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CALCAREOUS NANNOPLANKTON FROM THE TURONIAN-MAASTRICHTIAN SEQUENCE EAST OF EL QUSAIMA, NE SINAI, EGYPT

By

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دراسة أحافير النانوبلانكتون الجبرية من تتابع التورنيان - المسترختيان شرق منطقة القصيمة بشمال شرق سيناء - مصر

محمود فارس

* قسم تتابع الطباشيري المتأخر في المنطقة الواقعة شرق القصيمة بشمال سيناء إلى عدة نطاقات حياتيه على أساس ما تحتويه صخوره من احافير النانوبلانكتون الجبرية .
* أوضحت الدراسة الحالية بأن صخور السنتونيان Santonian غير ممثلة في منطقة البحث وقد يعزي ذلك إلى النشاط التكتوتي أو إلى ثغرة طباقية .
* يحدد الحد الفاصل بين عصري التورونيان والكونياسيان مع ظهور النوع Micula furcatus كما أن أختفاء النوع Eiffellithus Eximius يقع عند الحد الفيصل بين عصري الكامبنيان والمسترختيان .
* أوضحت دراسة نسب انواع المياه الباردة Micula Staurophora إلى نسب أنواع المياه الدافئة Watznaueria Barnesae إن درجات حرارة المياه السطحية القديمة أثناء التورونيان ، الكونياسيان والكامبنيان كانت دافئة نسبياً .
* هناك من الأدلة ما يشير إلى أنخفاض ملحوظ في درجات حرارة المياه السطحية أثناء الكامبنيان العلوي جداً وقد أستمر هذا الإنخفاض حتى نهاية العصر المسترختيان .
* إن التنوع في أعداد احافير النانوبلانكتون الجبرية كان كبيراً خلال عصري الكونياسيان والكامبنيان بينما قل بشكل ملحوظ ابان المسترختيان .

Key Words: Late Cretaceous, Nannofossils, Biozonation, Stage boundaries, Paleotemperatures, Diversity.

ABSTRACT

On terms of calcareous nannoplankton, the Turonian-Maastrichtian sequence in the studied area is subdivided into a number of nannoplankton zones. The recorded biozones represent the Turonian, Coniacian, Campanian and Maastrichtian, while the Santonian is missing due to structural activity and/or to stratigraphic hiatus in the investigated succession.

The Turonian/Coniacian boundary is defined by the first occurrence of *Marthasterites furcatus*, and the Campanian/Maastrichtian boundary can be placed at the extinction level of *Eiffellithus eximius.*

Warm water conditions are suggested for the Turonian, Coniacian and Campanian periods, as indicated by the increased values of the *Micula staurophora/Watznaueria barnesae* ratio.

There is some nannofossil evidences to suggest that the temperature was already declining in the uppermost Campanian and has continued throughout the Maastrichtian.

Coccolith diversity was high during the Coniacian and the Campanian and decreased rapidly to few species in the Maastrichtian.

INTRODUCTION

The stratigraphy and paleontology of the late Cretaceous rocks, exposed in Sinai, were investigated by many authors (e.g. Nakkady, 1950, Said and Kenawy, 1956; Shata, 1960,......)

Hewaidy and El Ashwah (in press) identified 129 benthonic foraminiferal species, from the Turonian-Maastrichtian sequence in the area east of El Qusaima. The paleoecologic applications and importance of this assemblage were discussed and used to throw light on the paleoecologic and environmental conditions which prevailed during the deposition of this sequence.

Hewaidy, (1987) studied the stratigraphy of the Esna Shale in the area east of El Qusaima. He puts the Cretaceous-Tertiary boundary at the Sudr-Esna Shale contact, where the first early Paleocene planktonic foraminifera appeared at the base of the Esna Shale.

The K/T boundary lies at the lowermost part of the Esna Shale, and the latest Maastrichtian and earliest Paleocene sediments are complete or nearly complete in the El-Qusaima area (Faris, 1988).

GEOLOGIC SETTING

The area east of El Qusaima includes a good Upper Cretaceous sequence exposed mainly in two mountains (Fig. 1).

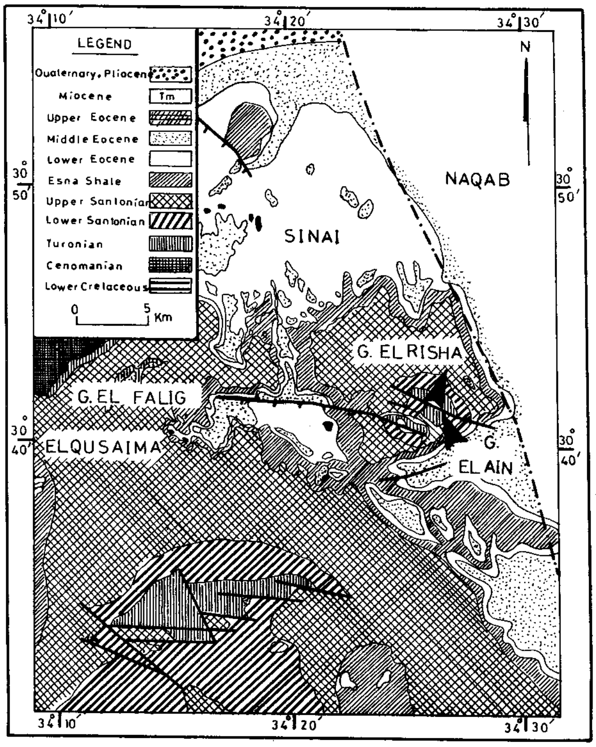

Fig. 1: Geological map of El Qusaima area (after Said, 1962)

The first one, Gebel El Risha, represents the core of a small anticline and includes Turonian, Coniacian and Campanian rocks. The other mountain, Gebel El Ain, forms the southern limb of that anticline including the Maastrichtian, Paleocene and Eocene sediments.

The Upper Cretaceous sequence in the studied area is divided into a number of rock units similar to those in the Gulf of Suez and Sinai regions. These units are arranged from base upwards as follows:

1. *Abu qada Formation* (Turonian)

This unit represents the oldest exposed formation in the area. It is composed of shale, marl, limestone and dolomitic limestone interbeds with cross bedded sandstone bed at the top.

2. *Wata Formation* (Turonian)

It overlies conformably the Abu Qada Formation. It consists of massive limestone and Cherty lime-stone beds. These beds rest on shale beds.

3. *Matulla Formation* (Coniacian)

This formation overlies conformably the Wata Formation. It is composed of yellowish soft friable marl.

4. *Sudr Formation* (Campanian-Maastrichtian)

This formation overlies unconformably the Matulla Formation and conformably underlies Esna Shale. The Sudr Formation is subdivided into the Markha and Abu Zenima members. The former member represents the lower part and it is composed of limestone, chalky limestone and shale beds. Meanwhile, the Abu Zenima member (the upper part) consists of a greyish yellow marl bed at the base covered by a white chalky limestone bed.

Calcareous nannoplankton zonation:

Outlines of the development of Cretaceous nannoplankton biostratigraphy can be found in (Manivit, 1971) and (Thierstein, 1973). Additional stratigraphic subdivisions have been proposed by (Bukry and Bramlette, 1970; Roth, 1973 and Thierstein, 1974, 1975).

For the age identification of late Cretaceous nannofossil assemblages (Sissingh's zonation, 1977) which was modified later by Perch-Nielsen, 1985) was utilized here.

The proposed zonal scheme used in this study is shown on (Fig. 2). The chrono-, litho-, and biostratigraphy of the late Cretaceous sequence in the studied area is shown on (Fig. 3).

The stratigraphic ranges of the identified nannoplankton species are shown on (Figs. 4-6).

In the following, the recognized nannoplankton zone are discussed and arranged chronologically from base to top:

1. *Lucianorhabdus maleformis Zone* (CC 12): (Sissingh, 1977).

Age: Turonian:

The *Lucianorhabdus maleformis* Zone is considered here the oldest zone recognized in the studied sequence. The base is defined by the occurrence of both *Eiffellithus eximius* and *Lucianorhabulus maleformis*, whereas its upper limit is known by the first occurrence of *Marthasterites furcatus.*

In the present study, the Turonian-Coniacian boundary is defined by the lowest occurrence of *Marthasterites furcatus.* (Manivit *et al*, 1977) and (Sissingh, 1977), however, placed the Turonian-Coniacian boundary just below the entry of the *Marthasterites furcatus.*

2. *Marthasterites furcatus* Zone (CC 13): (Crepek and Hay, 1969; emended Sissingh, 1977).

Age: early Coniacian:

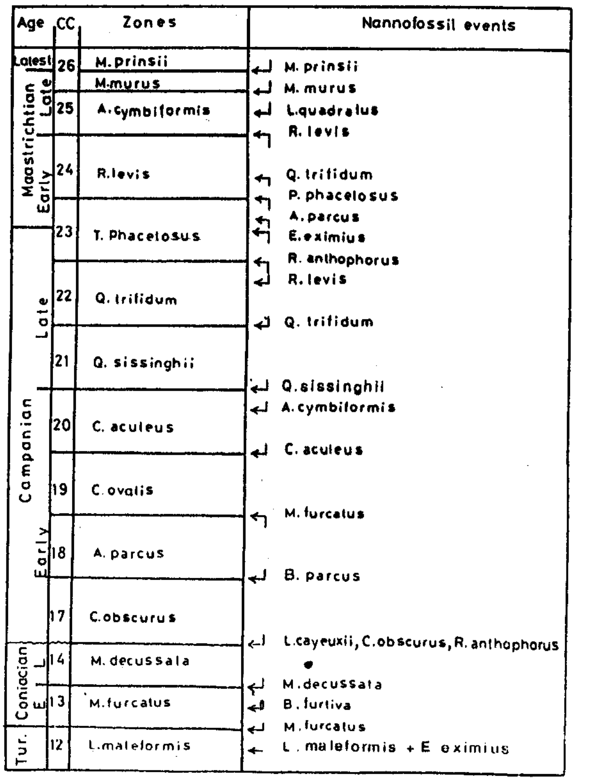

Fig. 2: Proposed Turonian, Coniacian, Campanian and Maastrichtian nannofossil zonation in the studied area.

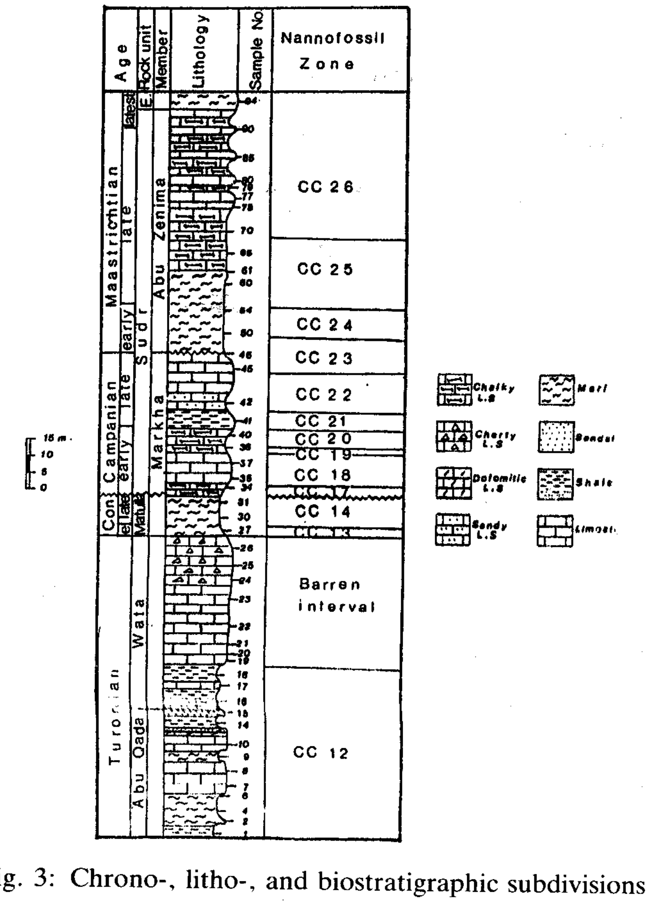

Fig. 3: Chrono-, litho-, and biostratigraphic subdivisions of the late Cretaceous sequence in the studied area.

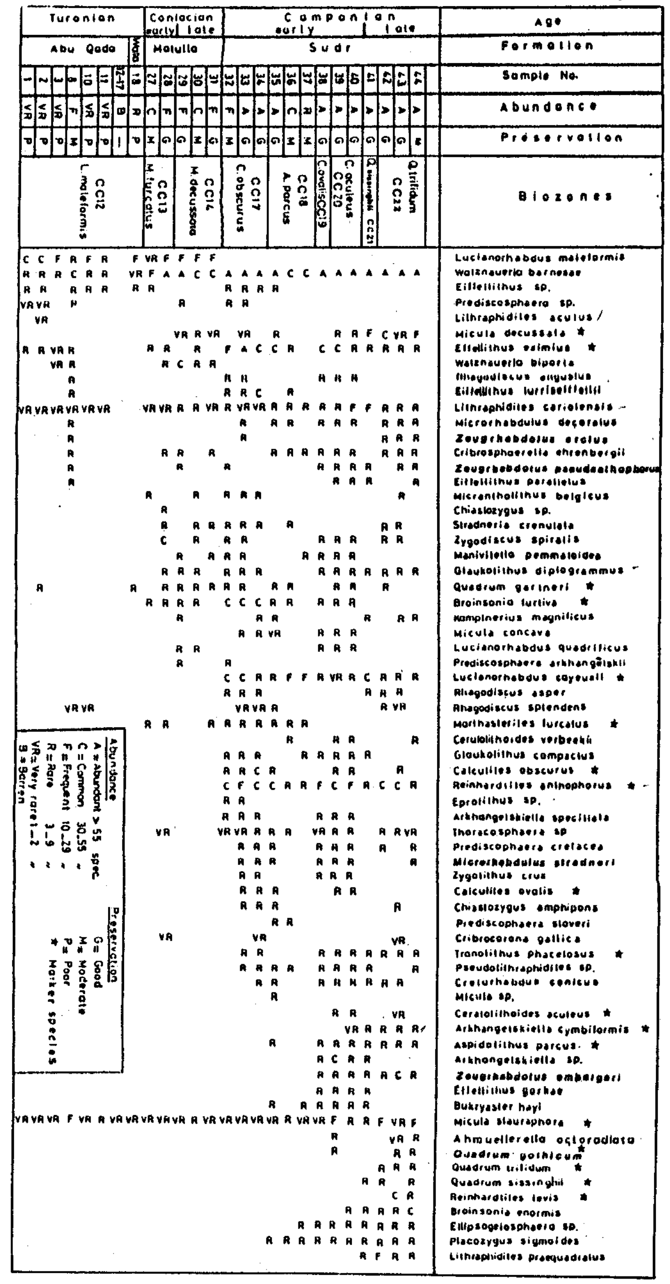

Fig. 4: Stratigraphic distribution of the identified nannofossil taxa in the studied section. Turonian-Campanian.

The zone is defined as the interval from the first occurrence of *Marthasterites furcatus* to the first occurence of *Micula decussata*. Moreover, *Marthasterites furcatus* is rare in our samples, and *Broinsonia furtiva* appears within the zone.

3. *Micula decussata* Zone (CC 14): (Manivit, 1971; emended Sissingh, 1977).

Age: early Coniacian:

The base of the zone is defined by the first occurrence of the zonal marker, but its top is defined by the first occurrence of *Reinhardtites anthophorous.*

Lucinorhabdus cayeuxii, Calculites obscurus and *Reinhardtites anthophorous* are found together in the upper part of the

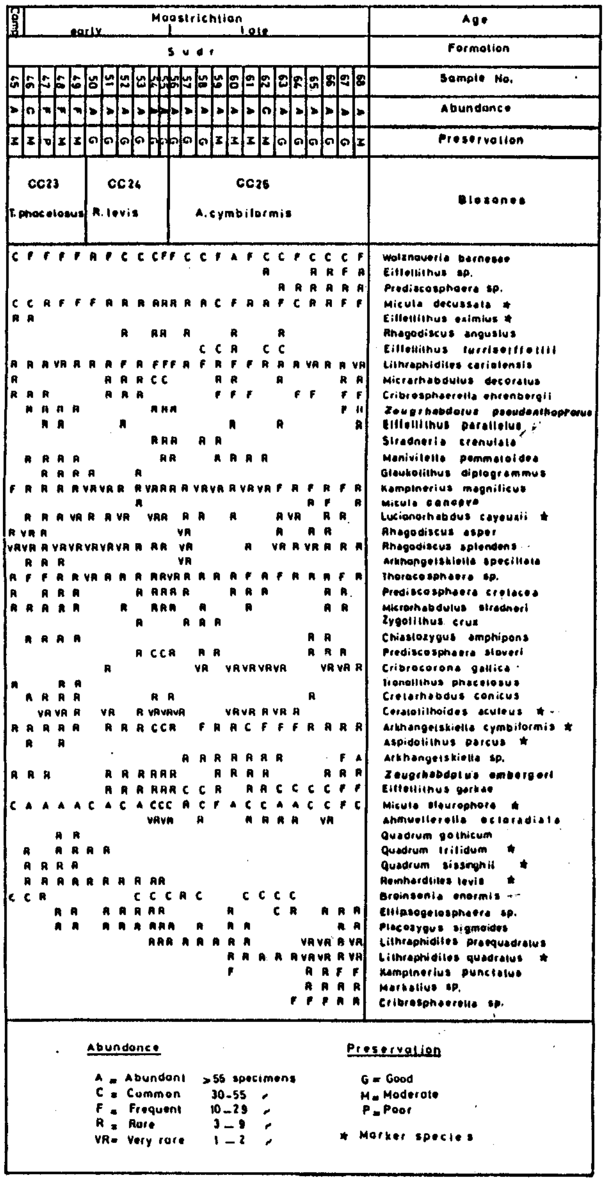

Fig. 5: Stratigraphic distribution of the identified nannofossil taxa in the studied section. Turonian-Maastrichtian.

CC 14 zone. According to the zonal scheme of (Sissingh, 1977), the CC 15-16 zones are missing in the studied sequence, and consequently Santonian sedimetns are missing. The absence of Santonian rocks is probably due to the structural activity in the studied area and/or to a stratigraphic gap.

4. *Caliculites obscurus* Zone (CC 17): (Sissingh, 1977).

Age: early Campanian:

The zone comprises the interval from the first occurrence of *Calculites obscurus* to the first occurrence of *Aspidolithus parcus (Broinsonia parca* of many authors).

The first occurrence of *Aspidolithus parcus* is an event that has been used for zonation and coincides well with the Santonian/ Campanian boundary in many sections in the world.

5. *Aspidolithus parcus* Zone (CC 18): (Sissingh, 1977).

Age: early Campanian:

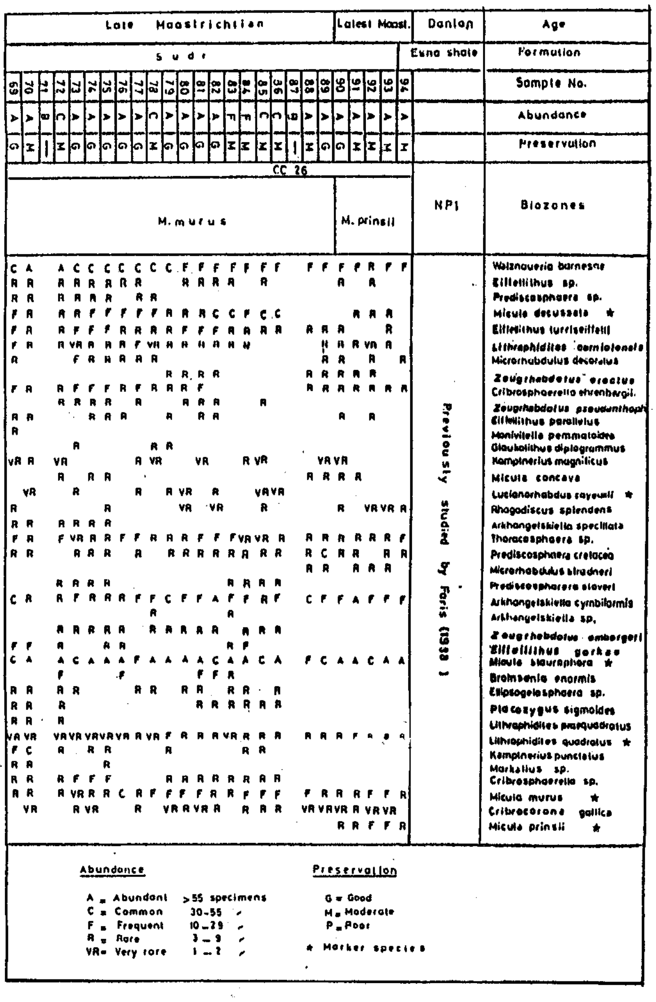

Fig. 6: Stratigraphic distribution of the identified nannofossil taxa in the studied section. Maastrichtian.

The zone is defined as the interval from the first occurrence of *Aspidolithus parcus* to the last occurrence of *Marthasterites furcatus.*

Ceratolithoides verbeekii appears in the CC 18 zone in the present sequence.

6. *Calculites ovalis* Zone (CC 19): (Sissingh, 1977).

Age: early Campanian:

The base of the *Calculites ovalis* zone is defined by the last occurrence *Marthasterites furcatus,* and its top is defined by the first occurrence of *Ceratolithoides aculeus.*

7. *Ceratolithoides aculeus* Zone (CC 20): (Crepek and Hay, 1969; emended (Martini, 1976).

Age: early Campanian:

The *Ceratolithoides aculeus* zone is defined as the interval from the first occurrence of *Ceratolithoides aculeus* to the entry of *Quadrum sissinghii.*

8. *Quadrum sissinghii* Zone (CC 21): (Sissingh, 1977).

Age: late Campanian:

The base of the zone is defined by the first occurrence of *Quadrum sissinghii,* where its top is defined by the first occurrence of *Quadrum trifidum.*

The first occurrence of *Arkhangelskiella cymbiformis* owns at the base of CC 21 zone in the studied sequence.

9. Quadrum trifidum Zone (CC 22): (Bukry and Bramlette, 1970; emended Sissingh, 1977).

Age: late Campanian:

The base of this zone is defined by the first occurrence of *Quadrum trifidum* and its top by the last occurrence of *Reinhardtites anthophorus.* The *Quadrum trifidum* Zone is recognizable easily and *Reinhardtites levis* appears in this zone.

10. Tranolithus phacelosus Zone (CC 23): (Sissingh, 1977).

Age: latest Campanian - early Maastrichtian:

The zone comprises the interval from the highest occurrence of *Reinhardtites anthophorus* to the highest occurrence of *Tranolithus phacelosus.*

In the present study, the Campanian/Maastrichtian boundary can be placed at the extinction level of *Eiffellithus eximius.*

11. Reinhardtites levis Zone (CC 24): (Sissingh, 1977).

Age: early Maastrichtian:

This zone is defined as the interval from the last occurrence of *Tranolithus phacelosus* to the last occurrence of *Reinhardtites levis.*

The last occurrence of *Reinhardtites levis* is generally accompanied by an increase in number of large *Arkhangelskiella* representatives in the studied area.

12. Arkhangelskiella cymbiformis Zone (CC 25): (Perch-Nielsen, 1972; emended Sissingh, 1977).

Age: late Maastrichtian:

The *Arkhangelskiella cymbiformis* Zone is defined as the interval from the last occurrence of *Reinhardtites levis* to the first occurrence of *Micula murus.*

In the current study, *Lithraphidites quadratus* appears in this zone.

13. Micula murus Zone (Martini, 1969; emended Perch-Nielsen *et al,* 1982).

Age: late Maastrichtian:

The zone is defined as the interval from the first occurrence of *Micula murus* to the first occurrence of *Micula prinsii.*

14. Micula prinsii Zone (Perch-Nielsen, 1979; emended Romein and Smit, 1981).

Age: latest Maastrichtian:

The *Micula prinsii* Zone is defined as the interval from the first occurrence of *Micula prinsii* to the beginning of the increased frequency of *Thoracosphaera operculata.*

The *Micula murus* Zone as well as the *M. prinsii* Zone are equivalent to the CC 26 zone of (Sissingh's, 1977).

The *Micula prinsii* Zone is represented by the uppermost part of the Sudr Formation and the basal part of the Esna Shale.

PALEOTEMPERATURE

Paleobiogeographical variations in nannoplankton assemblages were all documented for the Quaternary (McIntyre and Be, 1967; McIntyre *et al,* 1972) and Tertiary (Haq and Lohman, 1976; Haq, 1980) but less is known about the Cretaceous.

During most of the Cretaceous there are little differences between high and low latitude nannoplankton floras.

Roth, (1978) characterized *Micula murus, Quadrum gothicum,* and *Quadrum trifidum* as warm water species while *Nephrolithus frequens, Lithraphidites quadratus* and *Lithraphidites praequadratus* represent relatively cold water species.

According to (Daeven, 1983; Roth, 1978), the Cretaceous cool-water is characterized by the following nannofossil species: *Lithraphidites quadratus, L. praequadratus, L. carniolensis, Micula staurophora, Arkhangelskiella cymbiformis, Kampterius magnificus,* and *Ahmuellerella octoradiata.* On the other hand, the warm-water is distinguished by: *Watznaueria barnesae, Rhagodiscus splendens, Micula murus, Thoracosphaera spp, Ceratolithoides aculeus,* and *Lucianorhabdus cayeuxii.*

The *Micula staurophora/Watznaueria barnesae* ratio (M/W) is expressed in a bar diagram (Fig. 7). The percentage of warm-water to cool-water forms and the ratio between *M. staurophora* to *W. barnesae* expressed in logarithemic values are demonstrated on (Fig. 8).

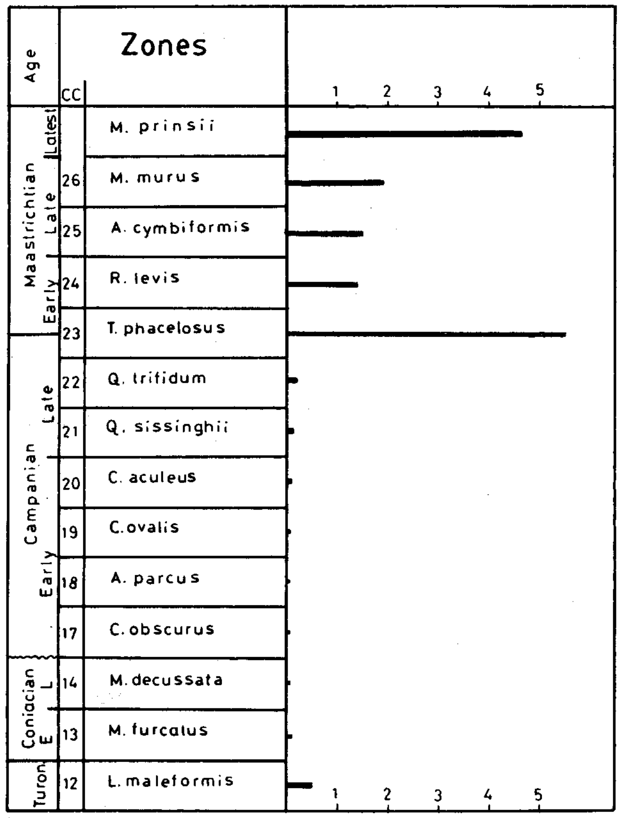

Fig. 7: Bar diagrams showing the frequency ratios of *Micula staurophora* to *Watznaueria barnesae* (M/W) in the Turonian-Maastrichtian of the studied sequence.

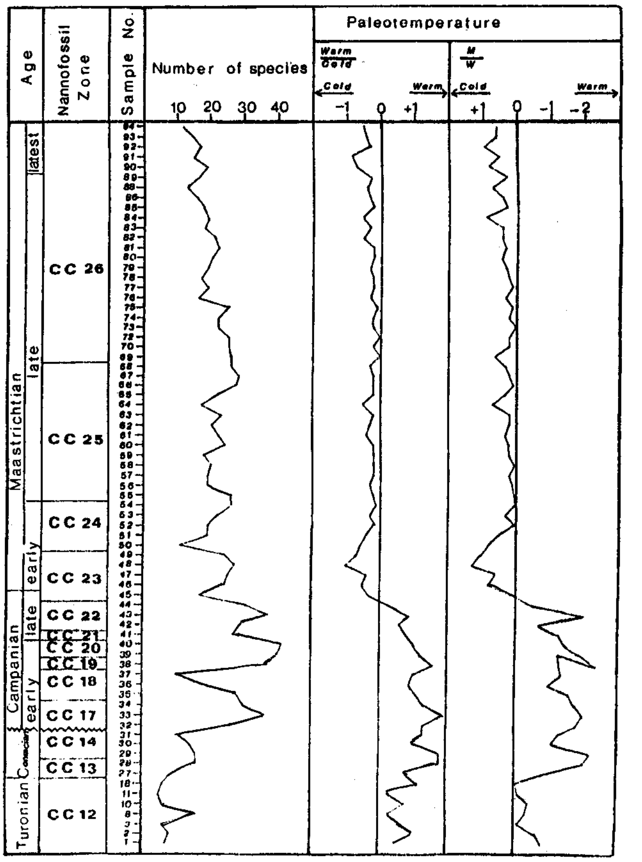

Fig. 8: Diversity and relative surface water temperature in the studied sequence.

The surface water paleotemperatures were relatively warm during the Turonian, Coniacian and Campanian periods (Fig. 8), as indicated by the predominance of the warm-water species.

It is evident that the latest Campanian and the early and late Maastrichtian are characterized by relatively cool-water temperature as indicated by the decreased values of the ratio between warm water to cool-water species and also by the higher values of the M/W ratio (Fig. 8).

COCCOLITH DIVERSITY

The coccolith diversity in the studied samples is shown together with relative surface-water temperature in (Fig. 8). The largest number of species occurred in the Coniacian. Coccolith diversity remained high throughout the Campanian, the time of transgression (Hewiady and El-Ashwah, in press).

As mentioned above, the Turonian, Coniacian and Campanian times are characterized by warm water paleotemperatures. This indicates that the nannoplankton diversity was controlled during these periods by the surface-water temperatures.

There are some indications that the number of species decreased during the Maastrichtian. This observation is in good agreement with that observed from the paleotemperature curve (Fig. 8), where cool-surface temperature was suggested for this time.

At the end of the Maastrichtian there was a rapid decline in the number of species, and the nannofossil assemblages changed significantly at the K/T boundary on the species level (Faris, 1988).

Distribution of some important nannofossil taxa:

The frequency distribution of some important nannofossil taxa for the Turonian-Maastrichtian interval is shown on (Fig. 9). The following results are obtained:

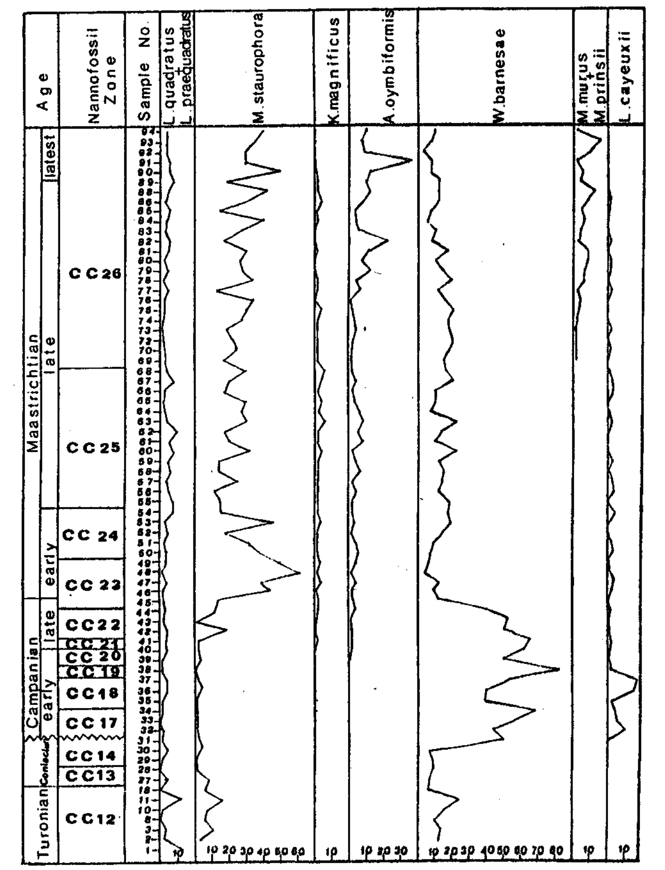

Fig. 9: Relative abundance (percentage) of the most important nannofossil species in the studied section.

1. *Watznaueria barnesae* had its maximum abundance during Campanian time and sharply decreased during the Maastrichtian.
2. *Micula staurophora* was distributed somewhat irregularly, but was more abundant in the Maastrichtian than in the Campanian.
3. The *Micula Staurophora/Watznaueria barnesae* ratio increased in the uppermost Campanian and upwards, and the highest ratios are generally recorded in the upper Maastrichtian. The distribution patterns of the *Micula staurophora* and *Watznaueria barnesae* in the studied sequence seems to be controlled by the surface water temperature.
4. *Lucianorhabdus cayeuxii* is abundant in early Campanian sediments and decreased during the Maastrichtian.

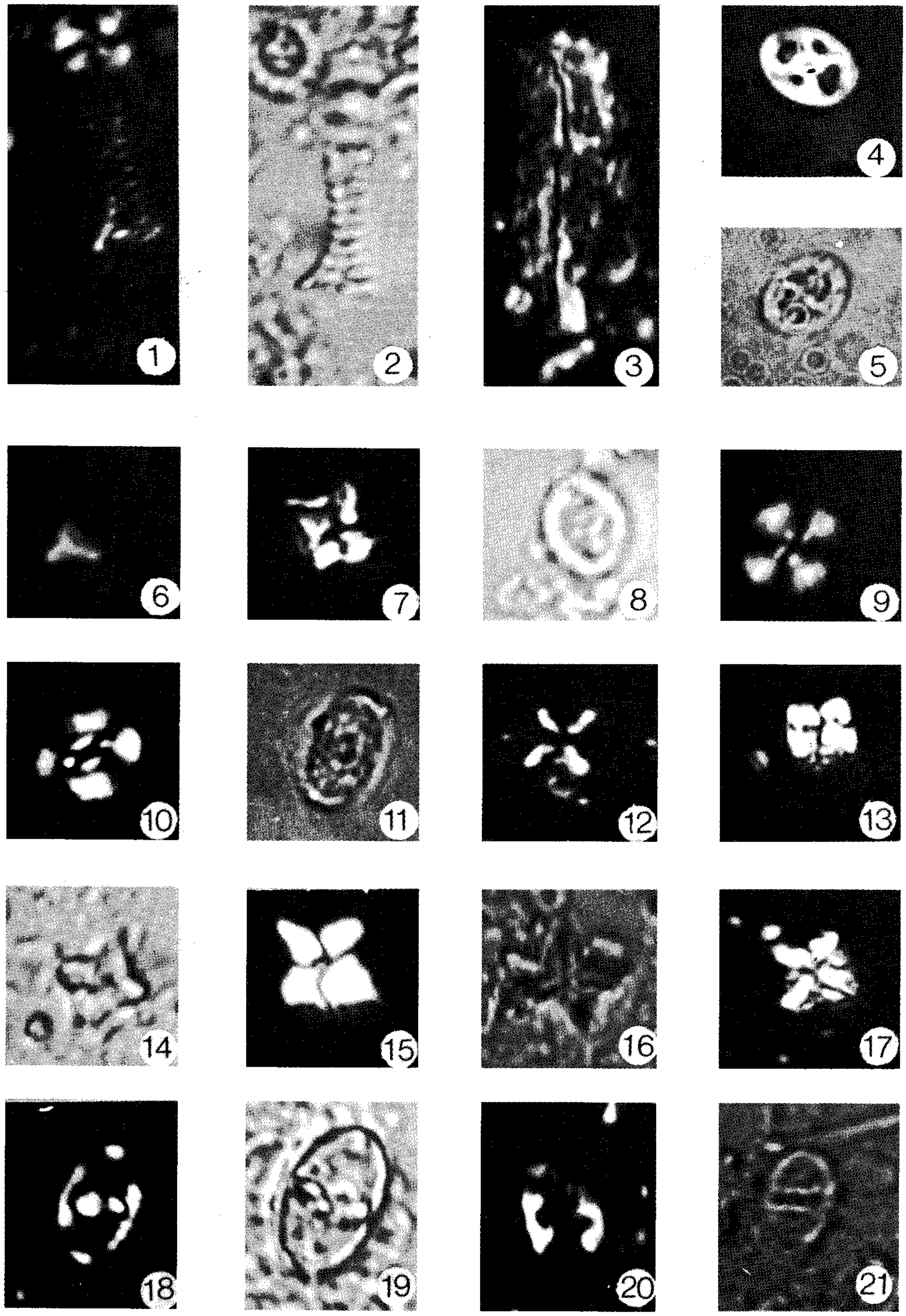

PLATE I
(All figures × 2000)

Fig. 1 & 2: *Microrhabdulus decoratus* Deflandre, Sample No. 92, *M. prinsii* zone. Fig. 3: *Lucianorhabdus cayeuxii* Deflandre, Sample No. 66, *A. cymbiformis* zone. Fig. 4 & 5: *Chiastozygus amphipons* (Bramlette and Martini) Gartner, Sample No. 43, *Q. trifidum* zone. Fig. 6: *Ceratolithoide aculeus* (Stradner) Prins & Sissingh, Sample No. 50, *R. levis* zone. Fig. 7: *Micula murus* (Martini) Bukry, Sample No. 78, *M. murus* zone. Fig. 8, 9 & 10: *Watznaueria barnesae* (Black) Perch-Nielsen, Sample No. 42, *Q. trifidum* zone. Fig. 11: *Rhagodiscus angustus* (Stradner) Reinhardt, Sample No. 63, *A. cymbiformis* zone. Fig. 12: *Micula decussata* Vekshina, Sample No. 40, *C. aculeus* zone. Fig. 13: *Quadrum gartneri* Prins & Perch-Nielsen, Sample No. 39, *C. aculeus* zone.Fig. 14 & 15: *Quadrum gothicum* (Deflandre) Prins & Perch-Nielsen, Sample no. 44, *Q. trifidum* zone. Fig. 16 & 17: *Micula staurophora* (Gardet) Stradner, Sample no. 30, *M. decussata* zone. Fig. 18 & 19: *Zeugrhabdotus pseudanthophorus* (Bramlette and Martini) Perch-Nielsen, Sample no. 80, *M. murus* zone. Fig. 20: *Eiffellithus gorkae* Reinhardt, Sample no. 68, *A. cymbiformis* zone. Fig. 21: *Glaukolithus diplogrammus* (Deflandre) Reinhardt, Sample no. 73, *M. murus* zone.

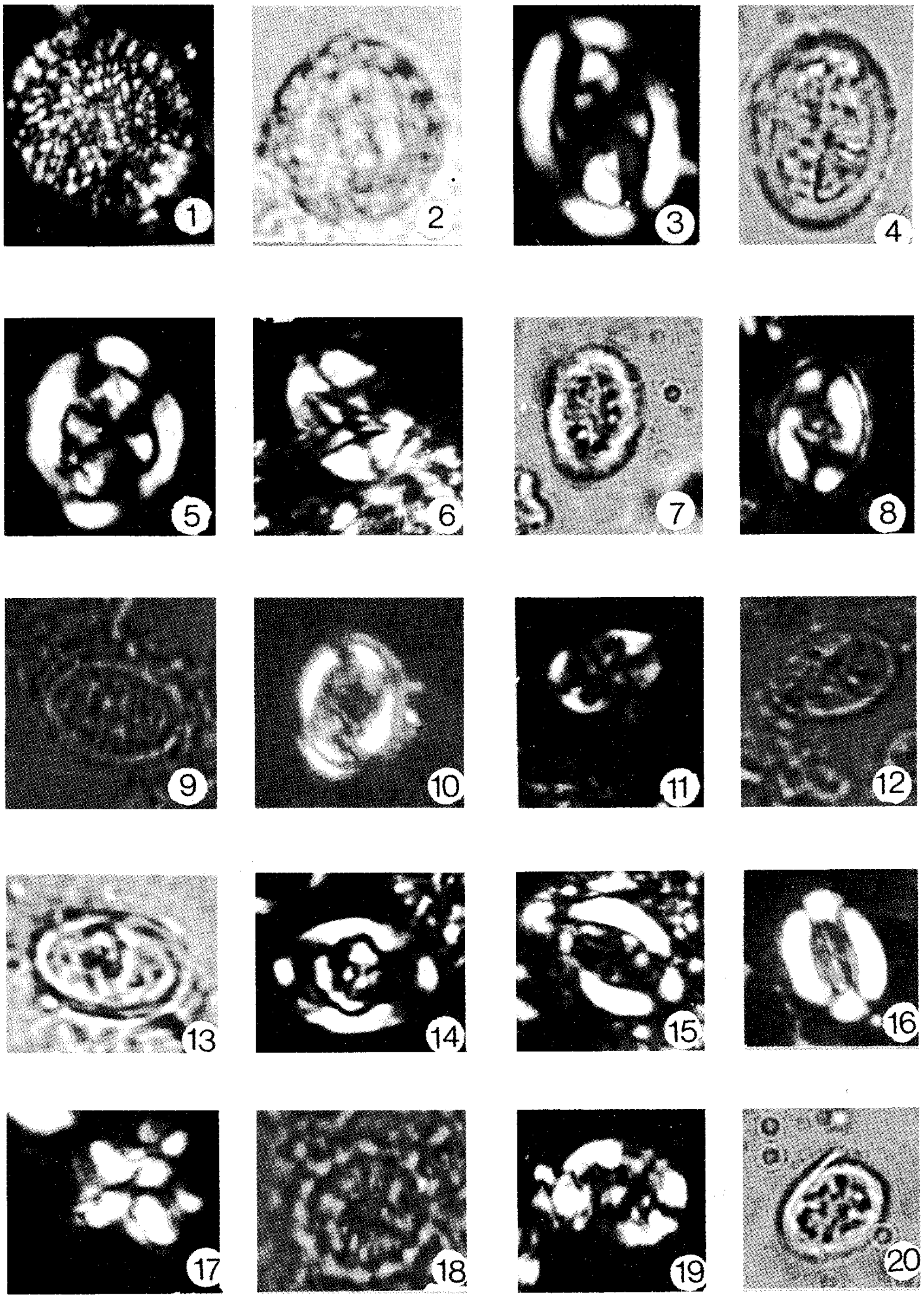

PLATE II
(All figures × 2000)

Fig. 1 & 2: *Thoracosphaera operculata* Bramlette and Martini, Sample no. 94, *M. prinsii* zone. Fig. 3, 4 & 5: *Arkhangelskiella cymbiformis* Vekshina, Sample no. 90, *M. prinsii* zone. Fig. 6, 11 & 12: *Eiffellithus turriseiffelii* (Deflandre) Reinhardt, Sample no. 34, *C. obscurus* zone. Fig. 7: *Stradneria crenulata* (Bramlette and Martini) Noel, Sample no. 42, *Q. trifidum* zone. Fig. 8: *Reinhardtites levis* Prins and Sissingh, Sample no. 42, *Q. trifidum* zone. Fig. 9 & 10: *Cribrosphaerella ehrenbergii* (Arkhangelsky) Deflandre, Sample no. 45, *T. phacelosus* zone. Fig. 113 & 14: *Zeugrhabdotus embergeri* (Noel) Perch-Nielsen, Sample no. 41, *Q. sissinghii* zone. Fig. 15: *Broinsonia enormis* (Shumenko) Manivit, Sample no. 70, *M. murus* zone. Fig. 16: *Arkhangelskiella sp.*, Sample no. 40, *C. aculeus* zone. Fig. 17: *Quadrum sissinghii* Perch-Nielsen, Sample no. 44, *Q. trifidum* zone. Fig. 18: *Prediscosphaera sp.*, Sample no. 91, *M. prinsii* zone. Fig. 19 & 20: *Ahmuellerellà octoradiata* (Gorka) Reinhardt, Sample no. 44, *Q. trifidum* zone.

5. Generally *Arkhangelskiella cymbiformis* is abundant in the Maastrichtian. It increases slowly from 1% in the CC 23 zone to 37% in the CC 28 zone.

6. *Kampterius magnificus* occurs from the early Campanian through Maastrichtian, but it is generally very rare or absent below the Maastrichtian.

CONCLUSIONS

The main results of this work can be summarized as follows:

1. On the basis of calcareous nannoplankton identified, the Turonian-Maastrichtian sequence in the studied area is sub-divided into a number of nannoplankton zones.

2. The current study reveals that Santonian rocks are missing. This may be due to the structural activity in the studied area, and/or to a stratigraphic gap.

3. The Turonian/Coniacian boundary is defined by the first occurrence of *Marthasterites furcatus.* The Campanian/ Maastrichtian boundary can be placed at the extinction level of *Eiffellithus eximius.*

4. During the Turonian, Coniacian and Campanian periods, the surface water temperatures were relatively warm. This is indicated by the predominance of warm-water species.

5. Cold conditions were suggested for the uppermost Campanian and Maastrichtian as evidenced by high values of the *Micula staurophora/Watznaueria barnesae* ratio and also by the decreased values of the warm-water forms to cool-water forms.

6. High species diversity is noticed in the Coniacian and Campanian (warm-water), while low coccolith diversity is observed during the Maastrichtian (cool-water). This indicates that the coccolith diversity is high in the warm-water and decreases rapidly to few species during the cooling climate. It also means that nannoplankton diversity was controlled by surface-water temperature.

7. The distribution patterns of *Micula staurophora* and *Watznaueria barnesae* in the studied sequence seems to be controlled by water paleotemperature flucatuations.

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