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Oligocene history and post-Oligocene lithostructural evolution of the continental margin of Côte d'Ivoire: contribution of seismic reflection

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Abstract: Analysis of 1500 km multi-channel seismic profiles allows to bring explanations on sedimentary and structural evolution of Côte d'Ivoire continental margin during Paleogene to Neogene. It reveals that important withdrawal of sea at Rupelian subjected the formed relief during rifting intracontinental at aerial actions provoking removal of important ante-Oligocene sediments. According to numerous eustatic fluctuations, after we attend at interaction construction/erosion which initially fosters chattian shreds formation, later on, facilitates thick sedimentary sequences post-Oligocene deposit. This sedimentary blanket, in Oligocene to Present time, is deformed by some rare faults.

Keywords: eustatic fluctuation, paleogene, neogene, removal, chattian shreds

1. INTRODUCTION

Located on the northern edge of the Gulf of Guinea **(Fig.1)**, the Ivorian continental margin is a passive margin, formed from the lower Cretaceous during the rifting between Equatorial Africa and South America at the opening of the Atlantic [1-11]. The formation of this margin is therefore the result of the play of large intracontinental setbacks which are in continuity with the major oceanic fractures of the central Atlantic [4,12]. The post-rift evolution is characterized by two important episodes in the history of the Ivorian margin. The first part of the Cenomanian transgression to the Oligocene discordance and the second is devoted to the post-Oligocene period [13]. This suggests that the Oligocene (23 - 37 MA) is one of the most significant periods in shaping the Ivorian margin.

Apart from the work of [14] on the Oligocene, no other scientific documentation exists on this subject. This work therefore contributes to the knowledge of the geodynamic evolution of the Ivorian continental margin during this period.

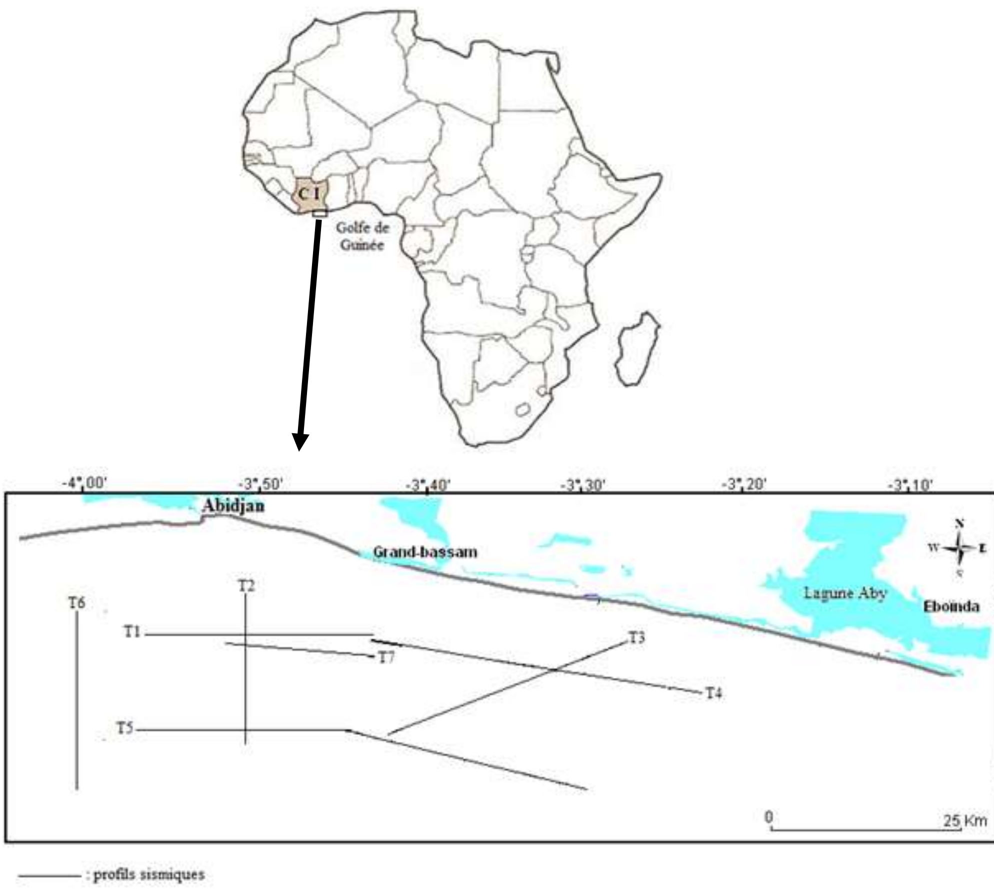

Figure 1: Location of the study area and plan of positioning of the seismic profiles [15]

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2. METHODOLOGY

This work is based on the exploitation of several seismic multitrace profiles offered free of charge by PETROCI (National Company of Petroleum Operations of Ivory Coast). To achieve the objective of this study, 1500 km of seismic profiles from several campaigns generally carried out in the 1970s on the margin of Abidjan, were interpreted. Before initiating the pointing of the reflectors and faults, geological documents related to seismic interpretation were collected.

The pointing: It consists of identifying different reflectors and faults on a seismic profile. It is recommended to start pointing through the seismic profiles passing through the drillings in order to obtain a perfect fit. During this work, the pointing was done manually and eight (8) reflectors corresponding to the roofs of the different stratigraphic stages were identified. With the aid of fine-tinted color pencils, we then follow the different horizons on the seismic sections, step by step, and we cover the entire study area, as far as the quality of the reflections allows.

3. RESULTS AND DISCUSSION

3.1. Evolution of the Ivorian margin from Oligocene to lower Miocene

3.1.1. Regressive and erosive phase: From the lower Cretaceous to the Oligocene, the enormous sedimentary overload (about 3 std), recorded in the Ivorian margin, will cause the subsidence of the crystalline basement below. This necessarily induces isostatic readjustment, compensating for an adjacent crustal bulge which increases with increasing sediment load. This uprising is certainly accompanied by a eustatic fall which is situated at Rupelian, by analogy with the curves of eustatic variations of [16-18] **(Fig.2).** This Rupelian regression is, no doubt, due to the recycling of water on the surface of the earth. In fact, enormous amounts of water evaporate on the surface of the oceans permanently under the effect of the sun. This oceanic water vapor will then precipitate in the form of rain on the continents where it feeds the rivers and finally regain the oceans. During the colder Cenozoic climatic periods, much of this evaporated water fell as snow that accumulated to form the ice caps and glaciers; which will undoubtedly cause a drop in the level of the oceans.

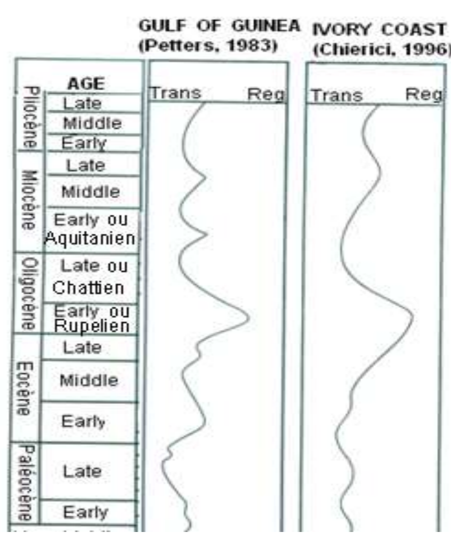

Figure 2: Curves of eustatic variations in Côte d'Ivoire and the Gulf of Guinea [17, 18]

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The general uplift of the continental shelf and the significant retreat of the sea to Rupelian which would last about five (5) million years, will together bring to the open the entire continental shelf. This will cause a great emersion of sediments previously deposited on the edges of the basin, thus leading to an intense erosion certainly air which cuts a large part of the paleogenic sediments and reaches in places those of the Upper Cretaceous **(Fig.3).** The consequence of the regressive phase is the remarkable absence of Rupelian deposits while the erosive episode leads to the sedimentary dismantling of the continental shelf, characterized by large excavations of ante-Oligocene sediments. The products resulting from this sedimentary destruction are deposited directly at the break of slope via the canyons and valleys left by the erosion. However, it is important to mention that in some areas of the continental shelf, this regressive phase is certainly not followed by erosion because there is indeed no trace of discordance in paleogenic sediments **(Fig.4).**

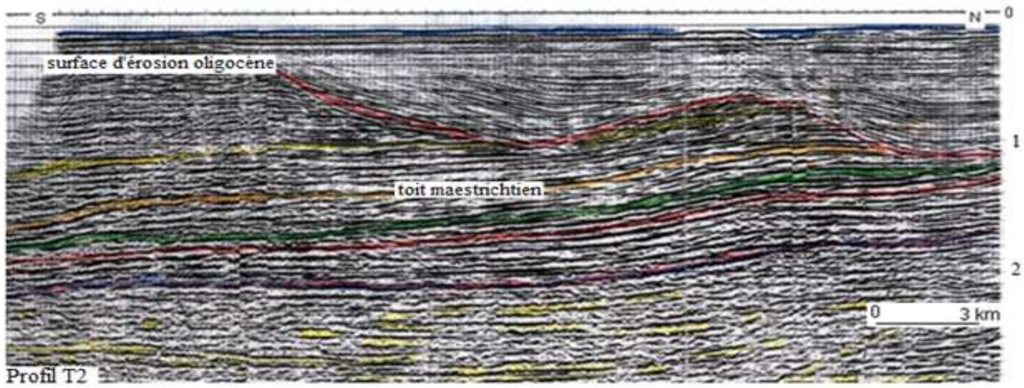

Figure 3: Profile showing the extent of Oligocene erosion reaching Cretaceous sediments to the north at about 1 std.

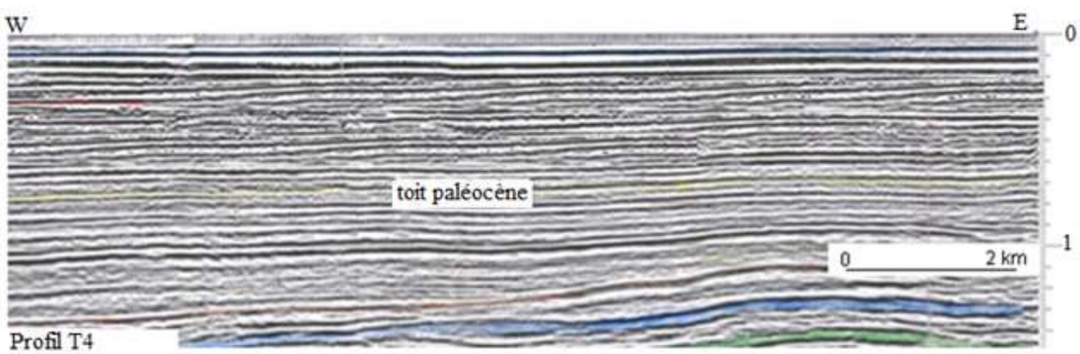

Figure 4: Absence of erosion traces in paleogenic sediments

3.1.2. Transgressive phase and Oligocene deposition superior: After the extensive ex-ante-oligocene sedimentation of the Rupelian, a marine recurrence asserts itself on the continental shelf from the Late Oligocene and favors the deposition of a Chattian-age sedimentary unit. This transgression thus creates a major discordance of Oligocene age easily detectable on most seismic profiles (cf **Fig.3**). This discrepancy surface can be identified, in this sector of the Ivorian margin, by values of average quadratic velocities, between 1500 and 1850 m / s, except for the "bottomless hole" canyon zone where speeds range from 1854 to 2087 m / s. However this new marine flood will be interrupted by a small regression that manifests itself in the lower Miocene (Aquitanian / Burdigalian), in correlation with the sea level variation curve of [17] (cf **Fig.2**). The erosion which probably follows this regression will scratch in places the previously deposited Chattian sediments; which justifies the absence of higher oligocene deposits in wells like Ivco 3, Ivco 26, D1-1X etc. Areas resistant to this erosive period will remain intact to form upper Oligocene flaps. This is well explained by the presence of Oligocene deposits in some wells like Ivco 6, Ivco 2, E1-1X etc.

3.1.3. Distribution of Oligocene sediment flaps: In general, the Oligocene flaps generated by eustatic variations are regular in the central part of the study area (**Fig.5**). This reflects the persistence of sedimentary inputs from this area of the continent. In addition, this can be interpreted as an area where the erosive force of the lower Miocene was not sufficient to excavate the Chattian sediments. On the other hand, there is a notable absence of Oligocene deposits both in the West and in the East (**Fig.5**). In the West, this is due to the presence of the "Trou Sans Fond" canyon, which has slopes affected by numerous slope instabilities, first causing the sediments to drain towards the axis of the canyon where they are then conveyed into the deep basin to probably form deep underwater cones and platform curb prisms. In the East, this lack of Oligocene could be justified by an intensification of erosion through the proliferation of overland watercourses.

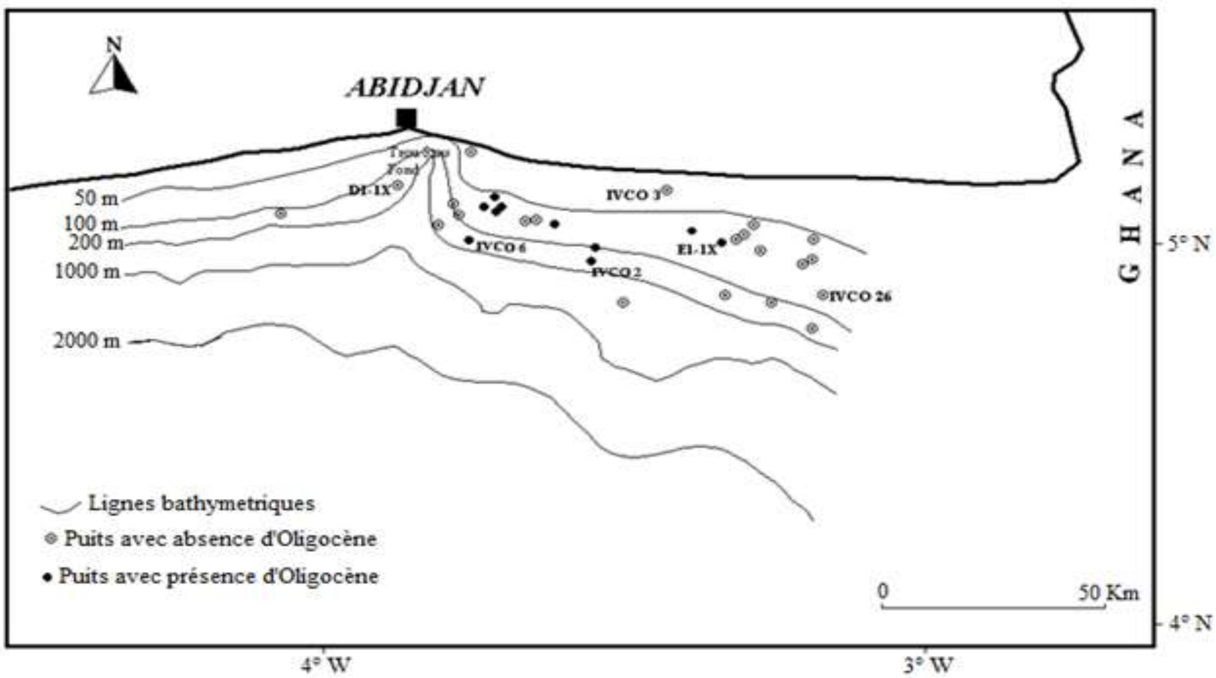

Figure 5: Oligocene flap distribution east of the continental shelf.

3.2. Litho-acoustic units from the Oligocene to the Present: On this profile (**Fig.6**), there are three (3) acoustic units separated by two fundamental unconformities. These units were correlated with the eustatic curve of [17] (cf **Fig.2**): unit 1 corresponds to Oligocene superior / Miocene, unit 2 is attributed to Pliocene, finally unit 3 to Quaternary. Regarding the sectors where there is no Oligocene or Miocene deposits, only the last two units are visible on the seismic profiles.

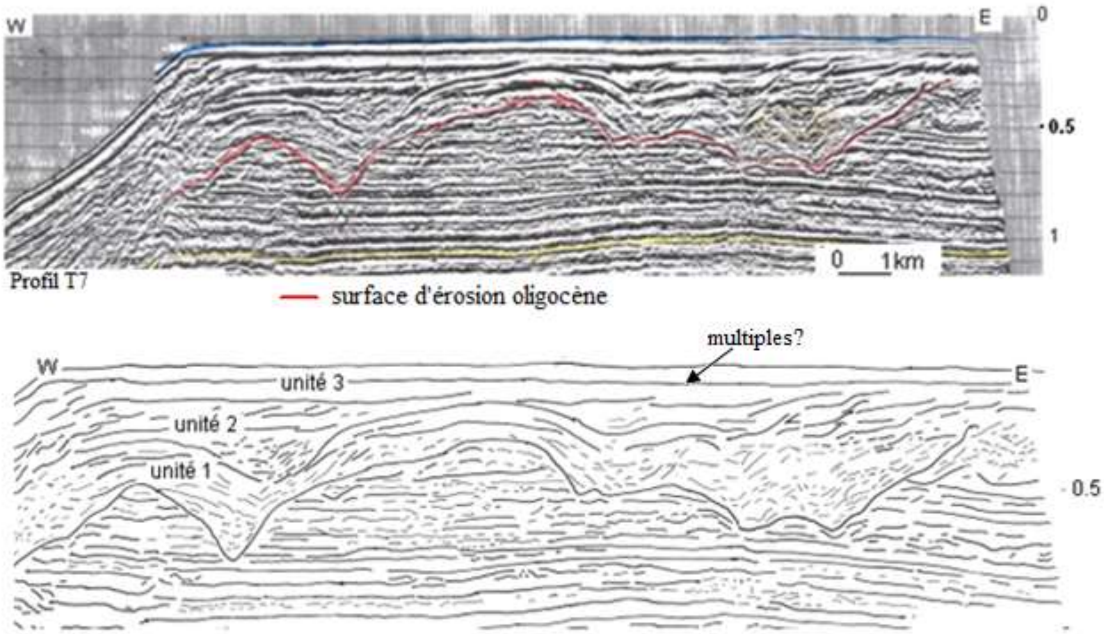

Figure 6: Seismic facies of different paleogenic / neogenic sedimentary units

Unit 1:

This unit presents a clear variation of acoustic facies according to the regions. Towards the west of the profile **(Fig.6),** it is formed by a set of discontinuous reflectors with high amplitude which butt onlap on the Oligocene erosive surface attesting to a transgressive period. The SW-NE profile (**Fig.7**), shows a fracturing within this sedimentary series, especially towards the North-East. In the south, near the continental slope, this unit presents a somewhat transparent facies organized in hollow and hump with sigmoid acoustic passages (**Fig.7**). All attests a development towards a detritalism more and more end to the rupture of slope. These fine detrital inputs from the neighboring continent are probably the result of a long transport process. They correspond to sandy or silty muds sedimented in shallow water under variable hydrodynamic conditions.

In the East **(Fig. 6**), in the areas where the depressions left by the Rupelian erosion are located, there is a local filling with variable amplitude reflectors. In these depressions, Unit 1 has a chaotic facies (**Fig. 6**), indicating the detrital nature of the sediments [9] that are certainly due to slope slumps in a high-energy sedimentation environment. The correlations with the drilling D1-1X, indicate that these deposits, of average Miocene age, consist essentially of clays with fine calcareous past. In areas where lower Miocene erosion (Aquitanian / Burdigalian) has been inactive, the Chattian sediments are the first to cover the bottom of the topographic depressions left by the Rupelian erosion.

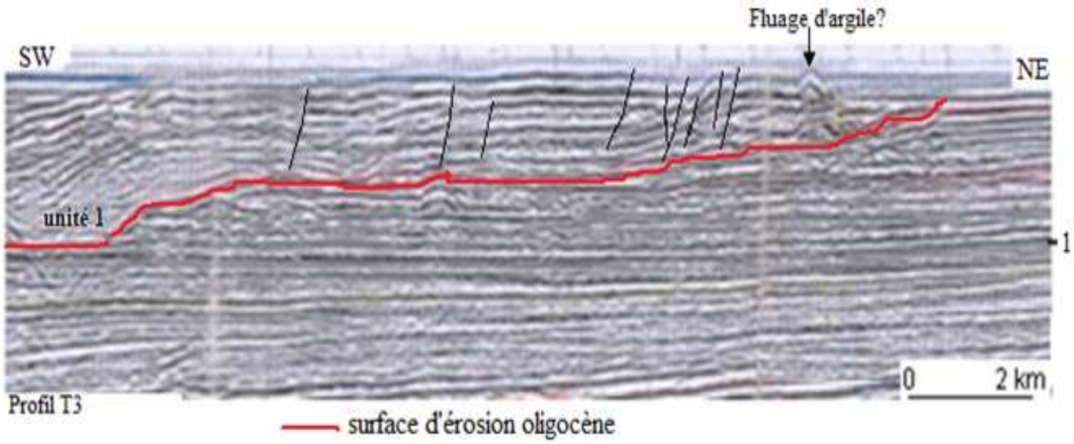

Figure 7: Fracturing in neogenic sediments and mud volcano to the northeast of the profile

Unit 2:

It is thinner to the north and rests unconformable on the previous unit. This acoustic ensemble is composed of strong reflectors, discontinuous in places, presenting a progradant-sigmoid configuration, especially in the East (**Fig.6).** This would indicate a significant input of detrital sediments. Of Pliocene age, these deposits offer a transgressive character with regard to the device onlap units. In topographic troughs, unit 2 is characterized by chaotic facies towards the west (**Fig.6**), as a result of sedimentation in a stirred medium. Towards the continental slope, it is possible to observe changes in dip (artificial dip) of the reflectors **(Fig.8**), probably caused by the abrupt variation of the water slice.

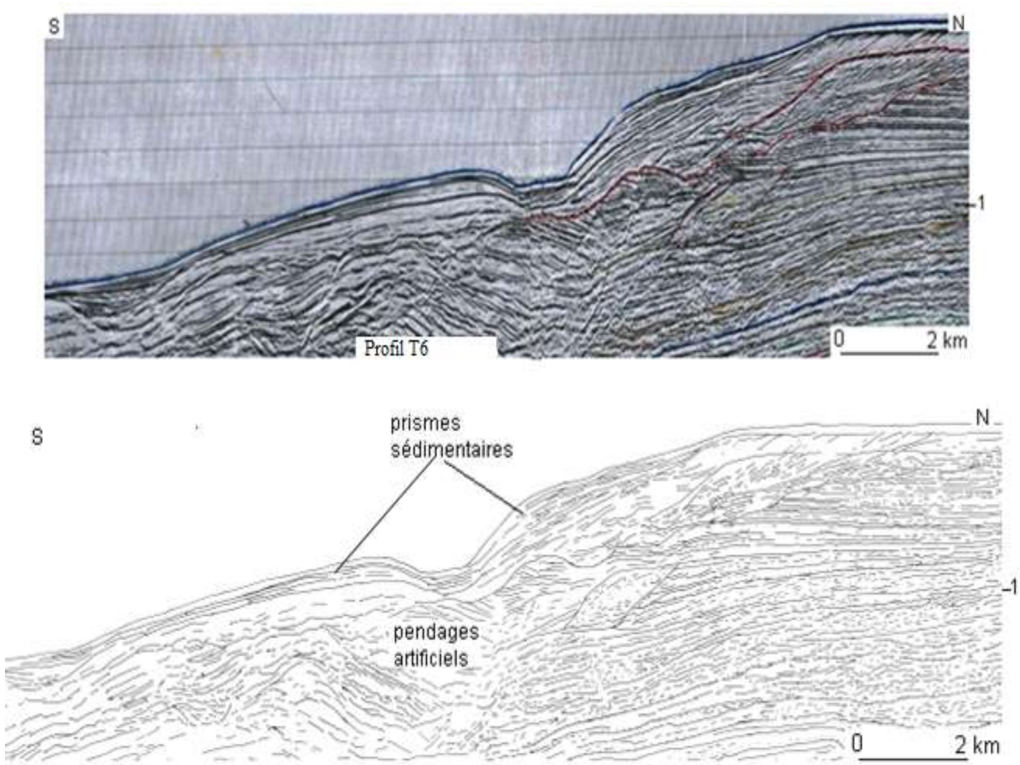

Figure 8: Profile showing sedimentary prisms in the summit unit and artificial dips underneath

Unit 3:

It is the summit unit of the Ivorian sedimentary basin. It overlaps with unconformity erosion all previous units (**Fig.6**). This unit overlooks the previous formation and reaches the top of the continental shelf. It has a well-defined acoustic facies, with strong, continuous and slightly uneven reflectors (**Figures 6** and **7**). This indicates continental shelf deposits in a low energy sedimentation environment. Some transparent facies as well as some seismic images showing probably clays of clay (**Fig.7**) that [19] attributed to volcanoes of surface sludge formed from gas volcanoes are observed locally.

At the slope break, we observe prograding sedimentary prisms **(fig.8**), witnesses of fluctuations in deposition conditions. Depending on the evolution of the sea level over time, the sedimentation rate, linked to the sedimentary mechanisms, changes. If the prograding material is bulky and the sedimentation rate falls, an important sedimentary prism is formed [20], a sigmoid envelope that is clearly visible on the lower edge of the Ivorian continental shelf (**Figure 8).**

Towards the west of the study area, in the vicinity of the "bottomless hole", auxiliary channels arranged in steps (**Fig. 9**) proliferate and also serve as drainage channels for sediments offshore. On these slopes, there is a disordered appearance of the reflectors (**Fig.10).** It would be sandy flow, muddy flows and slow landslides of sedimentary masses, all from the gravitational deposits that would result from the force of gravity; the transport is here by sliding on the slope under the action of sediment overload and gravity.

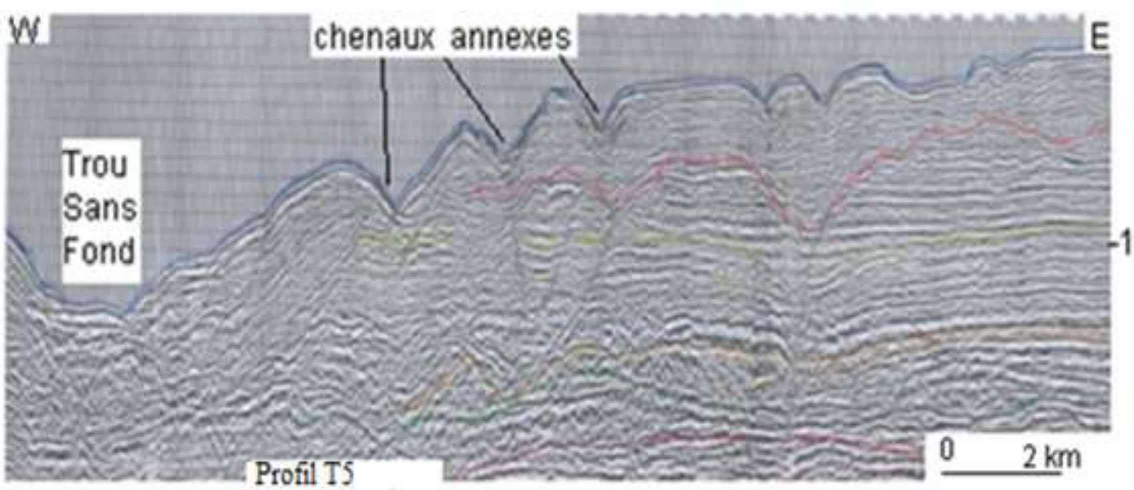

Figure 9: Annexary channels arranged in a step near the bottomless hole

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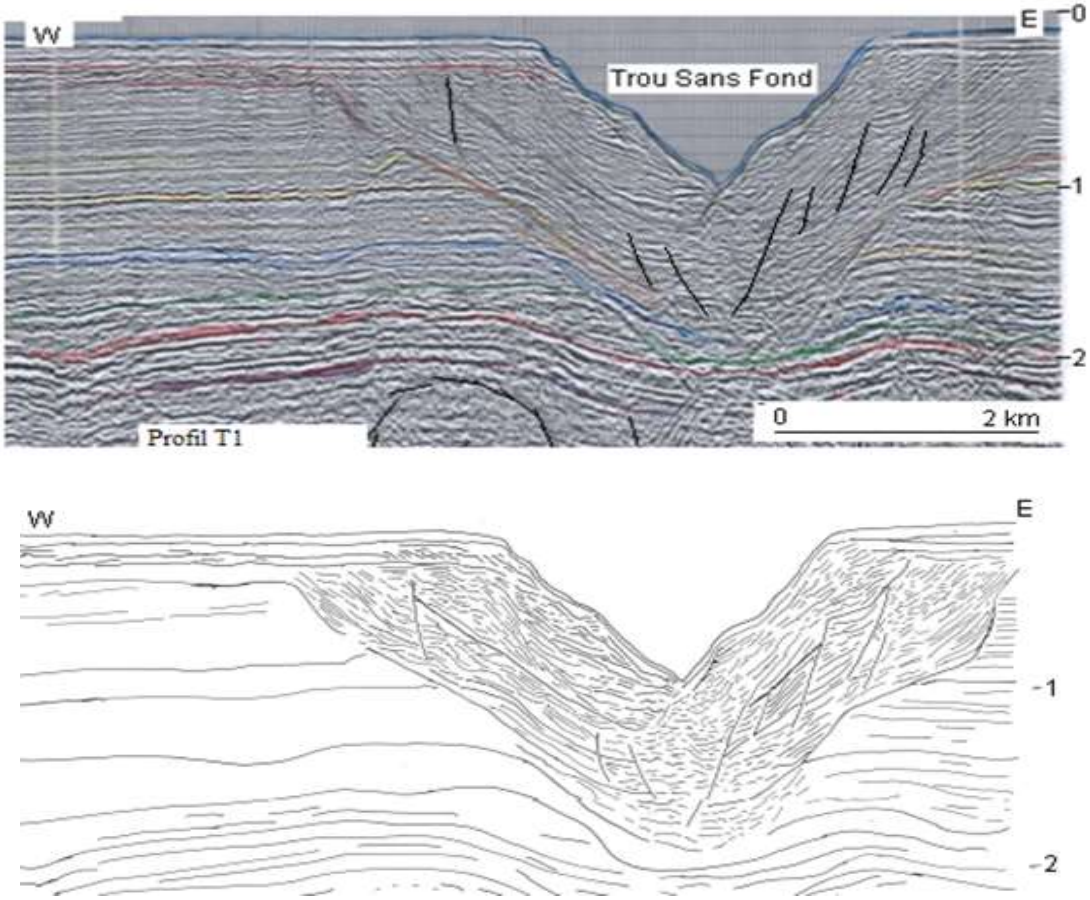

Figure 10: Disordered appearance of reflectors and gravity fractures on the slopes of the "bottomless hole".

3.3. Neotectonic analysis: In general, the eastern part of the continental margin of Côte d'Ivoire recorded some effects of tectonic activity during the post-Oligocene period. The paleotopography of the roof of the deformed sediments (units 1 and 2) (cf **Fig.7)** makes it possible to differentiate three main fault directions, NW-SE, NNE-SSW and NNW-SSE. These listric-type accidents are for the most part easily detectable on the seismic profiles.

The NW-SE faults are very frequent in the northern part but gradually attenuate and disappear towards the south of the study area.Similar faults have been described by [21] in Neogene and Quaternary sediments from Lower California to Mexico. They interpret these accidents as a direct consequence of a distorted tectonics that fits into the general tectonic setting of the western margin of the North American continent.
[22], for its part, revealed distensive and compressive structures in the Miocene and Plio-Quaternary series of the Saïs basin in Morocco.
In the same region of Sais in Morocco, [23] shed light on the geodynamic evolution of the Neogene region in the Quaternary. According to these authors, it is on the one hand, a filling of the Saïs basin by deep marine facies in the upper Miocene and, on the other hand, a major neotectonic reactivation of the South Rifian front and flexures of the medium. Atlas thus indicating a NS compression phase at NNW-SSE.
In view of this work, it is clear that these accidents, grouped in bundles in places and affecting Paleogenic and / or Neogene sediments of the Ivorian margin, could describe a tectonic phase proper. They

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correspond to normal faults that give a character of rocked blocks to deformed sediments (cf **Fig.7**) reflecting a distending movement of the continental lithosphere. This might suggest the existence of an extensive post-Oligocene episode of the Abidjan margin.

The NNE-SSW and NNW-SSE accidents, on the other hand, are singularly observable on the slopes of the "bottomless hole" canyon (**Fig.10**). These fractures do not describe true tectonics, rather they are produced by gravitational shifts probably resulting from differential compaction as already thought [13]. They show significant sedimentary instability that can be detected at the periphery of the bottomless hole [24]. These gravitational accidents seem very similar to those described by [25] in the western part of the Ivorian margin.On the other hand, no seismic profile indicates the presence of plicative structures in paleogenic / neogenic sediments.

4. CONCLUSION

The interpretation of the different profiles of seismic reflection through this sector of Ivorian continental margin made it possible to know the geodynamic evolution of the said margin during the period from Oligocene to Quaternary:

- ✓ **Sedimentary evolution**
  - ➢ In Paleogene, the general uplift of the Ivorian continental shelf accompanying the important marine regression to the lower Oligocene submits the continental shelf to intense erosion which deeply cuts the ante-Oligocene sediments.
  - ➢ At the Upper Oligocene, the sea invades its old domain and favors the deposit of a sedimentary series of Chattian age.
  - ➢ Following this transgressive phase, the Ivorian margin again enters a period of emersion in the lower Miocene causing ablation in places of previously deposited Chattian sediments. This resulted in the creation of Oligocene flaps because of their resistance to the agents of Aquitanian / Burdigalian erosion.
  - ➢ After this period, there is a real sedimentary construction of the continental shelf controlled by small eustatic variations.
- ✓ **Fractures**
  - ➢ The accidents are grouped according to three main systems oriented around the NW-SE, NNE-SSW and NNW-SSE directions. NW-SE fractures, numerous in the northern part of the study area, correspond to late reworkings of normal Albian faults. This would indicate a last distensive phase of the continental lithosphere.
  - ➢ The directions NNE-SSW and NNW-SSE, especially detectable on the slopes of the canyon of the "Bottomless Hole", are represented by accidents of gravitational types.

REFERENCES

1. A.SPENGLER et J.R.DELTEIL, Le bassin sédimentaire tertiaire de Côte d'Ivoire. In : Les bassins sédimentaires du littoral africain. Ass. Serv. Géol. Afri, Paris, 1966, 99 – 113.
2. G.ARENS, J.R.DELTEIL, P.VALERY, B.DAMOTTE, L.MONTADERT and P.PATRIAT, The continental margin of the Ivory Coast and Ghana. In The Geology of

Eastern Atlantic Continental Margin, Africa 4, Symp. Cambridge, Nation. Environn.Res. Counc., London, 1971, Rep. 70-16, 61-78.

3. E.BLAREZ, La marge continentale de Côte d'Ivoire – Ghana. Structure et évolution d'une marge continentale transformante. Thèse de doctorat, Univ. P. M. Curie (France), *1986*,188.
4. J.MASCLE and E.BLAREZ, Evidence for transform margin evolution from the Ivory Coast-Ghana Continental margin. Nature, 1987, 32, 378-381.
5. E.BLAREZ and J.MASCLE, Shallow structure and evolution of the Ivory Coast and Ghana transform margin. Marin. Petr.geol.1988, *5*, 54-64.
6. C.BASILE, J.MASCLE, C.AUROUX, J.P.BOUILLIN, G.MASCLE, K.GONZALVEZ DE SOUZA et le GROUPE EQUAMARGE, Une marge transformante type, la marge continentale de Côte d'Ivoire – Ghana : résultats préliminaires de la campagne Equamarge II, mars 1989 – C. R. Acad. Sci. Paris, t. 308, Série II, 1989,997 – 1004.
7. M.POPPOF, S.RAILLARD, J.MASCLE, C.AUROUX, C.BASILE et GROUPE EQUAMARGE, Analyse d'un segment de la marge transformante du Ghana: résultats de la campagne Equamarge II (mars 1989). C.R.Acad.Sci.Paris, t 308, série II, 1989, 418 – 487.
8. C.BASILE, Analyse structurale et modélisation analogique d'une marge transformante : l'exemple de la marge profonde de Côte d'Ivoire-Ghana. Thèse de doctorat, Univ. P.M.Curie (France), 1990, 205.
9. C.BASILE, J.P.BRUN et J.MASCLE, Structure et formation de la marge transformante de Côte d'Ivoire-Ghana: apport de la sismique réflexion et de la modélisation analogique Bull. Soc. France, t.163, 1992, 3, 207-216.
10. M.S.PIERRE et V.N'DA, Biostratigaphie et paléo environnements des dépôts crétacés au large d'Abidjan (Golfe de Guinée), Cretaceous Research, 1997, 18, 545-565.
11. C.B.SOMBO, C.S.DJRO, P.YACE et C.BODIER, Marge ivoirienne et ouverture de l'atlantique sud : Analyse synthétique. Rev. Sci. Bioterre, Edit. Univ. Côte d'Ivoire, 2003, 3, 1,69 – 97.
12. N.L.KOUAME, Marge continentale de Côte d'Ivoire: étude tectono-stratigraphique et des vitesses de propagation des ondes sismiques, Thèse de doctorat, Univ. F.H.B (Côte d'Ivoire), 2012, 217.
13. C.B.SOMBO, Etude de l'évolution structurale et sismo-stratigraphique du bassin sédimentaire off-shore de Côte-d'Ivoire, marge passive entaillée d'un canyon. Thèse de doctorat d'Etat ès sc., univ. Abidjan (Côte d'Ivoire), 2002,305, 2002.
14. P.SIMON et B.AMAKOU, La discordance oligocène et les dépôts postérieurs à la discordance dans le bassin sédimentaire ivoirien. Bull. Soc. Geol. France, 1984, (7), t XXVI, 6, 1117 – 1125.

15. PETROCI et BEICIP, Côte d'Ivoire Petroleum Evaluation. Répub. de C.I, Ministère des mines,1990, 99.

16. U.B.HAQ, J.HARDENBOL and R.P.VAIL, Mesozoic and Cenozoic chronostratigraphy and cycles of sea level change.SEPM, Spec. Pub., 1987, 42, 71 – 108.

17. W.S.PETTERS, Gulf of Guinea Planktonic Foraminiferal Biochronology and Geological History of the South Atlantic, J. foram. Res., 1983, 13, 32 – 59.

18. M.A.CHIERICI, Stratigraphie, paléoenvironnement et évolution géologique du bassin de Côte d'Ivoire-Ghana. Géologie de l'Afrique et de l'Atlantique Sud : actes colloques Angers 1994, 293 – 303, 1996.

19. A.N.ANSTEY, Sismique pour géologues, traduit par Leenhardt O. Erg. Boston, IHRDC, 1986, 190.

20. B.BIJU-DUVAL, Géologie sédimentaire : bassins, environnements de dépôts, formation du pétrole. Edit. TECHNIP, 1999, 27, ced.15, Paris (France), 714.

21. B.COLLETTA, J.ANGELIER, J.CHOROWICZ, L.ORTLIEB et C.RANGIN, Fracturation et évolution néotectonique de la péninsule de Basse-Californie (Mexique). C. R. Acad. Sc. Paris, 1981, t.292, Série II, pp 1043 – 1048.

22. L.AIT BRAHIM, Déformations et contraintes néogènes au niveau des Jbels Tratt-Zalarh et Aicha Mouguettaya Rift, Maroc. Bull. Inst. Scient., Rabat,1983,7, 33 – 40.

23. M.CHARROUD, B.CHERAI, M.BENABDELHADI, C.FALGUERES, Impact de la néotectonique quaternaire sur la dynamique sédimentaire du Saïs (Maroc): du bassin d'avant fossé pliocène au plateau continental quaternaire. Quaternaire, 2007, 18, (4), 327 – 334.

24. C.B.SOMBO, C.BODIER, J.P.TASTET, A.BROU, P.A.SOMBO et N.L.KOUAME, Le canyon du " Trou Sans Fond" (Côte d'Ivoire) : un exemple de l'interaction entre tectonique et eustatisme. Europ. Journ.Scient.Resear. 2012, 77, 4, 570 – 579.

25. G.CAPRONA, The continental margin of western Côte d'Ivoire: Structural framework inherited from intra-continental shearing. Thèse Publ. A 69, Geologiska Institutionen, 1992, 150.

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