

***Laffitteina* from the Maastrichtian-Thanetian shallow marine carbonates of the Aurès Basin (Northeastern Algeria): microfacies and stratigraphic distribution**

***Laffitteina* de los carbonatos marinos someros del Maastrichtiano-Thanetiano de la cuenca de Aurès (noreste de Argelia): distribución de microfacies y estratigráfica**

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ABSTRACT

The Maastrichtian-Thanetian Ncham Member of the Aurès Basin in northeastern Algeria contains variably lenticular microfossils, which are defined as *Laffitteina* genera. It is a large benthic foraminifera, studied from three stratigraphic sections. The systematic study of *Laffitteina* led identification of nine species, four of which, *Laffitteina marsicana*, *L. aff. mengaudi*, *L. monodi* and *L. erki* were recorded for the first time in the study area. Various species of *Laffitteina* were used as index fossils to recognize the K/Pg transition in the Aurès Basin. The last occurrence of *L. oztuerki* marks the end of the Maastrichtian, which was found in association with *Omphalocyclus macroporus* (Lamarck) in the upper Maastrichtian. The first occurrence of *L. erki* marks the Thanetian age, while the Danian and Selandian deposits are missing in the field after a general emersion in the early Paleocene, despite the absence of a visible non unconformity. It could therefore be proposed that the K/Pg transition may occur in the last 10 m of the Ncham Member. Concerning the paleoenvironment, *Laffitteina* is considered as a resistant foraminifera and thrives in meso- to eutrophic environments (lagoon). Microfacies data from the Upper Cretaceous-Lower Paleogene limestones of the Aurès Basin suggests a carbonate platform with shallowing-up sequential organization, mainly controlled by fluctuations in sea-level.

Keywords: *Laffitteina*, benthic foraminifera, Paleoenvironment, Aurès, Algeria.

RESUMEN

El Miembro Ncham del Maastrichtiano-Thanetiano de la cuenca de Aurès, en el noreste de Argelia, contiene especímenes variablemente lenticulares, que se definen como del género *Laffitteina*. Se trata de un gran foraminífero bentónico, estudiado a partir de tres secciones estratigráficas. El estudio sistemático de *Laffitteina* permitió identificar nueve especies, cuatro de las cuales, *Laffitteina marsicana*, *L. aff. mengaudi*, *L. monodi* y *L. erki*, se registraron por primera vez en la zona de estudio. Se utilizaron varias especies de *Laffitteina* como fósiles índice para reconocer la transición K/Pg en la cuenca de Aurès. La última aparición de *L. oztuerki* marca el final del Maastrichtiano, que se encontró en asociación con *Omphalocyclus macroporus* (Lamarck) en el Maastrichtiano superior. La primera aparición de *L. erki* marca la edad del Thanetiense, mientras que los depósitos del Daniano y del Selandiano faltan en el campo tras una emersión general en el Paleoceno temprano, a pesar de la ausencia de un hiato evidente. Por lo tanto, se podría proponer que la transición K/Pg se produce en los últimos 10 m del Miembro Ncham. En cuanto al paleoambiente, *Laffitteina* se considera un foraminífero resistente y prospera en ambientes de meso a eutróficos (laguna). Los datos de microfacies de las calizas del Cretácico Superior-Paleógeno Inferior de la cuenca de Aurès sugieren una plataforma carbonatada con una organización secuencial ascendente, controlada principalmente por las fluctuaciones del nivel del mar.

Palabras clave: *Laffitteina*, foraminíferos bentónicos, Paleambiente, Aurès, Argelia.

1. Introduction

The Late Cretaceous is one of the most significant periods in the geological history of the Earth planet, considering its end with the famous mass extinction of many genera and species of animals [Alvarez *et al.* (1980), Raup *et al.* (1982), Molina *et al.* (1996), Bambach *et al.* (2006), Schulte *et al.* (2010), Keller *et al.* (2010), Archibald *et al.* (2010), Longrich *et al.* (2011), Mc Ghee *et al.* (2013), Brusatte *et al.* (2015), James *et al.* (2016)]. The Aurès Basin in the Eastern Saharan Atlas is one of the most intriguing regions of northeastern Algeria. It includes major structural and tectonic events that have affected the region. As a result of this tectonic activity, the stratigraphic sequence records a greater complexity of facies changes and fluctuations in microfaunal contents (foraminifera in particular) that also reveal changes in the depositional environment.

In this work, which is based on data obtained in 2016 (Benmansour, 2016) and already partly published (Benmansour *et al.*, 2017) - where the authors explain how they defined the boundaries of the stages and sub-stages- we focused on the genus *Laffitteina* in Maastrichtian-Thanetian deposits. This genus was established in 1945 by Marie based on material from the Montian of France. The test of this genus is lenticular with a diameter of 3 mm and a thickness of 1 mm (Blanc, 1975). The members of this taxa have in common a single foramen, slit-shaped, straight, and areal, extending from a ventral interiomarginal position in an oblique direction into the dorsal parts of the septal face. They exhibit no foliar chamberlets but a plate of which the nature and its relation to the areal foramen is unclear (Hottinger, 2014).

Laffitteina is one of the few groups of larger, complex foraminifera surviving the Cretaceous–Cenozoic boundary event in shallow water (Billman *et al.*, 1980). It is widely present in the Maastrichtian from the Pyrenean Basin to the Middle East platforms (Consorti *et al.*, 2018). It occurs also in the Paleocene of the Middle East (Rahaghi, 1992; Inan *et al.*, 2004) where its stratigraphic distribution through the Cretaceous and Paleocene carbonates

is practically continuous (Hottinger 2014, in Consorti *et al.*, 2018).

According to Billman *et al.* (1980) and Hottinger (2014), *Laffitteina* thrive in meso- to eutrophic environments. The latest Maastrichtian–Danian low-stand phase [(Hallam and Wignall, 1999; Alegret *et al.*, 2001; Habib and Saeedi, 2007; Haq, 2014)] may have increased the tropism in shallow seas through the establishment of “pools” restricted in water circulation on shelves. This would provide environment for some resistant foraminifera represented by *Laffitteina*, *Elazigina*, and probably *Palaeoelphidium* (Consorti *et al.*, 2018). Belkhouja *et al.*, (2004) are also mentioned that the dominance of the *Laffitteina* implies the installation of lagoon setting with decreased salinity (up to 30 ‰).

In Algeria, the genus *Laffitteina* was first reported by Drooger (1952) by only two species: *L. bibensis* and *L. conica*. Subsequently, six species were recognized at least in the outcrop of El Kantara, western Aurès (Belkhouja and Bignot, 2004), namely: *L. boluensis* (Dizer, 1957); *L. conica* (Drooger, 1952); *L. mengaudi* (Astre, 1923); *L. cf. monodi* (Marie, 1946); *L. oeztuerki* (Inan, 1995) and *L. bibensis* (Marie, 1946).

The purpose of this paper is to describe the microfacies and assemblages of *Laffitteina* from the shallow marine carbonate of the Maastrichtian-Thanetian of the Aurès Basin and to establish deposits conditions at the K–Pg boundary.

2. Geological setting

The Upper Cretaceous - Paleocene sedimentary rocks are well exposed in the Aurès basin in the eastern part of the Saharan Atlas (northeastern Algeria) (Figure 1A). The Aurès has previously been mapped by Laffitte (1939), stratigraphically, sedimentologically and structurally studied by Dubourdieu (1956), Bertraneu (1955), Cruys (1955), Emberger (1960), Guiraud (1973, 1974, 1975), Vila (1980), Bureau (1986), Kazi Tani (1986), Aissaoui (1985), Ghandriche (1991), Addoum (1995) and Herkat (1999).

The succession, named by Benmansour *et al.* (2017) Ncham Member, belongs to be upper Campanian-Maastrichtian and Thanetian.

The Aurès Basin is characterized by a system of tilted blocks bordered by NW-SE to WNW-ESE-trending faults Guiraud (1973, 1990), Bellion *et al.* (1973), Vila(1980), Bureau (1986) et Kazi Tani (1986). Otherwise, NE-SW faults located

within the basin are characterized by transtensional movements. During the late Maastrichtian-Paleocene, the structural evolution in the Aurès Basin led to the development of slumps with slip parallel to the dip of the structure limbs, as seen in the upper Maastrichtian formations of the Tebessa Mountains (Herkat, 1999). Also, progressive unconformities of Paleogene on top of the

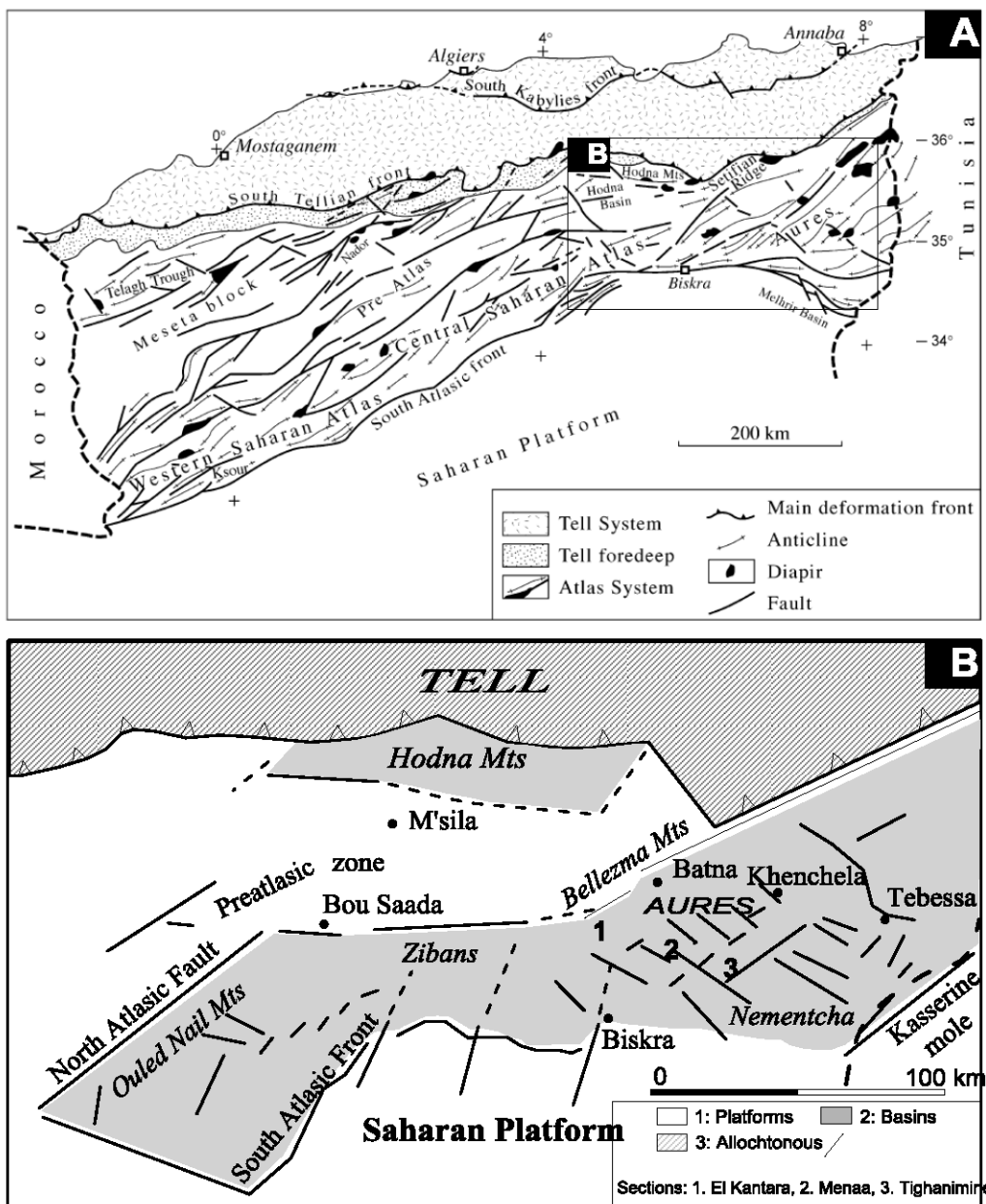


Figure 1 A. Main structural domains of northern Algeria and location of the studied area in the eastern part (modified from Michard *et al.*, 2008). B. Paleoenvironments of the Eastern Atlasic Domain (Herkat & Guiraud, 2006) and location of the sections, from West to East: El Kantara, Mena, and Tighanimine.

Maastrichtian are developed on the southern flank of the Djebel El Azreg anticline. These features suggest the onset of folding in the Aurès' anticlines at the end of the Cretaceous (Herakat *et al.*, 2006). A Palaeocene sedimentary break is observed at Djebel Azreg, in the central zone of the Aurès Massif, that the Eocene sediments unconformably overlying the Maastrichtian, whereas farther west this stage is recognized at Djebel Metlili, in the northern part of the Ziban range (Belkhodja and Bignot, 2004).

3. Materials and Methods

In this study, we use the same lithostratigraphic nomenclature adopted by Benmansour (2016) and Benmansour *et al.*, (2017) for the upper portion of the Upper Cretaceous-Lower Paleogene deposits of the Aurès Basin that constitute the Abiod Formation. The Ncham Member, representing the Maastrichtian-lower Thanetian limestones rocks (the upper part of the Abiod Formation), are sampled from three localities (Figure 1B) in the western Aurès (El Kantara section: GPS : 35°13'57" N and 5°42'6,93" E, with a thickness of 450 m), and the central Aurès, on both sides of Djebel El Azreg (Mena section: GPS : 35°11'08.44" N and 5°59'042,00" E, with a thickness of 200 m and Tighanimine: GPS : 35°9'30,19" N and 6°14'29,03" E, with a thickness of 300 m). A total of 232 thin sections were prepared from samples of hard limestones that collected from the localities described above using a monocular polarizing microscope, in order to describe microfacies and study the populations of *Laffiteina* in random sections. The number and kinds of samples depend on the geological settings (outcrop conditions, sampling units indicated by types and thickness of bedding and bed by bed sampling was conducted several times, if lithological changes were observed within the bed). Carbonate rocks in this study were classified following Dunham (1962), Folk (1959), and Embry and Klovan (1971) for reefal rocks texture. The palaeoenvironmental reconstruction is based on Wilson

(1975); Tucker and Wright (1990); Wright (1992); Scholle and Ulmer-Scholle (2003), and Flügel (2004). All the thin sections containing the *Laffiteina* species figured in this paper using a Sony Cyber-shot DSC-W670 16.1MP 1/2.3" CCD Compact Camera are deposited at the collection of Paleontology Laboratory, of the Geological Department, Batna 2 (Mostefa Ben Boulaïd) University, Algeria, under the collection label "K" for El Kantara section, "M" for Mena section and "T" for Tighanimine section, respectively.

4. Stratigraphic Setting

In northeastern Algeria, the Abiod Formation marks its location in the upper portion of the Late Cretaceous-Early Paleogene very clearly by its effect on the topography, as mentioned in north-central Tunisia by Robszynski *et al.*, (2010): a double line of low hills separated by a slight median depression. The Upper Cretaceous-Paleocene of the Aurès is organized in the landscape as double hills, separated by a middle part in a slight depression. This morphology corresponds to the tripartite composition of the Upper Cretaceous-Lower Paleocene with a lower member of alternances of marl-limestone, a middle member constituted mainly by marls and an upper member of massive and often chalky limestones, with a bright white patina (equivalence of Ncham Member in Kalaat Senan). The regularity of this trilogy is modified in some places by reductions, or even lacunae, visibly affecting the upper member. In this study, there is a clear reduction in thickness of the Ncham Member in Mena section, that explained by its location at the apex of tilted blocks and therefore the reduction in the space available for sedimentation.

This study is based on Ncham Member from three localities as mentioned above (Figure 1B): El Kantara section, Mena and Tighanimine section. This member is of Late Cretaceous-Early Paleogene age. As cited in 2016 (Benmansour, 2016) and Benmansour *et al.* (2017), the Campanian is identi-

fied by *Globotruncanita elevata*, *Globotruncana ventricosa*, *Radotruncana calcarata*, *Globotruncana falsostuarti* and by the Ammonite: *Nostoceras (Bostrychoceras) polyplacum* (ROEMER, 1841). The Campanian-Maastrichtian boundary could not be specified with the foraminifera. Nevertheless, it is located between the disappearances of *Globotruncana falsostuarti* and *Nostoceras (Bostrychoceras) polyplacum*. The Maastrichtian is highlighted in most sections by the existence of planktonic foraminifera *Rugoglobigerina macrocephala* and *Rugoglobigerina hexacamerata*. The lower Maastrichtian-upper Maastrichtian boundary was traced by the first appearance of the stratigraphic species *Omphalocyclus macroporus* which corresponds to the upper Maastrichtian. The Cretaceous-Paleogene boundary was identified by the first occurrence of *Laffitteina erki* which marks the Thanetian age.

- *In the El Kantara section*, the Ncham Member consists of about 450 m of massive limestones, which form the famous gorges of El Kantara. The member begins with bioclastic limestones very rich in bryozoans, echinoids, and Inoceramus. In the topmost of the member, bioclastic limestone beds become more common and are overlain by limestones with calcareous algae and *Laffitteina*. It is bounded by an erosional surface of indurated bioclastic limestones containing thalassinoides. Placed in the paleogeographic sketches proposed by the authors and more particularly on those established by Vila (1980) and Tawadros (2001), the El Kantara deposit appears to be located at the beginning of the trans-Saharan sea, at a short distance from the emerged lands of the Paleomaghreb. The Cretaceous-Thanetian period ends with a shallow marine sedimentation, very changeable, passing from infralittoral to mediolittoral and then to supralittoral (Belkhouja, 2004). The return of the sea begins in the upper Thanetian by the installation of a series of lakes where the Red Marls are deposited above the Ncham Member. The

constant presence of *Microcodium* in these marls is an indication of the proximity of emerging limestone outcrops in the process of karstification whose erosion brings into the gulf puffs of coarse terrigenous contributions: quartz and especially limestone microbreccias, remanified foraminifera, articles of *Microcodium* (Belkhouja, 2004).

- *In the Mena section*, the Ncham Member consists of about 200 m of massive limestones. It begins with a marl-limestone unit, in cm-to dm-thick beds, containing abundant bivalves, gastropods, and bryozoans. This unit ends with intensively bioturbated limestone beds with traces of thalassinoides. The upper part of the member consists of about 100 m of monotonous bioclastic limestone containing abundant bivalves, echinoids, gastropods, and bryozoans. At the top, calcareous algal beds have been recorded.
- *In the Tighanimine section*, the Ncham Member consists of about 300 m of massive bioclastic limestones. It constitutes an easily identifiable landmark in the topography of the Aurès. It presents two aspects, successively from the bottom to the top: 1- several levels of limestone appear in centimetric beds, sometimes bioclastic or with lumachellic aspect; with a progressive thickening towards the top, ending with an emersion surface, 2- the limestone becomes massive containing abundant accumulations of bivalves, echinoids, gastropods, bryozoans, and red algae.

5. Results

5.1. SYSTEMATIC PALEONTOLOGY

Species of *Laffitteina* from the Maastrichtian-Thanetian shallow-water carbonates of the Aurès Basin (northeastern Algeria) are described herein. The vertical distribution of species is shown in Figures 4, 5 and 6.

Order Foraminiferida Eichwald, 1930

Suborder Rotaliina Delage and Hérourard, 1896

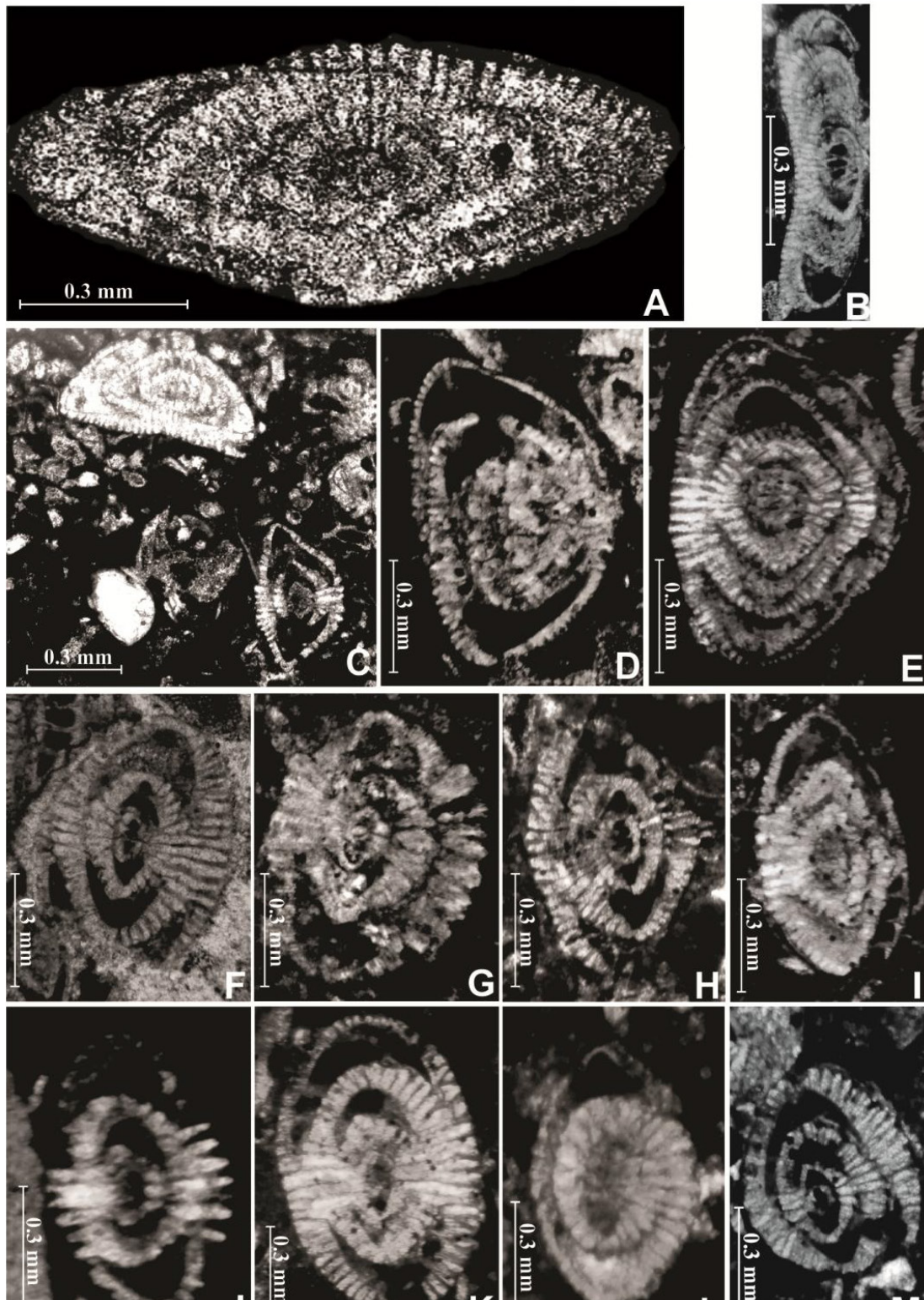


Figure 2 *Laffitteina* foraminifera in thin sections in the limestone beds of the Ncham Member. A, *Laffitteina mengaudi*. Axial section from El Kantara section. Sample K 71. B, *Laffitteina* aff. *mengaudi*. Axial section from El Kantara section. Sample K64. C-E, *Laffitteina conica*. Axial sections from El Kantara section. Samples K 44, K 54, K 74 and K 80 respectively. F-I, *Laffitteina oeztuerki*. Axial sections from El Kantara section. Samples K 23, K 65, K 73, K 82 respectively. J-M, *Laffitteina marsicana*, J&K. Axial sections from El Kantara section. Samples K 64 and K 77; L, Axial section from Mena section. Sample M 71; M. Axial section from Mena section. Sample T 22.

Superfamily Rotaliacea Ehrenberg 1839

Family Rotaliidae Ehrenberg 1839

Subfamily Laffitteininae Hottinger, 2014

Genus Laffitteina Marie 1946

Type species. *Laffitteina bibensis* Marie, 1946

Laffitteina mengaudi (Astre, 1923)

Figure 2A

1923 *Nummulites mengaudi* Astre, p. 360-368, Pl.12.

1945 *Laffitteina bibensis* n. gen. n.sp., Marie, p. 419-431, Figure 17-29

1945 *Laffitteina monodi* Marie, p. 419-431, Figure 17-29.

1952 *Laffitteina bibensis* Marie, Drooger, p. 99-100, pl. 16, Figure 9a, c, 11-15.

1957 *Laffitteina cf. bibensis* marie, Dizer, p. 38-41, pl. 1,2.

1957 *Laffitteina boluensis* s.sp. Dizer, p. 38-41, pl. 2.

1965 *Laffitteina marsicana* s.sp., Farinacci, p. 1245-1257, pl. 115-116.

1975 *Laffitteina mengaudi* (Astre), Blanc & Colin, p. 109-131, pl. 23-26.

1975 *Laffitteina mengaudi* (Astre), Blanc, p. 62, pl. 1-2.

1986 *Laffitteina mengaudi* (Astre), Sirel, p. 126, pl. 3.

1988 *Laffitteina mengaudi* (Astre), Radoicic, p. 22-24, pl. 4.

1998 *Laffitteina mengaudi* (Astre), Sirel, p. 88, pl. 46, Figures 1-23; non pl. 47, Figures 1-22.

Description. The test is inflated lenticular with broadly rounded periphery. In the axial section, umbilical and ventral sides are flattened or slightly convex. It has slightly trochospiral to nearly planispiral coiling.

Remarks. The test shape and the coiling type show similar characteristics to those of *L. mengaudi* illustrated by Marie from France (1946) and from Turkey (Sirel, 1996-1998).

Distribution. In this study, this specimen has been recorded from the late Maastrichtian of El Kantara section, at the level of samples K64-K70, K75, and K80. It occurs in the Maastrichtian-Paleocene limestones of Turkey (Sirel, 1996-1998) and in the late Maastrichtian of France (Marie, 1946).

Laffitteina aff. mengaudi (Astre, 1923)

Figure 2B

Description. The test is thin lenticular with a flattened shape and rounded periphery. It has a flat ventral side, while the umbilical side is slightly convex. The coiling is slightly trochospiral.

Remarks. This specimen is closely similar to that recorded from Turkey and described by Sirel (1996). It shows close similarity with *Laffitteina mengaudi* in having rounded periphery and trochospiral coil, but it differs from *L. mengaudi* in having thinner lenticular shell.

Distribution. It was recorded only in sample K 67, from the late Maastrichtian of El Kantara section. It was found in the Maastrichtian-Paleocene of Turkey (Sirel, 1996).

Laffitteina conica Drooger, 1952

Figure 2C-E

1952 *Laffitteina conica* Drooger, p. 100, Plate 16, Figure 10a-c, 16,17.

1996 *Laffitteina conica* Drooger, Sirel, p.20, Plate V, Figure 1-12; Plate, Plate VII, Figure 1-17.

1998 *Laffitteina aff. mengaudi* (Astre)—Sirel, pars, p. 90, pl. 48, Figure 16.

Description. The shell is conical, with a narrowly rounded margin and apex. The axial section is asymmetric, planispiral involute, and has a triangular outline. It has a flattened umbilical area, where the pillars are strongly thickened. The spiral side is convex to strongly convex.

Remarks. The asymmetrical axial section and the thickness of the pillars on the umbilical side are similar to those of *L. conica* described by Marie (1946) and Sirel (1996-1998).

Distribution. In this study, this species was found only in the upper Maastrichtian of El Kantara section, in samples K44, K48, K 54, K 74, K 77, and K 80. It is very rare in Turkey; it has been found in the Maastrichtian limestones of Bozandere place, Ilgaz mountains, north of Çankiri and in central Turkey (Sirel, 1996-1998). It is associated in this

locality with *Laffitteina* aff. *mengaudi* and *Laffitteina mengaudi*.

Laffitteina oeztuerki Inan, 1995
Figure 2F-I

1995 *Laffitteina oeztuerki* n. sp.: Inan, p. 111, pl. I, Figures 5–11.

1998 *Laffitteina koyulhisarica* n. sp.: Sirel, p. 92, pl. 52, Figures 1–22.

Description. The test is lenticular biconvex, wider in the central part. It has an almost bilateral symmetric shape with a subacute periphery. the plugs are prominent on both sides.

Remarks. This species differs from other species

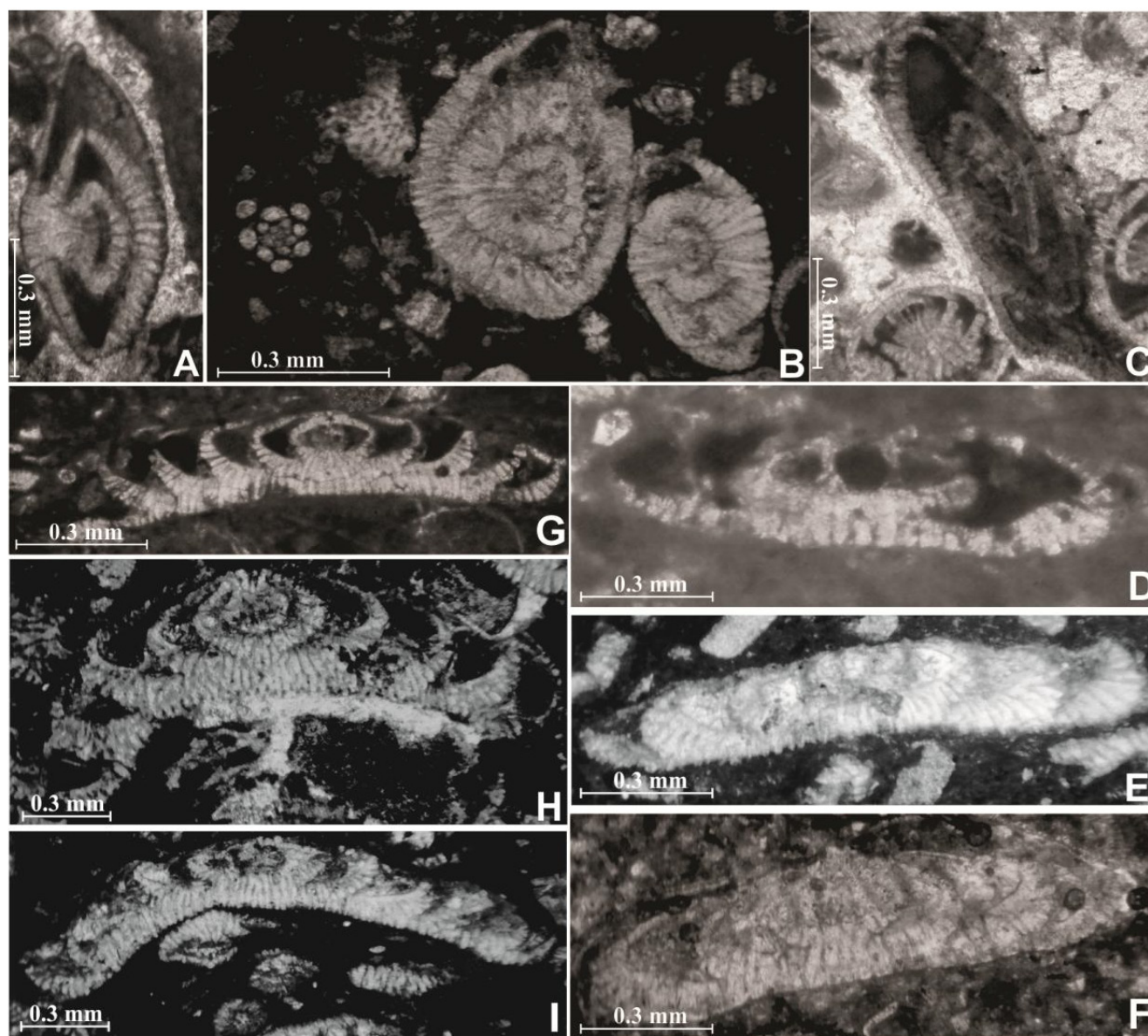


Figure 3 *Laffitteina* foraminifera in thin sections in the limestone beds of the Ncham Member. A-B, *Laffitteina boluensis*. Axial sections from El Kantara section. Samples K 39 and K 54. C-D, *Laffitteina monodi*. Axial sections from El Kantara section. Samples K 59 and K 82. E-G, *Laffitteina bibensis*, Axial sections from El Kantara section. Samples K 39, K 74, K88 respectively. H-I, *Laffitteina erki*, Axial sections from El Kantara section. Samples K 83 and K 89. I, *Laffitteina* aff. *mengaudi*. Axial sections from El Kantara section. Sample K64.

of *Laffitteina* in having a lenticular, biconvex and nearly bilateral symmetric. This species is comparable to those described by Inan (2004).

Distribution. It occurs in the upper Maastrichtian of Turkey (Meriç and Inan, 1995; Inan, 2004). In this study, it was recorded in the upper

Maastrichtian of El Kantara section, in samples: K 22, K 23, K 28, K 35, K 37, K 39, K 55, K 60, K 73, K 75, and K82.

Laffitteina marsicana Farinacci, 1965

Figure 2J-2M

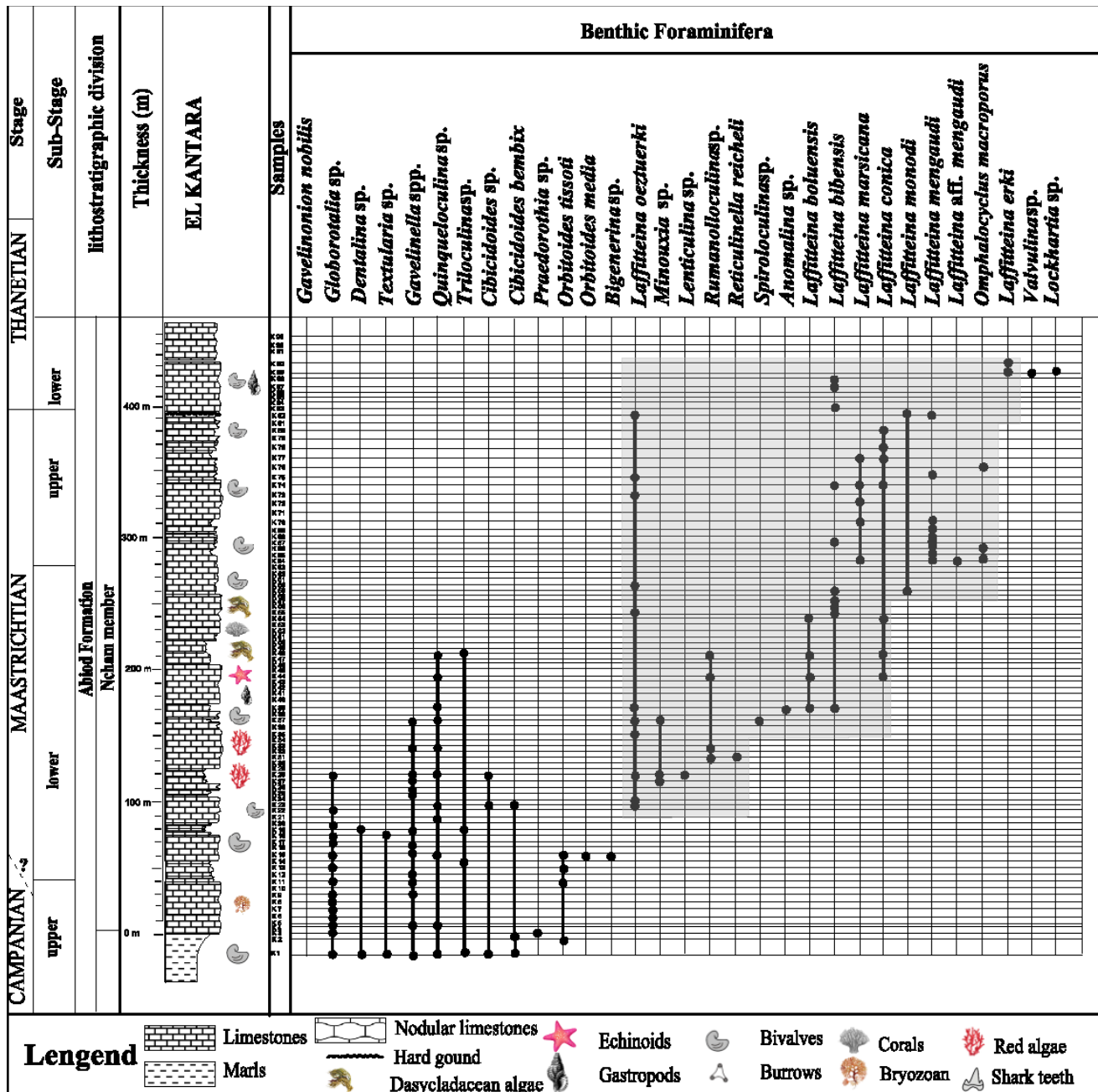


Figure 4 Vertical distribution of benthic foraminifera in El Kantara section, according to the order of the first appearance (Note: the legend in this figure is generalized also for the Figure 5 and Figure 6).

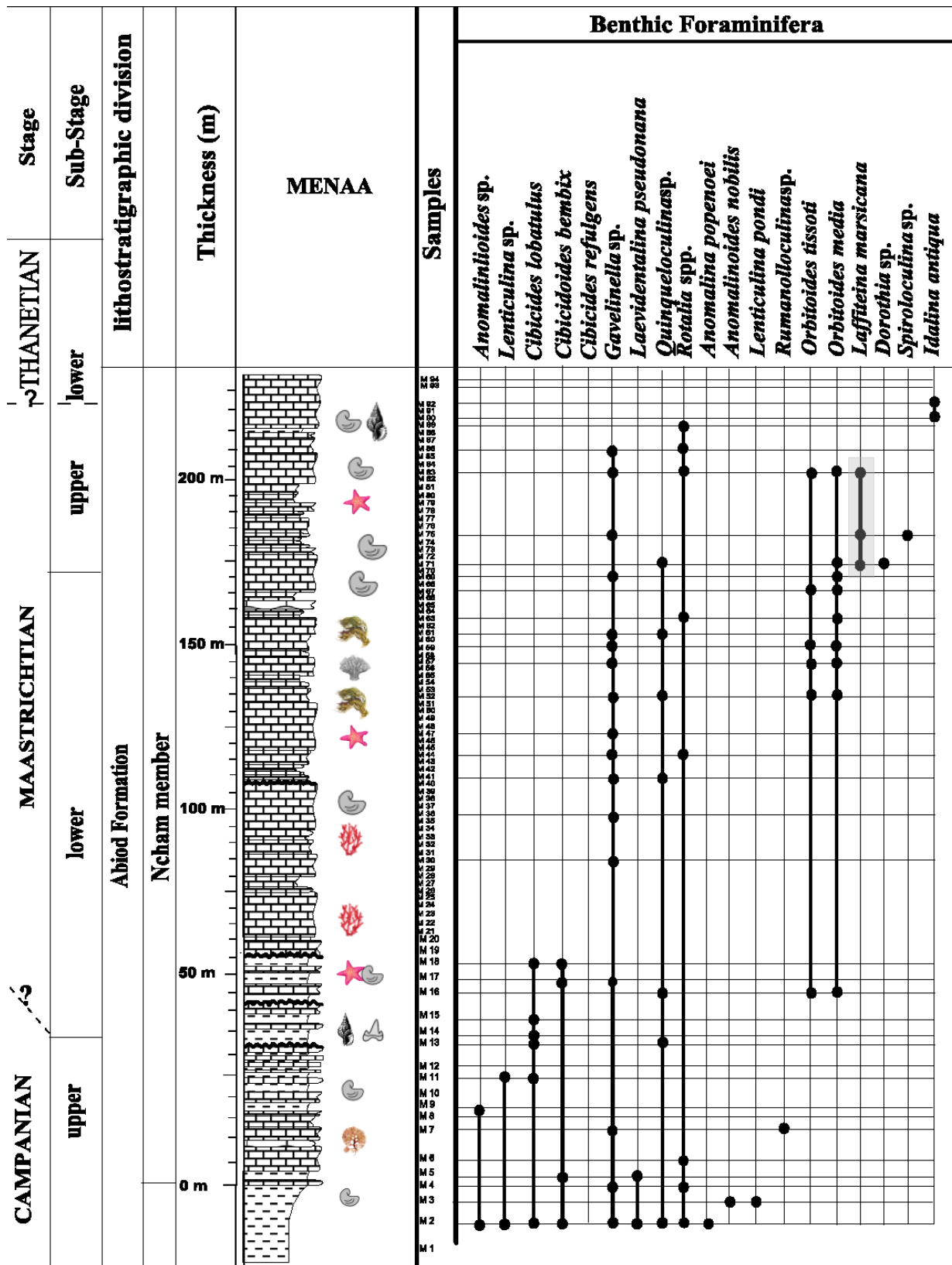


Figure 5 Vertical distribution of benthic foraminifera in Mena section, according to the order of the first appearance.

1965 *Laffitteina marsicana* Farinacci, p? Pl ?, Figure 8.2A–D.

1996 *Laffitteina marsicana* Farinacci: Inan, pl. I, Figures 3–6.

Description. It has a thick lenticular test with a rounded periphery. The umbilical side is more convex than the ventral side, which may, however, have a slight umbonal swelling. It has asymmetrical planispiral coiling.

Remarks. This species is distinguished from the other species of *Laffitteina* by its plano-biconvex and lenticular test.

Distribution. In the study area, it occurs in the early upper Maastrichtian of El Kantara section, in samples K 64, K 70, K 72, K 74, and K 77; in the Mena section, in samples: M 71, M 75 83 and in the Tighanimine section, in samples: T 22, T 24 and T 25. It is found also in the early upper Maastrichtian of Turkey (Inan, 1996).

Laffitteina boluensis Dizer, 1957
Figure 3A-B

1957 *Laffitteina boluensis* Dizer, n. sp., pl. 2, Figures 3-8

Description. The test is lenticular, biconcave with a planispiral coiling and an almost symmetrical shape. The margins are clearly blunt. It has thickened pillars, only on the umbilical side.

Remarks. This species shows similarities with *L. monodi*, but differs from the latter by its more compact septa and less loose equatorial section.

Distribution. It occurs in the late lower Maastrichtian of El Kantara section, in samples K 39, K 44, K K 48, and K 54. It was found in the middle Maastrichtian to the upper Danian of Turkey (Dizer, 1957).

Laffitteina monodi Marie, 1946
Figure 3C-3D

1998 *Laffitteina* aff. *mengaudi* (Astre)-Sirel, pars, p. 90, Pl.48, Figure16.

Description. The test is lenticular with an irregular shape and a rounded periphery. The shell is compressed, with flattened umbonal areas on both sides. It has a semi-evolute coiling. *Laffitteina monodi* is distinguished from *Laffitteina mengaudi* by its more compressed shell.

Remarks. The present specimen differs from *L. bibensis* by its general irregularity and by the decrease of its spiral side. It is closely similar to *L. monodi* illustrated by Marie (1946).

Distribution. In this study, this species was found only in the upper Maastrichtian of El Kantara section, in samples K 59 and K 82. It also present in the Montian of Mauritania (Marie, 1946).

Laffitteina bibensis Marie, 1946.
Figures 3E-3G

1923 *Nummulites mengaudi* n. sp.: Astre, p. 360, pl. 12

1946 *Laffitteina bibensis* n. sp.: Marie, p. 419, pl. V, Figures 1–3, 14–16.

1973 *Laffitteina mengaudi* (Astre): Blanc, p. 133, pls. 17, 18.

1975 *Laffitteina mengaudi* (Astre): Blanc, p. 61, pls. 1, 2.

1987 *Laffitteina bibensis* Marie-Loeblich and Tappan, p. 661, pl. 759, Figures 1–2, 9.

1996 *Laffitteina mengaudi* (Astre): Sirel, pl. I, Figures 1–22, pl. II, Figures 1–22, pl. III, Figures 1–11.

1998 *Laffitteina mengaudi* (Astre): Sirel, p. 88, pl. 46, Figures 1–23, pl. 47, Figures 1–22.

Description. The test is lenticular, almost planoconvex, or slightly biconvex. The chambers are hugging in asymmetrical chevrons. It has a flattened ventral side, while the umbonal side is flat (Figure 3F and 3G) or gently convex (Figure 3E),

Remarks. The specimen corresponds perfectly to the French specimens described and illustrated by Marie (1946; p 430, Figures 14-16). But it shows a distinct pattern in the convex umbonal side.

Distribution: In this study, It was recorded in the upper Maastrichtian to lower Thanetian of El Kantara section, in samples K 39, K 55, K 56, K 57, K 59, K67, K 74, K 83, K 87, and K 88. It is present

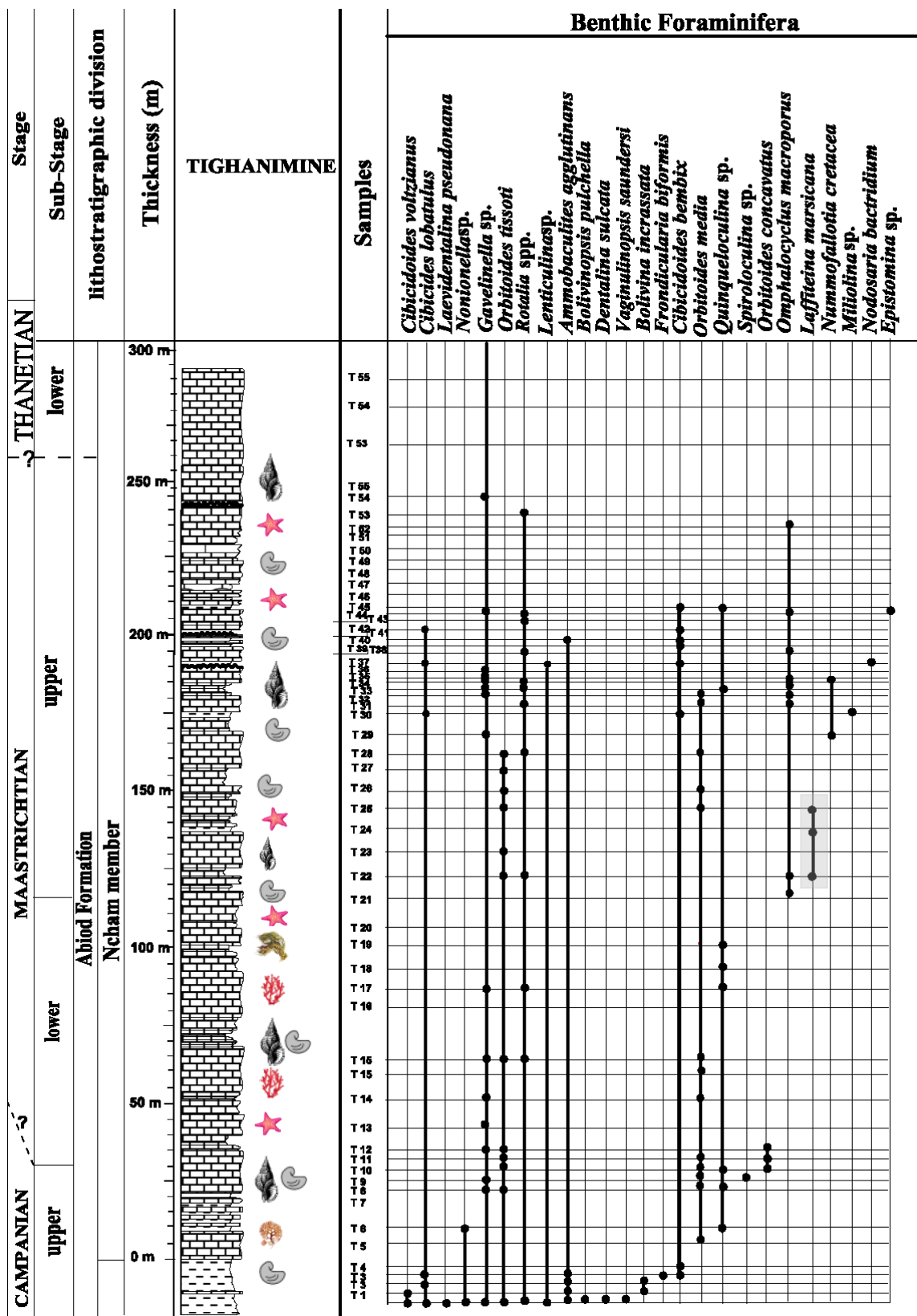


Figure 6 Vertical distribution of benthic foraminifera in Tighanimine section, according to the order of the first appearance.

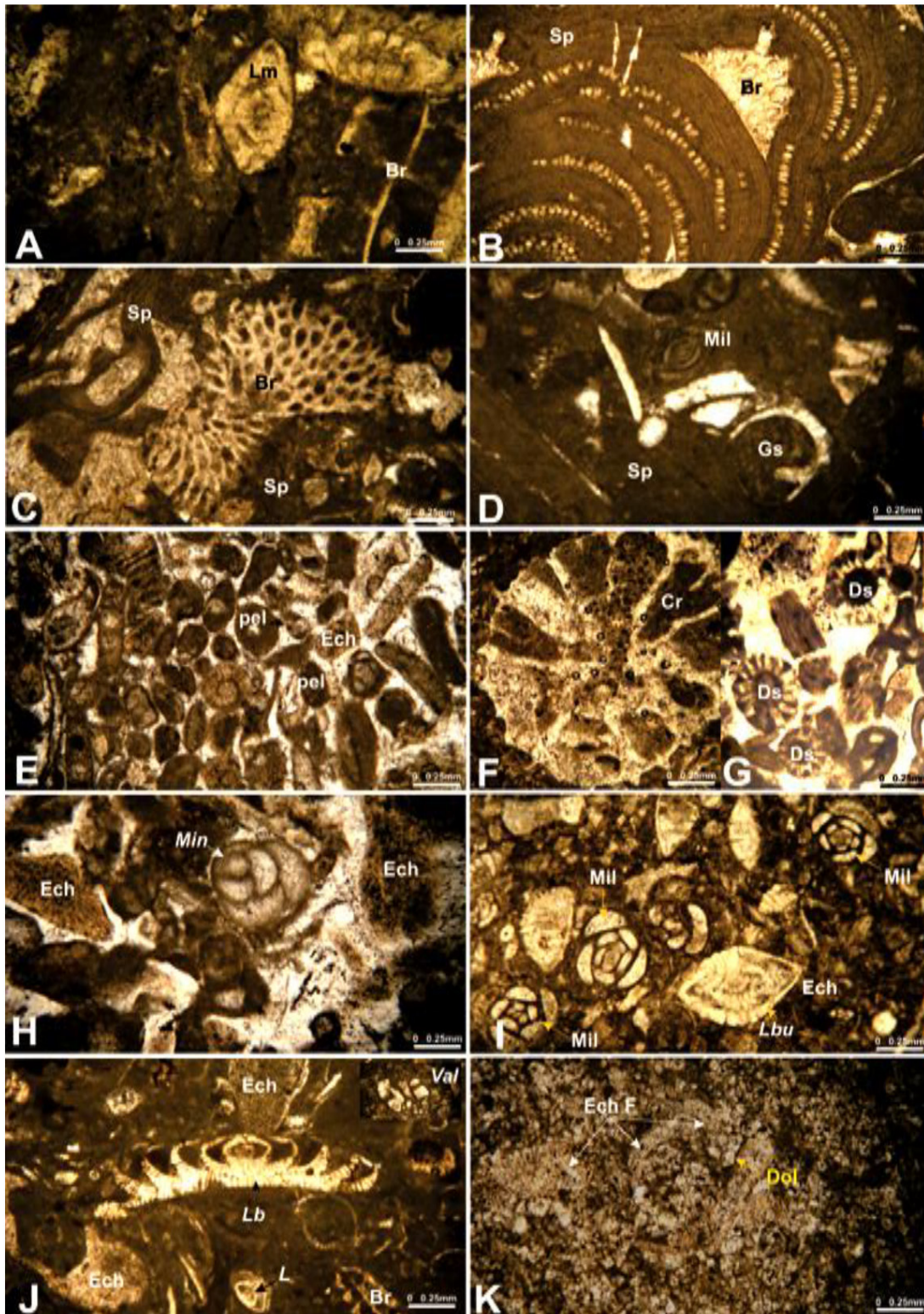


Figure 7 Thin sections of microfacies. A: F1: Bioclastic wackestone to packstone; B-D: F2. Algal bindstone Algal bindstone ; E-H: F3. Peloidal packstone to grainstone; I-J: F4. Foraminiferal wackestone to packstone; K: F5. Dolomitic mudstone. Abbreviations: Lm. *Laffitteina marsicana*; Br. Bryozoa; Sp. Sporolithon; Mil. Miliolids; Gs. Gastropods; pel. Peloids; Ech. Echinoids; Cr. Corals; Ds. Dasycladacean algae; Min. Minouxia; Lbu. *Laffitteina boluensis*; Val. Valvulina; Lb. *Laffitteina bibensis*; L. *Laffitteina*; Dol. Dolomites; Ech.F. Echinoid phantoms.

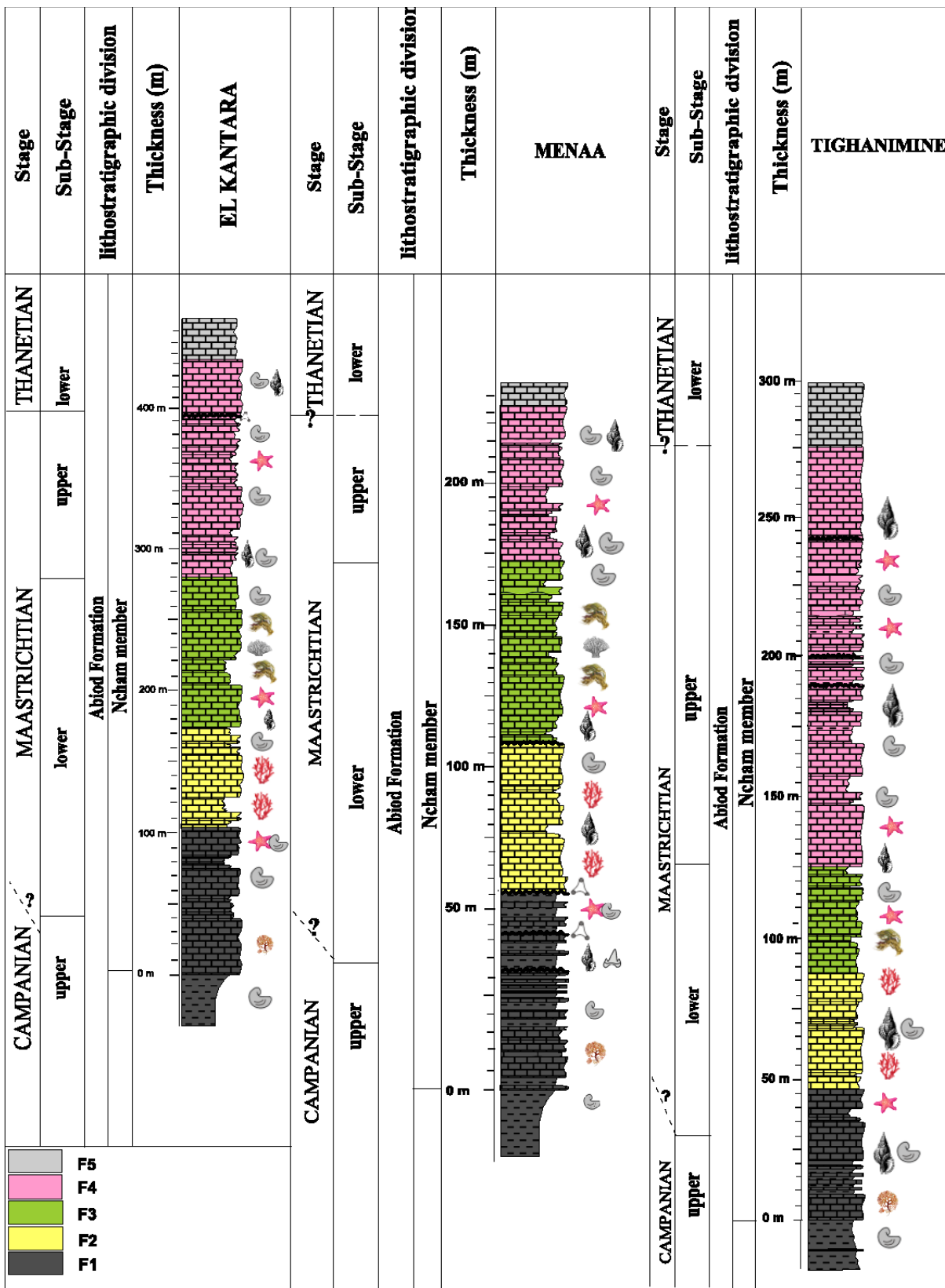


Figure 8 The vertical distribution of microfacies and their correlation between sections.

in the lower Danian of northwestern Europe (Bignot, 1987), in the Danian of Italy (Beckmann *et al.*, 1982), in Maastrichtian of Tunisia (Bismuth *et al.*, 1967), in the Paleocene of Libya (Berggren, 1974), in Maroc (Rahhali, 1970), in the Paleocene of Iran (Rahaghi, 1976, Bignot and Neumann, 1991), upper Maastrichtian-Danian of southwestern Slovenia (IGCP 286, 1991), Danian of Turkey (Fleury *et al.*, 1985; Serra-Kiel *et al.*, 1998), in the Adriatic (Drobne *et al.*, 1995), Slandian of southwestern Spain (Serra-Kiel *et al.*, 1996 and 1998).

Laffitteina erki (Sirel, 1969)

Figure 3H-3I

1957 *Laffitteina cf. bibensis* Marie, Dizer, pl. 1, Figures 1-6, pl. 2, Figures 1 and 2.

1969 *Orduina erki* n. sp.: Sirel, pl. 2, Figures 1-5.

1969 *Orduina erki* var. *conica* n. var.: Sirel, pl. 3, Figures 1-5.

1987 *Orduina erki* Sirel: Inan, pl. 8, Figures 1-7.

1987 *Orduina* aff. *erki conica* Sirel: Inan, pl. 8, Figure 8.

1994 *Laffitteina erki* (Sirel): Sirel, p. 47, pl. I, pl. II.

1995 *Laffitteina erki* (Sirel): Inan, pl. 2, Figures 1-5.

1998 *Laffitteina erki* (Sirel): Sirel, p. 91, pl. 51, Figures 1-8.

Description. The test is large and conical-shaped. It has a broadly rounded margin. The umbilical side is strongly concave, the spiral side is convex. Pillars Thickened only on the umbilical side.

Remarks. The specimen resembles *L. erki* described and illustrated by Sirel (1994 and 1996). But, it differs in being more elongated and arched.

Distribution. It occurs in the Thanetian limestones of Turkey (Sirel, 1996), and the lower Thanetian of El kantara section, in samples: K 83, K86, K 87, and K 89.

5.2. MICROFACIES DESCRIPTION

Figures 4, 5 and 6 represent the distribution of benthic foraminiferal associations found in the study area. Figure 7 presents the results of the petrographic analysis and the abundant compo-

nents from the Ncham Member. Five main microfacies were distinguished in the studied sections, where their vertical distribution was highlighted in Figure 8:

- Microfacies (F1): Bioclastic wackestone to packstone - *Laffitteina*, as well as miliolids, are rare constituents in this microfacies. Major grain types include bioclasts, which are composed of echinoids and bryozoans (Figure 7A). These allochems are bound by a micritic matrix.
- Microfacies (F2): Algal bindstone - This microfacies includes scattered bioclasts of bryozoans, gastropods, ostracods, and some benthic foraminifera (particularly *Laffitteina*), which are encrusted and bound by red algae (*Sporolithon*) (Figure 7B-7D). Microfacies (F3): Peloidal packstone to grainstone Major grain types include peloids, bioclasts, and benthic foraminifera. Bioclasts are composed of dasy-cladacean algae, corals, bivalves, gastropods, and echinoderms, which exceed 2 mm in diameter. Benthic foraminifera are present notably by *Laffitteina oeztuerki*, *Minouxia sp.*, *Lenticulina sp.*, *Rumanolloculina sp.*, and *Reticulinella reicheli*. These grains are cemented by a sparitic calcite cement (Figure 7E-7H).
- Microfacies (F4): Foraminiferal wackestone to packstone - The allochems are mainly composed of *Laffitteina* (*L. bibensis*, *L. oeztuerki*, *L. marsicana*, *L. conica*, *L. monodi*, *L. mengaudi*, and *L. aff. mengaudi*,...) and miliolids. There are also very low proportions of scattered *Anomalina*, echinoids fragments, and bryozoans in this microfacies. The bonded material consists of micrite (Figure 7I-7J).
- Microfacies (F5): Dolomitic mudstone - The *Laffitteina* limestones that constitute the microfacies F4 are terminated by dolomitized limestone of microfacies F5 microfacies. It consists of small homogeneous rhombohedral crystals of dolomite, with a size of about 100 µm associated with chrinoids phantoms (Figure 7K). These grains are cemented with a clear micrite.

6. Discussion

The first microfacies (F1) corresponds to bioclastic wackestone to packstone texture. This association consists of *Laffitteina* and miliolids with very little diversity, and a micritic matrix. The wackestone/packstone texture and the micritic matrix show a generalized low energy of a circalittoral environment. This facies is comparable to SMF2 of Wilson (1975).

The low abundance of *Laffitteina* indicates a progressive facies change and the disappearance of the stress conditions that controlled the proliferation of *Laffitteina*.

The second microfacies (F2) of algal bindstone texture, which is a modification proposed by Embry and Klovan (1971) for the Dunham (1962) Boundstone type of limestone where the framework organisms were encrusting and binding the sediment. These red algae limestones show *Sporolithon* (*Archaeolithothamnium* sp.) horizons containing scattered bioclasts of bryozoans, gastropods, ostracods, and foraminifera that probably formed within the reef ridge (barrier) of a very shallow and high-energy water environment. This facies is comparable to SMF7 of Wilson (1975).

The microfacies (F3) corresponds to peloidal packstone to grainstone texture. This microfa-

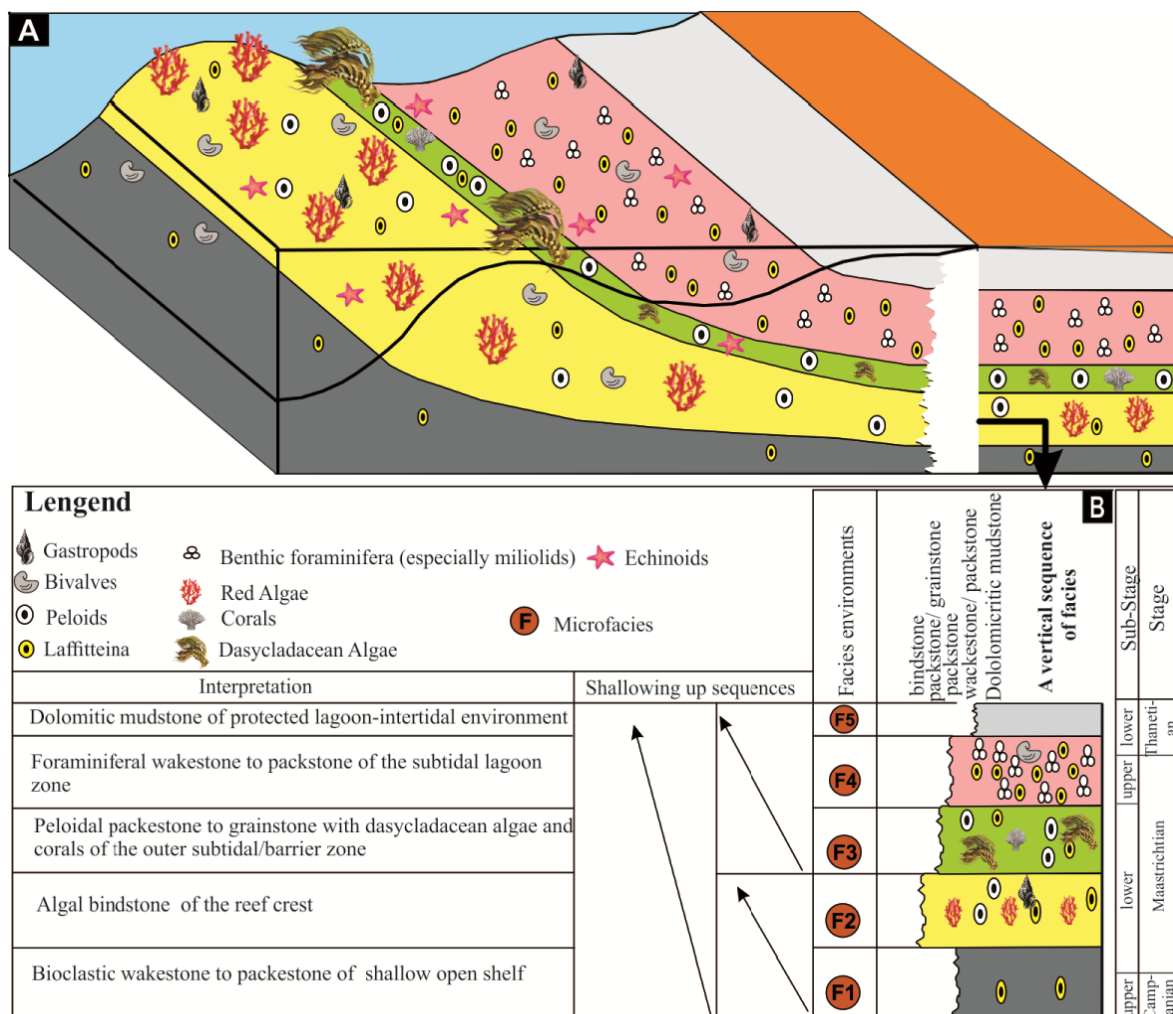


Figure 9 A. Sedimentological model of shallow rimmed shelves carbonate platform and the vertical microfacies distribution, B. A vertical sequence of facies corresponds to the recording of their lateral succession.

cies is mainly composed of non-skeletal grains (peloids) and some scattered bioclasts (notably Dasycladacean algae and corals). Typically, peloids and bioclastic shoals separate restricted lagoonal environments from deeper ramp environments (Flügel, 2010) and may act as broad and extensive barriers to currents and waves (Aghaei, 2012). This microfacies is comparable to SMF11 and SMF 12 described by Wilson (1975) indicating a shoal environment.

The fourth micofacies (F4) with foraminiferal wackestone to packstone texture correspond to *Laffitteina* and miliolids limestone. The low diversity of the other components (very rare echinoids and bryozoans) indicate that these sediments were deposited in protected, restricted, well-oxygenated and low-energy environments within the subtidal lagoon zone (Flügel, 2010; Wilson 1975), while the abundance of *Laffitteina* and miliolids indicates their tolerance to stressful conditions related especially to salinity variations and/or poor water circulation. This microfacies is very comparable to SMF18 described by Wilson (1975).

The fifth microfacies (F5) of dolomitic mudstone texture corresponds to facies SMF 23 of Wilson (1975). The dolomitization affecting the limestones reflects an almost complete absence of fauna, except for some echinoids phantom. Such a sediment may be a reflection of a very shallow and protected lagoon-intertidal like environment.

In the Aurès Basin, the microfacies analysis of the Upper Cretaceous-Lower Paleogene suggests a shallow rimmed shelves carbonate platform with sequential organization mainly controlled by sea-level fluctuations (Figure 9A). Interpreting the observed changes in relative sea-level in this area reflects significant facies changes from a shallow open shelf environment at the base to shallow lagoon environments at the top of a shallowing-up sequence (Figure 9B). These data can be linked to a global cooling of the planet, affecting land and oceans at the K/Pg transition. This global cooling is not without affecting the eustatism, which designates the oscillations of the sea-level, susceptible to make regress by contraction of the volume of

oceanic waters. These 2 regressions (temperature and eustatism) at the end of the Mesozoic, probably increased the conditions of “biological stress” (Li and Keller, 1998, Li *et al.*, 2000) which caused a massacre of the benthic fauna. The effects of marine regression have been observed in North America, Paris Basin (Courtilot, 1995) and in the Aurès Basin, through the appearance of gaps at the base of the Paleogene.

7. Conclusion

The following conclusions can be drawn from this study:

1. *Laffitteina mengaudi* (Astre), *L. aff. mengaudi* (Astre), *L. conica* Drooger, *L. monodi* Marie, *L. bibensis* Marie, *L. oeztuerki* Inan, *L. marsicana* Farinacci, *L. erki* (Sirel) and *L. boluensis* Dizer species are present in Algeria (Aurès Basin).

2. The species of *Laffitteina* genus in the Aurès Basin have been reported from the middle of the lower Maastrichtian to the lower Thanetian.

3. *Laffitteina* species can be used as index fossils to recognize the K/ Pg transition in the Aurès basin. The last occurrence of *Laffitteina oztuerki* marks the end of the Maastrichtian (Inan, 2004). It was found in its upper part of distribution, in association with *Omphalocyclus macroporus* (Lamarck), giving the age of the upper Maastrichtian. The first occurrence of *Laffitteina erki* marks the Thanetian age, it was found in association with *Valvulina*, which has never been mentioned in Cretaceous rocks.

Due to the absence of Danian and Selandian deposits (Belkhodja *et al.*, 2004) after general emersion during the lower Paleocene (Marzoqi and Pascal, 2000), the Thanetian rocks are concordant with Upper Cretaceous strata indicating perhaps a parallel unconformity. It could therefore be proposed that the K/Pg transition occurs in the last 10 m of the massive limestone of the Ncham Member, very low where Belkhoudja and Bignot drew the boundary Beyond this, it is proposed that the beginning of the Paleocene transgression is started at least in the middle Thanetian.

Conditions, which may have been determined by salinity variations and/or poor water circulation.

4. Analysis of microfacies and benthic foraminiferal assemblages suggests a shallow rimmed shelves carbonate with a shallowing-up sequential organization, primarily controlled by sea-level fluctuations.

Contributions of authors

The author of this article declares that he participated in all its elaboration: conceptualization, data analysis, methodological-technical development, writing of the original manuscript, drafting of the corrected and edited manuscript, graphic design, fieldwork, and interpretation.

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Conflicts of Interest.

The author declare no conflict of interest.

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