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RESEARCH ARTICLE

STUDY OF THE ARCHITECTURE OF SEDIMENTARY DEPOSITS IN THE IVORIAN ONSHORE BASIN THROUGH SEISMIC REFLECTION

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Abstract

The seismic profiles analysis of 4,533 km study area made it possible to study the sedimentary deposits in the Ivorian onshore basin. The method used consisted of manual plots of the seismic sections leading to the production of isochronos, iso-velocity, isobaths and isopac maps. As for the stratigraphic interpretation, it was used to develop a sedimentary model to extract information on the nature of sedimentary deposits and the mechanisms of their establishment based on the analysis of seismic facies. Examination of the different seismic profiles of the study area allowed the onshore sedimentary series to be subdivided into four main sequences which are: sequences I, II, III and IV. Thus, this analysis revealed two stages of sedimentary deposits linked to the behavior of the reflectors:

1. a syn-rift stage, characterized by significant fracturing in the sedimentation with faults and tilted blocks in the Lower Cretaceous;
2. a post-rift stage, corresponding to a less deformed sedimentation with parallel and continuous reflectors from the Upper Cretaceous to the present.

These two phases allow us to understand the stratigraphic evolution of the onshore basin.

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Introduction:-

The genesis and evolution of the Gulf of Guinea basins is part of the opening of the Atlantic Ocean, following the phenomenon of continental drift and the separation of the African and American continents during the Lower Cretaceous (Le Pichon and Hayes, 1971; Rabinowitz and LaBreque, 1979; Bellion, 1991; Mascle et al., 1986; Blarez et al., 1987; Benkhelil et al., 1989). The Ivorian sedimentary basin is a portion of the large sedimentary basin of the Gulf of Guinea (West Africa) which extends from the Liberian maritime border to the Ivorian-Ghanaian border. It includes a submerged part (offshore) and an emergent part (onshore), the study area.

Oil exploration in the Ivorian basin began in earnest in the 1950s with the first discoveries of bituminous in the onshore part of Eboinda. Various geophysical and geological works have been done in the offshore area which has led to the discovery and production of a large quantity of hydrocarbons in the Cretaceous formations. Apart from

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this scientific research in the submerged part, no scientific documentation exists on this subject in the onshore part. This study of the architecture of the onshore basin aims to reconstruct the history of the sedimentary filling of the onshore. For this purpose, this article therefore proposes to highlight the structural evolution of the onshore and to characterize the deposit environments of the emerged basin.

Presentation Of The Study Area

Located in the southern region of Côte d'Ivoire, the study area covers the land part of the Ivorian sedimentary basin. This area is about 360 km long from Sassandra in the west to the Ivorian-Ghanaian border in the east and 35 km wide. Its geographic coordinates are $5^{\circ} 40'$ to $2^{\circ} 44'$ W longitude and $5^{\circ} 00'$ to $5^{\circ} 30'$ east latitude (Figure 1) with an area of $8,500 \text{ km}^2$. The onshore basin is the extension of the sedimentary deposits of the Ivory Coast margin. This margin was formed during the opening of the equatorial Atlantic, which separated, the African and South American continents on either side of the Gulf of Guinea during the Lower Cretaceous, (BLAREZ, 1986; BLAREZ & MASCLE, 1987).

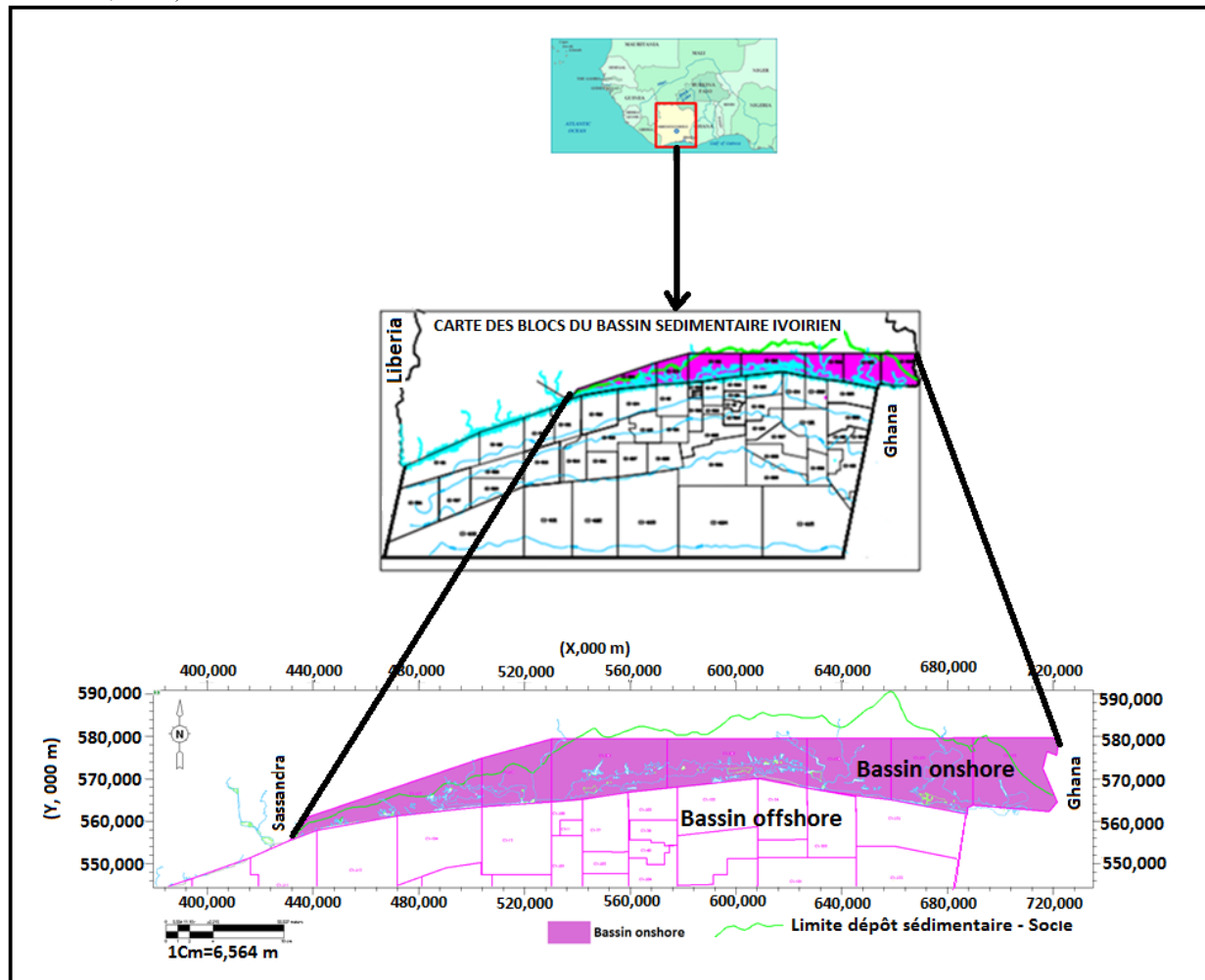
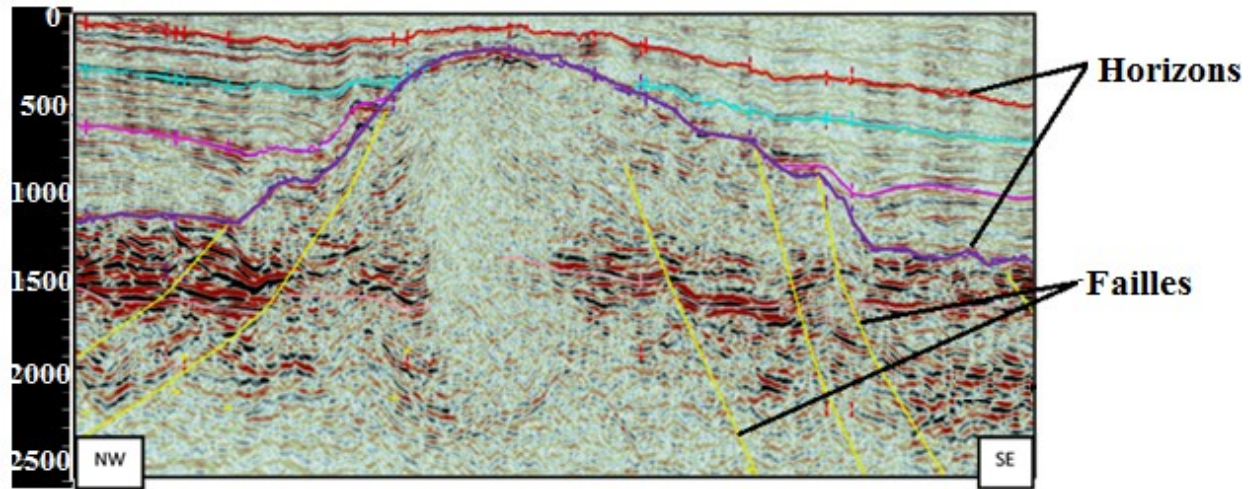


Figure 1:- Location of the study area.

Method:-

This study was based on the exploitation of several 2D seismic lines and geological data from 13 boreholes provided by the Exploration Department of PETROCI (National Petroleum Operations Company of Côte d'Ivoire). To achieve the objective of this study, 4,533 km of seismic profiles from various campaigns carried out in the 1980s on the onshore basin were interpreted. Before starting to survey the reflectors and faults, calibration of seismic sections to drilling data was performed. The analysis of the profiles identified four (4) reflectors corresponding to the tops of the different stratigraphic stages (Figure 2). This enabled us to produce isochronous, isobaths and isopachsmaps for a good interpretation.

Figure 2 :- A 2D seismic profile of the onshore basin plotted

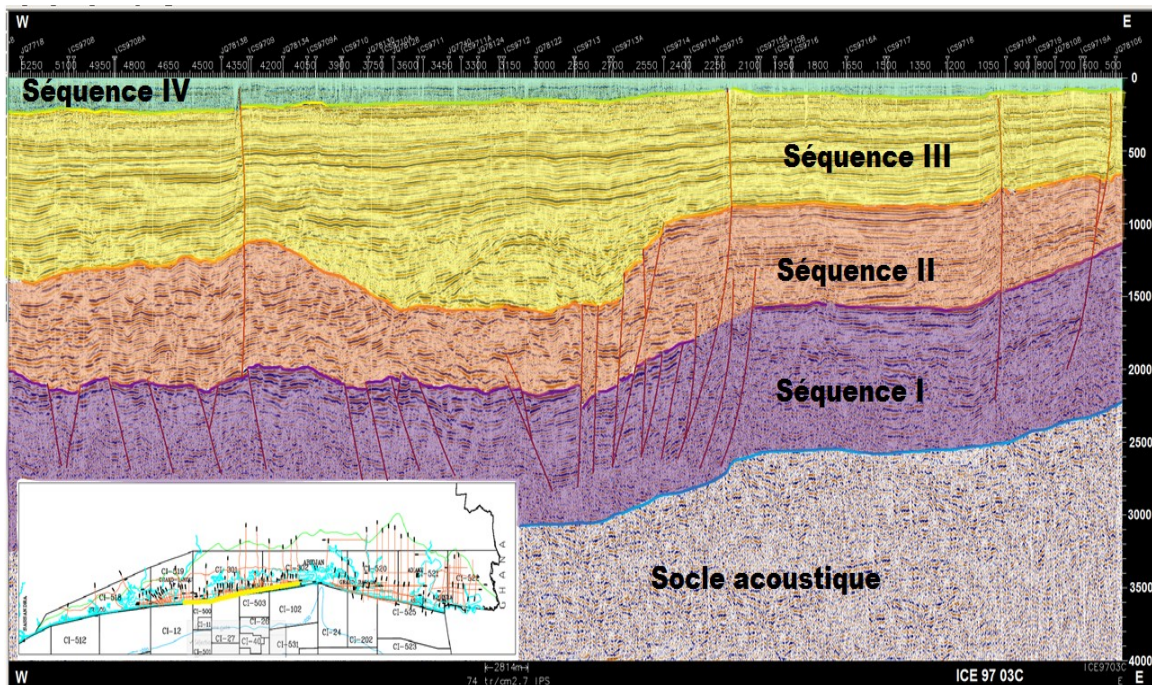


Results And Discussion:-

III - 1) Identification of deposit sequences on seismic profiles

Examination of the different seismic profiles of the study area allowed the onshore sedimentary series to be subdivided into four main sequences I, II, III and IV (Figure 3). These were examined one after the other in order to reconstruct the sedimentary evolution of the basin from its establishment until now.

Figure 3:- Section showing the presence of the 4 sedimentary sequences I, II, III and IV III - 1 - 1) Acoustic basement



The acoustic basement is characterized by an absence of reflection, the base on which sedimentary deposits rest. Three distinct zones can be observed on the seismic profiles:

1. a total absence of reflection (figure 4a) towards Adiadon in the west of the study area;
2. Lack of reflection is observed around 3500 ms in the center of the study area;
3. In the east, the seismic profiles as a whole show an absence of reflections from 700 ms (figure 4b).

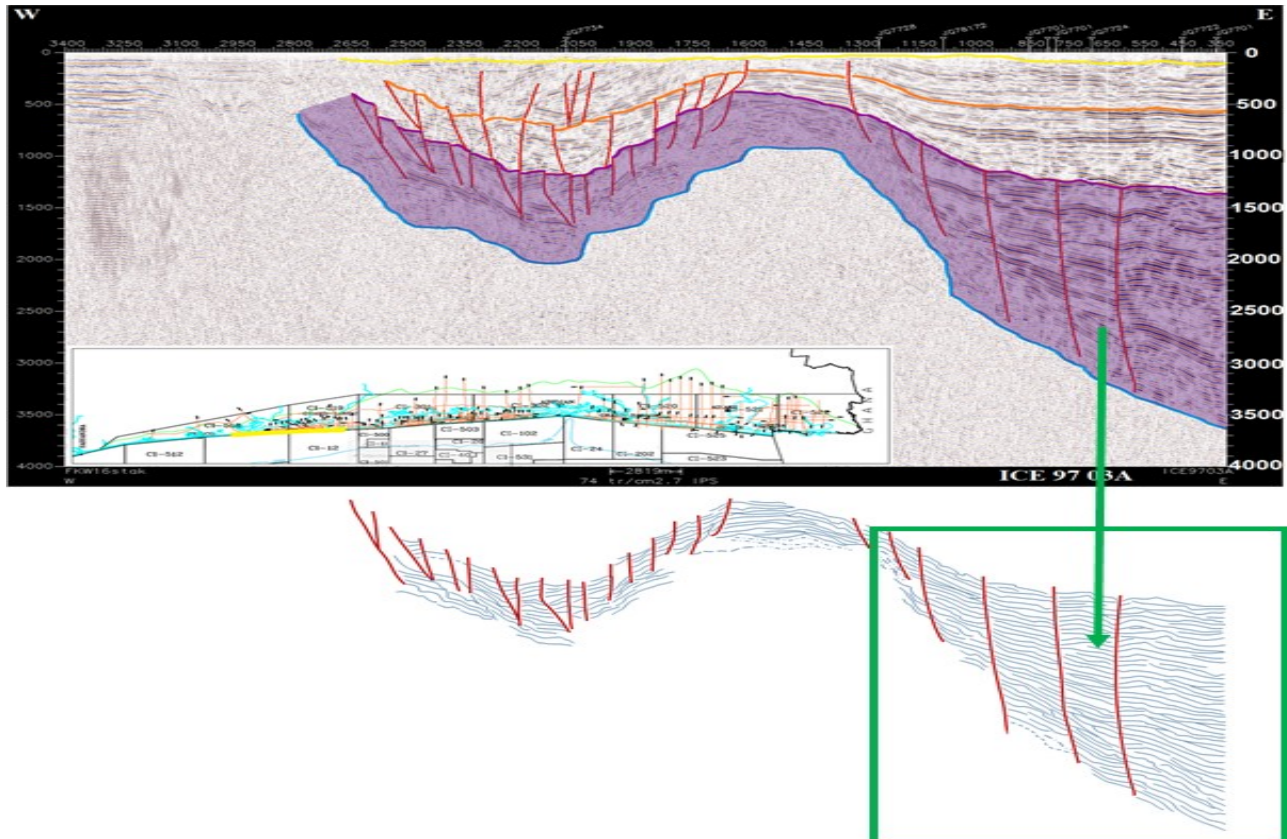


Figure 5:- Section showing the diverging reflectors towards the east.

III - 1 - 3) Sedimentary sequence II

In this sequence, the configuration of the reflectors is parallel to the east of the profile but it evolves in the west towards a facies where the reflections have a high amplitude and a medium frequency (see figure 5). Subsequently, in the Center, this configuration presents Hummocky facies with a high to medium amplitude and a low frequency and a facies characterized by continuous and bedded reflectors with a low amplitude and a low frequency (see figure 3). To the east, the seismic profiles present a transparent facies throughout the area.

III - 1 - 4) Sedimentary sequence III

The fourth sequence as a whole is characterized by a parallel configuration with reflectors exhibiting high amplitude, good continuity and medium frequency (figure 5). This sequence is based on the sequence II.

III - 1 - 5) Sedimentary sequence IV

The last sequence as a whole is characterized by a sub-parallel configuration with high to medium frequency, medium amplitude and medium continuity (cf. figure 5).

III - 2) Sedimentary evolution of the onshore basin

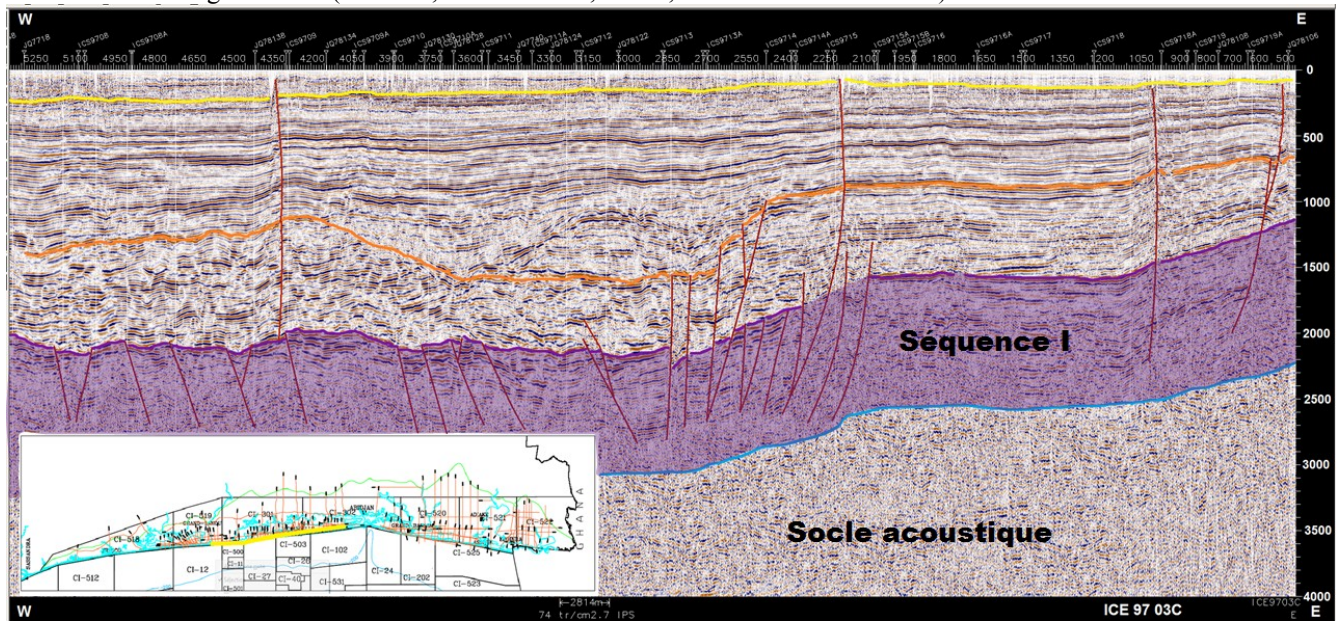
The analysis of the seismic profiles of the study area revealed two episodes of filling in the onshore basin. These episodes are consistent with the development of the two geodynamic phases. The first episode is characterized by sediments having recorded the presence of several normal faults from the basement. This episode is identified by the sedimentation of sequence II corresponding to the syn-rift phase of the establishment of the basin. As for the second episode, it presents an almost continuous sedimentation with almost an absence of faults and tilted blocks from sequence III to sequence V corresponding to the post-rift phase of the basin.

III - 2 - 1) Syn-rift stage

The syn-rift stage of the onshore corresponds to the deposit of sequence I, representing the period of sediment filling during rifting during the Lower Cretaceous. The seismic profiles show a rugged sedimentary basin with a significant thickness of the sequence I (Figure 6). The sediments of this sequence are affected by numerous normal faults giving

rise to structures which are a direct consequence of the divergent rifting mechanism. The map of the Lower Cretaceous from the drilling data indicated that this sequence has a thickness ranging from 200 to 3000 m of sediment (figure 7). The drilling data showed a lithology dominated by clays, sandstones and local conglomerates, the proportion of which varies over short distances, due to local fault control on the sedimentation.

On the different seismic profiles, this sequence presents a variety of seismic facies. Towards the west, the reflectors are sloping and their slope increases as they gotowards south (Figure 8). From west to central onshore, the configuration evolves from divergent reflectors to subparallel reflectors. In the east, the reflectors evolve towards transparent facies. These different configurations of sequence II confirm the hypotheses of the work of SOMBO (2002) where the first stage of sedimentation constitutes the phase of onfilling in the spaces left during the separation of the African and American continents. These deposits correspond to a period when the water level was low. This allowed a relatively large contribution of continental sediments to the slope break zone under weak conditions of weak subsidence in the west and strong subsidence in the center of the basin. The deposits are progradant on the North-South seismic profiles (figure 8) and participate periodically in the construction of the platform. Indeed, we can see progradant units with inclined reflections (figure 8). These internal reflectors are discontinuous, but divergent in appearance, characteristic of the platform edges to the west (VAIL et al., 1977). This deposition mechanism can be explained by a low sediment input in a stable environment where the water level is low (RAVENNE et al., 1980). The various progradation episodes encountered are the obvious consequence of the numerous fluctuations in sea level during the period of sequence II (SANGREE and WIDMIER, 1977; VAIL et al., 1987; PITMAN, 1978). In general, we started from thinner layers towards the edge of the basin in the West to end up with a break in the slope with a very significant thickening in the center, reflecting an accumulation of platform favored by subsidence. The first sediments of the Lower Cretaceous are generally continental dominated by clays, sandstones and conglomerates (Adiadon, Grand-Lahou, Bérou, Port-Bouet and Eboinda).



Séquence I - Synrift

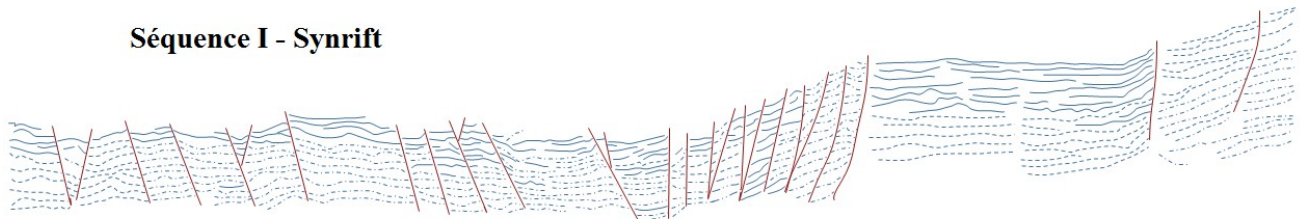


Figure 6:- Schematic profile showing syn-rift infill with discontinuous reflectors.

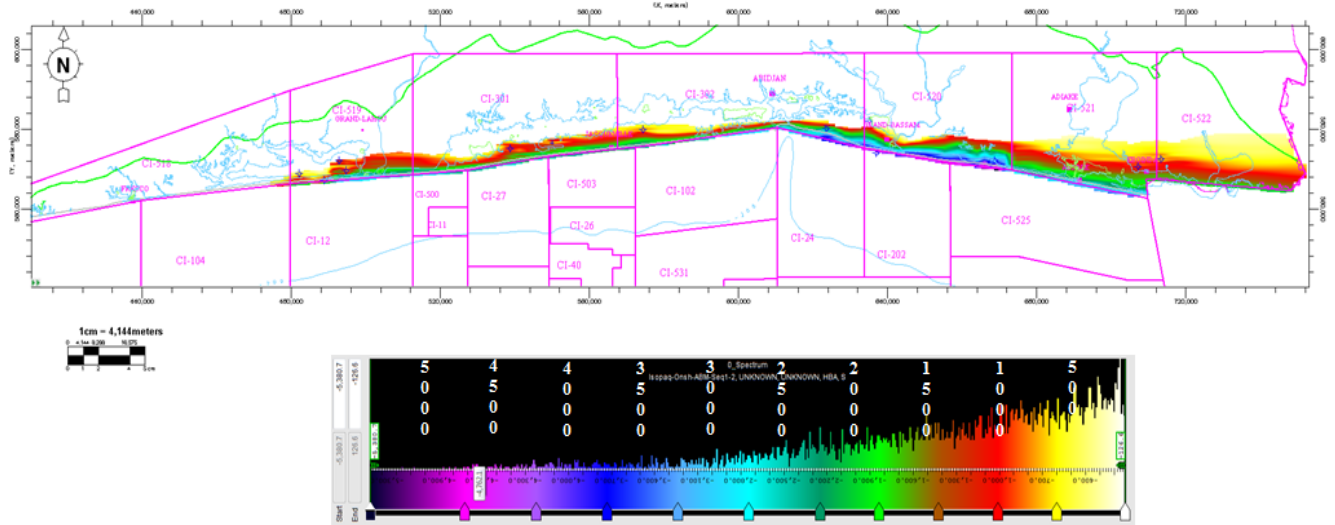


Figure 7:- Isopach map of the sedimentary deposits during the Lower Cretaceous.

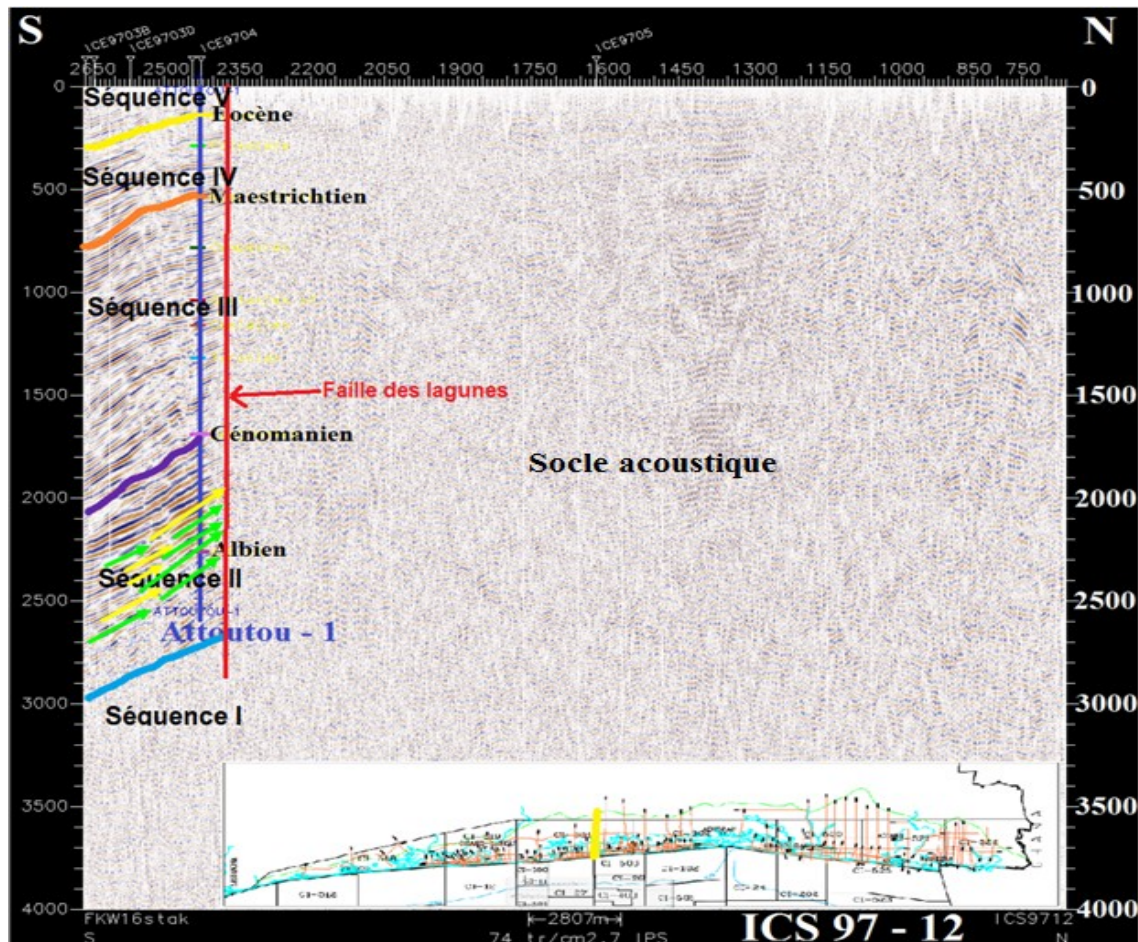


Figure 8:- North-South profile showing prograding units with tilted reflections

III - 2 - 2) Post-rift stage

The post-rift stage consists of sequences II, III and IV and has evolved from the Upper Cretaceous until today (Figure 9). It's a period of tectonic calmness. On the seismic profiles, the behavior of the parallel and continuous reflectors indicates that the sedimentation from the Upper Cretaceous to the present took place in a calm tectonic

environment. Apart from a few small local variations, the morphology of the Upper Cretaceous roof lacks major specificities. The thickness map from the Upper Cretaceous to the present gives the possibility of knowing the sediment distribution during the period from the Cenomanian to the Quaternary. The contours of the isopacs vary from 500 m to 5,000 m in thickness (Figure 10).

Examination of Sequences II, III and IV shows that the reflectors are parallel and uniform from east to west. The correct organisation of the internal reflections within these sequences is a corollary of good stratification. Deposits probably took place under low energy conditions, in a relatively calm platform-type environment where the water depth is low (RAVENNE, 1978; SCHLEE, 1981; CREMER, 1983; DROZ et al., 1985 ; POAG and MOUNTAIN, 1987). These deposits, in finely stratified banks, militate in favor of conditions of relative stability at sea level (VAIL et al., 1977, 1987). The sedimentary deposits of sequences IV and V are continuous on the seismic sections and appear well stratified. These sequences are mainly marked by the presence of glaucon, plastic, gray, black clays and the presence of fine limestone, sand and gravel levels in the boreholes. The formations crossed by the boreholes show the presence of a regional discordance due to the absence of the Oligocene in the Tertiary sedimentary series. This discrepancy is undoubtedly of eustatic origin that we can probably correlate with the drop in sea level dated 49.5Ma (HAQ et al., 1987). The post-rift phase has less deformed sedimentary intervals. This phase is represented by stratified reflections and characterized by tectonics where numerous listric growth faults are located in distinct stratigraphic intervals superimposed from the Upper Cretaceous to the Tertiary.

During the different phases of rifting, large areas influenced by extensive stresses give rise to graben systems in the basin. In the south of the "lagoon fault" and to the west of the "top of Adiadon", a depression was observable and records sediments of nearly 1,500 m deep. And east of this "top of Adiadon", a large depression called the "Jacqueville depression" records sediments over about 5,000 m deep (Figure 11).

A major unconformity called the Miocene base unconformity was identified during the Oligocene, separating the Miocene from the underlying sediments by an eroded surface in offshore works (SOMBO, 2002 and KOUAME, 2012). In this study, the presence of an erosion surface is not visible on the seismic profiles, but the geological report of the "Vitre 2" oil well indicates an absence of Oligocene deposits. This absence of deposits exists in the east of the basin because of the abnormal contact of the sedimentary series of the Lower Cretaceous (Sequence I) with those of the Miocene (Sequence III) in Vitre2 well (Figure 11). This discrepancy could be linked to the fall in sea level during the Oligocene.

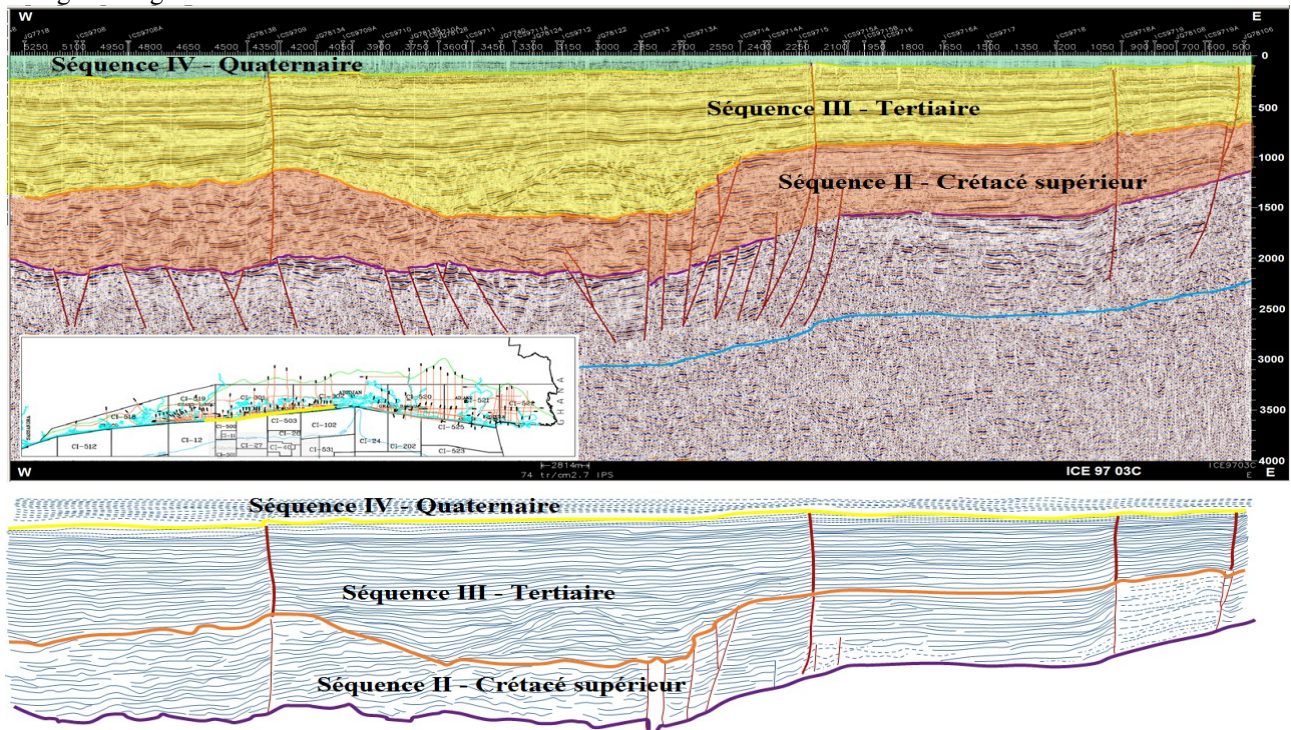


Figure 9:- Profile expressing the presence of the different configurations of post-rift reflectors.

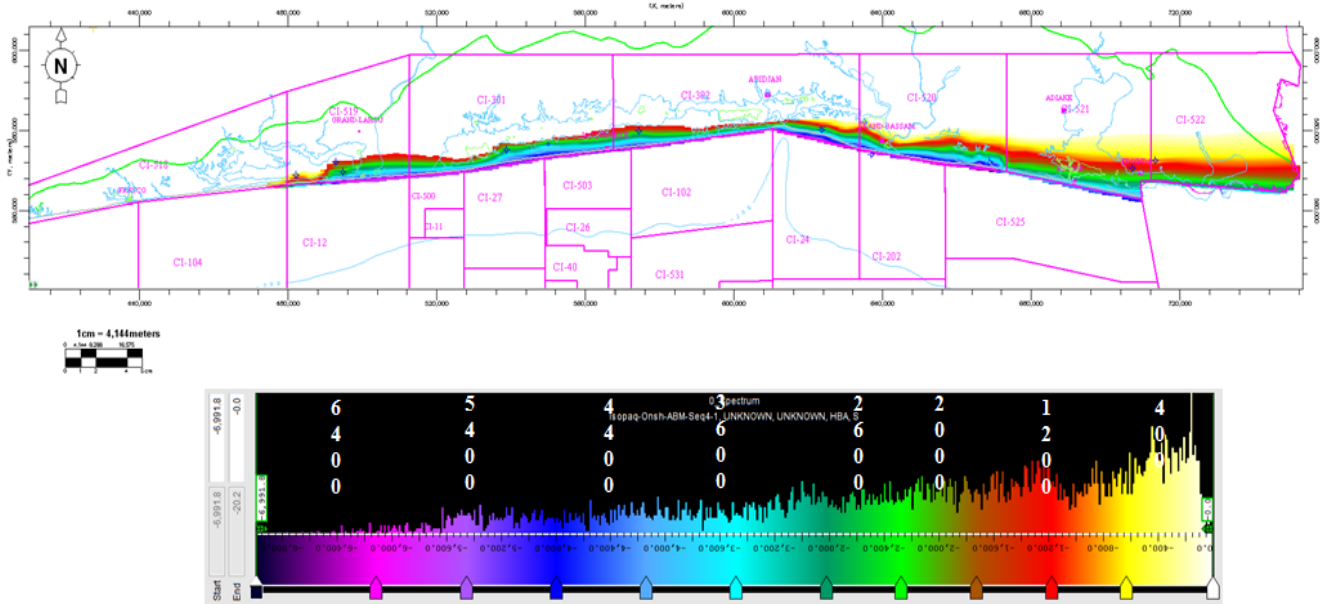


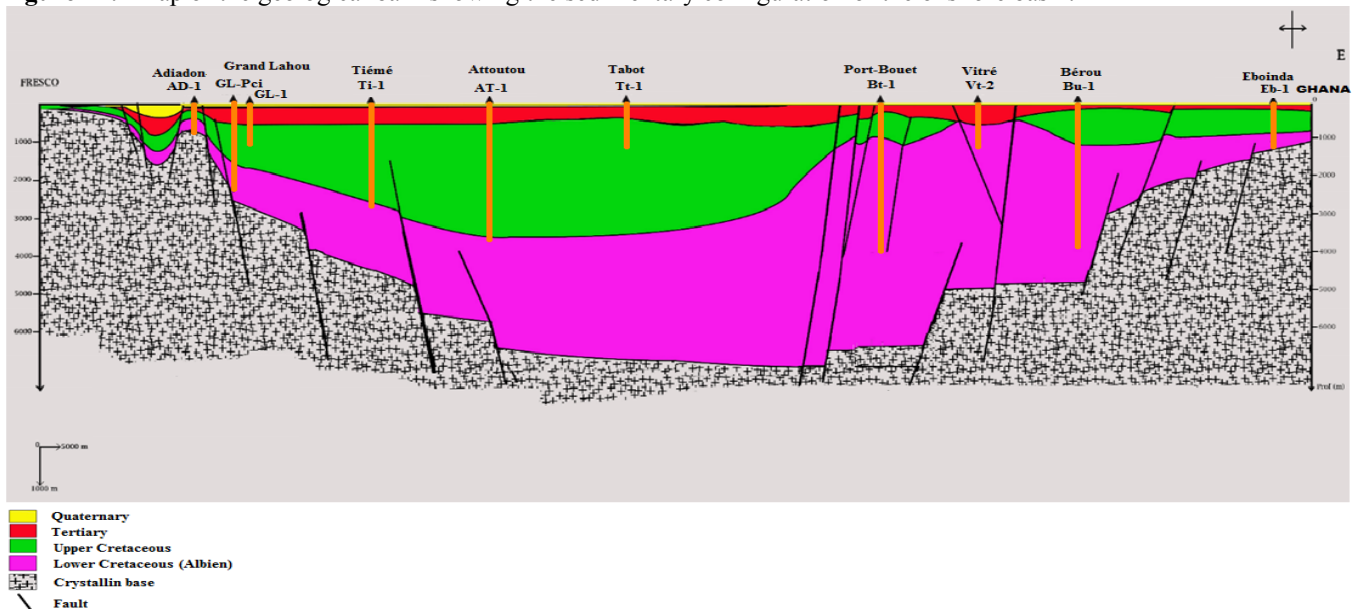
Figure 10:- Isopach map of sedimentary deposits from the Upper Cretaceous to the Present days.

Conclusion:-

The study of the onshore basin, by means of the 2D seismic profiles, has made it possible to identify four large units of deposits or seismic sequences whose analysis has made it possible to better understand the structural and sedimentary evolution. The interpretation of the various seismic profiles has made it possible to reconstruct the stratigraphic evolution of the onshore basin from the Cretaceous period to the present day. This study showed that the onshore part of the basin has undergone a history that is divided into two main stages of basin development namely the syn-rift (Lower Cretaceous) and the post-rift (Upper Cretaceous to present).

1. The syn-rift stage, corresponding to the deposits of sequence I of the study, represents the period of the first sedimentary deposits during the Lower Cretaceous characterized by significant fracturing in the sedimentation with the presence of normal faults.
2. The post-rift stage, corresponding to the establishment of sequences II, III and IV, is characteristic of a less deformed sedimentation with parallel and continuous reflections.

Figure 11:- Map of the geological bark showing the sedimentary configuration of the onshore basin.



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