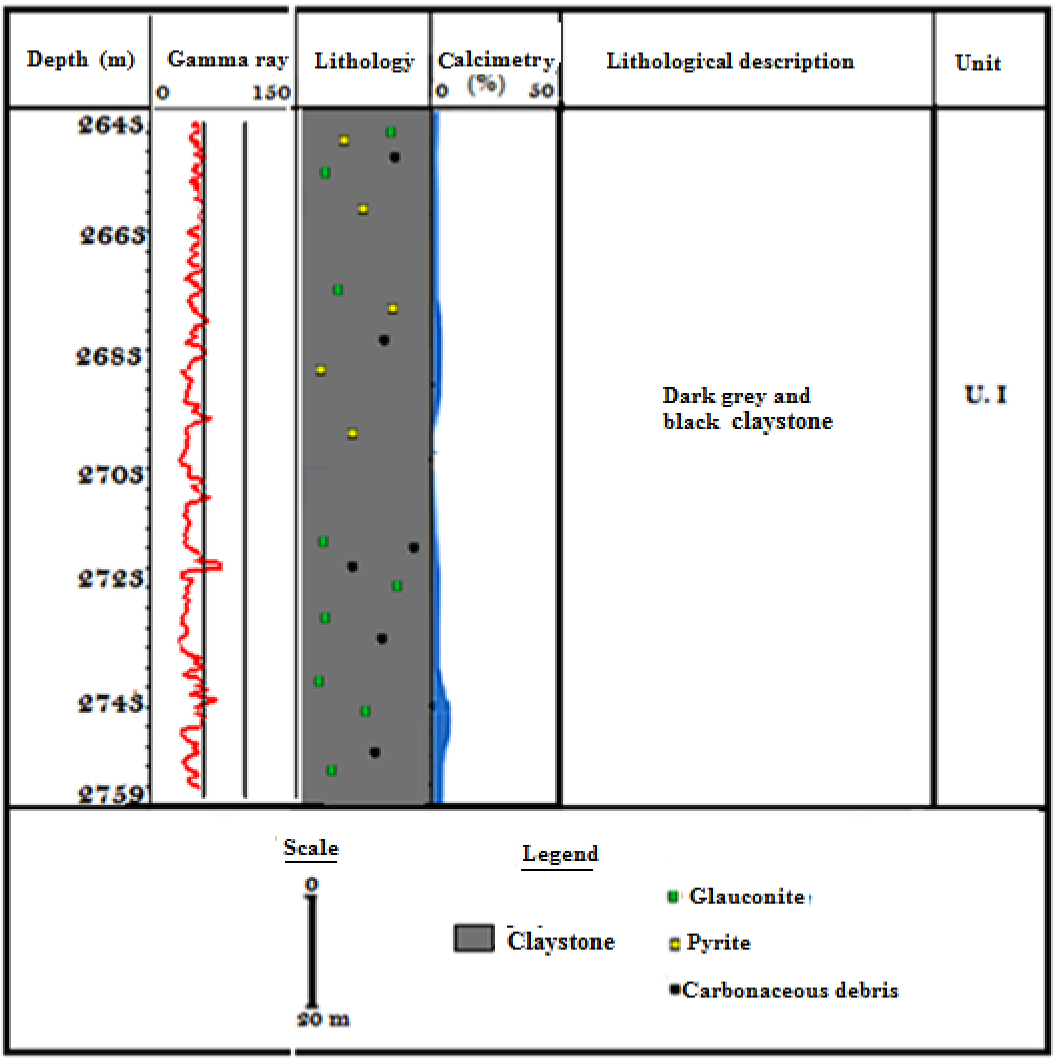

Fig. 2. Lithostratigraphic column and analysis of well L1

3.1.2 WELL L2

The studied interval of well L2 is between 2353 and 2402 m. The study of well L2 at this studied interval reveals two (2) units (figure 3):

- **Unit I (2353 m - 2389 m):** light to dark grey argillite;
- **Unit II (2389 m -2402 m):** alternating dark grey argillite and white to grey limestone.

3.1.2.1 UNIT I (2353 M -2389 M)

This unit consists solely of light to dark gray, massive to fissile, firm argillite. The medium is rich in glauconites (13%) and pyrites (4%), with a small amount of carbonaceous debris (3%). The calcium carbonate (CaCO3) content is negligible, ranging from 0.4 to 0.6%.

3.1.2.2 UNIT II (2389 M -2402 M)

Alternating dark-gray argillite and white to olive-gray limestone. The argillite is massive to fissile and soft. The limestone is friable to firm and mudstone to microcrystalline. Clay gradually gives way to limestone towards the base. The medium contains glauconites (8%) and pyrites (5%) with traces of carbonaceous debris. The calcium carbonate ($CaCO_3$) content is high, ranging from 17.8 % to 79.9 %. The calcium carbonate content of the samples ranges from 0.4 to 79.9%.

This well reveals a limestone facies at the base, followed by a disappearance of the limestone from 2382 m upwards. There are abundant glauconites with few pyrites and little carbonaceous debris, suggesting deposition in a shallow, confined, anoxic marine environment with very little continental influence. The depositional environment at the base is thought to be a medium to internal platform. The lithology confirms the deposition of sediments in a marine environment with low depositional energy. The anoxic environment, as evidenced by the presence of pyrites, would have been unfavorable to the survival of pre-existing organisms (calcareous test microfauna), resulting in the death of these animals. The shells would then have accumulated on the seabed, forming carbonate mud and then limestone rock under the effect of pressure and time. The lithostratigraphic column deduced from the analysis of samples from well L2 is shown in figure 3.

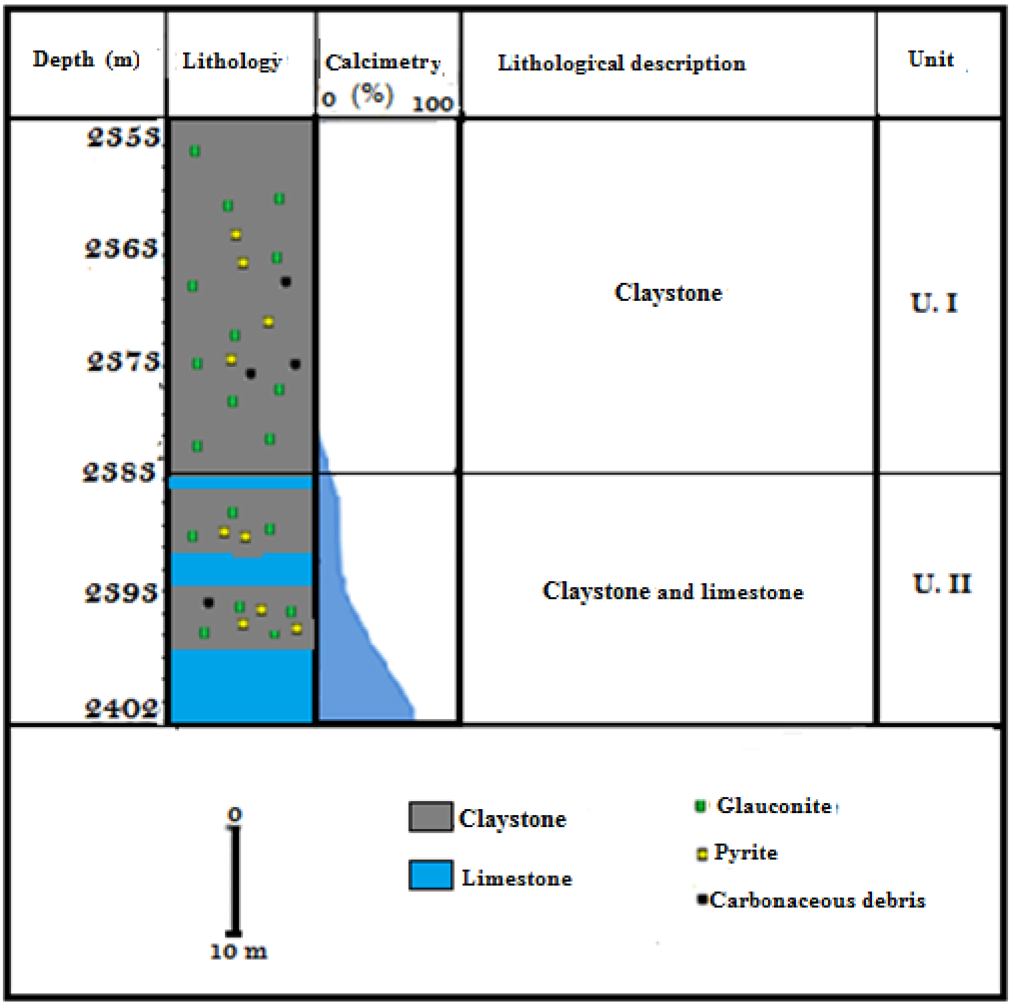

Fig. 3. Lithostratigraphic column and analysis of L2 well

3.1.3 WELL L3

The interval studied in shaft L3 ranges from 2376 m to 2617 m and reveals two units (figure 4):

-Unit I (2376 m - 2547 m): argillite with sandstone and sandstones;
-Unit II (2547 m - 2617 m): alternating argillite and sandstone.

3.1.3.1 UNIT I (2376 M - 2547 M)

This unit consists of argillite with sand and sandstone intergrades.

Four sub-units can be distinguished:

- **Sub-unit I (2376 m -2412 m):** Dark gray to black argillite with sand and sandstone interlayers. The clay is massive and firm. The sands are white, rarely smoky to pink and transparent to translucent. Sandstones are white with carbonate cement and fine to very fine grains. Glauconite is remarkably present (10%), with very little carbonaceous debris (2%), and calcium carbonate ($CaCO_3$) content is low, ranging from 2.32 to 5.88%.
- **Sub-unit II (2412 m -2445 m):** Grey argillite with some sandstone. The argillite is dark to black, massive and firm. The sandstones are white with carbonate cement and fine to very fine grains. Glauconites are abundant (18%), while pyrites are only slightly present (2%), with very little carbonaceous debris (3%). Calcium carbonate ($CaCO_3$) levels are low in this environment, ranging from 2.53% to 6.11%.
- **Sub-unit III (2445 m -2488 m):** This part consists of argillite with small sand and sandstone beds. The argillite is dark gray to black, massive and firm. The sands are transparent to translucent. Sandstones are white with calcareous cement. This zone

is rich in glauconites (15%) and carbonaceous debris (10%), with traces of pyrites (2%). The calcium carbonate (CaCO3) content is low, ranging from 2.53 to 4.21%.

- **Sub-unit IV (2488 m -2547 m):** Dark gray to black argillite with white and pinkish, transparent to translucent sands. The argillite is massive and firm. It contains a high proportion of glauconites (18%), carbonaceous debris (5%) and traces of pyrites. The calcium carbonate (CaCO3) content of the sediments is low, ranging from 1.89 to 5.67%.

3.1.3.2 UNIT II (2547 M -2617 M)

This part comprises alternating argillite and sandstone. The argillite is dark gray to black, solid and firm. The sandstones are white to gray with carbonate cement and fine to very fine grains. The environment includes a good presence of glauconites (10%), a small presence of carbonaceous debris (5%) and traces of pyrites. Calcium carbonate (CaCO3) content is low, ranging from 1.47 to 5.25%. Low calcium carbonate content ranging from 1.47 to 6.11%. As the 2376 -2547 m interval is essentially marked by argillites and abundant glauconites, this would suggest deposition in a marine environment. This environment is also poor in carbonaceous grains, with pyrites virtually non-existent, indicating a calm marine environment with weak continental influences. However, in the 2547-2617 m interval, alternating argillite and sandstone indicate an unstable, turbid environment. Associated with glauconites and carbonaceous grains, this would suggest an unstable and turbid shallow marine environment. This disturbance of the environment would be due to the unstable morphology of the Abidjan margin, affecting the type of sediment deposition in the area. The deposition of sediments in well L3 moved from a turbid marine environment (where the morphology of the Abidjan margin is unstable) to a calm marine environment (where the morphology is stable). The lithostratigraphic column (Figure 4) is a representation of the various observations and analyses carried out on well L3.

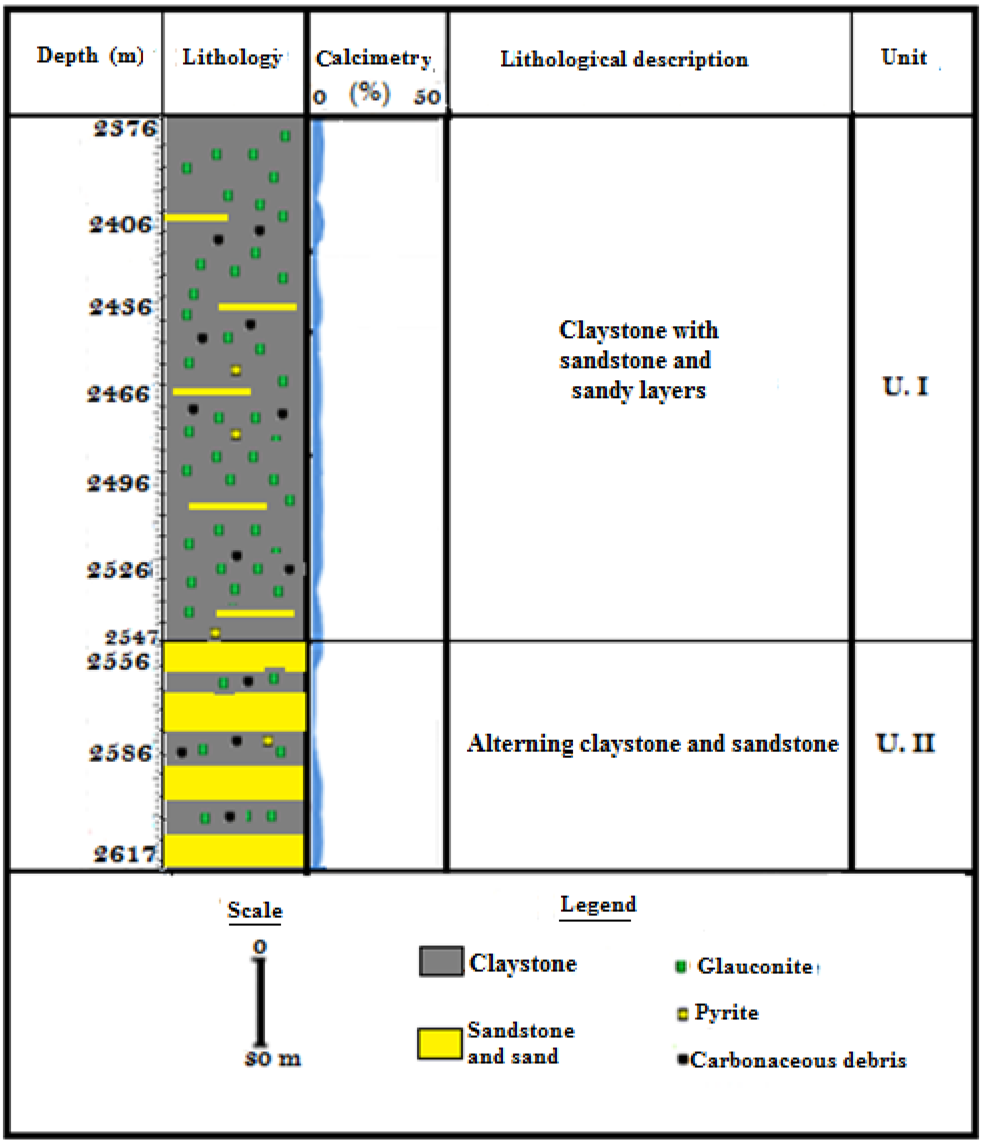

Fig. 4. Lithostratigraphic column and analysis of well L3

3.1.4 Well L4

A study of shaft L4 over the interval (2372 m -2712 m) reveals a unit consisting mainly of argillite and sand (Figure 5). The gamma ray signature is monotonic, with slightly low values. The argillite in this interval therefore contains fewer radioactive elements. The presence of non-clay formations (limestone, sand and sandstone) also confirms this signature.

The interval studied comprises five sub-units:

- **Sub-unit I (2372 m -2438 m):** Clay with occasional thick layers of limestone and sandstone and thin layers of sand. The argillite is dark-gray, in places slightly calcareous, massive and compact. Sandstones are white with calcareous to clayey cement. The sands are transparent to translucent and the limestones are white, friable and mudstones. This zone is rich in carbonaceous debris (8%) and glauconites (5%), with traces of pyrites. The environment is low in calcium carbonate, with levels ranging from 1.25 to 13.3%.
- **Sub-unit II (2438 m -2544 m):** This is marked by alternating dark-grey argillite and sand with traces of sandstone. The sands are white, pinkish and smoky, transparent to translucent. The unit contains glauconites (5%) and little carbonaceous debris (4%). Calcium carbonate ($CaCO_3$) content is low, ranging from 1.47 to 4.99%.
- **Sub-unit III (2544 m -2600 m):** This unit is represented by sands with argillite interlayers. The sands are white, pinkish and smoky, transparent to translucent. The argillite is dark gray, massive, soft to firm. It contains little carbonaceous debris (4%), with traces of glauconite. The calcium carbonate ($CaCO_3$) content is low, ranging from 2.91% to 5.82%.

- **Sub-unit IV (2600 m -2660 m):** Contains alternating sands and argillite with sandstone inlays. The sands are transparent to translucent. The argillite is light to dark gray. Sandstones are white to gray with calcareous cement. There is a slight presence of carbonaceous debris (4%) with traces of glauconite (3%). Calcium carbonate ($CaCO_3$) content is low, ranging from 2.1 to 5.19%.
- **Sub-unit V (2660 m -2712 m):** The clay is light gray and sometimes dark, massive and compact. They contain rare traces of glauconite and carbonaceous debris. Calcium carbonate ($CaCO_3$) content is low, ranging from 1.68 to 4.78%. However, carbonaceous grains are predominantly present, suggesting deposition in a marine environment with strong continental influences. As the mudstones are of marine origin, while the sands and sandstones are of continental origin, the lithology of shaft L5 suggests that the sediments were deposited in a turbid marine environment, with continental sediment inputs. This instability of the environment would be due to the unstable morphology of the Abidjan margin. Well L4 is marked by the presence of glauconites. The lithostratigraphic column for this well is shown in Figure 5, which shows that the well consists of clay and sand facies with calcium carbonate content ranging from 1.25 to 13.3%.

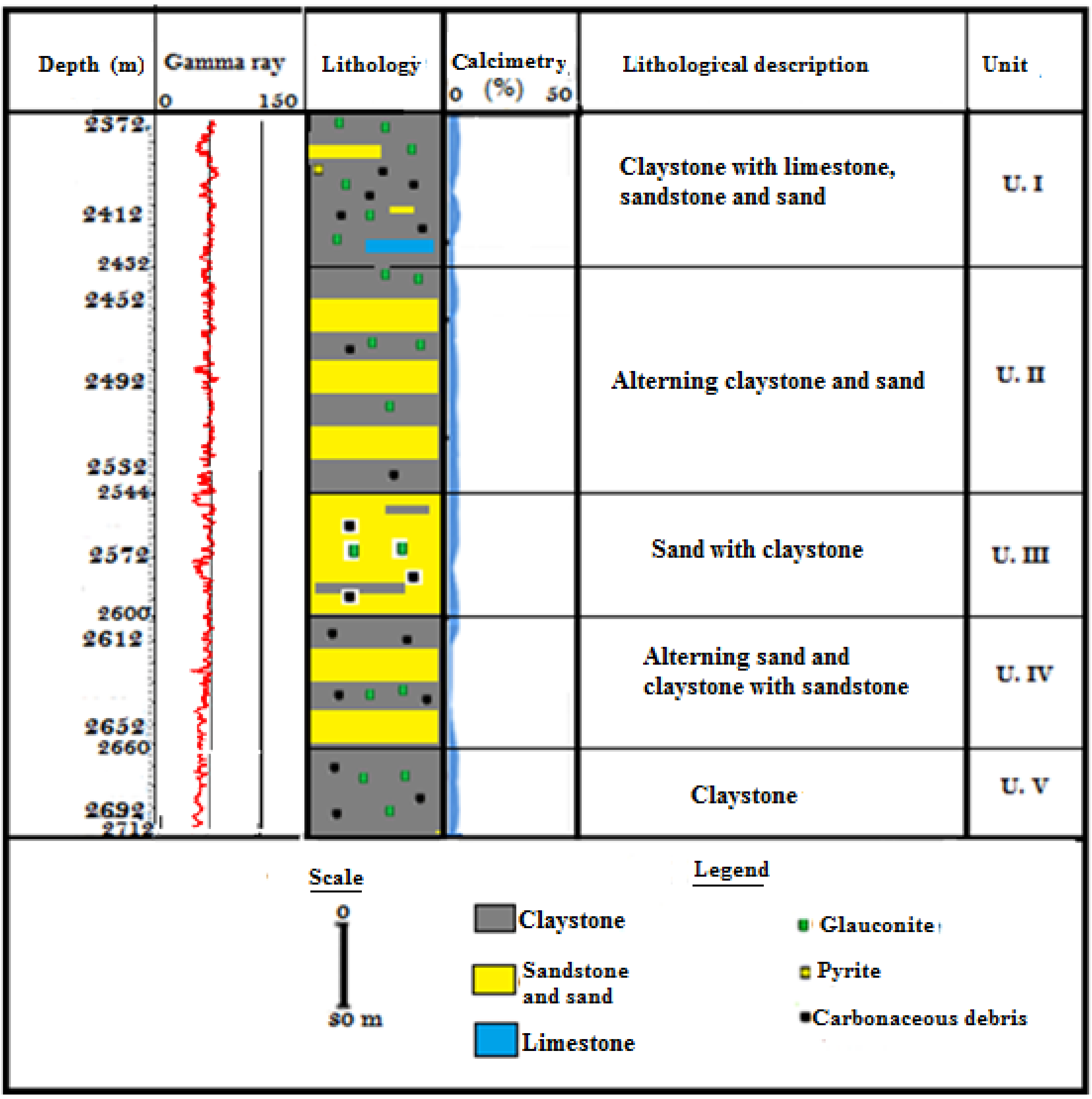

Fig. 5. Lithostratigraphic column and analysis of well L4

3.1.5 Well L5

Well L5 on the interval (2379 m -2676 m) comprises a single unit of alternating argillite, sand and sandstone (Figure 6). The gamma ray signature is low. This can be explained by the alternation of less radioactive sediments such as sands and sandstones, and the presence of clays containing less radioactive elements.

Three sub-units can be distinguished:

- **Sub-unit I (2379m -2485 m):** This consists of alternating argillite and sand with white to grey sandstones. The argillite is dark gray to brownish gray, massive, firm and only slightly calcareous in places. The sands are white, smoky to pinkish, transparent to translucent and angular to rounded. Sandstones are medium- to very fine-grained, with a silico-clay cement that is often slightly calcareous. Glauconites are abundant (8%) with little carbonaceous debris (3%). The unit is very low in calcium carbonate (CaCO3), ranging from 0.21 to 1.47%.
- **Sub-unit II (2485m -2617 m):** This unit comprises alternating argillite, sand and sandstone. The argillite is dark gray to brownish gray, massive, firm and often low in carbonate. Sands are white, smoky and pinkish, transparent to translucent and angular to rounded. Sandstones are white to dark gray, medium- to very fine-grained, with siliceous to clayey cement and limestone in places. There is little glauconite (5%) and very little carbonaceous debris (2%). This interval is very low in calcium carbonate (CaCO3), with levels ranging from 0.42 to 1.89%.
- **Sub-unit III (2617m -2676 m):** Mainly composed of alternating argillite and sandstone, with transparent to translucent sand. The argillite is dark gray to brownish gray, massive, firm and only slightly calcareous. Sandstones are white to gray with medium to very fine grains and silico-clay cement. Glauconites (6%) and little carbonaceous debris (3%) are present. This interval is very low in calcium carbonate (CaCO3), with levels ranging from 0.63 to 3.97%. The calcium carbonate content of the sediments ranges from 0.21 to 3.97%.

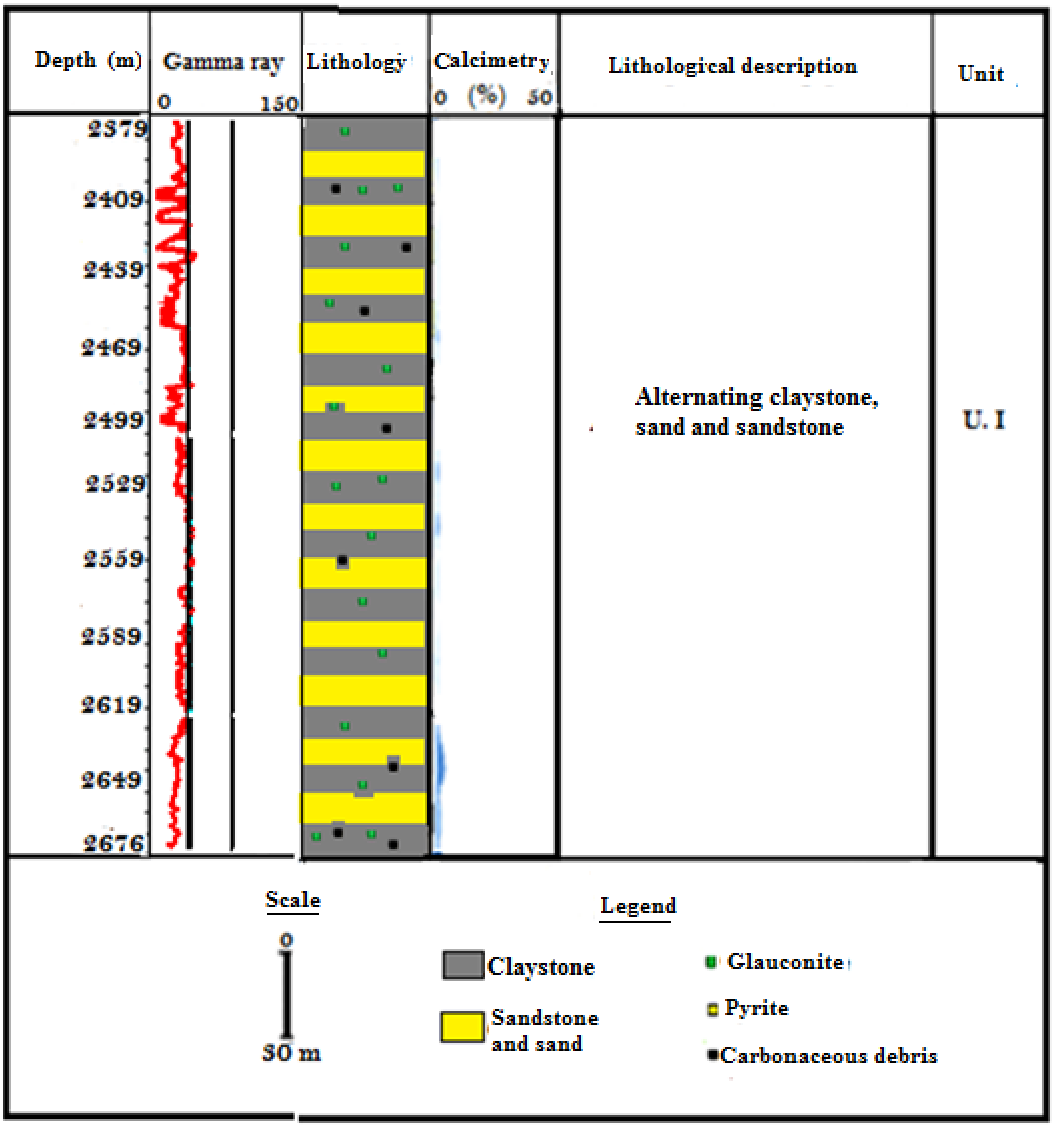

Fig. 6. Lithostratigraphic column and analysis of well L5

3.2 Lithostratigraphic Correlation Of Wells And Discussion

This section includes mineralogical and lithological correlations:

3.2.1 Mineralogical Correlation Of Wells

The Turonian of the Abidjan Margin is generally rich in glauconites. This richness increases from east to west. Turonian sediments were mainly deposited in a marine environment. However, pyrites are homogeneous in the pits. They are present to a small extent in the east, but are often scarce in the west. The sediments were therefore deposited in a semi-confined marine environment (to the west as well as to the east). Carbonaceous grains are rare in the east, but become richer towards the west. They cohabit with pyrites and glauconites. Turonian sediments were therefore deposited in a shallow marine environment, closer to the continent and semi-confined.

3.2.2 Lithological Correlation Of Wells

The lithological correlation of the five (5) wells studied is shown in figure 7. These cross-sections represent Turonian rocks. However, sedimentary facies analyses show that sediment distribution is not homogeneous across the wells.

Clay facies

Clay facies is the most dominant in the wells studied, with the notable presence of black shales. Clay facies is present in all wells. It makes up the bulk of the wells in the western part of the Abidjan margin, as opposed to the east, where it alternates with other sediments. The western part of the margin is thus represented by the dominant clay facies. The Turonian sediments of the western Abidjan margin were therefore deposited in a calm environment with low depositional energy. This can be explained by the Turonian transgression, during which the sea expanded, generating an essentially marine deposit of argillites.

Limestone facies

This facies is virtually absent from the wells. It is found only at the base of shaft L2, to the west of the Abidjan margin. This confirms deposition in a calm (marine) environment with low depositional energy in the western part of the margin. The clayey and calcareous sediments present in this zone confirm this depositional environment. The presence of limestone at the base of shaft L2 therefore implies the pre-existence of limestone deposits in the Turonian shafts. These deposits were certainly eroded during the great erosion (marine regression) that affected Turonian sediments. However, no correlation could be made with the other wells due to the absence of limestone in the other wells.

Sand and sandstone facies

Sand and sandstone facies are common in the wells, and occur mainly in alternation with argillite. These sediments were deposited in an unstable and disturbed environment in the central and eastern margin. There was variation between calm environments (clay facies) and turbulent environments (sandy and sandstone facies), resulting in alternating transgressive and regressive phases. The different lithological columns in the wells studied reveal that in the west of this part of the Ivorian basin, the Turonian is made up of low-energy sediments (argillite and limestone), whereas in the east and centre-west, the environment is turbulent, marked by reservoir-type sediments (sandstone and sand banks). The Turonian is not visible throughout the Abidjan margin. As can be seen in Figure 7, there is a large offset at the wells. The sediments are marked by severe erosion. This erosion is due to the Turonian regression that affected the Turonian rocks.

Black shales are typical of wells in the western part of the Abidjan margin, while sandstones, sands and argillites alternate in the eastern part.

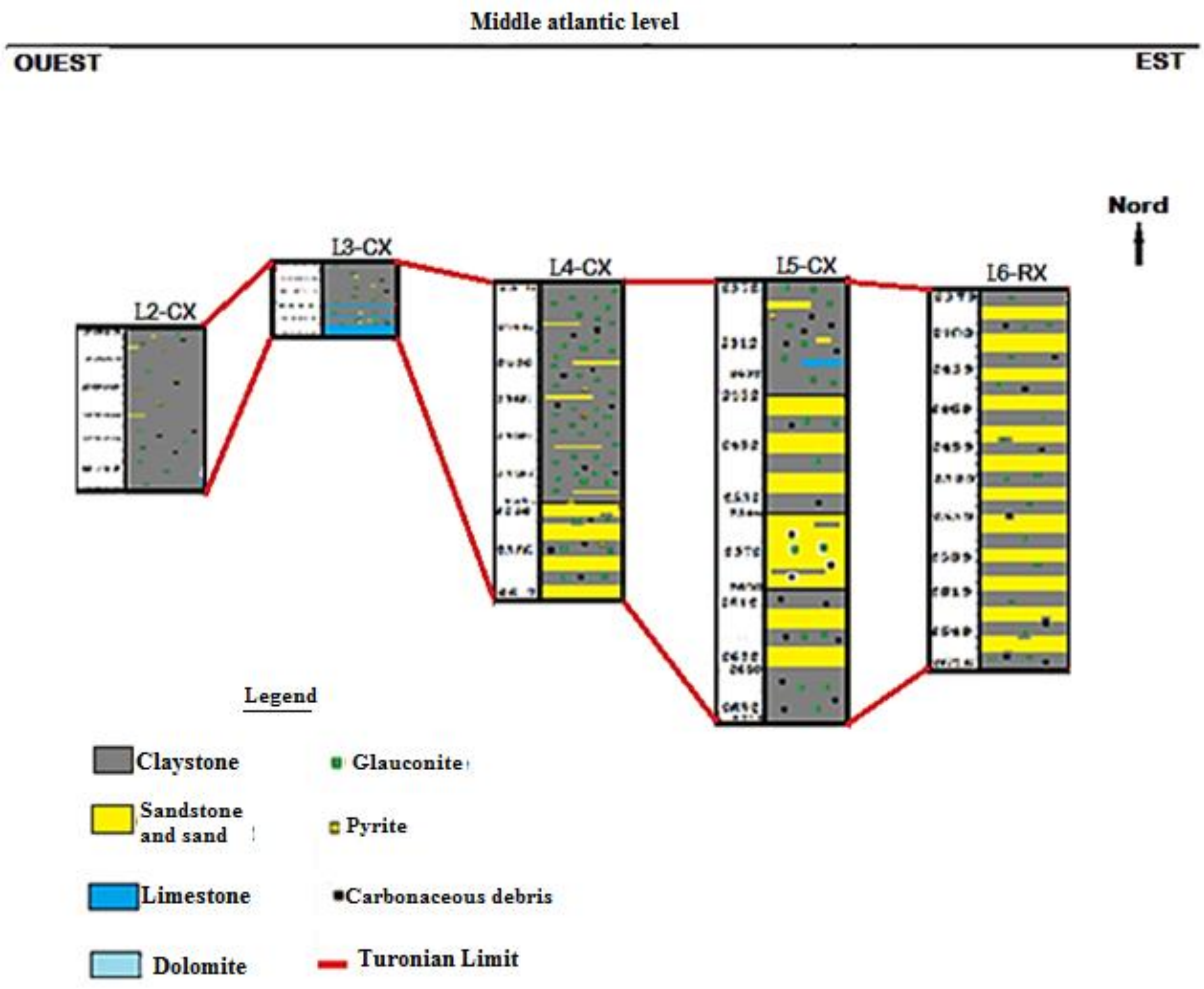

Fig. 7. West-East lithostratigraphic correlation of the Abidjan margin wells studied

3.3 LITHOLOGICAL SYNTHESIS

The lithological formations encountered in the Turonian of the Abidjan Margin consist of clay, sand, sandstone and limestone. In the west, argillite is strongly represented. Thick layers are found here. However, from the Centre-West to the East, the layers alternate between clay, sand and sandstone.

4 DISCUSSION

This study indicates that the Turonian of the Abidjan margin is made up of dark mudstones, sands, sandstones and limestones. [2] also described Turonian samples from the Ivorian sedimentary basin as consisting of black shales, sandstones and sandy fractions. These clays are dark in color, with a laminated appearance. Other authors such as [11], [17] and [18] concur with these results. According to [11], the Turonian is made up of laminated clays (black shales), limestone-cemented sandstones and limestone. According to [19], the Turonian is composed of alternating sandstones and argillites with calcareous interlayers. [17] also attested that the Turonian is characterized by clay and sandstone facies. However, the results obtained in this work indicate that the Turonian is rich in ***"black-shales".*** These deposits are unevenly distributed in the Turonian shafts of the Abidjan margin. They are mainly found to the west of the margin, while to the east they are less present, alternating with sandstones and sands. The work of [16] similarly shows that the stage is marked by black shales observed to the west and absent to the east. According to the latter, the distribution is sectorial and the west is more abundant. This differentiation can be explained by hydrodynamic variations in the Abidjan margin. Morphological instability in the eastern part of the Abidjan margin, favoring a turbulent environment, has affected the type of sedimentation in this zone. Sandstones, sands and mudstones are alternating as a result of deposition in an unstable environment. According to [16], this absence reflects the fact that the calm environment that prevailed during the deposition of the western formations became more agitated in the east, in a turbulent regime probably linked to the proximity of the coasts under the influence of eustatic movements and fluvial inputs. Furthermore, [19] indicates a West-East polarity of the Atlantic opening in the northern Gulf of Guinea. This polarity must have induced deeper, finer sedimentation to the west and relatively coarser sedimentation to the east. The lithological characteristics of the Turonian are not identical in all basins. In Benin, [20] show that the Turonian-Coniacian unit of a borehole studied is composed of sandstones with siliceous and/or ferruginous cement, quartz sand and, in suborder, kaolinitic clay and gravels. In Congo, according to geological syntheses carried out by petroleum geologists in 1990, the Loango dolomitic formation (Turonian) is made up of sandstone dolomite, silty clay and carbonate-cemented silstones. In Cameroon, the Turonian of the Douala Basin is characterized by two sedimentary cycles [22]. The first consists of alternating sandstones and sandy clays with rare calcareous intercalations, followed by faunal-rich clays and limestones. The second consists of sandstones topped by micaceous nodular clays with intercalations of lumachellic limestones. However, according to [23], homogeneous clay facies in the Turonian provide an excellent lithological reference for the Senegalese sedimentary basin. The clay fraction associated with these facies is very sparse. We note the presence of dark clays in the Turonian of Algeria's Saharan Atlas according to [24]. These *black shales* were deposited in silts, before the return of widespread marl sedimentation in the Lower Turonian. However, as can be seen, Turonian lithologies are not expressed identically in all basins. This may be due to the morphology of the basins, which influences the type of sedimentation. This is the case in the Ivorian basin (Abidjan margin), where the eastern part has a highly unstable morphology, with tectonics consisting of bottomless holes, the lagoon fault and the Ghana-Côte d'Ivoire wrinkle, all of which disrupt the type of sediment deposition in this area.

5 CONCLUSION

The Turonian of the Abidjan margin is made up of dark mudstones, sands, sandstones and limestones. This period is essentially marked by black shales. The limestone facies was most likely eroded during the great Turonian erosion. Turonian sediments are low in calcium carbonate. To the west of the Abidjan margin, the sediments (argillite and limestone) were deposited in a calm environment with low depositional energy due to the Turonian transgression, when the sea extended, generating an essentially marine deposit of argillites. The eastern part of the Abidjan margin is marked by alternating sandy, sandy and clayey facies due to sediment deposition in an unstable and disturbed environment. This lithological difference in the wells is thought to be the cause of the morphology of the Abidjan margin, where the eastern part has a highly unstable morphology, disrupting the type of sediment deposition in this zone. The Turonian sediments of the Abidjan Margin contain abundant glauconites, few pyrites and rare carbonaceous debris, and were therefore deposited in a shallow, semi-confined marine environment closer to the continent.

REFERENCES

[1] E. M. ETTACHFINI, A. SOUHEL, B. ANDREU, M. CARON, «La limite Cénomanien-Turonien dans le Haut Atlas central, Maroc». Geobios, 38 (1), 57-68, 2005.
[2] M. SOUA, «High-resolution biostratigraphy of planktonic foraminifera from the Cenomanian-Turonian transition and impact of the EAO-2 anoxic event on this group in the southern margin of the Thethys, example: Jerissa and Bargou region». Master's degree in Tectonic-Sedimentary Dynamics and Reservoir Characterization. Univ de Tunis-El Manar, Tunis, 71p, 2005.
[3] M. SOUA et N. TRIBOVILLARD, «Sedimentation model at the Cenomanian/Turonian transition for the Bahloul Formation in Tunisia». Geoscience Reviews, Vol 339 (10), 692-701, 2007.
[4] M. SOUA, «The Cenomanian-Turonian transition in Tunisia: Biostratigraphy of planktonic foraminifera and radiolarians, chemostratigraphy, cyclostratigraphy and sequence stratigraphy». Doctoral thesis. Université Tunis El Manar, Tunis, p316, 2011.
[5] D. DESMARES, M. TESTÉ, B. BROCHE, M. TREMBLIN, S. GARDIN, L. VILLIER, E. MASURE, D. GROSHENY, N. MOREL, P. RABOEUF, «High-resolution biostratigraphy and chemostratigraphy of the Cenomanian stratotype area (Le Mans, France) ». Cretaceous Research, Volume 106, 1-15, 2020.
[6] I.C. HANDOH, G.R. BIGG, E. J.W. JONES et, M. INOUE, «An ocean modeling study of the Cenomanian Atlantic: equatorial paleo-upwelling, organic-rich sediments and the consequences for a connection between the proto-North and South Atlantic». Geophysical Research Letters, 26 N° 2, 223-226, 1999.
[7] J. PHILIP, J. F. BABINOT, G. TRONCHETTI, E. FOURCADE, L. E. RICOU, R. GUIRAUD, Y. BELLION, J. P. HERBIN, P. J. COMBES, J. J. CORNÉE et J. DECOURT, «Late Cenomanian (94 to 92 Ma) ». Ed. Atlas Tethys palaeoenvironment maps, Paris, 153-178, 1993.
[8] A. E. M. NAIRN, L-E. RICOU, B. VRIELYNCK, Jean DERCOURT «The tethis ocean», vol 8, 3-70, 1995.

[9] F. BAUDIN, «Depositional controls on mesozoic source rocks in the tethys». Ed. paleogeography, paleoclimate, and source rocks. AAPG (American Association of Petroleum Geologists) studies in geology, 40, 191-211, 1995.

[10] P. NZOUSSI-MBASSANI, «The Cenomano-Turonian of the North Atlantic (Senegal Basin): depositional environment and diagenetic evolution. Petroleum implications». Doctoral thesis, University of Orléans, Paris, 234 p, 2004.

[11] K. M. BAMBA, Z. B. DIGBEHI, C. B. SOMBO, T. E. GOUA et L. V. N'DA, «Planktonic foraminifera, biostratigraphy and paleoenvironment of the Albo-turonian deposits of Côte d'Ivoire-West Africa». European Scientific Journal, vol. 30, n° 1, 1-11, 2011.

[12] A. KOUASSI, «Anoxic episode in the Atlantic Ocean, on the Ivory Coast margin, at the cenomanian/turonian boundary: petroleum interest». Doctoral thesis. Univ. Félix Huphouêt Boigny, Abidjan, 237 p, 2014.

[13] R. DJEFFAL, «Lithostratigraphic and sedimentological study of the turono-coniacian series of the Djebel Ich-Ali–Aurès- and Djebel Tuggurt –Monts de Belezma-Batna». Magister thesis, University of Batna 2, Batana, 1-152, 2014.

[14] M. Benyoucef, C. Meister, K. Mebarki, É. Läng, M. Adaci, L. Cavin, F.Z. Malti, D. Zaoui, A. Cherif & M. Bensalah, «Lithostratigraphic, paleoenvironmental and sequential evolution of the Lower Cenomanian-Turonian in the Guir region (western Algeria) ». Carnets Geol., vol. 16, nº 9, 271-296, 2016.

[15] A. KOUASSI, K. C. YAO, R. GOHA et H. AHIENTIO, «Sedimentological and geochemical characterization of black shales at the Cenomanian/Turonian (C/T) interface in the Côte d'Ivoire sedimentary basin (West Africa) ». International Journal Biological and Chemical Sciences, 11 N° 2, 874-885, 2017.

[16] I. B. OUATTARA, N. F. D. ANO, J. P. YAO N'GORAN, Y. N. COULIBALY, F.Y. P. ASSALE, A. K. KOUAMÉ, T. E. GOUA, H. KPLOHI et Z. B. DIGBEHI, «Lateral variation of black shale facies at the Cenomanian-Turonian boundary in the Abidjan margin (Ivory Coast sedimentary basin, Gulf of Guinea)).». Bioterre, Vol. 16, 28-29., 2016.

[17] M. KONE, «Thermal maturation and petroleum potential of oil well cuttings IVCO-10 of the bloc CI-02 of the Ivory Coast sedimentary basin». Master's thesis in earth sciences, University of Québec, Québec, 79 p, 1998.

[18] C. L. KOFFI, C. K. YAO, B. A. EGORAN et S. MONDE, «Petroleum potential of Cretaceous deposits on the San-Pedro margin». Bioterre, Vol. 15 (2017) 1-15.

[19] Z. B. DIGBEHI, K. E. GUEDE, K. AFFIAN, K. K. K. TOE BI, K. R. YAO et I. TAHI, «». Journal of Geography and Regional Planning, vol. 4, no 11, 644-655, 2011.

[20] N. YALO, A. ADJANOHOUN, G. L. ADISSIN et C. KAKI, «Geological formations of glauconia in the coastal sedimentary basin of Benin: potential uses for coastal soil fertilization». Bulletin of Agricultural Research in Benin, Number 62, 67 p, 2008.

[21] N. MOUKOLO, «The Congo River basin. Modalities of surface and underground flows. Approach to surface/ground water exchange in a continuous environment. (Hydrology - hydrogeology - hydrochemistry) ».Thesis for a Doctorate in Science. Univ. Cheikh Anta Diop, Dakar, 174 p, 2000.

[22] C. O. MBESSE, «The Paleocene-Eocene boundary in the Douala Basin (Cameroon). Biostratigraphy and paleoenvironmental reconstruction using dinoflagellates». Doctoral thesis. Univ. Yaoundé I, Yaoundé, 221p, 2012.

[23] M.F.K. NIANG, «Interpretation of geophysical data on the deep structure of the Senegalese sedimentary basin and the basement zone». Doctoral thesis, University Cheikh Anta Diop, Dakar, 114 p, 1995.

[24] D. GROSHENY, F. CHIKHI-AOUIMEUR, S. FERRY, F. BENKHEROUF-KECHID, M. JATI, F. ATROPS et W, «The Upper Cenomanian-Turonian (Upper Cretaceous) of the Saharan Atlas (Algeria) ». Bulletin of the Geological Society of France, vol. 179 n° 6, 593-603, 2008.