BIOSTRATIGRAPHY OF CRETACEOUS CALCAREOUS NANNOPLANKTON

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With Appendix by B. PRINS & W. SISSINGH[1)]

ABSTRACT

Sissingh, W. (1977). Biostratigraphy of Cretaceous calcareous nannoplankton. Geol. Mijnbouw, 56, p. 37-65.

The stratigraphical distribution of selected species of calcareous nannoplankton from sections of Cretaceous deposits in Tunisia, France, The Netherlands, West Germany, Great Britain, Denmark, Turkey, Oman and New Jersey was studied. A number of Late Cretaceous lineages was recognised, on which a proposal for a revised zonation is based. Twenty-six zones are distinguished for the Cretaceous interval. First-order correlations between zones and Cretaceous stage-stratotypes are discussed briefly. The Upper Cretaceous part of the proposed zonation has also been correlated with planktonic foraminiferal zones. One new genus and two new species are described.

1. INTRODUCTION

The contributions of studies of calcareous nannoplankton to Tertiary and Quaternary biostratigraphy are widely known and appreciated. The potential biostratigraphical significance of this group of fossils in the Cretaceous has also been recognised, but a detailed biozonation of proven validity and comparable to the one for the post-Cretaceous interval is not yet available.

To improve chronostratigraphical control for oil exploration purposes, the author studied calcareous nannoplankton assemblages from the Late Cretaceous deposits of the central and northern North Sea region.

The initial study was mainly based on the examination of core and sidewall samples from the Maastrichtian chalk interval encountered in a number of offshore exploration wells. In order to test the validity of these findings coeval strata with better preserved assemblages of calcareous nannoplankton were investigated from the area of the synclinal structure of Dyr el Kef in western Tunisia. This Tunisian study was extended into Campanian to Cenomanian and older strata.

In the course of the study several other sections of stratigraphical importance have also been investigated in detail. These sections include all the stratotypes of current Upper Cretaceous stages, and in addition several other key sections situated in France. A large number of sidewall samples from exploration wells drilled in Oman and Turkey were available as well.

Less attention has been paid to the Early Cretaceous calcareous nannoplankton. However, samples from the Aptian and Albian of the Dyr el Kef section in Tunisia, from northern France and from a number of localities in West Germany have been studied. In addition, samples taken from the Berriasian to Barremian strata of the type Speeton Clay Formation, outcropping along the Filey Bay in Yorkshire, England, have been examined.

2. PREVIOUS STUDIES

A review of Cretaceous nannoplankton zonations as available in literature is presented in Figure 1, which is discussed below. Excluding the specialised studies of *Nannoconus*, the results of which have been published by various authors since 1955, the first Cretaceous subdivision based on calcareous nannoplankton was presented by Stradner (1963). This author studied a large number of samples from West European countries and recognised seven successive associations.

Similar assemblage-zonations have been described by Stover (1966), Reinhardt (1966), Bukry (1969) and Black (1971).

Investigation of Cretaceous (and younger) calcareous nan-

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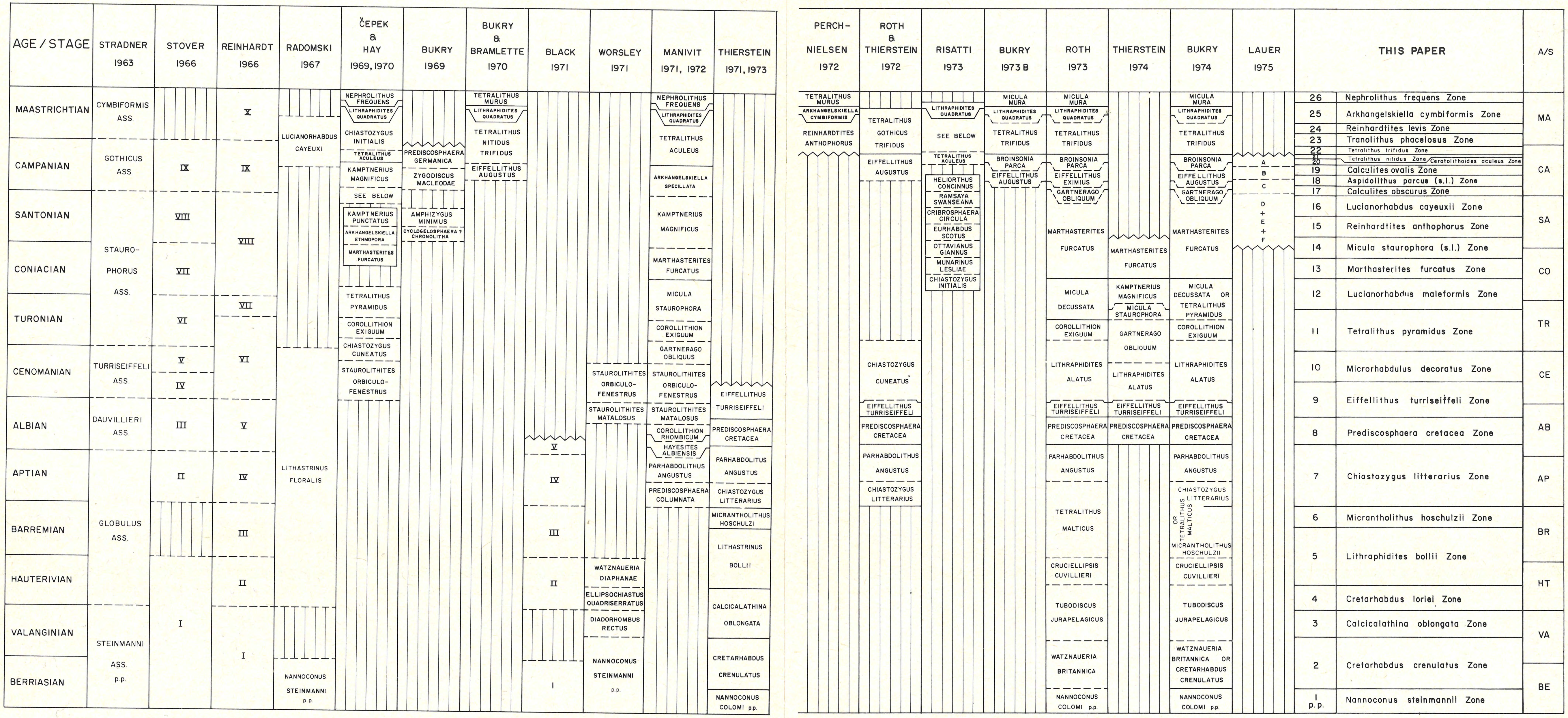


Fig. 1
Tentative correlation chart of Cretaceous calcareous nannoplankton zonations.

noplankton from the Polish Outer Carpathians enabled R a d o m s k i (1967) to distinguish three biostratigraphical units. Although the boundaries of Radomski's units are not clearly defined, these units may be considered to be the first formal nannoplankton (range-) zones defined for the Cretaceous interval.

C e p e k & H a y (1969, 1970) investigated Cenomanian to Maastrichtian samples collected in Kansas and in Alabama. The authors proposed a zonation comprising 12 range zones. The chronostratigraphical position of each zone is only discussed superficially. Furthermore, their sections did not cover the entire Cenomanian-Maastrichtian interval. In line with observations made by S m i t h (1975), the present study showed that the presence of *Tetralithus pyramidus* without *Marthasterites furcatus* in the uppermost part of the Kansas section indicates it to be not younger than Early Coniacian (early part). The lower part of the composite Alabama section may be of Late Santonian age because of the occurrence of *Lucianorhabdus cayeuxii* without *Calculites obscurus* (reported as *Tetralithus obscurus*). This part of the section may also belong to the Lower Campanian, since, in addition, it yielded *Aspidolithus parcus* (reported as *Arkhangelskiella parca*) and *Marthasterites furcatus*. Consequently, the first occurrence of *Calculites obscurus* probably has not been established correctly. Thus, a stratigraphical interval including at least part of the Coniacian and Santonian has not been covered in the study of C e p e k & H a y (1969, 1970).

B u k r y & B r a m l e t t e (1970) described four tentative zones in their report on coccolith age determinations of samples recovered during Leg 3 of the Joides Deep Sea Drilling Project in the South Atlantic Ocean. The authors interpreted their zones to be confined to the Campanian-Maastrichtian interval. The upper three zones are by now commonly accepted, but their lowermost *Eiffellithus augustus* Zone is relatively difficult to delimit as far as its lower boundary is concerned. This boundary is based on the first appearance of *Broinsonia parca* (now *Aspidolithus parcus*), a species belonging to a rather complicated and gradually evolving group (see L a u e r, 1975). The authors assume that the extinction level of *Eiffellithus augustus* (now *E. eximius*) is somewhat older or equal to that of the first appearance of *Tetralithus nitidus trifidus* during the Late Campanian. However, at least in the Dyr el Kef section (W. Tunisia) *E.*

eximius is still present in the Lower Maastrichtian, well above the first occurrence level of *T. trifidus* (see also Worsley, 1974, fig. 9).

Worsley (1971) defined seven formal Upper Jurassic to Lower Cretaceous zones based on a study of seven core samples taken from two holes during Leg 1 of the Deep Sea Drilling Project in the West Atlantic. Each sample was assigned to a different zone. Samples from the same coreholes have also been studied by other authors and the relative positions of the samples have become a matter of controversy (see Barnard & Hay, 1974). The proposed zonation was largely rejected by Thierstein (1971). Only the base of the *Nannoconus steinmanni* Zone has been accepted by Thierstein. It is identical with that of Thierstein'n *Nannoconus colomi* Zone and is also the lowermost datum plane of the biozonation proposed in this paper.

Manivit (1971, 1972) proposed a zonation for the Aptian to Danian interval based on examination of sample material from France. Her 15-fold Cretaceous subdivision includes a number of zones originally defined by Cepek & Hay (1969) but these zones were, however, not formally assigned to a particular chronostratigraphical level. The Aptian to Cenomanian zones were reviewed by Thierstein (1971).

Manivit's zonation for the Aptian to Albian interval differs considerably from Thierstein's (1971, 1973) zonal scheme, with the exception of the *Parhabdolithus angustus* Zone. In the present paper this zone has been rejected as well, since *P. angustus* was identified in Late Hauterivian to Barremian strata (samples RP 13, 12, 35, 33 and 4, see fig. 8) at Speeton. As far as Manivit's Upper Cretaceous subdivision is concerned, it is obvious from later studies that *Lithraphidites quadratus* has its entry clearly above the base of the Maastrichtian.

Thierstein (1971, 1973) made a thorough study of nannoplankton derived from latest Jurassic to Early Cenomanian deposits sampled in southeastern France, Switzerland and Great Britain as well as in South America (Trinidad, Venezuela). Samples from DSDP Leg 1 (West Atlantic) and Leg 14 (Central Atlantic) were included, as well as stratotypes of most Lower Cretaceous stages. Chronostratigraphical control was provided by data from cephalopods, calpionellids and foraminifera. The established (tentative) zonation comprised nine zones, which were recognised in widely scattered localities at corresponding chronostratigraphical intervals. It is essentially this zonation, supplemented by one new, tentative zone, which has been adopted for the Berriasian to Cenomanian in this paper.

Perch-Nielsen (1972) published data about the nannoplankton from the Maastrichtian deposits encountered during DSDP Leg 12. She distinguished three zones. The upper *Tetralithus murus* Zone had already been established by Martini (1969) and Bukry & Bramlette (1970). The new *Arkhangelskiella cymbiformis* Zone was introduced to characterise the interval between the extinction level of *Reinhardtites anthophorus* (now *R. levis?*) and the earliest occurrence of *Tetralithus murus* or *Nephrolithus frequens*. The present study has demonstrated that *N. frequens* probably appears a little later during the Maastrichtian than the first individuals (with four distinctly elongated units) of *T. murus* (now *Micula murus*).

Roth & Thierstein (1972) studied calçareous nannoplankton derived from cores recovered during Leg 14 of the DSDP. For the subdivision of the Cretaceous they applied the zonation originally proposed by Cepek & Hay (1969), Bukry & Bramlette (1970) and Thierstein (1971). The top of the uppermost Lower Cretaceous *Eiffellithus turriseiffeli* Zone is according to Roth & Thierstein (1972) marked by the first occurrence of *Chiastozygus cuneatus* or *Lithastrinus alatus*.

Campanian to Maastrichtian sections in Mississippi were studied by Risatti (1973). Nine nannofossil zones were reported, five of which based on new species. The ranges of these species as well as of zonal marker *Heliorthus concinnus* are still unknown outside the area studied by Risatti. The remaining three zones correspond to those of Cepek & Hay (1969b) who studied the same lithostratigraphical units outcropping in Alabama.

Bukry (1973b) (see also Bukry, 1973a) outlined an Upper Cretaceous-Tertiary zonation in his paper on coccoliths from sites in the Caribbean Sea cored during DSDP leg 15. The zones confined to the Cretaceous are more or less identical with those of Bukry & Bramlette (1970). A *Broinsonia parca* Zone was newly proposed. The zone has been defined as the interval between the last occurrence of *Eiffellithus augustus* (= *E. eximius*) and the first occurrence of *Tetralithus trifidus*. As mentioned above, the range of *E. eximius* probably extends into the Maastrichtian.

In a study of nannofossils of DSDP Leg 17, Central Pacific Basin, Roth (1973) created a new zonal subdivision by combining a number of Upper Cretaceous zones originally proposed by Manivit (1971) and Bukry & Bramlette (1970). He re-named some of these zones and also distinguished a *Broinsonia parca* Zone as characteristic of the interval between the last *Eiffellithus eximius* (*E. augustus* of Bukry) and the first *Tetralithus trifidus*. Two more Upper Cretaceous zones were newly proposed: a Santonian *Gartnerago obliquum* Zone situated between the extinction level of *Marthasterites furcatus* and the appearance of *Broinsonia parca* (now *Aspidolithus parcus*), and a Cenomanian *Lithraphidites alatus* Zone, which occupies the interval between the first presence of the zonal nominator and the first occurrence of *Corollithion exiguum*. The validity of the *Gartnerago obliquum* Zone is questionable, because during the present study it was found that *Marthasterites furcatus* disappeared from the record during the Early Campanian, after the first (regular) occurrence of *Tetralithus obscurus* (now *Calculites obscurus*) (cf. Cepek & Hay, 1969 and Manivit, 1971) as well as after the entry of *Aspidolithus* ex gr. *parcus*. The base of the Upper Cretaceous is henceforth taken to be marked by the entry of *Lithraphidites alatus* rather than by that of *Chiastozygus cuneatus*. Roth established his new

Lower Cretaceous biozonation based on those species which are relatively resistent to diagenesis. Some of the stratigraphical ranges attributed to these markers may therefore be too short and in need of further investigation.

Recently Bukry (1974) combined this zonal scheme with data from Stradner (1963), Cepek & Hay (1969), Thierstein (1971) and Bukry (1973b). In the same DSDP report on Leg 26, in the Indian Ocean, Thierstein (1974) developed a slightly different zonation for the Albian–Santonian interval. The upper boundary of the *Eiffellithus turriseiffeli* Zone was here also defined by the earliest occurrence of *Lithraphidites alatus*.

Recently Lauer (1975) summarised a coccolith zonation based on Arkhangelskiellaceae. He made a detailed study of the evolution of *Aspidolithus, Arkhangelskiella*, and *Gartnerago* occurring in the Santonian-Campanian deposits of the Fiqa Formation penetrated by bore holes drilled in Central Oman. Six zones (indicated in stratigraphical succession as F to A) were distinguished on the basis of the first occurrence of individual species (which are left in open nomenclature) or groups of species. Study of part of Lauer's sample material permitted a first-order correlation between some of his zones and the zonation proposed in this paper.

In a preliminary paper Verbeek (1976b) discussed the result of a study of the calcareous nannoplankton from a composite Upper Cretaceous section in the area of Dyr el Kef, W. Tunisia. Verbeek's range chart shows that the first appearance of the marker species *Tetralithus pyramidus, Lucianorhabdus maleformis, Marthasterites furcatus, Micula* ex gr. *staurophora, Ceratolithoides aculeus, Micula murus* and *Nephrolithus frequens* are more or less corresponding to the ones given in this paper. On the other hand it is felt that too long stratigraphical ranges are given particularly for *Lucianorhabdus cayeuxii, Calculites obscurus* and *Tetralithus nitidus*. The latter species may have been confused with *Tetralithus gothicus*. Fifteen Upper Cretaceous zones are recognised, of which some are new.

3. PRESENT STUDY

3.1. *General*

The preceding review has shown that over the last 15 years or so a relatively large number of biozonations has been proposed. Most, if not all, of these zonations include some zonal markers which are not (yet) objectively identifiable with the use of the light microscope and/or are too rare to be of practical value. Some of the reported ranges of markers are questionable and consequently the stratigraphical interval occupied by the zones based on these species will need additional attention. On the other hand previous biostratigraphical studies have demonstrated the existence of a number of useful species which sometimes have a very limited stratigraphical range. For the Upper Cretaceous interval, the main subject of this paper, the following significant species can be listed: *Marthasterites furcatus, Lithraphidites quadratus, Ceratolithoides aculeus, Micula murus* and a few other ones belonging to the *Tetralithus-Micula* group. The stratigraphical distribution of these species has been reexamined in the course of this study (3.3.2).

A high-power light microscope was used to analyse smear slides prepared from all the samples. A lambda plate inserted between the crossed nicols permitted the study of individual nannofossils in considerable detail. By rotation of the nannofossil relative to the crossed nicols system it was possible to distinguish minute and systematically crucial morphological details which otherwise could only have been examined by means of an electron microscope.

With the use of such an outfit, the primary zonal markers were selected on the basis of their recognisability, their general frequency of occurrence and (as far as possible) their known or assumed evolutionary origin. The zones are predominently based on the earliest occurrence of species (3.3.3).

Species easily recognisable, but occurring more scarcely are used to indicate subzones of secondary value, particularly so if only the datum level of their last occurrence appears to be of use. Such biostratigraphical units are not formally described here.

For the purpose of making comparisons a first-order correlation with Cretaceous stage-stratotypes and with the Upper Cretaceous planktonic foraminiferal zonation of Postuma (1971) has been established (3.3.4 and 3.3.5) Some other aspects of the zonation will be discussed separately (3.3.6 and 3.3.7).

3.2 *Material studied*

As nannoplankton from the Upper Cretaceous stages has been investigated more closely than that from the Lower Cretaceous stages, the most relevant study material is listed here in reverse stratigraphical order, i.e., from young to old. The geographical location of sampled sections is shown in Figure 2. The slides of most of the material studied are deposited with Shell Internationale Petroleum Maatschappij B.V. (EP/12.1), The Hague, The Netherlands. Type material of the new species is stored in the Micropalaeontological Collection of the Geological Institute, State University of Utrecht, The Netherlands.

3.2.1 *Maastrichtian*

a) Dyr el Kef, W. Tunisia.
b) ENCI Quarry at Maastricht, The Netherlands. Stratotype (Romein, 1962). The position of the studied samples is shown schematically in Figure 3.
c) Toms River, New Jersey (USA).

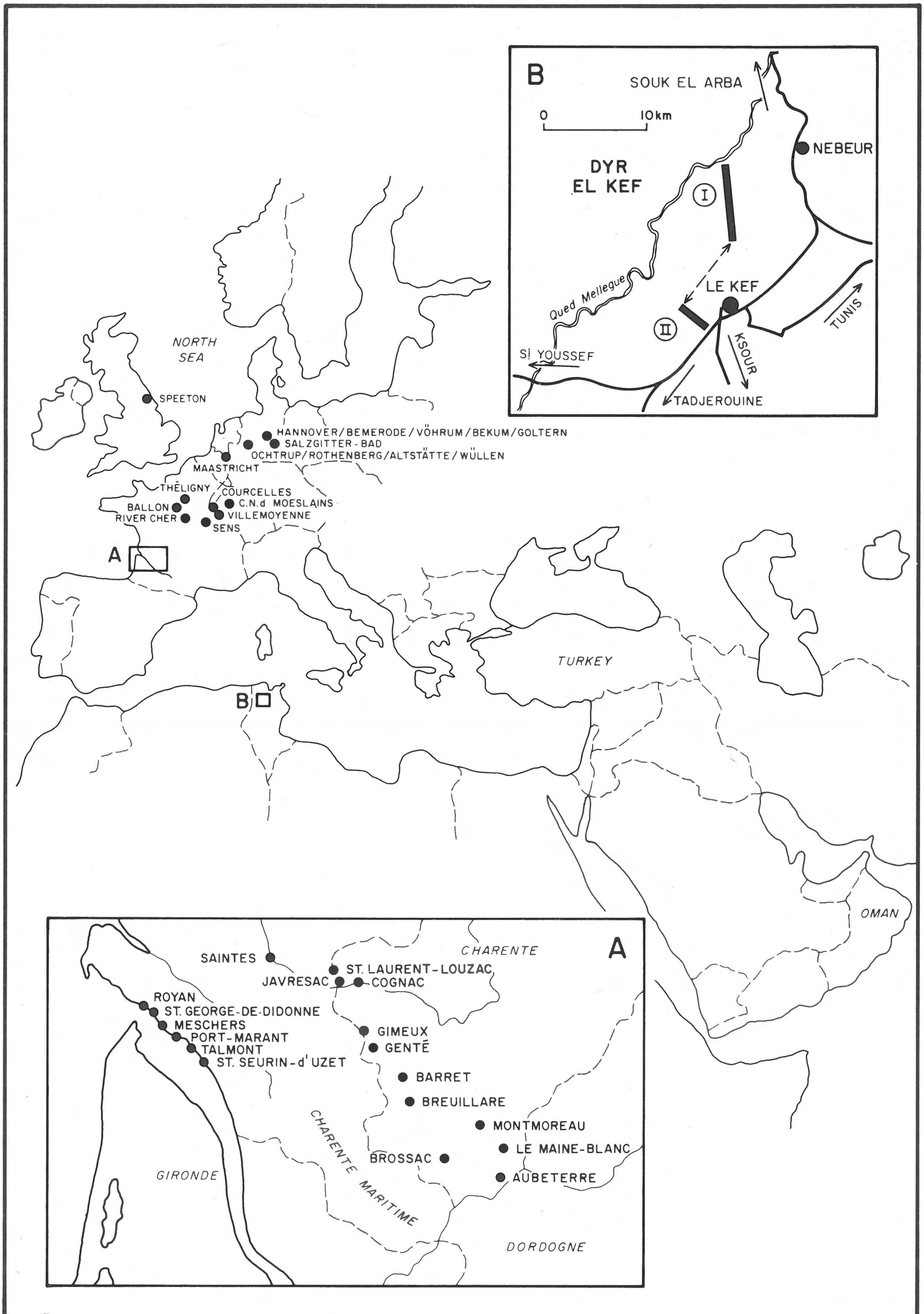


Fig. 2 Location map of sections studied. A. Gironde Estuary, S.W. France. B. Le Kef, W. Tunisia. Dyr el Kef section composed of section I (samples 2F 1-2F 162) and section II (samples 2F 163-2F 228). Correlation by means of key beds allowing superposition of both component sections without significant stratigraphical gap (Compagnie des Pétroles de Tunisie, unpublished data).

SAMPLES	ROMEIN, 1962	LITHOLOGICAL UNITS — UHLENBROEK, 1912	LITHOLOGICAL UNITS — ROMEIN, 1962	AGE
33,25 m 27,00 m 22,00 m 20,00 m	SECTION I	Md CA 15m	MAASTRICHT CHALK	MAASTRICHTIAN (TYPE)
17,00 m 15,00 m 12,00 m	SECTION I	Mc CA 10m	MAASTRICHT CHALK	MAASTRICHTIAN (TYPE)
7,00 m 5,00 m 3,00 m 0,00 m	SECTION I	Mb CA 20m	MAASTRICHT CHALK	MAASTRICHTIAN (TYPE)
12,25 m 9,50 m 6,25 m E 521	SECTION II	Mb	MAASTRICHT CHALK	MAASTRICHTIAN (TYPE)
E 520	SECTION II	Ma 5-10cm	"COPROLITE LAYER"	MAASTRICHTIAN (TYPE)
E 522 3,00 m 0,25 m	SECTION II	Cr 4 >3,5m	GULPEN CHALK	MAASTRICHTIAN (TYPE)

Fig. 3
Type Maastrichtian: Stratigraphical subdivision of the ENCI Quarry section at Maastricht (The Netherlands) and positions of the samples studied.

d) Several subsurface sections in The Netherlands, offshore Denmark and offshore Great Britain.

3.2.2 *"Dordonian"*

Type "Dordonian" exposures mentioned by C o q u a n d (1856) include Aubeterre and Le Maine-Blanc (near Pillac), Dept. Charente, France. The "Dordonian" at localities of S é r o n i e – V i v i e n (1959) near Barbezieu (Dept. Charente) have also been sampled.

a) *Aubeterre* (approx. 45 km S of Angoulême), S. France Samples ST 124 and 127: From the same localities as v a n H i n t e's (1965) samples Fr 824 and 825, respectively (see also Figure 4).

b) *Le Maine-Blanc* (approx. 6 km N of Aubeterre), S. France Sample ST 136: At the northern border of the hamlet of Le Maine-Blanc, behind the house with two small towers.
Sample ST 137: At the trifurcation in the road leading from road D 140 to Le Maine-Blanc and Le Main-la-Terre.

c) *Barret* (approx. 4 km W of Barbezieux), S. France Sample ST 107: In the village of Barret below a barn about 100 to 150 m north of the church.

d) *Breuillare* (approx. 5 km S of Barbezieux), S. France Samples ST 112 and 113: Along road N 10 near the hamlet Breuillare. The locality is comparable with that of Coupe M of S é r o n i e – V i v i e n (1959).

3.2.3 *Campanian*

a) *Dyr el Kef*, W. Tunisia.

b) *Aubeterre* (approx. 45 km S of Angoulême), S. France Stratotype (v a n H i n t e, 1965; G o h a r i a n, 1971). In the type area the same localities as those of v a n H i n t e (1965) and G o h a r i a n (1971) have been sampled. The stratigraphical distribution of a number of our samples is illustrated in Figure 4.
Samples ST 116-117, ST 118, ST 119-120, ST 121-122, ST 123, ST 125-126 and ST 128 are from localities corresponding very closely to those of v a n H i n t e's (1965) samples Fr 818, Fr 819, Fr 524-820, Fr 523-822, Fr 522, Fr 521-520 and Fr 823 respectively.
Samples ST 129, ST 130, ST 131, ST 132, ST 133 and ST 134-135 are from sections comparable to Coupe 2, Coupe 1, Coupe 9, Coupe 8, Coupe 3 and Coupe 7 of G o h a r i a n (1971), respectively.

c) *Grande Champagne*, S. France. Type (S é r o n i e – V i v i e n, 1959)
1) Gimeux (approx. 7 km SW of Cognac), S. France. Sample ST 98: At the cross road on the easternmost part of the village on top of the hill. This locality corresponds well with that of Coupe F of S é r o n i e – V i v i e n (1959).
2) Genté (approx. 7 km S of Cognac), S. France. Sample ST 99: Approximately 10 m south of the church of Genté along road D 148, close to the road to Salles d'Angles, D 107. This locality is comparable with that of Coupe H of S é r o n i e – V i v i e n (1959).

ST SAMPLES	COQUAND, 1856 — LITHOLOGICAL UNITS	COQUAND, 1857 — "ÉTAGES"		
	"SABLES JAUNÂTRES et ARGILES SABLEUSES A, ..."	"TERTIAIRE"		
124 127	"CALCAIRE B, avec Hippurites radiosus Desmoul., et Radiolites jouanneti Desmoul., ..., JAUNE, SOLIDE........"	3°	4°	"DORDONIEN"
128	CALCAIRE BLANC C, CRAYEUX, ..., pétri d'Ostrea vesicularis Lam., ..."			
125 126	"CALCAIRE CRAYEUX D, avec Sphaerulites hoeninghausii Desmoul.; ......"			
123	"DEUXIÈME BANC E d'Ostrea vesicularis, ..., ... CRAIE TENDRE, ..."	2°	3°	"CAMPANIEN"
121 122	"CALCAIRE JAUNÂTRE F, SOLIDE, ..., avec Ostrea vesicularis Lam., ..."			
119 122 117 118 116	"BANC d'une CRAIE GRISÂTRE G, ..., ... Ostrea vesicularis Lam., ..."			
	"..... CALCAIRE plus COMPACTE .... avec de NOMBREUX SILEX GRISÂTRES ...."	1°	2°	"SANTONIEN"

Fig. 4
Type Campanian: Stratigraphical subdivision of the valley wall section at Aubeterre (Dept. Charente, France) and positions of the samples studied.

d) *Toms River*, New Jersey (USA)

e) *Gironde Estuary* (northern side), S. France
All following localities correspond or are comparable with those of G o h a r i a n (1971, fig. 3).

1) St. Seurin-d'Uzet
   Sample ST 141: About 200 m south of the harbour
   Sample ST 142: About 300 m north of St. Seurin-d'Uzet.
2) Talmont
   Sample ST 144: Near the staircase, directly south of the 12th century Roman church.
   Sample ST 143: Behind the restaurant "Les Flots" at Le Caillaud.
3) Port-Marant
   Sample ST 145: From the southern side of the cliff at Port-Marant.
4) Meschers: Conche des Nonnes
   Samples ST 146 and 147: From the cliff bordering the parking place at the end of Avenue des Nonnes.
5) St. Georges-de-Didonne
   Sample ST 148: At the southern border of the Plage de Vallières.
6) Royan: Conche du Chay
   Sample ST 149: Along the beach, at the northern side of the bay.

f) *Montmoreau* (approx. 30 km S. of Angoulême), S. France.
Sample ST 138: Behind the castle, at the crossing of Rue des Mirandes and Rue du Chateau. This locality is mentioned by G o q u a n d (1858).

g) *Brossac* (Approx. 40 km SW of Angoulême), S. France
Sample ST 139: Along road D 7, halfway between the village and road N 731, near an old well. This locality was studied by G o h a r i a n (1971).

h) Several subsurface sections in The Netherlands, offshore Great Britain, Turkey and Oman.

3.2.4 *Senonian*

A formal stage-stratotype has not been designated, but part of the type deposits are generally considered to be exposed in the former quarry behind the railway station of Sens (Dept. Yonne), N. France.

The walls of this quarry are now plastered with cement, but approximately 400 m to the south "Craie blanche" is exposed, from which the samples ST 41 to 48 have been derived.

3.2.5 *Santonian*

a) *Dyr el Kef*, W. Tunisia

b) *Javresac* (W. of Cognac), S. France
Stratotype (S é r o n i e – V i v i e n, 1959; v a n H i n t e, 1965) Samples ST 89 to 91: From a section corresponding to Coupe D of S é r o n i e – V i v i e n (1959).

c) *St. Laurent-Louzac* (W. of Javresac), S. France
Samples ST 95 and 96: Along road D 144 approximately 300 m south of the entrance of Louzac. This locality is considered to correspond fairly well with that of Coupe C of S é r o n i e – V i v i e n (1959).

d) *Saintes* (approx. 25 km W of Cognac), S. France
Samples ST 101: Along road N 137, at the intersection of this road and the Rue des Anemones near the old (double) water-tower. Samples ST 102 and 103: At the crossing of the railroad Saintes-Saujon and road D 128, two km south of Saintes.

3.2.6 *Coniacian*

a) *Dyr el Kef*, W. Tunisia

b) *Cognac*, S. France
Stratotype (S é r o n i e – V i v i e n, 1959; v a n H i n t e, 1965). The relative positions of the samples collected from the type-section below the wall bordering Parc François I, along the Rue de la Font d'Enfer, are shown in Figure 5.

ST SAMPLES	COQUAND, 1858	COQUAND 1856		COQUAND 1857, 1858
	LITHOLOGICAL UNITS	"sous-étage"	"étage"	"étage"
	"CALCAIRES GLAUCONIEUX E avec Ostrea auricularis, ..."	2°	1°	"CONIACIEN"
78 79 82	"..... GRÈS VERDÂTRES D, CALCARIFÈRES DISPOSÉS en BANCS ÉPAIS et BIEN RÉGLÉS, ..."	1°		
80 81	".... SABLES VERDÂTRES C, FRIABLES, MÉLANGÉS d'ARGILES, ..."			
	"...CALCAIRES COMPACTES B, SANS FOSSILES,....."	("CRAIE INFÉRIEUR")		
	"CALCAIRES DURS A, à RUDISTES,........"			

Fig. 5
Type Coniacian: Stratigraphical subdivision of the section below the wall of Parc François I at Cognac (Dept. Charente, France) and positions of the samples studied. (samples ST 80 and ST 81 possibly from Coquand's (1858) unit D).

3.2.7 *Turonian*

a) *Dyr el Kef*, W. Tunisia

<table>
<tr><th rowspan="2">LOCALITIES</th><th rowspan="2">ST SAMPLES</th><th colspan="6">LITHOLOGICAL UNITS</th><th rowspan="2" colspan="2">AGE</th></tr>
<tr><th colspan="2">BUTT,1966</th><th colspan="2">LECOINTRE, 1959</th><th colspan="2">BELLIER, 1971</th></tr>
<tr><td></td><td></td><td colspan="2">"SENONIEN"</td><td colspan="2">CALCAIRE de CANGEY</td><td colspan="2">SENONIEN</td><td>SENON.</td><td>Early</td></tr>
<tr><td>CHISSEUX "Le BOIS de VINEUIL"</td><td>74</td><td colspan="2">TOURRAINE LIMESTONE
("TUFFEAU de TOURRAINE")</td><td colspan="2">TUFFEAU JAUNE de TOURRAINE
PIERRE du MENARS (POCÉ), de CLION, d'ÉCORCHEVEAU, de l'ÉTANG (LOCHES)</td><td colspan="2">"TUFFEAU" JAUNE</td><td rowspan="7">T U R O N I A N (Type)</td><td>Late</td></tr>
<tr><td>BOURRÉ</td><td>68 to 73</td><td colspan="2">BOURRE LIMESTONE
("TUFFEAU de BOURRÉ")</td><td colspan="2" rowspan="2">TUFFEAU BLANC MICACÉ dit PIERRE TENDRE, de BOURRÉ, LOCHES, PONCÉ, SAUMUR, LOUDUN, etc.</td><td colspan="2" rowspan="2">"TUFFEAU" BLANC MICACÉ</td><td rowspan="2">Middle</td></tr>
<tr><td>RICOISNE</td><td>63 to 67</td><td colspan="2">NOYERS CHALK
("CRAIE TUFFEAU de NOYERS")</td></tr>
<tr><td rowspan="5">FRETEVOU</td><td rowspan="2"></td><td rowspan="2">CHALK MEMBER WITH FLINT NODULES</td><td rowspan="4">FRETEVOU CHALK</td><td rowspan="3">CRAIE MARNEUSE à CHAUX HYDRAULIQUE (AMBOISE, TROGUES, PORTS, LIGUEIL, etc)</td><td>AVEC SILEX</td><td rowspan="4">CRAIE ARGILEUSE à INOCERAMUS LABIATUS</td><td rowspan="2">AVEC SILEX</td><td rowspan="4">Early</td></tr>
<tr><td rowspan="2">SANS SILEX</td></tr>
<tr><td rowspan="2">60 to 62</td><td rowspan="2">CHALK MEMBER WITHOUT FLINT NODULES</td><td rowspan="2">SANS SILEX</td></tr>
<tr><td colspan="2">MARNES à:
Terebratella carentonensis
Ditrupa deforme
SABLES de BOUSSE</td></tr>
<tr><td></td><td colspan="2">"SABLES GLAUCONIEUX à OSTRACÉES"</td><td colspan="2">OSTRACÉES</td><td colspan="2">CENOMANIEN</td><td>CENOM.</td><td>Late</td></tr>
</table>

Fig. 6
Type Turonian: Stratigraphical subdivision of the composite section of the Cher Valley (Dept. Indre-et-Loire, France) and positions of the samples studied.

b) *River Cher* (E. of Tours), N. France.

Stratotype (L e - c o i n t r e, 1959). The greater part of the type deposits have been sampled at the localities of B u t t (1966).

The stratigraphical succession of the type Turonian according to L e c o i n t r e (1959), B u t t (1966) and B e l l i e r (1971) is shown in figure 6 together with a review of the sampling of these type deposits.

1) Fretevou
   Sample ST 60: Near Butt's Locality 3
   Samples ST 61 and 62: Near Butt's Locality 2
2) Ricoisne
   Sample ST 63: Near Le Gibet, in the wall of a cave situated just off the eastern side of road N 675 from St. Aignan to St. Romain-sur-Cher, at the southern border of the woods.
   Sample St 64: In an abandoned quarry behind an isolated house (with a terrace with 5 pillars) at the northern border of the village of Ricoisne.
   Samples ST 65 to 67: About 0.5 km west to northwest of Ricoisne in a small quarry. These samples are considered to have been collected close to Butt's Locality 5.
3) Bourré
   Samples ST 68 to 71, ST 72 and 73: At Butt's Localities 7 and 8, respectively.
4) Chisseux
   Samples ST 74 and 75: Approximately at Butt's Locality 9.

3.2.8 *Cenomanian*

a) *Dyr el Kef*, W. Tunisia

b) *St. Ulphace – Théligny-Moulin de l'Aunay* (approx. 50 km ENE of Le Mans), N. France
   Neostratotype (M a r k s, 1967).

Most of the samples are from the exposures described by M a r k s (1967).

A lithocolumn and review of the samples, including some samples discussed by M a r k s (1967) and investigated on their content of calcareous nannoplankton by V e r b e e k (1976a) are given in Figure 7. Samples ST164, ST167, ST 168, ST 169 and ST 170 and 171 were collected at or close to the localities from where M a r k s' (1965) samples Fr 1161, Fr 1163, Fr 1164, Fr 1165 and Fr 1166 and 1167 were taken, respectively. Sample ST 165 was collected in the vicinity of the locality of sample ST 164, at the opposite side of the road, near the bifurcation for (i.a.) "la Pte. Gadberdière"

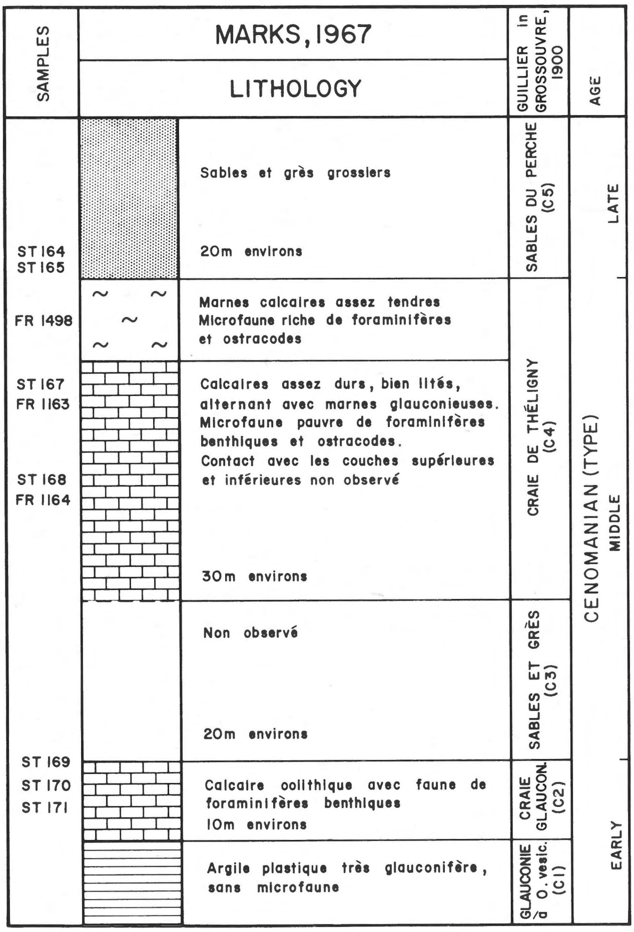


Fig. 7
Type Cenomanian: Stratigraphical subdivision of the section St. Ulphace – Moulin de l'Aunay (Dept. Sarthe and Dept. Orne, France) and positions of the samples studied.

c) *Ballon* (approx. 20 km N of Le Mans), N. France
Samples ST 172-174: From the "Couches à *Orbitolina complanata*", exposed below the donjon of Ballon.

3.2.9 *Lower Cretaceous*

a) In total 31 samples from the Aptian-Albian deposits of Dyr el Kef, W. Tunisia.

b) In total 21 samples from the Aptian-Albian of W. Germany including the following localities (collected under the guidance of Dr. E. Kemper, Bundesanstalt für Bodenforschung, Hannover).
Upper Albian: Bemerode, E. Hannover
Middle Albian: Tagebau Finkenkhule, Salzgitter-Bad (Spaeth, 1971); Ölbach bed, Wüllen (Kemper, 1968)
Lower Albian: Ziegelei Altwarmbüchen, W. Hannover; Zeigelei Vöhrum, Vöhrum
Upper Aptian: Ziegelei Poropor, Bekum; Ziegelei Borgers, Ochtrup (Kemper, 1968); Ziegelei Schneermann, Rothenberg (Kemper, 1968)
Lower Aptian: Ziegelei Gehrdener Berg, Goltern; Ziegelei Hündfeld, Altstätte (Kemper, 1968)

c) In total 7 samples from the type Middle Albian "Argilles tégulines" exposed at Côtes Noires de Moeslains, Villemoyenne and Courcelles, Dept. Aube, N. France (Larcher et al., 1965).

d) In total 27 samples from the Berriasian-Barremian type Speeton Clay, Filey Bay, Yorkshire, England. The relative positions of the samples are shown in in Figure 8.

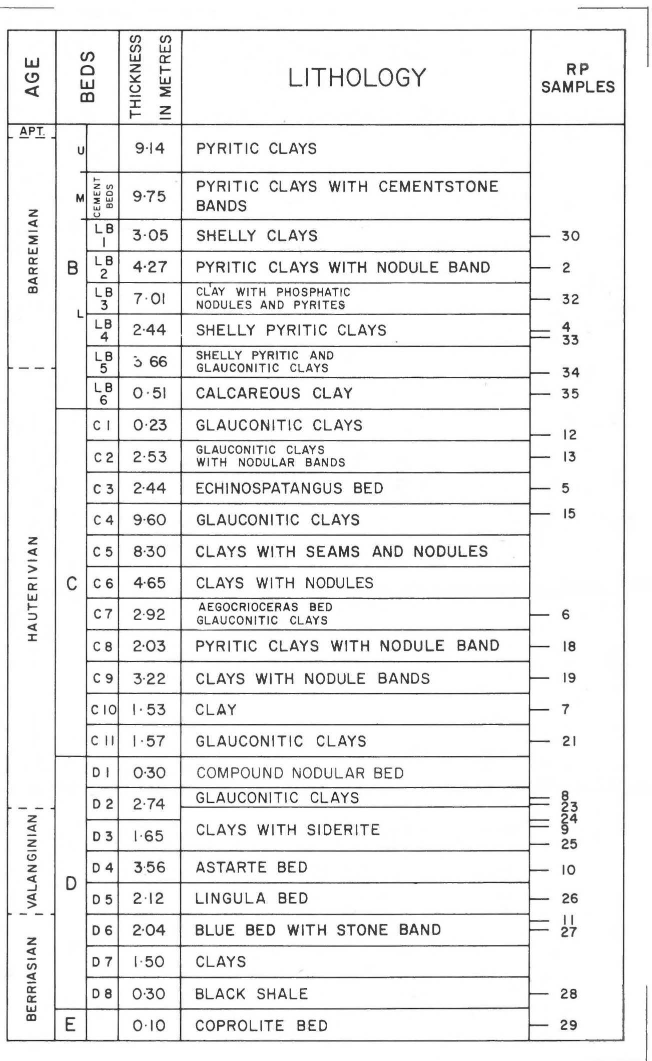


Fig. 8
Type Speeton Clay: Stratigraphical subdivision of the Filey Bay section (Yorkshire, England) and positions of the samples studied.

3.3 *Results*

3.3.1 *Distribution of selected species*

In general the Late Cretaceous sample assemblages of the Dyr el Kef section in W. Tunisia are very rich in species and specimens. Most of the Upper Cretaceous sections studied from France yielded smaller nannoplankton associations, frequently dominated by species which, apparently, are relatively resistent to diagenetic processes. The Early Cretaceous assemblages from W. Tunisia and W. Germany are mostly rather poor as well. However, the majority of those examined in the samples from the type Speeton Clay in England and from the type Middle Albian deposits in France are distinctly richer.

The stratigraphical distribution of those species selected to zone the Upper Cretaceous as well as of the Lower Cretaceous markers found at Speeton (England) is summarized in Figures 9 (encl.) and 10A-D. The results from the Lower Cretaceous (Aptian–Albian) of W. Tunisia, France and W. Germany are briefly discussed below (3.3.3, 3.3.4).

3.3.2 *Phylogenetic relationships between zonal markers*

During the investigation of individual Late Cretaceous species and genera, some evolutionary trends have been recognised (fig. 11). Those relevant to the present zonation will be briefly discussed here. The specifications of the applied species concept of the markers are found in the Appendix.

It has been noticed that *Lithraphidites quadratus* is derived from *L. carneolensis* by a (significant) broadening of the four costate ridges. Intermediate forms are known from the Maastrichtian of the Dyr el Kef section in W. Tunisia.

From the study of material from the same section it appeared that *Lucianorhabdus compactus* gradually developed a more restricted central canal in its prominent spine and that it is most likely that this species is ancestral to *L. maleformis* which possesses a more massive spine. Strong reduction of the basal plate and development of a more irregularly shaped spine in *L. maleformis* led ultimately towards *L. cayeuxii*.

Calculites obscurus probably evolved from *C. ovalis* by a change in the relative position of the four major units composing the central structure. Types intermediate between these two species still await detailed study.

The evolution of the *Tetralithus-Micula* group is characterised by a change in the relative position of the individual calcite blocks. Increasing "imbrication" and rotation in opposite directions of the proximal and distal parts of the four blocks in *Tetralithus* (cf.) *pyramidus*, ultimately led to the origin of *Micula* ex gr. *staurophora*, which is composed of eight or more elements. A separate phyletic line is apparently derived from the primitive types of *M.* ex gr. *staurophora*. This lineage is characterised by a reduction of the blocks in one of the two layers, accompanied or succeeded by a lateral extension of the blocks in the other layer as particularly known from *Micula murus* (s.s.).

There is also clear evidence that *Tetralithus nitidus* was derived from *T. pyramidus* via types including *T. gothicus* Deflandre, and that typical *T. trifidus* originated from *T. nitidus*.

The origin of the markers *Ceratolithoides aculeus* and *C. arcuatus* is obscure. Any relation to *Tetralithus*, as commonly suggested in the literature, is doubtful because of the more complicated microstructure and different birefringence of these objects. Detailed study of material from Dyr el Kef, Turkey and Oman has shown that *C. arcuatus* is derived from *C. aculeus* by the development of more laterally directed "wings". The transition between both types is very gradual. During the Maastrichtian *C. kamptneri* has evolved from *C. aculeus* (Prins, pers. communication).

The observed lineage of *Reinhardtites* is especially characterised by a gradual broadening of the plate area, which results in smaller openings along the central bridge structure. Two basic types have been selected as zonal markers: *R. anthophorus* ("small" openings) and *R. levis* (very small or completely sealed openings). Transitional types between *R. anthophorus* and *R. levis* (*R.* aff. *anthophorus* in figs. 9, 11, 12) are indicative of Late Campanian to earliest Maastrichtian. It has also been observed that *R. anthophorus* has apparently been evolved from a probably undescribed species with larger openings and a narrower plate area.

The evolution of Late Cretaceous *Aspidolithus* is distinctly characterised by an increase in general size and by a relative reduction of the central plate structure. The evolutionary trends have been outlined by L a u e r (1975).

3.3.3 *Discussion of the zones*

It is proposed that the Upper Cretaceous nannoplankton zonation be based on the lineages discussed above. The (composite) Cretaceous range chart (fig. 12) suggests a large number of biostratigraphical units, based on a study of the material listed in 3.2 (comprising over 500 samples) and on data from T h i e r s t e i n (1973). A selection of 26 units are described here as formal zones (fig. 13). The remaining units may be regarded as informal subzones of secondary value. Their characteristics are indicated in Figure 12. Most of these subzones can be recognised in the Dyr el Kef section (fig. 9). The Lower and lower Upper Campanian subzones (18a-19b, 21a, b) are also recognised in wells drilled in Oman. The Upper Campanian subzones (21a-c, 22b) are also present in wells drilled in Turkey. Some of the Maastrichtian subzones (23a en 25a, b) were identified in offshore wells on the Danish sector of the North Sea. The uppermost Maastrichtian subzone (25c) is also known from The Netherlands, from New Jersey (fig. 10A) as well as from literature.

Lower Cretaceous subzones may be distinguished in the sections at Speeton (4a, b) in England and at La Bédoule (7a), La Charce (7a), Gargas (7b) and Lescher-en-Diois (7b) in SE France (T h i e r s t e i n, 1973; see also 3.3.4).

For convenience the geological time units have arbitrarily been subdivided into an early and a late part. This subdivision corresponds only roughly to the one favoured by other authors.

A

AGES / STAGES	LOCALITIES	SAMPLES	CALCULITES OVALIS	LUCIANORHABDUS MALEFORMIS	MARTHASTERITES FURCATUS	REINHARDTITES ANTHOPHORUS	LUCIANORHABDUS CAYEUXII	CALCULITES OBSCURUS	ASPIDOLITHUS EX GR. PARCUS	BUKRYASTER HAYI	CERATOLITHOIDES ACULEUS	TETRALITHUS NITIDUS	CERATOLITHOIDES ARCUATUS	TETRALITHUS TRIFIDUS	TRANOLITHUS PHACELOSUS	REINHARDTITES LEVIS	ARKHANGELSKIELLA (LARGE FORMS COMMON)	ARKHANGELSKIELLA CYMBIFORMIS	LITHRAPHIDITES QUADRATUS	MICULA MURUS	NEPHROLITHUS FREQUENS	NANNOPLANKTON ZONATION
MAASTRICHTIAN (STRATOTYPE)	MAASTRICHT	33,25 – 15.00m																				26
		12.00m															X		X			
		7.00m															X	?	X			
		5.00m															X	X	X			
		3.00m															X	X				
		0.00m					?										X	X	X			
		12.25m					?										X	X	X		X	
		9.00m					X										X	X	X			
		6.25m															X	X	X		X	
		E 521															X	X	X			25 C
		E 520															X	X	X			
		E 522					X										X	X	X			
		3.00m															X	X	X			
		0.25m															X	X	X			
	TOMS RIVER	599' – 601'															X	X	X	?	X	26
		623' – 625'									X						X	X	X			25 C
		646' – 648'						X	X		X			X		X						23 A ?
DORDONIAN	AUBETERRE	ST 124										?										22-23
		ST 127										X		X	X							
	LE MAINE-BLANC	ST 136										?										21-23
		ST 137										X			X							
	BARRET	ST 107					X		X			X			X	X						22B -23 A
	BREUILLARE	ST 112													X							21-23A
		ST 113							X			X			X							
CAMPANIAN (STRATOTYPE)	AUBETERRE	ST 128													X							21
		ST 125					?		X			X										
		ST 126							X			X										
		ST 123					X		X			X			X							
		ST 122					X					X			X							
		ST 121							?			X			X							
		ST 119					X		X		X	X			X							
		ST 120							X						X							
		ST 117					X	X	X		X				X							
		ST 118				?	X		X		X	X			X							
		ST 116					X	X	X		X	X			X							
CAMPANIAN		ST 132							X			X			X							
		ST 135							X													
		ST 134										X			X							
		ST 133					X					X										
		ST 130					X															
		ST 129						?	X		X				X							
		ST 131					X				X				X							
	TOMS RIVER	668' – 670'	X	?		X		X				?										20-21A
		691' – 693'				X		X	X		X	?										
	GIRONDE ESTUARY	ST 149										X										
		ST 148					?		X		X				X							21-23A
		ST 147						X				X										
		ST 146					?	X	X		X	X			X							
		ST 145				?	X	X	X		X				X							21
		ST 144				X	X	X	X		X	X			X							
		ST 143					X	X	X		X				X							
		ST 142					X	X	X			X			X							22
		ST 141				X	X	X	X			X		X	X							
	MONTMOREAU	ST 138				X	X	X	X			X			X							21
	BROSSAC	ST 139										X			X							21-23
	GENTÉ	ST 99					X		X						X							18-20
	GIMEUX	ST 98		?		X	X								X							16-17

Fig. 10

A. Stratigraphical distribution of nannoplankton marker species in Campanian and Maastrichtian sections (see Fig. 13 for explanation of the zonal numbers).

B. Stratigraphical distribution of nannoplankton marker species in Coniacian, Santonian and Senonian sections (see Fig. 13 for explanation of the zonal numbers).

C. Stratigraphical distribution of nannoplankton marker species in Cenomanian and Turonian sections.

AGES / STAGES	LOCALITIES (B)	SAMPLES	CALCULITES OVALIS	TETRALITHUS PYRAMIDUS	LUCIANORHABDUS MALEFORMIS	MARTHASTERITES FURCATUS	MICULA EX GR. STAUROPHORA	REINHARDTITES ANTHOPHORUS	LUCIANORHABDUS CAYEUXII	CALCULITES OBSCURUS	ASPIDOLITHUS EX GR. PARCUS	NANNOPLANKTON ZONATION
SENONIAN STRATOTYPE	SENS	ST 41		x			x		x	x	x	18-20?
		ST 42	?	x			x		x	x	x	
		ST 43		?			x		x	?	?	
		ST 44	?	x	?		x	x	x	?	x	
		ST 45		x			x		x	x	x	
		ST 46		x	?		x		x	x		
		ST 47	?	x			x	?	x	x	x	
		ST 48	?	x	?		x	x	x	x	x	
SANTONIAN STRATOT.	JAVRESAC	ST 89		x	?		x		x			16
		ST 90	?	?	?		x	x	x			
		ST 91	x	x	?		x	x	x			
SANTONIAN	ST. LAURENT-LOUZAC	ST 95		x			x		x			16?
		ST 96		?			x					
	SAINTES	ST 101					x					16?
		ST 102		x	?		x	?	x			
		ST 103					x		x			
CONIACIAN STRATOT.	COGNAC	ST 78		x								13?
		ST 79		x			?					
		ST 80		x			?					
		ST 82		x			?					

AGES / STAGES	LOCALITIES (C)	SAMPLES	EIFFELLITHUS TURRISEIFFELI	LUCIANORHABDUS COMPACTUS	CALCULITES OVALIS	MICRORHABDULUS DECORATUS	TETRALITHUS PYRAMIDUS	LUCIANORHABDUS MALEFORMIS	NANNOPLANKTON ZONATION
TURONIAN STRATOTYPE	CHER VALLEY	ST 60	?				x		11-12
		ST 61	?				x		
		ST 62	?				x		
		ST 63							
		ST 64					x		
		ST 65					x		
		ST 66					x		
		ST 67					x		
		ST 68					x		
		ST 69					x		
		ST 70					x		
		ST 71					x		
		ST 72					x		
		ST 73					x		
		ST 74		x			x		
		ST 75					x		
CENOMANIAN STRATOTYPE	THĒLIGNY	FR1498	X	?					9
		ST 167	X						
		FR 1163	X						
		ST 168	?						
		FR 1164	X						
CENOMANIAN	BALLON	ST 172	X						9
		ST 173	X						
		ST 174	X	?					

AGES / STAGES	SAMPLES (D)	MICRANTHOLITHUS OBTUSUS/ HOSCHULZII	SPEETONIA COLLIGATA	PALAEOPONTOSPHAERA SALEBROSA	CRETARHABDUS CRENULATUS	CRETARHABDUS LORIEI	NANNOPLANKTON ZONATION
BARREMIAN	RP 30	X				X	?
	RP 2	X			X	X	
	RP 32				X	X	
	RP 4				X	X	
	RP 33	X			X	X	
HAUTERIVIAN	RP 34	X			X	X	5
	RP 35	X			X	X	
	RP 12	X			X		
	RP 13				X		
	RP 5	X			X	X	
	RP 15	X	X		X		4B
	RP 6	X		X	X		4A
	RP 18	X		X			
	RP 19	X		X	X		
	RP 7		X	X	X	X	
	RP 21	X	X	X	X	X	
	RP 8	X	X	X	X	X	
	RP 23	X	X	X			2-3
VALANGINIAN	RP 24		X				
	RP 9						
	RP 25						
	RP 10	X		X			
	RP 26						
BERRIASIAN	RP 11	X		X	X		
	RP 27	X	?	X	X		
	RP 28						
	RP 29						1 ?

D. Stratigraphical distribution of nannoplankton marker species in the Berriasian to Barremian Filey Bay section, Yorkshire (England).

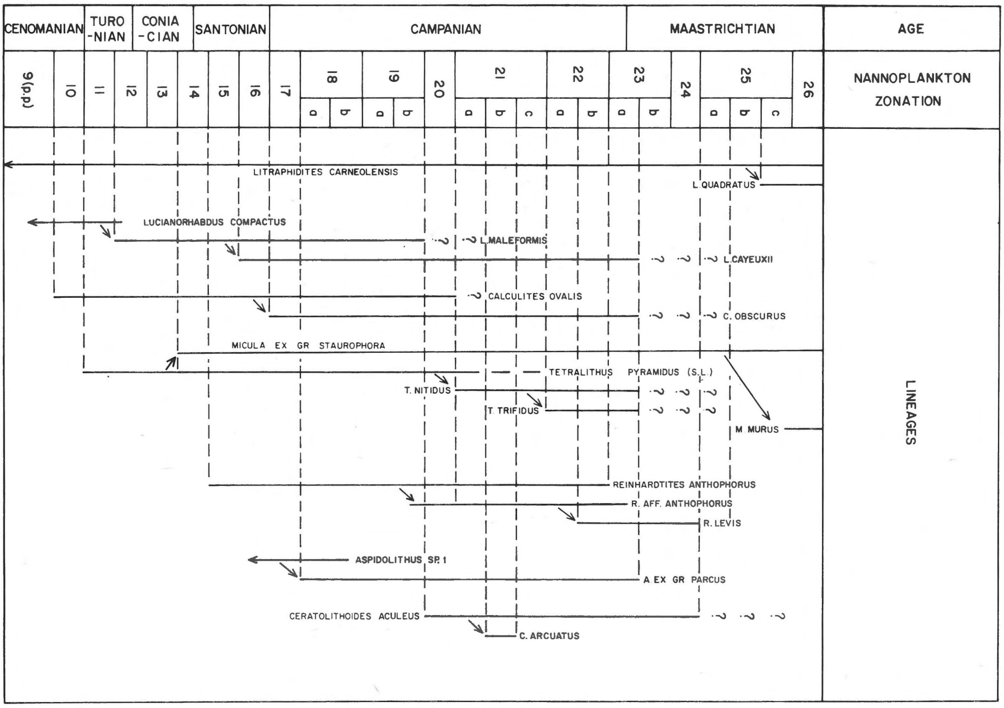


Fig. 11
Phylogenetic relationships between Late Cretaceous nannoplankton marker species (see Fig. 13 for explanation of the zonal numbers).

Critical examination of distribution charts of Cepek & Hay (1969), Roth (1973) and Thierstein (1973) showed that some of the new datum planes of the Cretaceous zonation are also recognizable in the sections studied by these authors. The two zones formally separated by such a datum plane are assumed to be present in their sections if there is no evidence of an unconformity. Consequently, the geographical distribution of zones reported below includes some more inferential occurrences of upper or lower parts of zones.

The following Cretaceous zones are defined in stratigraphical order, from old to young:

1. *Nannoconus steinmannii* partial – range zone

Definition: Interval from the first occurrence of *Nannoconus steinmannii* Kamptner to the first occurrence of *Cretarhabdus crenulatus* Bramlette & Martini emend.

Author: Worsley (1971), emended by Thierstein (1971) and in this paper.

Remarks: N. colomii (de Lapparent) Kamptner is considered by Thierstein (1971) to be a junior synonym of *N. steinmannii* Kamptner, since their stratigraphical ranges are identical. This argument is considered inconclusive, particularly since a few morphological differences between both species are present.

Furthermore, differences in the stratigraphical ranges are also recognized (see e.g. Moshkovitz, 1972).

Reference section: Broyon (Ardèche), SE France (Thierstein, 1973).

Geographical distribution: W. Atlantic (Worsley, 1971), Central Pacific (Roth, 1973), SE France, Switzerland, Algeria (Thierstein, 1973)?, Great Britain (Speeton) (fig. 10D).

Approx. age: Late Portlandian (late part) to Early Berriasian.

2. *Cretarhabdus crenulatus* partial – range zone

Definition: Interval from the first occurrence of *Cretarhabdus crenulatus* Bramlette & Martini emend. To the first occurrence of *Calcicalathina oblongata* (Worsley) Thierstein.

Author: Thierstein (1971).

Reference sections: Lacisterne (Hérault) and Ginestous-Les Oliviers (Hérault), SE France (Thierstein, 1973).

Geographical distribution: Central Pacific (Roth, 1973), SE France, Switzerland (Thierstein, 1973), Great Britain (see also Speeton, fig. 10d).

Approx. age: Late Berriasian to Early Valanginian.

3. *Calcicalathina oblongata* partial – range zone

Definition: Interval from the first occurrence of *Calcicalathina oblongata* (Worsley) Thierstein to the first occurrence of *Cretarhabdus loriei* Gartner.

Author: Thierstein (1971), emended in this paper.

Reference sections: Orpierre (Hautes-Alpes) and La

Charce I (Drôme), SE France (T h i e r s t e i n, 1973).

Geographical distribution: SE France (T h i e r s t e i n, 1973), Great Britain (see also Speeton, fig. 10D).

Approx. age: Late Valanginian.

4. *Cretarhabdus loriei* concurrent – range zone

Definition: Interval from the first occurrence of *Cretarhabdus loriei* Gartner to the last occurrence of *Speetonia colligata* Black.

Author: S i s s i n g h (this paper).

Reference section: Speeton (Yorkshire), England (sampled interval of RP 8-15, figs. 8, 10D).

Remarks: A two-fold subdivision of this zone is possible by means of *Palaeopontosphaera salebrosa* (Black) Prins & Sissingh (fig. 12).

Geographical distribution: SE France (T h i e r s t e i n, 1973), Great Britain (Speeton).

Approx. age: Early Hauterivian.

5. *Lithraphidites bollii* partial – range zone

Definition: Interval from the last occurrence of *Speetonia colligata* Black to the last occurrence of *Calcicalathina oblongata* (Worsley) Thierstein.

Author: T h i e r s t e i n (1971), emended in this paper.

Remarks: According to data presented by T h i e r s t e i n (1973) *Lithraphidites bollii* (Thierstein) is more or less confined to this sone (fig. 12).

Reference sections: La Charce II (Drôme), SE France and DSDP Leg 1 (site 4), W. Atlantic (T h i e r s t e i n, 1973).

Geographical distribution: SE France, Switzerland, W. Atlantic (T h i e r s t e i n, 1973), Great Britain (Speeton) (fig. 10D).

Approx. age: Late Hauterivian to Early Barremian.

6. *Micrantholithus hoschulzii* interval – zone

Definition: Interval from the last occurrence of *Calcicalathina oblongata* (Worsley) Thierstein to the first occurrence of *Chiastozygus litterarius* (Górka) Manivit.

Author: T h i e r s t e i n (1971), emended by T h i e r s t e i n (1973) and in this paper.

Reference section: Route d'Angles (Basses-Alpes), SE France (T h i e r s t e i n, 1973).

Geographical distribution: SE France, Trinidad (T h i e r s t e i n, 1973).

Approx. age: Late Barremian.

7. *Chiastozygus litterarius* partial – range zone

Definition: Interval from the first occurrence of *Chiastozygus litterarius* (Górka) Manivit to the first occurrence of *Prediscosphaera cretacea* (Arkhangelsky) Gartner.

Author: T h i e r s t e i n (1971), emended in this paper.

Reference section: Lescher-en-Diois (Drôme), SE France (T h i e r s t e i n, 1973).

Remarks: The base of this zone can also be characterised by the last (regular) occurrence of *Nannoconus bermudezii* Bronnimann and *N. steinmannii* Kamptner (D e r e s & A r c h e r i t e g u y, 1972). Two subzones may be recognised in this zone by means of *Micrantholithus obtusus* Stradner and *M. hoschulzii* (Reinhardt) Thierstein (fig. 12).

Geographical distribution: W. Atlantic (R o t h & T h i e r s t e i n, 1972), Central Pacific (R o t h, 1973), SE France, Great Britain (T h i e r s t e i n, 1973), S. Spain (R o m e i n, 1975), W. Germany (all localities mentioned in 3.2.9 except Wüllen, Salzgitter – Bad and Bemerode), W. Tunisia (Dyr el Kef).

Approx. age: Aptian to Early Albian (early part).

8. *Prediscosphaera cretacea* partial – range zone

Definition: Interval from the first occurrence of *Prediscosphaera cretacea* (Arkhangelsky) Gartner to the first occurrence of *Eiffellithus turriseiffeli* (Deflandre) Reinhardt.

Author: T h i e r s t e i n (1971) emended by T h i e r s t e i n (1973).

Reference section: Col-de-Palluel (Haute-Alpes), SE France (T h i e r s t e i n, 1973).

Geographical distribution: SE France, Switzerland, Great Britain, W. Atlantic, Kansas (T h i e r s t e i n, 1973), Central Pacific (R o t h, 1973), Indian Ocean (T h i e r s t e i n, 1974), Australia (P r o t o D e c i m a, 1974), S. Spain (R o m e i n, 1975), N. France (Côtes Noires de Moeslains, Villemoyenne, Courcelles), West Germany (Wüllen, Salzgitter-Bad), W. Tunisia (Dyr el Kef).

Approx. age: Early Albian (late part) (or Middle Albian of authors).

9. *Eiffellithus turriseiffeli* partial – range zone

Definition: Interval from the first occurence of *Eiffellithus turriseiffeli* (Deflandre) Reinhardt to the first occurrence of *Microrhabdulus decoratus* Deflandre.

Author: T h i e r s t e i n (1971), emended in this paper.

Reference section: Col de Palluel (Hautes-Alpes), SE France (T h i e r s t e i n, 1973).

Geographical distribution: SE France, Switzerland, Great Britain, W. & C. Atlantic, Kansas, Venezuela (T h i e r s t e i n, 1973), Central Pacific (R o t h, 1973), Indian Ocean (T h i e r s t e i n, 1974), Australia (P r o t o D e c i m a, 1974), S. Spain (R o m e i n, 1975), W. Germany (Bemerode), W. Tunisia (Dyr el Kef) (fig. 9), N. France (Ballon, Théligny). (fig. 10C)

Approx. age: Late Albian to Early Cenomanian (or Late Albian to Middle Cenomanian of authors).

10. *Microrhabdulus decoratus* partial – range zone

Definition: Interval from the first occurrence of *Microrhabdulus decoratus* Deflandre to the first occurrence of *Tetralithus pyramidus* Gardet.

Author: S i s s i n g h (this paper).

Reference sections: Dyr el Kef, W. Tunisia (sampled interval of 2F 10-12) (fig. 9).

Remarks: A further criterion to identify the base of this zone may be the first regular occurrence of *Calculites ovalis* (Stradner) Prins & Sissingh (fig. 12).

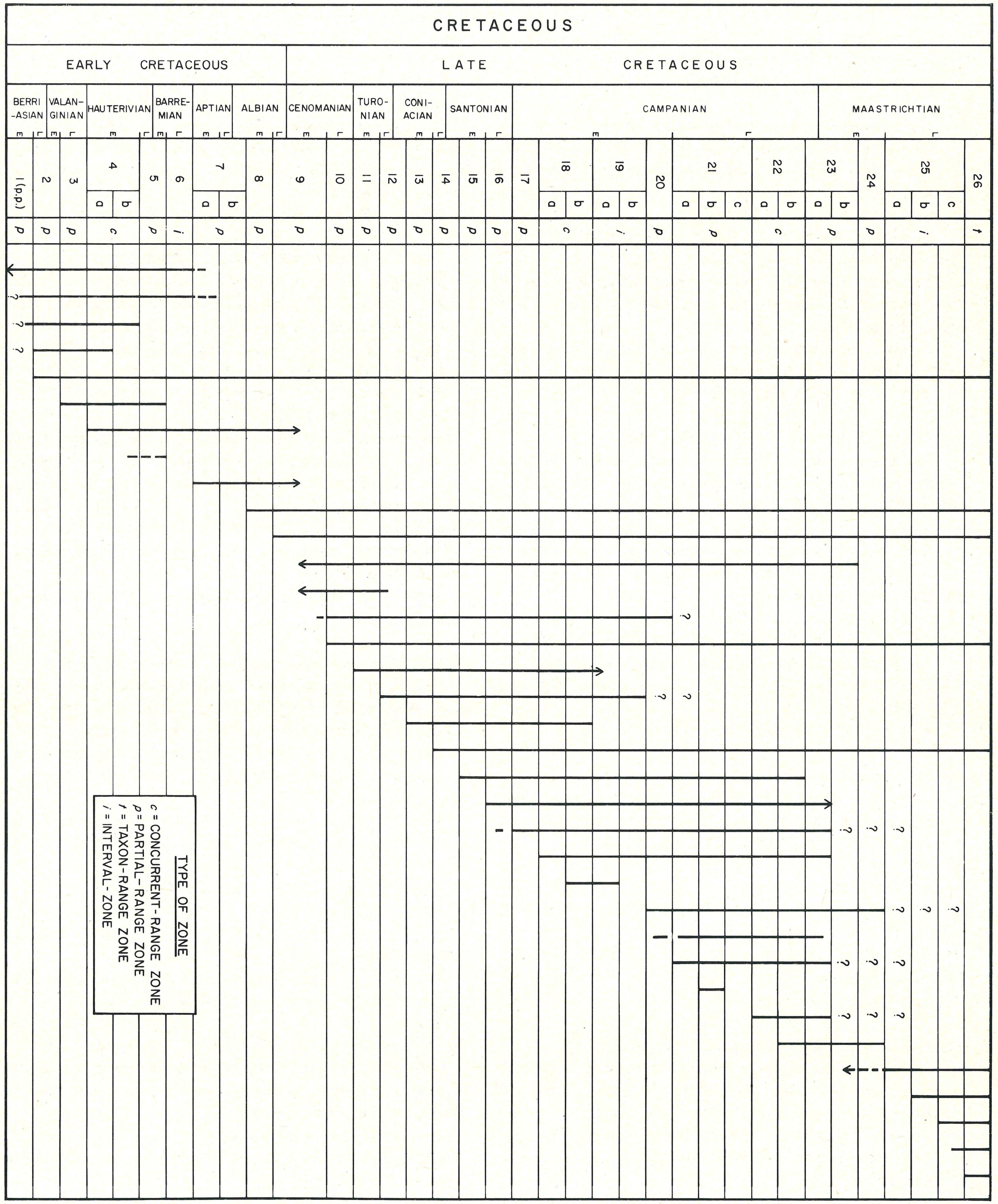
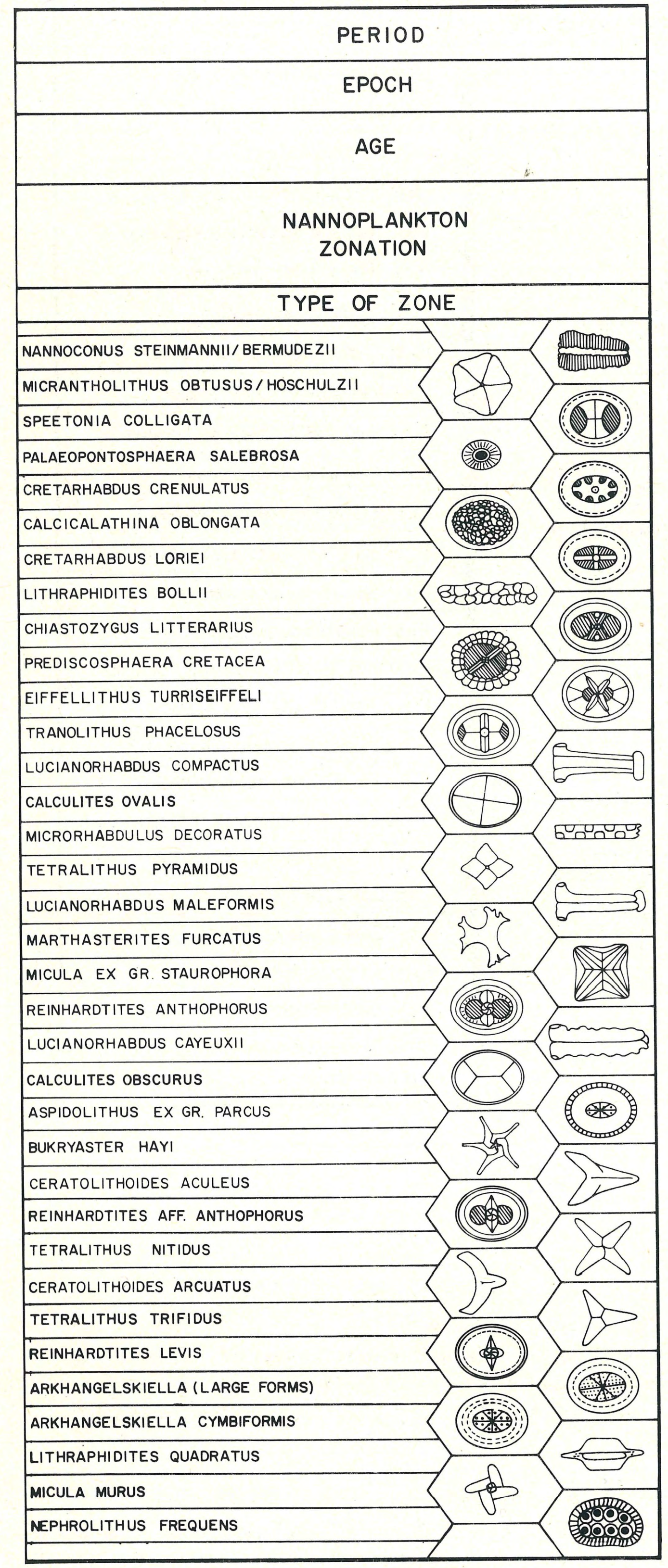


Fig. 12
Range chart of Cretaceous nannoplankton marker species (see Fig. 13 for explanation of the zonal numbers).



Geographical distribution: W. Tunisia (Dyr el Kef).
Approx. age: Late Cenomanian.

11. *Tetralithus pyramidus* partial – range zone

Definition: Interval from the first occurrence of *Tetralithus pyramidus* Gardet to the first occurrence of *Lucianorhabdus maleformis* Reinhardt.

Author: C e p e k & H a y (1969b), emended in this paper.

Reference sections: Bunker Hill – Luray Road, Wilson Reservoir in Russell County, Kansas (C e p e k & H a y, 1969b), Dyr el Kef, W. Tunisia (sampled interval of 2F 16-23) (fig. 9).

Remarks: Practice has shown that *Gartnerago* representatives appear frequently near the base of this zone.

Geographical distribution: Alabama, Nebraska, Kansas (C e p e k & H a y 1969), W. Tunisia (Dyr el Kef).

Approx. age: Early Turonian (possibly Late Cenomanian, late part, to Early Turonian).

12. *Lucianorhabdus maleformis* partial – range zone

Definition: Interval from the first occurrence of *Lucianorhabdus maleformis* Reinhardt to the first occurrence of *Marthasterites furcatus* (Deflandre) Deflandre.

Author: S i s s i n g h (this paper).

Reference section: Dyr el Kef, W. Tunisia (sampled interval of 2F 24-47) (fig. 9).

Remarks: The approximate base of this zone is indicated by the last occurrence of *Lucianorhabdus compactus* (Verbeek) P r i n s & S i s s i n g h (fig. 12). The first occurrence of *L. maleformis* also seems to coincide approximately with the first occurrence of *Eiffellithus eximius* (Stover) Perch-Nielsen (sensu lato).

Geographical distribution: Central Pacific (R o t h, 1973), Indian Ocean (T h i e r s t e i n, 1974), W. Tunisia (Dyr el Kef).

Approx. age: Late Turonian to Early Coniacian (early part).

13. *Marthasterites furcatus* partial – range zone

Definition: Interval from the first occurrence of *Marthasterites furcatus* (Deflandre) Deflandre to the first occurrence of *Micula* ex gr. *staurophora* (Gardet) Bramlette & Martini.

Author: C e p e k & H a y (1969), emended in this paper.

Reference section: Dyr el Kef, W. Tunisia (sampled interval of 2F 52-63) (fig. 9). Original type section of this zone along the Alabama River refuted because of misinterpretation by C e p e k & H a y (1969, 1970) (see 2).

Geographical distribution: Central Pacific (R o t h, 1973), Indian Ocean (T h i e r s t e i n, 1974), W. Tunisia (Dyr el Kef),? France (Cognac) (fig. 10B).

Approx. age: Early Coniacian (late part).

14. *Micula staurophora* (s.l.) partial – range zone

Definition: Interval from the first occurrence of *Micula* ex. gr. *staurophora* (Gardet) Bramlette & Martini to the first

P	E	AGE	CALCAREOUS NANNOPLANKTON ZONATION		DATUM INDICATORS
					Last Nephrolithus frequens
CRETACEOUS	LATE	MAASTRICHTIAN	26	Nephrolithus frequens Zone	First Nephrolithus frequens
			25	Arkhangelskiella cymbiformis Zone	Last Reinhardtites levis
			24	Reinhardtites levis Zone	Last Tranolithus phacelosus
		CAMPANIAN	23	Tranolithus phacelosus Zone	Last Reinhardtites anthophorus
			22	Tetralithus trifidus Zone	First Tetralithus trifidus
			21	Tetralithus nitidus Zone	First Tetralithus nitidus
			20	Ceratolithoides aculeus Zone	First Ceratolithoides aculeus
			19	Calculites ovalis Zone	Last Marthasterites furcatus
			18	Aspidolithus parcus (s.l.) Zone	First Aspidolithus ex gr. parcus
			17	Calculites obscurus Zone	First Calculites obscurus
		SANTONIAN	16	Lucianorhabdus cayeuxii Zone	First Lucianorhabdus cayeuxii
			15	Reinhardtites anthophorus Zone	First Reinhardtites anthophorus
		CONIACIAN	14	Micula staurophora (s.l.) Zone	First Micula ex gr. staurophora
			13	Marthasterites furcatus Zone	First Marthasterites furcatus
		TURONIAN	12	Lucianorhabdus maleformis Zone	First Lucianorhabdus maleformis
			11	Tetralithus pyramidus Zone	First Tetralithus pyramidus
		CENOMANIAN	10	Microrhabdulus decoratus Zone	First Microrhabdulus decoratus
	EARLY	ALBIAN	9	Eiffellithus turriseiffeli Zone	First Eiffellithus turriseiffeli
			8	Prediscosphaera cretacea Zone	First Prediscosphaera cretacea
		APTIAN	7	Chiastozygus litterarius Zone	First Chiastozygus litterarius
		BARREMIAN	6	Micrantholithus hoschulzii Zone	Last Calcicalathina oblongata
		HAUTERIVIAN	5	Lithraphidites bollii Zone	Last Speetonia colligata
			4	Cretarhabdus loriei Zone	First Cretarhabdus loriei
		VALANGINIAN	3	Calcicalathina oblongata Zone	First Calcicalathina oblongata
		BERRIASIAN	2	Cretarhabdus crenulatus Zone	First Cretarhabdus crenulatus
			1	Nannoconus steinmannii Zone	First Nannoconus steinmannii
J	L	PORTLANDIAN			

Fig. 13
Proposed Cretaceous nannoplankton zonation.

occurrence of *Reinhardtites anthophorus* (Deflandre) Perch-Nielsen emend.

Author: M a n i v i t (1971), emended in this paper.

Reference section: Dyr el Kef, W. Tunisia (sampled interval of 2F 77-118) (fig. 9).

Remarks: Contrary to our findings, M a n i v i t (1971, 1972) reports a reverse succession of *Micula staurophora* (Gardet) Bramlette & Martini (from Late Turonian) and *Marthasterites furcatus* (Deflandre) Deflandre (from Late Coniacian). It is possible that the *M.* ex. gr. *staurophora* datum plane corresponds to the horizon of the first abundant occurrence of *M. staurophora*, observed by T h i e r s t e i n (1974) within the Coniacian interval penetrated at Site 258(a) during DSDP leg 26.

Geographical distribution: W. Tunisia (Dyr el Kef),? Indian Ocean (T h i e r s t e i n, 1974).

Approx. age: Late Coniacian to Early Santonian (early part).

15. *Reinhardtites anthophorus* partial – range zone

Definition: Interval from the first occurrence of *Reinhardtites anthophorus* (Deflandre) Perch-Nielsen emend. to the first occurrence of *Lucianorhabdus cayeuxii* Deflandre.

Author: S i s s i n g h (this paper).

Reference section: Dyr el Kef, W. Tunisia (sampled interval of 2F 119-129) (fig. 9).
Geographical distribution: W. Tunisia (Dyr el Kef).
Approx. age: Early Santonian (late part).

16. *Lucianorhabdus cayeuxii* partial – range zone
Definition: Interval from the first occurrence of *Lucianorhabdus cayeuxii* Deflandre to the first (regular) occurrence of *Calculites obscurus* (Deflandre) Prins & Sissingh.
Author: S i s s i n g h (this paper).
Reference section: Dyr el Kef, W. Tunisia (sample interval of 2F 132-136) (fig. 9).
Remarks: Rare specimens of *C. obscurus* may occur in the upper part of the zone.
Geographical distribution:? Alabama (C e p e k & H a y, 1969), S. France (Javresac,? St. Laurent-Louzac,? Saintes) (fig. 10B). W. Tunisia (Dyr el Kef).
Approx. age: Late Santonian.

17. *Calculites obscurus* partial – range zone
Definition: Interval from the first (regular) occurrence of *Calculites obscurus* (Deflandre) Prins & Sissingh to the first occurrence of *Aspidolithus* ex. gr. *parcus* (Stradner) Noël.
Author: S i s s i n g h (this paper).
Reference section: Dyr el Kef, W. Tunisia (sampled interval of 2F 137-150) (fig. 9).
Geographical distribution:? Alabama (C e p e k & H a y, 1969), W. Tunisia (Dyr el Kef), The Netherlands, Central Oman.
Approx. age: Early Campanian (earliest part).

18. *Aspidolithus parcus* (s.l.) concurrent – range zone
Definition: Interval from the first occurrence of *Aspidolithus* ex. gr. *parcus* (Stradner) Noël to the last occurrence of *Marthasterites furcatus* (Deflandre) Deflandre.
Author: S i s s i n g h (this paper).
Reference section: Dyr el Kef, W. Tunisia (sampled interval of 2F 152-158) (fig. 9).
Remarks: By means of *Bukryaster hayi* (Bukry) Prins & Sissingh a subdivision of this zone into two subzones seems to be possible (fig. 12).
Geographical distribution: Alabama (C e p e k & H a y, 1969), Central Pacific (R o t h, 1973), W. Tunisia (Dyr el Kef), Central Oman, Great Britain.
Approx. age: Early Campanian (early part).

19. *Calculites ovalis* interval – zone
Definition: Interval from the last occurrence of *Marthasterites furcatus* (Deflandre) Deflandre to the first occurrence of *Ceratolithoides aculeus* (Stradner) Prins & Sissingh.
Author: Sissingh (this paper).
Reference section: Dyr el Kef, W. Tunisia (sampled interval of 2F 159-173) (fig. 9).
Remarks: Also this zone may be subdivided into two subzones by means of *Bukryaster hayi* (Bukry) Prins & Sissingh (fig. 12).
Geographical distribution: Alabama (C e p e k & H a y, 1969), Central Pacific (R o t h, 1973) W. Tunisia (Dyr el Kef), Central Oman.
Approx. age: Early Campanian (late part).

20. *Ceratolithoides aculeus* partial – range zone
Definition: Interval from the first occurrence of *Ceratolithoides aculeus* (Stradner) Prins & Sissingh to the first occurrence of *Tetralithus nitidus* Martini.
Authors: C e p e k & H a y (1969), emended in this paper.
Reference section: Alabama River, between White Bluff and Red Bluff in Dallas County, Alabama (C e p e k & H a y 1969).
Geographical distribution: Alabama (C e p e k & H a y, 1969), Central Pacific (R o t h, 1973), Central Oman.
Approx. age: Early Campanian (latest part).

21. *Tetralithus nitidus* partial – range zone
Definition: Interval from the first occurrence of *Tetralithus nitidus* Martini to the first occurrence of *Tetralithus trifidus* Stradner emend.
Author: S i s s i n g h (this paper).
Reference sections: Dyr el Kef, W. Tunisia (sampled interval of 2F 174-182) (fig. 9), Aubeterre, S. France (fig. 10A).
Remarks: *Ceratolithoides arcuatus* Prins & Sissingh nov. spec. suggests a subdivision into three subzones for this zone (fig. 12).
Geographical distribution: Central Pacific (R o t h, 1973), W. Tunisia (Dyr el Kef), S. France (Aubeterre, Montmoreau, Port Marant, Talmont) (fig. 10A), Turkey, Central Oman.
Approx. age: Late Campanian (early part).

22. *Tetralithus trifidus* concurrent – range zone
Definition: Interval from the first occurrence of *Tetralithus trifidus* Stradner emend. to the last occurrence of *Reinhardtites anthophorus* (Deflandre) Perch-Nielsen emend.
Author: B u k r y & B r a m l e t t e (1970), emended in this paper.
Reference section: Dyr el Kef, W. Tunisia (sampled interval of 2F 183-194) (fig. 9).
Remarks: Two subzones may be distinguished by means of *Reinhardtites levis* Prins & Sissingh nov. spec. (fig. 12).
Geographical distribution: Central Pacific (R o t h, 1973), W. Tunisia (Dyr el Kef), S. France (St. Seurin – d'Uzet) (fig. 10A), The Netherlands, Turkey.
Approx. age: Late Campanian (late part).

23. *Tranolithus phacelosus* partial – range zone
Definition: Interval from the last occurrence of *Reinhardtites anthophorus* (Deflandre) Perch-Nielsen emend. to the last occurrence of *Tranolithus phacelosus* Stover.
Author: S i s s i n g h (this paper).
Reference section: Dyr el Kef, W. Tunisia (sampled interval 2F 196-210) (fig. 9).
Remarks: The known range of *Aspidolithus* ex gr. *parcus* (Stradner) Noël indicates that this zone may be subdivided

into two subzones (fig. 12).

Geographical distribution: Alabama (Cepek & Hay, 1969), Central Pacific (Roth, 1973), W. Tunisia (Dyr el Kef), The Netherlands,? New Jersey (Toms River) (fig. 10A), Great Britain.

Approx. age: Late Campanian (latest part) to Early Maastrichtian (early part).

24. *Reinhardtites levis* partial – range zone

Definition: Interval from the last occurrence of *Tranolithus phacelosus* Stover emend. to the last occurrence of *Reinhardtites levis* Prins & Sissingh nov. spec.

Author: Sissingh (this paper).

Reference section: Dyr el Kef, W. Tunisia (sampled interval 2F 212-219) (fig. 9) (Provisional because of the presence of stratigraphical gaps and rare occurrence of *R. levis*).

Remarks: The last occurrence of *R. levis* virtually coincides with a distinct and interregional increase in number of large *Arkhangelskiella* representatives (fig. 12).

Geographical distribution: Central Pacific (Roth, 1973), W. Tunisia (Dyr el Kef), Denmark, Great Britain.

Approx. age: Early Maastrichtian (late part).

25. *Arkhangelskiella cymbiformis* interval – zone

Definition: Interval from the last occurrence of *Reinhardtites levis* Prins & Sissingh nov. spec. to the first occurrence of *Nephrolithus frequens* Górka.

Author: Sissingh (this paper).

Reference section: Dyr el Kef, W. Tunisia (sampled interval of 2F 220-225) (fig. 9).

Remarks: The *A. cymbiformis* Zone of Perch-Nielsen (1972) corresponds with the interval between the last occurrence of *Reinhardtites anthophorus* (Deflandre) Perch-Nielsen (now *R. levis*?) and the first occurrence of *Tetralithus murus* Martini (now *Micula murus* (Martini) Bukry) or *Nephrolithus frequens* and is therefore possibly comparable with our zone with the same name. Typical representatives of *Micula murus* appear for the first time on the record in the upper part of the zone. The stratigraphical distribution of *Arkhangelskiella cymbiformis* Vekshina emend. and *Lithraphidites quadratus* Bramlette & Martini allows to distinguish three subsones (fig. 12).

Geographical distribution: Alabama (Cepek & Hay, 1969), North Atlantic (Perch-Nielsen, 1972), Central Pacific (Roth, 1973), W. Tunisia (Dyr el Kef), The Netherlands (Maastricht) (fig. 10A), New Jersey (Toms River) (fig. 10A), Denmark, Great Britain.

Approx. age: Late Maastrichtian (early part).

26. *Nephrolithus frequens* taxon – range zone

Definition: Interval from the first to the last occurrence of *Nephrolithus frequens* Gorka.

Authors: Cepek & Hay (1969).

Reference sections: Lowndes County Road 7 from Braggs in Lowndes County to Grenville in Butler County (Alabama) (Cepek & Hay 1969b); ENCI Quarry, Maastricht, The Netherlands (sampled interval of section I: 6,25 m – 12,00 m) (figs. 3, 10A).

Remarks: The top of this zone is also marked by the extinction of many other Cretaceous nannoplankton species.

Geographical distribution: Poland (Górka, 1957), Alabama (Cepek & Hay, 1969; Worsley, 1974), W. Siberia (Bramlette & Martini, 1964), Denmark (Perch-Nielsen, 1969; Bukry, 1969), Sweden (Äberg, 1966), France (Bramlette & Martini, 1964; Manivit, 1971), Egypt (Perch-Nielsen & Pomerol, 1973), New Zealand (Bramlette & Martini, 1964), Australia (Worsley, 1974), The Netherlands (Maastricht (fig. 10A, see also Bramlette & Martini, 1964), W. Tunisia (Dyr el Kef) (fig. 9), New Jersey (Toms River) (fig. 10A; see also Worsley, 1974), Great Britain.

Approx age: Late Maastrichtian (latest part).

3.3.4 *Assumed correlations with Cretaceous stratotypes*

Correlations with stratotypes of Lower Cretaceous stages (fig. 14) are mainly based on data presented by Thierstein (1971, 1973).

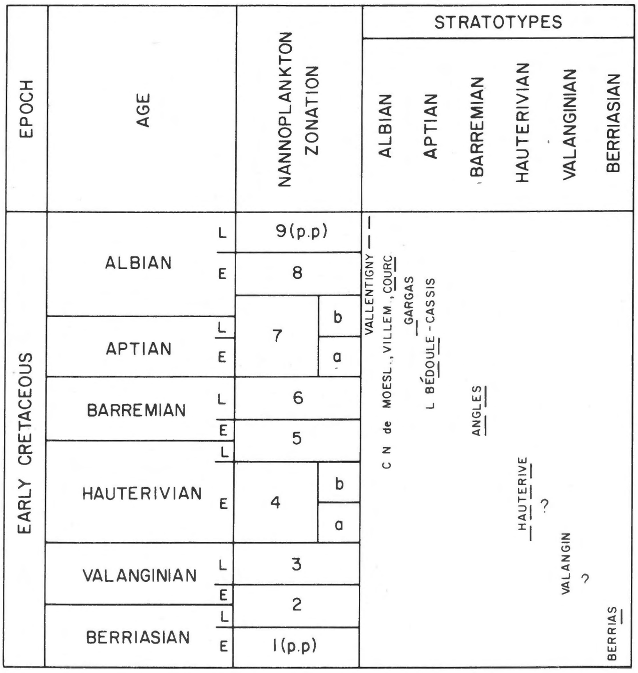


Fig. 14
Correlation of the Lower Cretaceous stage – stratotypes with the proposed nannoplankton zonation (see Fig. 13 for explanation of the zonal numbers).

The nannoplankton assemblage from the upper part of the type Berriasian deposits at Berrias (Dept. Ardèche, S.E. France) is referable to the lower part of the *Cretarhabdus crenulatus* Zone. This is indicated by the presence of *Cretarhabdus crenulatus*.

The calcareous nannoplankton of the type Valanginian has not yet been investigated.

The relative stratigraphical position of the type Hauterivian, exposed near Hauterive in the Jura Mountains (Switzerland) is not clear. *Micrantholithus obtusus/hoschulzii* and *Calcicalathina oblongata* are among the types present, but the critical (sub)zonal markers *Speetonia colligata, Lithraphidites bollii, Palaeopontosphaera salebrosa* and *Cretarhabdus loriei* have not been reported from the stratotype.

The lower part of the Barremian type-section near Angles (Dept. Basses-Alpes, S.E. France) belongs to the upper part of the *Lithraphidites bollii* Zone, based on the presence of *Lithraphidites bollii* and *Calcicalathina oblongata*. The upper part of this section is referred to the *Micrantholithus hoschulzii* Zone because of the absence of these two markers and *Chiastozygus litterarius*.

The association from the type-section of the Lower Aptian substage (or Bédoulian Stage) at La Bédoule-Station de Cassis (Dept. Bouches-du-Rhône, S.E. France) allows a correlation with the lower part (a) of the *Chiastozygus litterarius* Zone because of the co-occurrence of *Chiastozygus litterarius* and *Micrantholithus obtusus/hoschulzii*. The nannoplankton assemblage from the stratotype of the lower part of the Upper Aptian substage (or Gargasian Stage) at Gargas (Dept. Vaucluse, S.E. France) which includes *C. litterarius* does not contain *M. obtusus/hoschulzii*. For this reason the assemblage is assigned to the Aptian part of the upper part (b) of the *Chiastozygus litterarius* Zone.

The type Middle Albian "Argiles tégulines" exposed at Côtes Noires de Moeslains, Villemoyenne and Courcelles (Depts. Haute Marne and Aube, N.E. France) yielded a rich assemblage belonging to the *Prediscosphaera cretacea* Zone, because of the presence of small representatives of the zonal nominator and the absence of *Eiffellithus turriseiffeli*. Similar small representatives of *P. cretacea* are present in this zone in the Dyr el Kef area (W. Tunisia).

The type Upper Albian "Marnes de Brienne", outcropping near Vallentigny (Dept. Aube, N.E. France) contains, according to Manivit (1965) an assemblage with *Eiffellithus turriseiffeli*. If Manivit's determination is correct, a correlation with the lower part of the *Eiffellithus turriseiffeli* Zone is possible. Manivit also reports the species from Aptian strata in conflict with the opinion of Thierstein (1971, 1973) and our own observations.

The zonal correlations with Upper Cretaceous stage-stratotypes are shown in Figure 15.

The Cenomanian neotype strata belonging to the "Craie de Théligny" found in the region of St. Ulphace-Moulin de l'Aunay (Depts. Sarthe and Orne, N.W. France), contained an assemblage with *Eiffellithus turriseiffeli* and without *Microrhabdulus decoratus* and *Calculites ovalis* (fig. 10C). A correlation with the upper part of the *Eiffellithus turriseiffeli* Zone is therefore most likely. The samples derived from the "Sable du Perche" and "Craie glauconieuse" did not contain any calcareous nannoplankton.

The typical Cenomanian beds of Ballon yielded a rather rich and well preserved nannofossil association, which may also be referred to the upper part of the *Eiffellithus turriseiffeli* Zone.

The type Turonian section of Chisseux (Dept. Indre-et-Loire, N. France), situated in the "Tuffeau de Tourrain", probably belongs to the *Tetralithus pyramidus* Zone and/or to the lower (most) part of the *Lucianorhabdus maleformis* Zone because of the joint occurrence of *Tetralithus pyramidus* and *Lucianorhabdus compactus* (fig. 10C). *T. pyramidus* is regularly found in the type deposits exposed near Fretevou, Ricoisne and Bourne near Chisseux, but *L. compactus* has not been encountered.

The Coniacian stratotype at Cognac (Dept. Charente, S.W. France) contains a very poor assemblage with *Tetrali-*

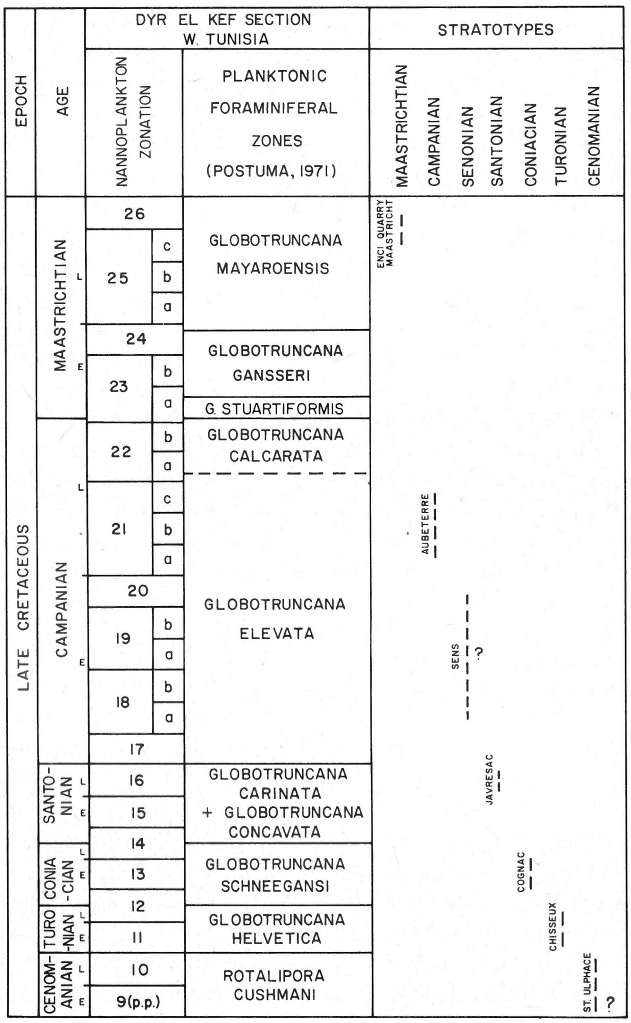


Fig. 15
Correlation of the Upper Cretaceous stage – stratotypes with Upper Cretaceous planktonic foraminiferal zones (after Postuma, 1971) and the proposed nannoplankton zonation (see Fig. 13 for explanation of the zonal numbers).

thus pyramidus and questionable representatives of *Micula* ex gr. *staurophora* (fig. 10B). The evolutionary stage of the latter group suggests an approximate correlation with the *Marthasterites furcatus* Zone. Three additional samples were studied from strata exposed in front of the gateway of the former seminary of Richemont (approx. 2 km north of Cognac), now "Institut Rural d'Education et d'Orientation". None of these samples from this classic locality of Coniacian strata mentioned by Coquand (1856, 1857, 1858) contained nannofossils.

At Javresac (Dept. Charente, S.W. France), the type Santonian beds contain *Lucianorhabdus cayeuxii* and are therefore correlatable with the *Lucianorhabdus cayeuxii* Zone (fig. 10B). The samples from St. Laurent-Louzac and Saintes also contain *L. cayeuxii* and, if a Santonian age is accepted, they probably belong to the same zone as those from the Santonian stage-stratotype.

The poorly preserved type-Senonian assemblage from Sens (Dept. Yonne, N. France) contains *Aspidolithus* ex gr. *parcus* (fig. 10B). The presence of this group indicates a correlation with the interval from the base of the *Aspidolithus parcus* (s.l.) Zone to the lower part (a) of the *Tranolithus phacelosus* Zone. Comparison with similarly preserved assemblages from the Upper Campanian (fig. 10A) of the Gironde Estuary (Dept. Charente – Maritime, S. France) suggests that those of the type Senonian may be older because of the consistent absence of *Tetralithus nitidus*. This opinion is tentative, but is in reasonable agreement with the literature. An Early Campanian age is also indicated by the co-occurrence of (questionable) *Calculites ovalis* and *Aspidolithus* representatives with relatively large central areas (see Lauer, 1975).

The assemblage of the type Campanian at Aubeterre (Dept. Charente, S.W. France) is referred to the *Tetralithus nitidus* Zone because of the frequent occurrence of *Tetralithus nitidus* and absence of *T. trifidus* (fig. 10A). The Campanian of Brossac and Montmoreau (which yielded a relatively rich, well preserved nannoplankton assemblage), mentioned by Coquand (1858) and Goharian (1971) is referable to the interval occupied by the *Tetralithus nitidus* Zone to *Tranolithus phacelosus* Zone (fig. 10A). The type Campanian deposits sensu Séronie-Vivien (1959), exposed near Genté in the Grande Champagne, yielded a nannoplankton flora characteristic of the interval of the *Aspidolithus parcus* (s.l.) Zone to the *Ceratolithoides aculeus* Zone. Those sampled at Gimeux belong to the *Lucianorhabdus cayeuxii* Zone and/or *Calculites obscurus* Zone (fig. 10A). Comparison with the zonation of Lauer (1975) showed that the assemblage of Genté is best referred to the *Aspidolithus* Zones B or C and that of Gimeux to the *Aspidolithus* Zones C (lower part) or D. Thus, the (type) Campanian strata at these two localities appear to be older than those at the classic localities of Aubeterre, Brossac and Montmoreau.

The (type) Dordonian deposits of Aubeterre, Le Maine-Blanc, Barret and Breuillare are best considered to be of Late Campanian age, although an Early Maastrichtian age for these strata cannot be ruled out with certainty (fig. 10A). Samples taken at Laguérie (S. of Barret) and at Campagne (nr. Laguérie), two other localities of Dordonian deposits mentioned by Séronie-Vivien (1959), contained a poor, non-diagnostic assemblage of nannofossils.

Nephrolithus frequens co-occurring with *Lithraphidites quadratus*, is known from the middle part of the Maastrichtian stratotype in the ENCI quarry near Maastricht (prov. of S. Limburg, The Netherlands) (fig. 10A). Therefore, this part of the stratotype belongs to the *Nephrolithus frequens* Zone. The lower interval of the section is assumed to belong to the upper part (c) of the *Arkhangelskiella cymbiformis* Zone, because of the presence of *L. quadratus* without *N. frequens*.

3.3.5 *Correlation with Upper Cretaceous Planktonic Foraminiferal Zones*

The planktonic foraminifera of the Upper Cretaceous sequence of the Dyr el Kef section, W. Tunisia, have been studied by J.A. Postuma (S.I.P.M., unpublished). The same samples of this section have been used for the nannoplankton investigations. Thus, a first-order correlation between the foraminiferal zonation of Postuma (1971) and the nannoplankton zonation has been established for the Late Cenomanian-Maastrichtian time interval (fig. 15).

3.3.6 *Comparison with the Late Cretaceous geochronological scale*

The biostratigraphical subdivision of the Campanian-Maastrichtian interval as presented here includes a relatively large number of zones (fig. 13). However, a plot of the number of formal zonal units of each stage against the approximate duration of each Late Cretaceous age as proposed recently by Obradovich & Cobban (1974), indicates a fairly regular zonal subdivision over the entire Late Cretaceous interval (fig. 16). Recent K-AR dating of glauconites from Campanian and Maastrichtian strata in The Netherlands and Belgium by Priem et al. (1975) support Obradovich & Cobban's (1974) age of the Campanian-Maastrichtian boundary of 70-71 million years. The opinion in literature that the proposed time span of the Campanian (approximately 11-12 m.y.) is (significantly) longer than that of the Maastrichtian (approximately 5-7 m.y.) seems also to be supported by data provided by Priem et al.

3.3.7 *Some additional remarks on the proposed zonation*

Under ideal circumstances, biozones should be recognizable at corresponding chronostratigraphical intervals on a world-wide scale. However, in Cretaceous times as during the Tertiary Period, some nannoplankton taxa lived exclusively or predominantly in the "tropical" (low latitude) or in the "boreal" (high latitude) regions. As far as Late Cretaceous markers are concerned, the present information suggests that *Bukryaster hayi, Ceratolithoides aculeus, Lithraphidites quadratus, Micula murus, Tetralithus nitidus* and *T. trifidus* are geographically confined to, or are most common in the "tropical climate belt". *Nephrolithus frequens* is regularly found in abundance in the North Sea Basin while it is less

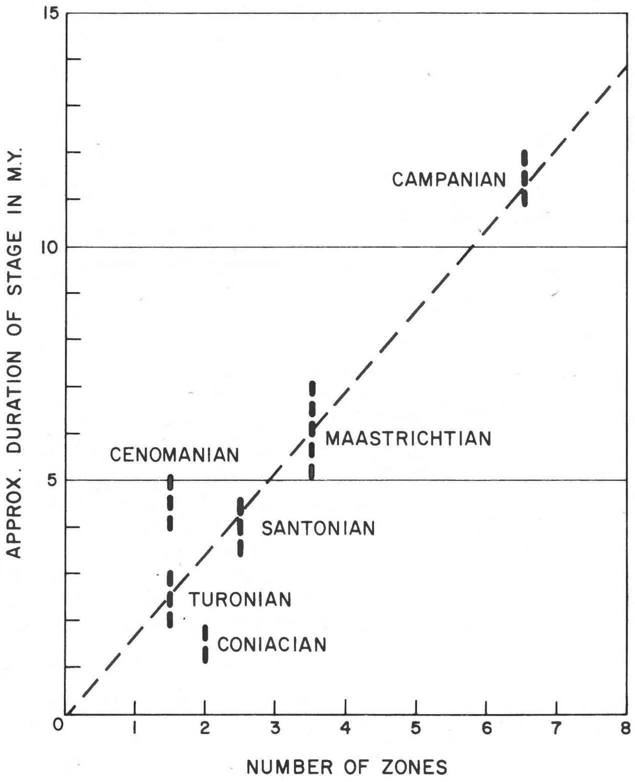


Fig. 16
Relation between approximate duration (in millions of years) of Cretaceous stages and number of distinguished nannoplankton zones of each stage.

common in the Dyr el Kef and probably, other low latitude sections. However, it is felt that as yet there is no conclusive evidence for the diachroneity of the *N. frequens* datum plane as claimed by Worsley (1974).

The extinction level of *Lucianorhabdus cayeuxii* is diachronous and can therefore only be used locally. In the Dyr el Kef section the species disappeared from the record during the Maastrichtian (fig. 9), but in the North Sea Basin it became extinct at the end of the Maastrichtian (see also Worsley, 1974).

In general the effectiveness of the Upper Cretaceous part of the zonation is assumed to be greatest in sedimentary basins situated at relatively low latitudes. The chronostratigraphical calibration of this part of the zonation needs further study, since it is largely based on foraminiferal data from the Dyr el Kef section in W. Tunisia. The effectiveness of the Lower Cretaceous zonation is probably more limited by post-depositional alterations of the fossil material than by variations in paleogeographical distribution patterns of marker species.

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APPENDIX

Systematics of selected Cretaceous marker species
(see Figure 12 and Plate 1 for illustrations)
B. Prins & W. Sissingh

I. *Early Cretaceous*

References for *Nannoconus bermudezii* Brönnimann, 1955 and *N. steinmannii* Kamptner, 1931 are found in Brönnimann (1955). Because of some difficulties in differentiating both species a combined stratigraphical range is given in Figure 12.

For the following two marker species references are found in Black (1971):

Palaeopontosphaera salebrosa (Black, 1971) Prins & Sissingh nov. comb. Basionym: *Cruciplacolithus salebrosus* Black, 1971, Proc. Yorkshire Geol. Soc., vol. 38(3), p. 397, pl. 30, fig. 4.
Remarks: This species is transferred to the genus *Palaeopontosphaera* Noël, 1965, because of the occurrence of a proximal shield and wall both composed of one layer. In distal view its extinction lines curve clockwise between crossed nicols. In *Cruciplacolithus* species these lines curve anti-clockwise distally.

Speetonia colligata Black, 1971 (= *Bipodorhabdus roeglii* Thierstein, 1971).

References for the applied concept of the following marker species are found in Thierstein (1973):

Calcicalathina oblongata (Worsley, 1971) Thierstein, 1971.
Chiastozygus litterarius (Górka, 1957) Manivit, 1971.
Cretarhabdus crenulatus Bramlette & Martini, 1964 sensu Thierstein (1971).
Cretarhabdus loriei Gartner, 1968 (= *Cretarhabdus multiforus* Black, 1971).
Eiffellithus turriseiffeli (Deflandre, 1954) Reinhardt, 1965 sensu Thierstein (1971).
Lithraphidites bollii (Thierstein, 1971) Thierstein, 1973.
Micrantholithus hoschulzii (Reinhardt, 1966) Thierstein, 1971.
Micrantholithus obtusus Stradner, 1963.

Because of some problems encountered in differentiating *Micrantholithus hoschulzii* and *M. obtusus* a combined stratigraphical range is given in Figures 10D and 12.

Prediscosphaera cretacea (Arkhangelsky, 1912) Gartner, 1968 sensu Thierstein (1973).

II.*Late Cretaceous*

Arkhangelskiella cymbiformis Vekshina, 1959 emend.

Arkhangelskiella cymbiformis Vekshina, 1959, p. 66, pl. 1, fig. 1, pl. 2, fig. 3; Bramlette & Martini, 1964, (pars), p. 297, pl. 1, figs. 3-8 (non pl. 1, fig. 9).

Remarks: Various types are referred to this species by various authors. In this paper the type is characterized by a relatively broad rim, clearly subdivided in two or more layers. In plan view these layers are visible as three or more concentric rings. The plate area bears large perforations per quadrant i.e. three along the long suture, and two along the short suture. There are no marginal perforations as in closely related species.

Aspidolithus ex gr. *parcus* (Stradner, 1963) Noël, 1969

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

Aspidolithus parcus (Stradner, 1963) Noël, 1969, p. 196, pl. 1, figs. 3, 4.

Broinsonia parca (Stradner, 1963) Bukry, 1969, p. 23, pl. 3, figs. 3-6.

Remarks: This group of closely related types includes all large *Aspidolithus* representatives with a relatively small plate area. Usually such types are designated to *A. parcus*. The *Aspidolithus* species 2-5 of Lauer (1975) belong to this group.

Bukryaster hayi (Bukry, 1969) Prins & Sissingh nov. comb.

Basionym: *Discoaster? hayi* Bukry, 1969, Univ. Kansas Paleont. Contr., Protista 2, art. 51, 1969, p. 65, pl. 38, figs. 10-12.

Bukryaster hayi (Bukry, 1969) Prins, 1971, pl. 1, fig. 3 (combination invalid I.C.B.N. Art. 33 B).

Calculites Prins & Sissingh nov. gen.

Derivatio nominis: Diminutive of calculus (Latin) = little stone.

Type species: *Tetralithus obscurus* Deflandre, 1959

Diagnosis: Heterococcoliths composed of a narrow rim, and a broad wall consisting of a limited number of calcite blocks. A plate structure is absent.

Description: In the electron microscope a narrow rim is visible, which surrounds the base of a broad and blocky wall. In the light microscope the rim is not always recognizable. The wall consists of a low number of calcite units, which may form a short central projection. The calcite blocks join in the centre, leaving no space for a plate structure.

Remarks: This genus differs from the morphologically closely related genus *Lucianorhabdus* Deflandre, 1959, by being constructed of large crystal units of different size and shape. The genus differs from the genera *Munarinus, Ottavianus, Russellia* and *Ramsaya* of Risatti (1973) in lacking a plate structure or a set of central openings.

Calculites obscurus (Deflandre, 1959) Prins & Sissingh, nov. comb.

Basionym: *Tetralithus obscurus* Deflandre, 1959, Rev. Micropal, vol. 2(3), p. 138, pl. 3, figs. 26-29; Martini, 1961, p. 3, pl. 1, fig. 2; Bramlette & Martini, 1964, p. 320, pl. 4, figs. 26-28; Stover, 1966, p. 162, pl. 7, fig. 10; Perch-Nielsen, 1968, p. 87, fig. 44, pl. 31, figs. 6-8, 10-11; Bukry, 1969, p. 63, pl. 37, figs. 11, 12; Manivit, 1971, p. 144, pl. 25, figs. 3-5; Risatti, 1973, p. 32, pl. 5, figs. 5-12.

Remarks: Because of a broad and badly understood variation in this group of nannofossils only the larger specimens with distinct and smooth or virtually smooth central elements in an arrangement typical for *C. obscurus* and *C. ovalis* are included.

Calculites ovalis (Stradner, 1963) Prins & Sissingh nov. comb. Basionym: *Tetralithus ovalis* Stradner, 1963, 6th W.P.C. Frankfurt, Sect. 1, paper 4, p. 12, pl. 6, fig. 7.

Remarks: See under *C. obscurus* (Deflandre, 1959) Prins & Sissingh, nov. comb.

Ceratolithoides aculeus (Stradner, 1961) Prins & Sissingh nov. comb.

Basionym: *Zygrhablithus aculeus* Stradner, 1961, Erdöl Zeitschr., vol. 77, p. 82, figs. 53-57.

Tetralithus aculeus (Stradner, 1961) Bukry & Kennedy, 1969, fig. 2(11-12); Risatti, 1973, p. 31, pl. 4, figs. 2-5, 13; Cepek & Hay, 1970, pl. 21, fig. 3; Manivit, 1971, p. 143, pl. 25, figs. 13-15.

Tetralithus sp. aff. *Tetralithus aculeus* (Stradner, 1961), in Gartner, 1968, p. 43, pl. 9, fig. 5, pl. 13, fig. 5.

Remarks: This species, as well as *C. arcuatus* nov. spec. (see below) is transferred to the genus *Ceratolithoides* Bramlette & Martini, 1964 because of the presence of types transitional between *C. aculeus* and *C. kamptneri* Bramlette & Martini, 1964 in samples of Maastrichtian age.

Ceratolithoides arcuatus Prins & Sissingh nov. spec. (Pl. 1, figs. 6a-d).

Derivatio nominis: arcuatus (Latin) = arched.

Diagnosis: A species of *Ceratolithoides* characterized by a reduced top resting on two long, curved horns, which make an angle of more than 90°.

Description: A reduced top, composed of a number of parallel calcite units is attached to an enlarged basal part. The base consists of two long, curving horns, forming an arc. The horns are pointed and curve gently at the inner side. The outer side is angular. The horns are not always equal in size. The angle between the horns varies. However, it is always far more than 90°.

Remarks: This species differs particularly from *C. aculeus* in having long basal horns. It differs from *C. kamptneri* in having a much greater angle between the horns. (Pl. 1, figs. 7a-d).

Dimensions: H: 4-6,5 μ; W: 4,5-7 μ.

Holotype: Slide T 293; 26 mm E, 6 mm S from Reference Point; sample 2F178, Upper Campanian of Dyr El Kef, W. Tunisia.

Depository: Micropalaeontological Collection of the Geological Institute, State University of Utrecht.

Known range: Upper Campanian.

Known geographical distribution: W. Tunisia, C. Oman, Turkey.

Lithraphidites quadratus Bramlette & Martini, 1964

Lithraphidites quadratus Bramlette & Martini, 1964, p. 310, pl. 6, figs. 16, 17, pl. 7, fig. 8; Perch-Nielsen, 1968, p. 84, pl. 25, figs. 8, 9; Gartner, 1968, p. 43, pl. 2, fig. 3, pl. 3, fig. 3, pl. 5, figs. 1, 2; Cepek & Hay, 1970, pl. 21, fig. 5; Manivit, 1971, p. 130, pl. 16, fig. 11; Risatti, 1973, p. 28, pl. 7, fig. 17.

Lucianorhabdus cayeuxii Deflandre, 1959

Lucianorhabdus cayeuxii Deflandre, 1959 (? pars), p. 142, pl. 3, fig. 30, pl. 4, figs. 11-17, 19-25, (? non pl. 4, fig. 18); Stradner, 1961, p. 82, figs. 45-48, 50; Stradner, 1963, pl. 6, fig. 6; Stover, 1966, p. 152, pl. 7, figs. 13, 14; Perch-Nielsen, 1968, p. 85, pl. 30, figs. 12-15; Manivit, 1971, p. 139, pl. 15, figs. 1, 2, pl. 16, figs. 5, 6.

Remarks: In a light-microscope with a lambda plate or quartz wedge inserted between the crossed nicols, better preserved specimens of this species, of *L. maleformis* Reinhardt, 1966, and of *L. compactus* (Verbeek, 1976) nov. comb. display a narrow rim. Therefore, in agreement with Wind (1975), these species are probably related to species originally described as *Tetralithus obscurus* Deflandre, 1959 and *T. ovalis* Stradner, 1963, since all these four species also show a four-fold subdivision of the central area in distal view.

Lucianorhabdus maleformis Reinhardt, 1966

Lucianorhabdus maleformis Reinhardt, 1966, p. 42, pl. 21, figs. 5, 7.

Lucianorhabdus cayeuxi Deflandre, 1959; in Gartner, 1968 (pars) p. 45, pl. 10, fig. 20, pl. 16, fig. 3 (non pl. 10, figs. 18, 19, pl. 12, fig. 7, pl. 16, fig. 4); Manivit, 1968, pl. 2, fig. 5.

Remarks: Well preserved representatives of this species from

Dyr el Kef appear to possess a peculiar calcite plug on top of the spine. This unit is apparently easily broken off. It is also present in *Lucianorhabdus compactus* (see below).

Lucianorhabdus compactus (Verbeek, 1976) Prins & Sissingh, nov. comb.

Basionym: *Isocrystallithus compactus* Verbeek, 1976, Proc. Kon. Ned. Akad. Wetensch., ser. B, vol. 79, p. 78, pl. 2, figs. 1-4.

Remarks: This species is here placed into the genus *Lucianorhabdus* Deflandre, 1959 because of a similar holococcolithid basal disc and spine, which terminates in a calcite plug (see also Wind, 1975). Consequently, *Isocrystallithus* Verbeek, 1976 is considered to be a junior synonym of *Lucianorhabdus*.

Marthasterites furcatus (Deflandre, 1954) Deflandre, 1959.

Discoaster? furcatus Deflandre, 1954 in Deflandre & Fert, 1954, p. 168, pl. 13, fig. 14.

Marthasterites furcatus (Deflandre, 1954) Deflandre, 1959, p. 139, pl. 2, figs. 3-12, pl. 3, figs. 1, 5; Stradner, 1961, p. 83, figs. 62, 63; Stradner in Stradner & Papp, 1961, p. 108, pl. 34, figs. 1, 2, 5; Stradner, 1963, pl. 2, fig. 11; Gartner, 1968, p. 42, pl. 18, fig. 6, pl. 20, fig. 18, pl. 21, fig. 3, pl. 23, fig. 2; Manivit, 1968. pl. 1, fig. 10; Cepek & Hay, 1970, pl. 20, fig. 5; Manivit, 1971, p. 140, pl. 16, figs. 7, 8.

Marthasterites furcatus furcatus (Deflandre), in Bukry, 1969, p. 65, pl. 39, figs. 2-4.

Marthasterites furcatus (Deflandre, 1954) var. *bramlettei* Deflandre, 1959, p. 139, pl. 3, fig. 2.

Marthasterites furcatus (Deflandre) *bramlettei* Deflandre, in Gartner, 1968, p. 42, pl. 21, fig. 15.

Marthasterites furcatus (Deflandre, 1954) var. *crassus* Deflandre, 1959, p. 139, pl. 2, fig. 17, pl. 3, figs. 3, 4.

Marthasterites furcatus (Deflandre) *crassus* Deflandre, in Gartner, 1968, p. 42, pl. 21, fig. 16; Bukry, 1969, p. 65, pl. 39, fig. 5.

Micula murus (Martini, 1961) Bukry, 1973

Tetralithus murus Martini, 1961, p. 4, pl. 1, fig. 6, pl. 4, fig. 42; Stradner in Stradner & Papp, 1961, p. 125, fig. 23(2); Stradner, 1963, pl. 6, fig. 5; Bramlette & Martini, 1964, p. 320, pl. 6, figs. 18-21.

Micula mura (Martini, 1961) Bukry, 1973a, p. 679.

Remarks: Special study of the genus has shown that this species consists of two superimposed layers, each comprising four calcite blocks. In typical and most evolved specimens one of these layers is strongly reduced, while the other layer is composed of four distinctly elongated elements, which are bent into a direction away from the reduced layer.

See I.C.B.N. (Art. 23) for explanation of the here slightly modified species name.

Micula ex gr. *staurophora* (Gardet, 1955) Bramlette & Martini, 1964

Discoaster staurophorus Gardet, 1955, p. 534, pl. 10, fig. 96.

Micula staurophora (Gardet, 1955) Stradner, 1963, p. 8, pl. 4, fig. 12 (combination invalid I.C.B.N. Art, 33B).

Micula staurophora (Gardet, 1955) Bramlette & Martini, 1964, p. 318, pl. 6, figs. 7-11.

Remarks: In this group all *Micula* representatives are included comprising eight or more elements. Based on number, shape and arrangement of the elements, different types can be distinguished in the electron microscope, but usually not by means of lightmicroscopy. See Thierstein (1974) for synonymy and discussion of the relationship between this group and *Tetralithus pyramidus* Gardet, 1955.

Microrhabdulus decoratus Deflandre, 1959

Microrhabdulus decoratus Deflandre, 1959, p. 140, pl. 4, figs. 1-5; Bramlette & Martini, 1964, p. 314, pl. 6, figs. 1, 2; Gartner, 1968, p. 44, pl. 6, fig. 12; Risatti, 1973, p. 28, pl. 10, figs. 14, 15.

Microrhabdulus decoratus var. *attenuatus* Deflandre, 1959, p. 141, pl. 4, figs. 6-8.

Remarks: During study of the stratigraphical distribution of this species in the Dyr el Kef section, an occasional confusion may have occurred with *Microrhabdulus stradneri* Bramlette & Martini, 1964. For this reason a combined stratigraphical distribution is given in Figure 9.

Nephrolithus frequens Górka, 1957,

Nephrolithus frequens Górka, 1957, p. 263, pl. 5, fig. 7; Perch-Nielsen, 1968, p. 56, fig. 23, pl. 7, figs. 12-14, pl. 18, figs. 1-9.

Nephrolithus barbarae Górka, 1957, p. 264, pl. 5, fig. 9; Bramlette & Martini, 1964, p. 302, pl. 2, fig. 10.

Nephrolithus furcatus Górka, 1957, p. 263, pl. 5, fig. 8.

Nephrolithus trientis Górka, 1957, p. 263, pl. 5, fig. 10.

Nephrolithus gorkae Äberg, 1966, p. 65, pl. 1, pl. 2, figs. 1-6, pl. 3, figs. 1-6; Bukry, 1969, p. 47, pl. 24, figs. 11, 12.

Reinhardtites anthophorus (Deflandre, 1959) Perch-Nielsen, 1968, emend. (Pl. 1, figs. 5a-d).

Rhabdolithus anthophorus Deflandre, 1959, p. 137, pl. 1, figs. 21, 22; Stradner, 1963, pl. 5, fig. 4.

Cretarhabdus? anthophorus (Deflandre, 1959) Bramlette & Martini, 1964, p. 299, pl. 3, figs. 1-4.

Reinhardtites anthophorus (Deflandre, 1959) Perch-Nielsen, 1968 (pars), p. 38, pl. 5, figs. 1, 5, 6 (non text-figs. 13, 14, pl. 5, figs. 2-4, 7, 8).

Zygodiscus elegans Gartner, 1968 (pars), p. 32, pl. 10, figs. 3-5 (non pl. 10, fig. 6), pl. 12, figs. 3, 4, pl. 27, fig. 1.

Reinhardtites? anthophorus (Deflandre) in Manivit, 1971 (pars), p. 89, pl. 20, figs. 9, 10, 13, 14 (non pl. 20, fig. 12).

Remarks: This species is characterized by moderately large openings surrounded by a wide plate-lining at both sides of the central bridge structure. The plate-lining often has a "blocky" or "pitted" microstructure. This latter feature is less obvious in types transitional to *R. levis* nov. spec. These transitional types are indicated in Figure 12 as *R.* aff. *anthophorus* (pl. 1, fig. 4).

Reinhardtites levis Prins & Sissingh nov. spec. (Pl. 1, figs. 1-3).

Reinhardtites anthophorus (Deflandre, 1959) Perch-Nielsen, 1968 (pars), text-figs. 13, 14, pl. 5, figs. 2-4, 7, 8, (non pl. 5, figs. 1, 5, 6).

Zygodiscus sp. in Risatti, 1973, pl. 10, figs. 18, 19.

Derivatio nominis: levis (Latin) = smooth.

Diagnosis: A species of *Reinhardtites* characterized by a very broad, smooth plate-lining enclosing a broad, rhombical bridge structure, surmounted by a short spine without flaring top part.

Description: A well developed rim with radiating rim elements surrounds at its proximal side a low wall. At its distal side it is connected to a broad, smooth plate-lining, leaving sometimes two small openings at both sides of the central bridge structure. In plan view the bridge is broadly rhombical and it extends less far in the direction of the rim than is found in the other species of the genus. The bridge carries a short, broad spine. So far no specimens have been observed, in which the spine terminates in a flaring top part.

Remarks: The species differs from *R. anthophorus* in having a much broader and smooth plate-lining. It differs from *R.* aff. *anthophorus* in having a bridge structure that extends less far in the direction of the rim.

Dimensions: 8 – 10,5 μ.

Holotype: slide T 294; 12,6 mm W, 5,3 mm S from Reference Point; sample 2F204, Lower Maastrichtian of Dyr el Kef, W. Tunisia; distal view. Depository: Micropalaeontological Collection of the Geological Institute, State University of Utrecht.

Known range: Uppermost Campanian to Lower Maastrichtian.

Known geographical distribution: W. Tunisia; North Sea Basin, including Denmark, Great Britain and The Netherlands; U.S.A.

Tetralithus nitidus Martini, 1961.

Tetralithus nitidus Martini, 1961, p. 4, pl. 1, fig. 5, pl. 4, fig. 41; Gartner, 1968 (pars), p. 42, pl. 13, fig. 3 (non pl. 9, fig. 14, pl. 13, fig. 4); Risatti, 1973 (pars), p. 32, pl. 4, figs. 18, 19, 24, 25 (non pl. 4, figs. 15, 20-23, pl. 9, figs. 1, 2).

Tetralithus gothicus Deflandre, 1959, Stradner in Stradner & Papp, 1961 (pars), pl. 40, fig. 13 (non text-fig. 23 (3)); Stradner, 1963, pl. 6, fig. 1.

Remarks: Detailed examination of *Tetralithus nitidus* showed that the species consists of four elements which at the "distal" and "proximal" side extend laterally. Extensions at both sides may be equally prominent. However, types with one short-rayed side and one long-rayed side occur as well and fall well within the general species variation. Only individuals with at least one long-rayed side are included in this species (see also under *T. trifidus*).

Tetralithus pyramidus Gardet, 1955 sensu Thierstein (1974).

Tetralithus pyramidus Gardet, 1955, p. 521, pl. 7, fig. 66;? Stradner in Stradner & Papp, 1961, p. 123, pl. 40, fig. 12, text-fig. 13 (1); Stradner, 1963 (pars), pl. 6, fig. 3, (non pl. 6, fig. 4).

Tetralithus gothicus Deflandre, in Gartner, 1968, pl. 24, fig. 4.

"*Micula pyramida* (Gardet, 1955)", Thierstein, 1974, pl. 12, figs. 4-8.

Remarks: In this study only short-rayed specimens composed of four elements are included in this species, since short-rayed three-fold individuals may also represent part of *Tetralithus trifidus* Stradner, 1961 (see below).

Tetralithus trifidus Stradner, 1961 emend.

Tetralithus gothicus Deflandre, forma *trifida* Stradner, in Stradner, 1963, pl. 6, fig. 2.

Tetralithus gothicus Deflandre, 1959 subsp. *trifidus* Stradner 1961 in Stradner & Papp, 1961, p. 124, fig. 23 (3).

Tetralithus nitidus Martini, 1961, in Manivit, 1971, pl. 25, figs. 22, 23; Gartner, 1968 (pars), pl. 9, fig. 14, pl. 13, fig. 4 (non pl. 13, fig. 3); Risatti, 1973, (pars), p. 32, pl. 4, fig. 15?, 20, 21 (non pl. 4, figs. 18, 19, 22-25, pl. 5, figs. 1, 2).

Tetralithus trifidus Stradner, 1961, in Bukry, 1973a, p. 680.

Remarks: In common with *Tetralithus nitidus* Martini, 1961, this species possesses long and slender extensions on both sides. Some specimens have one short-rayed side. Only specimens with three long extensions, on one side at least, are referred to this species.

Tranolithus phacelosus Stover, 1966

Tranolithus phacelosus Stover, 1966, p. 146, pl. 4, figs. 23-25, pl. 9, fig. 7.

"*Discolithus*" *orionatus* Reinhardt, 1966 (pars), p. 42, pl. 23, fig. 22 (non pl. 23, figs. 31-33).

Tranolithus orionatus (Reinhardt, 1966) Perch-Nielsen, 1968, p. 35, text-fig. 9, pl. 4, figs. 15-19; Manivit, 1971, p. 85, pl. 26 figs. 13-17.

Zygodiscus? phacelosus (Stover, 1966) Bukry, 1969, p. 61, pl. 35, fig. 12.

Remarks: The diagnosis of this species is emended to include only individuals which, as in the holotype, possess two large blocks at each side of a narrow and fragile bridge structure, a feature which has usually not been preserved.

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PLATE

Fig. 1-3
Reinhardtites levis Prins & Sissingh, n.sp.
fig. 1: holotype, distal view; fig. 2: paratype, proximal view;
fig. 3: paratype, distal view, specimen with small openings near the base of the spine. Tunisia, Dyr el Kef, 2 F 204; Maastrichtian.

Fig. 4
Reinhardtites sp. aff. anthophorus (Deflandre, 1959) Perch-Nielsen, 1968.
Tunisia, Dyr el Kef, 2 F 178; Campanian.

Fig. 5
Reinhardtites anthophorus (Delfandre, 1959) Perch-Nielsen, 1968 Tunisia, Dyr el Kef, 2 F 178; Campanian.

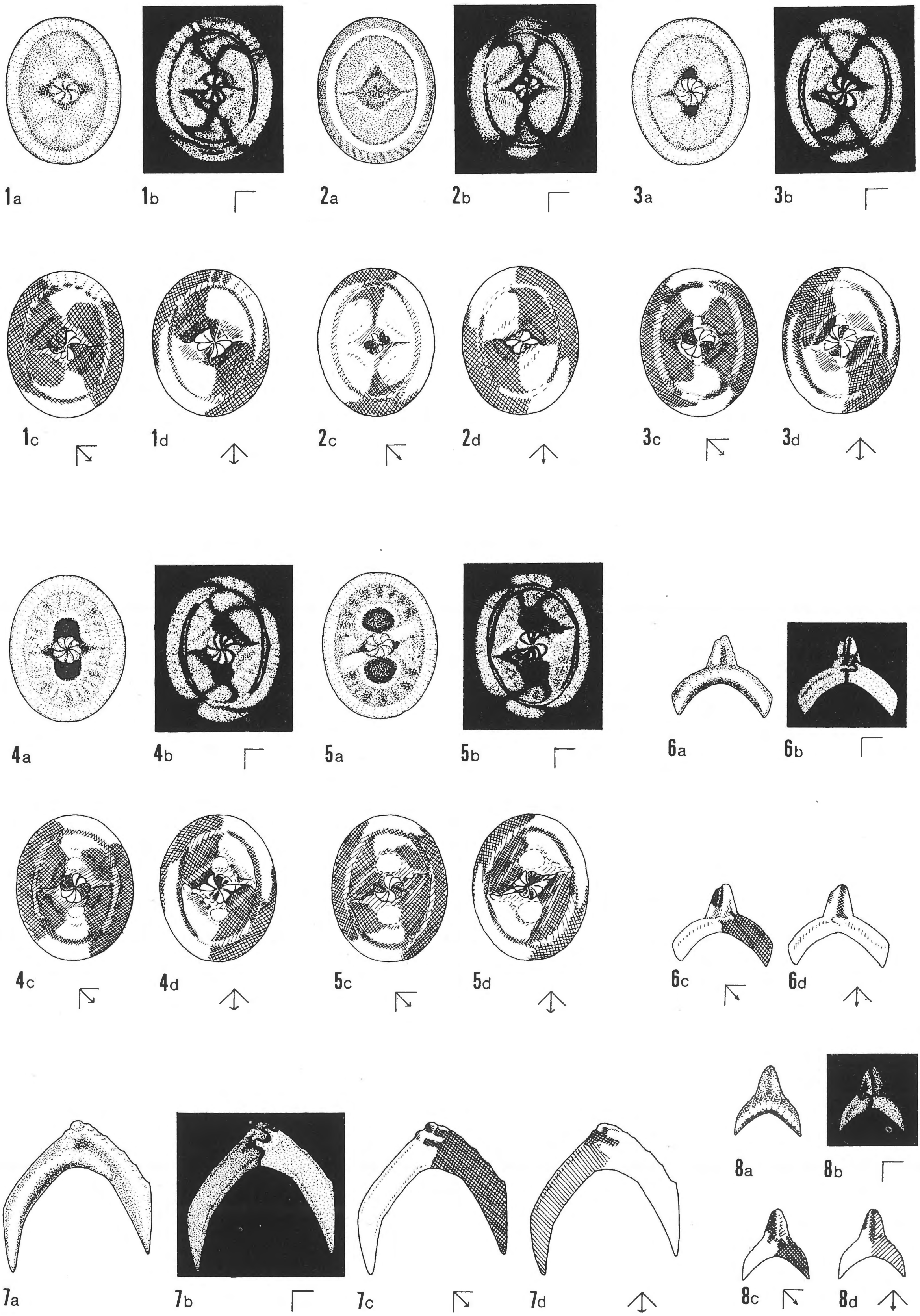
Fig. 6
Ceratolithoides arcuatus Prins & Sissingh, n.sp. holotype, Tunisia, Dyr el Kef, 2 F 178; Campanian.

Fig. 7
Ceratolithoides kamptneri Bramlette & Martini, 1964 France, Gan 791; Paleocene, reworked.

Fig. 8
Ceratolithoides aculeus (Stradner, 1963) Prins & Sissingh, n. comb.
specimen with well developed basal horns, approaching *C. arcuatus* n.sp. Tunisia, Dyr el Kef, 2 F 178; Campanian.

a = normal light; b = x nic 0°; c = x nic 0°, gypsum red one 45° (arrow); d = x nic 45°, gypsum red one 0° (arrow); cross-hatched areas: blue; blank areas: yellow.

magnification appr. 2600 x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