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PALAEONTOLOGY

UPPER CRETACEOUS CALCAREOUS NANNOPLANKTON ZONATION IN A COMPOSITE SECTION NEAR EL KEF, TUNISIA. I

BY

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(Communicated by Prof. C. W. DROOGER at the meeting of October 25, 1975)

ABSTRACT

A new calcareous nannopankton zonation for the Upper Cretaceous is based on 55 samples from the Kef secton in Tunisia. Fifteen zones are recognized in the Cenomanian-Maastrichtian.

INTRODUCTION

The area of El Kef, well known from the detailed work on the 1:50.000 geological map published by Burollet and Sainfeld (1956), contains a fairly complete composite marine section from Aptian to Middle Eocene (Lutetian). In recent years, J. Salaj (1974) published additional details on the Upper Cretaceous and Paleocene.

During the 6th African Micropaleontological Colloquim (1974), P. Marks collected a first set of samples for the Utrecht University; additional material was collected by R. R. Schmidt in 1975.

The present author studied the nannofossils in 55 samples covering the Cenomanian-Maastrichtian interval. The samples of El Kef contain rich and well-preserved Upper Cretaceous nannoplankton floras, in which so far more than one hundred and ten species have been recognized.

Details of this flora will be published together with information on other Cretaceous sections from Spain and France in a subsequent paper. Because El Kef seems to have the most complete zonation, this preliminary paper is meant to evoke criticism from and further elaboration by other nannofossil specialists, before publishing the final report.

I wish to thank P. Marks and R. R. Schmidt for providing the samples. All samples and hypotypes are stored in the collections of the Department of Stratigraphy and Paleontology, State University of Utrecht. I am grateful to W. W. Hay for discussing the zonation and to C. W. Drooger, P. Marks, R. R. Schmidt and A. J. T. Romein for their constructive criticism, to J. van der Linden for drawing the figures and composing the plates, and to C. Bakker for his assistance at the SEM. The SEM-micrographs were made at the University of Amsterdam.

METHOD OF INVESTIGATION

The samples have been prepared for calcareous nannoplankton examination by applying the gravity settling method. The SEM investigation was carried out with the method described by Hansen, Schmidt and Mikkelsen (1975). The routine study was done with a Leitz Orthoplan light microscope.

For determinations the papers of Stradner (1963), Cepek and Hay (1969a, b), Manivit (1971), Roth (1973) and Thierstein (1974) have been consulted in particular, as they contain the best information on Upper Cretaceous calcareous nannoplankton and the use in establishing biozonations (fig. 1). Samples from Spain and France served for further classification of taxa, and material from type deposits of several Upper Cretaceous stages for stratigraphic calibration.

THE ZONATION

After the first attempt to use Upper Cretaceous nannofossils for biostratigraphic purposes (Stradner, 1963), many more data have become available for establishing more useful biozonations. Zoning methods were not consistent, however, and complete sections had not been studied.

Cepek and Hay (1969a, b) and Manivit (1971) proposed zonations based on the entries of zonal markers. Further investigation shows that the ranges of some markers are incomplete; for some of them the present author gives a different taxonomic interpretation. The ranges of the markers proposed by Cepek and Hay and Manivit for the Lower and Middle Cenomanian and for the Middle Turonian were found to extend further downward. In addition, it appears that the species of the genus *Kamptnerius* used as zonal markers belong to one single species (Thierstein, 1974) and the same applies to species in the genus *Arkhangelskiella*.

The zonation of Roth (1973) has the disadvantage of being partially based on last occurrences, which renders correct recognition of the zones in samples with reworked material rather doubtful. Many data used by Roth are comparable to those from the Kef section, but his *Gartnerago obliquum* Zone and *Broinsonia parca* Zone have not been recognized in El Kef. For both zones the upper boundary seems to be older than the lower boundary.

The new-proposed zones are interval zones based exclusively on entries of zonal markers (fig. 2). Some of these markers are recognizable in morphological steps. For zonal markers, only those species are selected which may be found during a rather rapid examination of well-preserved assemblages. Last occurrences are considered less trustworthy to be used as stratigraphic events, because of the possible presence of reworked floral elements in younger sediments. Exits are given only in the description of the zones.

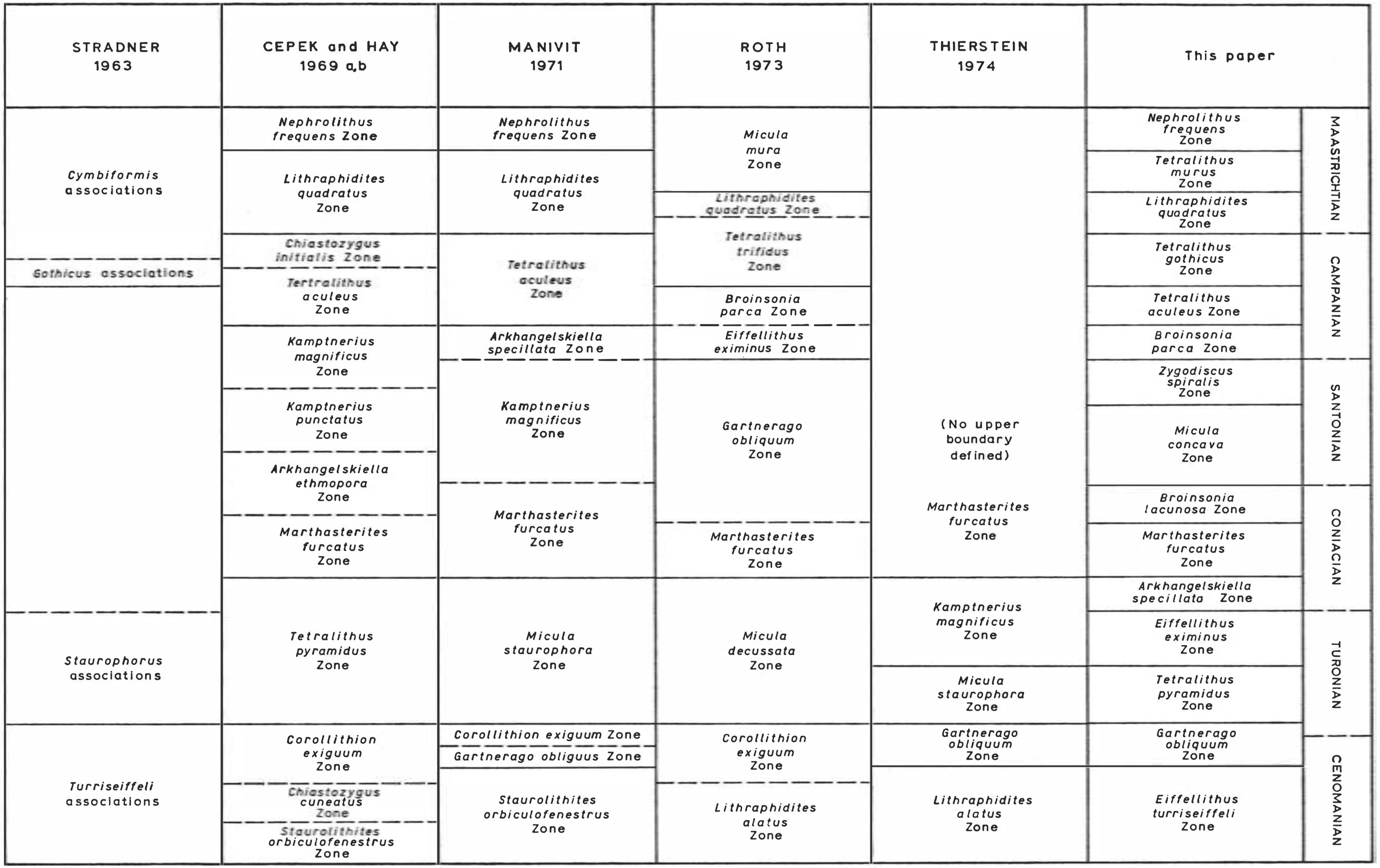
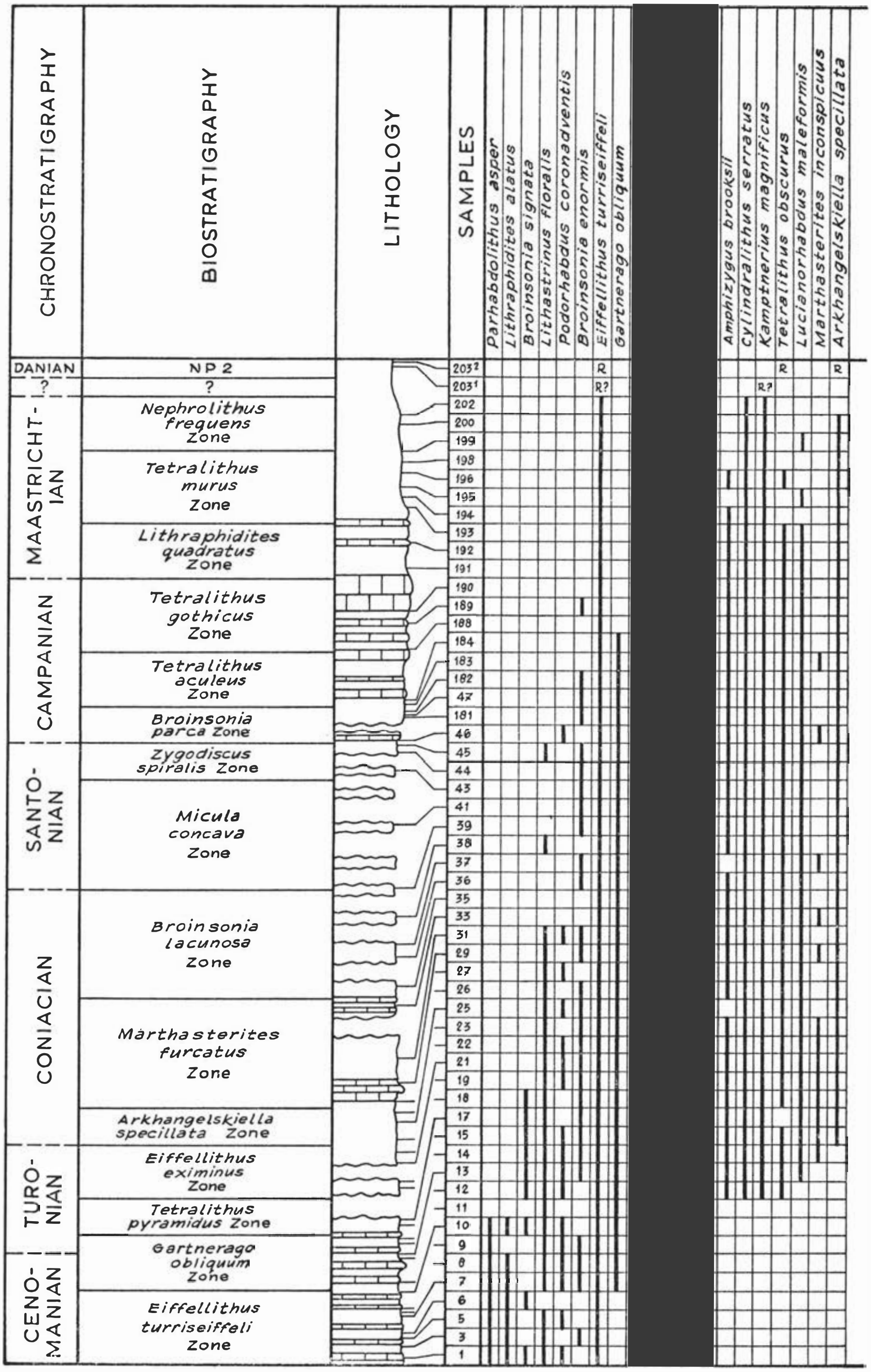


Fig. 1. Correlation chart of current Upper Cretaceous calcareous nannoplankton biozonations.


CHRONOSTRATIGRAPHY
BIOSTRATIGRAPHY
LITHOLOGY
SAMPLES
Parhabdolithus asper
Lithraphidites alatus
Broinsonia signata
Lithastrinus floralis
Podorhabdus coronadventis
Broinsonia enormis
Eiffellithus turriseiffeli
Gartnerago obliquum
Amphizygus brooksii
Cylindralithus serratus
Kamptnerius magnificus
Tetralithus obscurus
Lucianorhabdus maleformis
Marthasterites inconspicuus
Arkhangelskiella specillata
DANIAN
NP 2
?
MAASTRICHT-IAN
Nephrolithus frequens Zone
Tetralithus murus Zone
Lithraphidites quadratus Zone
CAMPANIAN
Tetralithus gothicus Zone
Tetralithus aculeus Zone
Broinsonia parca Zone
SANTO-NIAN
Zygodiscus spiralis Zone
Micula concava Zone
CONIACIAN
Broinsonia lacunosa Zone
Marthasterites furcatus Zone
Arkhangelskiella specillata Zone
TURO-NIAN
Eiffellithus eximinus Zone
Tetralithus pyramidus Zone
CENO-MANIAN
Gartnerago obliquum Zone
Eiffellithus turriseiffeli Zone
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R?

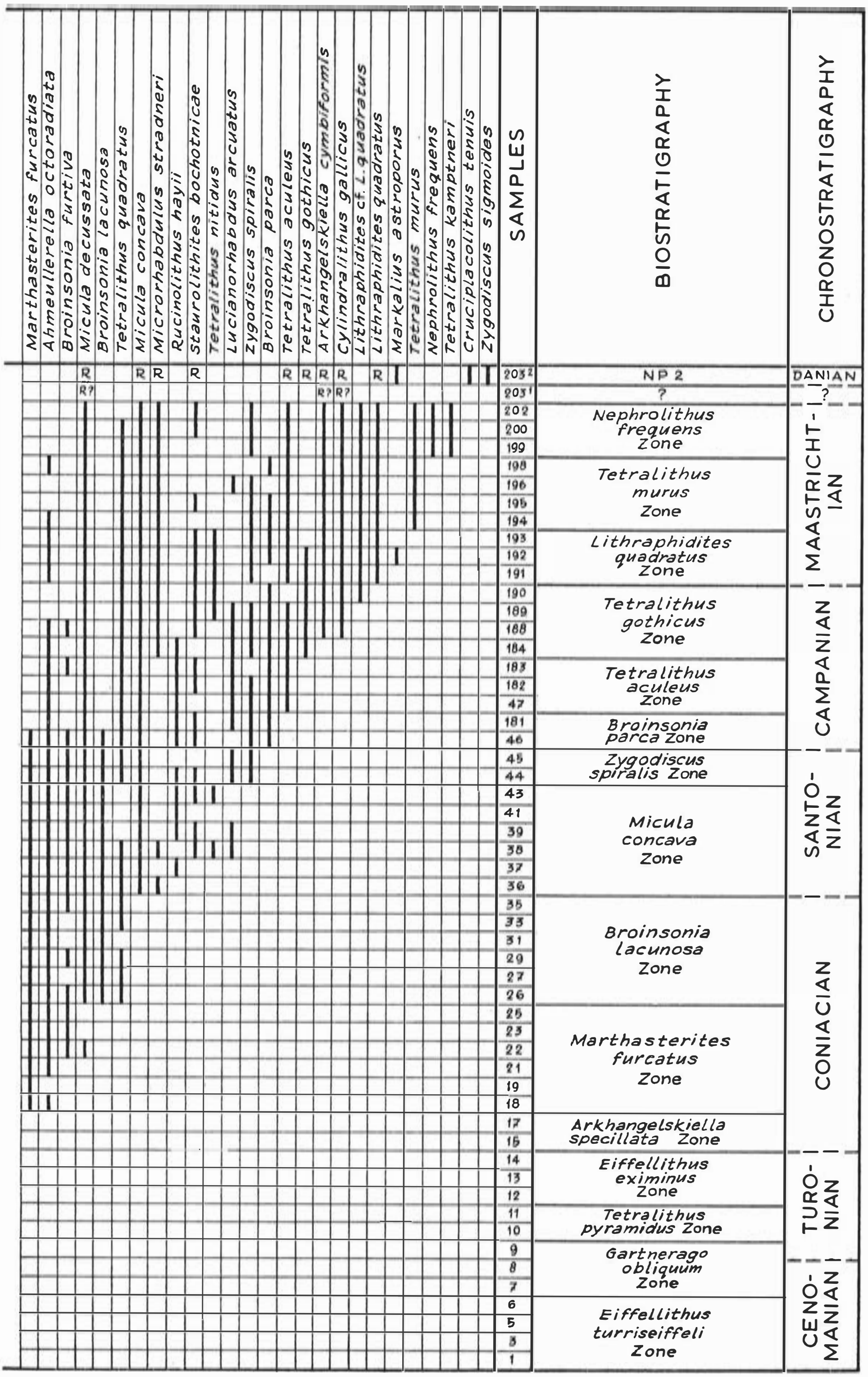

Fig. 2. Range chart of selected species of calcareous nannofossils in the Kef section, Tunisia (R=reworked).

The composite range chart (fig. 2) only contains the species that are of importance for recognizing the zones.

Eiffellithus turriseiffeli Zone

Diagnosis: Interval from the appearance level of *Eiffellithus turriseiffeli* (Deflandre) to the first occurrence of *Gartnerago obliquum* (Stradner).

Discussion: The first occurrence of *Eiffellithus turriseiffeli* has been described by Verbeek (in press). Ancestral forms of this species in Albian deposits were found to have bars, which are better aligned with the axis of the elliptical basal disc. Such forms must be assigned to an earlier zone. *Lithraphidites alatus* and *Bidiscus ignotus* (Gorka) are common in this zone. The specimens of *Lithraphidites alatus* Thierstein with a peak on each blade, as described by Thierstein (1974), occur only in the upper part of this zone.

Comparison: As defined here, this zone is comparable to the *Lithraphidites alatus* Zone (Roth, 1973). Roth's zonal name is considered less appropriate, because the umbrella-shaped forms of *Lithraphidites alatus* were found in samples from Albian rocks (unpublished section from Spain).

Distribution: El Kef section samples 1–6 and several reference samples from Spain and France.

Assignment: Lower and Middle Cenomanian.

Gartnerago obliquum Zone

Diagnosis: Interval from the first occurrence of *Gartnerago obliquum* to the appearance of *Tetralithus pyramidus* Gardet.

Discussion: *Lucianorhabdus cayeuxi* Deflandre and *Microrhabdulus ambiguus* Deflandre appear in the lower part of this zone. *Lucianorhabdus cayeuxi* is small and shows a basal disc, which is as broad as the spine. *Bidiscus ignotus* is abundant. Otherwise the flora is similar to that of the *Eiffellithus turriseiffeli* Zone. According to Stradner (1963) and Thierstein (1974), *Ahmeullerella octoradiata* (Gorka) has its first occurrence in the upper part of this zone, but this species was not found below the sediments that are assigned to the Coniacian in our sections.

Comparison: The lower boundary of this zone is the same as defined by Manivit (1971), but she proposed the first occurrence of *Corollithion exiguum* to define the upper boundary. In Cenomanian rocks the appearance level of this species however was found below the first occurrence of *Gartnerago obliquum* (Roth, 1973; Verbeek, 1975). The *Gartnerago obliquum* Zone of Roth (1973) was defined as the interval from the exit of

Marthasterites furcatus to the entry of *Broinsonia parca*, and as such Roth's zone is different from ours.

Distribution: El Kef section samples 7–9; reference section in France.

Assignment: Upper Cenomanian and Lower Turonian.

Tetralithus pyramidus Zone

Diagnosis: Interval from the appearance of *Tetralithus pyramidus* to the first occurrence of *Eiffellithus eximinus* (Stover).

Discussion: Only the coccoliths, which are composed of two layers of four cube-shaped elements, figured by Thierstein (1974) and listed as *Micula staurophora*, have their first occurrence in this zone. *Bidiscus ignotus* becomes less abundant. Although *Micula decussata* Vekshina is supposed to have its first occurrence at the same level as *Tetralithus pyramidus* Gardet, it is not found below the Middle Coniacian sediments of El Kef.

Comparison: The lower boundary of this zone seems to be somewhat older than the lower boundaries of the comparable *Micula staurophora* Zone of Manivit (1971) and the *Micula decussata* Zone of Roth (1973), because these authors correlated their zones to the Upper Turonian. The zones of Manivit and Roth distinctly range higher than our *Tetralithus pyramidus* Zone, because their upper limit is defined by the entry of *Marthasterites furcatus* Deflandre, which also marks the top of the *Tetralithus pyramidus* Zone of Cepek and Hay. *Marthasterites furcatus* appears three zones higher in the zonation proposed here.

Distribution: El Kef section samples 10 and 11 and reference samples from France.

Assignment: Middle Turonian.

Eiffellithus eximinus Zone

Diagnosis: Interval from the first occurrence of *Eiffellithus eximinus* to that of *Arkhangelskiella specillata* Vekshina.

Discussion: At the base of this zone the following species appear simultaneously in the Kef section: *Eiffellithus eximinus* (Stover), *Amphizygus brooksii* Bukry, *Cylindralithus serratus* Bramlette and Martini. *Kamptnerius magnificus* Deflandre and *Tetralithus obscurus* Deflandre. *Lucianorhabdus maleformis* Reinhardt and *Marthasterites inconspicuus* Deflandre enter this zone at a higher level. The entry of five species at one level might indicate a hiatus in the section. Near the top of the zone *Lucianorhabdus cayeuxi* becomes larger, and occasional specimens show a solid plug at the top.

Comparison: An *Eiffellithus eximinus* Zone has been described by Roth (1973) from a much higher stratigraphic level (Lower and Middle Campanian). Its diagnosis is different, i.e. the interval from the appearance of *Broinsonia parca* to the last occurrence of *Eiffellithus eximinus*.

Distribution: El Kef section samples 12–14.

Assignment: Upper Turonian.

Arkhangelskiella specillata Zone

Diagnosis: Interval from the entry of *Arkhangelskiella specillata* to the appearance of *Marthasterites furcatus* Deflandre.

Discussion: In this zone, specimens of *Arkhangelskiella specillata* have more than twelve perforations in each quadrant of the central structure. *Eiffellithus eximinus* becomes more abundant.

Comparison: Manivit (1971) described an *Arkhangelskiella specillata* Zone, in which the lower boundary also coincides with the first occurrence of *Arkhangelskiella specillata*. This zone is chronostratigraphically much higher, in the Lower-Middle Campanian. Since in our opinion *Arkhangelskiella specillata* and *Arkhangelskiella ethmopora* cannot be differentiated, the range of the former becomes extended downwards. So the lower boundary of the *Arkhangelskiella specillata* Zone, as defined in this paper, is at the level of the first occurrence of *Arkhangelskiella ethmopora* in Manivit.

Distribution: El Kef section samples 15–17. This zone is well recognizable in Kansas and Alabama (Cepek and Hay 1969a, b) and in France (Manivit, 1971).

Assignment: Lower Coniacian.

Marthasterites furcatus Zone

Diagnosis: Interval from the entry of *Marthasterites furcatus* to the entry of *Broinsonia lacunosa* Forchheimer.

Discussion: In the Kef section *Marthasterites furcatus* and *Ahmeullerella octoradiata* have the same appearance level. According to Stradner (1963) and to Thierstein (1974), *Ahmeullerella octoradiata* appears before *Marthasterites furcatus*.

In El Kef *Broinsonia signata* (Noel) is found to disappear from the column in this zone, but Thierstein (1973) gives the species a range into the Lower Campanian. *Broinsonia furtiva* Bukry has its first occurrence in the middle of the zone. In the Kef section *Micula decussata* appears at this level, but is known from Middle Turonian deposits in France already.

Comparison: The conspicuous entry of *Marthasterites furcatus* has lead to the introduction of several *Marthasterites furcatus* Zones (Cepek and Hay, 1969a, b; Manivit, 1971; Roth, 1973), which are all different due to deviations in the upper limits. Cepek and Hay used for the upper boundary of their zone the first occurrence of *Arkhangelskiella ethmopora*, which in our opinion starts well below the zone. The upper boundary of Manivit is the appearance of *Kamptnerius magnificus*, but this species is identical with *Kamptnerius punctatus* Stradner (see Thierstein, 1974), which is known from older sediments also (see the paper of Manivit). Roth defined his zone as the total range zone of *Marthasterites furcatus*. The present author adds a fourth definition for this zone.

Distribution: El Kef section samples 18–25.

Assignment: Upper part of the Lower Coniacian and Middle Coniacian.

Broinsonia lacunosa Zone

Diagnosis: Interval from the appearance of *Broinsonia lacunosa* to the entry of *Micula concava* Stradner.

Discussion: At the lower boundary the first occurrences of *Broinsonia lacunosa* and *Tetralithus quadratus* Stradner were found to coincide in the Kef section. Apart from the two species this zone has the same flora as the *Marthasterites furcatus* Zone, but *Broinsonia enormis*, *Podorhabdus coronadventis* and *Marthasterites inconspicuus* become rather rare and *Micula decussata* is more frequent. The earliest specimens of *Broinsonia lacunosa* show about seven perforations in each quadrant of the central structure, but most specimens from the top part of the zone have five perforations in each quadrant.

Comparison: *Broinsonia lacunosa* is the ancestral form of *Broinsonia parca* (Stradner) and taxonomically separated from *Broinsonia parca* by Forchheimer (1972). Thus *Broinsonia parca* of earlier authors may include *Broinsonia lacunosa*. Stradner (1963) reported *Broinsonia parca* from Turonian rocks together with *Marthasterites furcatus*, but afterwards both species were never reported from Turonian sediments again. As a consequence it is thought most likely that *Marthasterites furcatus* and *Broinsonia lacunosa* have their first occurrence not lower than in the Coniacian.

Distribution: El Kef section samples 26–35.

Assignment: Upper Coniacian.

Micula concava Zone

Diagnosis: Interval from the first occurrence of *Micula concava* (Stradner) to the first occurrence of *Zygodiscus spiralis* Bramlette and Martini.

Discussion: *Rucinolithus hayii* (Bukry) starts its range in this zone, and *Lithastrinus grilli* becomes rare. Three more, fairly rare species (*Lucianorhabdus arcuatus* Forchheimer, *Tetralithus nitidus* Martini, *Staurolithites bochotnicae* (Gorka) have their first occurrence about half way in this zone. It seems premature to define another zone or subzone based on one of these three species, the more so because none of these species has so far been reported from Santonian sediments elsewhere. *Micula concava* is a common species, but is often taken together with *Micula decussata*. *Micula concava* developed at about the Coniacian-Santonian boundary and has never been reported from older sediments.

Comparison: *Micula concava* has never been used as zonal marker before. The *Micula concava* Zone is comparable to the upper part of the *Marthasterites furcatus* Zone of Roth (1973).

Distribution: El Kef section samples 36–43.

Assignment: Lower and Middle Santonian.

Zygodiscus spiralis Zone

Diagnosis: Interval from the entry of *Zygodiscus spiralis* to the appearance of *Broinsonia parca*.

Discussion: *Micula decussata* becomes more abundant in this zone. The width of the central structure and the number of perforations in the central structure of *Broinsonia lacunosa* is decreasing. *Lithastrinus floralis* has its last occurrence at the top of this zone.

Comparison: *Zygodiscus spiralis* is reported from Santonian sediments by Roth (1973, DSDP Site 171 near Australia).

Distribution: El Kef samples 44 and 45.

Assignment: Upper Santonian; according to Roth, possibly Middle Santonian as well.

Broinsonia parca Zone

Diagnosis: Interval from the first occurrence of *Broinsonia parca* to the appearance of *Tetralithus aculeus* (Stradner).

Discussion: The lower boundary of the zone is placed at the level of appearance of the first *Broinsonia parca*, as figured by Stradner (1963, pl. 1, fig. 3). *Podorhabdus coronadventis*, *Lithastrinus grilli* and *Marthasterites furcatus* have their last occurrences in this zone. The number of perforations in each quadrant of the central structure of *Arkhangelskiella specillata* decreases to about eight. In the lower part of the zone *Broinsonia lacunosa*, from which *Broinsonia parca* developed, is still rare.

Comparison: Roth (1973) defined his *Broinsonia parca* Zone as the interval from the last occurrence of *Eiffellithus eximinus* to the first occurrence of *Tetralithus trifidus* (=*Tetralithus gothicus*). Neither datum level fits to our zonal boundaries, as may be seen in the range chart.

Distribution: El Kef samples 46 and 181 and reference samples from Spain.

Assignment: Lower part of the Lower Campanian.

UPPER CRETACEOUS CALCAREOUS NANNOPLANKTON ZONATION IN A COMPOSITE SECTION NEAR EL KEF, TUNISIA. II

BY

J. W. VERBEEK

(Communicated by Prof. C. W. DROOGER at the meeting of October 25, 1975)

Tetralithus aculeus Zone

Diagnosis: Interval from the entry of *Tetralithus aculeus* to the appearance of *Tetralithus gothicus* Deflandre.

Discussion: In this zone *Lucianorhabdus arcuatus* becomes more frequent. The very large specimens of *Lucianorhabdus cayeuxi* show a great variation in outline; plugs on the tops and basal discs may be present.

Comparison: *Tetralithus aculeus* Zones have been recognized by Cepek and Hay (1969a, b), and by Manivit (1971), but in both their publications the upper boundary is different from ours. Cepek and Hay defined the upper boundary as the entry of *Chiastozygus initialis* (Gorka), which is a very rare species and not present in the Kef samples. Manivit used the first occurrence of *Lithraphidites quadratus* Bramlette and Martini for the upper boundary. However, with such a definition this zone would cover almost the entire Campanian, in which a finer biostratigraphic subdivision is possible. *Tetralithus gothicus* is a well-known species in the Campanian and therefore useful as the marker for the upper boundary of this zone.

Distribution: El Kef section samples 47–183 and reference samples from Spain.

Assignment: Upper part Lower Campanian and lower part Middle Campanian.

Tetralithus gothicus Zone

Diagnosis: Interval from the first occurrence of *Tetralithus gothicus* Deflandre to the appearance of *Lithraphidites quadratus*.

Discussion: Two forms of *Tetralithus gothicus* were recognized, one with three arms and one with four. The specimens with four arms seem to be present somewhat earlier than the form with three arms. In Tunisia the specimens with three arms are more frequent but in Spain the four-arm forms. *Eiffellithus eximinus*, *Broinsoina enormis*, *Broinsonia furtiva*, *Gartnerago obliquum* and *Rucinolithus hayii* have their last occurrence in this zone. Slightly above the base of the zone *Arkhangelskiella cymbiformis* and *Cylindralithus gallicus* make their appearance. Because *Cylindralithus gallicus* has not been reported very frequently and *Arkhangelskiella cymbiformis* without perforations has been reported from Lower Campanian sediments by Roth (1973), neither species can as yet be used for a further formal subdivision of the zonation.

Comparison: Roth described a total range zone of *Tetralithus trifidus* (=*Tetralithus gothicus*), which in the Kef section extends higher than our *Tetralithus gothicus* (partial range) Zone. Our zone probably coincides with the lower part of the *Arkhangelskiella cymbiformis* Zone of Perch-Nielsen (1972).

Distribution: El Kef section samples 184–190 and reference samples from Spain.

Assignment: Upper part Middle Campanian and Upper Campanian.

Lithraphidites quadratus Zone

Diagnosis: Interval from the first occurrence of *Lithraphidites quadratus* to the first occurrence of *Tetralithus murus* Bramlette and Martini.

Discussion: Although *Lithraphidites quadratus* may be rare in certain sections, it is generally accepted as a worldwide marker for the Lower Maastrichtian. *Tetralithus gothicus* has its last and *Markalius astroporus* (Stradner) its first occurrence in this zone. Some specimens of *Tetralithus aculeus* show a decrease in length of the two distal elements.

Comparison: The diagnosis is identical to that given by Roth (1973). Cepek and Hay (1969a, b) and Manivit (1971) used the entry of *Nephrolithus frequens* Gorka for the upper boundary of the same nominal zone, a procedure that combines our zone with the next one.

Distribution: El Kef section samples 191–193.

Assignment: Lower Maastrichtian.

Tetralithus murus Zone

Diagnosis: Interval from the appearance of *Tetralithus murus* to the first occurrence of *Nephrolithus frequens* Gorka.

Discussion: *Amphizygus brooksii* and *Lucianorhabdus arcuatus* disappear in this zone. The two distal elements of *Tetralithus aculeus* are generally reduced more strongly than in the *Lithraphidites quadratus* Zone.

Comparison: Manivit (1971) mentioned identical ranges for *Tetralithus murus* and *Nephrolithus frequens*. *Tetralithus murus* was found in El Kef in Middle Maastrichtian sediments and *Nephrolithus frequens* only in the Upper Maastrichtian (age determinations based on planktonic foraminifera).

Distribution: El Kef section samples 194–198.

Assignment: Middle Maastrichtian.

Nephrolithus frequens Zone

Diagnosis: Interval from the first occurrence of *Nephrolithus frequens* to the extinction level of most Cretaceous calcareous nannofossils.

Discussion: This zone is the total range zone of *Nephrolithus frequens* and *Tetralithus kamptneri* n.comb. (=*Ceratolithoides kamptneri* Bramlette and Martini, 1964, p. 308, pl. 5, figs. 13–14). The latter species developed from *Tetralithus aculeus* by the almost complete reduction of the two distal elements. In this zone the genera *Braarudosphaera* or *Thoracosphaera* are usually abundant.

Comparison: The description of this zone is similar to that by Cepek and Hay (1969a, b) and by Manivit (1971).

Distribution: El Kef samples 199–202 and reference samples from Spain.

Assignment: Upper Maastrichtian.

The two higher samples of the Kef section are clearly different. The chronostratigraphic position of sample 203^1 is uncertain, because it contains very few Cretaceous coccoliths, which may all be reworked, and does not contain Tertiary nannoplankton. In addition to frequent Cretaceous forms, sample 203^2 contained *Cruciplacolithus tenuis*, but no *Chiasmolithus danicus*. So it must be placed in the NP 2 Zone of Martini (1971), which is of Paleocene age.

REMARKS ON SYSTEMATICS

Family Arkhangelskiellaceae Gartner, 1968
Genus *Arkhangelskiella* Vekshina, 1959
Type species: *Arkhangelskiella cymbiformis* Vekshina, 1959

Arkhangelskiella cymbiformis Vekshina
pl. 3, fig. 3

Arkhangelskiella cymbiformis Vekshina, 1959, p. 66, pl. 1, fig. 1; pl. 2, fig. 3a–c.
Arkhangelskiella cymbiformis Bukry, 1969, p. 21, pl. 1, fig. 1–3.

Remarks: This species is characterized by not more than five perforations in each quadrant of the central structure. See also remarks on *Arkhangelskiella specillata*.

Known range Upper (?) Campanian-Maastrichtian.

Arkhangelskiella specillata Vekshina
pl. 1, fig. 5

Arkhangelskiella specillata Vekshina, 1959, p. 67, pl. 1, fig. 2; pl. 2, fig. 5.
Arkhangelskiella specillata ethmopora Bukry, 1969, p. 21, pl. 1, fig. 4–7.
Broinsonia parca (Stradner) Bukry, 1969, partim, p. 23, pl. 3, fig. 9–10 (not pl. 3, fig. 3–8).

Remarks: Vekshina differenciated *Arkhangelskiella cymbiformis* from *Arkhangelskiella specillata* by the smaller number of perforations. The drawing of the holotype of *Arkhangelskiella specillata* shows nine perforations per quadrant and the holotype of *Arkhangelskiella cymbiformis* only three. In this paper specimens with more than five perforations are considered as *Arkhangelskiella specillata* and the specimens with five or less perforations as *Arkhangelskiella cymbiformis*.

Arkhangelskiella specillata ethmopora was described by Bukry as a subspecies with little spokes in the perforations. Afterwards *Arkhangelskiella ethmopora* was differentiated from *Arkhangelskiella specillata* by having larger perforations. However, the diameter of the perforations depends on the amount of overgrowth with secondary calcite and cannot be a feature to differentiate the two forms.

Because it is impossible to observe the spokes in the perforations when using a lightmicroscope, *Arkhangelskiella ethmopora* has not been recognized in this study.

Known range: Coniacian-Maastrichtian.

Genus *Broinsonia* Bukry, 1969
Type species: *Broinsonia dentata* Bukry, 1969

Broinsonia furtiva Bukry
pl. 1, fig. 8

Broinsonia furtiva Bukry, 1969, p. 22, pl. 2, fig. 7–8.
? *Broinsonia furtiva* Thierstein, 1974, partim, p. 637, pl. 10, fig. 7–14; pl. 11, fig. 1–4 (non pl. 11, fig. 5–8).

Remarks: *Broinsonia furtiva* is distinguished from *Broinsonia parca* and *Broinsonia lacunosa* by four prominent bars, which divide the central structure in four quadrants. Each quadrant shows a shield with large and irregular perforations. There is some indication of a spine at the center of the central structure where the bars meet. The specimen figured by Thierstein (1974, pl. 11, fig. 5–8) has no bars but a shield with circular perforations in the central structure, and is considered to be a *Broinsonia lacunosa.*

Known range: Coniacian-Santonian.

Broinsonia lacunosa Forchheimer
pl. 2, fig. 2

Broinsonia parca (Stradner) Bukry, 1969, partim, p. 23, pl. 3, fig. 5–8 (non pl. 3, fig. 3–5, 9–10).

Broinsonia lacunosa Forchheimer, 1972, p. 25, pl. 2, fig. 1.

? *Broinsonia furtiva* Bukry, Thierstein, 1974, partim, p. 637, pl. 11, fig. 5–8 (non pl. 10, fig. 7–14; pl. 11, fig. 1–4).

Remarks: *Broinsonia lacunosa* is characterized by a rather narrow rim and a large central structure with distinct perforations. The oldest forms have about seven perforations and the youngest about three perforations in each quadrant of the central structure. See also remarks on *Broinsonia parca.*

Known range: Middle Coniacian-Lower Campanian.

Broinsonia parca (Stradner) Bukry
pl. 2, fig. 6

Arkhangelskiella parca Stradner, 1963, p. 10, pl. 1, fig. 3.

Broinsonia parca (Stradner) Bukry, 1969, partim, p. 23, pl. 3, fig. 3–5 (non pl. 3, fig. 6–10).

Remarks: In the Kef section an evolutionary trend from *Broinsonia lacunosa* to *Broinsonia parca* was recognized. The specimens with a rim which is about as broad as the central structure or with the rim broader than the central structure are considered to belong to *Broinsonia parca,* and the specimens with a central structure which is distinctly broader than the rim are listed as *Broinsonia lacunosa.* Furthermore, *Broinsonia parca* has a prominent ridge at the distal side of the rim around the central structure. The ridge is less distinct or absent in the specimens belonging to *Broinsonia lacunosa.* The number of perforations cannot be used to differentiate the two species, because the holotype of *Broinsonia parca* is figured with three perforations in each quadrant of the central structure, whereas specimens of *Broinsonia lacunosa* are known with two perforations in each quadrant. The perforations of *Broinsonia lacunosa* are more distinct than the perforations of *Broinsonia parca.*

Known range: Campanian-Maastrichtian.

Family Eiffellithaceae Reinhardt emend. Perch-Nielsen, 1968
Genus *Nephrolithus* Gorka, 1957
Type species: *Nephrolithus frequens* Gorka, 1957

Nephrolithus frequens Gorka emend. Perch-Nielsen
pl. 3, fig. 7

Nephrolithus frequens Gorka, 1957, p. 263, pl. 5, fig. 7.
Nephrolithus frequens emend. Perch-Nielsen, 1968, p. 56, pl. 7, fig. 12–14; pl. 18, fig. 1–9; textfig. 23.

Remarks: This species may be easily confused with forms of *Parhabdolithus angustus* (Stradner) from Campanian and Maastrichtian sediments, because both have a similar outline. Such older forms are described by Roth (1973) as *Parhabdolithus* cf. *P. angustus* and one is figured here on pl. x, fig. x. *Nephrolithus frequens* has a rim, which is narrower at the concave side than at the convex side of the coccolith.
Known range: Upper Maastrichtian.

Family Microrhabdulaceae Deflandre, 1963
Genus *Lithraphidites* Deflandre, 1963
Type species: *Lithraphidites carniolensis* Deflandre, 1963

Lithraphidites cf. *L. quadratus* Bramlette and Martini
pl. 3, fig. 4

cf. *Lithraphidites quadratus* Bramlette and Martini, 1964, p. 310, pl. 6, fig. 16–17; pl. 7, fig. 8.

Remarks: These forms at both sides of the blade have similar concave ends as *Lithraphidites quadratus*, but they are longer and the blades are as narrow as in *Lithraphidites carniolensis*. In our opinion *Lithraphidites* cf. *L. quadratus* is a transitional form in the evolution from *Lithraphidites carniolensis* to *Lithraphidites quadratus*. Bramlette and Martini (1964) emphatically excluded these specimens from their description of *Lithraphidites quadratus*. In the Kef section the above species have nearly the same range as the nominate species, although the Upper Maastrichtian forms are usually shorter.
Known range: Upper Campanian-Maastrichtian.

Family Braarudosphaeraceae Deflandre, 1947
Genus *Tetralithus* Gardet, 1955
Type species: *Tetralithus pyramidus* Gardet, 1955

Tetralithus gothicus Deflandre
pl. 2, fig. 8; pl. 3, fig. 1

Tetralithus gothicus Deflandre, 1959, p. 138, pl. 3, fig. 25.
Tetralithus gothicus Deflandre, Stradner in Stradner and Papp, 1961, p. 124, pl. 40, fig. 13a–b, textfig. 13/2; textfig. 23/3a–c.
Tetralithus gothicus trifidus Stradner in Stradner and Papp, 1961, p. 124.
Tetralithus trifidus (Stradner) Bukry, 1973, p. 860.

Remarks: *Tetralithus gothicus* evolved from *Tetralithus pyramidus* by lengthening of the elements. *Tetralithus pyramidus* has forms with three and with four elements, which start their range at the same level and are generally considered to belong to one species. The three and four armed forms of *Tetralithus gothicus* are also found together. Because specimens with four arms are more frequent in Spain and those with three arms more frequent in Tunisia, it seems likely that the number of arms depended on ecological circumstances. For these reasons both forms are considered to belong to the same species.

Known range: Middle Campanian-Lower Maastrichtian.

Tetralithus kamptneri (Bramlette and Martini) Verbeek n.comb.
pl. 3, fig. 6

Ceratolithoides kamptneri Bramlette and Martini, 1964, p. 308, pl. 6, fig. 18–21.
Non *Ceratolithoides kamptneri* Manivit, 1971, p. 132, pl. 12, fig. 12–13.

Remarks: *Tetralithus kamptneri* evolved from *Tetralithus aculeus* by the reduction the two distal elements, which compose the top of this coccolith, and by some increase in length of the two proximal elements. Only specimens with the two distal elements almost completely reduced would fit the original description of Bramlette and Martini. The form figured by Manivit (1971) shows no more than a slight reduction must be classified in *Tetralithus aculeus*.

Known range: Upper Maastrichtian.

Tetralithus nitidus Martini
pl. 2, fig. 4

Tetralithus nitidus Martini, 1961, p. 4, pl. 1, fig. 5; pl. 4, fig. 41.

Remarks: This species differs from *Tetralithus gothicus* by having four little elements in the center.

Known range: Santonian-Lower Maastrichtian.

Genera incertae sedis
Genus *Micula* Vekshina, 1959
Type species *Micula decussata* Vekshina, 1959

Remarks: All species of this genus are composed of one cube-shaped element with depressed edges. The specimens of *Micula* figured by Roth (1973, pl. 20, fig. 4) and Thierstein (1974, pl. 12, fig. 1–11) are composed of eight elements and belong to an as yet unnamed genus that has its first occurrence in the *Tetralithus pyramidus* Zone.

Micula concava (Stradner) Bukry
pl. 2, fig. 3

Nannotetraster concavus Stradner in Martini and Stradner, 1960, p. 269, *Micula decussata concava* (Stradner) Bukry, 1969, p. 67, pl. 40, fig. 7–8.

Remarks: This species differs from *Micula decussata* in having long processes at the corners. *Micula concava* develops from *Micula decussata* close to the Coniacian-Santonian boundary. In Upper Campanian and Maastrichtian sediments, *Micula concava* has strongly depressed edges.

Known range: Santonian-Maastrichtian.

Micula decussata Vekshina
pl. 2, fig. 1

Micula decussata Vekshina, 1959, p. 71, pl. 1, fig. 6; pl. 2, fig. 11.

Remarks: This species is characterized by a cube shape with slightly depressed edges.

Known range: Middle Turonian-Maastrichtian.

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EXPLANATION TO THE PLATES

PLATE 1

Index species for the Cenomanian-Coniacian interval, Kef section, Tunisia.

Fig. 1. *Eiffellithus turriseiffeli* (Deflandre), Kef 13, Utrecht slide CH 3391, location V −7, +5, distal view, 7200×.
Fig. 2. *Gartnerago obliquum* (Stradner), Kef 23, Utrecht slide CH 3392, location V +3, +6, distal view, 5000×.
Fig. 3. *Eiffellithus eximinus* (Stover), Kef 27, Utrecht slide CH 3393, location V +8, +5 distal view, 7200×.
Figs. 4, 6. *Tetralithus pyramidus* Gardet, 4, Kef 10, Utrecht slide CH 3396, location V +4, +9, 7000×; 6, AFN 200, Utrecht slide CH 3399, location V +9, +4, 5600×.
Fig. 5. *Arkhangelskiella specillata* Vekshina, Kef 27, Utrecht slide CH 3393, location V −5, +3, distal view, 5800×.
Fig. 7. *Marthasterites furcatus* Deflandre, Kef 23, Utrecht slide CH 3392, location V +4, +7, 6600×.
Fig. 8. *Broinsonia furtiva* Bukry, Kef 37, Utrecht slide CH 3398, location V +2, +7, distal view, 7200×.

The locations listed on plates 1–3 refer to squares in a 200 mesh grid by means of a X–Y coordinate system from the central V-marking (see Hansen, Schmidt and Mikkelsen, 1975).

PLATE 2

Index species for the Coniacian-Campanian interval, Kef section, Tunisia.

Fig· 1. *Micula decussata* Vekshina, Kef 27, Utrecht slide CH 3393, location V +5, +8, 4100×.
Fig. 2. *Broinsonia lacunosa* Forchheimer, Kef 29, Utrecht slide CH 3395, location V −6, −7, distal view, 5000×.
Fig. 3. *Micula concava* Stradner, AFN 190, Utrecht slide CH 3387, location V +5, −8, 4500×.
Fig. 4. *Tetralithus nitidus* Martini, AFN 189, Utrecht slide CH 3390, location V −2, +4, proximal view, 5700×.
Fig. 5. *Zygodiscus spiralis* Bramlette and Martini, AFN 200, Utrecht slide CH 3399, location V +7, +2, distal view, 8800×.
Fig. 6. *Broinsonia parca* (Sradner), AFN 182, Utrecht slide CH 3388, location V +6, +6, distal view, 5000×.
Fig. 7. *Tetralithus aculeus* (Stradner), AFN 189, Utrecht slide CH 3390, location V +2, +3, side view, 7100×.
Fig. 8. *Tetralithus gothicus* Deflandre, Kef 59 (Upper Campanian) Utrecht slide CH 3394, location −7, +6, 3800×.

PLATE 3

Index species for the Campanian-Maastrichtian interval, Kef section, Tunisia.

Fig. 1. *Tetralithus gothicus* Deflandre, Kef 59 (Upper Campanian), Utrecht slide CH 3394, location V +8, +5, 7500×.
Fig. 2. *Lithraphidites quadratus* Bramlette and Martini, AFN 200, Utrecht slide CH 3389, location V +2, −6, side view, 7600×.
Fig. 3. *Arkhangelskiella cymbiformis* Vekshina, AFN 199, Utrecht slide CH 3387, location V +2, −9, distal view, 4800×.
Fg. 4· *Lithraphidites* cf. *L. quadratus* Bramlette and Martini, Kef 60 (Upper Campanian), Utrecht slide CH 3397, location V −5, +4, side view, 5200×.
Fig· 5. *Tetralithus murus* Bramlette and Martini, AFN 200, Utrecht slide CH 3399, location V +7, +5, proximal view, 7000×.
Fig. 6. *Tetralithus kamptneri* (Bramlette and Martini), AFN 200, Utrecht slide CH 3399, location V +1, +4, side view, 6700×.
Fig. 7. *Nephrolithus frequens* Gorka, AFN 200, Utrecht slide CH 3389, location V −4, −6, distal view, 8200×.
Fig. 8. *Parhabdolithus angustus* (Stradner), AFN 200, Utrecht slide CH 3389, location V +1, +4, proximal view, 8100×.

J. W. VERBEEK: *Upper Cretaceous calcareous nannoplankton zonation in a composite section near El Kef, Tunisia.*

PLATE 1

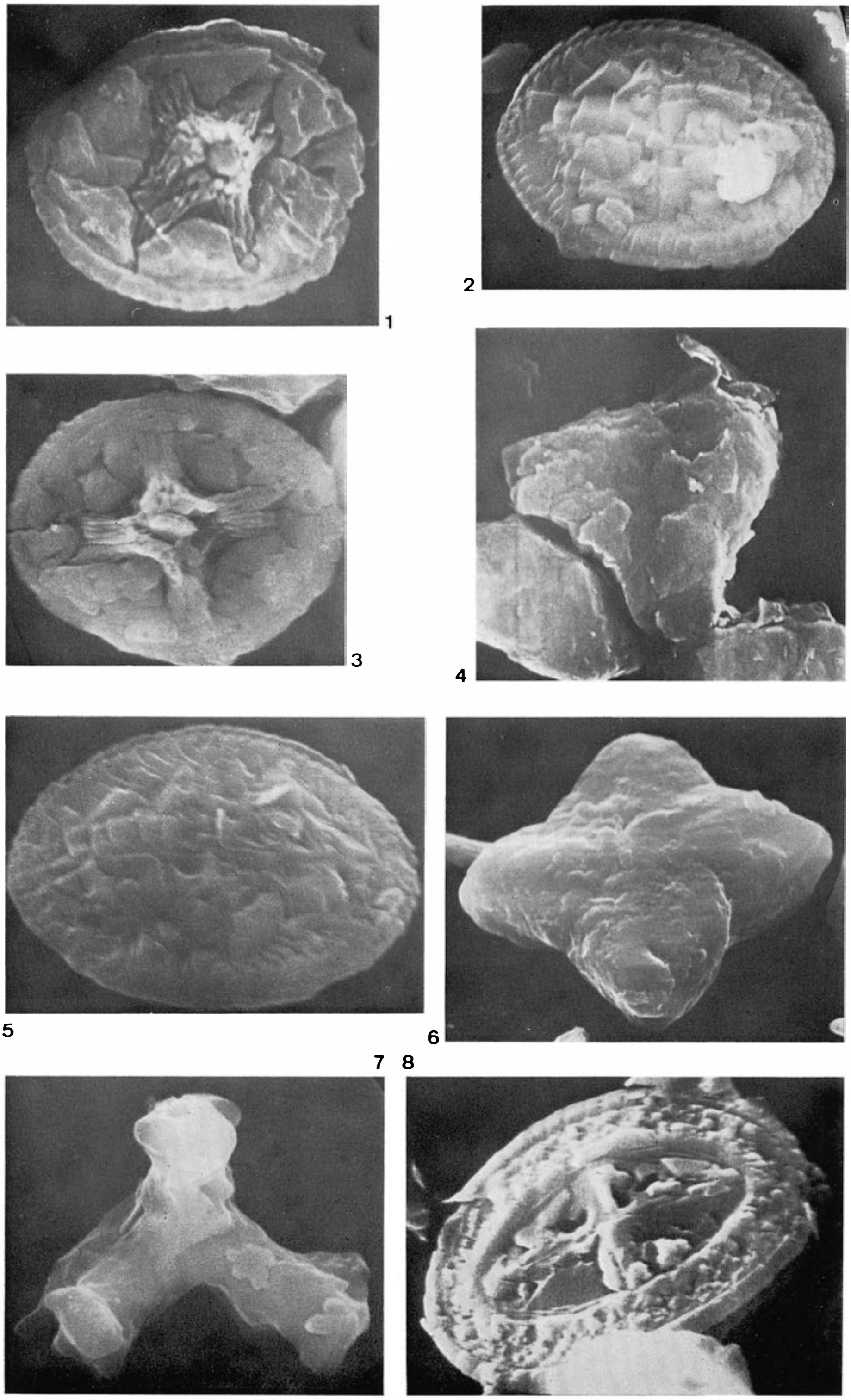

PLATE 2

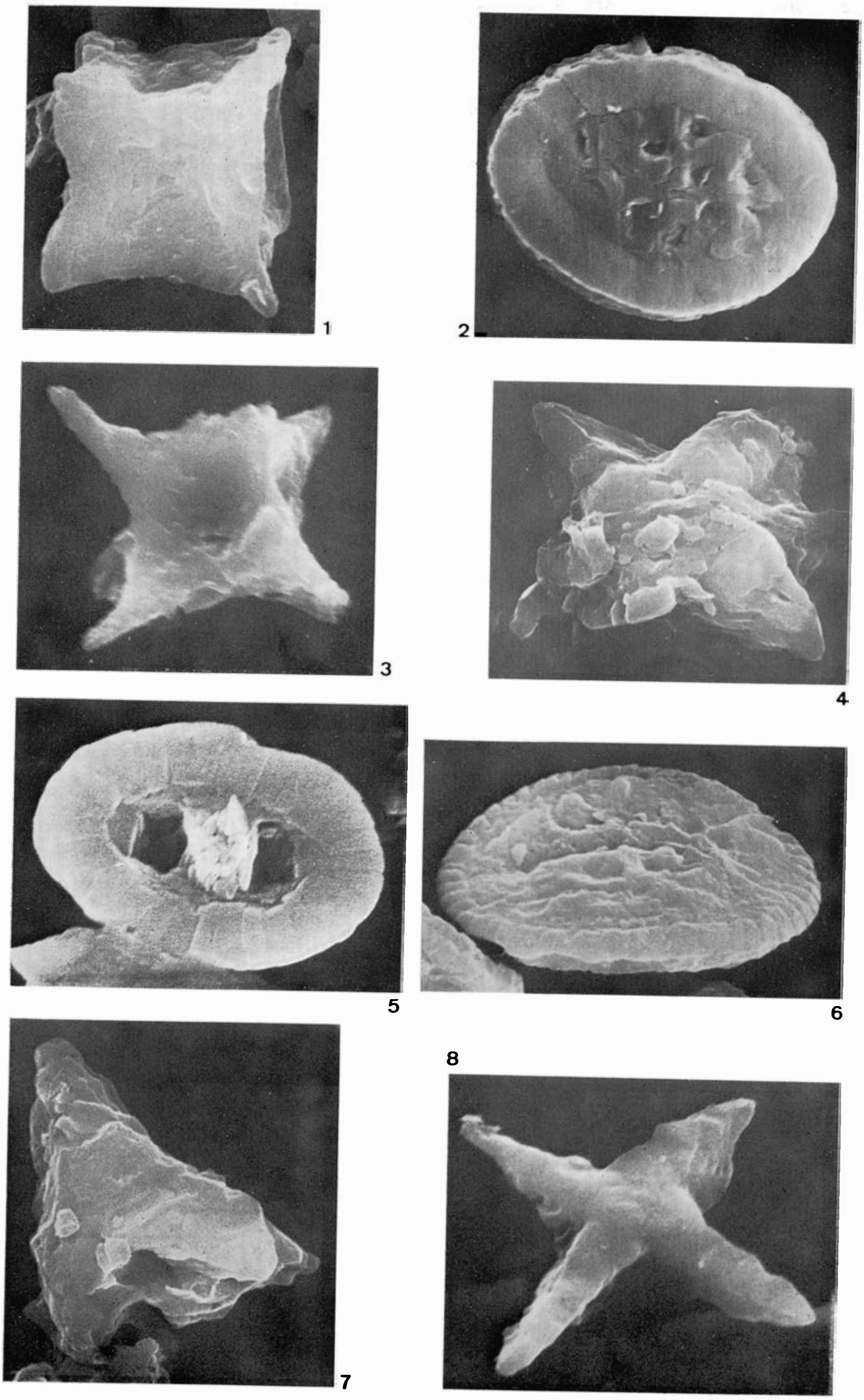

PLATE 3