http://dx.doi.org/10.15576/GLL/2023.3.73

GLL

Geomatics, Landmanagement and Landscape No. 3 • 2023, 73–94

INVESTIGATION OF LITHO-BIOSTRATIGRAPHIC CHARACTERISTICS AND GEOGRAPHICAL DISTRIBUTION OF CONIACIAN-SANTONIAN FORMATIONS: A CASE STUDY IN THE AURES MOUNTAINS, EASTERN SAHARAN ATLAS, ALGERIA

Fahima Bentahar, Nabil Defaflia, Sana Benmansour, Chemseddine Fehdi

Summary

The Coniacian-Santonian series in the Aures Mountains of northeastern Algeria is characterized by marly-dominated sedimentation processes. This study aims to comprehensively investigate this series by combining lithostratigraphic and biostratigraphic data. The unique paleogeographic position of the Aures basin supports the co-occurrence of diverse paleontological contents in the Upper Cretaceous sediments. The methodology employed in this study includes a detailed bio-lithostratigraphic analysis to subdivide the Coniacian-Santonian series into two distinct sets. The first set comprises alternating marl-limestone units that exhibit a high fossil concentration from the Coniacian age, while the second set mainly consists of marly sediments corresponding to the Santonian age. The results obtained from this study highlight the geographical distribution of litho-biostratigraphic characteristics and reveal the presence of two formations. The lower formation is characterized by carbonated marls intercalated with limestone banks, containing fossils of Peroniceras (*Tissotia tissoto*) from the Coniacian age. Meanwhile, the upper formation is predominantly marly and indicates the Santonian age by displaying fossils of Palcenticeras polypsis. Furthermore, a biostratigraphic analysis focused on foraminifers allows for the subdivision of the Coniacian-Santonian series in the Aures Mountains into three distinct biozones. The first biozone corresponds to the lower Coniacian age and is identified by the presence of Dicarinella primitiva. The second biozone represents the middle to upper coniacian age and contains Dicarinella concavata fossils. Finally, the third biozone, belonging to the Santonian age, is marked by the occurrence of Dicarinella asymetrica. The boundary between the Coniacian and Santonian series in the Aures Mountains is characterized by the first appearance of Dicarinella asymetrica and Palcenticeras polypsis species. This multidisciplinary study provides valuable insights into the litho-biostratigraphic characteristics and geographical distribution of the Coniacian-Santonian series in the Aures Mountains. The findings make a significant contribution to a better understanding of sedimentary processes and the paleontological content within this region during the Upper Cretaceous period.

Keywords

biostratigraphy • Foraminifera • Biozonation • Coniacian • Santonian • Aures • Algeria

1. Introduction

The lithological-biostratigraphic study and the identification of geological formations and biozonations of the Cretaceous period have attracted considerable interest of researchers and geoscientists. The Cretaceous period, spanning approximately 145 to 66 million years ago, represents a crucial interval in Earth's history characterized by dynamic geological and biological processes. A comprehensive understanding of the lithological and biostratigraphic characteristics of this period provides valuable insights into the evolutionary history of life, paleoenvironmental conditions, and the geological evolution of sedimentary basins.

The combination of lithology and biostratigraphy allows researchers to unravel the complex geological history of the Cretaceous, particularly in the context of chronostratigraphy and chrono-correlation. Lithological studies include the analysis and interpretation of rock types, sedimentary facies, depositional environments, and stratigraphic sequences. By conducting these investigations, essential information regarding lithological variability, sedimentary processes, and the depositional history of a specific region during the Cretaceous can be obtained.

Meanwhile, biostratigraphy focuses on the identification and correlation of fossil assemblages found within sedimentary rock layers. By examining the presence, distribution, and evolutionary characteristics of fossil organisms, biostratigraphic studies contribute to the establishment of biozones or biostratigraphic units, which serve as valuable chronostratigraphic markers. These biozones make it possible to correlate rock units across different geographic regions, and to better understand the spatial and temporal variations in sedimentary successions.

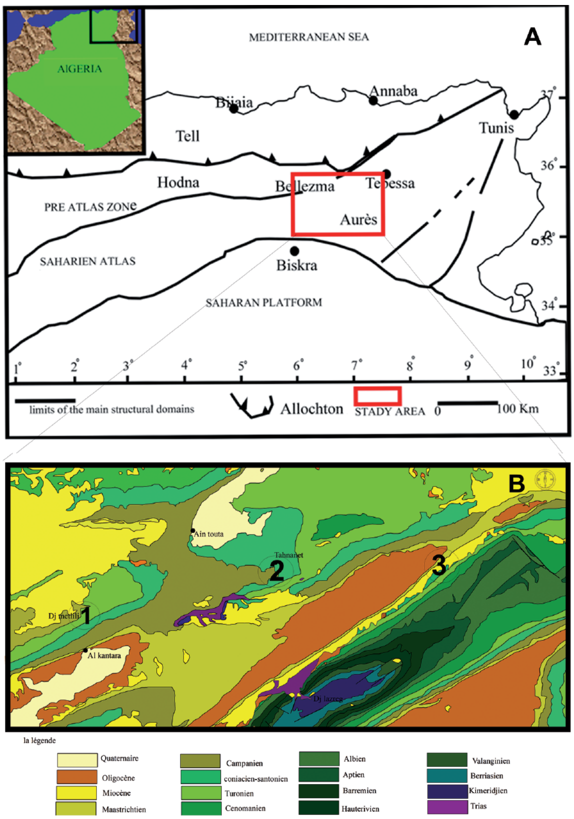
The Aures massif is a distinct region of eastern Algeria that occupies the eastern part of the eastern Saharan Atlas. It is characterized by well-defined anticlines and synclines with axes oriented N 50° to N60° E, resulting from the Atlasic phase [Laffite 1939]. The Atlasic direction is influenced by various fault systems organized around three orientations: NE-SW directional faults, NW-SE transverse faults, and E-W faults. The Cretaceous strata in the Atlasian region have an intracratonic position that is predominantly open to the Tethysian region and is known for platform sedimentation.

Previous stratigraphic and tectonic studies conducted in the Saharan region, including the Aures Mountains, have been carried out by researchers such as [Péron 1883, Laffite 1939, Bureau 1967, Bellion 1972, Guiraud 1973, Vila 1980, Bureau 1986, Kazi-Tan 1986, Benkherouf 1988, Yahiaoui 1990, Chikhi 1998, Harkat 1999, Benmansour 2016]. However, there is limited research on the Coniacian-Santonian series in the Aures Mountains. During the Upper Cretaceous, the sedimentation of the Aures Mountains was controlled by a system of tilted blocks [Bureau 1986], resulting in significant facies and fossil heterogeneity within the basin. The region exhibits remarkable faunal diversity, with dominant taxa including ammonites, inoceramites, and a microfaunal content rich in planktonic foraminifera.

This paper presents a lithological-biostratigraphic study aimed at identifying and characterizing various geological formations and establishing biozonations of the Coniacian-Santonian series of the Aures Mountains. The information obtained by this study will provide a basis for an accurate delineation of the boundary between these two series. Our investigation focuses on a distinct geographic region, providing a detailed analysis of lithological variations, sedimentary facies, and the distribution of fossil assemblages. By integrating lithological and biostratigraphic data, we aim to establish a comprehensive understanding of the Cretaceous geological history in this area, contributing to broader regional and global correlations. The results of this study will have significant implications for paleoenvironmental reconstructions, evolutionary studies, and the precise dating of Cretaceous sedimentary successions.

2. Materials and methods

The study area comprises three cross-sections situated in the southern zone of the Aures basin, specifically between the wilaya of Batna in the north and Biskra in the south (Fig. 1A, B). The three cross-sections are as follows:



Source: Laffite [1939]

Fig. 1. A. Main structural areas of North West Africa and the location of the study area in eastern Algeria. B. Extracted from the geological map of Aurès Laffite [1939]. 1 – El Kantara section; 2 – Beni Fedhala section; 3 – El Assas section

- El Kantara section: Located at coordinates 35°16’30” N and 5°45’47” E.
- Beni Fedhala section: Found at coordinates 35°21’00” N and 6°00’59” E.
- El Assas section: Positioned at coordinates 35°18’34” N and 6°16’44” E.

To conduct the study, over 300 samples of marl and limestone were systematically collected from the aforementioned three sections. The limestone samples were utilized to create thin sections for microscopic analysis. These thin sections were prepared at the sedimentary petrography laboratory of the University of Liège in Belgium. The marl samples underwent conventional micropaleontological washing method.

The primary objective of the microscopic analysis was to identify the microfauna present in the samples. The taxonomic determination of planktonic foraminifers was based on previous studies conducted by [Robaszynski et al. 1984, Caron 1985, Nederbragt 1991, Premoli-Silva 2004]. The analysis was supported by SEM (Scanning Electron Microscopy) microphotography performed at the Science and Technology Laboratory of Mohamed Kheidar Biskra University in Algeria.

By employing these techniques and equipment, our aim was to achieve a comprehensive understanding of the microfauna content and taxonomic composition of the samples collected from the three cross-sections in the Aures basin. The microscopic analysis, together with SEM microphotography, will provide valuable insights into the paleontological characteristics and sedimentary processes in the studied area.

3. Lithostratigraphy

El Kantara section

The Coniacien-Santonien series found on the southern side of Dj. Metlili presents several tens of meters on the outcrop where marl and limestone can be observed. This series is subdivided into two formations (Fig. 2).

Formation I

It is characterized by of the interchanging occurrence of marl and limestone. This formation, about 300 m thick, includes levels of lumachellic limestone interspersed with marl-limestone with gastropods, sea urchins and lamellibranchs. It is subdivided into two lithostratigraphic units (U1, U2).

Unit 1 (U1): marl-limestone (up to 200 m thick)

It consists of alternating layers of marl and limestone-marl, containing rich fauna, such as: inocerams, gastropods and ammonites, including (*Barroisiceras cf. tunetanum* (Fig. 5G, H), *Forrestria*, *Gouthiericerasroquei Peron*. The marls also contain debris of bryozoans such as: *Bifflustra Conopeum* and *Flustrina*, ostracods and echinoderms associated with abundant oyster debris.

Unit 2 (U2): Marls with intercalation of marl-limestone

This unit, about 170m thick, shows an alternation of marl and greyish bioclastic limestone beds (Fig. 3A). These marls are rich in gastropods, echinoderms, bivalves and ammonites, such as *Peroniceras*, *Tissotia tissoto*, *Tissotia ficheuri*, *Tissotia ewaldi*, *Tissotia fourneli*, *Tissotia tissotia thomasi*, *Tissotia tissoti inflata* (Fig. 5A).

Formation II

With a thickness of about 360 m, it is a predominantly marly lithological formation displaying greenish hue. It is characterized by passages formed by lumachellic limestone beds, comprising in particular gastropods, echinoderms and bivalves. Three units (U3, U4, and U5) make up this formation.

Unit 3 (U3): Marls thickness reaching 150 m

This unit is predominantly a marly interval (Fig. 3G) with intercalations of clayey limestone banks. It is rich in echinoderms, gastropods and *Paratexanitis inoceramus* sp., and *Cerithium* sp.

Unit 4 (U4): Marls with intercalation of marl-limestone 60 m

This unit is composed of alternating marls and bioclastic limestones, with the presence *of the inocerames cycloid Platyceramus.*

Unit 5 (U5): Marls 150 m

It is an interval of dark marl with occasional ammonites interspersed by centimetric banks of limestone-clayey nodular appearance. The entire unit is capped by a limestone bar.

Beni Fedhala section

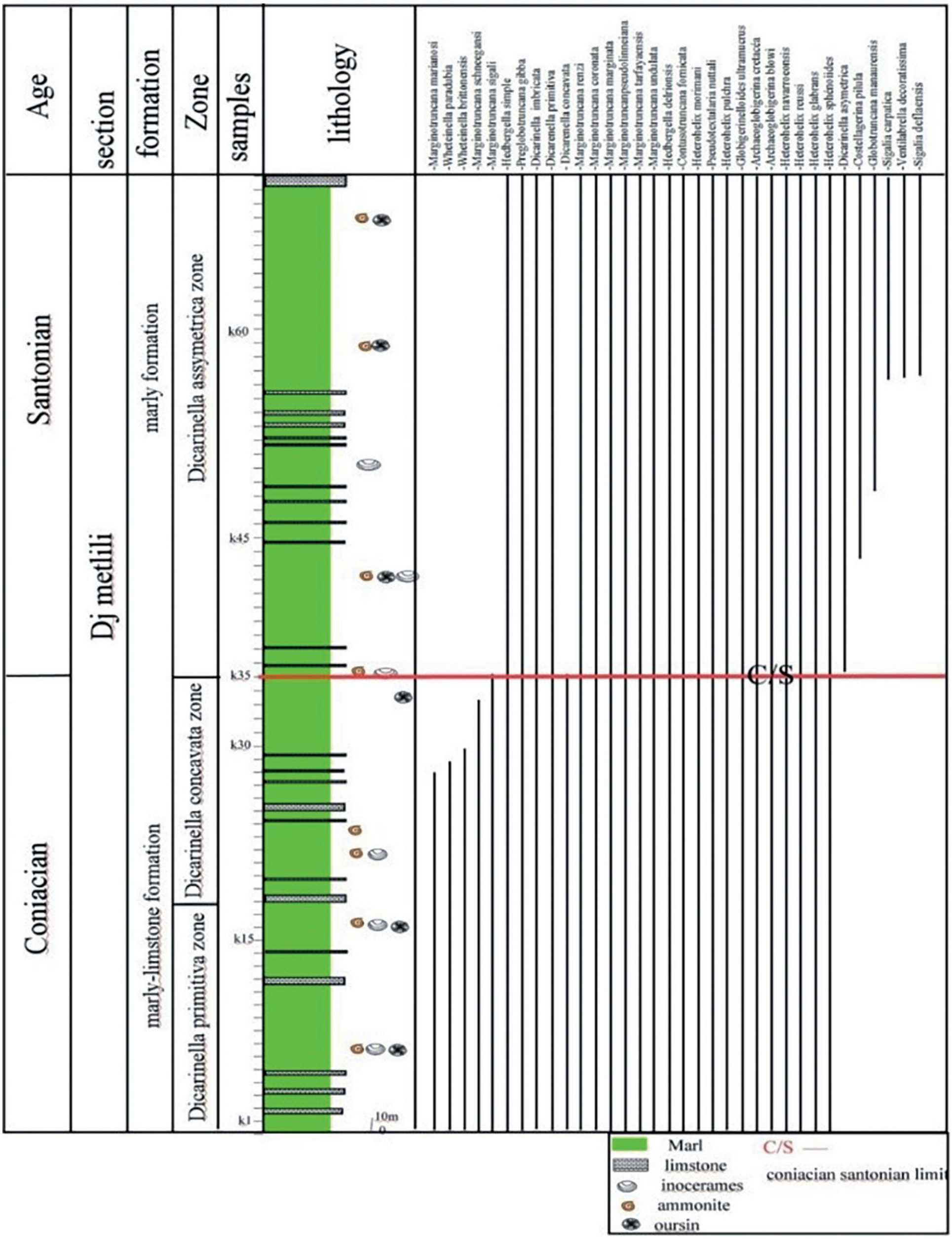
A 540 meter-thick marl-carbonate series from the Coniacian-Santonian period, in the form of outcrops in the valley of Beni Fedhala. This series is subdivided into four units (U1, U2, U3, U4) (Fig. 3):

Unit 1 (U1): Marls with ammonites (~ 30 m)

The formation is marly where beds of limestone ranging between 30 cm and 50 cm in thickness (Fig. 4B) are interspersed by a fossiliferous marly level (Fig. 4C, D) with ammonites; *Tissotia ewaldi* (Fig. 5 I), *Gauthiericeras roquei (Péron)*, *forrestria* (Fig. 5 D, E), echinoderms, bryozoans (Fig. 4C) and bivalves. The summit banks are characterized by bioturbations accompanied by traces of iron oxides.

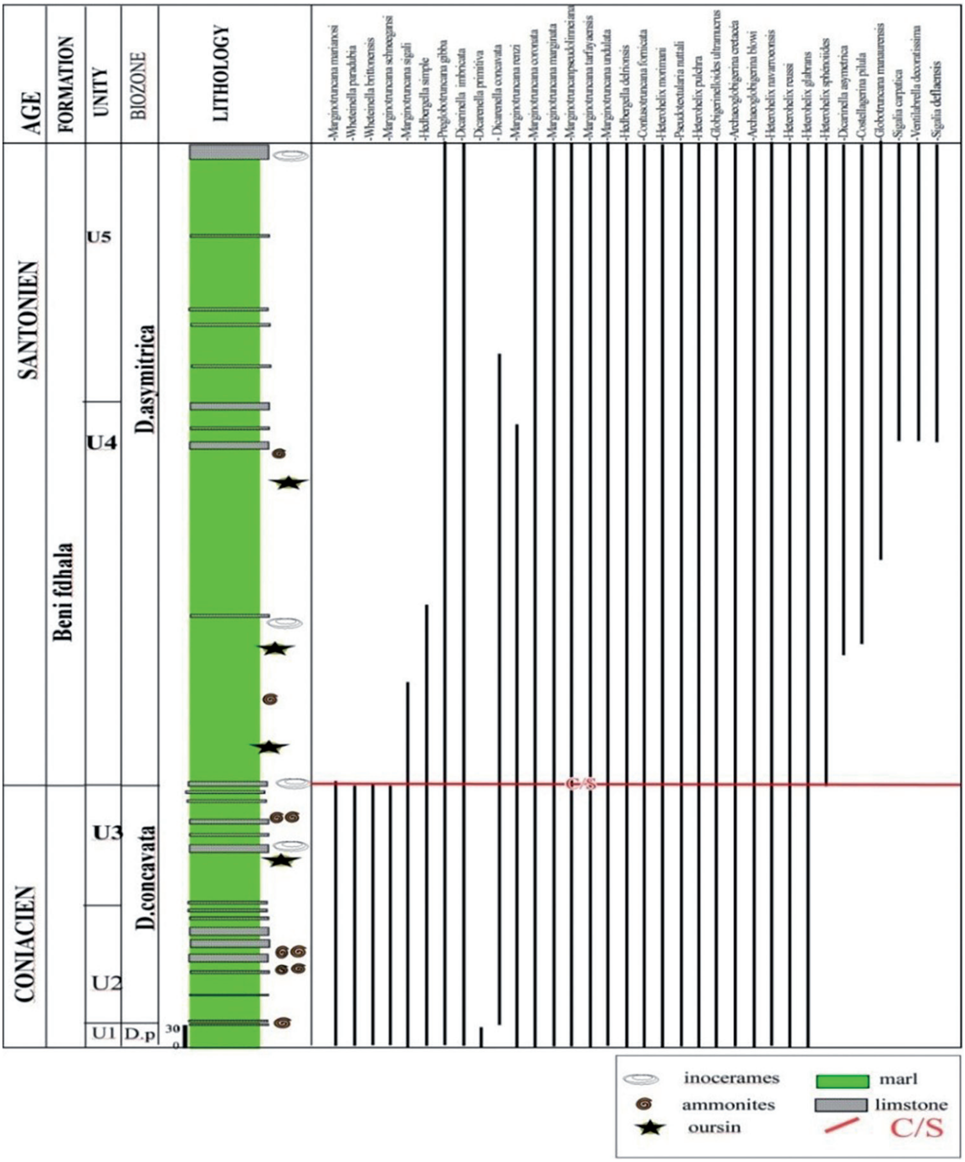
Unit 2 (U2): Marls with ammonites (85 m)

This unit primarily consists of marls and features ammonites such as *Tissotia ficheuri*, *Tissotia ewaldi*, *Tissotia fourneli*, *Tissotia tissotia thomasi*, echinoderms, bivalves and oysters at the base. Its middle section contains carbonate levels. These are of metric thickness (1 m to 1.5 m). The banks exhibit an oxidized surface and a noticeable bioturbations.



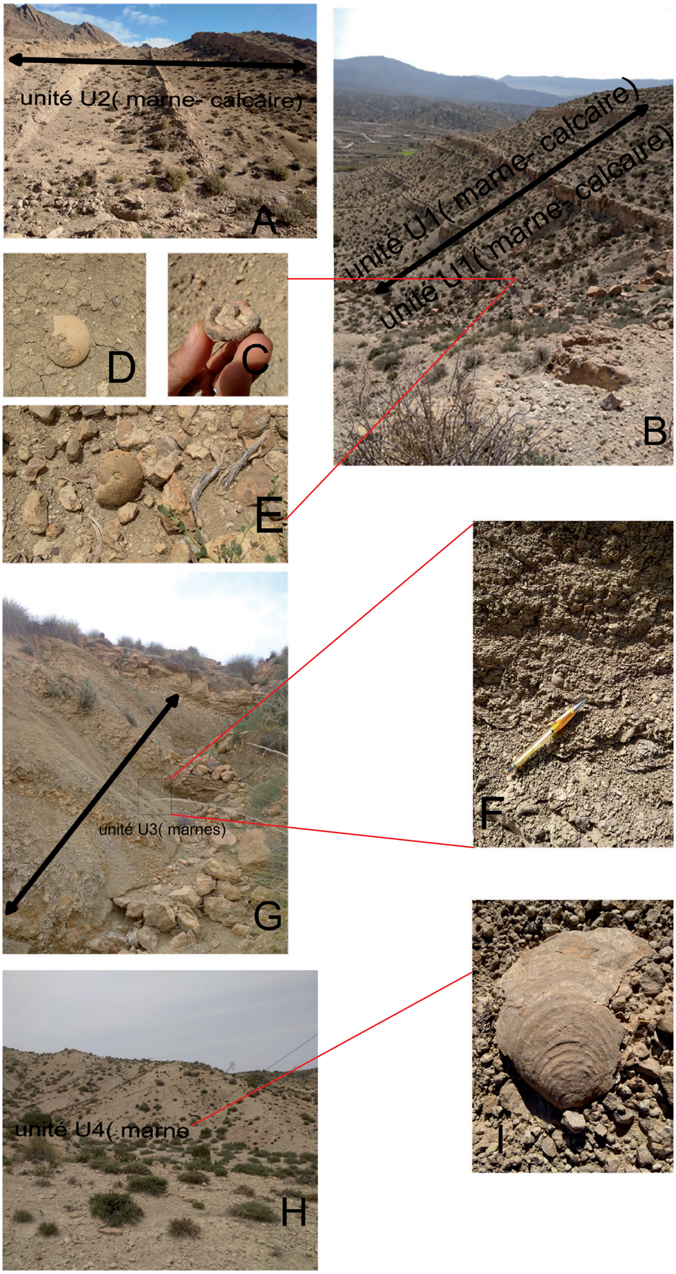
Author: Fahima Bentahar

Fig. 2. Vertical distribution of planktonic foraminiferal species at El Kantara section. See Figure 1 for location of the section



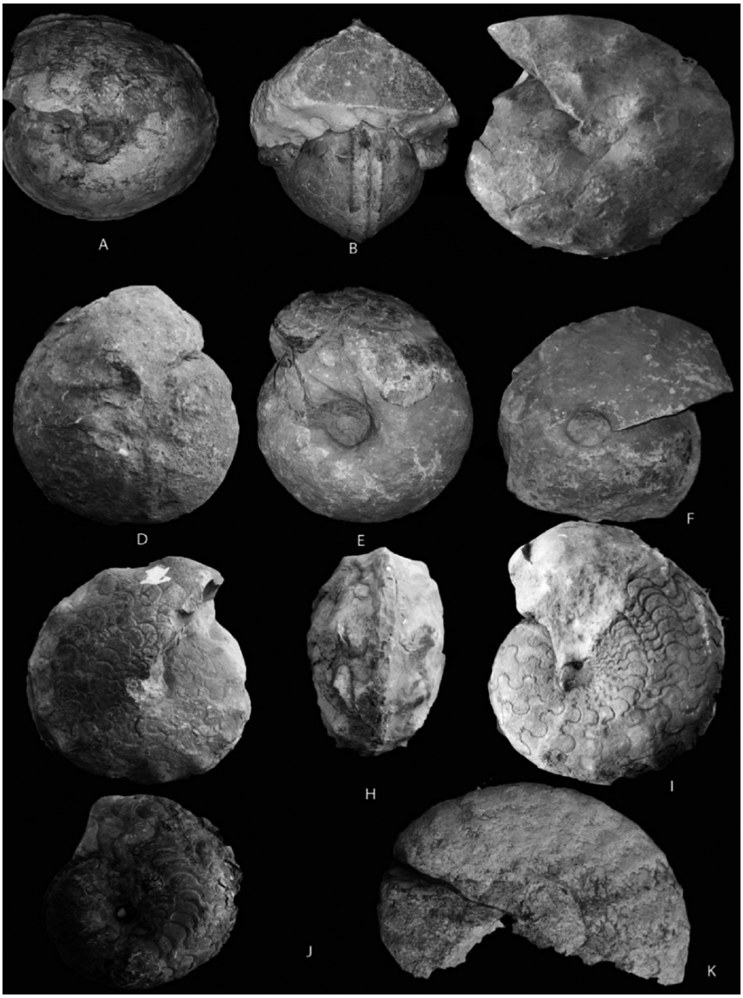
Author: Fahima Bentahar

Fig. 3. Vertical distribution of planktonic foraminiferal species at Beni Fedhala section. See Figure 1 for location of the section



Author: Fahima Bentahar

Fig. 4. Various lithological units: A – marl-limestone unit U2 from the El Kantara section; B – marl-limestone unit U1 from the Beni Fedhala section; C – Bryozoans; D, E – ammonites; F – detail of friable marl from the unit U3; G – marl from of El Kantara section; H – Unit U4 of the Beni Fedhala section. I – inocerams



Author: Fahima Bentahar

Fig. 5. A – *Tissotiatissoti Bayle var. inflate*; B, C – *Placenticeraspolypsis*; D, E – *Forrestria*; F – *Hemitissotiaturzoi*; G, H – *Barroisiceras cf. tunetanum*; I – *Tissotia ewaldi*; J – *Tissotiatissoti Bayle*; K – *Gauthiericerasmargae*

Unit 3 (U3): Intercalation marls with ammonites and limestone (180 m)

Its base is marked by the presence of two decimetric thick layers (50 cm) of biosclastic nodular limestonecomprising grains of glauconia, small spots of phosphate, algae. They are abundant in large inoceramus *Platyceramus cycloides*. We have not discovered the species *Texanites texanustexanus (Romer*), but according to Peron [1896] at this level there are such species as *Gauthiericeras margae* (Fig. 5K), and *Hemitissotia turzoi* (Fig. 5F), as well as large gastropods, *inoceramus* sp. The species makes their first appearance. The fossils of ammonite species coincide with a marly layer.

Unit 4 (U4): Marls with Placenticeras polypsis (390 m)

It begins with a thick greenish to greyish marly set, very rich in *Placenticeras polypsis* (Fig. 5B, C), echinoderms and bivalves (inocerams) (Fig. 4H, I). Centimetric layers of bioclastic clay limestones appear in its top part.

Unit 5 (U5): Marls (330 m)

It is characterized by an abundance of grey marl that is low in fossils and contains interspersed marly-clay limestone beds. The whole is capped by a bioclastic limestone flint bar. The basal surface of this bar is intensely bioturbated by horizontally oriented *Planolithes* and *Thalassinoides*. Its highest point is demarcated by intersecting laminar structures.

El Assas section

This section exhibits a thickness of about 460 m in the northern part of the Bouzina syncline. It is subdivided into three units (Fig. 6).

Unit 1 (U1): Marls with Placentoceras (160 m)

It begins with an interval of grayish clay marls with occasional ammonite debris *(Placentoceras*). Above there is are alternating marls and decimetric layers of bioclastic, lumachellic limestones, generally biomicritic with planktonic, phosphate foraminifers.

Unit 2 (U2): Gray marls with intercalation bioclastic limestones (220 m)

The formation is predominantly marly, gray in color, interspersed with centimetric and decimetric beds of bioclastic limestones phosphates. The surfaces of the ledges are often bioturbated and contain debris of bivalves, gastropods and bryozoans. Ammonites, gastropods and echinoderms are also present in some marly layers, which are at a metric scale.

Unit 3 (U3): Marls fossiliferous (80 m)

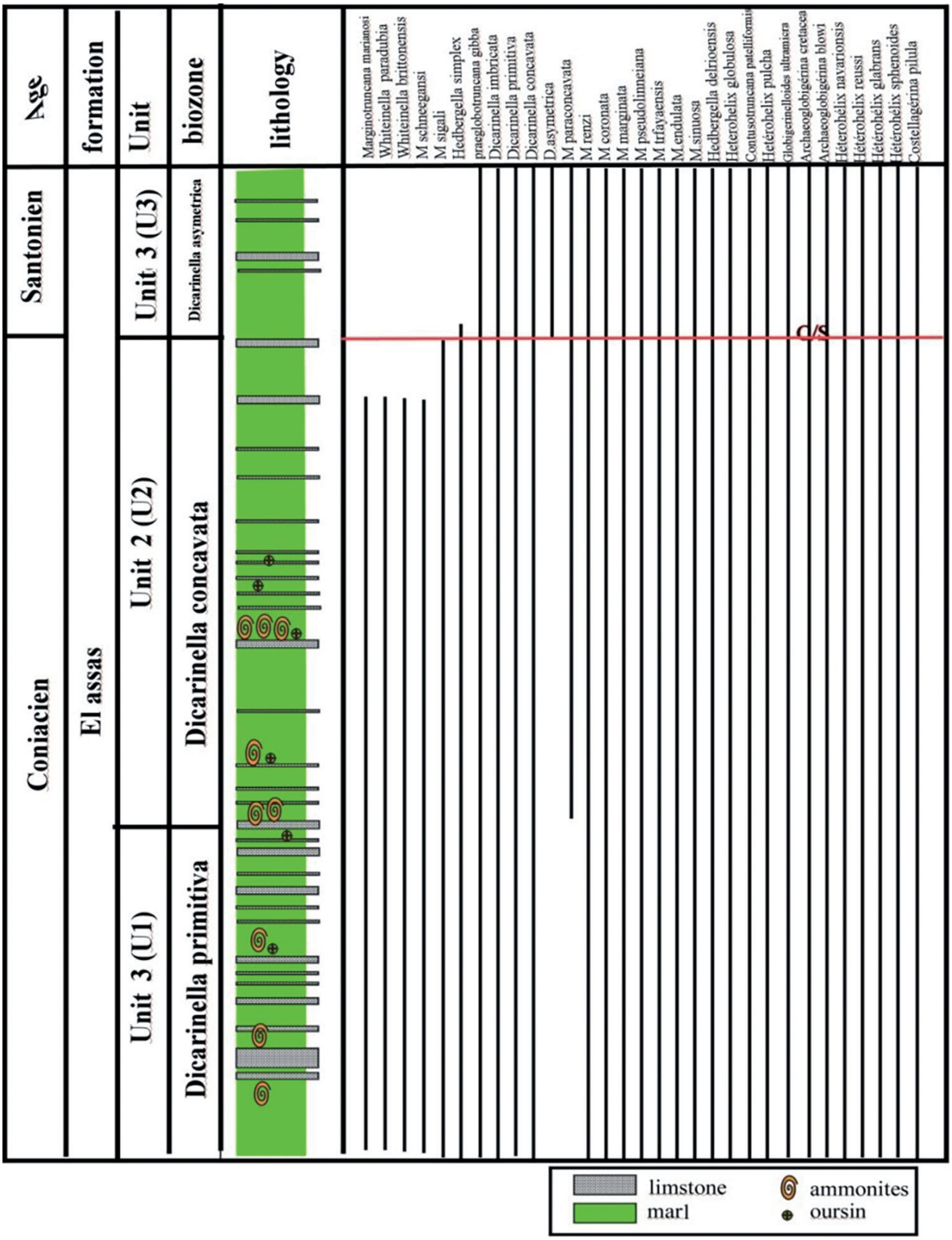
This unit comprises mainly marls, with intercalations of centimetric to decimetric beds of biomicritical limestones. The marls are grayish in color, fossiliferous, including echinoderms of various sizes, gastropods, oysters and ammonites.

4. Biostratigraphy

The biozonation adopted in this work is inspired by that established for the Mediterranean area of [Robaszynski et al. 1984], which is correlable with those of: Solakius [1984], Caron [1985], Sigal [1987], Sliter [1989], Premoli et al. [1994], Robaszynski and Caron [1995] for the terminal Cretaceous (Table 1).

Biozonation

Examination of thirty-four species allowed us to identify three planktonic foraminiferal biozones in the Upper Cretaceous (Coniacian-Santonian) sequence of the Aures



Author: Fahima Bentahar

Fig. 6. Vertical distribution of planktonic foraminiferal species at Koudiatel Assas section. See Figure 1 for location of the section

Basin. Two of these zones are interval zones (IZ), the IZ of *Dicarinella primitiva* and the IZ of *Dicarinella concavata*, between a date of first appearance (FAD) and a date of last appearance (LAD). One zone of total range (ZRT), the ZRT of *Dicarinella asymetrica*, defined by the first and last appearance (total range) of the designated taxon The biozones identified in this study are briefly described below in ascending order:

El Kantara section

34 species have been identified in this section. They can be assembled into 3 biozones (Fig. 6).

***Dicarinella primitiva Dalbiez* zone (Lower Coniacian)**

By definition, it is an interval zone (IZ) which is determined by the interval between the first occurrences (FAD) of the indicator species of *Dicarinella primitive* until the appearance of (FAD) *Dicarinella concavata* Brotzen. The *Dicarinella primitiva* zone has been described and attributed to the lower Coniacien [Robaszynski et al. 1984, Caron 1985].

In this interval, assemblage of 27 species of planktonic foraminifera with the species index (Fig. 7E) including several significant species:

Dicarinella imbricata,
Marginotruncana schneegansi,
Marginotruncana sigali,
Marginotruncana pseudolinneiana,
Witheinellap aradubia,
Witheinella brittonensis,
Preaglobotruncana gibba,
Archaeoglobigerina blowi,
Archaeoglobigerina cretacea,
Dicarinella imbricate,
Dicarinellaprimitiva,
Globigerinelloi desultramicra,
Heterohelixglobulosa (Fig. 7I)
Whiteinella paradubia
Whiteinella brittonensis
Pseudotextularia nuttalli
Praeglobotruncana gibba
Heterohelix navarroensis
Heterohelix pulchra
Heterohelix sphenoides
Heterohelix carinata
Marginotruncana coronata
Marginotruncana marginata
Marginotruncana sigali
Marginotruncana tarfayaensis
Marginotruncana undulata

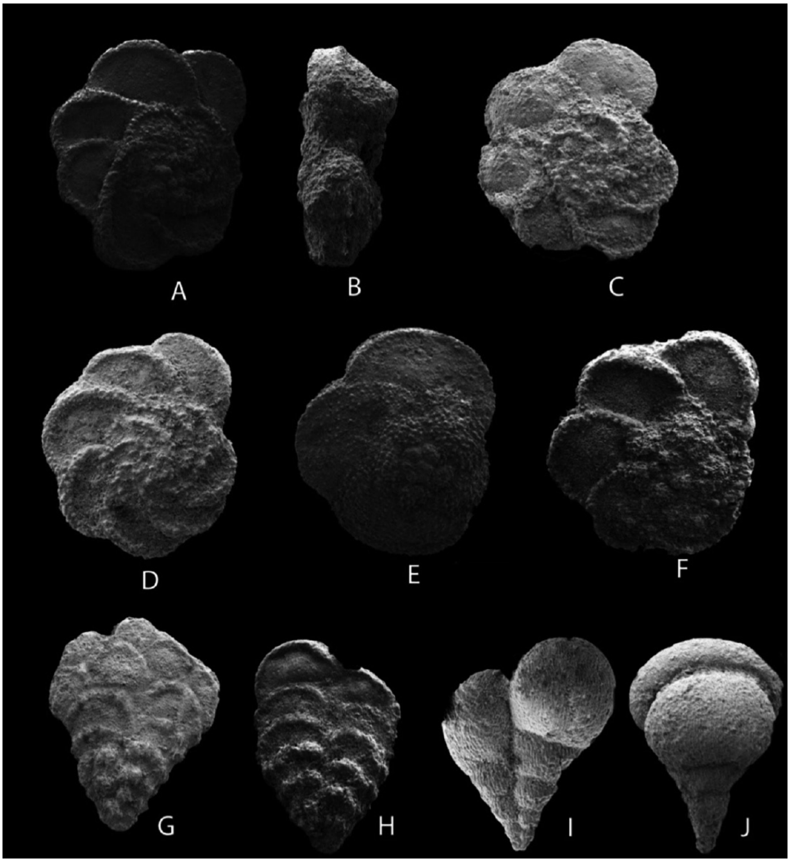
***Dicarinella concavata* zone (Upper Coniacian)**

The *Dicarinella concavata* IZ, of Coniacian-early Santonian age has been described by many authors, including: Robaszynski et al. [1984], Caron [1985], Sliter [1989], Robaszynski and Caron [1995], Robaszynski et al. [1998], Robaszynski [1998], Premoli-Silva and Sliter [1994], Robaszynski et al. [2000] and Premoli-Silva [2004]. This zone covers an interval characterized by the rarity of the species *Dicarinella concavata* until the first appearance (FAD) of the species *Dicarinella asymetrica* [Sigal 1955]. This area at *Dicarinella concavata* marks the Upper Coniacian (1955) [Sigal 1955, Bellier 1983, Robaszynski et al. 1984, Caron 1985, Robaszynski and Caron 1995, Rami et al. 1997, Premoli Silva and Sliter 1999, Özkan-Altine and Özcan 1999, Robaszynski et al. 2000, Sari 2009, Farouk and Faris 2012].

Table 1. Biozonation of lower Coniacien-upper Santonien interval proposed by various authors

<table>
<tr><th rowspan="2">Stage</th><th rowspan="2">Age</th><th colspan="7">Planktonic and ammonite foraminifera zone and subzones</th></tr>
<tr><th>Caron [1985] in Europe</th><th colspan="2">Gradstein [2008] in Europe</th><th colspan="2">Blaszkiewicz et al. [1980]</th><th>Robaszynski et al. [2000]</th><th>Present work</th></tr>
<tr><td rowspan="3">Santonien</td><td>Upper</td><td rowspan="3">Dicarinella asymetica</td><td rowspan="3">Dicarinella asymetica</td><td>Margina truncana manaurensis</td><td rowspan="3">Placenticeras polyopsis</td><td>Placeparaplan</td><td rowspan="3">Dicarinella asymetica</td><td rowspan="3">Dicarinella asymetica</td></tr>
<tr><td>Middle</td><td>Sigalia decoratissima</td><td rowspan="2">Texanites gallicus</td></tr>
<tr><td>Lower</td><td>Sigalia carpatica</td></tr>
<tr><td rowspan="5">Coniacien</td><td rowspan="2">Upper</td><td rowspan="2">Dicarinella concavata</td><td rowspan="2">Dicarinella concavata</td><td rowspan="2">Dicarinella concavata</td><td colspan="2">Paratexanites Serrato marginatus</td><td rowspan="5">Dicarinella concavata</td><td rowspan="2">Dicarinella concavata</td></tr>
<tr><td colspan="2">Gauthiericeras margea</td></tr>
<tr><td rowspan="3">Lower</td><td rowspan="3">Dicarinela primitiva</td><td rowspan="3">Dicarinella primitiva</td><td rowspan="3">Dicarinella primitiva</td><td colspan="2">Peroniceras tridorsatum</td><td rowspan="3">Dicarinella primitiva</td></tr>
<tr><td colspan="2">Forrestria petrocoriensis</td></tr>
<tr><td colspan="2">No characteristic ammonites</td></tr>
</table>

Source: Fahima Bentahar



Author: Fahima Bentahar

Fig. 7. Scanning electron images of planktonic foraminifera: A–B. *Dicarinella asymetrica* (Sigal). A. spiral view. B. umbilical view. C. *Marginotruncana marginata* (Reuss). D. *Marginotruncana pseudo linneiana* Pessagno (Reuss). E. *Dicarinella primitiva* (Dalbiez). F. *Dicarinella concavata* (Brotzen). G. *Sigalia decoratissima* (De Klasz). H. *Sigalia carpatica* (Salaj and Samuel). I. *Heterohelix cf. globulosa*. J. *Pseudotextularia nuttalli* (Voorwijk)

In this study, the occurrence of the species *Dicarinella concavata* (Fig. 7F) is associated with several species of planktonic foraminifera in this area (Fig. 2, 3, 6):

Archaeoglobigerina blowi
Archaeoglobigerina cretacea
Contusotruncana fornicate
Dicarinella imbricate
Dicarinella primitiva (Fig. 7E)
Globigerinelloides ultra-micra
Heterohelix carinata
Marginotruncana coronata
Marginotruncana paraconcavata
Marginotruncana marginata
Marginotruncana sigali
Pseudotextularia nuttalli (Fig. 7J)
Whiteinella paradubia

***Dicarinella asymetrica* Sigal zone (Lower-Upper Santonian)**

It is a 'total range zone', where the species *Dicarinella asymetrica* characterizes a total extension. This area includes the units: U3, U4, U5 (El Kantara section), U2 (El Assas section) and U2 (Beni Fedhala section). This zone is defined by the indicator *Dicarinella asymetrica*, which is reported as an index of the Coniacian-Santonian boundary [Robaszynski et al. 2000, Melinte and Lamolda 2002, Gradsteinet al. 2012]. This zone is characterized by the FAD and LAD of the nominate taxon, and corresponds to the Middle-Late Santonian [Robaszynski et al. 1984, Caron 1985, Sliter 1989, Robaszynski and Caron 1995, Premoli-Silva and Sliter 1994, Robaszynski 1998, Robaszynski et al. 2000, Premoli-Silva 2004].

The Planktonic foraminifera are identical to the previous association, with some new species that are generally scarce, such as *Ventilabrella decoratissima* and *Sigalia carpatica*, but also indicating the disappearance of species such as *Marginotruncana schneegansi.*

The foraminiferal assemblage in the studied sections is composed of the following species:

Witheinella paradubia,
Witheinella brittonensis,
Marginotruncana sigali,
Contusotruncana fornicate,
Dicarinella asymetrica (Fig. 7 A, B),
Dicarinella concavata (Fig. 7 F),
Dicarinella imbricate,
Pseudotextularia nuttalli,
Sigalia décoratissima (Fig. 7 G)
Hedbergella simplex
Heterohelix glabrans
Marginotruncana coronata
Globotruncanita stuartiformis
Marginotruncana paraconcavata
Marginotruncana pseudolinneiana (Fig. 7D)
Marginotruncana tarfayaensis
Sigalia carpatica (Fig. 7D)

Beni Fedhala section

We have identified 34 species of planktonic foraminifera in the Beni Fedhala section. They can be assembled in 3 biozones:

1. zone to *Dicarinella primitive*,
2. zone with *Dicarinella concavata*,
3. zone with *Dicarinella asymetrica.*

El Assas section

We have identified 31 species of planktonic foraminifera in the section of El Assas. They can be assembled in 3 biozones:

1. zone to *Dicarinella primitive*,
2. zone with *Dicarinella concavata*,
3. zone with *Dicarinella asymmetrica.*

5. Results

The vertical succession of the deposits and the distribution of the faunal content of the studied sections allowed us to divide the Coniacian-Santonian series into two formations: marly-limestone formation, characterized by alternating limestone and marl beds that are very rich in fossils; and a marl formation, characterized by intervals of green marls that are increasingly low in fossils. The faunal assemblage of the studied sections in general corresponds to proximal environments such as ammonites as well as to distal environments such as inocerams [Robaszynski et al. 2000].

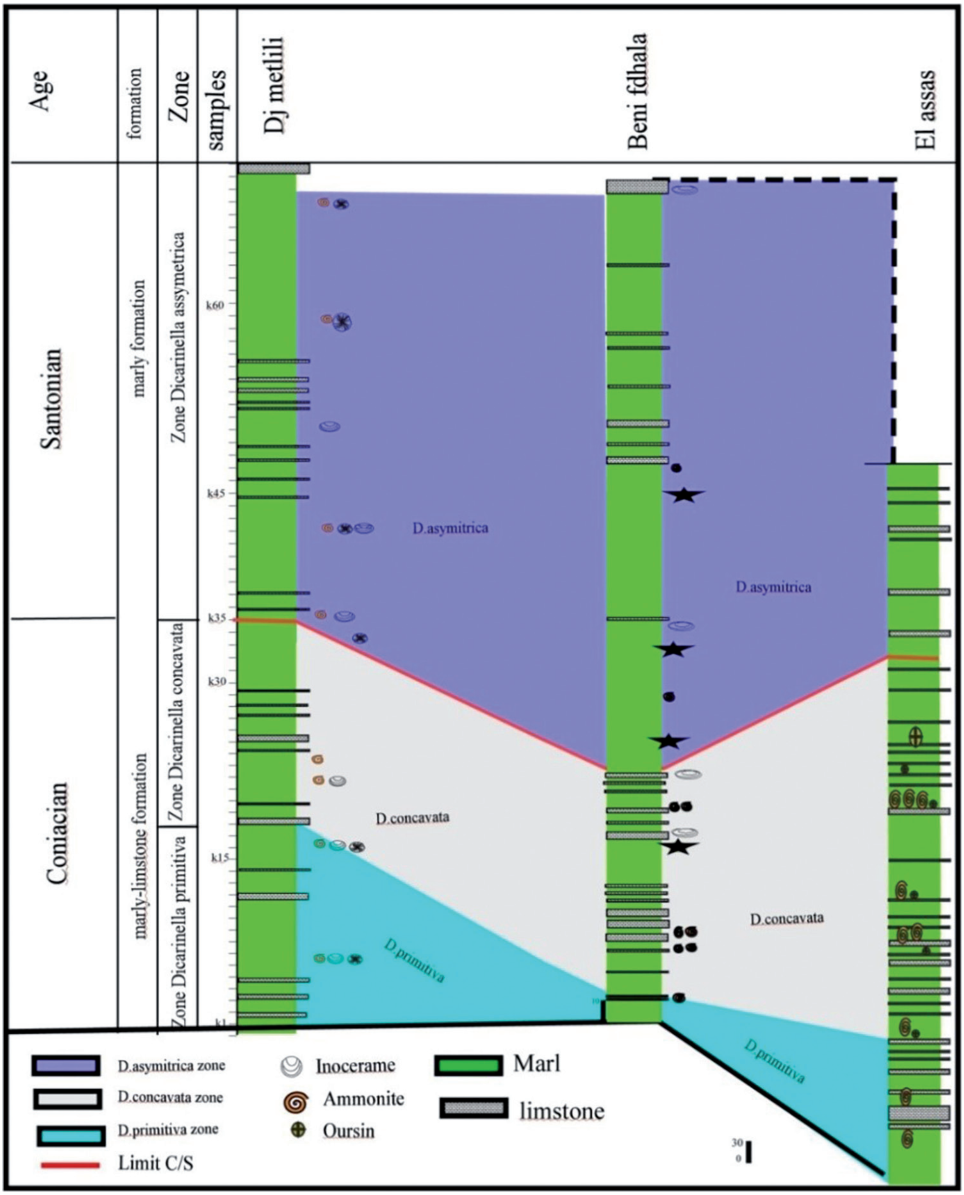
The biostratigraphic study of the planktonic foraminifers association of the three sections: El Kantara, Beni Fedhala and koudiat El Assas in the Aures basin shows three biozones (Fig. 8):

1. ***The Dicarinella primitiva zone*** is notable for the presence of the species *Dicarinella primitiva* with its association of planktonic foraminifera, and the presence of the *Barroisiceras tunetanum* ammonites That correspond to the *Barroisiceras tunetanum* zone interval. This allowed us to assign it to the Lower Coniacian. This appearance is placed towards the sample.

   K6-15 (El Kantara section), the Bn 2 sample (Beni Fedhala section) and the As 6-10 sample (El Assas section).
2. ***Dicarinella concavata zone***. The Dicarinella concavata species with its rarity and the association of foraminifers as it appears for the first time in sample K30 (El Kantara section), in sample Bn16 (Beni Fedhala section) and in sample As15-16 (El Assas section), with the presence of debris *of Gauthiericeras margae* and *Hemitissotia turzoi* which appeared at the level of Beni Fedhala section. This association corresponds to the *Peroniceras tridorsatum* interval zone, which allows them to be assigned to the Middle and Late Coniacian.
3. The last biozone features the first appearance of *Dicarinella asymetica*, in sample K35 (El Kantara section) dating from the basal part of the Santonian. The Coniacian/Santonian passage would be exhibited by the appearance of *Placenticeras polypsis* species and the presence of *Platyceramus cycloides* cf. These appearances correspond to the samples: K35 (El Kantara section), Bn30 (Beni Fedhala section), As23 (El Assas section).

Limits of Coniacien – santonien boundaries

According to the recommendations formulated during the 'Second Symposium on the Limits of the Cretaceous Stages' held in Brussels in 1995, the lower limit of the Santonian stage is defined by the appearance of the *Inoceram cladoceramus undulatoplicatus.* This species is not found in the Aures and Tunisia but we find other markers such as *Placenticeras polypsis* and *Platyceramus cycloides* and the appearance of the species of *Dicarinella asymetrica* in Tunisia; proposed *Platyceramus cycloides* to define the C/S boundary because this species of inoceramids appears to have a wider geographic distribution [El Amri and Zaghbib-Turki 2005].



Author: Fahima Bentahar

Fig. 8. Correlation of cross-sections and position of the Coniacien-Santonien boundary in the Aures Mountains

Then the Coniacian/Santonian transition in the Aures was displayed by the first appearance of *Placenticeras polypsis* species and the presence of *Platyceramus cycloides cf*. These occurrences correspond to the samples: K35 (El Kantara section), Bn30 (Beni Fedhala section). As23 (El Assas section) is confirmed by the appearance of the species of *Dicarinella asymetrica* (Fig. 8). The variations in facies and the thickness of the lithostratigraphic units of studied sections and the change of fossilifer content such as the ammonites the inocerames and the foraminiferest gives evidence of a strong increase in paleodepth between the Late Coniacian and the Middle to Late Santonian.

6. Conclusion

This research work presents a comprehensive lithostratigraphic and biostratigraphic study of the Coniacian-Santonian interval, complemented by a micropaleontological investigation focusing on planktonic foraminiferous assemblages. The Aures basin, due to its unique paleogeographic position, serves as an exceptional location, where diverse paleontological contents coexist in the sedimentation of the Upper Cretaceous.

During the Coniacian and Santonian periods, the Aures basin underwent significant sedimentary processes, forming dominant sedimentary series. Through detailed bio-lithostratigraphic analysis, the studied series has been divided into two formations. The first formation consists of alternating marl-limestone units with a high fossil content, indicating a Coniacian age. The second formation predominantly comprises marly sediments corresponding to the Santonian age.

The planktonic foraminiferal assemblages from the three sections studied (El Kantara, Beni Fedhala, and Koudiate Lassas) were meticulously analyzed, leading to several key conclusions. A total of thirty-four species were identified, allowing for the recognition of three planktonic foraminiferal biozones within the Upper Cretaceous (Coniacian-Santonian) sequence of the Aures basin. These biozones, in ascending order, are as follows: Biozone 1 corresponds to the Interval Zone (IZ) with *Dicarinella primitiva*, representing the Lower Coniacian; Biozone 2 is the IZ with *Dicarinella concavata*, indicating the Upper Coniacian; and Biozone 3 is the Total Range Zone (TRZ) with *Dicarinella asymetrica*, characterizing the Santonian stage.

Based on the biostratigraphic studies conducted on the three sections (El Kantara, Beni Fedhala, and El Assas) in the Aures region, the Santonian-Coniacian boundary (C/S) is positioned at the upper limit of the unit and is marked by the first appearance of the species *Dicarinella asymetrica*, along with the presence of *Placenticeras polypsis* and *Platyceramus cycloides* cf.

These results contribute significantly to the understanding of the stratigraphic and biostratigraphic characteristics of the Coniacian-Santonian interval in the Aures Basin. The identification of planktonic foraminiferal biozones provides valuable markers for correlating sedimentary units across different regions. Furthermore, the precise determination of the Santonian-Coniacian boundary helps in accurate age dating and supports regional and global correlations. This research sheds light on the geological history and paleoenvironmental conditions during the Upper Cretaceous period in the Aures Basin, facilitating further paleontological and evolutionary studies in the region.

Acknowlegments

We are grateful to Prof. Marmi Ramdhane for fruitful discussions about the stratigraphy of the Coniacian deposits. We are very grateful to Dr. Khalifa Adderbak, Dr. Feredrique Boulvain, and Pr. Brinis Nafaa who contributed remarkably to the improvement of this paper.

References

Bellier J. 1983. Planktonic foraminifera of the Cretaceous of northern Tunisia. Systematics, biozonation, stratigraphic use from the Albian to the Maastrichtian. Doctoral Thesis in Sciences, Pierre et Marie Curie University, Paris, 250.

Bellion Y. 1972. Geological and hydrogeological study of the western end of the Bélezma Mountains (Algeria). 3rd Cycle Doctoral Thesis, Paris V, 186.

Benkherouf F. 1988. Microbiostratigraphic and paleoenvironnement of cénomanien marls of Dj. Dyr (Tebessa, Algéria). Revue de Micropaléontologie, 69–78.

Benmansour S. 2016. The Compano-Maastichtian series of the anticline of djelazreg: lithostratigraphy, poléobiodiversity and sedimentology (Aurès, eastern Algeria). Doctoral thesis. University of Batna 2, 306.

Besser H., Dhaouadi L., Hadji R., Hamed Y., Jemmali H. 2021. Ecologic and economic perspectives for sustainable irrigated agriculture under arid climate conditions: An analysis based on environmental indicators for southern Tunisia. Journal of African Earth Sciences, 104134.

Boulemia S., Hadji R., Hamimed M. 2021. Depositional environment of phosphorites in a semiarid climate region, case of El Kouif area (Algerian-Tunisian border). Carbonates and Evaporites, 36(3), 1–15.

Brahmi S., Baali F., Hadji R., Brahmi S., Hamad A., Rahal O., ... Hamed Y. 2021. Assessment of groundwater and soil pollution by leachate using electrical resistivity and induced polarization imaging survey, case of Tebessa municipal landfill, NE Algeria. Arabian Journal of Geosciences, 14(4), 1–13.

Bureau D. 1967. Description of an overlap on the southern flank of Dj. Touggourt (Monts du Bélezma, Algerie). Bull. Soc. Geol. Fr., 237–239.

Bureau D. 1986. Sedimentary approach to structural dynamics: Mesozoic evolution and orogenic becoming of the northern part of the Saharan ditch (South-West Constantinois and Aurès, Algeria). Doctorate thesis. Pierre and Marie Curie University, Paris, 441.

Caron M. 1985. Cretaceous planktonic foraminifera. In: Plankton Stratigraphy. Eds. H.M. Bolli, J. Saunders, K. Perch-Nielsen. Cambridge University Press, Cambridge, 17–86.

Chikhi F. 1998. The Upper Cretaceous Rudists of Algeria: A Paleontological Study. Paleoecological and Biostratigraphic Data. Doctoral thesis. University of Sciences and Technology, Alger.

El Amri Z., Zaghbib-Turki D. 2005. Biostratigraphic characterization of the Coniacian/Santonian passage in the regions of Ellès and El Kef (northern Tunisia). Journal of Iberian Geology, 99–111.

Farouk S., Faris M. 2012. Late Cretaceous calcareous nanno-fossil and planktonic foraminiferal bioevents of the shallow-marine Carbonate platform in the Mitla Pass, west central Sinai, Egypt. Cretaceous Research, 50–65.

Gradstein F., Ogg J., Schmitz Mogg G. 2012. The Geological Time Scale. Elsevier, 144.

Guiraud R. 1973. Post-Triassic evolution of the alpine chain in Algeria, according to the study of the Hodna Basin and neighboring regions. Doctoratès Sciences, Nice, 270.

Hamad A., Abdeslam I., Fehdi C., Badreddine S., Mokadem N., Legrioui R., Hadji R., Hamed Y. 2021. Vulnerability characterization for multi-carbonate aquifer systems in semiarid climate, case of Algerian-Tunisian transboundary basin. International Journal of Energy and Water Resources, 1–14.

Harkat M. 1999. High sea level sedimentation from the Upper Cretaceous of the Eastern Saharan Atlas and the Aures: sequential stratigraphy, quantitative analysis Biocenoses, palaeogeographic evolution and geodynamic context. Doctoral thesis of sciences, USTHB, Alger, 802.

Kallel A., Ksibi M., Dhia H.B., Khélifi N. (eds.). 2018. Recent advances in environmental science from the Euro-Mediterranean and surrounding regions: proceedings of Euro-Mediterranean Conference for Environmental Integration (EMCEI-1), Tunisia 2017. Springer International Publishing.

Kazi-Tani N. 1986. Geodynamic evolution of the North African border: The North-Algeria intra-plate domain. Mega sequential approach. Thesis sciences. Univ. Pau, 871.

Kerbati N.R., Gadri L., Hadji R. et al. 2020. Graphical and Numerical Methods for Stability Analysis in Surrounding Rock of Underground Excavations. Example of Boukhadra Iron Mine NE Algeria. Geotechnical and Geological Engineering, 1–9.

Laffite R. 1939. Geology study of Aurès. Doctorate in sciences. Paris, Bulltin. Service. Geol. Map. Algeria, 484 .

Mahleb A., Hadji R., Zahri F., Chibani A., Hamed Y. 2022. Water-Borne Erosion Estimation Using the Revised Universal Soil Loss Equation (RUSLE) Model Over a Semiarid Watershed: Case Study of Meskiana Catchment, Algerian-Tunisian Border. Geotechnical and Geological Engineering, 1–14.

Melinte M., Lamolda M. 2002. Calcareous nannofossils around the Coniacian/Santonian boundary interval in the Olazagutia section (N. Spain). In: Year: Aspects of Cretaceous Stratigraphy and Palaeobiogeography. M. Wagreich (ed.), Österreichische Akademie der Wissenschaften schriftenrieh der erdichenwwissenschaften, 4,15, Kommenschaften 4, 351.

Nederbragt A. 1991. Late Cretaceous Biostratigraphy and Development of Heterohalicidae (Planktic Foraminifera) in Biostratigraphy and Paleoceanographic Potential of Cretaceous Planktic Foraminifera Heterohelicidae. Centrale Huisdruk Kerj Vrije, Universitiet Amesterdam Academisch profschrift, 61–125.

Özkan-Altine S., Özcan E. 1999. Upper Cretaceous plank-tonic foraminiferal biostratigraphy from NW Turkey: Calibration of the stratigraphic ranges of larger benthonic foraminifera. Geological Journal, 287–301.

Péron A. 1883. Essay of a geological description of Algeria. Ann. Sci. Geol., 202.

Peron M. 1896. Les ammonites du Crétacé superieur de l'Algerie. Mém. Soc. Géol., France, 25–88.

Premoli Silva I., Sliter V. 1999. Cretaceous paleoceanography: Evidence from planktonic foraminiferal evolution. Geol. S. Am., 301–328.

Premoli-Silva I. 2004. Practical Manual of Cretaceous Planktonic Foraminifera. International School on Planktonic Foraminifera, 3° Course: Cretaceous. Universities of Perugia and Milan, Tipografia Pontefe-licino, Perugia, Italy, 283.

Premoli Silva I., Sliter V. 1994. Cretaceous planktonic foraminiferal biostratigraphy and evolutionarytrends in the Bottaccione section, Gubbo, Italy. Paleontografia Italica, 189.

Rami A., Zaghbib-Turki D., El Ouardi H. 1997. Biostratigraphy (Foraminifera) and tectono-sedimentary control of the Upper Cretaceous in the region of Mejez El Bab (northern Tunisia). Mediterranean Geol, 101–123.

Robaszynski F. 1998. Planktonic foraminifera-upper cretaceous, chart of cretaceous biochronostratigraphy. In: Mesozoic and Cenozoic Sequence Stratigraphy of European Basins. Eds. P.C. De Graciansky, J. Hardenbol, P.R. Vail. Society for Sedimentary Geology, 782.

Robaszynski F., Caron M. 1995. Cretaceous planktonic foraminifera: Commentary on the Europe-Mediterranean zonation. Bulletin of the Geological Society of France, Paris, 681–692.

Robaszynski F., Caron M. 1995. Cretaceous planktonic foraminifera: Commentary on the Europe-Mediterranean zonation. Bulletin of the Geological Society, Paris, 681–692.

Robaszynski F., Caron M., Gonzalez Donozo J., Wonders A.H. 1984. European Working Group on Planktonic Foraminifera. Atlas of Late Cretaceous Globotruncanids. Journal of Micropaleontology, 26/3–4, 145–305.

Robaszynski F., Gonzalez Donozo J., Linares D., Amédr F., Caron M., Dupuis C., … Gartners S. 2000. The Upper Cretaceous of the Kalaat Senan region, central Tunisia. Integrated litho-biostratigraphy zones of ammonites, planktonic foraminifera and nannofossils from the upper Turonain to the Maastrichtien. Explor Research Centre Bulletin, Alf Aquitaine, 359–490.

Sari B. 2009. Planktonic foraminiferal biostratigraphy of the Coniacian-Maastrichtian sequences of the Bey Dağları Autochthon, western Taurides, Turkey. Thin section zonation. Cretaceous Research, 1103–1132.

Sigal J. 1955. North African micropaleontological notes from the Cenomanian to Santonian: zones and limits in pelagic facies. Report Som. Sessions Company Geological. France, 157–160.

Sigal J. 1987. A zonal scale of the Mediterranean Cretaceous and some reflections aroused by its establishment particularly in connection with the Danian. Review of Micropaleontology, 32–51.

Sliter W. 1989. Biostratigraphic zonation for Cretaceous planktonic foraminifers examined in thin section. Journal of Foraminiferal Research, 19, 1–19.

Solakius N. 1984. Taxonomy of some Globotruncanidae and biozonation of the late Maastrichtian of the El Haria Formation at Kef en Nsoura, Enfidaville region, EasternTunisia. Notes from the Geological Service of Tunisia, 1–37.

Taib H., Ben Abbas Ch., Khiari A., Hadji R. 2022. Geomatics-based assessment of the Neotectonic landscape evolution along the Tebessa-Morsott-Youkous collapsed basin, Algeria. Geomatics, Landmanagement and Landscape, 3, 131–146.

Tamani F., Hadji R., Hamad A., Hamed Y. 2019. Integrating Remotely Sensed and GIS Data for the Detailed Geological Mapping in Semi-Arid Regions: Case of Youks les Bains Area, Tebessa Province, NE Algeria. Geotechnical and Geological Engineering, 1–11.

Vila J.M. 1980. The Alpine chain of eastern Algeria and the Algerian-Tunisian borders. Doctoral thesis. Sciences Nat., Pierre et Marie Curie University, Paris VI, 665.

Yahiaoui A. 1990. The lower part of the Upper Cretaceous marl-limestone series (Upper Cenomanian to Lower Coniacian) between Batna and El Kantara (Eastern Algeria): Stratigraphy, Sedimentology and Paleogeography. Doctoral thesis. University of Nancy I, 207.

Fahima Bentahar
Department of Earth Sciences, University of Tébessa
Constantine Road,12022,Tebessa, Algeria
ORCID: 0009-0000-3263-7952

Nabil Defaflia
Department of Earth Sciences, University of Tébessa
Constantine Road,12022, Tebessa, Algeria
ORCID: 0000-0002-6943-3416

Sana Benmansour
Department of Geology
Institute of Earth and Universe Sciences, University Batna 2
53 Constantine Road, Fesdis, Batna 050778, Algeria
ORCID: 0000-0002-3046-8451

Chemseddine Fehdi
Department of Earth Sciences, University of Tébessa
Constantine Road, 12022, Tebessa, Algeria
ORCID: 0000-0002-6319-3837