New Aspects on Tethyan Cretaceous Fossil Assemblages.
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# 2.2. A review of low-latitude "Tethyan" calcareous nannoplankton assemblages of the Cretaceous

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## Abstract

Distinctive low-latitude ("Tethyan") and high-latitude (boreal-austral) nannofossil assemblages can be recognized in Early Cretaceous, Mid-Cretaceous and Late Cretaceous times. Early and Mid-Cretaceous Tethyan assemblages are situated within a broad equatorial belt about 40° N to S. During the Late Cretaceous nannofossil bioprovincialism increases resulting in the existence of typical Tethyan/tropical, subtropical and high-latitude nannofossil species.

## 1. Introduction

Coccoliths, the minute calcareous skeletal elements of unicellular marine, planktonic protists (coccolithophorids), form a major component of marine sediments. Coccolithophores are predominantly autotrophic and therefore photosynthisizing living cells are restricted to the upper 200 meters of the water column. Studies of production, transportation and thanatocoenosis of modern coccoliths show that species diversity and distribution patterns are largely controlled by surface-water temperature (e. g. ROTH & BERGER, 1975), although assemblages change markedly during the sinking process through the water column (HONJO, 1976). Besides the strong latitudinal control of Recent calcareous nannoplankton distribution, other factors such as salinity, surface water fertility (especially nutrient advection caused by upwelling water masses), oceanic water circulation and proximity to the shore are known to influence nannofloral distributions (e. g. BUKRY, 1974; OKADA & HONJO, 1975; REID, 1980; ZHANG & SIESSER, 1986). Another important factor governing the distribution

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of coccoliths in oceanic sediments is dissolution during transportation and deposition, especially in depths below the calcite lysocline (THIERSTEIN, 1980).

It can be assumed that the controlling factors of Ancient coccolith distributions are more or less the same as for Recent calcareous nannoplankton. As a consequence studies of coccolith assemblages have proven to be a powerful tool in Cenozoic palaeoceanographic reconstructions as indicators of temperature and to a lesser degree fertility or salinity of oceanic surface waters (e. g. HAQ & LOHMANN, 1976; HAQ, 1980; RUDDIMAN & MCINTYRE, 1976). For the interpretation of Mesozoic coccolith assemblages the problem of the increasing influence of postdepositional, diagenetic alterations of assemblages arises. Dissolution and overgrowth result in an increase of the most resistant species such as *Watznaueria barnesae* and *Micula decussata* in the Cretaceous (THIERSTEIN, 1981). Samples with poorly preserved coccoliths are a major problem in palaeoceanographic reconstructions for the Mesozoic (e. g. ROTH, 1981).

The existence of Late Cretaceous latitudinal nannofossil provinces were for the first time demonstrated by WORSLEY & MARTINI (1970). They showed that occurences of *Micula murus* are strictly confined to low latitudes and *Nephrolithus frequens* only to high latitudes. Lateron, investigations of Mid-Cretaceous and Late Cretaceous coccolith assemblages also indicated latitudinal, water-temperature control for several other species and groups (e. g. ROTH & BOWDLER, 1981; THIERSTEIN, 1981).

This paper concentrates on various aspects of "Tethyan" coccolith assemblages. In nannofossil terms, "Tethyan" can be regarded as a synonym to "low-latitude", indicating the existence of a more or less broad, worldwide equatorial belt of compareable "tropical" nannofossil assemblages. No significant differences in nannofossil assemblage compositions can be demonstrated between the Pacific and the "Tethys" in a geological/tectonic sense, which is the former ocean lying along the later Alpine-Himalayan-Indonesian orogenic belt.

## 2. Early Cretaceous

(Berriasian, Valanginian, Hauterivian, Barremian)

The Early Cretaceous was characterized by the rise of calcareous nannoplankton to become the major source of calcareous material to the oceanic system, resulting in a gradual shallowing of the calcite lysocline during the Early Cretaceous. Data on Early Cretaceous coccolith distribution and provincialism are scarce, although latitudinal differences are known to exist from the Late Jurassic onwards (COOPER, 1989). THIERSTEIN (1989) also indicated pronounced neritic-oceanic gradients. The first low-latitude, shallow-marine nannofloral element recognized for the Early Cretaceous was the genus *Nannoconus* (e. g. THIERSTEIN, 1973), although occurences of certain species of this group were later also reported from mid-latitudes and oceanic plateaus (PERCH-NIELSEN, 1979; ROTH, 1981).

Table 1: Taxonomic index of Cretaceous calcareous nannofossil species

*Biscutum constans* (GORKA 1957) BLACK 1959
*Calcicalathina oblongata* (WORSLEY 1971) THIERSTEIN 1971
*Ceratolithoides aculeus* (STRADNER 1961) PRINS & SISSINGH in SISSINGH 1977
*Conusphaera rothii* (THIERSTEIN 1971) JAKUBOWSKI 1986
*Corollithion silvaradion* FILEWICZ et al. in WISE & WIND 1977
*Cretarhabdus surirellus* (DEFLANDRE 1954) REINHARDT 1970
*Crucibiscutum salebrosum* (BLACK 1971) JAKUBOWSKI 1986
*Cruciellipsis cuvillieri* (MANIVIT 1966) THIERSTEIN 1971
*Cyclagelosphaera margerelii* NOEL 1965
*Cylindralithus serratus* BRAMLETTE & MARTINI 1964
*Eprolithus floralis* (STRADNER 1962) STOVER 1966
*Helicolithus trabeculatus* (GORKA 1957) VERBEEK 1977
*Lithraphidites bollii* (THIERSTEIN 1971) THIERSTEIN 1973
*Lithraphidites quadratus* BRAMLETTE & MARTINI 1964
*Marthasterites furcatus* (DEFLANDRE in DEFLANDRE & FERT 1954) DEFLANDRE 1959
*Micula decussata* VEKSHINA 1959
*Micula murus* (MARTINI 1961) BUKRY 1973
*Nannoconus abundans* STRADNER & GRÜN 1973
*Nannoconus borealis* PERCH-NIELSEN 1979
*Nannoconus truitti* BRÖNNIMANN 1955
*Nephrolithus frequens* GORKA 1957
*Octocyclus magnus* BLACK 1972
*Quadrum trifidum* (STRADNER in STRADNER & PAPP 1961) PRINS & PERCH-NIELSEN in MANIVIT et al. 1977
*Rhagodiscus asper* (STRADNER 1963) REINHARDT 1967
*Repagulum parvidentatum* (DEFLANDRE & FERT 1954) FORCHHEIMER 1972
*Seribiscutum primitivum* (THIERSTEIN 1974) FILEWICZ et al. in WISE & WIND 1977
*Sollasites falklandensis* FILEWICZ et al. in WISE & WIND 1977
*Sollasites horticus* (STRADNER et al. 1966) CEPEK & HAY 1969
*Speetonia colligata* BLACK 1971
*Tegulalithus septentrionalis* (STRADNER 1963) CRUX 1986
*Tegumentum striatum* (BLACK 1971) CRUX 1989
*Thiersteinia ecclesiastica* WISE & WATKINS in WISE 1983
*Tubodiscus verenae* THIERSTEIN 1973
*Watznaueria barnesae* (BLACK 1959) PERCH-NIELSEN 1968
*Zeugrhabdotus elegans* (GARTNER 1968) MUTTERLOSE 1988
*Zeugrhabdotus embergeri* (NOEL 1959) PERCH-NIELSEN 1984
*Zeugrhabdotus sisyphus* (GARTNER 1968) CRUX 1989
*Zygodiscus spiralis* BRAMLETTE & MARTINI 1964

A first overview about the general composition of Tethyan nannofloras of the Early Cretaceous was given by THIERSTEIN (1973, 1976). Recently, MUTTERLOSE & HARDING (1987), APPLEGATE et al. (1989), COOPER (1989), CRUX (1989), and MUTTERLOSE (1989) compared Tethyan nannofossil assemblages with those from the Boreal Early Cretaceous of NW Europe (Great Britain, North Sea, Northern Germany). The following conclusions can be drawn from Early Cretaceous nannofossil assemblages:

1. Typical low-latitude, Tethyan nannofloras are dominated by the genera *Nannoconus, Micrantholithus, Lithraphidites, Watznaueria* and *Rhagodiscus* (THIERSTEIN, 1973; WIND & CEPEK, 1979; APPLEGATE et al., 1989; MUTTERLOSE, 1989). The nannoconids show greater diversities than in the boreal realm (PERCH-NIELSEN, 1989).

2. Tethyan or warm water species, which are very rare or absent in high latitude samples are the nannoconids of the "*Nannoconus truittii*-assemblage" (e. g. MUTTERLOSE, 1989), *Lithraphidites bollii, Speetonia colligata, Cruciellipsis cuvillieri, Calcicalathina oblongata, Conusphaera rothii, Tubodiscus venerae* (CRUX, 1989: Tab. 8.1). Species with high abundances in the Tethyan Early Cretaceous, but also found within the Boreal realm are *Watznaueria barnesae, Zeugrhabdotus embergeri, Cretarhabdus (Stradneria) crenulatus,* and *Rhagodiscus asper.*

3. The Tethyan "*Nannoconus truittii*-assemblage" reaches as far north as the Irish Sea. The southernmost occurences are known from Surinam, but related nannoconids are found also in Mozambique (DERES & ARCHERITEGUY, 1980; MUTTERLOSE, 1989). Nannofloras from deep sea drilling cores offshore North Carolina (DSDP Leg 93) and Portugal (ODP Leg 103) represent assemblages of the northern Tethys (APPLEGATE et al., 1989), whereas assemblages of northern Germany and Great Britain have a Boreal character. This indicates a belt of Tethyan assemblages between 35° S and 45° N.

4. Transgressive events with influxes of warm water Tethyan elements into northern and southern mid- to high-latitude regions are characterized by extremely high abundances of *Rhagodiscus asper* up to 50%, together with nannoconids and *Cyclagelosphaera margerelii* (CRUX, 1989; MUTTERLOSE, 1989).

5. Typical Boreal (and Austral) species of the Early Cretaceous are *Crucibiscutum salebrosum, Tegulalithus septentrionalis, Sollasites arcuatus, Sollasites horticus, Corollithion silvaradion, Tegumentum striatum, Zeugrhabdotus sisyphus* (APPLEGATE et al., 1989; COOPER, 1989; CRUX, 1989). Endemic species of the Boreal NW Europe include *Nannoconus borealis* and *N. abundans.*

6. The diversities of the assemblages show no significant tendency to decrease from low-latitudes polewards. The highest diversities are reported from NW Europe (COOPER, 1989; CRUX, 1989), although this unexpected distribution pattern can be also explained by the lack of quantitative data for non-European sequences.

### 3. Mid-Cretaceous
(Aptian, Albian, Cenomanian, Turonian)

The Mid-Cretaceous oceanic circulation was largely driven by differences in salinity with relatively low temperature gradients and less vigorous than that of the Cenozoic (BRALOWER & THIERSTEIN, 1984). The reorganization of this "sluggish" circulation towards higher temperature gradients and cold, nutrient-rich bottom waters seems to have taken place around the Cenomanian-Turonian boundary (e. g. KUHNT et al., 1986). The Mid-Cretaceous palaeoceanic situation was characterized by a shallowing of the calcite compensation depth by about 2 kilometers to dephts between 2,5 and 3,5 km (ROTH & KRUMBACH, 1986). There are four general trends in the distribution of Mid-Cretaceous nannofossils recognized by ROTH (1981), ROTH & BOWDLER (1981), ROTH & KRUMBACH (1986), WISE (1988), APPLEGATE et al. (1989), and MUTTERLOSE (1989):

1. There exists a wide belt of more or less uniform "tropical-subtropical" nannofossil assemblages from about 40° N to 40° S. Tethyan nannofossil assemblages correspond to this broad low latitude belt but no typical Tethyan assemblage composition can be given because of other controlling factors such as oceànic upwelling. Samples from Tethyan regions show nearly the same overall composition as those from Boreal sections (BRALOWER, 1988). Nevertheless, Tethyan assemblages are characterized by a predominance of *Watznaueria barnesae* and common *Prediscosphaera, Cretarhabdus* and *Eiffellithus* (e. g. BRALOWER, 1988). Also most of the Nannoconids are considered to be indicators of warm surface waters from the Tethys (MUTTERLOSE, 1989: "*Nannoconus truittii*-assemblage") and are therefore a common element of Tethyan assemblages, especially from neritic environments.

2. Surface water fertility gradients caused by upwelling waters along the eastern margin of the Atlantic strongly influenced nannofossil distributions. This results in a pronounced east-west gradient in assemblage composition. Indicators of high fertility waters are *Biscutum constans* and species of *Zygodiscus, Vagalapilla* and *Braarudosphaera* (ROTH & BOWDLER, 1981; ROTH & KRUMBACH, 1986).

3. High latitude assemblages of northern (Boreal) and southern (Austral) affinities show a more or less similar composition with dominance of several species such as *Serbiscutum primitivum, Zygodiscus spiralis* and *Eprolithus floralis* (ROTH & KRUMBACH, 1986). Species like *Serbiscutum primitivum, Sollasites falklandensis, Octocyclus magnus* and *Repagulum parvidentatum* seem to be restricted to high latitudes (ROTH & BOWDLER, 1981; WISE, 1988).

4. Nearly monospecific "blooms" of nannofossil species (e. g. *Corollithion, Zeugrhabdotus elegans, Biscutum constans*) occur preferentially in assemblages of high- and mid-latitudes. These blooms are ascribed to strong upwelling of nutrient-rich, cold waters and possibly lower salinities due to partly restricted surface water conditions (WISE & WIND, 1977; ROTH & BOWDLER, 1981; NOEL, BREHERET & LAMBERT, 1987; WISE, 1988).

## 4. Coniacian-Santonian

So far no general overview about the distribution patterns of nannofossil assemblages of Coniacian-Santonian times does exist. Palaeoceanographic reconstructions by means of nannofossils are hindered by the lack of oceanic sections with carbonate deposition during this time span because of a global highstand of the calcite compensation depth (e. g. WISE, 1988). An increase in nannofossil provincialism since the Turonian can be deduced by comparing the magnitude of the Mid-Cretaceous oceanic circulation with the Late Cretaceous situation. The Coniacian-Santonian seems to be also relatively "quiet" in regard of nannofossil evolution because often only one nannozone can be recognized, especially in oceanic sections (*Marthasterites furcatus* total range zone, e. g. CEPEK & HAY, 1969; STRADNER & STEINMETZ, 1984). *Marthasterites furcatus* is a tropical to subtropical element only sporadically found within mid- to high latitudes (PERCH-NIELSEN, 1979; CRUX, 1982).

Tethyan assemblages are characterized by high abundances of *Watznaueria barnesae* and rare *Micula* species (percentages below 1%, WAGREICH, 1986). Other common genera include *Eiffellithus*, *Prediscosphaera*, *Glaukolithus*, *Cretarhabdus*, *Cribrosphaerella* and *Tranolithus*. Within nearshore environments holococcoliths such as *Lucianorhabdus*, *Calculites*, *Orastrum*, *Russelia* and *Pharus* show high diversification within the Tethyan realm compared with northern assemblages. Southern high latitudes are characterized by *Thiersteinia ecclesiastica* together with *Repagulum parvidentatum* and *Serbiscutum primitivum* (WISE, 1988). Blooms of *Helicolithus trabeculatus*, a rare species in Tethyan assemblages, are reported by WATKINS et al. (1989) from the Santonian of southern high latitudes of the Falkland and Kerguelen Plateaus.

## 5. Campanian-Maastrichtian

It is generally assumed that there was an increase in temperature gradients between low and high latitudes from the Mid- to the Late Cretaceous (e. g. BARRON, 1983). For the Maastrichtian a major temperature decrease has been suggested because of increased nannofossil provincialism (WORSLEY, 1974; ROMEIN, 1977), resulting in distinct low, middle and high latitude assemblages (e. g. THIERSTEIN, 1976, 1981). Also the diversity of assemblages increases from the Mid to the Late Cretaceous (e. g. DOEVEN, 1983; CEPEK et al., 1985). As a consequence Campanian-Maastrichtian nannofossil thanatocoenoses are about twice as diverse as modern ones (THIERSTEIN, 1981: 377).

*Micula decussata* is the most resistant nannofossil species of the Campanian-Maastrichtian (THIERSTEIN, 1980, 1981). Therefore strong dissolution leads to enrichment of this species and *Watznaueria barnesae* and dissolution of the more susceptible ones.

The following conclusions can be drawn about Campanian-Maastrichtian nannofossil distribution patterns:

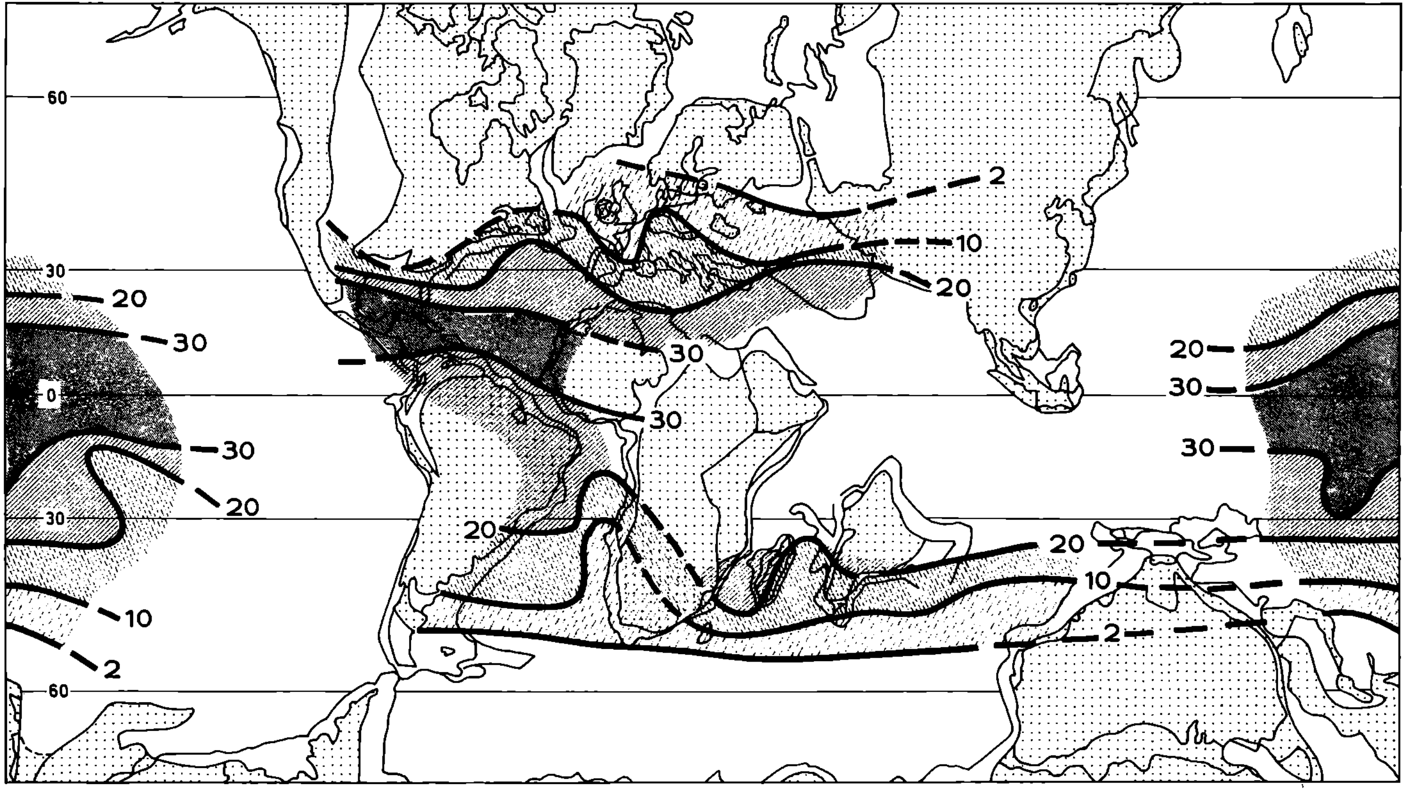


Fig. 1: Average percentage abundances of *Watznaueria barnesae* in Campanian-Maastrichtian assemblages after THIERSTEIN (1981: Fig. 15) (Mercator projection for 80 m. y. after BARRON et al., 1981).

1. *Watznaueria barnesae* is a typical low latitude, warm water species. Abundances over 30% are only reported from the tropical, Tethyan realm (comp. Fig. 1). BUKRY (1973) even noted complete absence of *Watznaueria barnesae* in some high latitude assemblages. As a consequence the ratio between *Micula* and *Watznaueria* (and *Cyclagelosphaera* ) has been suggested as a rough estimation of surface water temperature gradients (WIND, 1979; DOEVEN, 1983). This ratio is also applicable to poorly preserved assemblages, because both *Micula* and *Watznaueria* are dissolution resistant species. Tethyan assemblages display low M/W-ratios less than 1.

2. Other typical Tethyan, warm-water elements of the Maastrichtian are *Micula murus, Cylindralithus serratus* and *Cretarhabdus surirellus* (THIERSTEIN, 1981). The distribution pattern of Tethyan assemblages defines a relatively narrow tropical "Tethyan" belt between 30° N and S (Fig. 1).

3. A subtropical assemblage could be identified by THIERSTEIN (1981), characterized by abundance peaks of *Quadrum trifidum, Ceratolithoides aculeus* and *Lithraphidites quadratus* in samples of paleolatitudes about 30° N or S.

4. High latitude assemblages consist of high percentages of *Micula decussata* and the genera *Vagalapilla, Reinhardtites, Prediscosphaera, Kamptnerius,* and *Eiffellithus*. Especially, *Nephrolithus frequens* is an element of high latitude assemblages of the Late Maastrichtian (WORSLEY & MARTINI, 1970) which is only occasionally reported from low latitude Tethyan assemblages (e. g. SHAFIK & STRADNER, 1971; PRIEWALDER, 1973).

## 6. Discussion

A review of Cretaceous nannofossil assemblages indicates increasing latitudinal nannofossil provincialism probably as a consequence of increasing oceanic temperature gradients in the Late Cretaceous and of a general decrease of temperature (e. g. BARRON, 1983). Weak nannofossil provincialism could be documented as early as for the Late Jurassic giving way to a compareable paleobiogeographic situation at the beginning of the Cretaceous (COOPER, 1989). The nannofossil assemblages of the Cretaceous generally display more or less uniform compositions with dominance of the same genera in samples of both low and high latitude. Only few species are characteristic for certain paleolatitudinal provinces. "Warm" and "cold" water species of the Cretaceous show no straightforward size or shape variations as for example dextral and sinistral coiling of planktonic foraminifera.

Tethyan, that means low-latitude, nannofossil assemblages of the Early and Mid-Cretaceous correspond to a broad equitorial belt reaching as far as 40° N and S. Within this belt nannofossil assemblages show strong differences resulting from upwelling waters and nearshore trends. In contrast, nannofossil assemblages of the Campanian-Maastrichtian are strongly influenced by latitudinal trends and biogeographic boundaries defined by nannofossils roughly parallel latitudes. Tropical, Tethyan assemblages are often characterized by high amounts of *Watznaueria barnesae* and certain other species, although influences apart from surface water temperature could be recognized (e. g. THIERSTEIN, 1981; DOEVEN, 1983). However, the lack of quantitative data especially for samples from Tethyan land sections hinderes a more precise examination of Tethyan nannofossil assemblages.


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