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ScienceDirect
C. R. Palevol 8 (2009) 511–526
Comptes Rendus Palevol

General palaeontology (Biostratigraphy)

Biostratigraphy and geodynamic impact in the uppermost part of the northeastern coastal basin of Togo

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Received 29 August 2008; accepted after revision 18 May 2009
Available online 14 July 2009

Presented by Philippe Taquet

Abstract

Lithological and micropaleontological studies of core-samples from five boreholes drilled in the northeastern part of the coastal basin of Togo allow for a specification of the stratigraphy and the paleogeography of this area during the Maastrichtian and Paleogene. A lithological analysis reveals a marine series consisting of a Lower Maastrichtian unit, a Middle Paleocene to Eocene unit, and an upper unit attributed to the Continental terminal *sensu lato*. The biostratigraphical study, based on planktonic foraminifera, has led to a characterization of the basin in terms of biozones ranging from the *Globotruncana aegyptiaca* to the *Abathomphalus mayaroensis* biozones and biozones P5 to P11, thus specifying a Middle to Upper Maastrichtian, an Upper Paleocene and a Lower to Middle Eocene units. The paleogeographical evolution of the area shows that the series recorded two sedimentary cycles: the first one stops at the end of the Cretaceous and the second one in the Paleogene. ***To cite this article: P.Y.D. Da Costa et al., C. R. Palevol 8 (2009).***

Résumé

Impact biostratigraphique et géographique dans le secteur nord-est du bassin côtier togolais. L'étude lithologique et micropaléontologique des carottes de cinq sondages exécutés dans le secteur nord-est du bassin côtier togolais a permis de préciser la stratigraphie et la paléogéographie de ce secteur au cours du Maastrichtien et du Paléogène. L'analyse lithologique met en évidence une série marine comportant un ensemble inférieur maastrichtien, un ensemble moyen paléocène à éocène et un ensemble supérieur attribué au Continental terminal *sensu lato*. L'étude biostratigraphique, basée sur des foraminifères planctoniques permet d'y caractériser les biozones allant de la biozone à *Globotruncana aegyptiaca* à la zone *Abathomphalus mayaroensis* et les biozones P5 à P11 définissant ainsi un Maastrichtien moyen à supérieur, un Paléocène supérieur et un Eocène inférieur à moyen. L'évolution paléogéographique montre que cette série comprend deux cycles sédimentaires : le premier se termine à la fin du Crétacé et le second au Paléogène. ***Pour citer cet article : P.Y.D. Da Costa et al., C. R. Palevol 8 (2009).***

Keywords: Coastal basin of Togo; Stratigraphy; Maastrichtian; Paleogene; Biozone; Foraminifera; Tectonics; Paleogeography

Mots clés : Bassin côtier togolais ; Stratigraphie ; Maastrichtien ; Paléogène ; Biozone ; Foraminifères ; Tectonique ; Paléogéographie

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1631-0683/$ – see front matter
doi:10.1016/j.crpv.2009.05.003

1. Introduction

The West-African coastal basins (from Morocco to South Africa) owe their origin to the break-up of Gondwana and the opening-up of the South Atlantic Ocean. Therefore, they are rarely older than Cretaceous. For instance, the age of deposits in the coastal basins of the Central Atlantic is Aptian, Albian (Lower Cretaceous) or Cenomanian to Pliocene. Reyment [51,52], Reyre [53] and many other authors have reviewed the stratigraphic sequences of the West-African sedimentary basins.

Numerous micropaleontological and sedimentological studies of Mesozoic and Tertiary formations, realized during the past few years, have brought into evidence some homogeneity in the stratigraphic and paleogeographic results along the West-African coast. Useful data may be found in many papers, notably those by Monciardini [41], Ducasse et al. [20], Kogbe and Me'hes [32], Anglada et al. [5], Bellion [6], Rat et al. [50], Ly and Anglada [40], Petters [44,45,46,47] and Johnson et al., [26].

These coastal basins are very rich in fossils and contain similar fossil fauna. The biostratigraphy of the most of them, mainly based on foraminifera, provides numerous biozones of international value. Their stratigraphic subdivisions are known in very great detail. The oldest sediments are of non-marine and continental origin. Moreover, some lithostratigraphic landmarks, specifically limestones with *Togocyamus seefriedi* Oppenheim (Middle to Upper Paleocene), overlain by glauconitic horizon (typified of Paleocene/Eocene boundary) and attalpugite (palygorskite) level (typical of Lower to Middle Eocene), are recognized in all of these basins. The marine deposits are covered by a continental detrital formation with siderolithic facies known as "Continental terminal". The age of this formation is Middle Eocene to Quaternary [19,27,32,36,37,57]. The last transgression delayed the deposition of this formation in most of the costal basins (Senegal, Ghana and Ivory Coast).

The paleogeographic evolution in these basins is characterized by three sedimentary cycles. The first transgression took place during the Campanian or Maastrichtian, according to locations. Deposits during this time include sandstones, limestones and claystones. The Cretaceous-Cenozoic transition (K/T boundary) is well documented [9,15,18,22,23,30,43,48,55,56]. According to places, K/T transition is characterized by: (1) mixed microfauna assemblages (foraminifera, ostracods) from both Maastrichtian and Lower Paleocene; (2) a depositional gap of the terminal Maastrichtian or Early Paleocene (*Eugubina* zone); or (3) devoid of planktonic foraminifera in deposits.

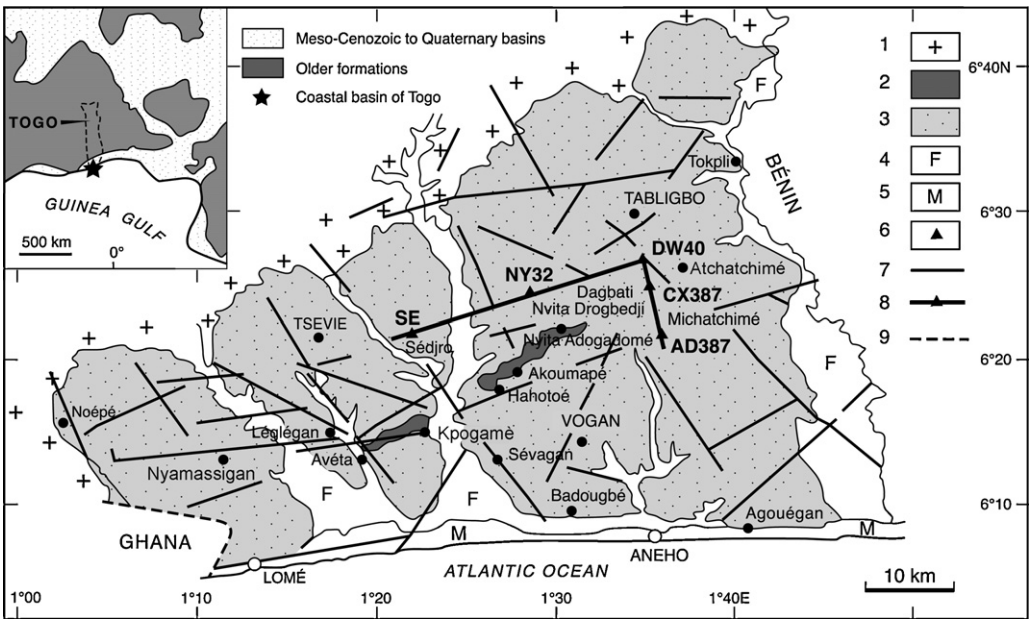

Fig. 1. Structural map of the Togo coastal basin with the locations of the investigated boreholes (after Motorolla [42]). 1: Pan African basement; 2: Hahotoé-Kpogamè phosphatic complex; 3: "Continental terminal" deposits; 4: Fluvio-lacustrine deposits; 5: Lagoonal to marin deposits; 6: Studied borehole; 7: Fault; 8: SW-NE and NW-SE profiles; 9: Uncertain border.

Fig. 1. Carte structurale du bassin côtier du Togo avec la localisation des sondages étudiés (d'après Motorolla [42]). 1 : socle panafricain ; 2 : complexe phosphaté de Hahotoé-Kpogamè ; 3 : dépôts du « Continental terminal » ; 4 : dépôts fluviolacustres ; 5 : dépôts marins à lagunaires ; 6 : sondage étudié ; 7 : faille ; 8 : profils SW-NE et NW-SE ; 9 : frontière incertaine.

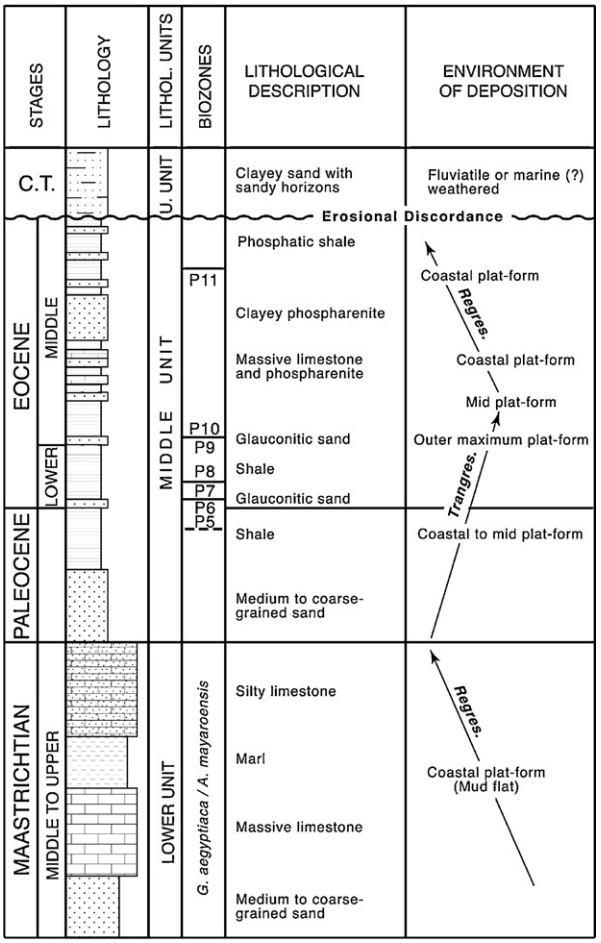

Fig. 2. Summary of the stratigraphy of the investigated area (Northeastern part of the coastal basin of Togo).
Fig. 2. Synthèse stratigraphique de la zone étudiée (secteur nord-est du bassin côtier du Togo).

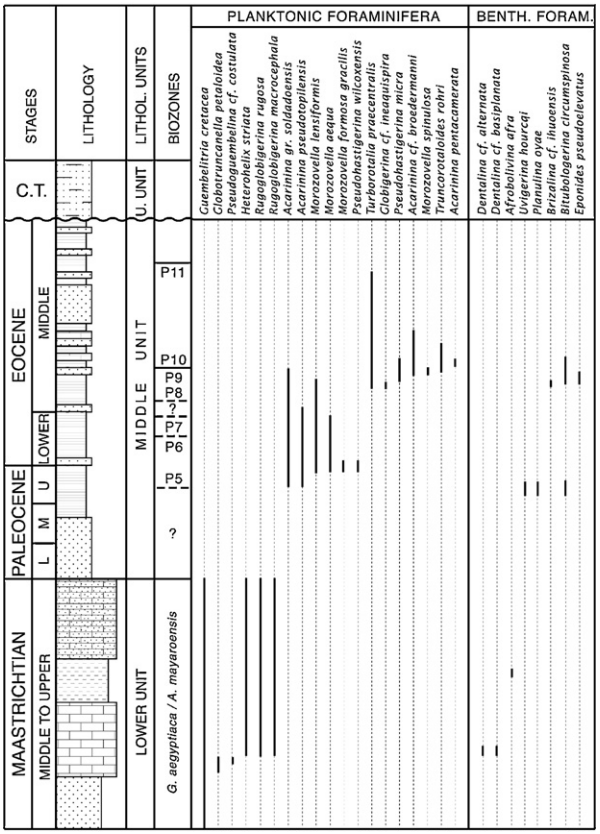

Fig. 3. The stratigraphical distribution of planktonic and benthonic foraminifera in the investigated series (Northeastern part of the coastal basin of Togo).
Fig. 3. Répartition stratigraphique des foraminifères planctoniques et benthiques dans la série étudiée (secteur nord-est du bassin côtier du Togo).

The second transgression occurred during the Danian and attained its maximum development during the Eocene. The marine sedimentation, essentially biochemical is typified by limestones (Paleocene), palygorskite shales (Lower Eocene) and phosphates deposits (Middle and Upper Eocene). The regression, which followed this transgression, took place more or less swiftly according to places, sometimes leading to a lack of the Upper Paleogene. After a period of emergence, going from the end of the Eocene to the Lower Oligocene, the last cycle began generally at the Upper Oligocene. The Mio-Pliocene regressive phase was generally accompanied by an important erosion related to the tectonic setting associated to a warm and wet climate.

This article summarizes, with a few lateness, the results obtained by Y.D. Da Costa during her first researches on the northeastern part of the coastal basin of Togo [13].

The coastal basin of Togo corresponds to a part of the Gulf of Benin basin which extends from the Southeast Ghana to the Southwest Cameroon (Fig. 1). It is a basin of Cretaceous/Tertiary age lying unconformably on the internal units of the Pan African Dahomeyide orogenic belt. The structure of this basin is the result of the fault tectonics [42], associated to passive margins, that influenced the conditions of sedimentation, the distribution of microfauna, and the hydrographic network. The sedimentary pile in the coastal basin of Togo is subdivided into three main units [13,25,26]:

- the Tabligbo Group, calcareous and detrital, of Maastrichtian to Lower Eocene age. This group includes three formations: (1) the Tabligbo sands, which include sands, sandy limestones and mudstones with foraminifera (Heterohelicides and Rugoglo-

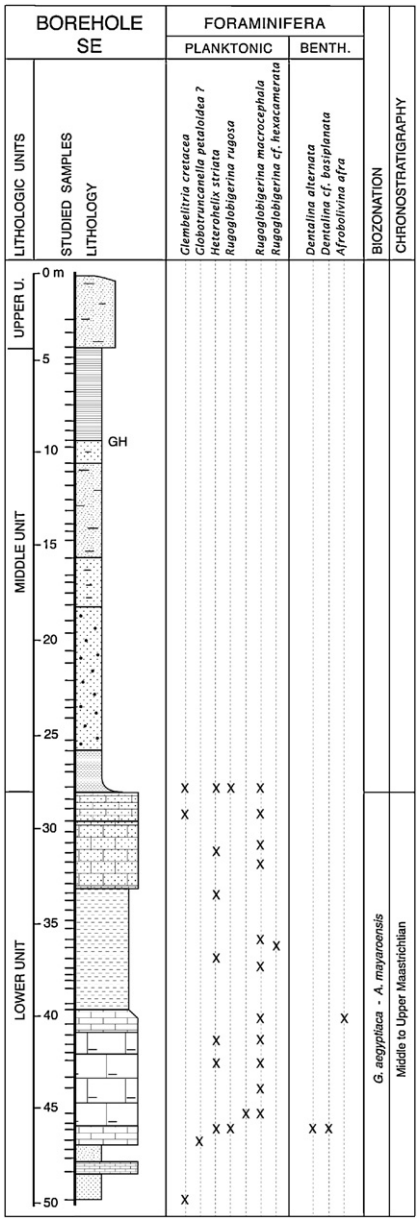

Fig. 4. Stratigraphical range chart of the planktonic and benthonic foraminifera arranged following the first appearance datum in the SE borehole (Northeastern part of the coastal basin of Togo).

Fig. 4. Répartition stratigraphique des espèces de foraminifères planctoniques et benthiques classées par ordre d'apparition dans le sondage SE (secteur nord-est du bassin côtier du Togo).

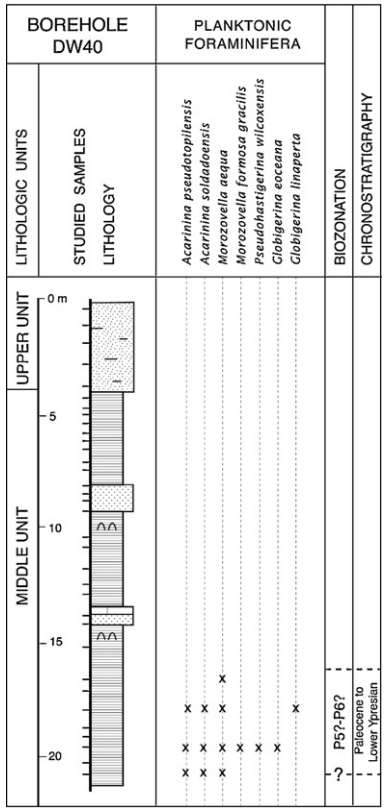

Fig. 5. Stratigraphical range chart of the planktonic foraminifera arranged following the first appearance datum in the DW40 borehole (Northeastern part of the coastal basin of Togo).

Fig. 5. Répartition stratigraphique des espèces de foraminifères planctoniques classées par ordre d'apparition dans le sondage DW40 (secteur nord-est du bassin côtier du Togo).

bigerinides) indicating a Maastrichtian age; (2) the Tabligbo limestones which comprise the basal limestones, with *Togocyamus seefriedi* Oppenheim and ostracodes indicating P3 zone of the Paleocene, and upper glauconitic limestones with *Globorotalia* (*Morozovella*) and *Lenticulina midwayensis* of P4 zone (Upper Paleocene); (3) the Tabligbo shales, with palygorskite bearing planktonic foraminifera of P6 zone (basal Ypresian);

- the Hahotoé-Kpogamè Phosphatic Complex (phosphatic limestones, phospharenites and phosphatic shales) of Lower to Middle Eocene age;
- the "Continental terminal", composed mainly of terrigenous detrital sediments, in an erosional discordance on the various underlying formations.

Previous biostratigraphic works were mostly done using foraminifera assemblages. The first micropaleontologic study (Lys in Slansky: [54,55,56] brings into evidence an Upper Maastrichtian, a Paleocene and a Lower to Middle Eocene sequences. Later, biostratigraphic reviews, following the works executed in the Tabligbo and Hahotoé-Kpogamè areas [25,26], led to distinguish the Upper Maastrichtian and a certain number of biozones (P3 to P9) corresponding to Middle Paleocene and Lower-Middle Eocene.

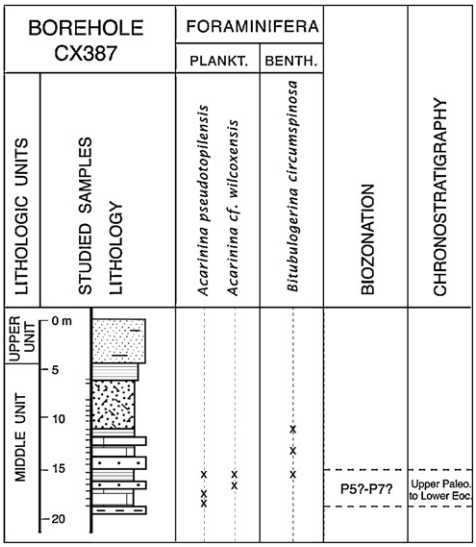

Fig. 6. Stratigraphical range chart of the planktonic and benthonic foraminifera arranged following the first appearance datum in the CX387 borehole (Northeastern part of the coastal basin of Togo).
Fig. 6. Répartition stratigraphique des espèces de foraminifères planctoniques et benthiques classées par ordre d'apparition dans le sondage CX387 (Secteur nord-est du bassin côtier du Togo).

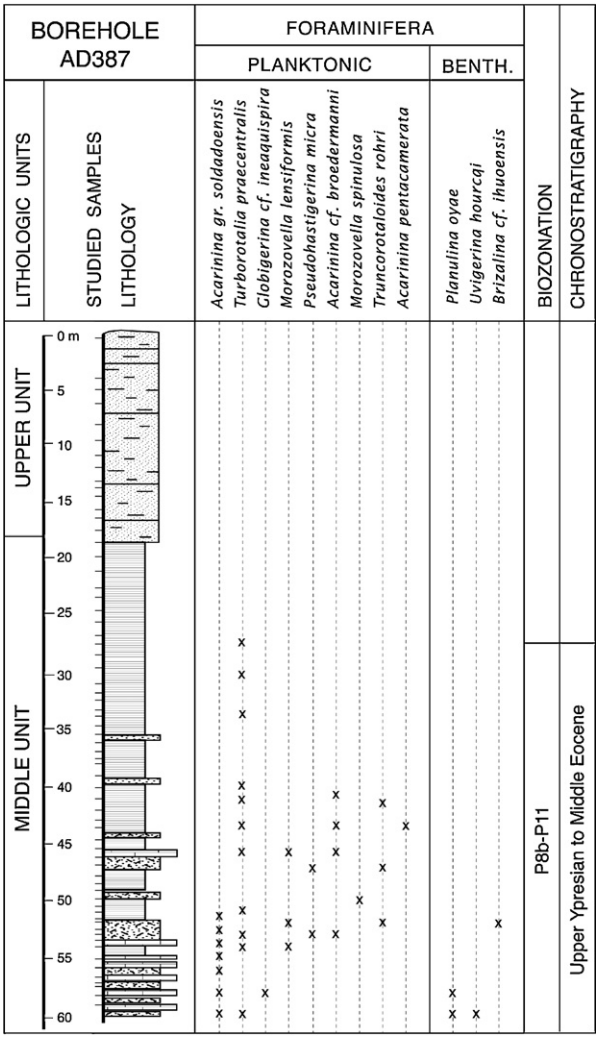

Fig. 7. Stratigraphical range chart of the planktonic and benthonic foraminifera arranged following the first appearance datum in the AD387 borehole (Northeastern part of the coastal basin of Togo).
Fig. 7. Répartition stratigraphique des espèces de foraminifères planctoniques et benthiques classées par ordre d'apparition dans le sondage AD387 (secteur nord-est du bassin côtier du Togo).

The new biostratigraphic data of the present work, notably based on foraminifera, make it possible to establish a more complete biozonation of the Paleogene series and to give further information on the paleogeographic evolution of the coastal basin of Togo.

Our objective is to carry out a biozonation of the sedimentary series in this northeastern part of the basin, based on lithological and micropaleontological studies of five boreholes located along SW-NE and NW-SE profiles (Fig. 1). These are the Sédjro (SE) Nyita (NY32), Dagbati-Watchidomé (DW40) and Dagbati (CX387 and AD387) boreholes. These boreholes drilled for phosphates investigations crossed 20 m to 60 m of sediments and have intersected the Continental terminal, Middle to Lower Eocene, Paleocene, and Maastrichtian.

2. Lithological and micropaleontological studies

2.1. Lithological analysis

A synthesis of lithological data from the boreholes leads to the identification of series made of three lithological units (Fig. 2):

- a lower unit, encountered only in the borehole SE (the 50–28 m interval). It consists, at the base, of medium- to coarse-grained sands, followed by limestones intercalated with marls, becoming silty at the top. Some of these beds are rich in organic matters;
- a middle unit, encountered in all the boreholes, consists of an alternation of sands (becoming glauconitic toward the top) and shales, followed (particularly in the boreholes CX 387 and AD 387) by massive phosphatic limestones, phospharenites that are clayey in places, and phosphatic shales. The shales (boreholes DW40 and NY32) are intercalated with fine limestone horizons and glauconitic sands, and sometimes gypsum and organic matters;

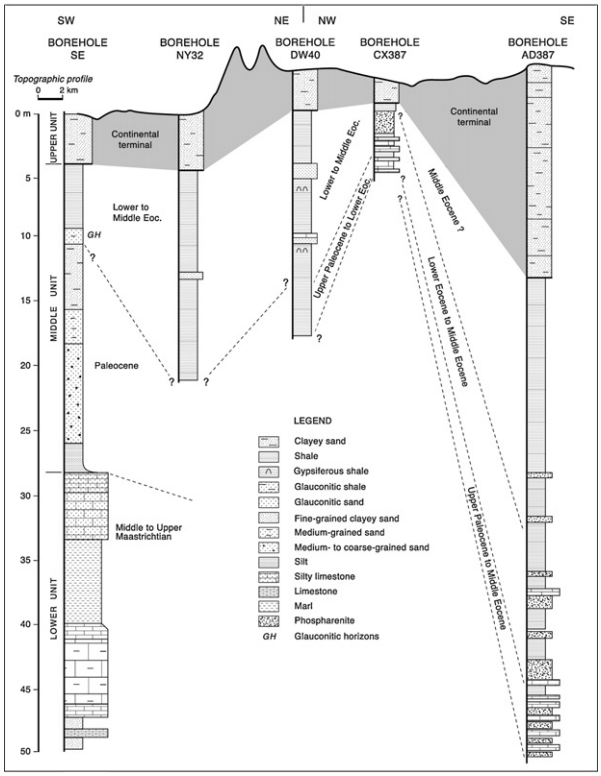

Fig. 8. Lithostratigraphical and biostratigraphical correlations between the studied boreholes along SW-NE and NW-SE profiles (Northeastern part of the coastal basin of Togo; Fig. 1).
Fig. 8. Corrélations lithostratigraphiques et biostratigraphiques entre les sondages étudiés suivant les profils SW-NE et NW-SE (secteur nord-est du bassin côtier du Togo ; Fig. 1).

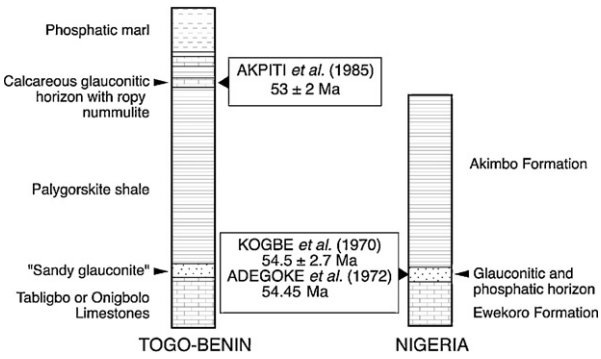

Fig. 9. Stratigraphical position of glauconitic horizons in the coastal basins of Togo-Benin-Nigeria (after Johnson [25]).
Fig. 9. Localisation des niveaux glauconieux dans les bassins côtiers du Togo-Bénin-Nigeria (d'après Johnson [25]).

- the upper unit constituting the uppermost part of all the studied boreholes. It consists of clayey sands of variable grain sizes and sandy shales containing small quartz pebbles, sandy layers and granules of iron oxides. In the boreholes NY32 and AD387, rare indeterminate benthic foraminifera are encountered in the lower part of the sequence assigned to the "Continental terminal".

It is noted that the components of these three units evolve differently in the two studied profiles (Fig. 8). In the SW-NE profile, the boreholes SE, NY32 and DW40 define an area more or less parallel to the coast, with few variations of facies and thickness: the middle unit is a relatively homogeneous facies, clayey to sandy and containing two glauconitic marker horizons. In contrast, in the NW-SE profile, the middle unit is characterized by a significant variation in facies: clayey at DW40, it becomes a phosphatic clay at CX387. Furthermore, the borehole AD387 is located in an open sea area where the middle and upper units are very thick.

The lower unit and shales of the middle unit (encountered in the boreholes DW40 and NY32) constitute an equivalent of the Tabligbo Group, but the Tabligbo limestones are absent in the area. Therefore, phosphatic deposits of this area (boreholes CX387 and AD387) belong to the Hahotoé-Kpogamè Phosphatic Complex [25,26].

2.2. *Biostratigraphical study*

Biostratigraphical data were obtained from planktonic foraminifera (Fig. 3) recovered from the boreholes at Sédjro (SE), Dagbati-Watchidomé (DW40) and Dagbati (CX387 and AD387).

The biostratigraphical subdivisions presented here are based on the work of Caron [12], for the Upper Cretaceous, and of Blow [10,11], and Tourmakine and Lutterbacher [58] for the Paleogene. These subdivisions are made difficult by the poverty of the sediments in planktonic foraminifera.

In the Sédjro borehole (SE; Fig. 4), the assemblage of planktonic foraminifera encountered between 28 and 50 m allows the investigated area to be assigned to the Middle to Upper Maastrichtian. This assemblage consists of *Guembelitria cretacea* (Cushman), *Rugoglobigerina macrocephala* Brönnimann, *R.* cf. *Hexacamerata* Bronnimann, *R. rugosa* (Plummer), *Heterohelix striata* (Ehrenberg) and *Globotruncanella petaloidea*? (Gandolfi) whose stratigraphic range includes the *Globotruncana aegyptiaca-mayaroensis* biozones.

The P5 to P11 biozones of Blow, that correspond to the top of Upper Paleocene and to the Lower and Middle Eocene, have been identified in the boreholes DW40, CX387 and AD387 (Figs. 5–7). Moreover, the following planktonic foraminifera have been iden-

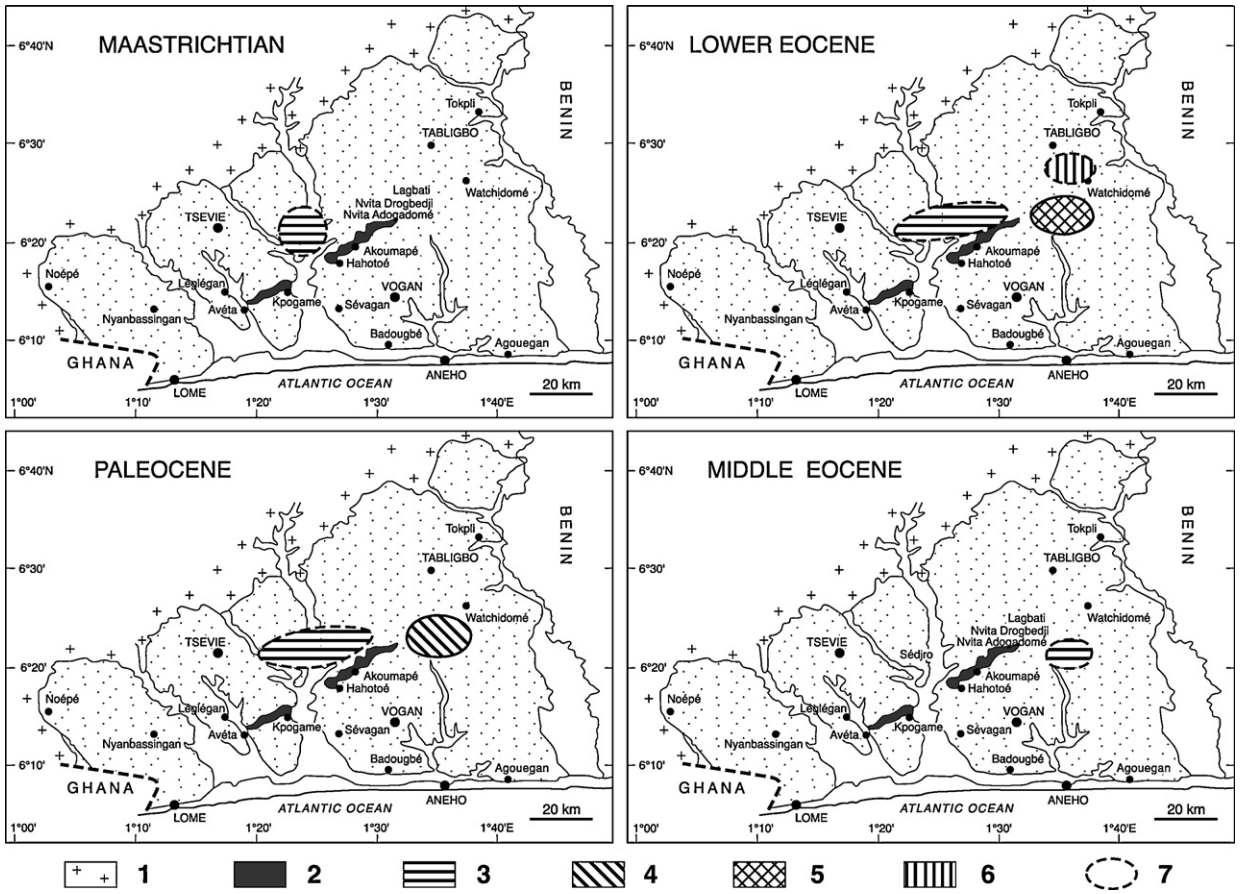

Fig. 10. Paleogeographical evolution of the investigated area (Northeastern part of the coastal basin of Togo). 1: panafrican basement; 2: Hahotoé-Kpogamè phosphatic complex; 3: coastal platform environment; 4: coastal to mid platform environment; 5: outer platform environment; 6: mid to outer platform environment; 7: provisional limit.

Fig. 10. Évolution paléogéographique de la zone étudiée (secteur nord-est du bassin côtier du Togo). 1 : socle panafricain ; 2 : complexe phosphaté de Hahotoé-Kpogamè ; 3 : plate-forme littorale ; 4 : plate-forme littorale à moyenne ; 5 : plate-forme externe ; 6 : plate-forme moyenne à externe ; 7 : limite provisoire.

tified here: *Morozovella aequa* (Cushman & Renz), *Pseudohastigerina wilcoxensis* (Cushman & Ponton) *Morozovella formosa gracilis* (Bolli), *M. lensiformis* (Subbotina), *Acarinina* gr. *soldadoensis* (Brönnimann), *A. pentacamerata* (Subbotina), *Turborotalia praecentralis* (Blow), *Pseudohastigerina micra* (Cole) and *Truncorotaloides rohri* Brönniman and Bermudez. These species of foraminifera are also described in neighbours coastal basins (Senegal, Ivory Coast, Ghana, Benin and Nigeria) and in Iullemmeden basin [9,18,22,23,33,39,50].

The different planktonic foraminiferal assemblages have led to the identification of a sedimentary series that goes from the Maastrichtian to Middle Eocene. Nevertheless, the composition of the microfauna varies with the studied site. If the Middle to Upper Maastrichtian appears to have been well dated, the rest of the series on the contrary is less so. Indeed, the P1 to P4 biozones were not identified in the studied area. A gap during the Lower and Middle Paleocene is therefore possible in this area.

2.3. The role of lithostratigraphical markers in dating lithostratigraphical units

The scarcity or the absence of microfossils in the sediments prevented the dating of the stratigraphical units identified in some boreholes. This is particularly true for the middle unit in the boreholes SE and NY32, and for the upper unit in all the boreholes (Fig. 8).

The middle lithological unit in the boreholes SE and NY32, which could not be dated with microfossils, contains a glauconitic horizon that allows the separation of the Paleocene from the Eocene. Actually, this horizon (borehole SE) is probably the equivalent of

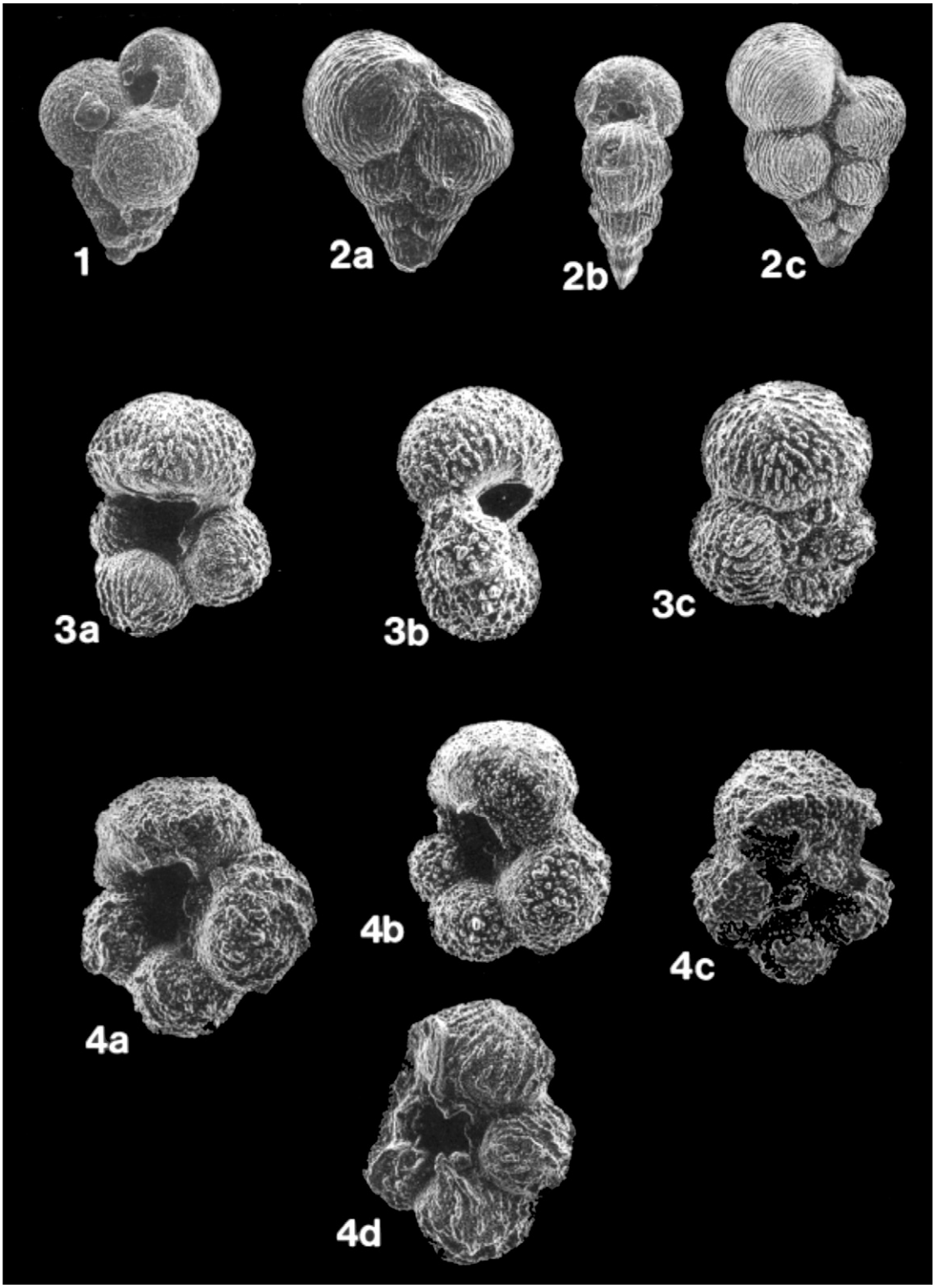

Plate 1. **1**. *Guembelitria cretacea* (Cushman); Middle to Upper Maastrichtian; SE (28.60; 29.40; 50 m) × 440. **2**. *Heterohelix striata* (Ehrenberg); Middle to Upper Maastrichtian; **a**: side view; SE (46,20 m) × 360; **b**: edge view; SE (46.20 m) × 320; **c**: side view; SE (34.16 m) × 320. **3**. *Rugoglobigerina macrocephala* Brönnimann; Middle to Upper Maastrichtian; **a**: umbilical side; SE (36.75 m) × 200; **b**: spiral side; SE (36.75 m) × 200;

the glauconitic horizon containing the ropy nummulite *Ranikothalia* [26] and located at the top of the Tabligbo limestones (Zéglégan, Nyamassigan, Atchatchimé and Akoumapé boreholes). Such a fossil is absent in the studied area. This glauconitic horizon is found again at the top of the shales that overlie the Onigbolo limestones in Benin or the limestones known as the Ewekoro formation in Nigeria, which are probably lateral equivalents of the Tabligbo limestones (Fig. 9). This glauconitic horizon, dated at 54.5 ± 2.7 Ma [1,3,31] constitutes a good marker denoting the transition from Paleocene to Eocene. However, the glauconitic horizon of the borehole NY32 could be the one dated at 53 ± 2 Ma [1,4,31].

3. Paleogeographical evolution of the area studied

Lithological and biostratigraphical data obtained during this study make it possible to trace the paleogeographical evolution of this area from the Maastrichtian to the "Continental terminal" (Figs. 2 and 10).

3.1. The Maastrichtian

During the Maastrichtian, sedimentation was essentially calcareous, with a significant detrital component at the base (see the lower lithological unit in the borehole SE, Fig. 4). The depositional environment of the coastal platform type, at the beginning, underwent oceanic influences that progressively diminished from the base toward the top. This is indicated by the reduction in planktonic foraminifera and their replacement by a population of benthic foraminifera composed of *Afrobolivina afra* (Reyment), *Dentalina* cf. *megalopolitana* (Reuss), *D. basiplanata* (Plummer), *D.* cf. *alternata* (Cushman), *Spiroplectamina* cf. *nuda* (Lalicker), *S.* sp., *Cibicides* sp., *Marginulina* sp. and *Quinqueloculina* sp.

3.2. The Paleocene

The section considered is barren in the boreholes SE and NY32 and, consequently, is ranging in age from the Paleocene (supposed) to Lower-Middle Eocene (probable). Only the borehole SE could contain a coarse detrital horizon prior to P5, but it may be of Maastrichtian age. The top of the Upper Paleocene corresponds to the lower part of the middle stratigraphical unit in the boreholes DW40 (?), CX387 and AD387. It is characterized by a platform type sedimentation whose exposure to the open ocean varies from one borehole to another: coastal to mid platform type environment (sites CX387 and AD387), favourable for the formation of an alternating calcareous and phospharenitic sediments rich in planktonic foraminifera; the observed benthic association is little diversified and restricted to *Eponides pseudoelevatus* (Graham, De Klasz & Rerat), *Uvigerina hourcqi* (Graham, De Klasz & Rerat), and *U. alazanensis* (Nuttall).

3.3. The Lower Eocene

The Lower Eocene corresponds to the middle stratigraphical unit. It is characterized by a predominantly detrital platform type sedimentation whose degree of oceanic influence varies with location:

- at Sédjro and Nyita (boreholes SE and NY32, respectively), the absence of planktonic foraminifera and the sporadic presence of benthic foraminifera indicate a mid to coastal type platform environment;
- at Dagbati- Watchidomé (borehole DW40), the very high percentage of planktonic foraminifera (pelagic index of 60–70%) indicates an outer platform type environment;
- at Dagbati, the environment could be an open coastal platform, given the numerical superiority of benthic over planktonic forms (borehole CX 387). On the other hand, the abundance of planktonic species (pelagic index of 40–60%) in the borehole AD 387 indicates a mid to outer platform environment.

In these Lower Eocene deposits, the benthic foraminiferal assemblage encountered includes (in addition to the types cited in the Paleocene) *Bitubulogerina circumspinosa* De Klasz & Rerat, *Brizalina advena striatella* (Cushman), *B.* cf. *ihuoensis* (Reyment), *Bulimina* cf. *propinqua* (Stache) and *Planulina oyae* (Reyment).

c: edge view; SE (36.75 m) × 240. **4**. *Rugoglobigerina rugosa* (Plummer); Middle to Upper Maastrichtian; **a**: umbilical side; SE (35.75 m) × 260; **b**: umbilical side; SE (35.75 m) × 260; **c**: spiral side; SE (35.75 m) × 260; **d**: umbilical side; SE (45, 26 m) × 220.

Planche 1. **1**. *Guembelitria cretacea* (Cushman) ; Maastrichtien moyen à supérieur. SE (28,60 ; 29,40 ; 50 m) × 440. **2**. *Heterohelix striata* (Ehrenberg) ; Maastrichtien moyen à supérieur ; **a** : vue latérale ; SE (46,20 m) × 360 ; **b** : profil ; SE (46,20 m) × 320 ; **c** : vue latérale ; SE (34,16 m) × 320. **3**. *Rugoglobigerina macrocephala* Brönnimann ; Maastrichtien moyen à supérieur ; **a** : face ombilicale ; SE (36,75 m) × 200 ; **b** : face spirale ; SE (36,75 m) × 200 ; **c** : profil ; SE (36,75 m) × 240. **4**. *Rugoglobigerina rugosa* (Plummer) ; Maastrichtien moyen à supérieur ; **a** : face ombilicale ; SE (35,75 m) × 260 ; **b** : face ombilicale ; SE (35,75 m) × 260 ; **c** : face spirale ; SE (35,75 m) × 260 ; **d** : face ombilicale ; SE (45,26 m) × 220.

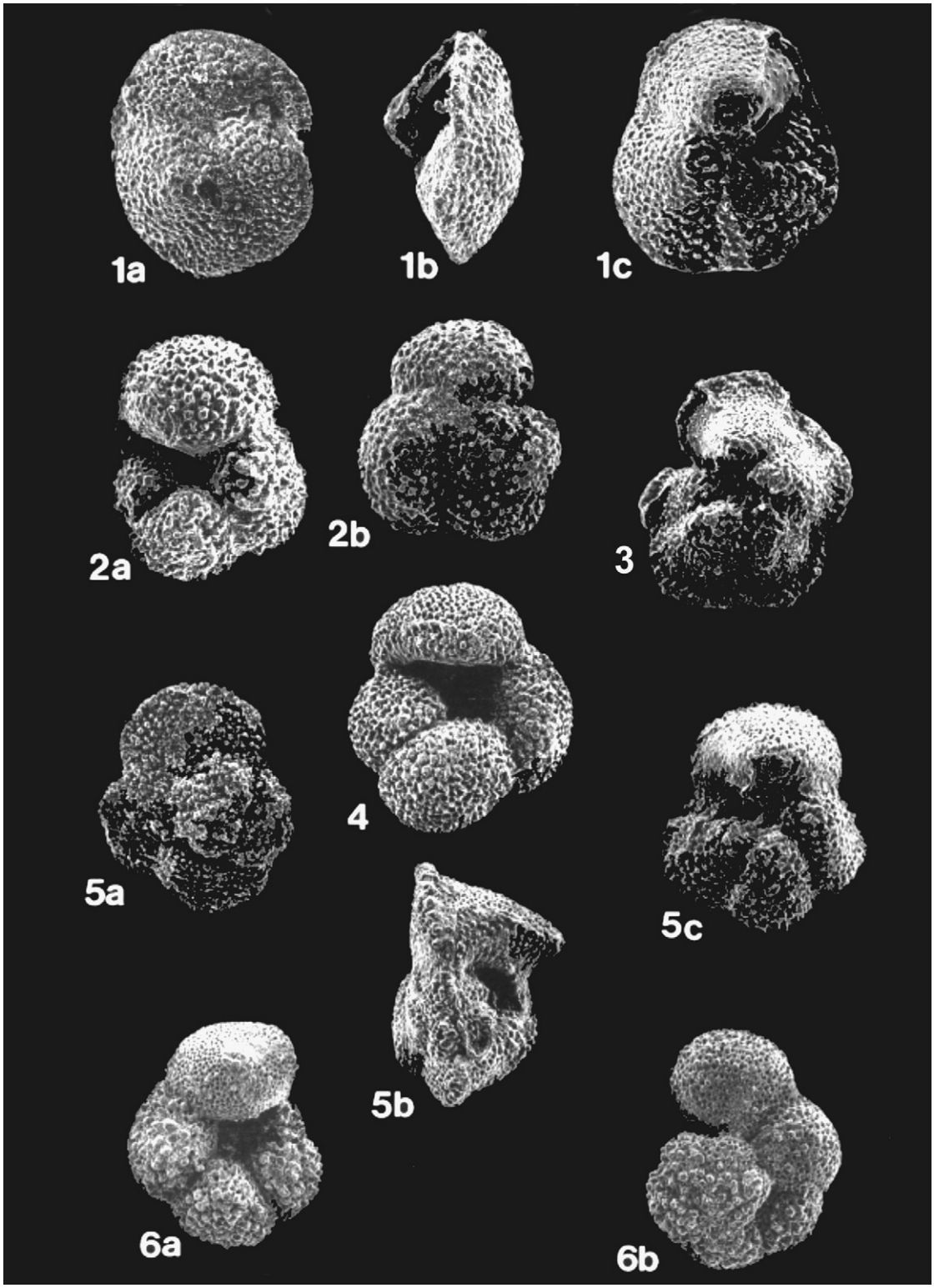

Plate 2. **1**. *Morozovella lensiformis* (Galessner); Ypresian; **a**: spiral side; AD387 (51.41 m) × 300; **b**: edge view; AD387 (51.41 m) × 400; **c**: umbilical side; AD387 (51.41 m) × 440. **2**. *Acarinina pseudotopilensis* (Subbotina); Ypresian to Middle Eocene; **a**: umbilical side; DW40 (18; 19.42; 20.80 m) × 220; **b**: spiral side; DW40 (19.42 m), CX387 (16.57; 18.86; 19.72 m) × 300. **3**. *Morozovella formosa gracilis* (Bolli); Ypresian to

3.4. The Middle Eocene

The Middle Eocene corresponds to the upper part of the middle lithologic unit (borehole AD387). The swift decrease in planktonic and benthic foraminifera, from the base toward the top, indicates a coastal platform environment whose relation with the high tide diminishes toward the top of the series. The benthic foraminifera are restricted to the types cited for the Lower Eocene.

A middle unit, encountered in all the boreholes, consists of an alternation of sands (becoming glauconitic toward the top) and shales, followed (particularly in the boreholes CX387 and AD387) by massive phosphatic limestones, phospharenites that are clayey in places, and phosphatic shales. The shales (boreholes DW40 and NY32) are intercalated with fine limestone horizons and glauconitic sands, and sometimes gypsum and organic matters.

The middle unit (which consists of sands, glauconitic sands, shales and phosphatic deposits) corresponds to a transgressive sedimentary cycle. The transgression started during the Upper Paleocene and became more pronounced toward the top of the Lower Eocene, as indicated by an increase in the percentage of planktonic foraminifera. The sedimentary environment changes from coastal platform during the Upper Paleocene to a mid to outer platform in Lower Eocene. Regression probably takes place at the base of the Middle Eocene and continued to its top.

This evolution is comparable to that observed in the rest of the coastal basin of Togo, and in Senegal, where the main Tertiary transgression persists up to the Eocene, reaching its maximum during the Lower Eocene [26,39,40]. On the other hand, in the Iullemmeden basin [4,6,16,17], the Tertiary transgression took place during the Upper Paleocene and was followed by an Eocene regression.

3.5. The Continental terminal

The uppermost lithological unit of the studied area is defined as the Continental terminal [14,59]. These sediments have suffered a widespread superficial alteration observable in most of the West-African coastal basins [19,35-37].

3.6. Impact of tectonics on the sedimentation and the distribution of microfauna during the Paleogene

Important variations in the sedimentation and the micropaleontological content are observed in all the investigated boreholes (Fig. 8).

3.6.1. Sedimentological variations

Our comments will be limited to the Tertiary because the Maastrichtian was attained only in the Sédjro borehole (SE).

The undated sandy horizon of SE might represent a *pro parte* Paleocene. In the other boreholes, it corresponds to gypsiferous shales (at NY32) or to shales with intercalations of phospharenites and limestones or marls (at CX387).

During the Eocene, significant lateral facies variations are observed: at SE and NY32, the Eocene is composed of shales with glauconitic horizons; on the other hand, in the other boreholes (DW40, CX387 and AD387), the series is more heterogeneous (gypsiferous shales with organic matter, limestones, glauconitic sands, marls, phospharenites**,** phosphatic shales).

3.6.2. Variations in benthic foraminiferal assemblages

Benthic foraminiferal associations vary with the studied profiles. From east to west, the foraminiferal assemblages become poorer in species and in individual fossils while there is a diversification from north to south.

Middle Eocene; **a**: umbilical side; DW40 (19, 42 m) × 180. **4**. *Acarinina gr soldadoensis* (Brönnimann); Ypresian to Middle Eocene; a: umbilical side; DW40 (18; 19.42; 20.80 m) × 220. **5**. *Morozovella aequa* (Cushman & Renz); Paleocene to Ypresian; **a**: spiral side; × 200; profil; × 200; **c**: umbilical side; × 200; DW40 (18; 19.42; 20.80 m). **6**. *Truncorotaloides rohri* (Brönniman & Bermudez); Lower to Middle Eocene; **a**: umbilical side; AD387 (51.41 m) × 160; **b**: spiral side; AD387 (51.41 m) × 200.

Planche 2. **1**. *Morozovella lensiformis* (Galessner) ; Yprésien ; **a** : face spirale ; AD387 (51,41 m) × 3 00 ; **b** : profil ; AD387 (51,41 m) × 400 ; **c** : face ombilicale ; AD387 (51,41 m) × 440. **2**. *Acarinina pseudotopilensis* (Subbotina) ; Yprésien à Eocène moyen ; **a** : face ombilicale ; DW40 (18 ; 19,42 ; 20,80 m) × 220 ; **b** : face spirale ; DW40 (19,42 m), CX387 (16,57 ; 18,86 ; 19,72 m) × 300. **3**. *Morozovella formosa gracilis* (Bolli) ; Yprésien à Eocène moyen ; face ombilicale ; DW40 (19,42 m) × 180. **4**. *Acarinina gr soldadoensis* (Brönnimann) ; Yprésien à Eocène moyen ; face ombilicale ; DW40 (18 ; 19,42 ; 20,80 m) × 220. **5**. *Morozovella aequa* (Cushman & Renz) ; Paléocène à Yprésien ; **a** : face spirale ; × 200 ; profil ; × 200 ; **c** : face ombilicale ; × 200 ; DW40 (18 ; 19,42 ; 20,80 m). **6**. *Truncorotaloides rohri* (Brönniman & Bermudez) ; Eocène inférieur à Eocène moyen ; **a** : face ombilicale ; AD387 (51,41 m) × 160 ; **b** : face spirale ; AD387 (51,41 m) × 200.

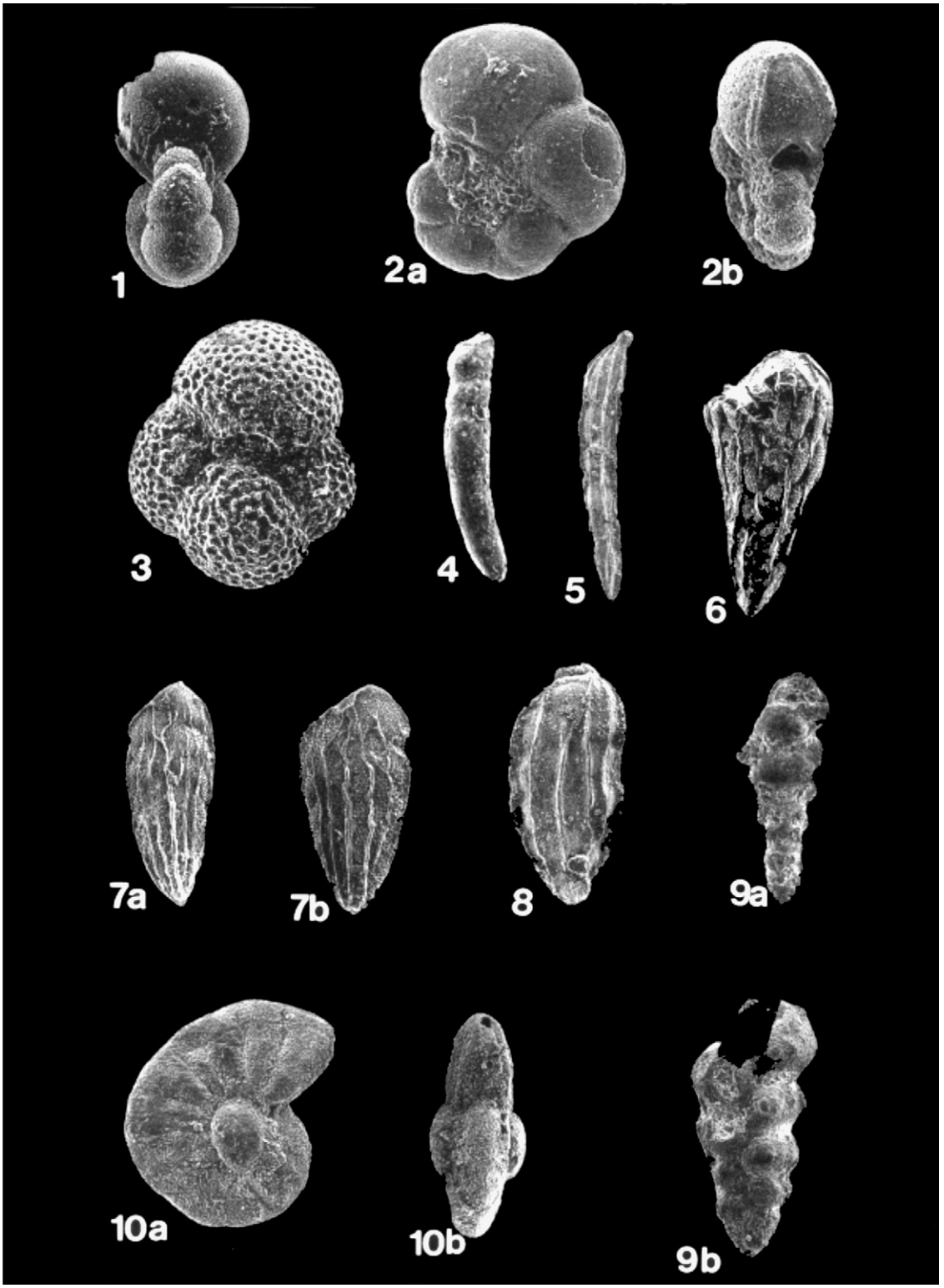

Plate 3. **1**. *Pseudohastigerina wilcoxensis* (Cushman & Ponton); Ypresian to Middle Eocene; edge view DW40 (19.42 m) × 200. **2**. *Pseudohastigerina micra* (Cole); Lower to Middle Eocene; **a**: side view; AD387 (47.29 m) × 300; **b**: edge view; AD387 (47.29 m) × 440. **3**. *Globigerina eoceana* Gümbel; Ypresian to Middle Eocene; umbilical side; DW40 (19.42 m) × 320. **4**. *Dentalina basiplanata* (Plummer); Middle to Upper Maastrichtian;

An imbalance in the distribution of species is noted in the studied area. Most of the Paleogene species collected are limited to particular sites. In particular, the genera *Eponides, Brizalina, Planulina, Bitubulogerina*, *Uvigerina and Lenticulina* are only present and abundant in the boreholes CX387 and AD387**,** characterized by a depositional environment in which planktonic foraminifera are more abundant.

The significant vertical and lateral variations observed in the distribution of facies, and of benthic foraminifera, as well as the variation of the tickness from north to south (north-south profile), could be linked to the impact of fault tectonics occurring during the reworking of the continental margin of the coastal basin of Togo. This tectonic event has transected the basement and its cover assemblage into geodynamic blocks corresponding to a system of horsts and grabens. The latter constitute "microbasins" in which the conditions for sedimentation and for life are different. The boreholes CX387 and AD387 are located in a tectonic depression which, becoming a phosphatic trap [25,26], favoured benthic and planktonic foraminiferal populations. Indeed, mumerous faults (Fig. 2) have been described in this basin [21,42], mainly three major fault groups, oriented east-west, NE-SW and NW-SE. These faults, also identified in others West-African basins [6,8,22,24,28,49,55,56], are related to the Pan African tectonic event [2]. The reactivation of the Pan African paleostress in these basins influenced the conditions of sedimentation and the distribution of microfauna.

4. Conclusions

The lithological and micropaleontological analysis of five boreholes of the investigation area confirms previous stratigraphic results and provides new data to complete the biostratigraphical and paleogeographical sets proposed by Johnson [25,26], in the coastal basin of Togo, for the Maastrichtian to Lower Tertiary period.

As regards lithostratigraphy, correlations between the coastal basins of the Gulf of Benin region have revealed lithostratigraphical markers, especially the glauconitic horizon that made it possible to date a slightly fossiliferous Paleogene in some boreholes. However, this should be confirmed in the future through biostratigraphical studies by the use, for example, of palynomorphs.

The biostratigraphic data, mainly based on foraminifera, enable to characterize some new biozones: G*lobotruncana aegyptiaca* to *Abathomphalus mayaroensis* biozones (Middle to Upper Maastrichtian) and P10 to P11 biozones (Middle Eocene). Furthermore, gaps have been noted in the series, notably in the P1–P4 biozones corresponding to the Lower and Middle Paleocene.

Given the scarcity of marker horizons, the boundaries between biozones are often difficult to establish, and so the boundary between the Paleocene and Eocene is not well defined. This is also true for the upper boundary of the Middle Eocene which appears to be incomplete in the studied area.

The Cretaceous-Cenozoic transition (K/T boundary), well defined in West Africa [34], is studied for the first time here. This latter is crossed by a single borehole (SE), in which Maastrichtian microfauna disappear at the top of the Cretaceous series. Nevertheless, additional studies (lithological, biostratigraphical, sedimentological and geochemisty) would be required to examine the biotic and environmental changes recorded across this K/T transition in the coastal basin of Togo.

The results obtained by the present work throw new light on the marine fluctuations during the Maastrichtian and Paleogene periods in the coastal basin of Togo. The analysis of planktonic and benthic foraminiferal associations and the sediments allow the distinction of two sedimentary cycles which are well known in the

SE (46.20 m) × 100. **5**. *Dentalina cf. alternata* (Cushman); Middle to Upper Maastrichtian; SE (46.20 m) × 100. **6**. *Afrobolivina afra* (Reyment); Middle to Upper Maastrichtian; SE (40.45 m) × 100. **7**. *Brizalina cf. ihuoensis* (Reyment); Eocene; **a**: side view; AD387 (51.41 m) × 160; **b**: side view; AD387 (51.41 m) × 200. **8**. *Uvigerina hourcqi* (Graham, De Klasz & Rérat); Eocene; AD387 (59.68 m) × 200. **9**. *Bitubulogerina circumspinosa* (De Klasz & Rérat); Eocene; **a**: edge view; × 130; **b**: side view; CX387 (11.71; 14; 18 m) × 200. **10.** *Planulina oyae* (Reyment); Eocene; **a**: side view; AD387 (57.40; 59.68 m) × 200; **b**: edge view; AD387 (57.40; 59.68 m) × 200.

Planche 3. **1**. *Pseudohastigerina wilcoxensis* (Cushman & Ponton) ; Yprésien à Eocène moyen ; profil ; DW40 (19,42 m) × 200. **2**. *Pseudohastigerina micra* (Cole) ; Yprésien à Eocène moyen ; **a** : face latérale ; AD387 (47,29 m) × 300 ; **b** : profil ; AD387 (47,29 m) × 440. **3**. *Globigerina eoceana* Gümbel ; Yprésien à Eocène moyen ; face ombilicale ; DW40 (19,42 m) × 320. **4**. *Dentalina basiplanata* (Plummer) ; Maastrichtien moyen à supérieur ; SE (46,20 m) × 100. **5**. *Dentalina cf. alternata* (Cushman) ; Maastrichtien moyen à supérieur ; SE (46,20 m) × 100. **6**. *Afrobolivina afra* (Reyment) ; Maastrichtien moyen à supérieur ; SE (40,45 m) × 100. **7**. *Brizalina cf. ihuoensis* (Reyment) ; Eocène ; **a** : face latérale ; AD387 (51,41 m) × 160 ; **b** : face latérale ; AD387 (51,41 m) × 200. **8**. *Uvigerina hourcqi* (Graham, De Klasz & Rérat) ; Eocène ; AD387 (59,68 m) × 200. **9**. *Bitubulogerina circumspinosa* (De Klasz & Rérat) ; Eocène ; **a** : profil ; × 130 ; **b** : face latérale ; CX387 (11,71 ; 14 ; 18 m) × 200. **10**. *Planulina oyae* (Reyment) ; Eocène ; **a** : face latérale ; AD387 (57,40 ; 59,68 m) × 200 ; **b** : profil ; AD387 (57,40 ; 59,68 m) × 200.

West-African coastal basins, mainly in Senegal, Ivory Coast, Benin and Nigeria [7,9,23,33,39,48]. The first one ended at the top of the Maastrichtian and the second one in the Paleogene. The Paleogene transgression is typified in all the West-African coastal basins by a biochemical sedimentation (limestones, palygorskite shales and phosphates) and similar fossils such as echinoderm fauna (*Togocyamus seefriedi*), and ropy nummulites (*Ranikothalia*). These two transgressions were also recorded in the intracratonic Iullemmeden basin [4,16,29,38]. These marine fluctuations during the Maastrichtian and Paleogene periods prove a linkage between the costal basins and those located within in the heart of the African continent as the Iullemmeden basin (Plates 1–3).

Acknowledgements

We are thankful to Professors Ivan de Klasz, Komlavi F. Seddoh and Jacques Lang for their contribution to the successful completion of this research project. Many thanks to Roland Trompette, Yves Bellion, Thibault de Garidel and an unknown reviewer who improved the final version of our paper.

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