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# QUANTITATIVE ANALYSIS AND PALEOENVIRONMENTAL RECONSTRUCTION OF THE MIDDLE CENOMANIAN DEPOSITS FROM SOUTHERN BELLEZMA-BATNA MOUNTAINS (NORTHEASTERN ALGERIA)

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ABSTRACT – The middle Cenomanian deposits of the southern part of the Bellezma-Batna Mountains, northeastern Algeria, have been investigated to evaluate the response of Foraminifera to variations of paleo-bathymetry, oxygen, and salinity. The Djebel Azeb section, with a thickness of 40 m, is composed of a clay-marl mass interspersed with lumachellic limestone layers. It makes up the middle part of the ''Marnes de Smail'' Formation. The *Turrilites acutus* Subzone of the upper part of the *Acanthoceras rhotomagense* Zone corresponds to the *Aspidiscus cristatus* Total Range Zone, and the *Rotalipora cushmani* Zone was recognized based on the study of ammonites, scleractinian and planktic foraminifera in this section. The statistical analysis of the foraminifera yielded only one assemblage of planktic foraminifera with globular chambers and trochospiral test belonging to the Cenomanian–Turonian; no association is typically restricted to the middle Cenomanian. The benthic foraminifera are poorly represented, belonging to the orders Textulariina, Lituolina, Trochamminina, Verneuilinina, Loftusiina, Orbitolinina, Miliolina, and Rotaliina. These foraminifera assemblages indicate that the bottom-water conditions during the middle Cenomanian were characterized by periodic changes in the oxygen and salinity. All planktic foraminifera species are opportunists related to poorly oxygenated, eutrophic conditions interspersed by a short interval of well-oxygenated environment with *Planolites*. The maximum abundance of *Whiteinella* and *Muricohedbergella* and the minimum amount of *Planoheterohelix* species within the Cenomanian of Djebel Azeb reflect dwindling palaeosalinity during this time, except for a slight increase in the middle of the section.

**Keywords:** Foraminifera, corals, biostratigraphy, oxygen, salinity, Cretaceous.

RESUMO – Os depósitos cenomanianos médios da parte sul das montanhas Bellezma-Batna, no Nordeste da Argélia, foram investigados para avaliar a resposta dos foraminíferos a variedades de paleo-batimetria, oxigênio e salinidade. A seção Djebel Azeb, com uma espessura de 40 m, é composta por uma massa argilo-marlosa intercalada com camadas de calcário lumaquílico. Compõe a parte central da formação "Marnes de Smail". Uma Subzona de *Turrilites acutus* da parte superior da Zona de *Acanthoceras rhotomagense* corresponde à Zona de Alcance Total de *Aspidiscus cristatus* e a Zona de *Rotalipora cushmani* foi reconhecida com base no estudo de amonites, escleractínios e foraminíferos planctônicos nesta secção. A análise estatística dos foraminíferos produziu apenas um conjunto de foraminíferos planctônicos com câmaras globulares e teste trocoespiral pertencentes ao Cenomaniano–Turoniano; nenhuma associação é tipicamente restrita ao Cenomaniano médio. Os foraminíferos bentônicos estão mal representados, pertencentes às ordens de Textulariina, Lituolina, Trochamminina, Verneuilinina, Loftusiina, Orbitolinina, Miliolina e Rotaliina. Estes conjuntos de foraminíferos indicam que as condições da água de fundo durante o Cenomaniano médio são caracterizadas pela periodicidade no oxigênio e salinidade. Todas as espécies de foraminíferos planctônicos são oportunistas relacionadas com condições eutróficas e pouco oxigenadas intercaladas por um curto intervalo de ambiente bem oxigenado com planólitos. A abundância máxima de *Whiteinella* e *Muricohedbergella* e a quantidade mínima de espécies de *Planoheterohelix* dentro do Cenomanian de Djebel Azeb reflete a diminuição da paleosalinidade durante este tempo, exceto um ligeiro aumento no meio da secção.

**Palavras-chave:** Foraminifera, corais, bioestratigrafia, oxigênio, salinidade, Cretáceo.

## INTRODUCTION

The Djebel Azem area is located in the Bellema-Batna Mountains range of southern Algeria (Figures 1A and B). It comprises carbonate platform deposits that are mainly from the Jurassic and Cretaceous periods (Marmi, 1995). It is bordered by the Aures Basin to the southwest and constitutes the eastern extension of the Hodna mountains. This region also limits the Barika Basin to its east (Bureau, 1972, 1975; Bellion, 1972; Vila, 1980). The Bellezma-Batna Mountains are part of the Algerian Saharan Atlas domain, which extends from the Moroccan High Atlas to the Tunisian Atlas.

From a structural perspective, the Bellezma-Batna Mountains are characterized by large folds of NE-SWdirection that were affected by NW-SE dextral accidents. The structure of this area was generated mainly by the Atlasic and Alpine phases (Yahiaoui, 1990; Herkat, 2007). Because of this tectonic activity, the stratigraphic sequence records a great complexity of facies changes and fluctuations of the microfauna contents (foraminifera and ostracods) that reveal changes in the depositional environment.

Most stratigraphic and sedimentological studies of northeastern Algeria and Bellezma-Batna Mountains have been focused mainly on fossil bioaccumulations at the Cenomanian–Turonian boundary (Chikhi-Aouimeur, 1983, 1998, 2010; Herkat, 2007; Grosheny *et al*., 2008; Ruault-Djerrab& Kechid-Benkherouf, 2010; Chikhi-Aouimeur *et al*., 2011; Ruault-Djerrab *et al*., 2012; Aouissi *et al*., 2018, 2022; Slami *et al*., 2018; Bensekhria *et al*., 2019, Mendir *et al*., 2019; Benmansour, 2023). However, paleoenvironmental investigations in this area have not been undertaken since the study of Yahiaoui (1990). The aim of this work is to establish a lithostratigraphical study with a micropaleontological investigation of the planktic and benthic foraminifera to improve the Cenomanian biostratigraphy, and to highlight the relationship between foraminifera and the paleoenvironment features.

## MATERIAL AND METHODS

Lithological and paleontological descriptions are given for the Djebel Azeb section (geographic coordinates: 35°34'15.90"N and 06°11'33.42.6"E) (Figure 1C). The results presented here are based on the analysis of 48 samples that are arranged regularly along the section. The marly samples (27 samples) were prepared by the standard mechanical and chemical washing methods. In all, 500 g of sediment were soaked in water that contained a small quantity of hydrogen

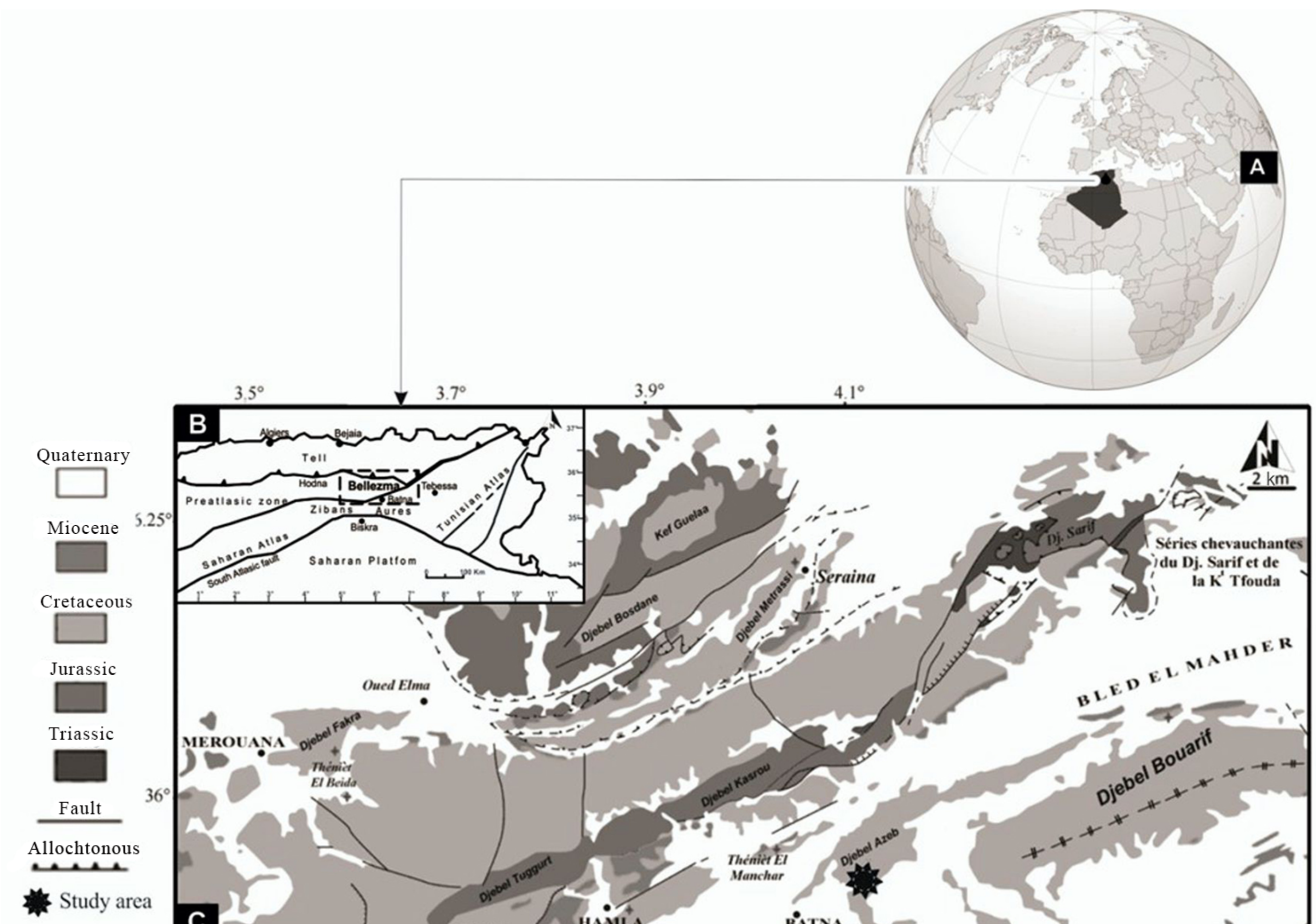


**Figure 1. A**, geographic location of Algeria. **B**, main structural domains of northwest Africa and location of the studied area in eastern Algeria (*in* Herkat, 2007). **C**, geological map of the studied area (according to the geological map 1/50,000 of Merouana-el ksar; *in* Salmi-Laouar *et al*., 2019).

peroxide for 24 hours. After disintegration, the mixture was washed over three sieves of 1 mm, 200 µm, and 63 µm mesh to remove the clay fractions. Afterward, the residue was dried and examined for foraminifera and ostracods. More than 200 specimens were counted in each sample. The collected specimens were photographed using the Scanning Electron Microscope (SEM) of the Department of Mechanics, Abrouk Madani Center, University of Batna 2. A total of 21 thin sections were made of the hard limestone levels, where foraminifera were also identified using a monocular polarizing microscope and photographed using a Sony Cyber-shot DSC-W670 16.1 MP 88 1/2.3” CCD compact camera. The collected material is stored in the collection of the Paleontology Laboratory of the Geological Department of Batna 2, Mostefa Ben Boulaïd University, Algeria.

The taxonomy used in the description of foraminifera follows Robaszynski & Caron (1979), Robaszynski *et al*. (1984), Caron (1985), and Amédro & Robaszynski (2008). The biozonation of Kennedy & Gale (2017) is used for the ammonites.

Paleoenvironmental and paleoecological indicators were obtained using the results of the count of microfauna. About 300 individuals of ostracods and foraminifera (benthic and planktic) were collected from each marl sample. Total abundance, *i.e*., the total number of species (ostracods and foraminifera), the relative abundance of planktic foraminifera versus total foraminifera, the relative abundance of keeled planktic foraminifera *versus* globular forms, the relative abundance of agglutinated foraminifera *versus* the total benthic foraminifera, and the P/P+B ratio (“oceanicity index”) are commonly used to estimate the depositional depth (Boltovskoy & Wright, 1976; Gibson, 1989; Van der Zwaan *et al*., 1990, 1999). All primary data are given in Table 1.

## LITHOLOGY

The Djebel Azeb section forms the middle part of the “Marnes de Smail” Formation, which was first introduced in the lithostratigraphy of Algeria in the early 1990s by Yahiaoui (1990) to designate the Cenomanian marine deposits. The study area reaches about 40 m-thick and is dominated by marls with the intercalation of some thin limestone layers. This Formation can be divided into units:

*Unit I: Yellowish marl-limestones with bivalves*

This unit, of about 20 m-thick, comprises yellowish marls with bivalves (*Ceratostreon flabellatum* (Goldfuss, 1833), *Ilymatogyra africana* (Lamarck, 1801), *Rhynchostreon suborbiculatum* (Lamarck, 1801)) ammonites (*Eucalycoceras batnense* Collignon, 1937), gastropods, and echinoids, interbedded with thin limestone beds. This unit is also rich in corals assigned to *Aspidiscus cristatus* (Lamarck, 1801), giving it a middle to late Cenomanian age (Pomel, 1872; Gill & Lafuste, 1987; Gill & Chikhi, 1991; Pandey *et al*., 2011). However, according to Aouissi *et al*. (2018) and Salmi-Laouar *et al*. (2019), the age of this unit is only middle Cenomanian. This unit is topped by an erosional surface and is composed of indurated bioclastic limestones containing fragments of bivalves and *Planolites*, which are well-observed.

*Unit II: Yellowish to greenish marl-limestones with ammonites*

This unit is about 20 m-thick. It consists of 9 m of alternations of yellowish marls containing embedded *Calycoceras* (*Newboldiceras*) *asiaticum* (Jimbo, 1894) and isolated corals with 2 m of gray and fine-grained limestones beds. The upper part of this unit consists of alternations of fine-bedded bioclastic limestone, of about 30 cm-thick, and greenish marls with many macrofossils: *Calycoceras* (*Newboldiceras*) *asiaticum* (Jimbo, 1894), *Turrilites acutus* Passy, 1832, *Aspidiscus cristatus* (Lamarck, 1801), pholadomids, gastropods, and some echinoids.

## BIOSTRATIGRAPHY

The Cenomanian succession of the studied area contains various faunal assemblages. Ammonites, planktic foraminifera, and corals have been collected from the “Marnes de Smail” Formation. On the basis of these assemblages, a biostratigraphic framework is established.

### Zonation based on ammonites and corals

The Djebel Azeb section is rich in corals that have been attributed to *Aspidiscus cristatus* (Lamarck, 1801). These corals are distributed throughout all the section. According to Ayoub-Hannaa (2011), the middle Cenomanian is defined by the *Aspidiscus cristatus* (Lamarck, 1801) Total Range Zone. Associated faunal elements found in this biozone are similar to those found in Egypt by Ayoub-Hannaa (2011). There are mainly oysters: *Ceratostreon flabellatum* (Goldfuss), *Ilymatogyra africana* (Lamarck, 1801), and *Rhynchostreon suborbiculatum* (Lamarck, 1801).

According to Aouissi *et al*. (2018, 2020) and Salmi-Laouar *et al.* (2019), in the Batna province, most of the specimens of *Aspidiscus cristatus* were collected in the middle part of the “Marnes de Smail” Formation. The stratigraphic distribution of this scleractinian established by these authors extends the *Cunningtoniceras inerme* Zone from the base of the middle Cenomanian, to the *Acanthoceras jukesbrownei* and the *Acanthoceras amphibolum* Zone, at the top of the middle Cenomanian (Table 2). The abundance distribution of this taxon corresponds to the *Acanthoceras rhotomagense* Zone, from the middle part of the middle Cenomanian (Aouissi *et al*., 2020).

The recorded ammonite assemblages in the Azeb section consist of *Eucalycoceras batnense* Collignon, 1937 (Figure 2A), which occurs at the base of the section (in sample 16). This species has a long-range, that coexists with *Turrilites costatus* and *Turrilites acutus* within the *Acanthoceras rhotomagense* Zone (Kennedy & Gale, 2017). At the base of the unit II (in sample 27), *Calycoceras* (*Newboldiceras*) *asiaticum* (Jimbo, 1894) (Figure 2B) is reported. It indicates a middle and lower upper Cenomanian age (Kennedy & Gale, 2017). *Turrilites acutus* Passy, 1832, in samples 33 and 44 (Figures 2C–D) indicates the base of the succeeding *Turrilites acutus* Subzone

**Table 1.** Count of the microfauna and vertical evolution of the main paleoenvironmental parameters in the Djebel Azeb section. **Abbreviations: B**, benthic foraminifera; **BA**, agglutinated benthic foraminifera; **BC**, calcareous benthic foraminifera; **BT**, total sorting of benthic foraminifera; **E (m)**, paleo-depth in meters; **O**, ostracods; **OL**, smooth ostracods; **OR**, ornate ostracods; **OT**, total sorting of ostracods; **P**, Planktic foraminifera; **PC**, keeled planktic foraminifera; **PG**, globular planktic foraminifera; **PT**, total sorting of planktic foraminifera; **S**, samples; **T**, total sorting.

| S | T | OT | O% | Or | OR% | Os | Os% | BT | B% | BC | BC | BA | BA% | PT | P% | PC | PC% | PG | PG% | P/P+B | C/C+G | F/F+O | E(m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 315 | 133 | 42.2 | 0 | 0 | 133 | 100 | 30 | 9.52 | 17 | 56.7 | 13 | 43.3 | 152 | 48.25 | 0 | 0 | 152 | 100 | 0.83 | 0 | 0.57 | 198.7 |
| 9 | 342 | 165 | 48.2 | 0 | 0 | 165 | 100 | 81 | 2..7 | 55 | 67.9 | 26 | 32.1 | 96 | 28.07 | 0 | 0 | 96 | 100 | 0.54 | 0 | 0.51 | 97.38 |
| 11 | 338 | 112 | 33.1 | 8 | 7.14 | 104 | 93 | 91 | 26.9 | 38 | 41.8 | 53 | 58.2 | 135 | 39.94 | 0 | 0 | 135 | 100 | 0.59 | 0 | 0.66 | 148.1 |
| 13 | 301 | 81 | 26.9 | 0 | 0 | 81 | 100 | 104 | 34.6 | 18 | 17.3 | 86 | 82.7 | 116 | 38.53 | 0 | 0 | 116 | 100 | 0.52 | 0 | 0.73 | 141 |
| 14 | 306 | 115 | 37.6 | 0 | 0 | 115 | 100 | 16 | 5.22 | 3 | 18.8 | 13 | 81.3 | 175 | 57.18 | 0 | 0 | 175 | 100 | 0.91 | 0 | 0.62 | 272.5 |
| 16 | 312 | 105 | 33.7 | 0 | 0 | 105 | 100 | 22 | 7.05 | 7 | 31.8 | 15 | 68.2 | 185 | 59.29 | 0 | 0 | 185 | 100 | 0.89 | 0 | 0.66 | 293.6 |
| 17 | 273 | 100 | 36.6 | 0 | 0 | 100 | 100 | 8 | 2.93 | 0 | 0 | 8 | 100 | 160 | 58.6 | 0 | 0 | 160 | 100 | 0.95 | 0 | 0.61 | 286.5 |
| 19 | 300 | 95 | 31.7 | 0 | 0 | 95 | 100 | 180 | 60 | 150 | 83.3 | 30 | 16.7 | 25 | 8.33 | 0 | 0 | 25 | 100 | 0.12 | 0 | 0.68 | 48.48 |
| 22 | 268 | 135 | 50.4 | 0 | 0 | 135 | 100 | 66 | 24.6 | 57 | 86.4 | 9 | 13.6 | 67 | 25 | 0 | 0 | 67 | 100 | 0.5 | 0 | 0.49 | 87.37 |
| 26 | 300 | 140 | 46.7 | 0 | 0 | 140 | 100 | 35 | 11.7 | 30 | 85.7 | 5 | 14.3 | 125 | 41.66 | 0 | 0 | 125 | 100 | 0.78 | 0 | 0.53 | 157.5 |
| 27 | 304 | 102 | 33.6 | 0 | 0 | 102 | 100 | 66 | 21.7 | 11 | 16.7 | 55 | 83.3 | 136 | 44.73 | 0 | 0 | 136 | 100 | 0.67 | 0 | 0.66 | 175.5 |
| 28 | 262 | 141 | 53.8 | 5 | 3.54 | 136 | 96 | 40 | 15.3 | 39 | 97.5 | 1 | 2.5 | 81 | 30.91 | 0 | 0 | 81 | 100 | 0.66 | 0 | 0.46 | 107.7 |
| 29 | 324 | 123 | 38 | 1 | 0.81 | 122 | 99 | 26 | 8.02 | 14 | 53.8 | 12 | 46.2 | 175 | 54.01 | 0 | 0 | 175 | 100 | 0.87 | 0 | 0.62 | 243.6 |
| 30 | 303 | 91 | 30 | 31 | 34.1 | 60 | 66 | 80 | 26.4 | 5 | 6.25 | 75 | 93.8 | 133 | 43.89 | 0 | 0 | 133 | 100 | 0.62 | 0 | 0.7 | 170.4 |
| 31 | 90 | 50 | 55.6 | 4 | 8 | 46 | 92 | 18 | 20 | 16 | 88.9 | 2 | 11.1 | 22 | 24.44 | 0 | 0 | 22 | 100 | 0.55 | 0 | 0.44 | 85.67 |
| 33 | 300 | 45 | 15 | 0 | 0 | 45 | 100 | 103 | 34.3 | 100 | 97.1 | 3 | 2.91 | 150 | 50 | 0 | 0 | 150 | 100 | 0.59 | 0 | 0.84 | 211.4 |
| 37 | 216 | 139 | 64.4 | 110 | 79.1 | 29 | 21 | 51 | 23.6 | 30 | 58.8 | 21 | 4.,2 | 26 | 12.03 | 0 | 0 | 26 | 100 | 0.33 | 0 | 0.35 | 55.26 |
| 38 | 304 | 170 | 55.9 | 70 | 41.2 | 100 | 59 | 6 | 1.97 | 5 | 83.3 | 1 | 16.7 | 128 | 42.1 | 0 | 0 | 128 | 100 | 0.95 | 0 | 0.44 | 159.9 |
| 39 | 303 | 152 | 50.2 | 65 | 42.8 | 87 | 57 | 12 | 3.96 | 2 | 16.7 | 10 | 83.3 | 139 | 45.87 | 0 | 0 | 139 | 100 | 0.92 | 0 | 0.49 | 182.7 |
| 40 | 314 | 140 | 44.6 | 62 | 44.3 | 78 | 56 | 41 | 13.1 | 4 | 9.75 | 37 | 90.2 | 133 | 42.35 | 0 | 0 | 133 | 100 | 0.76 | 0 | 0.55 | 161.3 |
| 41 | 275 | 53 | 19.3 | 23 | 43.4 | 40 | 75 | 76 | 27.6 | 5 | 6.57 | 71 | 93.4 | 136 | 49.45 | 0 | 0 | 136 | 100 | 0.64 | 0 | 0.77 | 207.3 |
| 42 | 337 | 99 | 29.4 | 9 | 9.09 | 90 | 91 | 145 | 43 | 22 | 15.2 | 123 | 84.8 | 123 | 36.49 | 0 | 0 | 123 | 100 | 0.45 | 0 | 0.79 | 131.2 |
| 43 | 307 | 98 | 31.9 | 3 | 3.06 | 95 | 97 | 66 | 21.5 | 27 | 40.9 | 39 | 59.1 | 143 | 46.57 | 0 | 0 | 143 | 100 | 0.68 | 0 | 0.68 | 187.3 |
| 44 | 261 | 127 | 48.7 | 15 | 11.8 | 112 | 88 | 63 | 24.1 | 33 | 52.4 | 30 | 47.6 | 71 | 27.2 | 0 | 0 | 71 | 100 | 0.52 | 0 | 0.51 | 94.44 |
| 45 | 275 | 118 | 42,9 | 13 | 11 | 105 | 89 | 72 | 26.2 | 60 | 83.3 | 12 | 16.7 | 85 | 30.9 | 0 | 0 | 85 | 100 | 0.54 | 0 | 0.57 | 107.7 |
| 46 | 276 | 110 | 39.9 | 48 | 43.6 | 62 | 56 | 84 | 30.4 | 52 | 61.9 | 32 | 38.1 | 82 | 29.71 | 0 | 0 | 82 | 100 | 0.49 | 0 | 0.6 | 103.2 |
| 48 | 262 | 154 | 58.8 | 43 | 27.9 | 111 | 72 | 36 | 13.7 | 24 | 66.7 | 12 | 33.3 | 72 | 27.48 | 0 | 0 | 72 | 100 | 0.66 | 0 | 0.41 | 95.38 |

of the upper *Acanthoceras rhotomagense* Zone of the middle Cenomanian age (Kennedy & Gale, 2017) (See Table 2).

The confrontation of the data delivered by the different authors mentioned above (Ayoub-Hannaa, 2011; Aouissi *et al*., 2018; Slami-Laouar *et al*., 2019) concerning ammonites and corals (*Aspidiscus cristatus*) with those obtained from this study, made it possible to assign a middle Cenomanian age to the Djebel Azeb section (Dj. Azeb section).

**Zonation based on planktic foraminifera**

The low diversity of planktic foraminifera (Figure 3) and the absence of index and keeled taxa make it difficult to determine their zonal distribution.

Based on the data collected from previous works, summarized in the Table 2, the *Rotalipora greenhornensis* Subzone (Premoli-Silva & Verga, 2004) of the lower *Rotalipora cushmani* Zone (Gradstein *et al*., 2004; Premoli-Silva & Verga, 2004; Amédro & Robaszynski, 2008) was adopted for the Dj. Azeb section.

## PALEOECOLOGICAL INTERPRETATION

In the last 20 years, foraminiferal paleoecology became a significant field of micropalaeontology. According to Kalanat *et al*. (2016), important changes in foraminiferal assemblages can be interpreted as reflecting ecological responses to paleo-oceanographic variations. Among other foraminifera, the ecology of planktic foraminifera is useful in sea level changes analysis from Middle and Late Cretaceous sequences (Hart & Carter, 1975; Nebrigic, 2006; Ardestani *et al*., 2013).

Within a stratified water column with normal salinity, nutrients, and good oxygen content, recent planktic foraminifera reaches their highest diversity (Hart, 1980a, b; Leckie *et al*., 1998; Hallock *et al*., 1991; Keller *et al*., 2001; Keller & Pardo, 2004a). In these environmental conditions, large, keeled, deep-water dwelling forms (K strategists, such as: *Rotalipora* and *Helvetoglobotruncana*) proliferate. However, diversity is low and opportunistic taxa (r strategists, like: *Planoheterohelix*, *Muricohedbergella* and *Whiteinella*) are common when environmental conditions are more severe (Keller *et al*., 2001; Coccioni & Luciani, 2004; Reolid *et al*., 2016).

The Dj. Azeb outcrop is characterized by the dominance of planktic foraminifera compared to the benthic foraminifera and ostracods. They are varying from 8% in samples B19 to 59% in sample 16 (see Figure 3 and Table 1), knowing that the percentage of planktic foraminifera (P%) is calculated by: the number of planktics (100%)/the total of microfossils (planktic + benthic + ostracods). The species richness changes from one (in samples 13, 14, 16, 27, 33, and 39) to four (in sample 9). In all samples, only morphotypes of planktic foraminifera with globular chambers and trochospiral test are present (Figure 4). They included *Muricohedbergella delrioensis*, *Muricohedbergella planispira*, *Muricohedbergella* sp., *Clavihedbergella simplex*, *Whiteinella* sp., *Whiteinella baltica*, *Planoheterohelix globulosa* and *Planoheterohelix moremani.* Keeled forms are absent in all the studied section. Benthic foraminifera were poorly represented in the samples collected in the study area (percentage varies from 1.97% in sample 38 to 43% in sample 42). Although 18 taxa were identified (Figures 5 and 6), of which 8 were identified at species level, two cf. and eight were identified at genera level.

The species richness changes from one to six. Infaunal forms are dominant relative to epifaunal ones. They belong to the Textulariina (*Textularia* sp. and *Eggerellina* sp.), Lituolina (*Ammomarginulina loricata* and *Ammobaculites* sp.),

**Table 2.** Middle Cenomanian fauna and microfauna biozonations and their correlation with Djebel Azeb section.

<table>
<tr><th rowspan="3">Age</th><th colspan="15">Tethys realm biozonation</th></tr>
<tr><th colspan="3">Gale (1995) : W Europe</th><th colspan="2">Premoli-Silva and Verga (2004)</th><th colspan="2">Amédro and Robaszynski (2008): NW Europe</th><th colspan="2">Kennedy et al. (2013; 2017): NW Europe</th><th colspan="2">Aouissi et al. (2018; 2020) bellezma-Batna Mountains</th><th colspan="4">This study</th></tr>
<tr><th>Ammonites Zone</th><th>Ammonites Subzone</th><th>Planktic foraminifera</th><th colspan="2">Planktic foraminifera</th><th>Ammonites</th><th>Planktic foraminifera</th><th>Ammonites Zone</th><th>Ammonites Subzone</th><th>Ammonites</th><th>Corals</th><th>Ammonites Zone</th><th>Ammonites Subzone</th><th>Planktic foraminifera</th><th>Corals</th></tr>
<tr><td rowspan="4">middle Cenomanian</td><td colspan="2">Acanthoceras jukesbrownei</td><td rowspan="2">Rotalipora cushmani</td><td rowspan="3">Rotalipora cushmani</td><td rowspan="3">Rotalipora greenhornensis</td><td>Acanthoceras jukesbrownei</td><td rowspan="3">Rotalipora cushmani</td><td>Acanthoceras jukesbrownei</td><td></td><td>Acanthoceras jukesbrownei Acanthoceras amphibolum</td><td rowspan="4">Aspidiscus cristatus</td><td>Acanthoceras jukesbrownei</td><td>?</td><td>?</td><td></td></tr>
<tr><td rowspan="2">Acanthoceras rhotomagense</td><td>Turrilites acutus</td><td rowspan="2">Acanthoceras rhotomagense</td><td rowspan="2">Acanthoceras rhotomagense</td><td>Turrilites acutus</td><td rowspan="2">Acanthoceras rhotomagense</td><td rowspan="3">Acanthoceras rhotomagense</td><td>Turrilites acutus</td><td>Rotalipora cushmani ?</td><td>Aspidiscus cristatus</td></tr>
<tr><td>Turrilites costatus</td><td rowspan="2">Rotalipora reicheli</td><td>Turrilites costatus</td><td rowspan="2">?</td><td rowspan="2">?</td><td rowspan="2"></td></tr>
<tr><td colspan="2">Cunningtoniceras inerme</td><td colspan="2">Rotalipora reicheli / Rotalipora globotruncanoides</td><td>Cunningtoniceras inerme</td><td>Rotalipora reicheli</td><td>Cunningtoniceras inerme</td><td></td><td>Cunningtoniceras inerme</td></tr>
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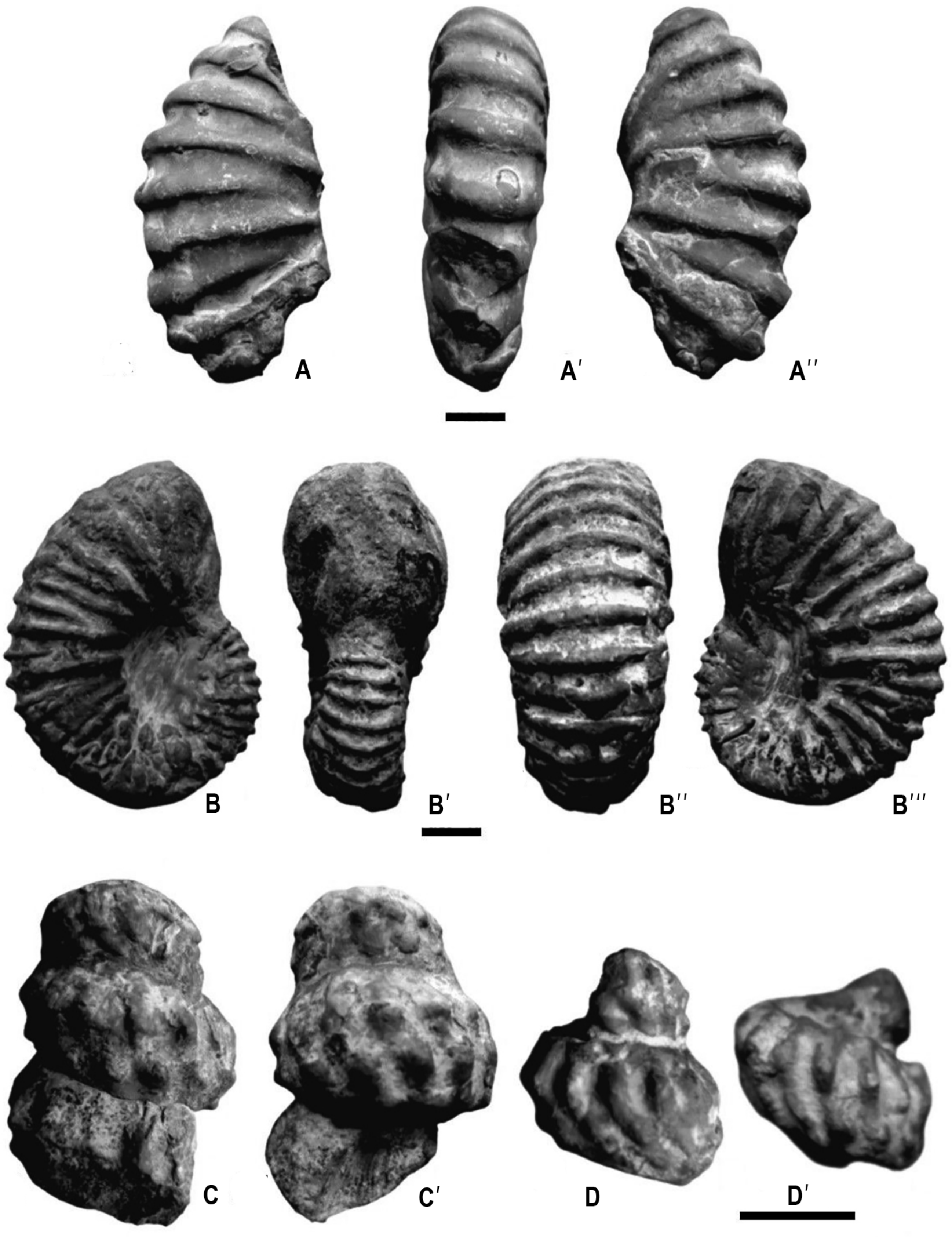


**Figure 2.** Assemblage of ammonites. **A**, *Eucalycoceras batnense* Collignon, 1937; **B**, *Calycoceras (Newboldiceras) asiaticum* (Jimbo, 1894); **C-D**, *Turrilites acutus* Passy, 1832. Scale bars: 10 mm.

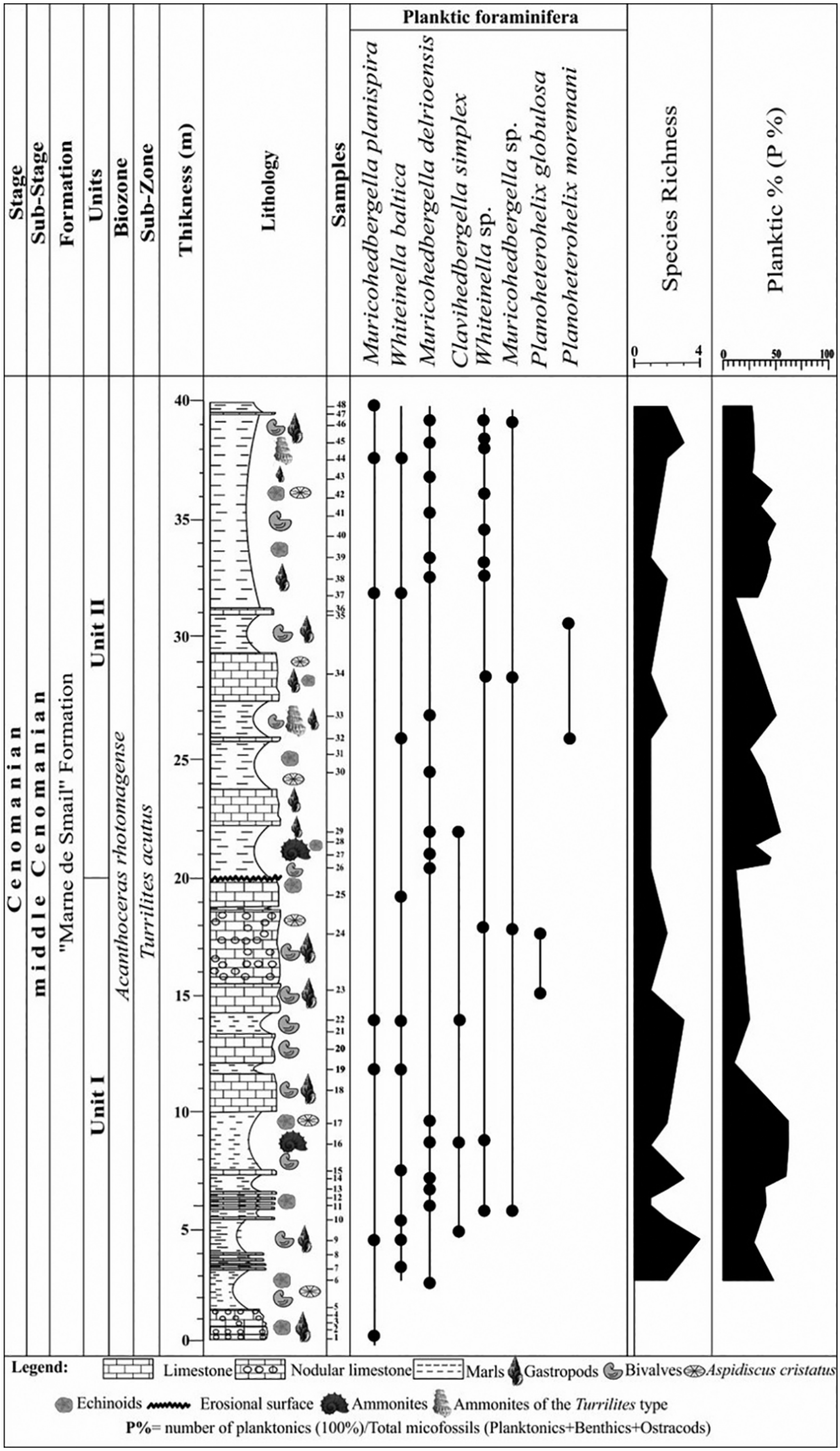


**Figure 3.** Planktic foraminifera: distribution and quantitative parameters.

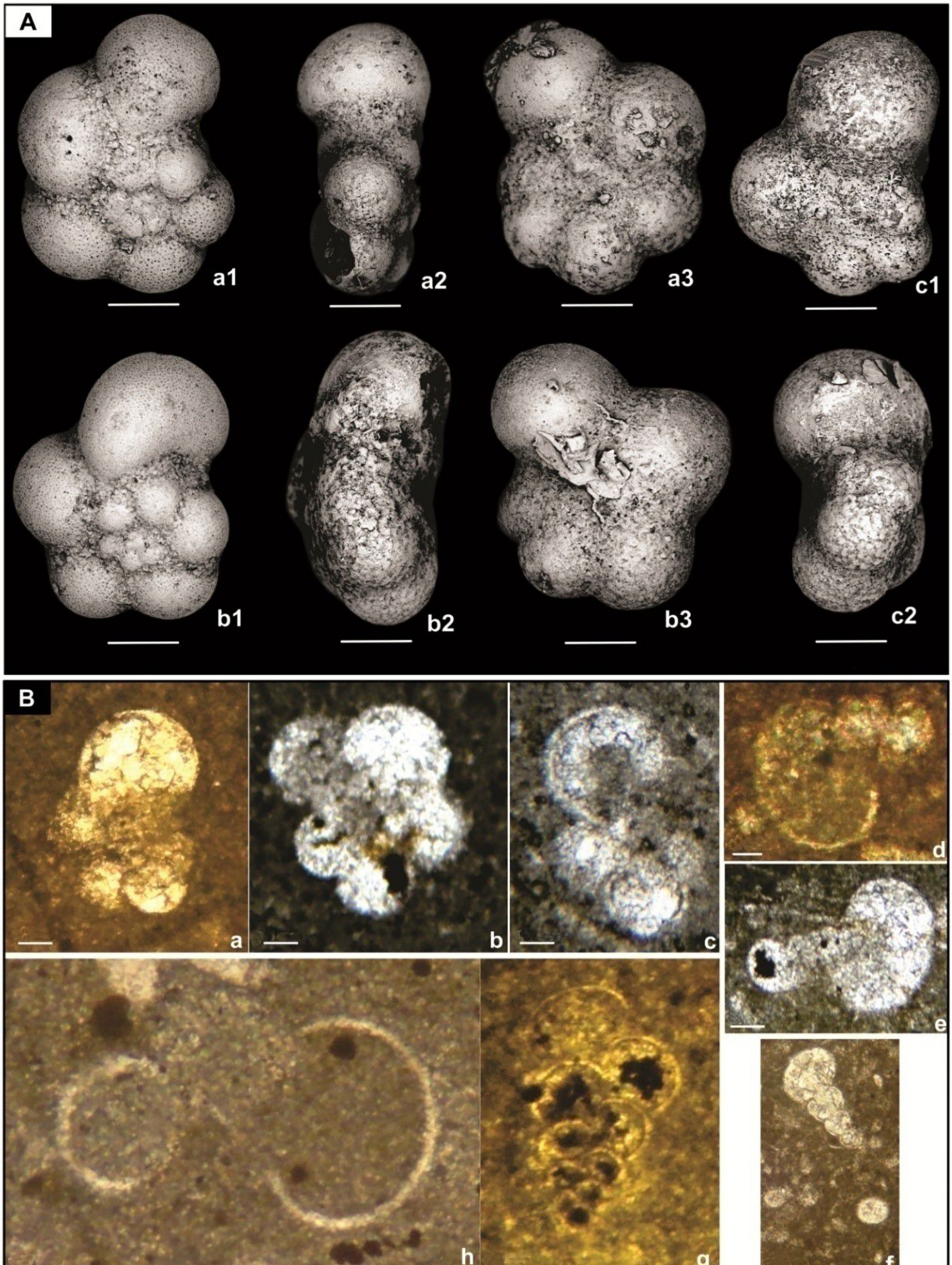


**Figure 4.** Planktic foraminifera. **A**, Scanning electron micrographs: **1**, spiral side; **2**, lateral view; **3**, umbilical side; **a1–a3**, *Muicohedbergella planispira*; **b1–b3**, *Muicohedbergella delrioensis*; **c1–2**, *Whiteinella baltica*. **B**, Planktic foraminifera in thin sections: **a-b**, *Muricohedbergella delrioensis*; **c**, *Muricohedbergella* sp.; **d–h**, *Whiteinella* sp.; **e**, *Whiteinella baltica*; **f–g**, *Planoheterohelix globulosa*. Scale bars: A = 100 µm; Ba–g = 0.1 mm; Bh = 0.05 mm.

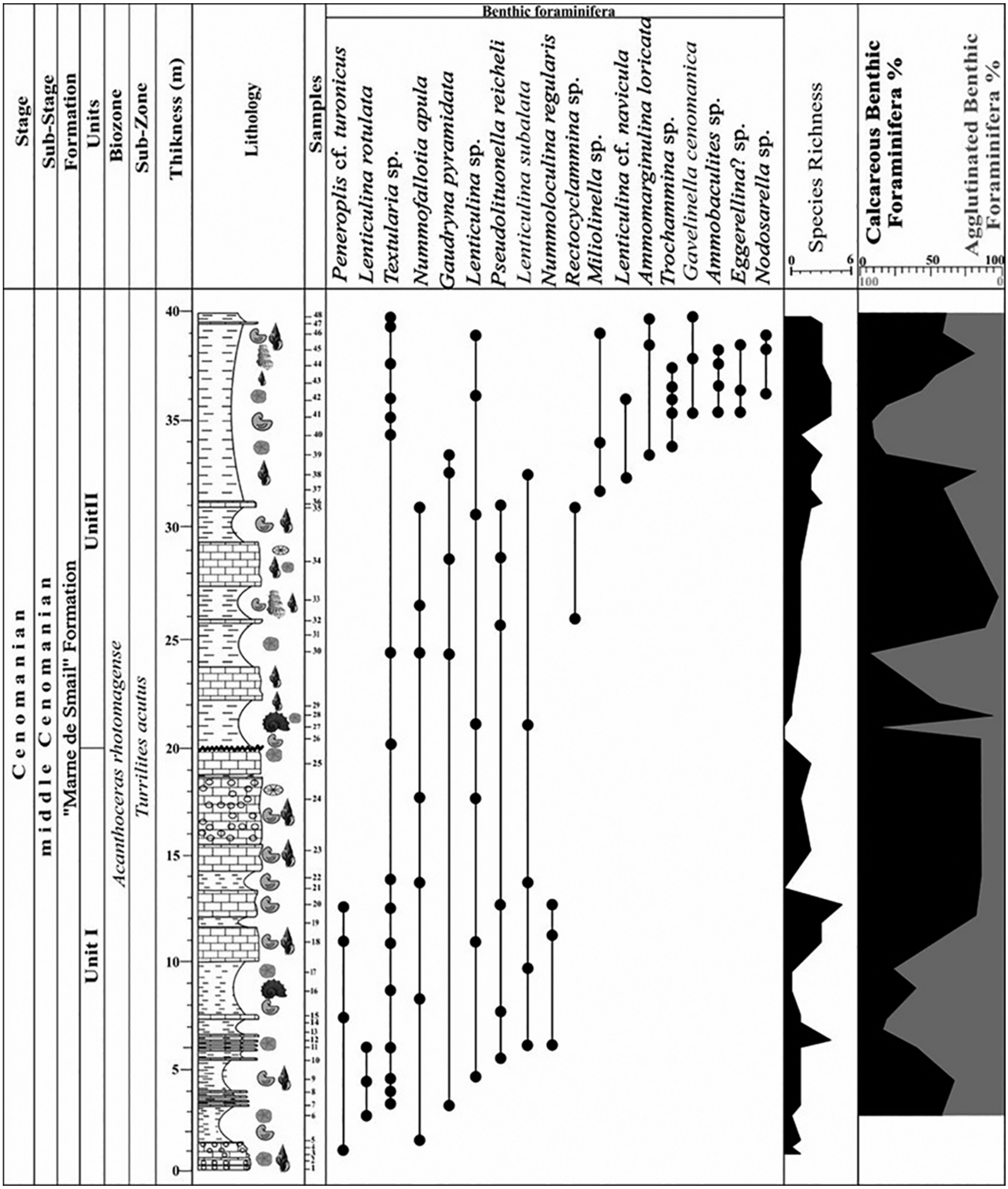


**Figure 5.** Benthic foraminifera: distribution and quantitative parameters.

Trochamminina (*Trochammina* sp.), Verneuilinina (*Gaudryna pyramida*), Loftusiina (*Rectocyclammina* sp.), Orbitolinina (*Pseudolituonella reicheli*), Miliolina (*Miliolinella* sp., *Peneroplis* cf. *turonicus*, *Nummoloculina regularis*, *Nummofallotia apula*), and Rotaliina (*Lenticulina subalata*, *Lenticulina rotulata*, *Lenticulina* cf. *navicula*, *Lenticulina* sp., *Gavelinella cenomanica*, and *Nodosarella* sp.). Based on changes in distribution and diversity of foraminifera, the planktic/benthic foraminiferal ratios and paleodepth, three regressive cycles are distinguished (Figure 7). In each cycle, the maximum depth is synchronous with the abundance of *Mu. delrioensis*, which is considered as a deep-dwellers form and is also documented in oxygen-deficient environments (Coxall *et al.*, 2007; Ando *et al.*, 2010; Reolid *et al.*, 2015, 2016). The high proportion of the agglutinated taxa, mainly Textulariina, indicates deep water depths (Holbourn *et al.*, 2001), probably

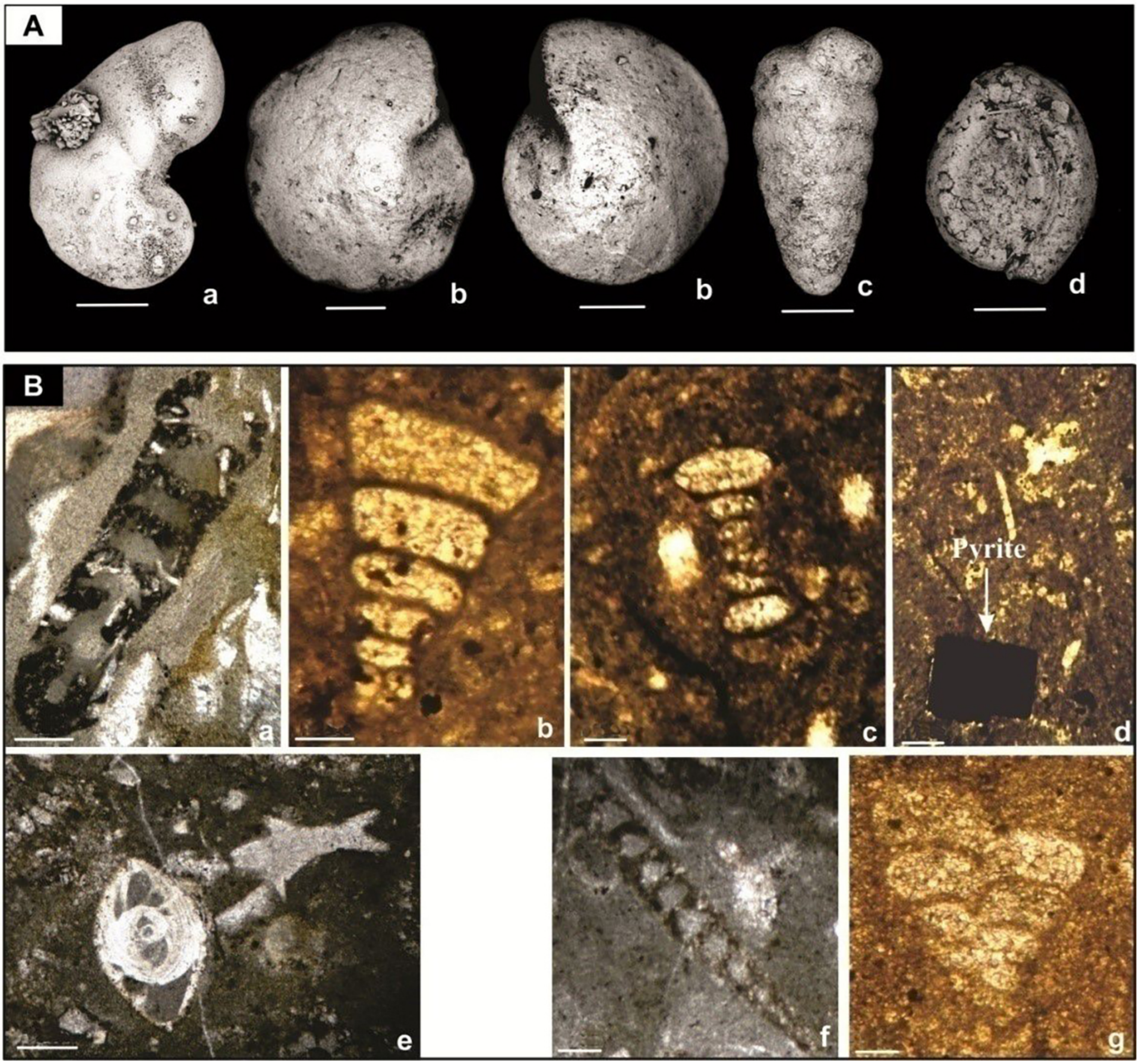


**Figure 6.** Benthic foraminifera. **A**, Scanning electron micrographs: **a**, *Lenticulina* sp.; **b**, *Lenticulina subalata*; **c**, *Textularia* sp.; **d**, *Milionella* sp. **B**, benthic foraminifera in thin sections: **a**, *Ammobaculites* sp.; **b**, *Pseudolituonella reicheli*; **C**, *Nummoloculina regularis*; **d**, Pyrite *Whiteinella* sp.; **e**, *Nummofallotia apula*; **f**, *Peneroplis* cf. *turonicus*; **g**, *Textularia* sp. Scale bars: A = 100 µm; B = 1 mm.

an outer shelf or upper slope environment (Tronchetti,1981; Grosheny &Tronchetti, 1988). The ends of these cycles are dominated by *Muricohedbergella planispira* and *Whiteinella baltica*. Stable isotope analysis revealed that these two species are restricted to shallow waters and are dominant in surface waters (Hart, 1999; Price & Hart, 2002). It also revealed that these two species are opportunist surface-dwellers adapted to poorly oxygenated, eutrophic waters (Coccioni & Luciani, 2004; Reolid *et al*., 2015) or to variable salinity and nutrient levels (Keller & Pardo, 2004a, b). This association of planktic foraminifera is synchronous with a comparable abundance of Rotaliina which characterizes shallow shelf environments (Sliter & Baker, 1972; Grosheny & Malartre, 2002). Toward the end of the unit I, the occurrence of *Planoheterohelix* (*Heterohelix* before Haynes *et al*., 2015) is recorded. It is known as a high-tolerant species and an indicator of poorly oxygenated eutrophic conditions (Keller *et al*., 2004). At the top of the unit I, a surface with *Planolites* is identified. This ichnofabric is interpreted as a short, well-oxygenated interval punctuating an oxygen-depleted environment (Rodríguez-Tovar *et al*., 2009).

In order to understand the paleosalinity of the environment during the Cenomanian in Dj. Azeb section, planktic foraminifera are used for this purpose since they are considered as proxies in paleosalinity interpretations. The genera *Muricohedbergella* and *Whiteinella* are among the most typical species that are useful in interpreting salinity changes in ancient marine paleoecosystems (Wolff *et al*.,

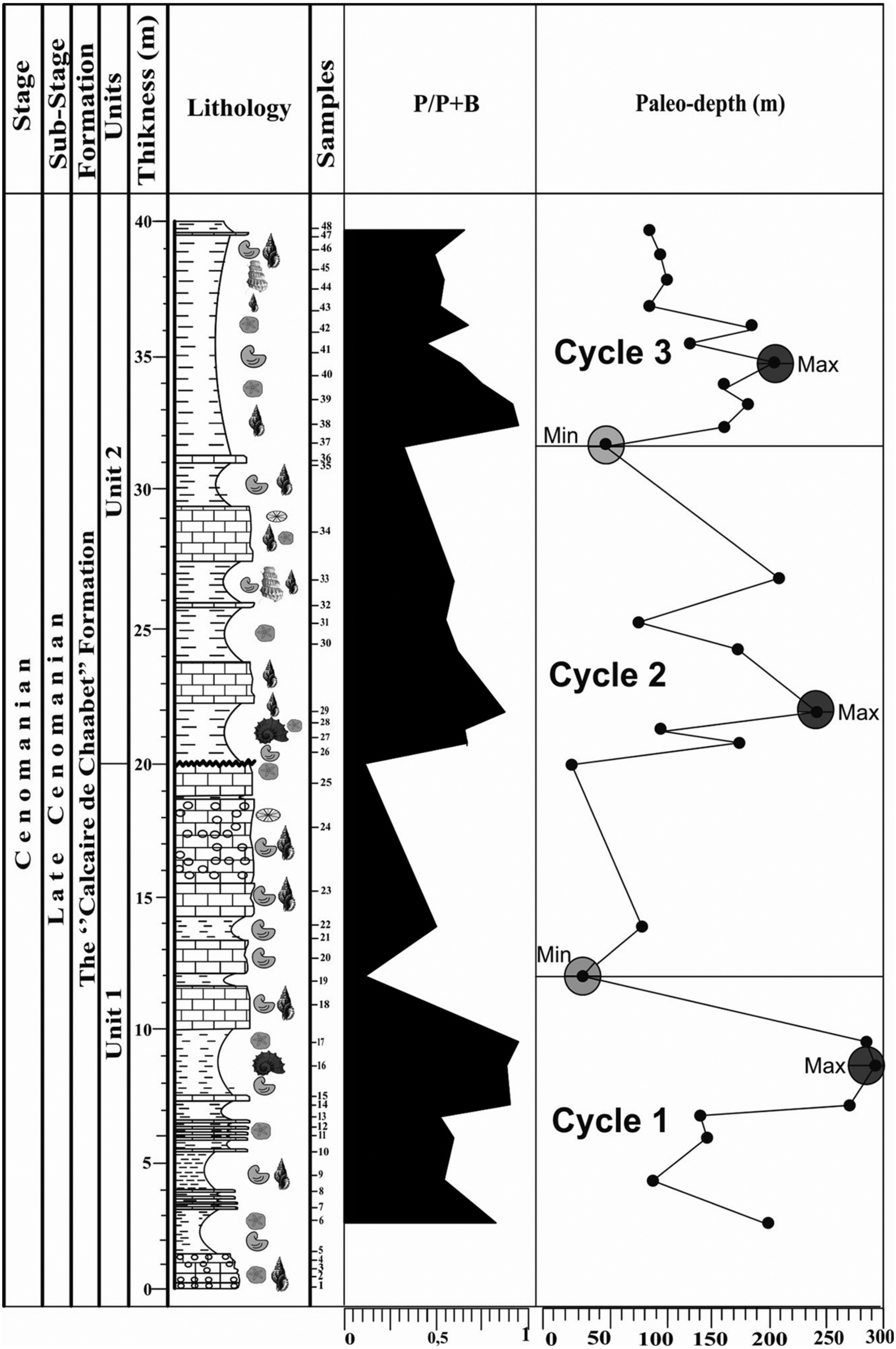


**Figure 7.** Paleobathymetry indicators.

1999; Pierre, 1999; Ardestani *et al*., 2013). The maximum abundance of *Whiteinella* and *Muricohedbergella* and the minimum amount of *Planoheterohelix* species within the Cenomanian sediments, reflect dwindling palaeosalinity during this time. In contrast, a minimum frequency of *Whiteinella* and *Muricohedbergella* and a maximum number of *Planoheterohelix* species represent an increase in the salinity of the marine environment. In the studied section, *Whiteinella* and *Muricohedbergella* are dominated in the quasi-totality of the section, except at the summit of the Unit I and the beginning of the Unit II, where *Planoheterohelix* appeared. Overall, these data show that the salinity of Djebel Azeb decreased during the middle Cenomanian, except a slight increase in the middle of the section.

## CONCLUSIONS

The Djebel Azeb section of the Bellezma-Batna Mountains in northeastern Algeria has been studied in detail. The present study focuses on lithostratigraphy, biostratigraphy, and the frequency and abundance of foraminifera. These analyses produced the following results:

1. The Djebel Azeb succession coincides with the middle part of the "Marnes de Smail" Formation. It shows a powerful clay-marl mass interspersed with lumachellic limestone beds.

2. The studied section has been assigned to the middle Cenomanian based on the *Turrilites acutus* Subzone of the upper part of the *Acanthoceras rhotomagense* Zone, which corresponds to the *Aspidiscus cristatus* Total Range Zone. The low diversity of planktic foraminifera, and the absence of keeled and index taxa, makes it difficult to establish a zonal assignment for the studied section. However, an attempt has been made based on the biozonation of corals and ammonites. According to the data of planktic foraminifera, collected from the Djebel Azeb outcrops, a Subzone of *Rotalipora greenhornensis* of the lower *Rotalipora cushmani* Zone was adopted for this outcrop.

3. The study of foraminifera has been performed on 48 samples, revealing only one assemblage of planktic foraminifera with globular chambers and trochospiral test. They are recognized as belonging to the Cenomanian-Turonian; no association is typically restricted to the middle Cenomanian. The benthic foraminifera are poorly represented, belonging to the orders Textulariina, Lituolina, Trochamminina, Verneuilinina, Loftusiina, Orbitolinina, Miliolina, and Rotaliina.

4. The Djebel Azeb section is characterized by the dominance of planktic foraminifera indicative of severe environmental conditions, reflected by the low diversity and the dominance of opportunistic taxa (r strategists, *Planoheterohelix*, *Muricohedbergella*, and *Whiteinella*).

5. Some statistical calculations of foraminifera reflect an alternation between deep-water conditions, synchronous with the abundance of deep-dwellers forms of *Mu. delrioensis* and shallow water environment contemporary with the dominance of opportunistic surface-dweller forms of *Muricohedbergella planispira* and *Whiteinella baltica*.

6. All planktic species reported from the studied section are interpreted as opportunists related to poorly oxygenated, eutrophic conditions. These oxygen depletion conditions are punctuated by a short, well-oxygenated interval with *Planolites*.

7. The bottom water conditions in the studied area are characterized by periodic changes of salinity. The maximum abundance of *Whiteinella* and *Muricohedbergella* and the minimum amount of *Planoheterohelix* species within the Cenomanian sediments reflect dwindling palaeosalinity during this time. In contrast, a minimum frequency of *Whiteinella* and *Muricohedbergella* and a maximum number of *Planoheterohelix* represent an increase in the salinity of the marine environment.

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## REFERENCES

Amédro, F. & Robaszynski, F. 2008. Zonation by ammonites and foraminifers of the Vraconnian-Turonian interval: a comparison of the Boreal and Tethyan domains (NW Europe/Central Tunisia). *Carnets de Géologie*, **2**:1–5.

Ando, A.; Huber, B.T. & MacLeod, K.G. 2010. Depth-habitat reorganization of planktonic foraminifera across the Albian/Cenomanian boundary. *Paleobiology*, **36**:357–373. *doi:10.1666/09027.1*

Aouissi, R.; Salmi-Laouar, S.; El Qot, G.M. & Ferré, B. 2020. Cenomanian cephalopods of Bellezma-Aures mountains, NE Algeria: Taxonomy and biostratigraphy. *Annales de Paléontologie*, **106**:1–23.

Aouissi, R.; Salmi-Laouar, S.; El Qot, G. & Moneer, E.S.M. 2022. Cenomanian bivalves from Batna Mountains (Saharan Atlas, NE Algeria). *Revista Brasileira de Paleontologia*, **25**:255–273. *doi:10.4072/rbp.2022.4.02*

Aouissi, R.; Salmi-Laouar, S. & Ferré, B. 2018. Macro-invertébrés du Cénomanien du Djebel Metrassi (Batna, NE Algérie): Systématique et biostratigraphie. *Estudios Geológicos*, **74**:367–449.

Ardestani, M.S.; Vahidinia, M. & Sadeghi, A. 2013. Paleoceanography and paleobiogeography patterns of the Turonian-Campanian foraminifers from the Abderaz Formation, North Eastern Iran. *Open Journal of Geology*, **3**:19–27

Ayoub-Hannaa, W.S. 2011. *Taxonomy and palaeoecology of the Cenomanian-Turonian macro-invertebrates from Eastern Sinai, Egypt*. University of Wurzburg, Ph.D. thesis, 386 p.

Bellion, Y.J. 1972. *Etude géologique et hydrogéologique de la terminaison occidentale des Monts de Bellezma (Algérie)*. Thèse Doctorat. Université Paris 6, Ph.D. thesis, 221 p.

Benmansour, S. 2023. Upper Cretaceous bivalves from Northeastern Algeria: Description and paleobiogeography. *Journal of African Earth Sciences*, **198**:1–18. *doi:10.1016/j.jafrearsci.2022.104787*

Bensekhria, A.; Marmi, R. & Yahiaoui, A. 2019. Cenomanian and lower Turonian relative chronology and palaeoenvironmental framework of the Nouader site (Aures Basin, northeastern Algeria). *Geological Magazine*, **156**:1877–1891. *doi:10.1017/S0016756819000153*

Boltovskoy, E. & Wright, R. 1976. *Recent Foraminifera*. The Hague, Junk, 515 p.

Bureau, D. 1972. Le Cenomanien et le Turonien des Monts de Batna (Aures). *Société géologique de France*, **5**:206–207.

Bureau, D. 1975. Esquisse géologique des Monts du Bellezma (Aures, Algérie). *Publication du Service de Carte Algérie, Bulletin*, **45**:75–92.

Caron, M. 1985. Cretaceous planktic foraminifera. In: H.M. Bolli; J.B. Saunders & K. Perch-Nielsen (eds.) *Plankton Stratigraphy*, Cambridge University Press, p. 17–86.

Chikhi-Aouimeur, F. 1983. Etude paléontologique de quelques Rudistes de l'Aptien supérieur du Djebel Ouenza (Algérie Nord-Orientale). *Annales de l'Université de Provence Géologie Méditerranéenne*, **101**:33–48.

Chikhi-Aouimeur, F. 1998. Sauvagesiinae du Cénomanien supérieur de la région de Berrouaguia (Sud d'Alger, Algérie). In: J.P. Masse & P.W. Skelton (eds.) *Quatrième Congrès International sur les Rudistes*, Geobios, Mémoire Spécial, vol. 22, p. 101–109.

Chikhi-Aouimeur, F. 2010. *L'Algérie à travers son Patrimoine paléontologique : les Rudistes*. Baosem, 269 p.

Chikhi-Aouimeur, F.; Grosheny, D.; Ferry, S.; Herkat, M.; Jati, M.; Atrops, F.; Redjimi-Bourouiba, W. & Benkhrouf-Kechid, F. 2011. Lithofaciès, paléogéographie et corrélations au passage Cénomanien-Turonien dans l'Atlas saharien (Ouled Nail, Zibans, Aurès et Hodna, Algérie). *Mémoire du Service Géologique National d'Algérie*, **17**:67–83.

Coccioni, R. & Luciani, V. 2004. Planktonic foraminifera and environmental changes across the Bonarelli Event (OAE2, Latest Cenomanian) in its type-area: a high-resolutionstudy from the Tethyan reference Bottaccione section (Gubbio, Central Italy). *Journal of Foraminiferal Research*, **34**:109–129. *doi:10.2113/0340109*

Coxall, H.K.; Wilson, P.A.; Pearson, P.N. & Sexton, P.F. 2007. Iterative evolution of digitate planktonic foraminifera. *Paleobiology*, **33**:495–516. *doi:10.1666/06034.1*

Gibson, T.G. 1989. Planktonic/benthonic foraminiferal ratios: modern patterns and Tertiary applicability. *Marine Micropaleontology*, **15**:29–52. *doi:10.1016/0377-8398(89)90003-0*

Gill, G.A. & Chikhi, F. 1991. Remarks on new occurrences of *Aspidiscus*, a Cenomanian scleractinian coral in the Persian Gulf and in Algeria. *Lethaia*, **24**:349–350. *doi:10.1111/j.1502-3931.1991.tb01485.x*

Gill, G.A. & Lafuste, J. 1987. Structure, répartition et signification paléogéographique d'*Aspidiscus*, hexacoralliaire cénomanien de la Téthys. *Bulletin de la Société Géologique de France*, **3**:921–934.

Gradstein, F.M.; Ogg, J.G.; Smith, A.G.; Bleeker, W.; &Lourens, L.J. 2004. A new geologic time scale, with special reference to the Precambrian and Neogene. *Episodes*, **27**:83–100. *doi:10.18814/epiiugs/2004/v27i2/002*

Grosheny, D.; Chikhi-Aouimeur, F.; Ferry, F.; Benkherouf-Kechid, F.; Jati, M.; Atrops, F. & Redjimi-Bourouiba, W. 2008. The Upper Cenomanian-Turonian (Upper Cretaceous) of the Saharan Atlas (Algeria). *Bulletin de la Société Géologique de France*, **179**:593–603.

Grosheny, D. & Malartre, F. 2002. Reconstruction of outer shelf paleoenvironments in the Turonian–Coniacian of Southeast France (micropaleontology – sedimentology). *Marine Micropaleontology*, **47**:117–141. *doi:10.1016/S0377-8398(02)00107-X*

Grosheny, D. & Tronchetti, G. 1988. Réponse des foraminifères benthiques aux variations des conditions de milieux: exemple du Santonien de la Cadière d'Azur (S.E. France). *Revue de Paléobiologie*, **86**:437-445.

Hallock, P.; Premoli Silva, I. & Boersma, A. 1991. Similarities between planktonic and larger foraminiferal evolutionary trends through Paleogene paleoceanographic changes. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **83**:49–64. *doi:10.1016/0031-0182(91)90075-3*

Hart, M.B. 1980a. The recognition of mid-Cretaceous sea-level changes by means of foraminifera. *Cretaceous Research*, **1**:289–297. *doi:10.1016/0195-6671(80)90040-3*

Hart, M.B. 1980b. A water-depth model for the evolution of the planktic Foraminiferida. *Nature*, **286**:252–254. *doi:10.1038/286252a0*

Hart, M.B. 1999. The evolution and biodiversity of Cretaceous planktic Foraminiferida. [Evolution et diversité des Foraminiferida planctoniques du Crétacé]. *Geobios*, **32**:247–255.

Hart, M.B. & Carter, D.J. 1975. Some observation on the Cretaceous foraminifera of south-east England. *Journal of Foraminiferal Research*, **5**:114–126. *doi:10.2113/gsjfr.5.2.114*

Haynes, S.J.; Huber, B.T. & Macleod, K.G. 2015. Evolution and phylogeny of mid-Cretaceous (Albian-Coniacian) Biserial planktic foraminifera. *Journal of Foraminiferal Research*, **45**:42–81. *doi:10.2113/gsjfr.45.1.42*

Herkat, M. 2007. Application of correspondence analysis to palaeobathymetric reconstruction of Cenomanian and Turonian (Cretaceous) rocks of eastern Algeria. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **254**:583–605. *doi:10.1016/j.palaeo.2007.07.011*

Holbourn, A.; Kuhnt, W. & Soeding, E. 2001. Atlantic paleobathymetry, paleoproductivity and paleocirculation in the late Albian: The benthic foraminiferal record. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **170**:171–196. *doi:10.1016/S0031-0182(01)00223-1*

Kalanat, B.; Vahidinia, M.; Vaziri-Moghaddam, H. & Mahmudy-Gharaie, H. 2016. Planktonic foraminiferal turnover across the Cenomanian –Turonian boundary (OAE2) in the northeast of the Tethys realm, Kopet-Dagh Basin. *Geologica Carpathica*, **67**:451–462.

Keller, G.; Berner, Z.; Adatte, T. & Stueben, D. 2004. Cenomanian–Turonian and delta C13, and delta O18, sea level and salinity variations at Pueblo, Colorado. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **211**:19–43. *doi:10.1016/j.palaeo.2004.04.003*

Keller, G.; Han, Q.; Adatte, T. & Burns, S.J. 2001. Palaeoenvironment of the Cenomanian–Turonian transition at Eastbourne, England. *Cretaceous Research*, **22**:391–422. *doi:10.1006/cres.2001.0264*

Keller, G. & Pardo, A. 2004a. Disaster opportunists Guembelitrinidae: index for environmental catastrophes. *Marine Micropaleontology*, **53**:83–116. *doi:10.1016/j.marmicro.2004.04.012*

Keller, G. & Pardo, A. 2004b. Age and environment of the Cenomanian-Turonian global stratotype section and point at Pueblo, Colorado. *Marine Micropaleontology*, **51**:95–128. *doi:10.1016/j.marmicro.2003.08.004*

Kennedy, W.J. & Gale, A.S. 2017. Trans-Tethyan correlation of the Lower–Middle Cenomanian boundary interval; southern England (Southerham, near Lewes, Sussex) and Douar el Khiana, northeastern Algeria. *Acta Geologica Polonica*, **67**:75–108. *doi:10.1515/agp-2017-0005*

Leckie, R.M.; Uretich, R.F.; West, O.L.O.; Finkelstein, D. & Schmidt, M.G. 1998. Paleoceanography of the southwestern Western Interior Sea during the time of the Cenomaniane–Turonian boundary (Late Cretaceous). In: M.A. Arthur & W.E. Dean (eds.) *Stratigraphy and Paleoenvironments of the Cretaceous Western Interior Seaway, Concepts in Sedimentology and Paleontology*, SEPM Society for Sedimentary Geology, p. 101–126.

Marmi, R. 1995. *Les Sebkhas du sud-constantinois et leur cadre géologique: apports sédimentologiques et géochimiques*,. Université de Nancy 1, Ph.D. thesis. .

Mendir, S.; Salmi-Laouar, S.; Ferré, B.; Belhai, D.; Aouissi, R. & Degaïchia, A. 2019. Les ammonites du Cénomanien des massifs de Hameimat (Tébessa, Atlas saharien oriental, Algérie): systématique et biostratigraphie. *Revue de Paléobiologie*, **38**:229–254.

Nebrigic, D.D. 2006. *Cenomanian–Turonian planktic foraminiferal bioevents during the time of global oceanic anoxic event 2 and maximum sea level rise, Western Interior Basin and Texas Gulf Coast*. University of Texas at Dallas, Ph.D. Thesis, 465 p.

Pandey, D.K.; Fürsich, F.T.; Gameil, M. & Ayoub-Hanna, W.S. 2011. *Aspidiscus cristatus* (Lamarck) from the Cenomanian sediments of Wadi Quseib, east Sinai, Egypt. *Journal of the Palaeontological Society of India*, **56**:29–37.

Pierre, C. 1999. The Carbon and Oxygen isotope distribution in the Mediterranean water masses. *Marine Geology*, **153**:41–55. *doi:10.1016/S0025-3227(98)00090-5*

Pomel, A. 1872. *Paléontologie ou description des animaux fossiles de la province d'Oran. Zoophytes, 5ème fascicule, Spongiaires*. Oran, Perrier, 256 p.

Premoli Silva, I. & Verga, D. 2004. *Practical manual of Cretaceous planktonic foraminifera*. In: D. Verga & R. Rettori (eds.), *International School on Planktonic Foraminifera*, University of Perugia and Milan, 283 p.

Price, G.D. & Hart, M.B. 2002. Isotopic evidence for early to mid-Cretaceous ocean temperature variability. *Marine Micropaleontology*, **46**:45–58. *doi:10.1016/S0377-8398(02)00043-9*

Reolid, M.; Sanchez-Quinonez, C.A.; Laia Alegret, L. & Molina, E. 2015. Palaeoenvironmental turnover across the Cenomanian-Turonian transition in Oued Bahloul, Tunisia: Foraminifera and geochemical proxies. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **417**:491–510. *doi:10.1016/j.palaeo.2014.10.011*

Reolid, M.; Sanchez-Quinonez, C.A.; Laia Alegret, L. & Molina, E. 2016. The biotic crisis across the Oceanic Anoxic Event 2: Palaeoenvironmental inferences based on foraminifera and geochemical proxies from the South Iberian Palaeomargin. *Cretaceous Research*, **60**:1–27. *doi:10.1016/j.cretres.2015.10.011*

Robaszynski, F. & Caron, M. 1979. *Atlas de foraminifères planctoniques du Crétacé moyen* (*Mer boreale et Tethys*). Cahiers de Micropaléontologie, part 1. Paris, Editions du Centre National de la Recherche Scientifique, 181 p.

Robaszynski, F.; Caron, M.; Gonzales-Donoso, J.M. & Wonders, A.A.H. 1984. Atlas of late Cretaceous Globotruncanids. *Revue de Micropaléontologie*, **26**:145–305.

Rodríguez-Tovar, F.J.; Uchman, A. & Martín-Algarra, A. 2009. Oceanic anoxic event at the Cenomanian-Turonian boundary interval (OAE-2): ichnological approach from the Betic Cordillera, southern Spain. *Lethaia*, **42**:407–417. *doi:10.1111/j.1502-3931.2009.00159.x*

Ruault-Djerrab, M.; Ferré, B. & Kechid-Benkherouf, F. 2012. Etude micropaléontologique du Cénomano-Turoniendans la région de Tébessa (NE Algérie): implications paléoenvironnementales et recherche de l'empreinte de l'OAE2. *Revue de Paléobiologie*, **31**:127–144.

Ruault-Djerrab, M. & Kechid-Benkherouf, F. 2010. Micropaleontological study (foraminifera, ostracods) and characterization of the paleoenvironment of middle Cretaceous deposits (DjebelChemla area, north-eastern Algeria). *Arabian Journal of Geosciences*, **4**:1289–1299.

Salmi-Laouar, S.; Ferré, B. & Aouissi, R. 2019. Abondance d'*Aspidiscus cristatus* (Lamarck, 1801) dans la Formation des Marnes de Smail de la région de Batna (NE d'Algérie): Une espèce caractéristique pour le Cénomanien moyen. *Carnets Geologie*, **19**:185–197.

Slami, R.; Salmi-Laouar, S.; Ferré, B.; Aouissi, R. & Benkherouf-Kechid, F. 2018. Biostratigraphie, géochimieetréponse des composantes microfauniques aux variations environnementales au passage Cénomanien–Turonien à Théniët El Manchar (Monts de Bellezma, Batna, NE Algérie). *Estudios Geológicos*, **74**:1–20.

Sliter, W.V. & Baker, R.A. 1972. Cretaceous bathymetric distribution of benthic foraminifers. *The Journal of Foraminiferal Research*, **2**:167–183. *doi:10.2113/gsjfr.2.4.167*

Tronchetti, G.1981. *Les foraminifères crétacés de Provence: Aptien-Santonien*. Université de Provence, Ph.D. thesis, 559 p.

Van der Zwaan, G.J.; Duijnstee, I.A.P.; Den Dulk, M.; Ernst, S.R.; Jannink, N.T. & Kouwenhoven, T.J. 1999. Benthic foraminifers: proxies or problems? A review of paleocological concepts. *Earth- Science Reviews*, **46**:213–236. *doi:10.1016/S0012-8252(99)00011-2*

Van der Zwaan, G.J.; Jorissen, F.J. & de Stigter, H.C. 1990. The depth dependency of planktic/ benthic foraminiferal ratios: constraints and applications. *Marine Geology*, **95**:1–16. *doi:10.1016/0025-3227(90)90016-D*

ZwaanVila, J.M. 1980. *La chaîne alpine d'Algérie orientale et des confins algéro-tunisiens*. University of Pierre and Marie Curie, Ph.D. Thesis, 665 p.

Wolff, T.; Grieger, B.; Hale, W.; Dürkoop, A.; Mulitza S.; Pätzold, J. & Wefer, G. 1999. On the Reconstruction of Paleosalinites. In: G. Fischer & G. Wefer (eds.) *Use of Proxies in Paleoceanography: Examples from the South Atlantic*, Springer-Verlag, p. 207–228.

Yahiaoui, A. 1990. *La partie inférieure de la série marno-calcaire du Crétacé supérieur (Cénomanien supérieur à Coniacien inférieur) entre Batna et El Kantara (Algérie orientale): Stratigraphie, Sédimentologie et Paléogéographie*. Université de Nancy, Ph.D. Thesis, 324 p.

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