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Microfaunistic and biostratigraphic study of the Ypresian (Early Eocene) - Lutetian (middle Eocene) deposits in the Eocene of the Mkarcha section (EM) in the eastern external Rif (MOROCCO): paleoenvironmental implications

K. L. DJEYA[1]*, K. K. K. TOE-BI [2], C. L. KOFFI [3], N. J.-P. YAO [1] A. TOUFIQ[4], M. OUAD[4], Z. B. DIGBEHI[1]

1. Department of Marine Geosciences, UFR of Earth Sciences and Mining Resources, University Felix Houphouet Boigny, 22, P.O. Box 582 Abidjan 22, Cote d'Ivoire.

2 Department Geosciences, UFR of Biological Sciences, University Pelefero Gon Coulibaly of Korhogo, Box 1328, Korhogo.

3 Department of Mines and Reservoirs, UFR of Geological and Mining Sciences University of Man, Cote d'Ivoire, Box 20, Man.

4. Laboratory of Environment Geosciences and Techniques, Department of Geology, Faculty of Sciences, University Chouaïb Doukkali, Box 20, 24000 El Jadida, Morocco.

**Corresponding author, Email address: djeyabli@gmail.com*

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**Corresponding author, Email address: djeyabli@gmail.com*

Phone: +(225)0707564239

Abstract

The Mkarcha section (EM) studied outcrops in the pelagic deposits of the outer Rif. The objective of this work it is biostratigraphic and paleoecological reconstruction of the deposits at the Eocene Ypresian- Lutetian transition from the microfauna. To do this, 31 samples were collected from the outcrop of the Mkarcha section (pelagic deposits of the Outer Rif) at the Eocene Ypresian-Lutetian transition in the pelagic deposits of the Moroccan Outer Rif (South of the Tsouls unit). The sorting of this section revealed the presence of about 10098 individuals distributed in a majority of planktonic forms estimated at 7929 individuals or 78.52 %, 2036 calcareous benthic foraminifera or 20.16 % and 133 benthic agglutinated foraminifera or 1.32 %. This set of foraminifera is associated with ostracods (32 individuals) and rare shark teeth (3 specimens). Ypresian-Lutetian transition is recognized by associations of planktonic foraminifera characteristic of the Early and Middle Basal Eocene materialized within the E-zones. Ypresian is characterized by the *A. pentacamerata* and *A. camerata* zones, while Lutetian is marked by the *G. muttali* zone. These foraminifera were identified and used for dating the formations in the section. Paleocological reconstruction of the seafloor was performed based on the presence of the foraminifera and sedimentological data allowed us to consider that the depositional environment experienced a transgression because the depositional environments of the sediments are from the middle to the outer platform.

1. Introduction

Several studies on stratigraphy, micropalaeontology, palynology and geochemistry have been conducted in many regions of the world, in order to determine the causes of major climatic changes that mark the Paleogene system, such as the Lower Eocene climatic optimum, or EECO (52- 50 Ma) [1, 2]. At the level of Morocco, the Cenozoic and more particularly the Paleogene has been studied by several authors who contributed to a division of this interval [3, 4]. Thus, they have shown that the Eocene was the seat of significant thermal variations [1, 5]. In addition, the Danian extensional biozones have been highlighted in the Moroccan Rif [3]. Despite all these important investigations, several stages remain poorly defined [6]. The main objective of the present study is to characterize the Early Eocene (Late Ypresian) - Middle Eocene (Early Lutetian) transition through the lithological section carried out. It consists in establishing the lithology of the formations crossed by the section. Secondly, it will allow to define the characteristics of the transition from the Early Eocene to the Middle-late Eocene as well as the paleoecology of the study area.

2. Geological framework of the study area

2.1 Geological context

The rif is the western termination of an alpine chain from the Tethys (Figure 1). It is part of a Betico-Rifo-Tellian structural ensemble, around the western Mediterranean, which connects to the Apennines through Sicily [7]. The structure of the Betic-Rifine arc corresponds to a stacking of nappes characterized by divergent outward discharges from the Rif and the Betic Cordilleras [8]. In the northern part of Morocco, the Rif domain contrasts with the other Moroccan geological domains by its structural history in a Mediterranean setting. The Rifan chain is the result of a complex tectonic process, the scenario of which has been the subject of numerous studies [9-14]. The structure of this region indicates large elements distributed in superimposed thrust sheets, resulting from overthrow by recent tectonic movements. The large units form concentric structural zones on the map, which are particularly homologous between the Rifan Range in Morocco and the Cordillera Betica in Spain. Longitudinally, these zones are discontinuous and curved; they are generally distinguished by their different geomorphological characteristics [15]. The frontal overlap of the Prérif on the autochthonous is clearly marked, both geomorphologically and stratigraphically. In the south, the foreland comprises a series (Atlasian) not exceeding the Jurassic and covered by a transgressive Upper Miocene. The stratigraphic and structural details of the autochtonous Prerif contact have been described by [16]. The structure of the Betic- Rib arc corresponds to a stack of nappes characterized by divergent outward discharges of the Rif and Betic cordilleras [8] (Figure. 1A).

2.2 Study area

This section is located on the 1/50000 geological map of Bab El Mrouj-Taza North, in the southern part of the Tsoul unit (upper pre-terranean unit) precisely in the locality of Mkarcha. The section is accessible about 20 Km from Taza, by a track thet runs along the depression on the southern edge of the first reliefs of the Tsoul unit (Figure. 1B).

3. Material and Methods

The 31 samples used in this work come from a section taken from the outcrop in the south of the Tsoul unit (upper pre-rifain unit) precisely in the locality of Mkarcha. Their analysis focused on the mricropalaeontological study coupled with a paleoecological study. After an attack with peroxide (hydrogen peroxide), the cuttings were washed (a column of 3 sieves; 200 µm, 125 µm and 63 µm) and dried in an oven then bagged. With the help of a mounted needle and a binocular magnifying glass, the foraminifera are sorted. The determination of genera and species is done by comparing the criteria described on the forms with those known in the bibliography [18-21]. It allowed to perform a point count of the microfossil shapes. Biostratigraphic interpretations are based on new biozonations of planktonic foraminifera (E and O zones) [22-23].

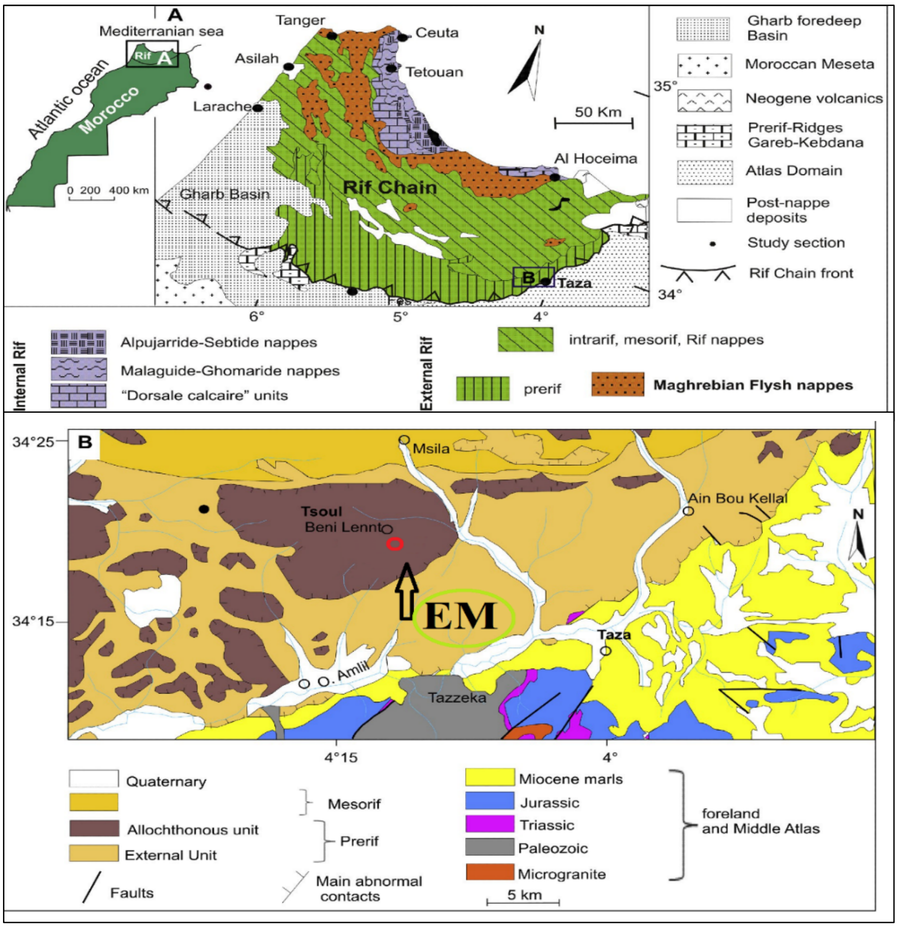

Figure.1 A. Location map of the Mkarcha section **B**. Simplified structural map of the Rifaine chain (Guedé *et al.;* 2014)

4. Results and interpretation

4.1 Lithology of the Mkarcha section (EM)

This section includes from bottom to top three (3) units (Figure. 2) which are:

- Unit E1 (EM 31- EM 15)

This unit which constitutes the basal part of the section, is a succession from bottom to top of calcareous marly sediments of decimetric thickness at the base, in the middle of less thick marl and at the top of marl-limestone of metric thickness.

- Unit E2 (EM 15-EM7)

In this unit, we note a sandstone bed with marly passages. Pyrite with medium to coarse, white, translucent and rounded, sub-rounded to sub-angular quartz grains are incidentally noted.

- Unit E3 (EM7-EM1)

It constitutes the summit part of the section composed of a succession of marly- limestone sediments of decametric thickness at the base, of less thick marl in the center and at the top of marly limestone of metric thickness.

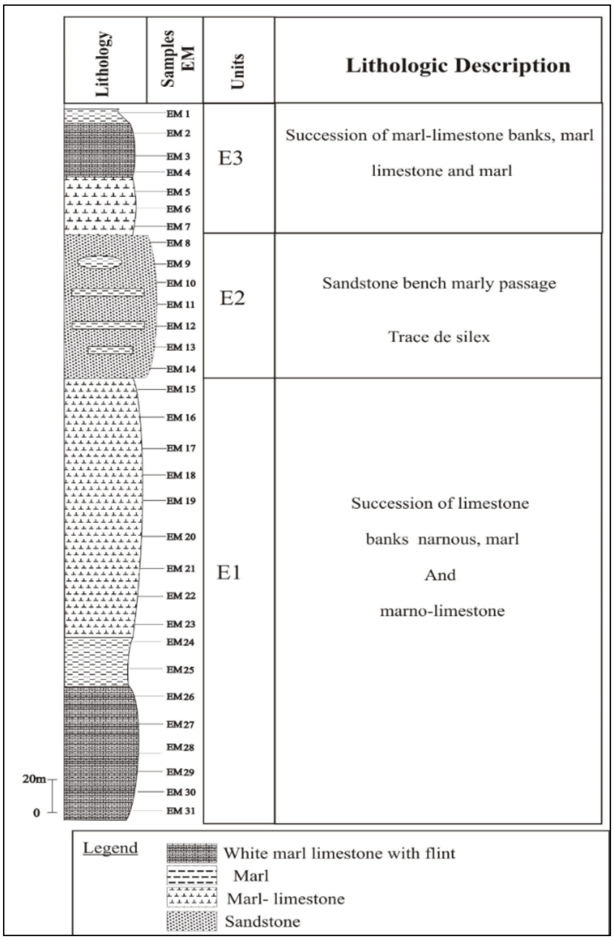

Figure 2. Lithology and calcimerics of the Mkarcha section (EM)

4.2 Biostratigraphy

The microfauna is about 10098 individuals distributed in a majority of planktonic forms estimated at 7929 individuals (or 78.52%), then comes a population of calcareous benthic foraminifera with 2036 individuals representing 20.16 % and finally by those of agglutinated benthic foraminifera with 133 individuals or about 1.32 %. This group of foraminifera is associated with ostracods (32 individuals) and rare shark teeth (3 specimens).

4.2.1 Planktonic foraminifera

Planktonic foraminifera represent 78.52 % of the total population of foraminifera and are divided into 18 genera and 107 species (Figure. 3).

4.2.2 Benthic foraminifera

Benthic foraminifera have an estimated population of 2169 individuals, or 21.48% of the total population of foraminifera (Fig 3), represented as follows:

- 133 agglutinated benthic foraminifera or 1.38% of the foraminifera,
- 2036 calcareous benthic foraminifera or 20.16% of the foraminifera, recorded.

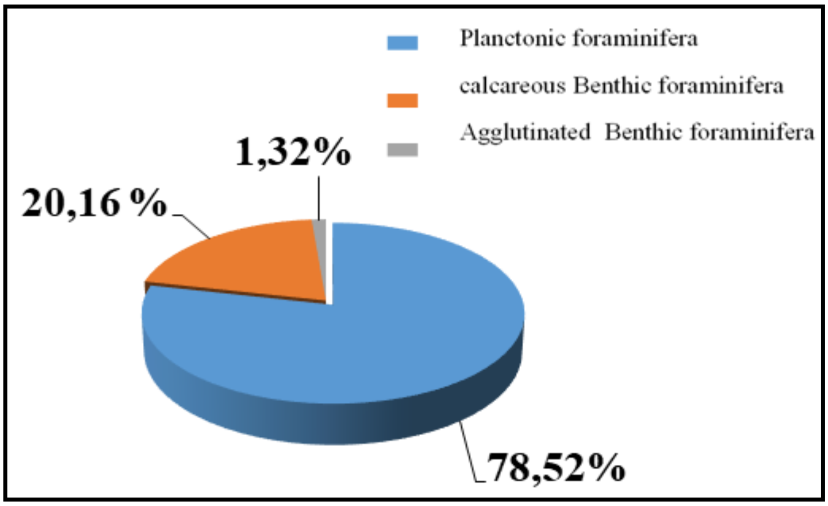

Figure 3. Sectoral representation of planktonic and benthic foraminifera in the EM section

4.3 Stages in the EM section

In this Mkarcha section (EM), the stratigraphic distribution of the main species of planktonic foraminifera encountered reveals two stages (Figure. 4): the Lower Eocene and the Middle Eocene.

4.3.1 Lower Eocene-Middle Eocene boundary

The transition between the Lower Eocene and Middle Eocene in this section (EM) is located at EM 15. This transition is identified by the disappearances (genera *Acarinina* and *Morozovella*) and appearances (genera *Hantkenina* and *Globigerinatheka*) as well as their species. The first appearance of the species *Hantkenina liebusi* (characteristic form of the Middle Eocene) at the EM 15 level allowed the recognition of the Middle Eocene wall. This presence also allows us to define the roof of the Lower Eocene.

- In the Early Eocene, we find the association of the species *Acarinina quetra*, *A. asnaensis, A. esnehensis, A. cf. angulosa, A. soldadoensis, A.* pseudotopilensis, *Morozovella caucasica, M. lensiformis, M. subbotinae*. In fact these species begin their disappearance progressively from the base of this stage to the summit part. They are for the most part genera *Acarinina* and *Morozovella.* This disappearance of the two genera in this interval of the section confirms the Lower Eocene. Therefore the top of this interval is indicated by the appearance of the species *Hantkenina liebusi* at EM 15.
- In the Middle Eocene we have the appearance of new specific genera. These are the genera *Hantkenina, Globigerinatheka* and *Turborotalia* associated with some Morozovella and *Acarinina* whose reigns have persisted until this level. The characteristic association of this interval is composed of the species, *Globigerinatheka subconglobata*, G. index, *Acarinina primitiva*, *A. bullbrooki*, *A. topilensis, Hantkenina dumblei, H. liebusi, Turborotalia boweri, T. pomeroli T. passagnoensis, Morozovelle crassata, M. lehneri.* The early Lutetian is the only sub-stage determined in the interval.

4.3.2 Biozonations

The vertical extension of the index species allows us to recognize five (5) biozone (E 5 to E 9) in the whole of these two stages (Lower Eocene and Middle Eocene). Among them, the biozones *Morozovella aragonensis/M. subbotinae*, *Acarinina pentacamerata*, *A. cuneicamerata* have been recognized in the Lower Eocene while the biozones *Guemberlitrioides nuttalli*, *Globigerinatheka kugleri*/ *Morozovella aragonensis* correspond to the Middle Eocene.

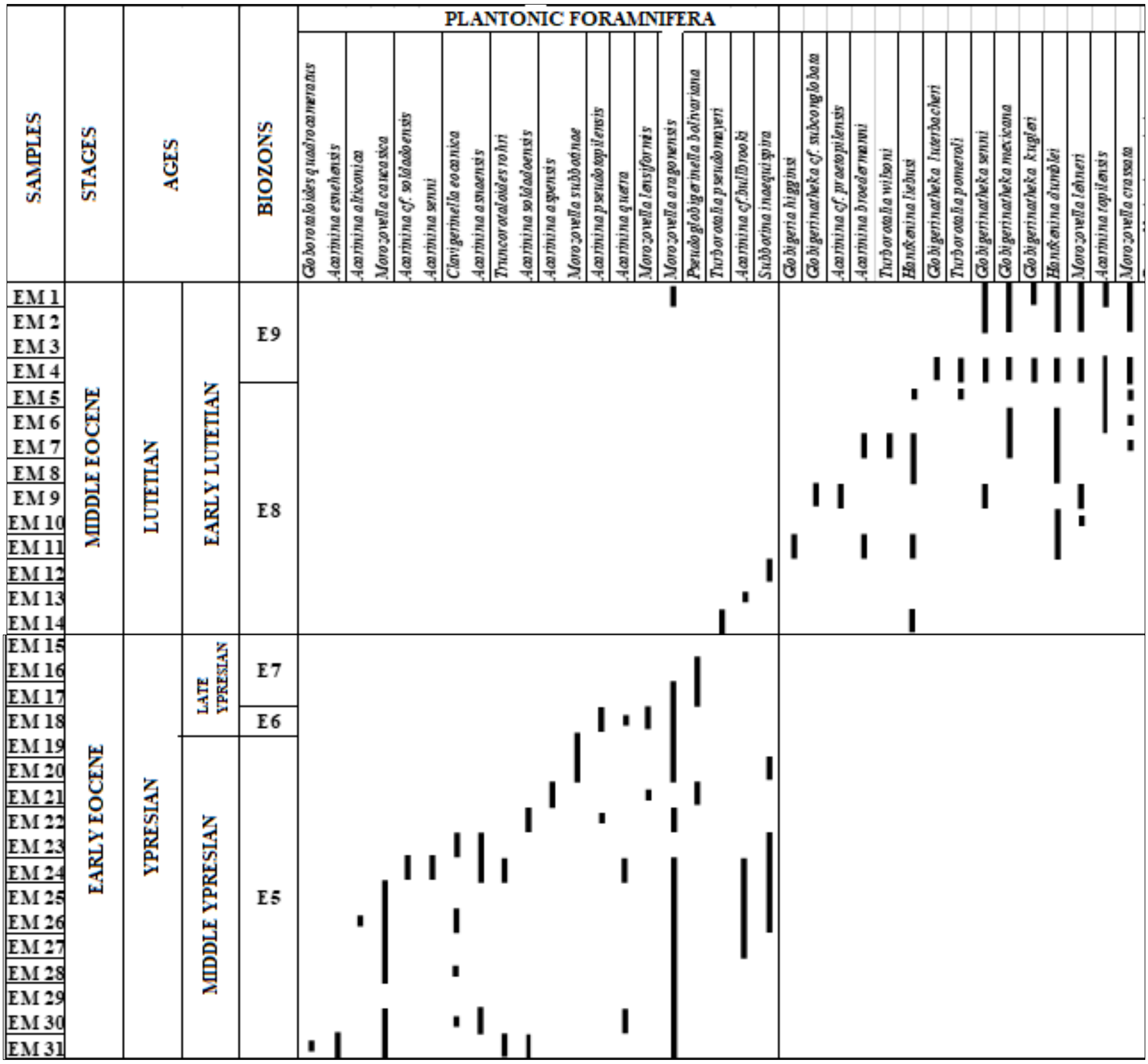

Figure 4. **Vertical distribution of foraminifera in the EM section**

4.3.3.1 Morozovella aragonensis / Morozovella subbotinae Zone (E5)

The *Morozovella aragonensis*/ *Morozovella subbotinae* zone is included in the EM31-EM19 interval and is more than 250 m long, respresenting almost half of the EM section. It is composed of marly limestones, marlstones and marly limestones. The first appearance of the *Morozovella aragonensis* species at EM 31 allows to fix the wall of the zone. As for its roof; it is the disappearance of the species *Morozovella subbotinae* at EM 19 that allows us to characterize it.

4.3.3.2 Zone with Acarinina pentacamerata (E6)

This zone is included between the last appearance of *Morozovelle subbotinae* at EM 19 and the first appearance of *A. cuneicamerata* at EM 18. Also the first appearance of *Morozovella lensiformis* allows to confirm the wall of the zone.

4.3.3.3 Zone with Acarinina cuneicamerata (E7)

In the absence of the index species (*Guembilitrioides nuttalli*), which allows the roof of the *Acarinima cuneicamarata* zone to be characterized, the first appaearance of *Hantkenina liebusi* at EM 15 allows the roof of this zone to be recognized, as well as the transition between the Lower and Middle Eocene. The roof of the zone (E7) coincides whith the beginning of the almost simultaneous disappearance of several species with keeled and spiny morphologies.

4.3.3.4 Zone with Guembelitrioides nuttalli (E8)

The roof of the *Guembelitrioides nuttalli* zone is situated at the level of EM 5 with the appearance of the species *Globigerinatheka kugleri*. This zone marks the base of the Middle Eocene and is about 150m thick. The species that make their first appearance (*Turborotalia* and *Globigerinatheka*).

4.3.3.5 Globigerinatheka kugleri / Morozovella aragonensis zone (E9).

The *Globigerinatheka kugleri*/ *Morozovella aragonensis* zone is identified at the base of the EM 4-EM1 interval by the first appearance of *Globigerinatheka kugleri*. Indeed, the last appearance of *Morozovella aragonensis* makes it possible to recognize its roof wich coincides with the end of the section. This zone is more specifically attributed to the Lower Lutetian.

5. Paleoenvironment of the EM section

5.1. Lower Eocene interval

The stage contains calcareous- marl sediments, marl, and marl-limestone. This sedimentation characterizes a medium depth deposittional environment. This depth provides the conditions for the deposition of carbonate-dominated sediments. The energy of deposition is low. The pelagic index, which ranges from 70 to 90%, argues for a medium depth depositional environment (Figure. 5). These interpretations are corroborated in this area by a population of robust, keeled test faunas that thrive in deep marine environments. Planktonic foraminifera are rich and very diverse with 17 genera (Figure 4). Throughout the section, the genera *Acarinina* and *Subbotina*e dominate. In addition, in this interval (Lower Eocene) the genera *Morozovella* and *Acarinina* (Fig. 4) are the most dominant and allow us to consider a mid- shelf deposit.

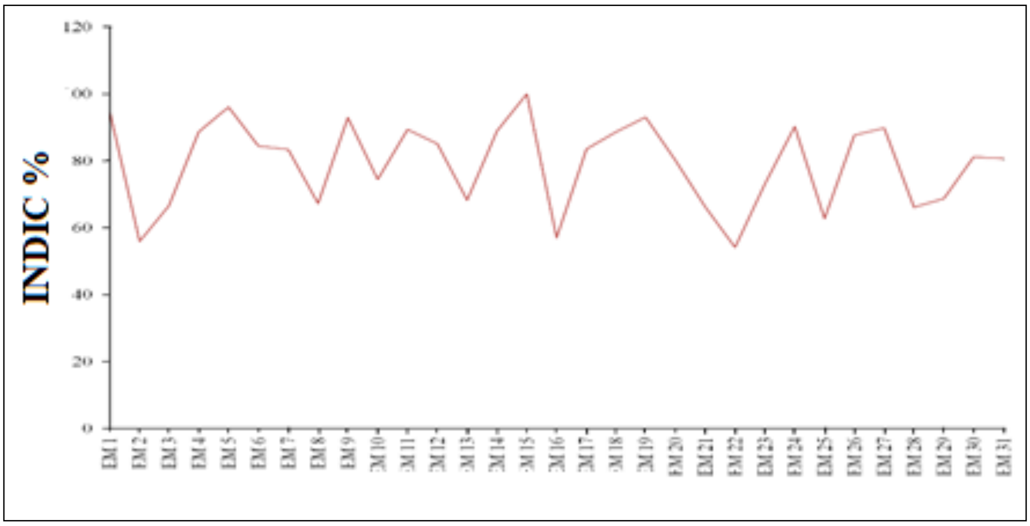

Figure 5. Pelagic Indic of Mkarcha section (EM)

5.2 Middle Eocene interval

This interval is composed of marl and limestone banks, marly limestone and marl associated with a sandstone bank. These deposits logically evoke a medium deep and calm environment. However, the presence of sandstone banks suggests an evolution of the energy level from a calm environment to an agitated environment. Moreover, the arguments in favor of a deep environment are gathered. This is supported firstly by the pelagic index which has a value of 81% (Figure. 5). Secondly, by the diversification in quality and quantity of the pelagic microfauna, a sign of a rise in the water level. All the data reflect an open marine depositional environment of the external platform type. Ultimately, the depositional environments of the Mkarcha section (EM) sediments vary from the middle to the outer shelf. The depositional environment has undregone transgression.

6. Discussion

6.1 Lithology

The lithological synthesis of the studies sections reveals sedimentation is dominated by carbonate deposits. However, we note some low levels of carbonates at some levels of the cuts suggesting an agitated environment, unfavorable conditions for limestone deposition [24, 25, 26]. These conditions would rather be favorable to detrital deposits as observed in the present work. These carbonate deposits are generally carried out under conditions of calm sedimentation under a fairly significant depth. They correspond to a marine transition phase where the low supply of detrital sediments favors carbonate sedimentation [27, 28]. For [29]. The limestones, in the outer platform domain testify to deep sedimentation.

6.2 Biostratigraphy

In the Lower Eocene the microfauna is rich and diverse dominated by individuals of the genera *Acarrina* and *Morozovelle* mainly [26]. This association is recognized in part similar in the Early

Eocene, in the Touijine section in Central-Northern Tunisia by [30]. In the Ivorian Basin precisely on the San-Pedro margin (at Fresco) [31]. Highlights the undifferentiated Early Eocene in Cliff 1 and Borehole 1 of Fresco. He determines the Ypresian age from the species *Acarinina primitiva*, *Morozovella acuta, Planorotalites chapmani, Subbotina velascoensis, Globigerina Gr. eocaena including Morozovella aequa, M. subbotinae* which were identified as in the present work. Furthermore [32]. Also identifies the Lower Eocene in Egypt in the northern Sinai, highlighting five (5) biozones in the Lower Eocene (Ypresian). The author established an equivalence with the biostratigraphic scale of [33]. Which served us in the establishment of our biozones defined from only the zone with Morozovella formosa (P6) (E4) to the zone with, *Acarinina pentacamerata* (P8) (E6). It is therefore only the *Morozovella formosa* (P6) (E4) biozone that is comparable to the work of [32]. In addition, the species described in the Sanai in Egypt were recognized in the present study, notably *Morozovella eaqua, Acarinna soldadoensis, Acarinna angulosa, Igorina broedermanni, Morozovella caucassica Acarinina pentacamerata.* The present results are to be compared with those of [34]. On the stratigraphic scales established in the Caribbean, those of [35]. In Libya, **[36]**, Egypt, tropical and subtropical regions by [37], those of [38, 39], generalized scales of [19, 33, 40, 32] performed in Egypt. The upper limit of the Middle Eocene coincides with the extinction of spiny planktonic foraminifera **[41, 6]**. In contrast, the wall experiences new appearances. Two new genera make their appearance at the beginning of the Middle Eocene precisely in the Lower Lutetian. These are the genera *Turborotalia*, and *Globigerinatheka*. For **[42]**. The two forms are typical of cold zones **[43]**. In his work in the subantarctic domain considers the association of the middle Eocene to be an association of temperate climate affinity. These forms thus appeared at the base of the Lutetian in answer to the drop in temperature. According to **[42]** and **[44]** , the Middle Eocene is also known to be the site of extinction of most of the spiny and keeled forms consisting of the genera *Morozovella* and *Acarinina*, including the disappearance of *Acarinina bullbrooki,* which characterizes the Middle Eocene roof.

Conclusion

The synthesis of lithological and biostratigraphic data has made it possible to reconstruct the environments that evolved from the inner to the middle platform (Lower Eocene), from the middle to the outer platform (Middle Eocene). For the Upper Eocene it is of external platform.

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ANNEXE

PLATE 1. Early Eocene

1: *Acarinina soldadoensis* (Bronnimann, 1952) (Early Eocene)

1-a: spiral view- Mkarcha section EM, 23

1-b: detail of a x1500

2 : *Acarinina aspensis* (Colom, 1954) (Early Eocene)

5: Mkarcha section EM, 23

3-: *Acarinina cuneicamerata* (Blow, 1979), (Early Eocene)

3-a: Mkarcha section EM, 22

3-b: detail of section x1500

4-: *Acarinina pentacamerata* (Subbotina, 1947), (Early Eocene), Mkarcha section EM 9

5-: *Morozovella aragonensis* (Nuttall, 1930), (Early Eocene)

5a: Mkarcha section, EM 23

5b: Mkarcha section, EM 30

6-: *Morozovella caucasica* (Glaessner, 1937), (Early Eocene)

6-a: coupe Mkarcha, EM 31

6-b detail of a (carène) x 900

7- : *Morozovella lensiformis* (Subbotina, 1953), Mkarcha section, EM 23, (Early Eocene)

8- : *Parasubbotina inaequispira* (Subbotina, 1953), 11: Mkarcha section, EM 23, (Early Eocene)

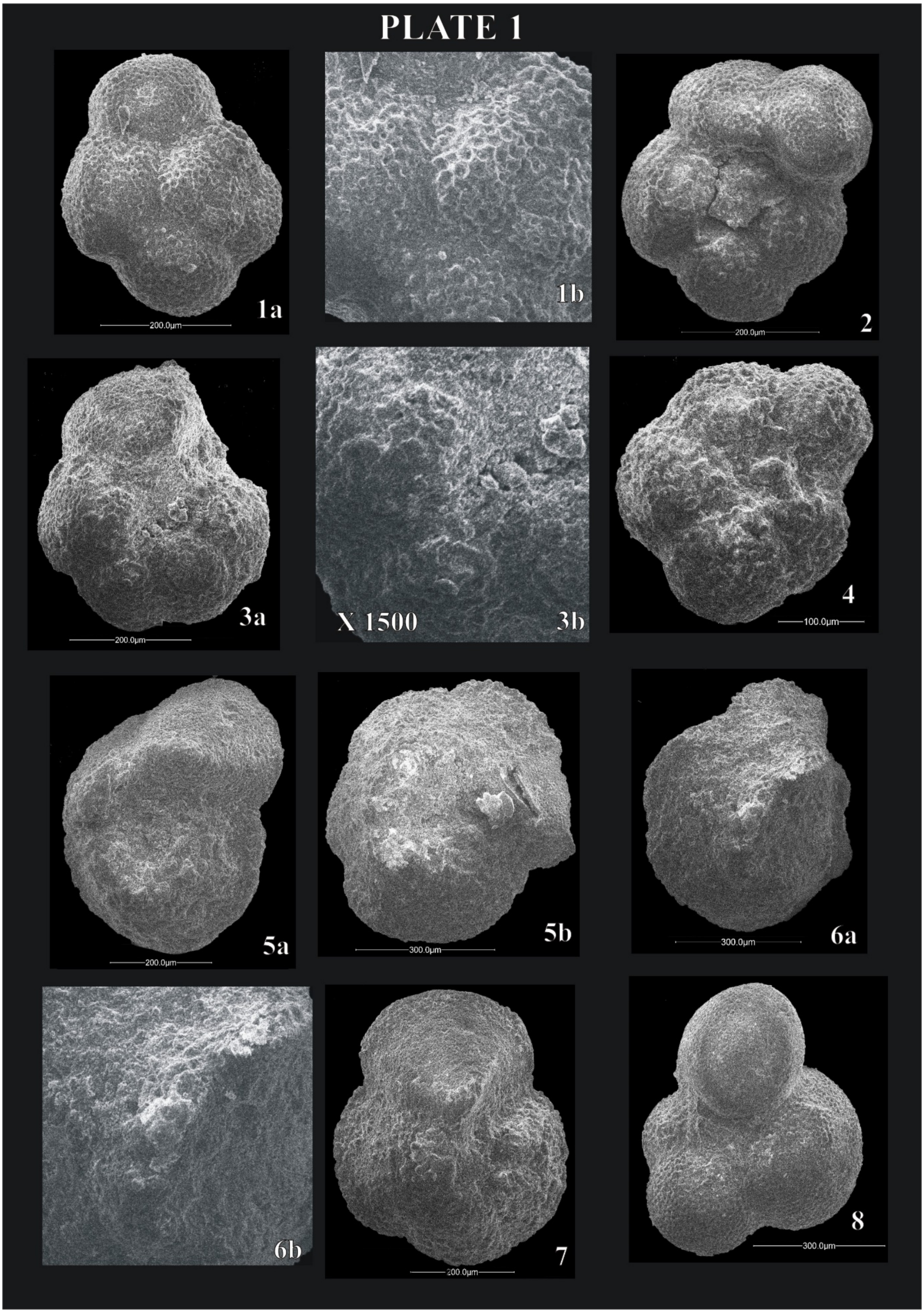
PLATE 1
1a
200.0µm
1b
2
200.0µm
3a
200.0µm
X 1500
3b
4
100.0µm
5a
200.0µm
5b
300.0µm
6a
300.0µm
6b
7
200.0µm
8
300.0µm

PLATE 2. Middle Eocene

1-*Acarinina broedermanni* (Cushman and Bermùdez, 1949), Mkarcha section, EM 23, (Middle Eocene)
2--: *Acarinina bullbrooki* (Bolli, 1957), (Middle Eocene)
2 a-b : Mkarcha section, EM 24
3-*Clavigerinella eocanica* (Nutall, 1928) , Mkarcha section, EM17 (Eocène moyen)
4-: *Globigerinatheka kulgeri* (Bolli, Loeblich & Tappan, 1957), Mkarcha section (EM5), (Middle Eocene)
5-*Hantkenina dumbei* (Weinzierl and Applin, 1929), (Middle Eocene)
5-a : Mkarcha section, EM 4
5-b : Mkarcha section, EM 1
5-c: Mkarcha section, EM 6
6-: *Parasubbotina eoclava* (Coxall, Huber and Pearson, 2003), Mkarcha section, EM21 (Middle Eocene)
7: *Hantkenina liebusi* (Shakhoina, 1937), (Middle Eocene), Mkarcha section, EM 5
8-: *Pseudoglobigerinella bolivariana* (Petters, 1954 Mkarcha section, EM21
(Middle Eocene)
9- *Turborotalia cf. pomeroli,* (Tourmakine et Bolli, 1970) Mkarcha section, EM31 (Middle Eocene)

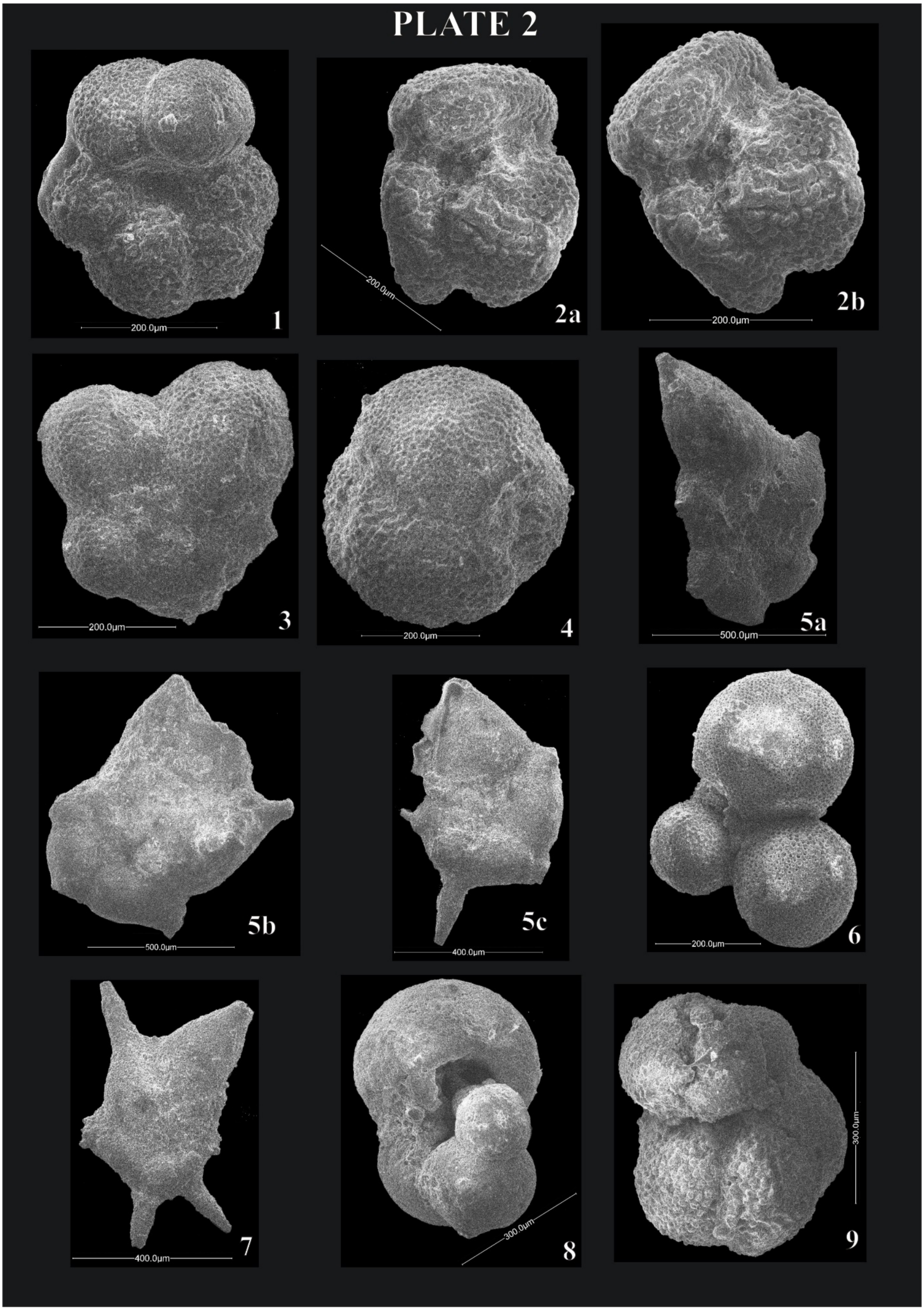
PLATE 2
200.0µm
1
200.0µm
2a
200.0µm
2b
200.0µm
3
200.0µm
4
500.0µm
5a
500.0µm
5b
400.0µm
5c
200.0µm
6
400.0µm
7
300.0µm
8
300.0µm
9

PLATE 3. Middle Eocene (Follows)

1-: *Subbotina corpulenta* (subbotina, 1953) (Middle Eocene)

1a: Mkarcha section, EM 11

1-b: Mkarcha section IH 21

2- *Subbotina eoceana* (Guembel, 1868) (Middle Eocene)

2-a: Mkarcha section, EM23

2-b: Mkarcha section, EM 6

3: *Subbotina hagni* (Gohrbandt, 1967) Mkarcha section EM5, (Middle Eocene)

4: *Turborotalia frontosa* (subbotina, 1953), (Middle Eocene): Mkarcha section EM 17