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Phytoplankton from the Anoxic Sediments of the Barremian (Lower Cretaceous) of North-West-Germany

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With 12 Figures, 6 Tables and 4 Plates

NW-Germany
Calcareous Nannofossils
Dinocysts
Lower Cretaceous
Barremian
Anoxic Sediments
Environment

Contents

Zusammenfassung

Erstmalig wird das Phytoplankton (Coccolithen, Palynomorphe) des höheren Unter-Barrême und des tieferen Ober-Barrême (= Mittel-Barrême alter Gliederung) von NW-Deutschland beschrieben. Die vertikalen Florenassoziationsabfolgen, die die lithologischen Wechsel nachvollziehen, lassen eine Dreigliederung des untersuchten Schichtenabschnittes zu. Nach einer durch eine individuenarme Flora gekennzeichneten Phase nimmt im mittleren Abschnitt, im Hauptblätterton (höheres Unter-Barrême), der Anteil an Phytoplankton sprunghaft zu. Oberhalb des Hauptblättertons erfolgt ein deutlicher Rückgang des Phytoplanktonteils. Sedimentologische und paläontologische Befunde belegen, daß es sich bei dem Hauptblätterton um ein Sediment des anoxischen Milieus handelt.

Die Dinoflagellaten-Zysten werden im Hauptblätterton durch eine arten- und individuenreiche Warmwasserflora, im unteren und oberen Abschnitt durch eine artenreiche, individuenarme Kaltwasserflora repräsentiert. Der feingeschichtete Hauptblätterton, der im gesamten niedersächsischen Unterkreide-Becken zu finden ist und nach makropaläontologischen Befunden ein synchron gebildetes Sediment darstellt, besteht aus feinen hellen und dickeren dunklen Laminae. Erstere zeigen im Dünnschliff eine Anreicherung von Coccolithen, wobei es z. T. zu einer Mikrolinsenschichtung gekommen ist. Die hellen Laminae werden als incipient chalk facies, also Vorläufer der Schreibkreide-Fazies, verstanden.

Coccolithen und Dinoflagellaten-Zysten deuten darauf hin, daß es sich bei dem Hauptblätterton um ein Sediment des

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warmen Wassers handelt. Vermutlich sind die Coccolithenanreicherungen auf saisonale Phytoplanktonblüten zurückzuführen, die zu der Bildung der typischen Laminae führten.

Abstract

For the first time the phytoplankton (coccoliths, palynomorphs) of the higher Lower Barremian and the lower Upper Barremian (= Middle Barremian of the old zonation) is described from NW-Germany. The vertical association sequence correlates with lithological changes and a tri-partite division can be recognised. Within the middle part of the sequence (the Hauptblätterton = higher Lower Barremian), the percentage of the phytoplankton is enormously increased. Sedimentological and palaeontological observations indicate that the Hauptblätterton was deposited under anoxic conditions.

In the Hauptblätterton, the dinocysts are represented by a high abundance – high diversity warm water flora, in contrast to the high diversity – low abundance cold water flora below and above the Hauptblätterton. The finely laminated Hauptblätterton, a synchronous stratum to be found all over the Lower Saxony Basin, consists of thin pale and thick dark laminae. In thin sections the former show an enrichment of coccoliths, mainly in microlenses. These are interpreted as an incipient chalk facies, a forerunner of the Schreibkreide facies.

Coccoliths and dinocysts indicate that the Hauptblätterton was deposited under warm water conditions. The coccoliths were probably enriched by seasonal plankton blooms, which caused the typical lamination.

1. Introduction

In the Lower Cretaceous of NW-Germany and adjacent areas there are repeated occurrences of sediments which were deposited under anoxic/kenoxic conditions. This type of sediment is known from the Berriasian (Ölschiefer), the Barremian (Blätterton, Blätterschiefer) and the Lower Aptian (Fischschiefer, Töck) (compare Fig. 1).

The Barremian anoxic sediments, in which layers of "normal" clay are intercalated, start in the Lower Barremian with a discrete finely laminated horizon, the Hauptblätterton, which is the topic of this paper.

As the sedimentology, petrology and palaeontology of this Lower Barremian Hauptblätterton differ from that of the "normal" clay facies, different authors have worked on various aspects of this sediment. MICHAEL (1967, 1968, 1974) analysed the microfauna (foraminifera, ostracods); KEUPP (1979) described the calcispheres; KEMPER & ZIMMERLE (1978), GAIDA et al. (1981) examined the geochemistry and sediment petrology; MUTTERLOSE (1983) worked on a biostratigraphy based on belemnites.

The lamination is explained as an alteration of pale layers rich in coccoliths and dark layers rich in dinocysts (KEUPP & MICHAEL, 1979). The thickness of a single layer varies between 0,03–3 mm. Apart from a few scattered samples examined by MICHAEL (1964) and ČEPEK & KEMPER (1981) no thorough attempt has been made to analyse the microplankton (calcareous nannoplankton, dinocysts, miospores) from this horizon.

2. Material and Localities

The Blätterton facies is to be found not only in the Lower Saxony Basin, but also in the North Sea. Material has been examined from 11 different localities (compare Fig. 2).

a) Former clay pit Roklum / Mattierzoll
TK 25 Hessen, no. 3930,
re: 44 13 800, h: 57 70 470

This pit, which is now infilled, exposed (up to 1968) a section which ranged from the *discofalcatus*-zone (Upper Hauterivian) to the *brunsvicensis*-zone (lower Upper Barremian). This section lies to the east of the basin, where the thickness of the Hauptblätterton amounts to 17 m. According to MICHAEL (1967) and BENDER (1960) there occur 1–2 thin Blätterton layers (not exceeding 50 cm) below the Hauptblätterton, and at least 8–9 distinctive Blätterton layers varying between 10–50 cm in thickness above the Hauptblätterton.

Literature: The foraminifera have been examined by MICHAEL (1967, 1968), a lithic log and the biostratigraphy have been detailed by MUTTERLOSE (1983: 13).

b) Exploration well Konrad 101
TK 25 Lebenstedt Ost, no. 3828,
re: 35 97 115, h: 57 82 780.

From December 1984 – April 1985 an exploration well was drilled in the Salzgitter area. This well supplied cores of the Upper Cretaceous and of parts of the Lower Cretaceous from the Albian – Hauterivian. The Hauterivian rests with a hiatus on limestones of Tithonian age. The Barremian has a total thickness of about 85 m (depth 476,70–562,00 m), although there is a hiatus in the Upper Barremian. According to the core description, the Hauptblätterton has a thickness of about 6,40 m (depth 547,00–553,40 m) but after a reexamination of the cores the Hauptblätterton does seem to extend from depth 538,00–553,40 m having a thickness of 15,40 m. Above the Hauptblätterton several thin layers of Blätterton are described.

c) Shaft Konrad 1
TK Lebenstedt Ost, no. 3828,
re: 35 96 024, h: 57 84 271

This shaft was sunk between April 1958 and January 1960 in order to exploit Upper Jurassic iron ores. The Lower Cretaceous (Albian to Hauterivian), rests unconformably on Thithonian and consists of 570 m of mainly marly clays. The overall thickness of the Barremian is 136 m, that of the Hauptblätterton is 17 m, the lithologic description is not very detailed. Several thin Blätterton layers occur above the Hauptblätterton.

Literature: The foraminifera are described by MICHAEL (1967, 1968).

d) Refuse pit Hoheneggelsen
TK 25 Lesse, no. 3827,
re: 38 81 375, h: 57 85 475

This depository for chemical waste exposes a 63 m thick section of Upper Barremian sediments, including the upper part of the *brunsvicensis*-zone and *germanica*-zone. These beds contain 7 thin Blätterton layers in the Upper Barremian. The Hauptblätterton, which is known from wells, has a thickness of more than 20 m. It may be subdivided by intercalated "normal" clay.

Literature: Belemnite biostratigraphy in MUTTERLOSE (1983), lithology in MUTTERLOSE (1984).

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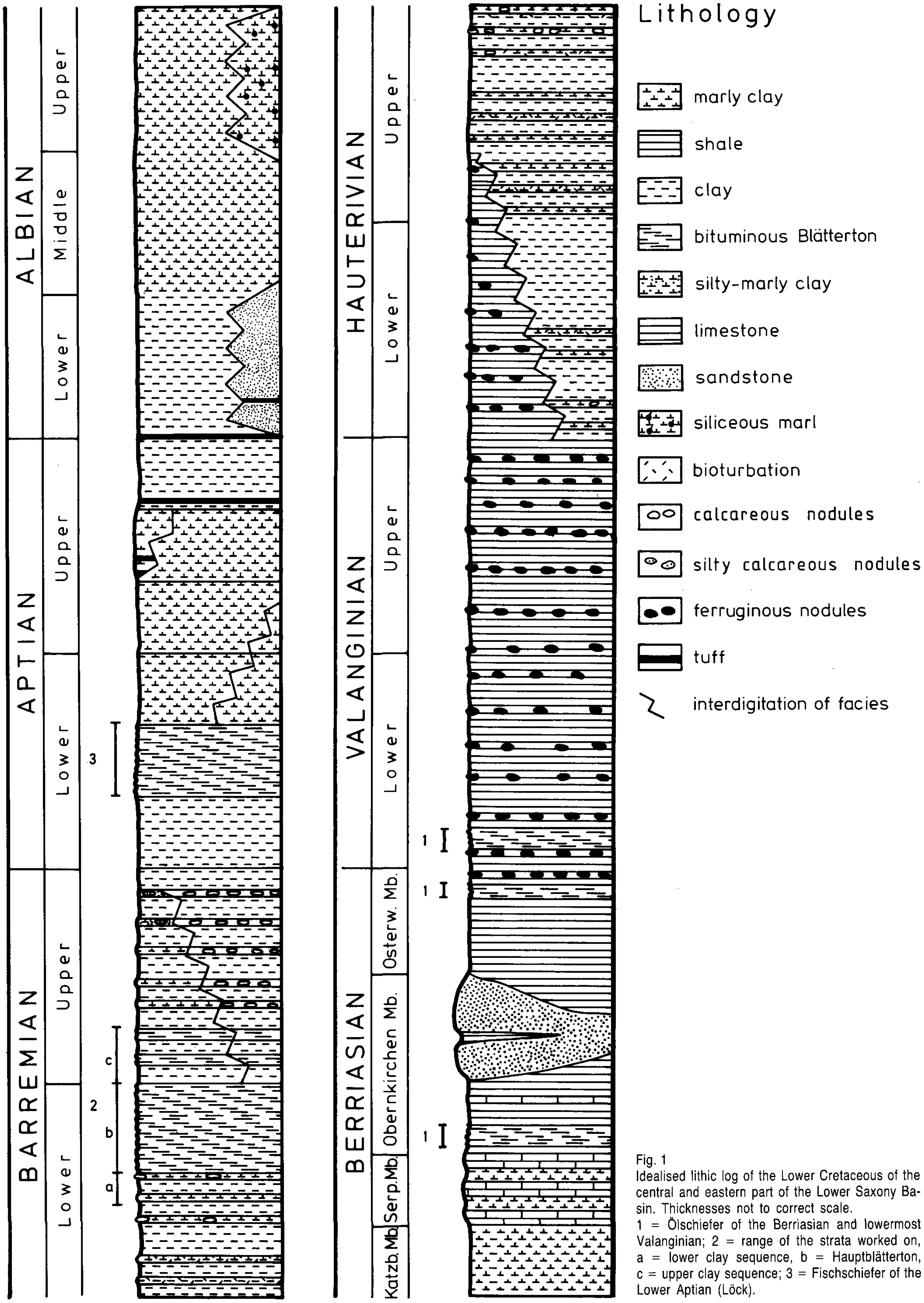

Fig. 1
Idealised lithic log of the Lower Cretaceous of the central and eastern part of the Lower Saxony Basin. Thicknesses not to correct scale.
1 = Ölschiefer of the Berriasian and lowermost Valanginian; 2 = range of the strata worked on, a = lower clay sequence, b = Hauptblätterton, c = upper clay sequence; 3 = Fischschiefer of the Lower Aptian (Löck).

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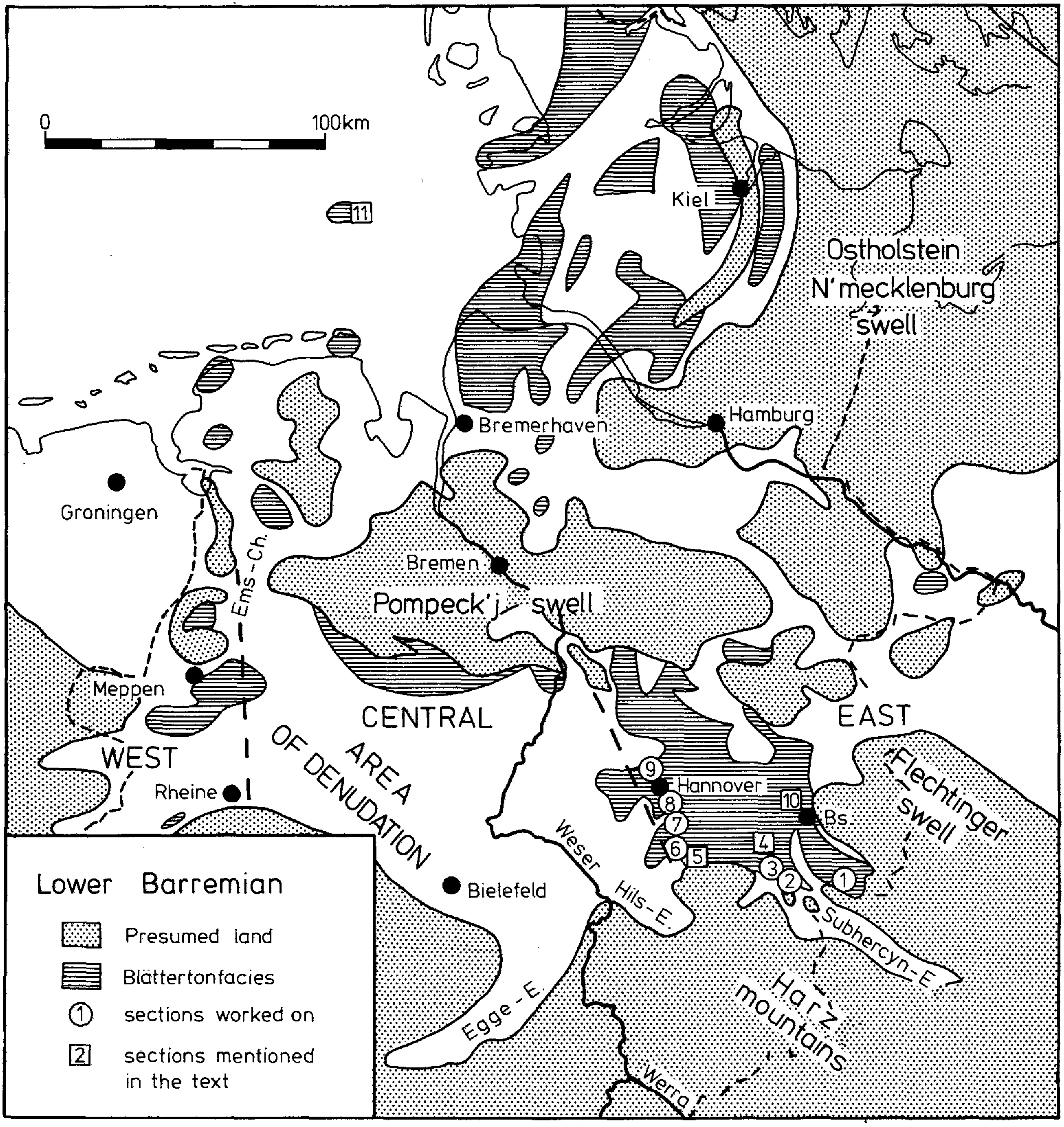

Fig. 2: Palaeogeographical map of the Lower Saxony Basin and the distribution of the Lower Barremian Blättertonfacies.
Ch = Channel, E = Embayment. The dark dotted lines mark the boundaries of the western, central and eastern parts of the basin localities: 1 = Roklum; 2 = well Konrad 101; 3 = shaft Konrad 1; 4 = Hoheneggelsen; 5 = Bockemeyer, Bergmann/Hildesheim; 6 = Moorberg/Sarstedt; 7 = Gott/Sarstedt; 8 = Aegi/Hannover; 9 = Letter; 10 = Wenden; 11 = Heligoland.

e) Former clay pits Bockemeyer, Bergmann/Hildesheim

TK 25 Hildesheim, no. 3825,
re: 35 66 275, h.: 57 81 912 (Bockemeyer)
TK 25 Hildesheim, no. 3825,
re: 35 66 175, h: 57 81 912 (Bergmann)

Unfortunately there is no exact data available from the many pits which worked Barremian clay at the beginning of this century. BRAHMS (1913) mentions a distinctive Blätterton bed of about 4 m thickness from the upper part of the *elegans*-zone, which is slightly younger than the Hauptblätterton discussed above. Belemnites with Blätterton matrix attached support the idea that this horizon is identical to the Hauptblätterton.

Literature: The fish fauna, which has mainly been found in the Hauptblätterton, has been described by BRAHMS (1913).

f) Refuse pit Moorberg/Sarstedt (Fig. 3)

TK 25 Sarstedt, no. 3725,
re: 35 59 880, h: 57 89 550

In this former clay pit, which is now filled in with refuse, strata of Barremian and Hauterivian age were worked. The Lower Barremian and Hauterivian have an

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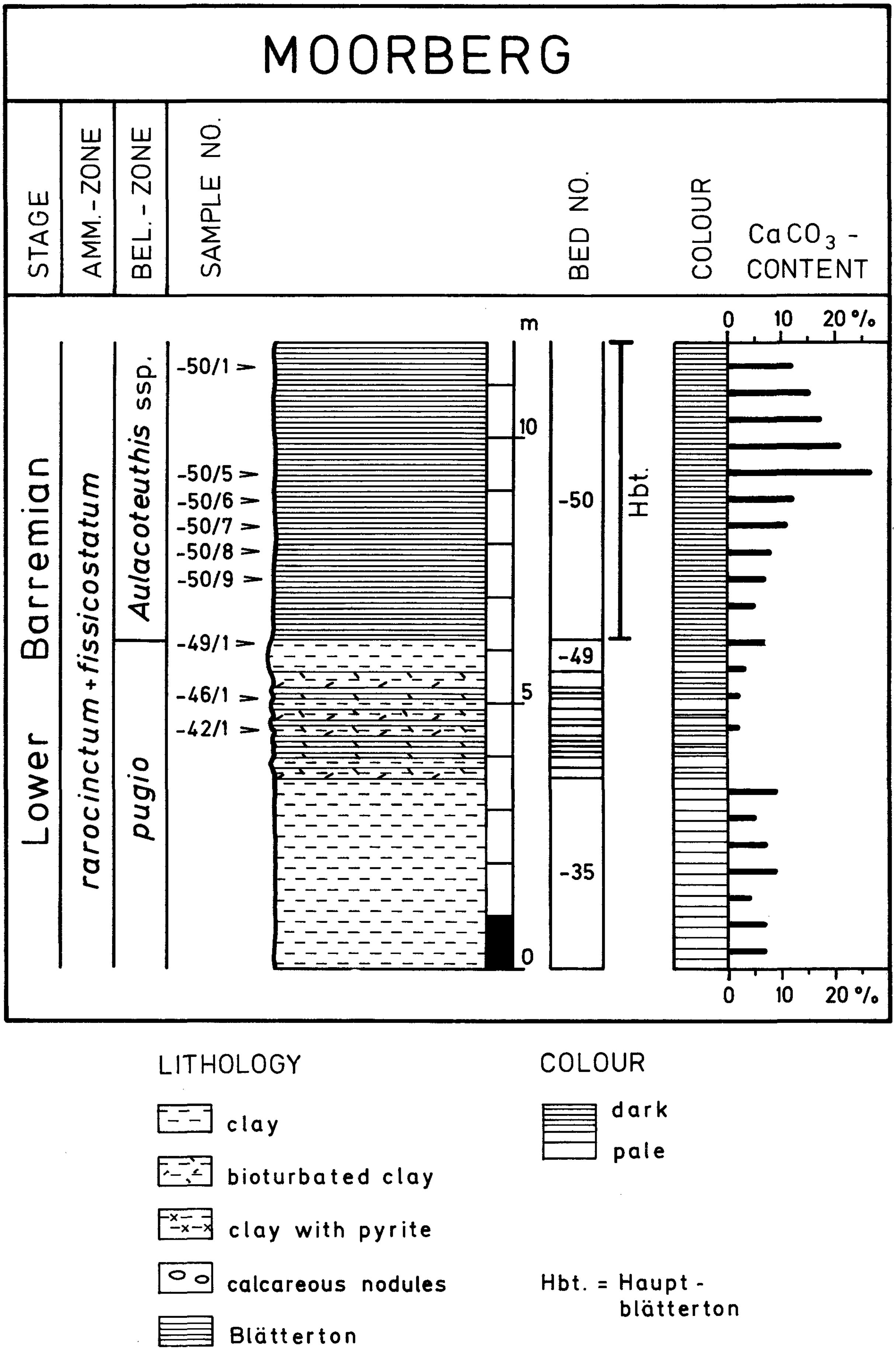

Fig. 3: Lithological log of the Moorberg section.
Hbt = Hauptblätterton. The sample numbers correspond to those examined for calcareous nannofossils (Tab. 1).

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overall thickness of 84 m, the sequence is reduced in thickness due to its position near the Hildesheim peninsula and the Sarstedt-Lehrter salt dome. The Hauptblätterton (exposed up to 1976) has a thickness of 5,6 m. The position of the samples is marked in Fig. 3.

Literature: Lithology described by MUTTERLOSE (1978, 1984), calcispheres by KEUPP & MICHAEL (1979), geochemistry in GAIDA et al. (1981).

g) Clay pit Gott/Sarstedt (Fig. 4)

TK 25 Sarstedt, no. 3725,
re: 35 60 400, h: 57 90 650

This is the only exposure of the Hauptblätterton which is still worked. The 74 m thick clay section is of Late Hauterivian, Barremian and Late Aptian age (*gottschei-depressa*-zone, *nutfieldiensis-nolani*-zone).

The Hauptblätterton is 5,6 m thick, no Blätterton layers occur below, but three thin layers are present above it (see Fig. 4).

Literature: The belemnite biostratigraphy and lithology are described by MUTTERLOSE (1983, 1984), the geochemistry by KEMPER & ZIMMERLE (1978), calcispheres by KEUPP & MICHAEL (1979).

h) Underground excavation Aegidientorplatz/Hannover (Fig. 5)

TK 25 Hannover, no. 3624,
re: 35 50 725, h: 58 04 225

In the course of the excavation for the underground railway in Hannover, about 28 m of sediments of Early and Late Barremian age (*Aulacoteuthis-brunsvicensis*-zone)

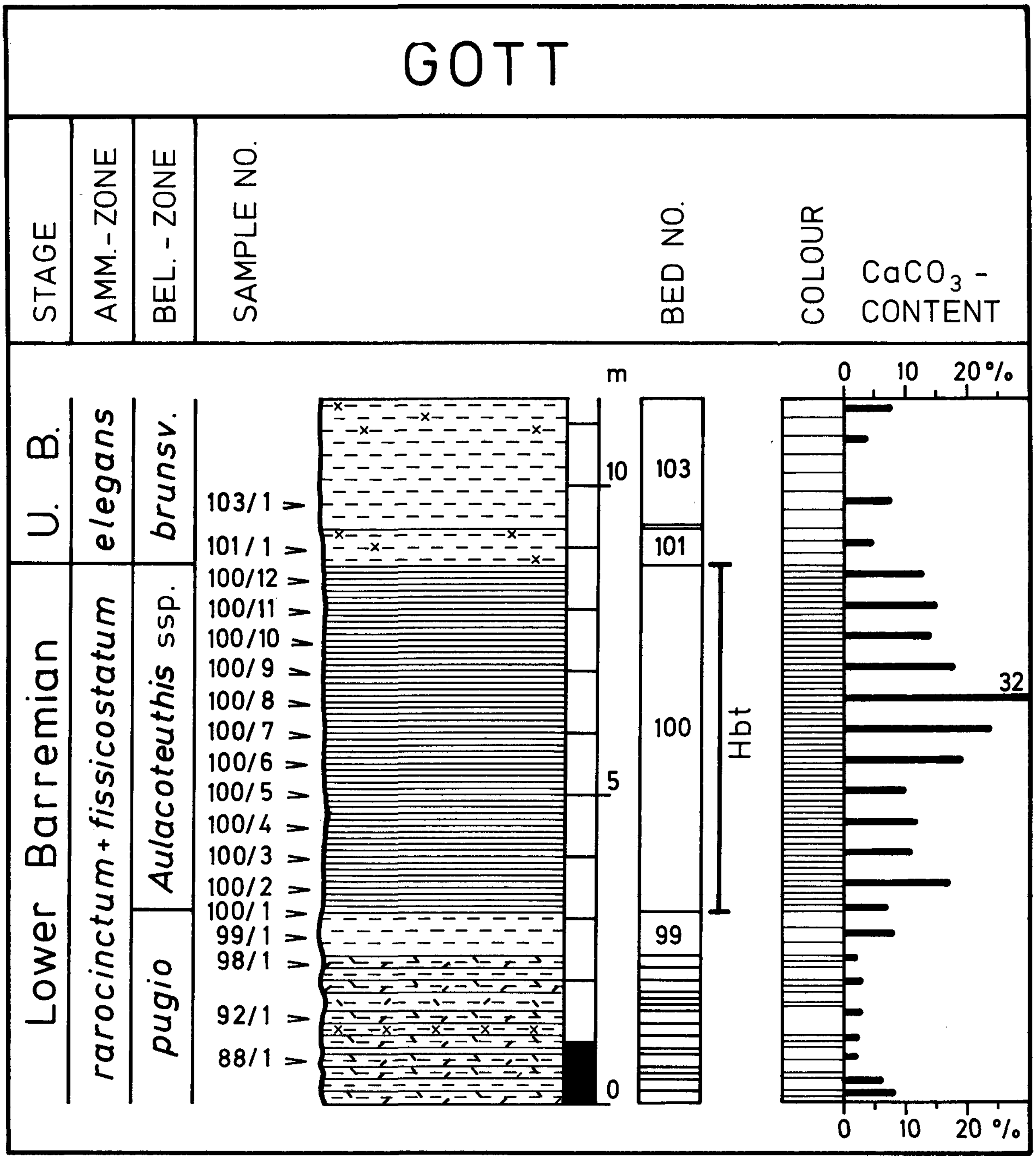

Fig. 4: Lithological log of the Gott section.
Hbt = Hauptblätterton. The sample numbers correspond to those examined for calcareous nannofossils (Tab. 2). For the legend see Fig. 3.

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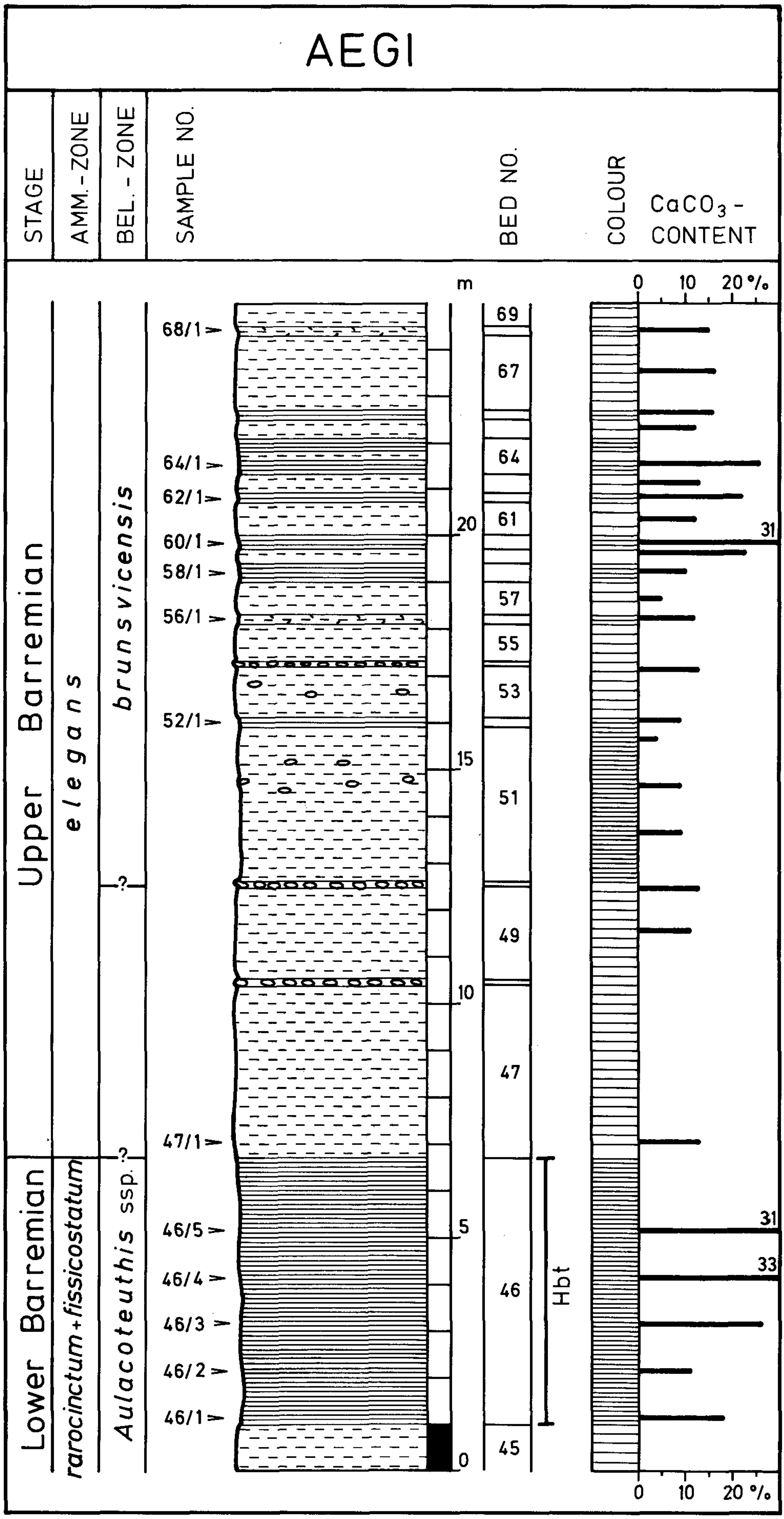

Fig. 5: Lithological log of the Aegi section.
Hbt = Hauptblätterton. The sample numbers correspond to those examined for calcareous nannofossils (Tab. 3). For the legend see Fig. 3.

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were measured in autumn 1977. The Hauptblätterton is about 5,70 m thick, 7 distinctive thin Blätterton layers occur above the Hauptblätterton (see Fig. 5).

Literature: The fauna has been discussed by IMMEL & MUTTERLOSE (1980), the calcispheres by KEUPP & MICHAEL (1979).

i) Ditch section, Letter (Fig. 6)

TK 25 Garbsen, no. 3532,
re: 35 44 250, h: 58 08 275

In autumn 1979, 8 m of Lower Barremian clays were exposed in a temporary ditch section, of which the Hauptblätterton comprised half (see Fig. 6).

Literature: Belemnites and biostratigraphy in MUTTERLOSE (1983).

j) Canal section Wenden

TK 25 Braunschweig Nord, no. 3629,
re: 43 99 425, h: 58 01 675 to
re: 44 00 325, h: 58 02 475

The Mittellandkanal was excavated between 1927 and 1933 exposing Barremian sediments of 150 m thickness, including about 6,60 m of Hauptblätterton. KUMM (1936) recognised more than 22 thin Blätterton layers above and at least one below the Hauptblätterton.

Literature: Lithology and biostratigraphy discussed by KUMM (1936).

k) Heligoland

Scuba divers collected material of Early Cretaceous age east of Heligoland from the "Skit Gatt" on the sea bed. According to the belemnites preserved with Blätterton matrix, the *Aulacoteuthis*-zone is developed in the Blätterton facies. Apart from the Hauptblätterton, several thinner Blätterton layers, each of which is separated by 2–3 m of clay, may be differentiated above the Hauptblätterton (personal communication H. H. STÜHMER).

3. Biostratigraphy and Palaeogeography of the Hauptblätterton

3.1. Biostratigraphy

The established stratigraphic zonation of the Barremian is based on either ammonites or belemnites. The

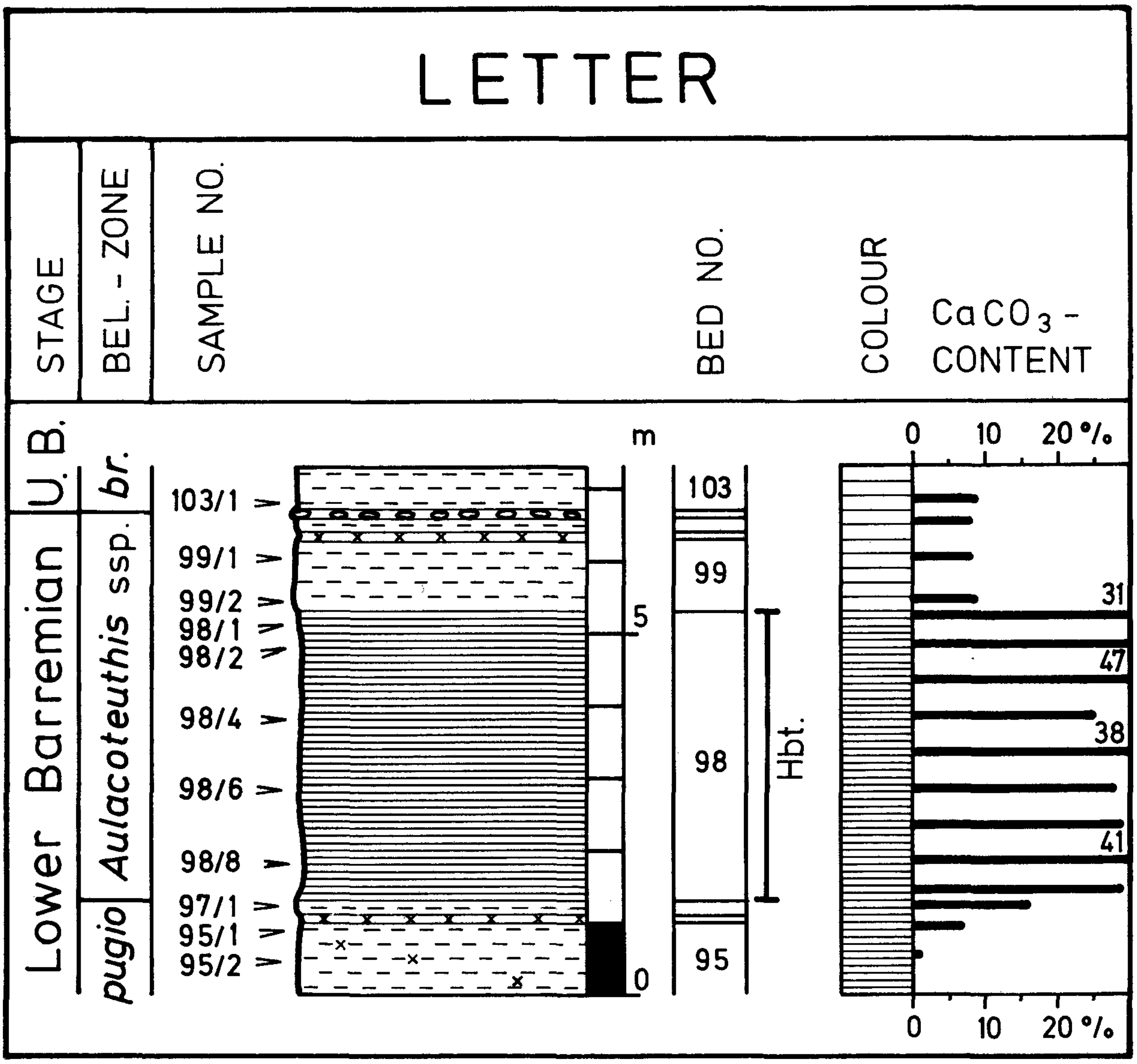

Fig. 6: Lithological log of the Letter section.
Hbt = Hauptblätterton. The sample numbers correspond to those examined for calcareous nannofossils (Tab. 4). For the legend see Fig. 3.

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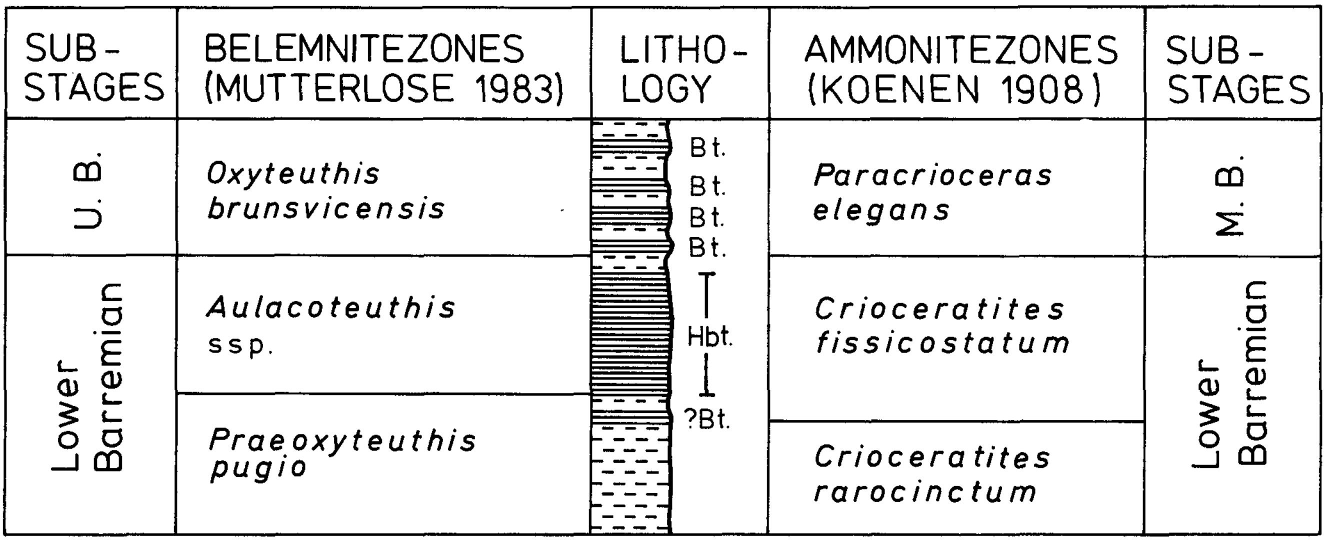

Fig. 7: Biostratigraphy of the Lower and lower Upper Barremian in NW-Germany.
Hbt = Hauptblätterton.

ammonite succession was worked out basically by Koenen (1908), however most of the material was not collected bed by bed. According to Immel (1978, 1979), Immel & Mutterlose (1980) and Mutterlose's own bed by bed collections of recent years, *Crioceratites elegans* (Koenen) and *C. (C.) roeveri* (Koenen) have been found just above the Hauptblätterton in various sections (Moorberg, Gott, Konrad 1). Although crioceratitid ammonites have been noticed in the Hauptblätterton no data at the species level is available due to their poor preservation. A zonal scheme is given in Fig. 7.

Belemnites are much more abundant in these beds and a detailed zonation has been suggested by Mutterlose (1983). The Hauptblätterton is characterised by the genus *Aulacoteuthis* Stolley which is part of an evolutionary lineage. Several species of *Aulacoteuthis* can be distinguished which render an even more detailed biostratigraphic subdivision of the Hauptblätterton. A range chart has been compiled (see Fig. 8). Material from Heligoland, Konrad 101, Hildesheim and Wenden have confirmed that the genus *Aulacoteuthis* is mainly restricted to the Hauptblätterton. Specimens from Heligoland still embedded in the Blätterton matrix have been referred to *Praeoxyteuthis* (Stolley) and *Aulacoteuthis descendens* Stolley, both of which occur in the Hauptblätterton.

Belemnites from Konrad 101 show a similar distribution pattern: the upper part of the Hauptblätterton (538–541,50 m) has yielded *Aulacoteuthis compressa* Mutterlose and *A. descendens* Stolley, the clay immediately above *Oxyteuthis pseudogermanica* Mutterlose (537,03 m) and *Oxyteuthis brunsvicensis* Stolley (531,90 m). Brahms (1913) described the fish fauna of the old pits near Hildesheim and mentions a Blätterton layer 4 m thick from the upper part of the *elegans*-zone (*C. elegans, C. roeveri*). There are also belemnites with an adherent Blätterton matrix known from these pits. These are referred to *Praeoxyteuthis pugio* (Stolley) and support the idea of the Hauptblätterton being of late Lower Barremian age.

Kumm (1936) found *Praeoxyteuthis pugio* in the lower 2,7 m of the Hauptblätterton and *A. speetonensis* (Pavlow), *A. absolutiformis* (Sinzow) and *A. descendens* Stolley in the upper 4 m of the Hauptblätterton from Wenden. According to this data the Hauptblätterton is probably a synchronous sediment of late Lower Barremian age.

Further thinner Blätterton layers are known from the Upper Barremian (sensu Mutterlose 1983). The youngest Blätterton layers are known from the *germanica*-zone of Hoheneggelsen. Kumm (1936) proved these to belong to the *depressa*-zone of the uppermost Barremian. The thickness of these Blätterton layers varies between 10 cm–1 m, often not exceeding 30 cm. The number of layers differs from exposure to exposure: seven in Roklum, eight in Hoheneggelsen, three in Gott, ten in the Aegidientor section and at least twenty-four in Wenden.

The only thin Blätterton layers known from below the Hauptblätterton are described by Kumm (1936) from Wenden. One 10 cm thick horizon occurs 1,90 m below the Hauptblätterton, with more layers further down.

Another Blätterton layer about 4,50 m below the Hauptblätterton is quoted by Bender (1960).

In the following text the thick *Aulacoteuthis*-bearing Blätterton is referred to as the Hauptblätterton. A two-fold division of the Barremian (into Lower Barremian and Upper Barremian) is used.

3.2. Palaeogeography

The Lower Saxony Basin formed a relatively narrow, elongated subsiding basin, extending about 280 km in an E–W and 80 km in a N–S direction. This basin was bordered in the south by the Rhenanian massif, in the north by an uplift, the Pompeckj' swell, and in the west by the East Netherland Triassic High. Narrow marine connections existed with the neighbouring basins in Valanginian – Hauterivian time: towards the east via the Polish–Danish Basin and towards the north via three straits in the Pompeckj's archipelago. Due to a regression in the Early Barremian the palaeogeographical conditions changed considerably, only the northern seaways remained open. Thus it became a restricted embayment of the North Sea Basin. These conditions changed in the late Lower Aptian when the Pompeckj' swell became submerged. According to the palaeogeographical reconstructions the Blätterton

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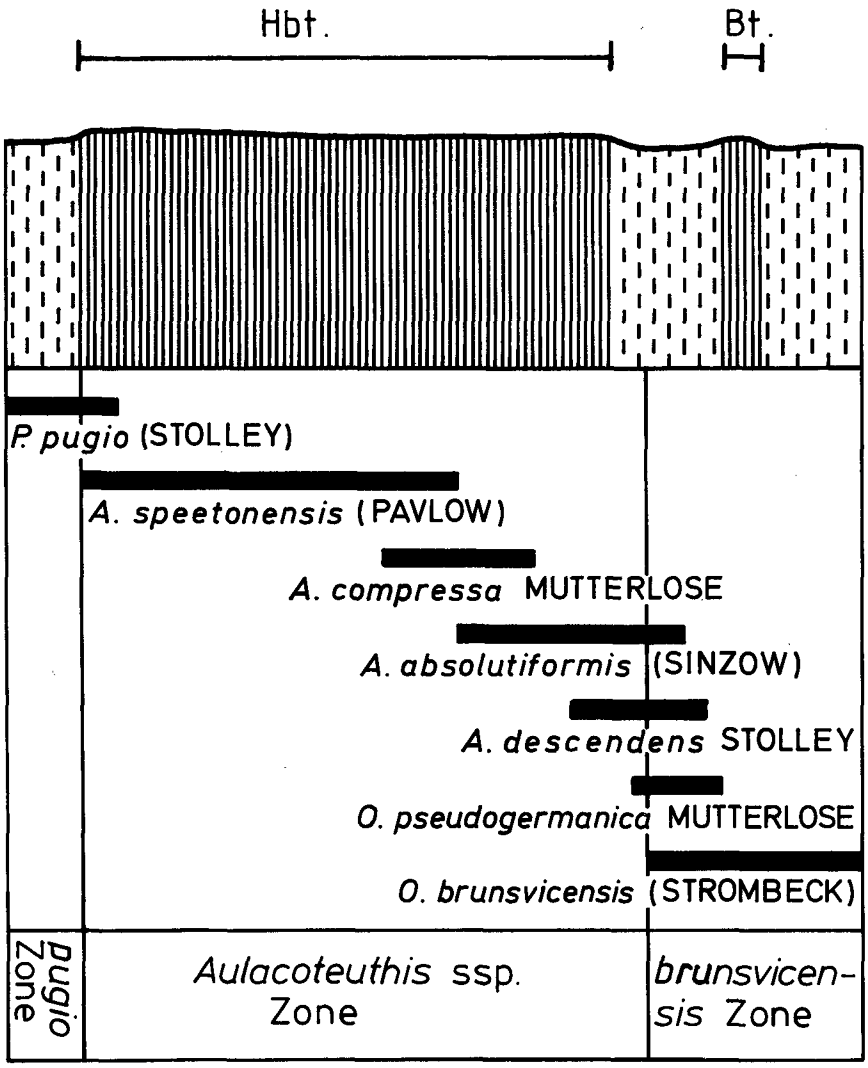

Fig. 8: Ranges of various species of the Oxytheuthidae in the Hauptblätterton of NW-Germany.
Hbt = Hauptblätterton; Bt = Blätterton.

facies seems to represent a regressive phase. The greatest thickness of the Hauptblätterton is to be found in the area furthest from the northern seaways, in the eastern part of the basin (see Fig. 2).

The Barremian Blätterton facies however, is not only known from the NW-German Lower Cretaceous basin, but also from the North Sea (West Netherlands Basin, Broad Fourteen Basin, Central Graben, Norwegian Danish Basin) and comparable sediments have been described by RAWSON & MUTTERLOSE (1983) from Speeton (NE England). No detailed biostratigraphic or lithologic information is available for the North Sea deposits, except for those of Speeton, where the Lower Cretacous outcrops along the coast. About 7,5 m (beds LB1F–LB1A) of the Lower B and Basal Cement Beds (*pugio*- and lower *germanica*-zone, Lower and lower Upper Barremian) are represented by laminated shales, which contain silty streaks. The more argillaceous laminae are rich in finely disseminated plant debris. According to the belemnites these cycles occur at the identical biostratigraphic level (*Aulacoteuthis*-zone) of the Hauptblätterton. Possibly these laminated shales represent the marginal facies of the Hauptblätterton.

Within NW-Germany the Hauptblätterton is up to now known from the eastern and western parts of the basin and from Heligoland, while the central part of the basin lacks Barremian sediments due to erosion. In contrast to recent views, the Emsland Hauptblätterton is found at the same stratigraphic level of the Lower Barremian as the Hauptblätterton deposits elsewhere in Germany. The Hauptblätterton in this area has a thickness of about 10 m (ELSTNER, personal communication), shows the same rich fish fauna, is barren of benthic foraminifera and the beds above are rich in pyrite (see Fig. 2). In the Brechte Mulde the Hauptblätterton is replaced by a clay-siltstone containing silt lenses, interpreted by KEMPER (1976: 144) as a tempestite.

4. Sedimentology and Petrology

The petrology and geochemistry of the Hauptblätterton has been described by KEMPER & ZIMMERLE (1978) and GAIDA et al. (1981). As these results are based on a few samples, additional material, collected bed by bed, has been examined with respect to mineralogy, geochemistry and sedimentology.

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Macroscopically the Hauptblätterton is finely laminated, consisting of pale and dark laminae, the thickness of which varies between 0,03–3 mm.

According to MICHAEL (1974: 35) the dark clay laminae are enriched in dinocysts, while the pale layers contain abundant coccoliths. Thin sections of the Hauptblätterton from Gott, Roklum and Hoheneggelsen were prepared in the bedding plane and perpendicular to it. The thin sections clearly showed that the pale laminae are often in the form of microlenses about 0,25 mm long and 0,15 mm thick. The carbonate microlenses are composed of coccoliths, representing an incipient chalk facies.

No bioturbation has been observed in the Hauptblätterton, but the ichnogenus *Chondrites* is quite common in the thin Blätterton layers in the Upper Barremian. The lack of bioturbation in the Hauptblätterton may be explained by anoxic or kenoxic conditions prevailing at the sea bed, there being no benthic fauna. When these conditions changed endobenthic organisms returned and the thin Blätterton layers especially rich in organic material were then heavily bioturbated (e. g. by *Chondrites*).

Carbonate analysis (titration) of the sections (see Figs. 3–6) clearly show that the beds below and above the Hauptblätterton, here referred to as the lower and upper clay sequences, are rather poor in calcium carbonate, while the Hauptblätterton contains a higher proportion, varying between 10–30 %.

The petrographic analysis of 4 thin sections from the Gott section (100/1, 100/2, 100/7, 100/12) gave results as follows: grains of pyrite and brown haematite are embedded in bituminous clay ±calcitic matrix, with quartz grains up to 100 µm diameter making up to 5 % by volume of the samples. Further minerals noticed in the slides are plagioclase (rare), glauconite, light mica (very rare) and occasionally heavy minerals. The pores have been filled with diagenetic chlorite (very rare), chalcedony and orthoclase (crystals up to 200 µm in diameter). Apart from pyrite, the following heavy minerals have been observed: zircon (rare), tourmaline (rare), rutile (very rare), garnet and staurolite. The overall amount of the heavy minerals is too small to differentiate between the samples or to speculate about the source area.

It is unusual for such large clastic quartz grains to be present in such a lithology as that of the Hauptblätterton.

The following samples from the Gott section have been studied using x-ray radiograms: 89/1, 99/1, 100/1, 100/4, 100/7, 100/8, 101/1, 103/1. The samples from the lower and upper clay sequences contain pyrite, gypsum and calcite, the proportions of these three minerals being greater in the Hauptblätterton, (calcite especially so). The proportions of the clay minerals montmorillonite/illite and kaolin do not vary significantly throughout the samples. According to the petrology the lower clay sequence/Hauptblätterton boundary is sharp, the Hauptblätterton/upper clay sequence boundary is not so well defined.

The amount of organic carbon incorporated in the sediment is increased in the Hauptblätterton:

Gott 98/1 – C org 1,80 %,
Gott 100/1 – C org 3,87 %,
Gott 100/5 – C org 3,79 %,
Gott 100/12 – C org 2,99 %.

5. The Fauna of the Hauptblätterton

5.1. Macrofauna

The macrofauna consists mainly of nektonic groups such as ammonites, belemnites, teuthids, fishes, reptiles, while benthic forms are very rare. BRAHMS (1913: 15) however mentions some bivalves, *Pecten, Anomia, Nucula, Avicula, Lucina* and the gastropod *Aphorrhais* from the *elegans*-Blätterton of Hildesheim.

In the Hauptblätterton of the Gott section tiny thin-shelled *Pecten* occur along with *Orbiculoidea* d'ORBIGNY which is supposed to be pseudoplanktonic (SEILACHER, 1982).

Nektonic organisms dominate the faunas, which consist mainly of belemnites and fish remains. Specimens of the genus *Aulacoteuthis* are most abundant, the only Lower Cretaceous belemnites found up to now with a well preserved phragmocone. A private collector recently found a teuthid gladius at Gott displaying a similar excellent state of preservation to that of these *Aulacoteuthis* specimens. Coleoids in a similar mode of preservation are only known from the Fischschiefer (Lower Aptian).

These findings indicate a lack of benthic life and a lack of water movement so allowing preservation of these delicate parts. The same conditions favoured the preservation of reptiles and fishes which are very common in these beds (BRAHMS, 1913), whilst ammonites occur only occasionally. Driftwood is also common, as are well preserved fern leaves which are believed to be derived from the nearby Hildesheim peninsula.

5.2. Microfauna

The foraminifera and ostracods of the Hauptblätterton have been analysed by MICHAEL (1967, 1968). The diversity and number of individuals of benthic forms is very small in these beds, according to MICHAEL (1967: 131) never more than 10 species occur in one sample.

Apart from 2–3 agglutinated species (e. g. *Trochammina, Ammodiscus*), very tiny, thin-shelled calcareous species are known, which are independent of facies control. The same observations have been made by ELSTNER (pers. communication) in the Hauptblätterton of the Emsland. The occurrence of *Lagena* cf. *hexagona* is interesting, as it is only known from the Polish Upper Cretaceous and the Gulf of Naples. Possibly this Tethyan species indicates a warm water influence in NW-Germany.

6. Coccoliths

6.1. Methods and sample preparation

For the examination of the calcareous nannoplankton under the light microscope, grains have been prepared according to the method described by HAY (1965) und ČEPEK (1981). The evaluation of the samples was carried out under a ZEISS polarising microscope, for each sample 300 determinable individuals or a maximum of 200 view fields were counted. Some of the samples were investigated under a scanning electron microscope. In addition, 34 thin sections were examined

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under the light microscope and also using the S. E. M. because of their content and distribution of coccoliths.

6.2. Biostratigraphy

Various authors working in different areas have proposed nannoplankton zonations for the uppermost Hauterivian and the Lower Barremian (ROTH, 1973; BUKRY, 1974; THIERSTEIN, 1973, 1974; SISSINGH, 1977; PERCH-NIELSEN, 1979; TAYLOR, 1982). In the Boreal realm, the zonal index fossil *Nannoconus abundans* STRADNER & GRÜN, appears in the *variabilis*-zone (uppermost Hauterivian) of Speeton (TAYLOR, 1982: 50). Another important index fossil for this interval may be *Nannoconus borealis* PERCH-NIELSEN up to now only described from the Barremian of Speeton by PERCH-NIELSEN (1979: 266) and of the Lower Aptian (?) of SW-France (DERES & ACHÉRITÉGUY, 1980). In the Tethys the extinction of *Calcicalathina oblongata* (WORSLEY) and *Microrhabdulus bollii* THIERSTEIN are used to define the top of the *Microrhabdulus bollii*-zone, both species are however uncommon in the Boreal realm. Apart form these, several species of nannoconids may be used for biostratigraphy in the Tethys (DERES & ACHÉRITÉGUY, 1980).

As nearly all the sections studied have yielded *Nannoconus abundans* throughout, they can be assigned to the *N. abundans*-zone (compare Tab. 1–4). In NW-Germany *N. abundans* first appears in the *discofalcatus*-zone of late Hauterivian age, but becomes scarce above the Hauptblätterton. The top of the *N. abundans*-zone has still to be defined for NW-Germany. Most of the other nannoconids (*N. globulus* BRÖNNIMANN, *N. elongatus* KAMPTNER, *N. kamptneri* BRÖNNIMANN) are long ranging species (Tithonian – Barremian, Barremian – Santonian, Valanginian – Lower Aptian) typical of the Tethyan realm. *N. borealis* is only known from the Barremian of Speeton and the Lower Aptian (?) of SW France. Unfortunately the first occurrence is not exactly dated at Speeton. PERCH-NIELSEN (1979: 167) described specimens from the Middle B-beds (MB); these beds (above the Lower B-beds) are rarely exposed at Speeton and there is evidence of bedding plane slip. According to RAWSON & MUTTERLOSE (1983), who described the lower part of the MB-beds, these should be placed in the *brunsvicensis*-zone (Upper Barremian). The range for *N. borealis* has to be extended into the Lower Barremian, but as it has not yet been found further down in the lowermost Barremian or in the uppermost Hauterivian (MUTTERLOSE in prep.) it might turn out in future to be a good marker species, starting in the *Aulacoteuthis*-zone, possibly extending into the Upper Barremian.

The record of *Diadorhombus rectus* WORSLEY from the Blätterton of the Aegidientorplatz section is important (Tab. 3). *D. rectus* was previously thought to be restricted to the Valanginian of the Tethys (THIERSTEIN, 1976: 338). There are no records of this species from Speeton. *Lithastrinus septentrionalis*, which has been found in most samples, is probably another good marker species, possibly restricted to the Lower Barremian, for it has not been found further down in the uppermost Hauterivian.

6.3. Floral distribution

For the discussion of the floral distribution and its dependancy on the lithology, the logs are divided into 3 sections: a lower clay sequence, the Hauptblätterton and an upper clay sequence. The following abbreviations are used:

A = Aegidientorplatz section,
G = Gott section,
L = Letter section,
M = Moorberg section,
n =number of samples examined.

The number of individuals of a family are expressed as percentages of the whole population.

6.3.1. The Lower Clay Sequence

Samples from the lower clay sequence are only available from Letter (n = 3), Gott (n = 3) and Moorberg (n = 3), see Figs 3, 4, 6. These three sections are similar in that the samples just below the Hauptblätterton show very poor preservation, specimens are normally etched and often no coccoliths have been found at all: Letter (Tab. 4) and Moorberg (sample no. 42/1, Tab. 1). The samples yielding calcareous nannoplankton show a very impoverished flora in comparison to the Hauptblätterton. In the Gott section no specimens of the Podorhabdaceae, the Braarudosphaeraceae and Lithastrinaceae have been found and in the Moorberg section in addition to these the Biscutaceae, the Sollasitaceae, the Nannoconaceae and the Microrhabdulaceae are missing (see Figs. 9,10,12). The last three families are reduced in number in Gott and only to be found in one sample out of three, each family making up to 1 % of the total assemblage. However, in both sections the Ellipsagelosphaeraceae (G: 35–39 %, M: 80 %), the Zygolithaceae (G: 13–24 %, M: 17 %) and the Retecapsaceae (G: 2–4 %, M: 2 %) are common. Within the Ellipsagelosphaeraceae, *Watznaueria barnesea* BLACK is by far the dominant species, making up to 56 % (G 92/1), 21 % (G 98/1) and 70 % (M 49/1) of the total floral content.

The whole floral composition suggests a highly corrosive environment, those families which were not very solution-resistant were removed by dissolution and hence the flora appears depleted of these forms. The flora appears to be dominated by those families, e. g. Ellipsagelosphaeraceae, which are more resistant. According to ROTH & KRUMBACH (in press) coccolith assemblages in which *W. barnesae* makes up more than 40 % of the total amount have undergone dissolution.

6.3.2. The Hauptblätterton

A different number of samples have been examined from the various localities, Aegidientorplatz (n = 5), Letter (n = 5), Gott (n = 12), Moorberg (n = 6), although the thickness of all sections is about the same.

In general in all sections the state of preservation is much better than in the lower clay sequence. The etching is less and all the samples contain enough material for a statistical evaluation. All sections yielded a rich flora including the families Ellipsagelosphaeraceae, Zygolithaceae, Retecapsaceae, Podorhabdaceae, Biscutaceae, Stephanolithiaceae, Braarudosphaeraceae, Lithastrinaceae, Sollasitaceae, Nannoconaceae and Microrhabdulaceae, some of which were missing from the lower clay sequence (see Figs. 9–12). These families can be arranged in three groups according to their distribution patterns.

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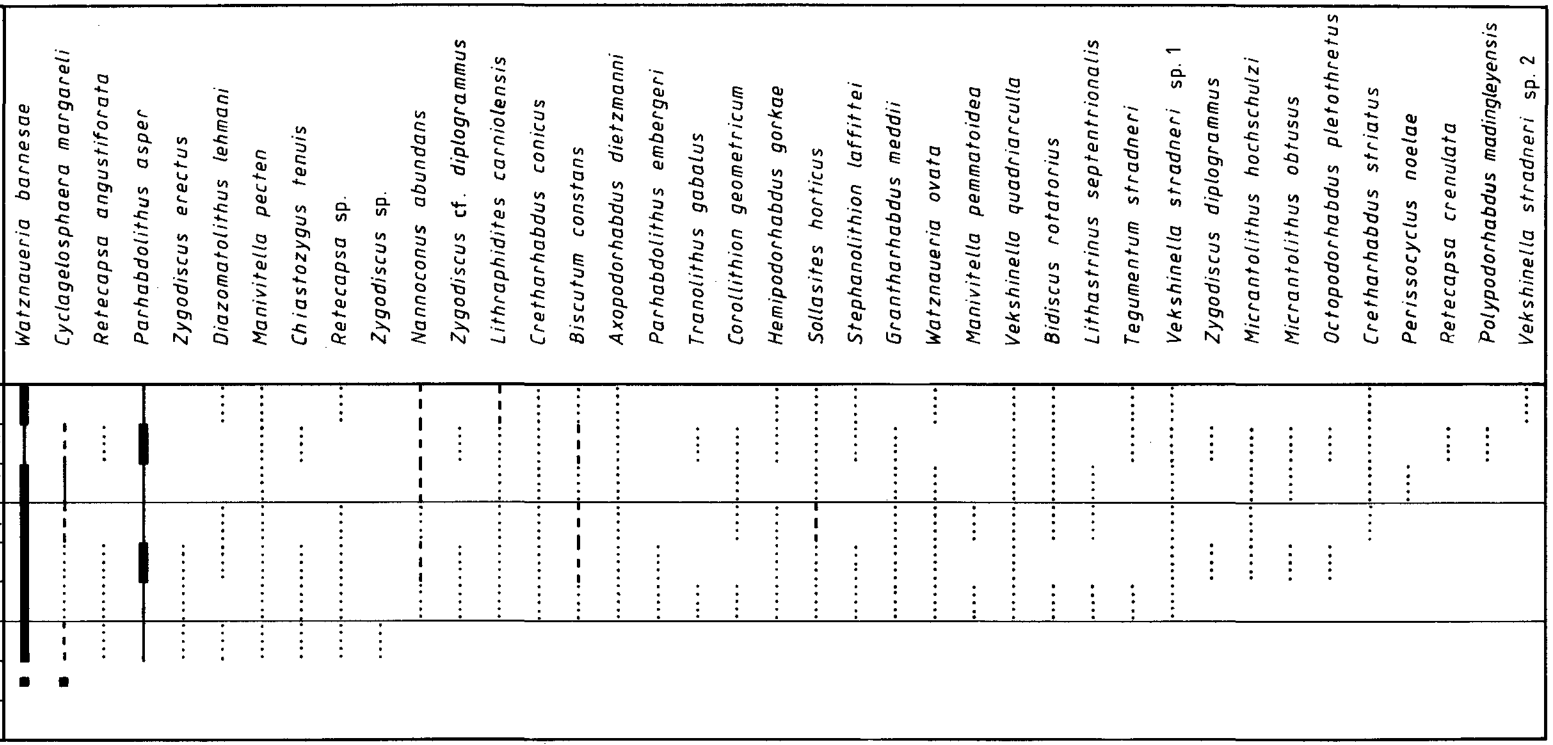
Table 1: Ranges of calcareous nannofossils for the Moorberg section.
For the exact position of the samples see Fig. 3.

MOORBG.

Lithology	Preservation	Number of species	Sample number	Individuals (i)	Sight (f)	ratio i/f	ratio i/mm2
Hauptblätterton	+	20	-50/1	326	45	7,2	51,7
	+	30	-50/5	334	50	6,7	47,7
	+	21	-50/6	327	35	9,3	66,7
	-	22	-50/7	326	104	3,1	22,4
	-	26	-50/8	324	35	9,3	66
	-	27	-50/9	330	21	15,7	112
	-	8	-49/1	173	210	0,8	5,9
		2	-46/1	23	220		
		0	-42/1	0	217		



Samples containing more than 30 specimens: ···· ≤ 4,9 % - - - ≤ 9,9 % —— ≤ 29,9 % ▬ > 30 %, otherwise ■ present

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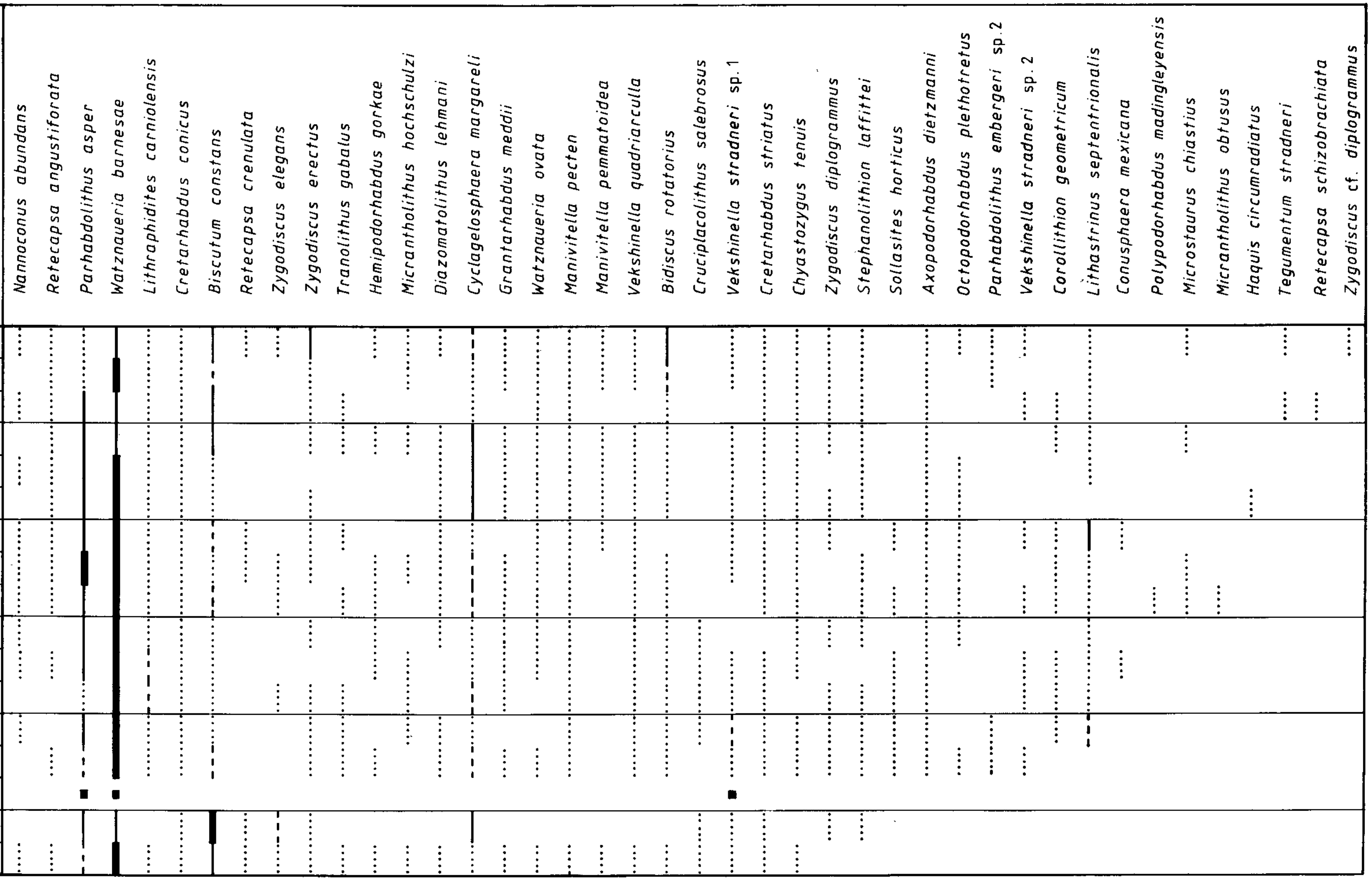
Table 2: Ranges of calcareous nannofossils for the Gott section.
For the exact position of the samples see Fig. 4.

Lithology	Preservation	Number of species	Sample number	Individuals (i)	Sight (f)	Ratio i / f	Ratio i / mm²
	+	33	103/1	323	21	15,4	109,9
	±	23	101/1	331	112	3,0	21,1
Hauptblätterton	±	23	100/12	316	95	3,3	23,8
	+	27	100/11	349	40	8,3	62,3
	+	22	100/10	354	35	10,1	72,2
	+	23	100/9	307	48	6,4	45,7
	+	27	100/8	300	41	7,3	52,3
	+	28	100/7	315	13	23,6	168,7
	+	29	100/6	306	70	4,4	31,2
	±	22	100/5	314	110	2,9	20,4
	±	25	100/4	312	150	2,1	14,9
	±	24	100/3	294	200	1,5	10,5
	+	25	100/2	310	65	4,8	34,1
	±	26	100/1	339	85	4,0	28,5
		3	99/1	10	200		
	-	12	98/1	105	233	0,5	3,8
	-	25	92/1	333	211	1,6	11,3



Samples containing more than 30 specimens: ...... ≤ 4,9% --- ≤ 9,9% —— ≤ 29,9% ▬ > 30%, otherwise ■ present

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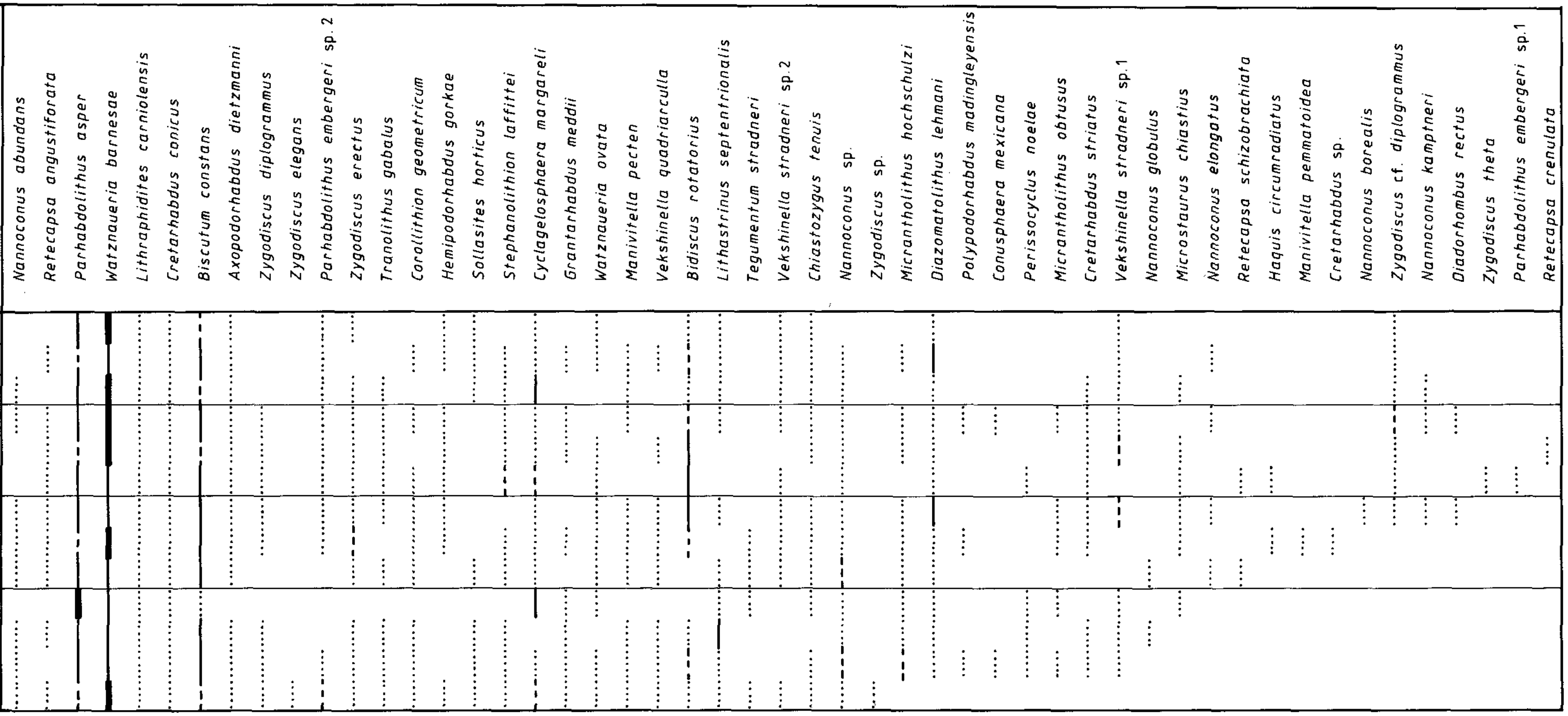
Table 3: Ranges of calcareous nannofossils for the Aegi section.
For the exact position of the samples see Fig. 5.

AEGI Lithology	Preservation	Number of species	Sample number	Individuals (i) / Sight (f)	Ratio i/f	Ratio i/mm²
	±	19	68/1	326 / 40	8,2	58,2
Bt.	+	26	64/1	326 / 16	20,4	145,5
Bt.	+	24	62/1	326 / 15	21,7	155,2
Bt.	+	33	60/1	353 / 12	29,4	210
Bt.	±	26	58/1	334 / 45	7,4	53
	+	27	56/1	346 / 13	26,6	190
Bt.	+	33	52/1	344 / 25	13,8	98
	+	32	47/1	340 / 10	34	243
Hauptblätterton	+	26	46/5	340 / 47	7,2	51,7
	+	16	46/4	344 / 35	9,8	70,2
	+	25	46/3	322 / 52	6,2	44,2
	+	30	46/2	325 / 36	9,0	64,5
		27	46/1	364 / 50	7,3	52



Samples containing more than 30 specimens: ⋯⋯ ≤ 4,9% - - - ≤ 9,9% —— ≤ 29,9% ▬ > 30%, otherwise ■ present

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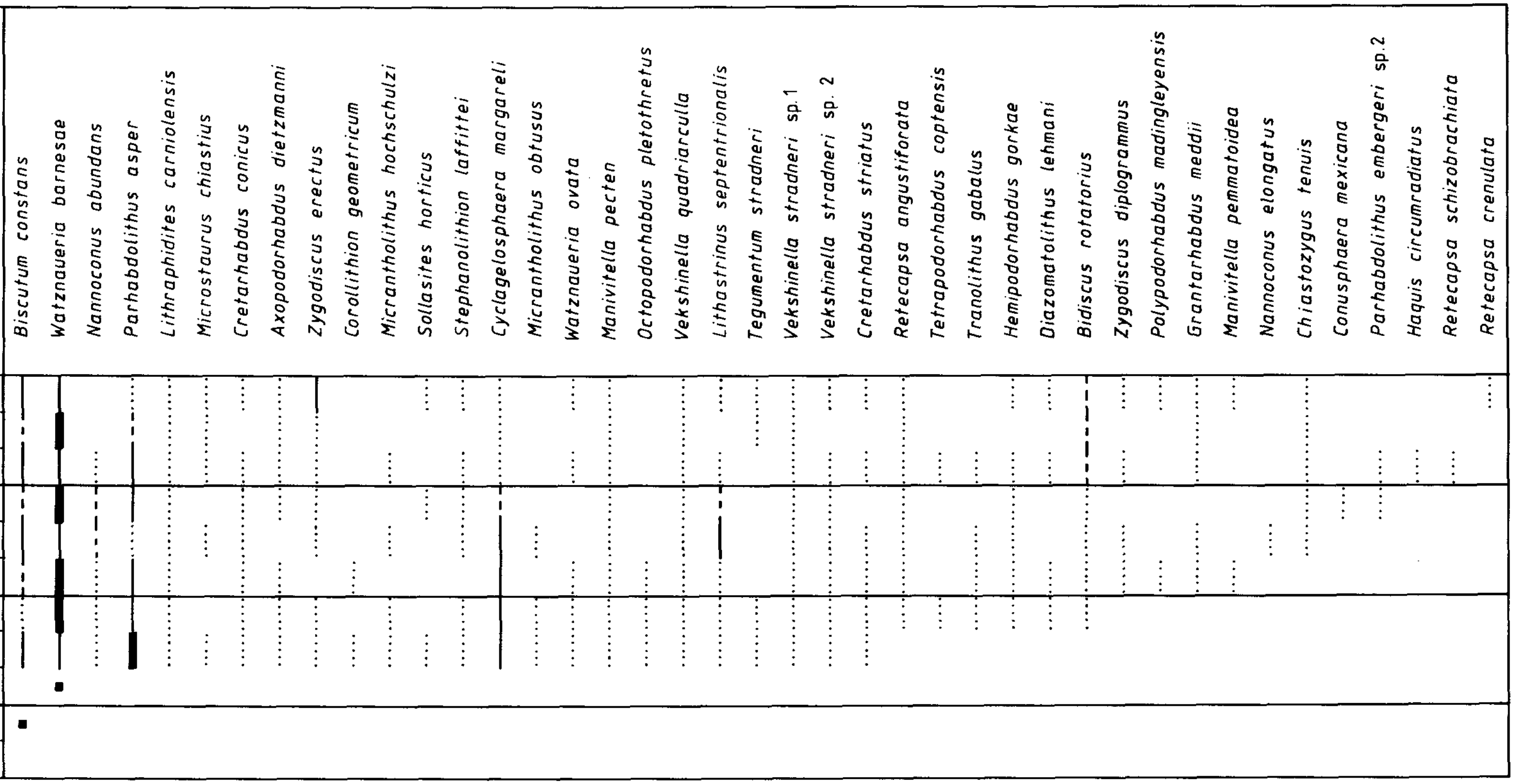
Table 4: Ranges of calcareous nannofossils for the Letter section.
For the exact position of the samples see Fig. 6.

LETTER Lithology	Preservation	Number of species	Sample number	Individuals (i)	Sight (f)	ratio i/f	ratio i/mm2
	±	29	103/1	312	21	14,9	106,1
	-	16	99/1	302	80	3,8	27
	+	31	99/2	328	47	7,0	49,8
Hauptblätterton	±	22	98/1	317	65	4,9	34,8
	+	26	98/2	340	16	21,3	151,8
	±	26	98/4	328	30	10,9	78,1
	+	27	98/6	338	20	16,9	120,7
	+	24	98/8	310	24	12,9	92,3
		1	97/1	1	220		
		1	95/4	2	220		
			95/2	0	220		



Samples containing more than 30 specimens: ···· ≤ 4,9 % --- ≤ 9,9 % —— ≤ 29,9 % ▬ > 30 % , otherwise ■ present

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Lithology	Sample number	Number of species	Individuals (i)	Sight (f)	Ratio i / f
Hauptblätterton	-50/1	20	326	45	7,2
	-50/5	30	334	50	6,7
	-50/6	21	327	35	9,3
	-50/7	22	326	104	3,1
	-50/8	26	324	35	9,3
	-50/9	27	330	21	15,7
	-49/1	8	173	210	0,8
	-46/1	2	23	220	
	-42/1	0	0	217	

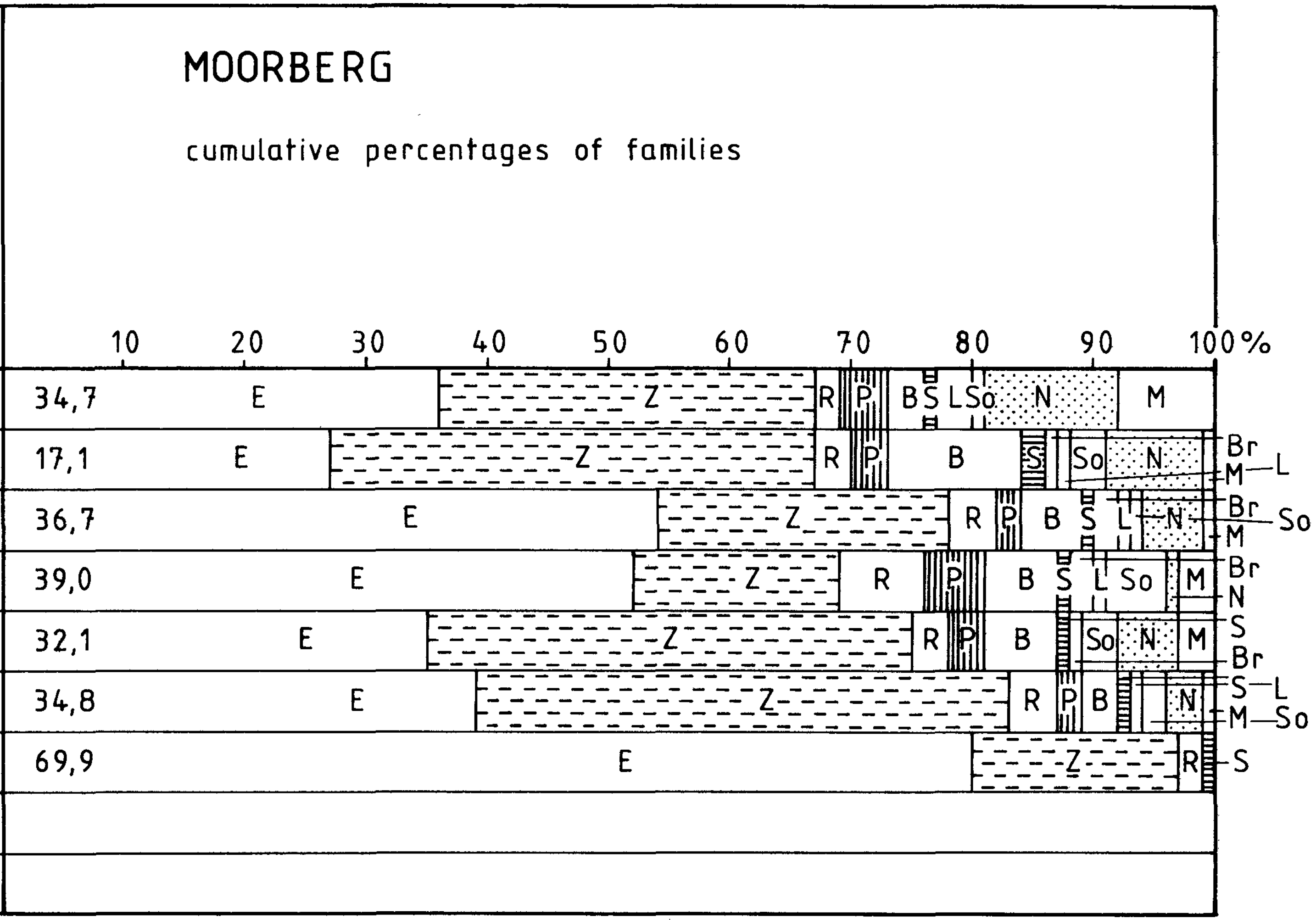
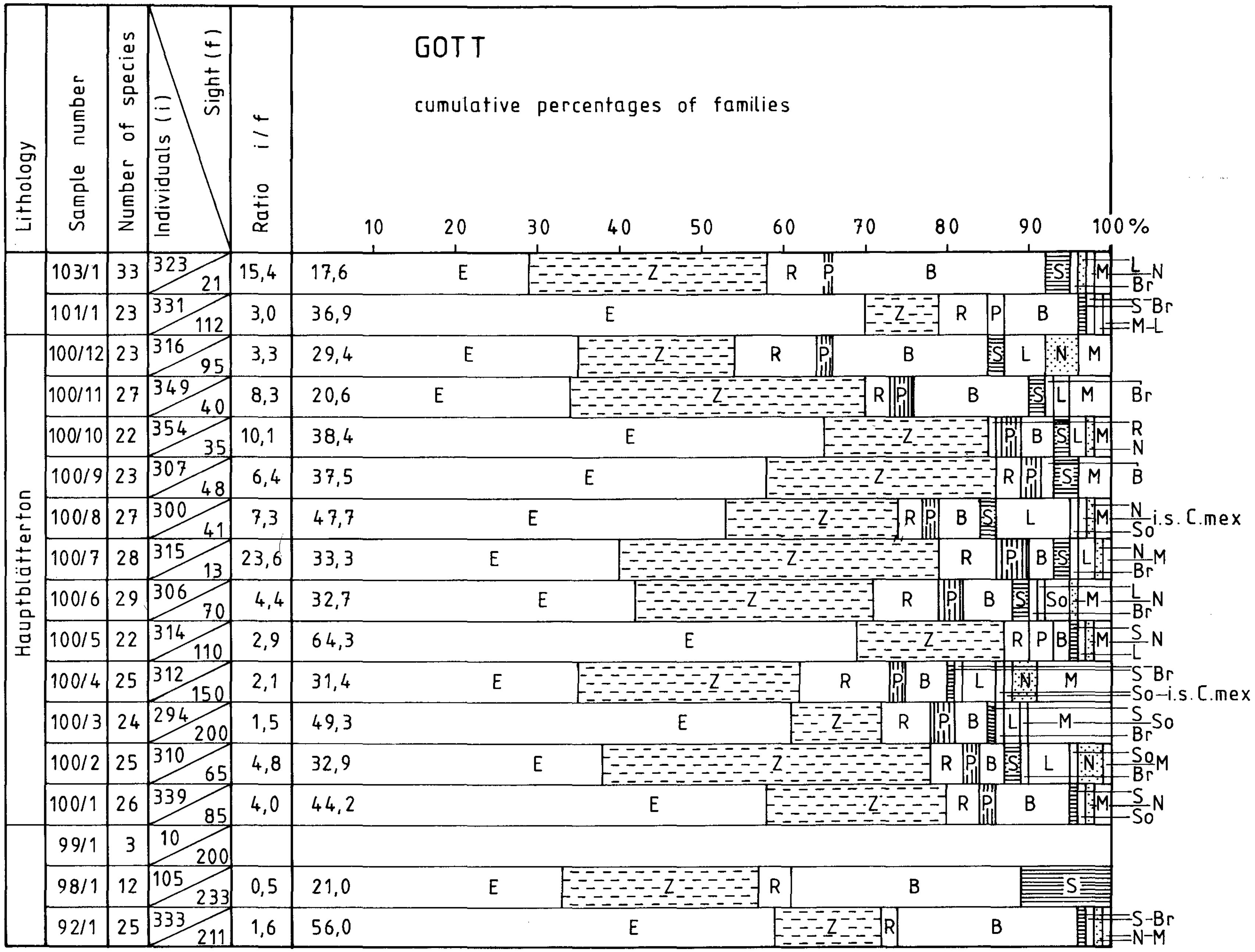


Fig. 9: Cumulative percentages of families for the Moorberg section. The percentages in the column of the Ellipsagelosphaeraceae correspond to the total amount of *W. barnesae*.



Lithology	Sample number	Number of species	Individuals (i)	Sight (f)	Ratio i / f	
	103/1	33	323	21	15,4	17,6
	101/1	23	331	112	3,0	36,9
Hauptblätterton	100/12	23	316	95	3,3	29,4
	100/11	27	349	40	8,3	20,6
	100/10	22	354	35	10,1	38,4
	100/9	23	307	48	6,4	37,5
	100/8	27	300	41	7,3	47,7
	100/7	28	315	13	23,6	33,3
	100/6	29	306	70	4,4	32,7
	100/5	22	314	110	2,9	64,3
	100/4	25	312	150	2,1	31,4
	100/3	24	294	200	1,5	49,3
	100/2	25	310	65	4,8	32,9
	100/1	26	339	85	4,0	44,2
	99/1	3	10	200		
	98/1	12	105	233	0,5	21,0
	92/1	25	333	211	1,6	56,0

Fig. 10: Cumulative percentages of families for the Gott section. The percentages in the column of the Ellipsagelosphaeraceae correspond to the total amount of *W. barnesae*.

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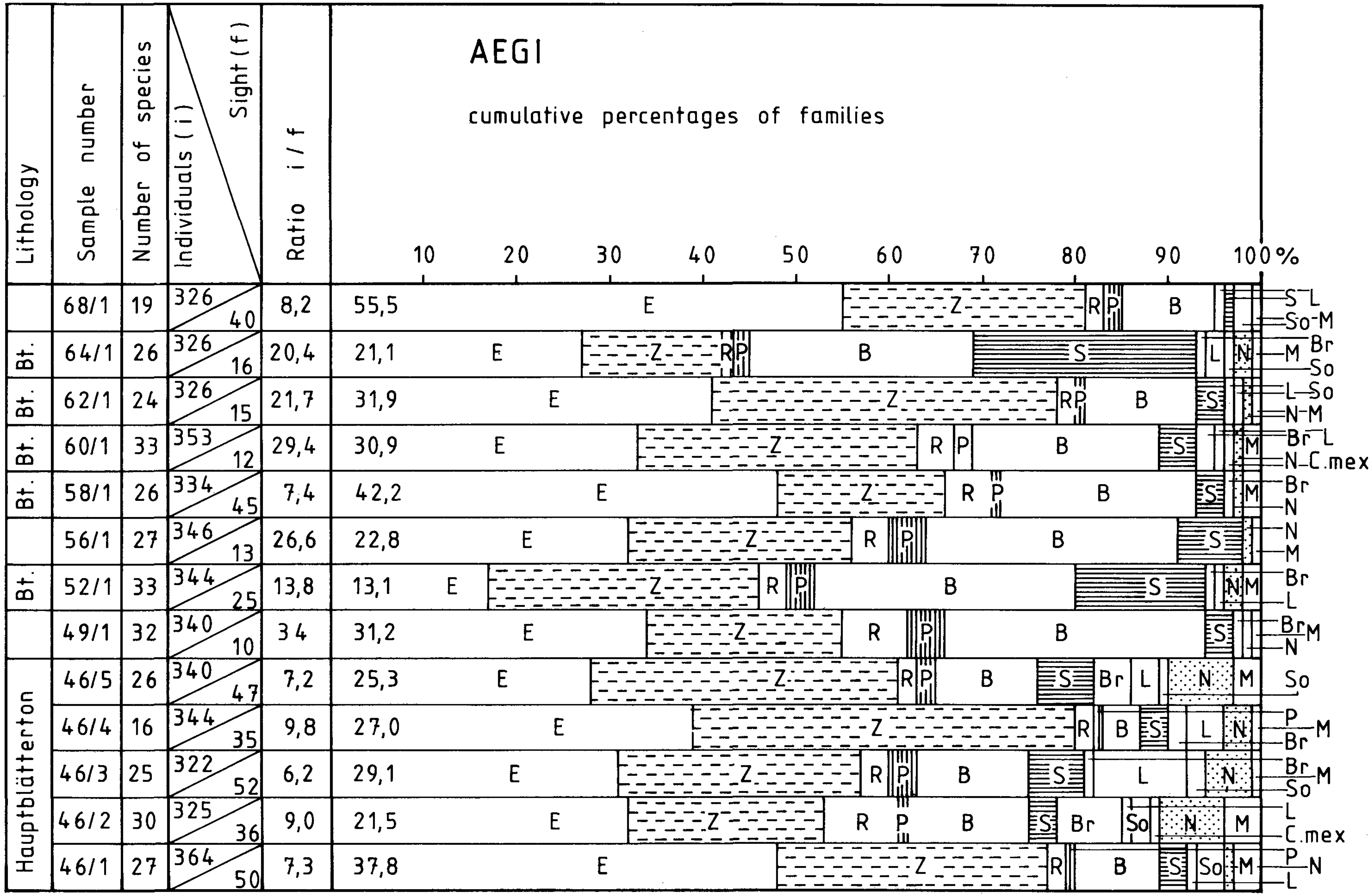

Lithology	Sample number	Number of species	Individuals (i) / Sight (f)	Ratio i/f	E
	68/1	19	326 / 40	8,2	55,5
Bt.	64/1	26	326 / 16	20,4	21,1
Bt.	62/1	24	326 / 15	21,7	31,9
Bt.	60/1	33	353 / 12	29,4	30,9
Bt.	58/1	26	334 / 45	7,4	42,2
	56/1	27	346 / 13	26,6	22,8
Bt.	52/1	33	344 / 25	13,8	13,1
	49/1	32	340 / 10	34	31,2
Hauptblätterton	46/5	26	340 / 47	7,2	25,3
	46/4	16	344 / 35	9,8	27,0
	46/3	25	322 / 52	6,2	29,1
	46/2	30	325 / 36	9,0	21,5
	46/1	27	364 / 50	7,3	37,8

Fig. 11: Cumulative percentages of families for the Aegi section. The percentages in the column of the Ellipsagelosphaeraceae correspond to the total amount of *W. barnesae*.

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Lithology	Sample number	Number of species	Individuals (i)	Sight (f)	Ratio i/f
	103/1	29	312	21	14,9
	99/1	16	302	80	3,8
	99/2	31	328	47	7,0
Hauptblätterton	98/1	22	317	65	4,9
	98/2	26	340	16	21,3
	98/4	26	328	30	10,9
	98/6	27	338	20	16,9
	98/8	24	310	24	12,9
	97/1	1	1	220	
	95/1	1	2	220	
	95/2		0	220	

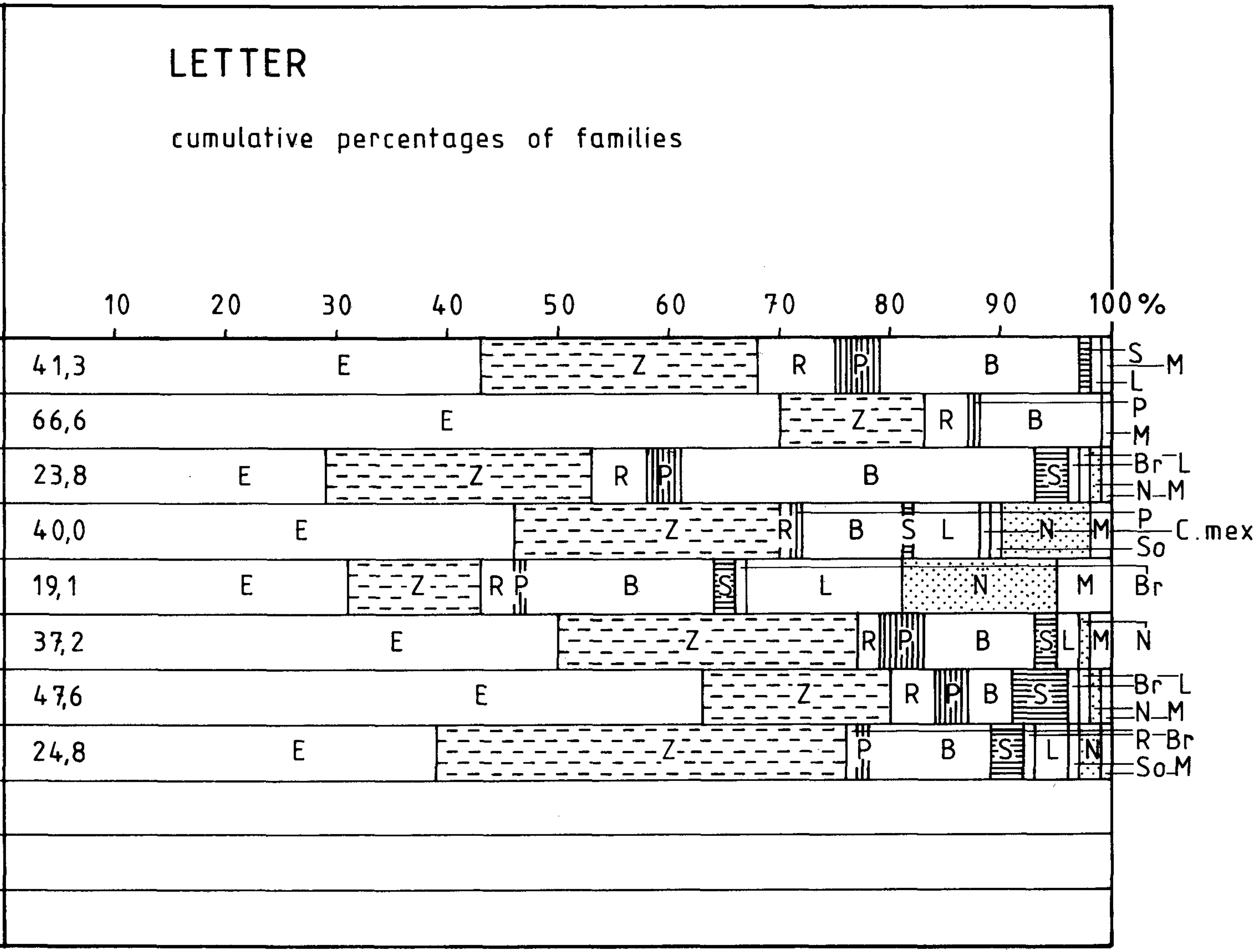

Fig. 12: Cumulative percentages of families for the Letter section. The percentages in the column of the Ellipsagelosphaeraceae correspond to the total amount of *W. barnesae*.

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In the first group the Ellipsagelosphaeraceae are by far the most dominant (A: 28–48 %, G: 34–69 %, Letter: 31–63 %, Moorberg: 27–54 %), followed by the Zygolithaceae (A: 21–41 %, G: 11–39 %, L: 12–37 %, M: 17–44 %), the Retecapsaceae (A: 2–8 %, G: 1–11 %, L: 1–4 %, M: 2–7 %), the Podorhabdaceae (A: 1–3 %, G: 1–3 %, L: 4–17 %, M: 2–5 %), the Biscutaceae (A: 11–13 %, G: 2–14 %, L: 1–5 %, M: 3–11 %) and the Stephanolithiaceae (A: 3–24 %, G: 1–2 %, L: 1–5 %, M: 1–2 %). All these families have been found in all sections in all samples. Most of these correspond to the solution resistant forms from the lower clay sequence.

The second group, which is much rarer than the first, comprises the Nannoconaceae (A: 1–7 %, G: 1–7 %, L: 1–16 %, M: 1–11 %) and the Microrhabdulaceae (A: 1–4 %, G: 0–10 %, L: 1–5 %, M: 1–8 %). These families show a different distribution, for they are present in all samples from Aegidientorplatz, Letter and Moorberg, but absent in some samples from Gott. This group which is not known from the lower clay sequence seems to include much more delicate forms less resistant to dissolution and possibly the presence of this group primarily indicates good ecological conditions.

The Braarudosphaeraceae (A: 0–9 %, G: 0–1 %, L: 0–1 %, M: 0–2 %), the Lithastrinaceae (A: 1–10 %, G: 0–10 %, L: 1–12 %, M: 0–3 %) and the Sollasitaceae (A: 1–3 %, G: 0–1 %, L: 0–3 %, M: 1–6 %) are included in the third group. Species of this group are rarer than those of group two, they do not occur in all samples from any section. The Sollasitaceae might however also be placed in group two (see Fig. 9–12).

The Braarudosphaeraceae, Lithastrinaceae and Sollasitaceae are absent from the following samples: Aegidientorplatz 1,–,–, Letter 2,–,3, Gott 6,2,6, Moorberg 2,1,–.

It becomes obvious from these data that the distribution of coccoliths in the Hauptblätterton of one section differs from sample to sample both in diversity and number of individuals, e. g. in the Gott section the number of individuals varies between 315 individuals per 13 fields (no. 100/7) to 294 per 200 fields (no. 100/3).

Comparing the various sections and their coccolith assemblages it is noticeable that there are considerable differences not only in the floral composition of one section but also between the different sections.

Aegidientorplatz has the most balanced number of individuals (which is indicated by the ratio i/f), is surpassed by many samples from other sections (it ranges between 7–9). The total amount of the Ellipsagelosphaeraceae is rather small and the number of families represented is the highest of all sections. From the families of the third group only the Braarudosphaeraceae is missing in one sample. This section very clearly proves that the number of individuals and the number of families represented in one sample are not necessarily correlated. Thus this section does seem to have the most unaltered floral composition.

The floral distribution of the other sections is not as balanced as the one of the Aegidientorplatz section. The number of individuals varies considerably, some of the families of group three are missing, mainly in the Gott section. Again there is not necessarily a correlation between the number of individuals and the number of species or families. Sample Gott 100/7 has a ratio /f) of 23,6 containing 28 species and 10 families, the llipsagelosphaeraceae make up to 40 %, sample Gott 0/6 has a ratio (i/ f) of 4,4 containing 29 species and 1 families.

6.3.3. The Upper Clay Sequence

For the Aegidientorplatz section the percentage figures of coccoliths given first correspond to those of the clay facies, the second set of figures to those of the Blätterton facies (single layers). Families of the first group (with the exception of the Stephanolithiaceae) are represented in all samples:

○ Ellipsagelosphaeraceae (A: 32–55 %, 17–48 %, G: 29–70 %, L: 29–70 %).
○ Zygolithaceae (A: 21–26 %, 15–37 %, G: 9–29 %, L: 13–25 %).
○ Retecapsaceae (A: 2–7 %, 1–5 %, G: 6–7 %, L: 5–7 %).
○ Podorhabdaceae (A: 2–4 %, 1–3 %, G: 1–2 %, L: 1–4 %).
○ Biscutaceae (A: 10–24 %, 12–28 %, G: 9–26 %, L: 11–32 %).
○ Stephanolithiaceae (A: 1–7 %, 3–24 %, G: 1–3 %, L: 0–3 %).

Within the Ellipsagelosphaeraceae, which are slightly more numerous than in the Hauptblätterton, *Watznaueria barnesae* is dominant. In the Aegidientorplatz section the percentage of Ellipsagelosphaeraceae is higher in the "normal" clay than in the Blätterton.

The Nannoconaceae (A: 0–1 %, 1–2 %, G: 0–1 %, L: 0–1 %) and the Microrhabdulaceae (A: 0–1 %, 1–2 %, G: 1–3 %, L: 1 %) are not very common, totally absent in a couple of samples and much rarer than in the Hauptblätterton.

The distribution in the thin Blätterton layers and the "normal" clay facies in Aegidientorplatz differs significantly. Both families do occur in the Blätterton samples throughout, but are partly missing in the clay facies.

The third group consisting of the Braarudosphaeraceae (A: 0–1 %, 0–2 %, G: 0–1 %, L: 0–1 %), the Lithastrinaceae (A: 0–1 %, 0–2 %, G: 1 %, L: 0–1 %) and the Sollasitaceae (A: –, 0–1 %, G.: –, L: –) are even rarer, reduced in comparison to the Hauptblätterton. Again the Blätterton layers are richer in these forms though they are occasionally missing.

The floral content of the upper clay sequence is comparable to the Hauptblätterton concerning the number of individuals but not concerning the diversity. Within the upper clay sequence the Blätterton layers are richer in the rarer forms than is the "normal" clay facies.

The tendency for the coccolith distribution of various sections to differ, already noted in the Hauptblätterton, is confirmed in this sequence. Aegidientorplatz yielded by far the most diverse flora.

The fact that the coccolith assemblages of the Hauptblätterton and the upper clay sequence are similar in abundance may be explained by the way the samples were prepared. According to the preparation technique used the slides which were examined have not been extracted from certain laminae. Thus material from coccolith rich and poor layers within the Hauptblätterton have been mixed. This might explain variations within the Hauptblätterton as well.

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6.4. Preservation and Dissolution

One problem in evaluating fossil coccolith assemblages is the role played by dissolution. The fairly good preservation and the rare etching of the coccoliths in the Hauptblätterton indicate the lack of dissolution. Another hint for the absence of solution is the presence of *Haquius circumradiatus, Corollithion geometricum (= C. ellipticum), Polypodorhabdus madingleyensis (= Cretarhabdus lorriei), Diadorhombus rectus* and *Bidiscus rotatorius (= Discorhabdus rotatorius)* in the Hauptblätterton. These species are easily destroyed by solution processes (THIERSTEIN, 1976). According to the occurrence of these species the examined sections can be subdivided into a lower part (the lower clay sequence), and an upper part (the Hauptblätterton and the upper clay sequence). The lower part is barren of the solution prone forms, apart from sample Gott 92/1. This accounts for the low numbers of individuals and the low diversities found in these samples.

The upper part yielded one or several of these species per sample (apart from one sample – Aegidientorplatz 46/4). Thus it seems probable that the original floral assemblage of the Hauptblätterton and the upper clay sequence is not influenced by solution processes. The better preservation of coccoliths in the Hauptblätterton cannot be explained as being due to an increase of expandable mixed-layer clay minerals, these being present in almost equal proportions throughout the sections.

According to ROTH & KRUMBACH (in press) assemblages with more than 40 % *W. barnesae* are too affected by dissolution to reflect species composition accurately. In Figs. 9–12 the percentage of *W. barnesae* is given in parentheses in the column of Ellipsagelosphaeraceae. The Hauptblätterton of the Aegidientorplatz section shows the best preservation, the worst is for the Gott section, where the 40 % limit is overstepped in four samples. However, in contrast to the obvservations of ROTH & BOWDLER (1981) and ROTH & KRUMBACH (in press) the nannofossil assemblages with over 40 % of *W. barnesae* do not necessarily display a low diversity. Thus most of the samples from the Hauptblätterton yield unaltered or only slightly altered coccolith assemblages, while the samples of the lower clay sequence are heavily biased by solution processes.

6.5. Coccolith Distribution and Lamination

The Hauptblätterton and the Blätterton consist of thin pale and thicker dark laminae. Macroscopically these dark laminae may be up to 3 mm thick, showing an internal lamination; they represent the "normal" clay facies rich in pyrite and clastic material.

The pale laminae, which are macroscopically thinner than the dark ones, are mainly built up by coccoliths; their thickness varies between 30 μ and 80 μ. Thin sections did, however, show that the dark layers, varying between 30 μ and 100 μ in thickness are thinner than the pale ones (KEMPER, in prep.). This is due to the fact that the dark laminae show an internal fine rhythmical lamination.

Pyrite and clastic material is reduced in these pale laminae. Thin sections examined under the light microscope clearly show that the pale laminae are often not laterally continuous but that they are lenses built up by calcareous nannoplankton. In these microlenses, which have a length of up to 0,25 mm and a width of up to 0,15 mm, certain species are enriched. Lenses mainly built up by *Nannoconus* ssp., or *Watznaueria barnesae*, or *Zygodiscus* ssp., or *Parhabdolithus asper* have been observed. This indicates a current winnowing effect due to which certain species / genera were locally enriched.

6.6. Palaeobiogeography and Warm Water Forms

Coccolith assemblages recovered from sediments record surface water salinity and fertility and also surface water temperature, as long as the assemblages have not been heavily biased by dissolution (e. g. Cenozoic nannoplankton distribution and diversity was controlled largely by surface water temperature: BUKRY, 1978). Cretaceous nannoplankton distribution patterns and diversity have not been well studied, thus less information is available.

THIERSTEIN (1976) tried to differentiate between tropical, Boreal and Austral floral assemblages. *Conusphaera mexicana, Nannoconus* ssp. and *Diadorhombus rectus* are restricted to tropical and subtropical paleolatitudes. These tropical and subtropical latitudes correspond to the Tethyan realm (Berriasian – Barremian) of other authors. This distribution pattern is however contradicted by PERCH-NIELSEN (1979) who quotes *Nannoconus* ssp., from Speeton, Spitzbergen and even the Falkland plateau, thus interpreting it as a cosmopolitan genus. More recently DERES & ACHÉRITÉGUY (1980) redescribed the genus *Nannoconus* and gave detailed range charts and geographical distributions. The bulk of the genus, which occurs from the Tithonian to the Campanian, is found in the Mediterranean province of the Tethyan realm and in southern N-America and Central America where it can be rock-building. Nannoconids are also known from the Indo-Pacific province (SW-Africa and Mozambique). On the other hand DERES & ACHÉRITÉGUY (1980) report this genus from the Boreal realm as well: from the Berriasian/Valanginian of Ireland, the Barremian and Albian of the North Sea and the Albian of NW Germany. According to these data *Nannoconus* is a cosmopolitan genus.

Unfortunately so far, no exact stratigraphic levels are known for these Boreal *Nannoconus* occurrences to enable correlation with macropalaeontological observations.

However, it seems possible that *Nannoconus* is a Tethyan-derived genus whose palaeobiogeographical distribution is controlled by the palaeogeographical setting, palaeocurrents and warm surface water temperatures. This is supported by the following facts:

1) *Nannoconus* is a solution resistant form (THIERSTEIN, 1976), thus it might be found in all Boreal Lower Cretaceous sediments, especially in the Valanginian and Hauterivian when the palaeogeographical conditions were more suitable than in the Barremian.
2) Apart from *Nannoconus* other possible warm water forms like *C. mexicana* and *D. rectus* do occur in the Hauptblätterton.
3) The idea of warm surface water temperatures during the deposition of the Hauptblätterton is supported by dinocysts.

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4) In the Mediterranean part of the Tethyan realm *Nannoconus* is the dominant form of calcareous nannoplankton in the Lower Cretaceous. *Nannoconus* is often enriched to such an extent that it forms nearly pure *Nannoconus* limestones. In the Boreal realm, although coccoliths are abundant, *Nannoconus* (apart from certain exceptions) has a very scattered distribution.
5) The Upper Aptian of NW-Germany yields a rich *Nannoconus* assemblage associated with a well preserved fauna of Tethyan-derived planktonic foraminifera and warm temperature belemnites.

This is not contradicted by occasional records of *Nannoconus* throughout the Boreal Lower Cretaceous. Horizons with abundant nannoconids may be interpreted as periodic warm water ingressions. These ideas are supported by samples from the Hauptblätterton of the western part of the basin, derived from wells south of Meppen (see Fig. 2). These show a typical Hauptblätterton assemblage very similar to the ones from the eastern part of the basin, rich in nannoconids (*N. abundans*) and *L. septentrionalis*.

Conusphaera mexicana, which was first described from Mexico and is well known from the Tethyan realm, has been reported by TAYLOR (1982: 47) from a bed in the *amblygonium*-zone of Speeton. This coincides with observations of MICHAEL (1979: 311) who postulated that in *amblygonium*-zone times (earliest Hauterivian) warm water currents transported Tethyan-derived forms into the Lower Saxony and North Sea Basins.

D. rectus has up to now only been found in the Tethyan realm, its occurrence in NW-Germany supports the idea of warm water influences during the deposition of the Hauptblätterton.

THIERSTEIN (1976) and ROTH (1979: 23) consider *Conusphaera, Micrantholithus, Nannoconus* and *Lithraphidites* to be near shore species common in the neritic environment, which supports the idea that the Hauptblätterton was deposited under shallow water conditions and not to be a deep water sediment.

7. Dinocysts

For the purpose of this study, twelve samples collected from the Hauptblätterton of Gott were examined along with three samples immediately below and above this bed. In addition to the samples marked in Fig. 4 the following samples have been examined.

83/1 about 1,7 m below bed 84
109/1 about 1,2 m above bed 103
114/1 about 2,5 m above bed 103
138/1 about 2,6 m above bed 103.

All samples yielded dinocyst microfloras. These dinocyst assemblages have been analysed in various ways and the information obtained has been used to make certain palaeoenvironmental interpretations. However, the reader is urged to take into account EVITT's eloquent observations on dinocyst population size and assemblage composition (EVITT, 1985: 40), when assessing these interpretations.

7.1. General Distribution

Most of the samples examined contained a rich and diverse dinocyst microflora. However, there are noticeable patterns and trends in the occurrence of these palynomorphs. The following descriptions are made in conjunction with Tabs. 5a, b, c, 6.

In the stratigraphically oldest sample (83/1) there is a varied and fairly abundant dinocyst microflora. Samples 88/1 and 98/1 not only show a decrease in diversity of the assemblages, but also in the absolute numbers of dinocysts recovered. This trend continues through samples 100/1 and 100/2. Many species have disappeared by this level, there are few noticeable first occurrences (*Ovoidinium* sp. being the one exception, see Tab. 5c).

Sample 100/3 shows a sudden decrease in the yield of dinocysts accompanied by a dramatic increase in the species diversity from around 45 species per sample in the older samples to about 60 in 100/3. This higher level of diversity is maintained through to sample 100/8. The samples from 100/4 to 100/8 also contain a vast number of dinocysts – numbers which actually increase up to sample 100/8.

Sample 100/9 shows a marked decrease in the absolute numbers of dinocysts, but only a small reduction in species diversity. This is the start of a general trend of declining numbers and diversity of the dinocyst microflora which continues through 100/10 and 100/11.

Samples 100/12 and 109 yielded a very impoverished population of cosmopolitan species (about 30 species). The youngest samples (114 and 138) reveal a gradual increase in species diversity, but the percentage of dinocysts within the palynoflora rises only marginally.

7.2. Terrestrial/Marine Palynomorph Relationships and their Implications

The relative proportions in which the groups of palynomorphs (shown in Tab. 6) were recovered from these samples can be utilised to make certain interpretations about palaeoenvironmental parameters operative at the time of depositon of the Hauptblätterton.

Samples 83/1 to 98/1 are all dominated by marine palynomorphs, the smaller terrestrial component being composed of equal proportions of saccate pollen and trilete spores. The high percentage of triletes relative to saccates, along with the presence of non-saccate gymnosperm pollen, indicate the site of depositon was not far offshore (see ERDTMAN, 1969: 118).

It is noticeable that in general terms the total plankton percentages decrease from 83/1 to 100/3. This latter sample seems to represent the culmination of an unusual set of palaeoenvironmental conditions, for the dinocyst assemblage becomes reduced in absolute numbers but is enriched with respect to species diversity. As trilete spore and non-saccate pollen abundances also fall, this is presumably not due to a nearershore situation. This low abundance high diversity dinocyst flora may owe its structure to a reduction in nutrient supply. Similar low abundance, high diversity assemblages of dinoflagellates are nowadays found in waters of reduced phosphate content (GRAHAM, 1942). The 100/3 assemblage may have been subjected to similar environmental controls.

From 100/4 there is a dramatic increase in total plankton abundance up to 100/8 where it accounts for 56 % of the assemblage. The terrestrial palynomorph component over the same interval shows a marked de-

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Table 5a: Ranges of dinocyst and acritarch species recovered from the studied samples of the Gott section.
Abundances: △ = <5; ○ = 5–10; ● = 10–20; □ = 20–50; ■ = >50.

AGE	EARLY BARREMIAN															LATE BARR.		
SPECIES \ SAMPLE	83/1	88/1	c98/1	100/1/83	100/2/83	100/3/83	100/4/83	100/5/83	100/6/83	100/7/83	100/8/83	100/9/83	100/10/83	100/11/83	100/12/83	109	114	138
Trichodinium ciliatum.	○	▷																
Druggidium cf. rhabdoreticulatum.	○		▷															
Spiniferites dentatus.							▷	▷										
Kleithriaspaeridium corrugatum.	○	○	○	○	▷		▷	○	▷	▷								
Muderongia staurota.				▷		▷	▷	▷	○	▷								
Muderongia crucis.			▷	▷	▷	▷				▷	○							
Pterodinium cingulatum.	▷		▷			▷		▷	○		▷							
Cribroperidinium sp.I.	▷		▷			▷			▷		▷	▷						
Meiourogonyaulax amalsis.		▷		▷		▷	▷	▷	▷	○	▷	▷						
Wallodinium krutschi.	○	●	○	○	○	○	○		○			○						
Cassiculosphaeridia magna.	○	○	○	○	○				▷		▷	▷		▷				
Druggidium augustum.			▷	▷	▷	■		○			□	○	▷	▷				
Nexosispinum vetusculum.	○	○	○	▷	▷	●	▷	▷		▷	▷			○				
Pterodinium cornutum.	▷					▷	▷	○	▷	▷	▷	▷	▷	▷				
Cymatiosphaera sp. nov..				▷	▷	□	●	□	□	□	□	●	○	○	○			
Wallodinium lunum.	○	○	○	▷	▷	▷		▷		▷	▷		▷	▷	▷			
Oligosphaeridium sp. nov..	▷		▷		▷												▷	
Pseudoceratium pelliferum.	●	●	●	●	●	□	●	□	□	□	□	●	●	●	○	▷	▷	
Gardodinium trabeculosum.	○	○	○	○	○						▷					▷		○
Heslertonia heslertonensis.	○	○	○	▷	▷											▷		○
Batioladinium longicornutum.	▷		▷	▷														
Kleithriasphaeridium simplicispinum.	○	○	○										▷	▷		▷	○	○
Scriniodinium campanulum.	○	○	○	○	○								▷	▷				▷
Subtilisphaera terrula.	○	○	○				▷				▷		▷		○	○		▷
Dinocyst gen. et sp. nov.	▷			○	○	●	●	□	■	□	●	●	○				▷	▷
Achomosphaera neptuni.	▷	▷							▷			▷	○	●	▷			▷
Callaiosphaeridium spp..	▷		▷			○		▷	▷		▷	○	▷	▷				
Canningia sp. nov..	○	○	○	○	○	●	○	●	●	●	●	●	●	○	▷	▷		▷
?Canningia sp. nov..		▷			▷	▷			▷	▷	▷			▷	▷	▷	▷	
Cassiculosphaeridia reticulata.	●	●	○	○	○	●	●	□	□	□	□	●	●	○	○	○	○	○

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Table 5b: Ranges of dinocyst and acritarch species recovered from the studied samples of the Gott section.
Abundances: △ = <5; ○ = 5–10; ● = 10–20; □ = 20–50; ■ = >50.

AGE	EARLY BARREMIAN															LATE BARR.		
SAMPLE / SPECIES	83/1	88/1	c98/1	100/1/83	100/2/83	100/3/83	100/4/83	100/5/83	100/6/83	100/7/83	100/8/83	100/9/83	100/10/83	100/11/83	100/12/83	109	114	138
Chlamydophorella nyei.	●	●	●	●	●	■	□	■	□	●	●	●	○	○	△	△	△	○
Cleistosphaeridium sp. nov.	△	△	○	○	○	■	■	■	■	□	■	○	○	△		○	○	○
?Cleistosphaeridium sp.	△	△			△	△		△		△	△			△				△
Cometodinium whitei.	△	△	△	□	○	○	○	○	○	●	●	△	△		△	△	△	
Coronifera oceanica.		△	△						△			△		△		△	△	△
Cribroperidinium edwardsii.	○	○	○	○	△			△			△	△				△	△	△
C. sp. II.	△	△	△	△	△	○	○	○	○	○	○	△	△	△		△	△	
?Cymatiosphaera sp.				○	○	●	○	●	●	●	○		○	△	△	△	△	
Dingodinium alberti.	□	●	□	●	●	■	□	■	■	□	■	●	●	●	○	○	○	○
Diphasiosphaera stolidota.	●	●	●	○	○	△	△	○	△		△		△	△		△	△	
Discorsia nanna.	△					△			△								△	
Druggidium jubatum.	●	●	●	○	○		●	□	●	□	□	●	●	●	○	△	△	△
Dinocyst gen. et sp. nov.	○																△	○
Exochosphaeridium phragmites.	○	○	○		△	○		○	○		○					△		
Florentinia spp..	△					△		△	△		△						△	△
Gonyaulacysta exsanguia.	△	△		△	△	□	□	□	□	●	●	○	○					△
G. fastigiata.	△					△	△	●	△	△				△				
?G. fimbriata.							△	□	△				△	●	△			
G. helicoidea.	○	○	○	○	○	□	●	●	□	○	●	○	○	○	△	○	○	○
Hystrichodinium voigtii.	○	○	○	○	○	●	●	●	●	●	●	○	○	○		△	△	△
Hystrichosphaerina schindewolfii.						△		△			△							
Lihodnia sagena.	△	△	△	△	△		△		△	△	○	△	△	△	△			△
Occisucysta tentoria.	△		△	△		△		△		△	△							
Oligosphaeridium complex.	○	○	○	○	○	□	●	□	□	□	●	○	○	○	△	△	△	△
O. pulcherrimum.			△					△	△				△	△	△			△
Phoberocysta neocomica.	△	△		△	△	●	△		△	△	△	△	△	△	△		△	△
Polysphaeridium spp..	○	○	○	○	□	■	■	■	■	■	■	□	□	○	△	△	△	△
Protoellipsodinium spp.	○	○	○	○	●	○	●	●	○	○	○	○	○	○	△	△	△	
Sirmiodinium grossi.	△	△			△	△	△	△	○	△								
Tanyosphaeridium spp.	○	○	○	○	○	●	●	●	●	●	●	●	○	○	△		○	○

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Table 5c: Ranges of dinocyst and acritarch species recovered from the studied samples of the Gott section.
Abundances: △ = <5; ○ = 5–10; ● = 10–20; □ = 20–50; ■ = >50.

AGE	EARLY BARREMIAN															LATE BARR.		
SAMPLE / SPECIES	83/1	88/1	c98/1	100/1/83	100/2/83	100/3/83	100/4/83	100/5/83	100/6/83	100/7/83	100/8/83	100/9/83	100/10/83	100/11/83	100/12/83	109	114	138
Trichodinium castaneum.	—	—	△	△	△	○	△	△	—	△	—	△	△	△	△	—	—	△
T. speetonensis.		△	△	○	○	●	○	□	□	□	□	○	○	○	—	△	—	—
Oligosphaeridium abaculum.			△	△	△	□	●	□	□	□	●	○	○	△	△	—	—	—
Ovoidinium sp. nov..			△	□	□													
Acritarch gen. et sp. nov..			○	○	□	○	○	□	□	—	□	○	—	○	△	—	—	—
Cyclonephelium sp..					△	○	△	○	○	○	○	—	—	△	—	—	—	—
Cribroperidinium sp. III.					△	△	△	△	△	△	△	—	—	—	△	—	—	—
Aptea anaphrissa.						△	△	■	■	■	●	■	●	●				
Cribroperidinium sp. IV.						○	△	△	△	—	—	—	△	△	—	—	—	△
Dinocyst gen. et sp nov.II.						△	△	—	△	—	△	△	△	△				
Kleithriasphaeridium fasciatum.						△	△	—	△	—	△	△	△	△	—	—	—	△
Peridiniacean sp.						△	—	△	△	△	△	—	—	△				
Gonyaulacysta sp..						△	—	—	—	—	—	△	—	—	△			
Pterodinium sp..						△	—	—	—	—	—	○	△	△	△	△		
?Gonyaulacysta confossa.							●	□	□	●	△							
Hystrichosphaeridium arborispinum.							○	□	■	□	□	●	●	○	△			
?Pareodinia sp..									○	△	△	—	△	○	—	—	—	—
Dissiliodinium sp..												△	△	△	—	—	—	○
Oligosphaeridium sp. nov. II.													△	△	—	—	—	△
Exiguisphaera plectilis.																△	—	△
Cerbia tabulata.																	△	△
Pseudoceratium pelliferum subsp. solcispinum.																		○

crease in trilete spore abundances and a gradual disappearance of non-saccate gymnosperm pollen. This indicates a much greater distance from the site of deposition to the palaeoshoreline. Saccate pollen also decreases markedly, but maintains a minimum 20 % „background" count throughout the interval.

Sample 100/9: also a high diversity, low abundance dinocyst sample with a composition similar to 100/3, seems to reflect a return to the conditions prevalent at the time of deposition of the latter sample. After 100/9 the total plankton count and species diversity decrease steadily up to samples 109, after which they gradually begin to increase again (samples younger than 138 have up to 40 % total plankton). The terrestrial palynomorph component of these samples (100/10 to 138), exhibits a concomitant reversal of the plankton trend. However, saccate gymnosperm pollen is to some extent independent of this trend – its long distance transport capabilities (ERDTMAN, 1954: 13–14) maintaining a minimum 20 % „background" presence in these samples. A similar feature is displayed by the trilete spore assemblages. The samples with low trilete abundances contain predominantly small, unsculptured *Gleicheniidites* type spores. Those samples with high trilete abundances maintain this minimum 10 % small, smooth trilete count but also contain additional larger spores such as *Pilosisporites, Cicatricosisporites, Concavissimisporites* and *Verrucosisporites*.

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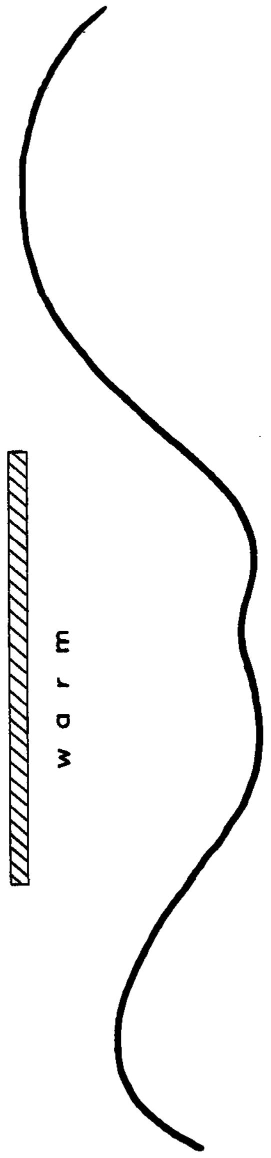
Table 6: Breakdown of palynofloral components in the Gott section.
Percentage composition of the following groups: dinocysts, acritarchs, saccate gymnosperm pollen (dominantly *Classopollis*, but including rare *Eucomiidites* and *Ephedripites*), trilete spores and others (fungal spores, tasmanitids, "simple sacs" and foram test-linings). Total palyno-plankton percentage (dinocysts + acritarchs) and dinocyst species diversity also tabulated along with inferred distance from palaeoshoreline.

AGE	PALYNOMORPH GROUP % / SAMPLE	DINOCYSTS	ACRITARCHS	SACCATE GYM. POLLEN	TRILETES	NON-SACCATE GYM. POLLEN	OTHER	TOTAL PLANKTON %	APPROX. PLANKTON SP. DIVERSITY	INFERRED DISTANCE FROM SHORELINE. ◀ NEAR-SHORE OFF-SHORE ▶
LATE BARR.	183 x/4	28	6	30	30	2	4	34	50	
	138	15	7	36	34	2	6	22	40	
	114	24	7	36	27	3	3	31	35	
	109	11	9	46	24	4	6	20	30	
EARLY BARREMIAN	100/12/83	13	3	53	21	4	6	16	30	
	100/11/83	25	3	37	25	3	5	30	45	
	100/10/83	32	7	36	15	3	7	39	45	
	100/9/83	25	5	46	14	5	5	30	45	
	100/8/83	48	8	27	11	0	6	56	60	
	100/7/83	45	7	28	15	0	5	52	55	
	100/6/83	48	7	26	11	1	7	55	60	
	100/5/83	32	4	43	11	1	8	36	60	
	100/4/83	35	7	33	14	2	9	42	60	
	100/3/83	27	4	42	16	1	10	31	70	
	100/2/83	35	9	33	14	1	6	44	50	
	100/1/83	30	6	35	20	3	7	36	40	
	c98/1	32	11	22	28	1	6	43	45	
	88/1	29	12	23	27	1	8	41	40	
	83/1	45	5	26	17	3	5	50	50	

From these trends it is possible to infer that in just pre-Hauptblätterton times at Gott, palynofloras were dominantly marine, but the site of deposition was not far offshore due to the large percentages of trilete spores and non-saccate pollen which have restricted tranpsort distances (Hoffmeister, 1954; Woods, 1955). Sample 100/3 was laid down as the site of deposition took on a more offshore aspect (lower trilete and non-saccate percentages). The decreased dinocyst productivity may have been due to the competition caused by the introduction of deeper water (or off-shore), higher salinity dinoflagellate species, or to a perturbation in nutrient supply. An offshore environment persisted during the deposition of samples 100/4 to 100/8 – sample 100/9 (and certain individuals of certain species in 100/8) being transitional in character, similar to 100/3. The palynofloras in the sediments laid down after 100/9 indicate a return to a nearer shore situation, the lower

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plankton component and higher trilete element to these assemblages indicating a position further inshore than that of pre-Hauptblätterton times.

7.3. Palaeotemperature Control on the Dinocyst Population

When studying fossil populations it is often difficult, if not impossible, to isolate one or a suite of physiological parameters as being responsible for a particular feature exhibited by the population. The following section is what is believed to represent one example of when it has proved possible to do this.

The case in point is that of the morphologic variation in dinocysts of the species *Pseudoceratium pelliferum* GOCHT. This species is a constant and important component of the dinocyst assemblage in every sample studied and exhibits a distinct range of morphology.

The fossil genus *Pseudoceratium* GOCHT belongs to a group of Cretaceous dinocysts which is believed to be phylogenetically related to the modern dinoflagellate genus *Ceratium* SCHRANK (WALL & EVITT, 1975). A normal phenomenon associated with a motile theca of *Ceratium* is that of autotomy (KOFOID, 1908). This is a device whereby the length of the horns of the dinoflagellate theca is reduced by the creation of section planes which cut off the distal portion of the horns. This process is clearly temperature controlled and related to the specific surface area and flotation properties of the theca. In warm water the length of the horns of a species of *Ceratium* are proportionally longer than they are in cold water. Thus a long-horned *Ceratium* subjected to a colder water environment would undergo autotomy, reducing the length of its horns to compensate for the change in physical parameters. If reversion to warmer conditions occurs, then the horns regenerate, lengthening again, to compensate for the change. Thus a warmer water body would contain longer horned thecae of one particular species than would a colder water body. These relative horn lengths would be reflected in any resting cyst stage produced by the organism.

There is a striking difference between populations of *Pseudoceratium pelliferum* cysts extracted from different samples. All the cysts are clearly referable to the same species, possessing the same gross morphology and ornamentation. However, the dimensions of the three projecting horns (apical, lateral and antapical) are radically different from sample to sample. A short-horned morph is dominant in samples 83/1 to 100/1 and 100/9 to 138, whereas a long-horned morph characterises samples 100/2 to 100/8. The lengths of the horns in the short-horned morph populations being only 38 % of that of the long-horned morphs (see Pl. 3, Figs. 4, 8). This variation in the horn length of the *Pseudoceratium pelliferum* cyst population is interpreted as being due to an increase in the temperature of the water body during the deposition of the high dinocyst diversity part of the Hauptblätterton, relative to that of the water body before and after this event. Sample 100/8, although dominated by long-horned morphs, is the only sample to show a mixing of forms; however, the short horned morphs are very rare and there are few intermediate forms.

7.4. Additional Characteristics of the Dinocyst Population

Within the overall distribution of dinocysts, several further features can be discerned. One of the most obvious is the apparent facies control of several common species of dinocysts. The most striking examples of this are provided by *Gardodinium trabeculosum* (GOCHT) ALBERTI, 1961, *Heslertonia heslertonensis* (NEALE & SARJEANT) DUXBURY, 1980, *Batioladinium longicornutum* (ALBERTI) BRIDEAUX, 1975, *Klesthriasphaeridium simplicispinum* (DAVEY & WILLIAMS) DAVEY, 1974 and *Subtilisphaera terrula* (DAVEY) HARDING (1986), along with several new, as yet unnamed types. These species are present in moderate abundance in samples 83/1 to 100/2 and disappear completely after this, only to reappear in the section above 100/11 (*Batioladinium longicornutum* does not reappear until bed 183). This conspicuous gap in occurrences from the middle part of the Hauptblätterton indicates a strong palaeoenvironmental control operating on many of the species. *Druggidium augustum* HARDING (in press) may have been specially adapted to life in the type of environment portrayed by samples 100/3, 100/8 (in part) and 100/9, as it is common in all of these and very rare elsewhere.

Another obvious character of the dinocyst assemblages is the explosion in numbers of particular species in particular samples. Species that had occurred in frequencies of one or two per sample in samples 83/1 to 100/2 suddenly reach almost flood abundance in samples 100/3 to 100/8 (e. g. *Cleistosphaeridium* sp. nov. (Pl. 3, Figs. 23, 9, 10), and several types of acritarch (Pl. 4, Figs. 10, 11). Often one sample will contain a handful of species in much greater abundance than the rest of those present. This is typified by *Aptea anaphrissa* (SARJEANT) SARJEANT & STOVER, 1978 in samples 100/5 to 100/8, *Cribroperidinium confossa* DUXBURY, 1977 in 100/4 to 100/8 and *Rhynchodiniopsis fimbriata* DUXBURY, 1980 in 100/5 and 100/11. From the findings above, these species can be interpreted as either deeper water forms or offshore forms. Taking coccolith observations into account, the latter interpretation is preferred. Those dinocyst species conspicuous by their absence in the Hauptblätterton can therefore be interpreted as nearshore species.

One other species to show significant morphological differences is *Gonyaulacysta exsanguia*. Specimens from the Hauptblätterton have undulate parasutural crests. Specimens from samples below and above the Hauptblätterton have parasutural crests bearing narrow, elongate, bifurcating spines (almost "acanthate" – see SARJEANT (1982) for definitions), (Pl. 3, Figs. 9, 10). It is uncertain what significance the development of spines has but it may be an adaptation to shallower, more turbulent environments.

There is a notable change in the composition of the dinocyst population reflected in the relative proportions of peridiniacean cysts to gonyaulacacean cysts. The former type is relatively common in samples 83/1 to 100/2 and 100/10 to 138 (largely as *Subtilisphaera terrula* and *Ovoidinium* sp.), the samples in between containing virtually none. Present day dinoflagellate populations are dominated by peridiniaceans in reduced salinity, nearshore environments. These decline in abundance with distance from the shore – offshore populations being dominated by gonyaulacacean forms. Cyst populations also reflect this distribution (see HARLAND,

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1973: 699). It is becoming increasingly obvious that the same situation prevailed during the early Cretaceous (e. g. peridiniacean dominated brackish-water Wealden dinocyst assemblages BATTEN, 1985; HUGHES & HARDING (1985); HARDING, 1986). The Hauptblätterton distributions of peridiniacean cysts provide additional confirmation of a phase of offshore deposition for the Hauptblätterton itself.

7.5. Preservation and Taphonomy

All the organic residues obtained were in an excellent state of preservation, with no sign of degradation. Reworked palynomorphs might be expected to be in a less well preserved state. However, the only reworked dinocysts identified were picked out by virtue of their distinctive morphologies. Well preserved specimens of the genera *Meiourogonyaulax* and *Dichadogonyaulax*, along with *Nannoceratopsis ambonis* (DRUGG) RIDING, 1984 and *N. gracilis* ALBERTI, 1961, have been isolated with certainty. The presence of these forms indicates a Middle Jurassic provenance for at least part of the clastic material.

The volume of organic residues obtained from these samples per standard weight of rock is striking. This is especially so for samples 100/3 to 100/8 which each yielded over twice the volume of organic matter obtained from pre- and post-Hauptblätterton samples.

7.6. Biostratigraphic Comments

Despite the temporal brevity of the studied section several common and distinctive cyst species reveal restricted stratigraphic ranges. *Aptea anaphrissa* is restricted to the middle section of the Hauptblätterton facies. The range of this species confirms the correlation of the Hauptblätterton with Bed LB1 of the Speeton Clay succession in Yorkshire. *Aptea anaphrissa* is restricted to Bed LB1 (DUXBURY, 1977, 1980, author's own observations). This correlation was first noted by RAWSON & MUTTERLOSE (1983). Other species exhibiting range-tops are *Cassiculosphaeridia magna* DAVEY, 1974 (100/11), *Kleithria sphaeridium corrugatum* DAVEY, 1974 (100/7), *Nexosispinium vetusculum* (DAVEY) DAVEY 1979b (100/11), *Endoscrinium campanula* (GOCHT) STOVER & EVITT, 1978 (138), *Spiniferites dentatus* (GOCHT) (GOCHT) DUXBURY, 1977 (100/5), *Trichodinium ciliatum* sensu DAVEY, 1974 (88/1); important first occurrences are *Hystrichosphaeridium arborispinum* DAVEY & WILLIAMS 1966b (100/4), *Trichodinium speetonensis* DAVEY, 1974 (88/1), *Dissiliodinium* sp. (100/9), *Cerbia tabulata* DAVEY & VERDIER) BELOW, 1981 (114) and *Pseudoceratium pelliferum* subsp. *solcispinum* DAVEY, 1974. *Meiourogonyaulax sagena* DUXBURY, 1980, previously reported as Upper Barremian (DUXBURY, 1980) has been found to range from the Hauterivian – Barremian boundary through to the Upper Barremian at Gott. Descriptions of new species encountered in this study will appear elsewhere at a later date.

The high sampling frequency and utilization of electron microscope observation techniques in this study has permitted fine detail resolution of the biostratigraphy. It must be borne in mind however, that because of these detailed observations it has been possible to infer many fluctuations in palaeoenvironmental conditions. As a result of these changes many of the observed species ranges may not be true temporal ranges but artificial ones (i. e. shorter ranges) due to the palaeoenvironmental control of the population at the site of deposition.

8. Interpretation of the Results

As it has already been pointed out by MICHAEL (1974), KEMPER & ZIMMERLE (1978) and KEUPP & MICHAEL (1979) the palaeontological and sedimentological evidence support the idea that the Hauptblätterton was deposited under anoxic or partly oxygen-depleted conditions (kenoxic). This theory is supported by the following observations:

1) The undisturbed lamination (i. e. lack of bioturbation)
2) Abundance of well preserved fishes, reptiles and coleoidea
3) Benthic organisms are rare (bivalves), some may have been pseudoplanktonic. Benthic foraminifera are very rare and of a small size.
4) High percentages of organic carbon and pyrite
5) Enrichment of coccoliths in the thin pale laminae.

These data show parallels with the bituminous Toarcian Posidonienschieferfazies which has recently been investigated by KAUFFMANN (1978), SEILACHER (1982) and RIEGRAF et al. (1984). RIEGRAF (1985: 61) summarised the various models devised to explain the formation of such facies:

1) silled basin model (e. g. SEILACHER, 1982),
2) salt boss model (JORDAN, 1974),
3) algal-fungal mat model (KAUFFMANN, 1978),
4) near-bottom current model (BRENNER & SEILACHER, 1978).

For the Barremian Blätterton facies a combination of various models seems most convincing.

1) The silled basin theory which caused stagnant conditions is difficult to apply for the Barremian Blätterton facies as these sediments are found not only in the Lower Saxony Basin but in the North Sea as well. Furthermore several Blätterton horizons occur in the Upper Barremian implying a recurrent breakdown and re-establishment of the barriers.
2) The Blätterton facies is not only restricted to the salt domes and primary or secondary marginal basins, but is to be found everywhere in NW-Germany. Additionally a synchronous rising of saltstructures, which has to be postulated for the Hauptblätterton facies, seems very unlikely.
3) The genesis of the Toarcian laminae is explained by KAUFFMANN (1978) as due to algal-fungal mats causing a faunally depleted milieu in the sediment. No algal mats have been observed in the Hauptblätterton.
4) Stronger bottom currents would have caused an oxygenated environment. It seems more likely to explain the Blätterton facies as being due to an oxygen depleted zone in the overlying water column.

In post Hauptblätterton and Blätterton times the oxygenation was reestablished and a rich benthic life (leading to increased bioturbation) was possible again.

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For the Hauptblätterton these anoxic or kenoxic conditions prevailed for a longer time, while in Upper Barremian time a constant change of anoxic/oxygenated conditions caused the periodic alternation of clay and Blätterton. The Hauptblätterton itself is comparable to this Upper Barremian clay / Blätterton sequence, but on a finer scale. Laminae of "normal" clay alternate with those rich in coccoliths.

The Blätterton facies accumulated under a regressive regime, in contrast to the Liassic Posidonienschiefer. Some coccolith genera found in the Hauptblätterton indicate a neritic, shallow water environment.

Within the Gott section there occur recycled Westphalian palynomorphs in the lower part and recycled Middle Jurassic ones in the upper part of the Hauptblätterton. There is no problem to derive the Middle Jurassic material from sediments which outcrop in the Sarstedt area. The Westphalian palynomorphs are, however, more difficult to explain, for sediments of Westphalian age are not known from the Harz Mts. Thus, material must have been transported from the Rhenanian massif.

The calcareous nannoplankton and the dinocysts in the Hauptblätterton suggest a warm tropical climate. The massive increase of organic plankton incorporated in the clays of the middle part of the Hauptblätterton seems to be a direct consequence of the inferred temperature rise of the water body over the same interval.

Solubility of oxygen in sea water is dependant on temperature – a rise in temperature of 5 % will create a 10 % drop in the level of dissolved oxygen (RILEY & CHESTER, 1971). Thus less oxygen will be transferred from the surface to deeper water given a rise in temperature. The resulting more anoxic environment is then less able to oxidize the sinking organic matter, so that a greater percentage of this will be incorporated in the sediments (DE BOER, 1982).

This increase in temperature might explain the fact that the middle part of the Hauptblätterton (sample 100/3 – 100/8) yielded over twice the volume of organic matter obtained from pre- or post-Blätterton samples. This constant "rain" of dinocysts and organic debris may have poisoned the bottom water thus intensifying the kenoxic conditions above the sediment. The pale laminae which are rich in coccoliths represent an incipient chalk facies – a forerunner of the Upper Cretaceous "Schreibkreide" – and may be explained by seasonal plankton blooms. The incipient chalk layers are intercalated with dark laminae which are enriched in clastic material, representing the "normal" facies.

The plankton blooms postulated here can be explained by seasonal variations of the surface water temperature caused by a current system coupled with a constant level of nutrient supply.

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References

ALBERTI, G.: Zur Kenntnis mesozoischer und alttertiärer Dinoflagellaten und Hystrichosphaerideen von Nord- und Mitteldeutschland sowie einigen anderen europäischen Gebieten. – Palaeontographica, **A 116**, 1–58, 4 Tab., 12 Taf., Stuttgart 1961.

BATTEN, D. J.: Two new dinoflagellate cyst genera from the non-marine Lower Cretaceous of southeast England. – N. Jb. Geol. Paläont. Mh., **1985**/7, 427–437, 5 Abb., 2 Taf., Stuttgart 1985.

BELOW, R.: Dinoflagellaten-Zysten aus dem Hauterive bis unteren Cenoman Südwestmarokkos. – Palaeontographica, **B176**, 1–145, 90 Abb., 15 Taf., Stuttgart 1981.

BENDER, F.: Bericht über die Profilaufnahme und das horizontierte Bergen von Fossilien im Barrême der Tongrube der Ziegelei Roklum, Kreis Wolfenbüttel vom 7.–11. 6. 1960. – Unveröff. Bericht , NLfB, 6 S., Hannover 1960.

BRAHMS, H.: Die Fischfauna des Barrêmien bei Hildesheim. – Inaug. Diss. Tübingen, 92. S., Leipzig 1913.

BRENNER, K. & SEILACHER, A.: New aspects about the origin of the Toarcian Posidonia Shales. – N. Jb. Geol. Paläont. Abh., **157**, 1/2, 11–18, 4 Abb., Stuttgart 1979.

BUKRY, D.: Cretaceous and Paleogene coccolith stratigraphy, DSDP, Leg 26. – Initial Reports of the Deep Sea Drilling Project, **26**, 669–673, 7 Abb., Washington 1974.

BUKRY, D.: Biostratigraphy of Cenozoic marine sediments by calcareous nannofossils. – Micropaleontology, **24**, 44–60, New York 1978.

ČEPEK, P.: Kalzitisches Nannoplankton. In: BENDER, F.: Angewandte Geowissenschaften, **1**, 407–414, 3 Abb., Stuttgart 1981.

ČEPEK, P. & KEMPER, E.: Der Blättertonstein des nordwestdeutschen Barrême und die Bedeutung des Nannoplanktons für die fein laminierten, anoxisch entstandenen Gesteine. – Geol. Jb. **A58**, 3–13, 2 Taf., Hannover 1981.

DAVEY, R. J.: Dinoflagellate cysts from the Barremian of the Speeton Clay, England. – Birbal Sahni Inst. of Paleobotany, Spec. Pub. **3**, 41–46, 6 Abb., 9 Taf., Lucknow 1974.

DAVEY, R. J.: Marine Apto-Albian palynomorphs from holes 400A and 402A, I. P. O. D. Leg 48, Northern Bay of Biscay. – In: MONTADERT, L., ROBERTS, D. G. et al.: Init. Reps. of the D. S. D. P., **48**, 547–577, 3 Abb., 8 Taf., Washington (U. S. Govt. Printing Office) 1979a.

DAVEY, R. J. & WILLIAMS, G. L.: The genus *Hystrichosphaeridium* and its allies. In: DAVEY, R. J., DOWNIE, C., SARJEANT, W. A. S. and WILLIAMS, G. L.: Studies on Mesozoic and Cainozoic dinoflagellate cysts. – Bull. B. M. (N. H.) Geol. Suppl., **3**, 53–106, 66 Abb., 26 Taf., London 1965B.

DE BOER, P. L.: Cyclicity and the storage of organic matter in Middle Cretaceous pelagic sediments. In: EINSELE, G. & SEILACHER, A. (Eds.): Cyclic event stratification. – 456–475, 6 Abb., Berlin – Heidelberg – New York 1982.

DERES, F. & ACHÉRITÉGUY, J.: Biostratigraphie des Nannoconidés. – Bull. Centre Rech. Explor. – Prod. Elf-Aquitaine, **4**/1, 1–53, 2 Abb., 5 Tab., 9 Taf., Pau 1980.

DUXBURY, S.: A palynostratigraphy of the Berriasian to Barremian of the Speeton Clay of Speeton, England. – Palaeontographica, **B160**, 17–67, 21 Abb., 15 Taf., Stuttgart 1977.

DUXBURY, S.: Barremian phytoplankton from Speeton, east Yorkshire. – Palaeontographica, **B173**, 107–146, 17 Abb., 13 Taf., Stuttgart 1980.

ERDTMAN, G.: An introduction to pollen analysis. – Chronica Botanica Col., 239 p., Waltham, Mass., U. S. A., 1954.

ERDTMAN, G. : Handbook of palynology. – Munksgaard, 486 p., Copenhagen 1969.

EVITT, W. R.: Sporopollenin dinoflagellate cysts: their morphology and interpretation. – A. A. S. P. Foundation, 333 p., Austin 1985.

GAIDA, K. H., GEDENK, R., KEMPER, E., MICHAELIS, W., SCHEUCH, R., SCHMITZ, H.-H. & ZIMMERLE, W.: Lithologische, mineralogische und organisch-geochemische Untersuchungen an Tonsteinen und Tonmergelsteinen der Unterkreide Nordwestdeutschlands (unter besonderer Be-

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rücksichtigung der Schwarzschiefer). – Geol. Jb., **A58**, 15–47, 8 Abb., 2 Tab., 2 Taf., Hannover 1981.

Graham, H. W.: Studies on the morphology, taxonomy and ecology of the Peridiniales. – Publs. Carnegie Inst., **542**, 134 p., Washington 1942.

Harding, I. C.: An early Cretaceous dinocyst assemblage from the Wealden of southern England. – Spec. Paps. in Palaeontology, **35**, 95–106, 4 Abb., 2 Taf., London (1986).

Harding, I. C.: Archaeopyle variability in early Cretaceous partiform gonyaulacoid dinocysts of the genus *Druggidium* Habib. – J. Micropalaeontology, 3 Abb., 2 Taf., London (in press).

Harland, R.: Dinoflagellate cysts and acritarchs from the Bearpaw Formation (Upper Campanian) of southern Alberta, Canada. – Palaeontology, **16**, 665–706, 13 Abb., 5 Taf., London 1973.

Hay, W. W.: Calcareous Nannofossils. In: Kummel, B. & Raup, D.: Handbook of Paleontological Techniques. – 3–7, San Francisco – London 1965.

Hoffmeister, W. S.: Microfossil prospecting for petroleum. – U. S. Patent Office, Patent no. 2, 686, 108, Washington 1954.

Hughes, N. F. & Harding, I. C.: Wealden occurrence of an isolated Barremian dinocyst facies. – Palaeontology, **28**, 555–565, 1 Abb., 3 Taf., London 1985.

Immel, H.: Die Crioceratiten (Ancyloceratina, Ammonoidea) des mediterranen und borealen Hauterive – Barrême (Unterkreide). – Palaeontographica, **A163**, 1–85, 14 Abb., 13 Tab., 9 Taf., Stuttgart 1978.

Immel, H.: Die Ammonitengliederung des mediterranen und borealen Hauterive und Barrême unter besonderer Berücksichtigung heteromorpher Ammoniten der Gattung *Crioceratites* Leveille. – Newsl. Strat., **7**/3, 121–141, 7 Tab., Stuttgart 1979.

Immel, H. & Mutterlose, J.: Barrême-Cephalopoden aus dem kretazischen Untergrund des Stadtgebietes von Hannover (NW-Deutschland). – Paläont. Z., **54**, 3/4, 241–266, 12 Abb., 1 Tab., Stuttgart 1980.

Jordan, R.: Salz- und Erdöl/Erdgas-Austritt als Fazies bestimmende Faktoren im Mesozoikum Nordwest-Deutschlands. – Geol. Jb., **A13**, 1–64, 2 Abb., 1 Taf., Hannover 1974.

Kaufman, E.: Benthic environments and paleoecology of the Posidonienschiefer (Toracian). – N. Jb. Geol. Paläont. Abh., **157**, 1/2, 18–36, 3 Abb., Stuttgart 1979.

Kemper, E.: Geologischer Führer durch die Grafschaft Bentheim und die angrenzenden Gebiete mit einem Abriß der emsländischen Unterkreide. – 5. Aufl., 206 S., Nordhorn – Bentheim 1976.

Kemper, E.: Klima der Kreide-Zeit, Kap. 5.1. (in prep.).

Kemper, E. & Zimmerle, W.: Die anoxischen Sedimente der präoberaptischen Unterkreide NW-Deutschlands und ihr paläogeographischer Rahmen. – Geol. Jb. **A45**, 3–41, 2 Abb., 1 Tab., 3 Taf., Hannover 1978.

Keupp, H. & Michael, E.: Calciodinelloidea aus der Blätterton-Fazies des nordwestdeutschen Unter-Barremium. – Ber. naturhist. Ges. Hannover, **122**, 7–69, 2 Abb., 11 Taf., Hannover 1979.

Koenen, A. v.: Die Ammoniten des nordwestdeutschen Neocom. – Textbd. 451 S., Tafelbd. 55 Taf., Berlin 1902.

Kofoid, C. A.: Exuviation, autotomy and regeneration in *Ceratium*. – Univ. California Publs. Zool., **4**/2, 345–386, 33 Abb., Berkeley 1908.

Kumm, A.: Die Schichtenfolge im Kanaleinschnitt bei Wenden. – Jb. Preuß. Geol. L. A., **57**, 14–47, 2 Abb., 3 Taf., Berlin 1936.

Michael, E.: Mikroplankton und Sporomorphe aus dem nordwestdeutschen Barrême. – Mitt. Geol. Inst. T. H. Hannover, **2**, 22–48, 3 Abb., 5 Taf., Hannover 1964.

Michael, E.: Die Mikrofauna des nordwestdeutschen Barrême. Teil I: die Foraminiferen des nordwestdeutschen Berrême. – Palaeontographica, Suppl. **12**, 176 S., 8 Abb., 22 Tab., 26 Taf., Stuttgart 1967.

Michael, E.: Variations in the number of species of benthonic foraminifera in the Barremian of northwestern Germany. – Palaeogeography, Palaeoclimatology, **4**, 287–303, 5 Abb., 2 Tab., Amsterdam 1968.

Michael, E.: Zur Palökologie und Faunenführung des norddeutschen Unter-Kreide-Meeres. – Geol. Jb. **A 19**, 68 S., 9 Abb., 1 Tab., 3 Taf., Hannover 1974.

Mutterlose, J.: Ontogenie und Phylogenie der Belemnitenart *Hibolites jaculides* Swinnerton, 1937 aus dem Hauterivium (Unterkreide) von NW-Deutschland (Sarstedt) und NE-England (Speeton). – Mitt. geol. Inst. Techn. Univ. Hannover, **16**, 37–117, 22 Abb., 1 Tab., 5 Taf., Hannover 1978.

Mutterlose, J.: Phylogenie und Biostratigraphie der Unterfamilie Oxyteuthinae (Belemnitida) aus dem Barrême (Unter-Kreide) NW-Europas. – Palaeontographica, **A180**, 1–90, 56 Abb., 8 Tab., 10 Taf., Stuttgart 1983.

Mutterlose, J.: Die Unterkreide-Aufschlüsse (Valangin – Alb) im Raum Hannover – Braunschweig. – Mitt. geol. Inst. Univ. Hannover, **24**, 25 Abb., 1 Tab., 1 Taf., Hannover 1984.

Mutterlose, J.: Subtropical belemnites and coccoliths as warmwater indicators from the NW-German Aptian (in prep.).

Perch-Nielsen, K.: Calcareous nannofossils from the Cretaceous between the North Sea and the Mediterranean. In: Wiedmann, J. (ed.): Aspekte der Kreide Europas. – I. U. G. S. Series A, **6**, 223–272, 24 Abb., 2 Taf., Stuttgart 1979.

Rawson, P. & Mutterlose, J.: Stratigraphy of the Lower B and basal Cement Beds (Barremian) of the Speeton Clay, Yorkshire, England. – Proc. Geol. Ass., **94**/2, 133–146, 7 Abb., Edinburgh 1983.

Riding, J. B.: Observations on the Jurassic dinoflagellate cyst *Nannoceratopsis ambonis* Drugg, 1978. – J. Micropalaeontology, **3**, 75–79, 1 Abb., 1 Taf., London 1984.

Riegraf, W.: Mikrofauna, Biostratigraphie und Fazies im Unteren Toarcium Südwestdeutschlands und Vergleiche mit benachbarten Gebieten. – Tübinger mikropaläont. Mitt., **3**, 232 S., 33 Abb., 12 Taf., Tübingen 1985.

Riegraf, W., Werner, G. & Löscher, F.: Der Posidonienschiefer. Biostratigraphie, Fauna und Fazies des südwestdeutschen Untertoarciums (Lias). – 195 S., Stuttgart (Enke) 1984.

Riley, J. & Chester, R.: Introduction to marine geochemistry. – 446 S., London (Academic Press) 1971.

Roth, P.: Calcareous Nannofossils. Leg 17, Deep Sea Drilling Project. – Initial Reports of the Deep Sea Drilling Project, **17**, 695–795, 2 Abb.d, 9 Tab., 27 Taf., Washington 1973.

Roth, P : Cretaceous calcareous nannoplankton diversity and Paleoceanography. – IV. Int. Palynol. Conf. Lucknow (1976–77), **2**, 22–33, 5 Abb., Lucknow 1979.

Roth, P. & Bowdler, J.: Middle Cretaceous calcareous nannoplankton biogeography and oceanography of the Atlantic Ocean. – S. E. P. M. Special Publication, **32**, 517–546, 22 Abb., Tulsa, Oklahoma 1981.

Roth, P. & Krumbach, K.: Middle Cretaceous calcareous nannofossil biogeography and preservation in the Atlantic and Indian Oceans: Implications for paleoceanography (in press).

Sarjeant, W. A. S.: Dinoflagellate cyst terminology: a discussion and proposals. – Can. J. Botany, **60**/2, 922–945, 7 Abb., Ottawa 1982.

Sarjeant, W. A. S. & Stover, L. E.: *Cyclonephelium* and *Tenua*: a problem in dinoflagellate cyst taxonomy. – Grana, **17**, 47–54, Uppsala 1978.

Seilacher, A.: Ammonite shells as habitants in the Posidonia shales of Holzmaden – floats or benthic islands? – N. Jb. Geol. Paläont. Mh., **1982**, 98–114, 10 Abb., Stuttgart 1982.

Sissingh, W.: Biostratigraphy of Cretaceous calcareous nannoplankton. – Geologie en Mijnbouw, **56**, 37–65, 16 Abb., 1 Taf., Amsterdam 1977.

Taylor, R.: Lower Cretaceous (Ryazanian to Albian) calcareous nannofossils. In: Lord, A. (ed.): A stratigraphical index of calcareous nannofossils. – 40–80, 4 Abb., 2 Tab., Chichester (Ellis Horwood Ltd.) 1982.

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THIERSTEIN, H.: Tentative Lower Cretaceous calcareous nannoplankton zonation. – Eclogae geol. Helv., **64/3**, 459–488, 5 Abb., 8 Taf., Basel 1971.

THIERSTEIN, H.: Lower Cretaceous calcareous nannoplankton biostratigraphy. – Abh. Geol. B.-A., **29**, 52 S., 25 Abb., 6 Taf., Wien 1973.

THIERSTEIN, H.: Mesozoic calcareous nannoplankton biostratigraphy of marine sediments. – Marine Micropaleontology **1** (1976), 325–362, 8 Abb., 5 Taf., Amsterdam 1976.

WALL, D. & EVITT, W. R.: A comparison of the modern genus *Ceratium* Schrank, 1973, with certain Cretaceous marine dinoflagellates. – Micropaleontology, **21**, 14–44, 11 Abb., 3 Taf., New York 1975.

WOODS, R. D.: Spores and pollen, a new stratigraphic tool for the oil industry. – Micropaleontology, **1**, 368–375, 2 Abb., 1 Taf., New York 1955.

Plate 1

Calcareous nannofossils from the Hauptblätterton (Lower Barremian) of Gott (NW-Germany)

Fig. 1: Fracture plane of the Hauptblätterton (Gott) illustrating the distribution of calcareous nannofossils (*Nannoconus* sp., *Polypodorhabdus madingleyensis*).
SEM photo, ×3500.

Fig. 2: Thin section vertical to the bedding plane, showing a pale microlense purely built up by calcareous nannofossils.
Thin section 1 from the base of the Hauptblätterton (Gott). LM, ×-nicols, neg. no. 47/3, ×145.

Fig. 3: Cut out from Fig. 2, showing parts of the pale microlense consisting of calcareous nannofossils (mainly *Nannoconus* sp., *Nannoconus abundans*).
Thin section 1 from the base of the Hauptblätterton (Gott). LM, ×-nicols, neg. no. 47/18, ×370.

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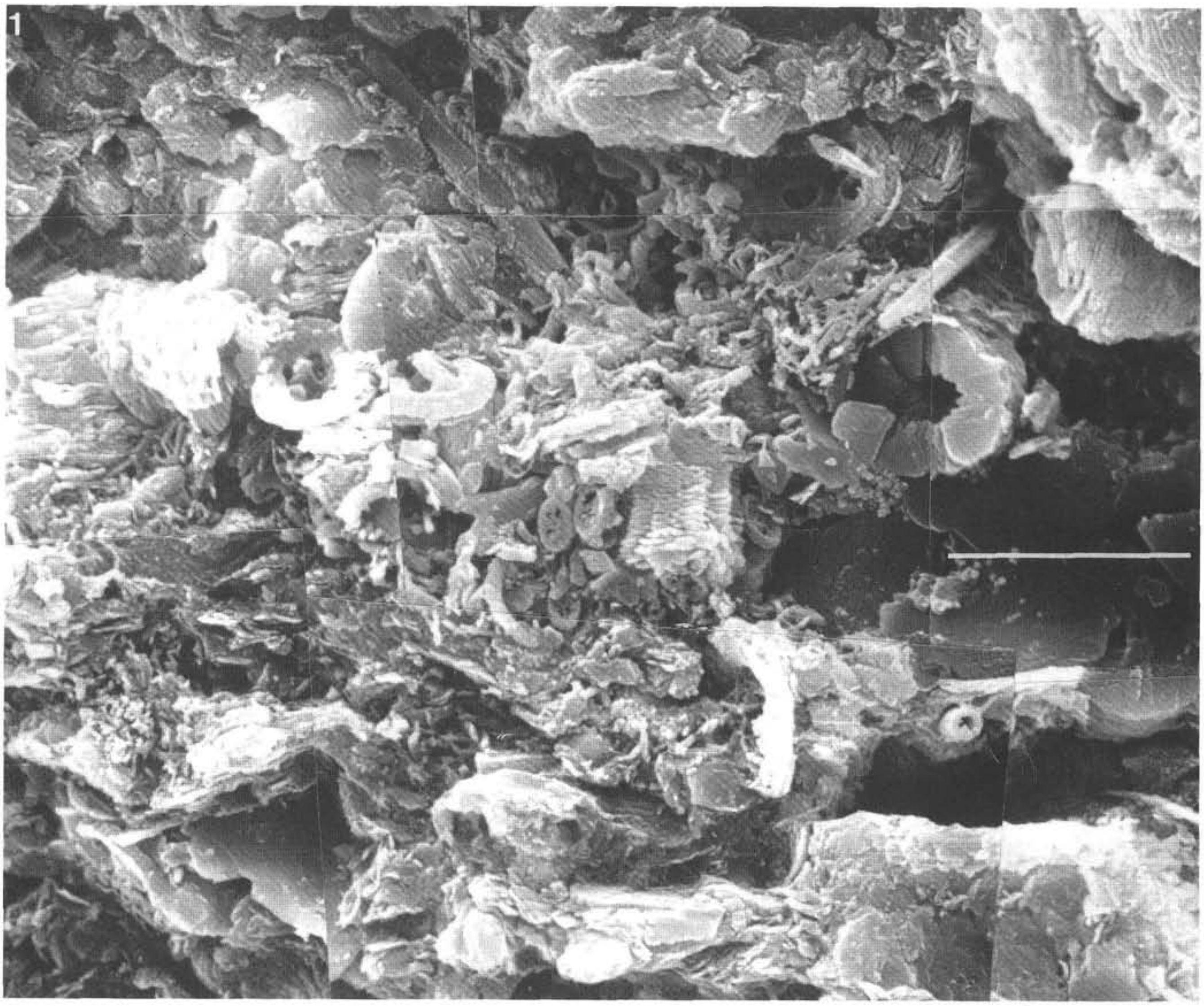

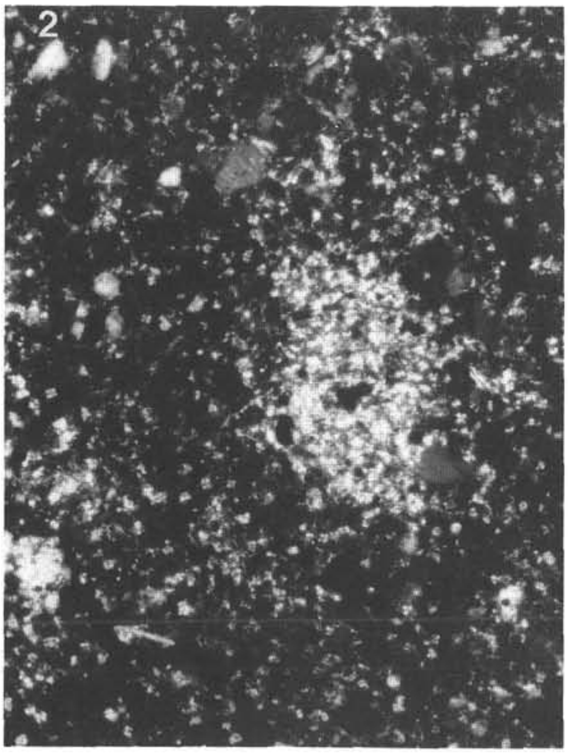

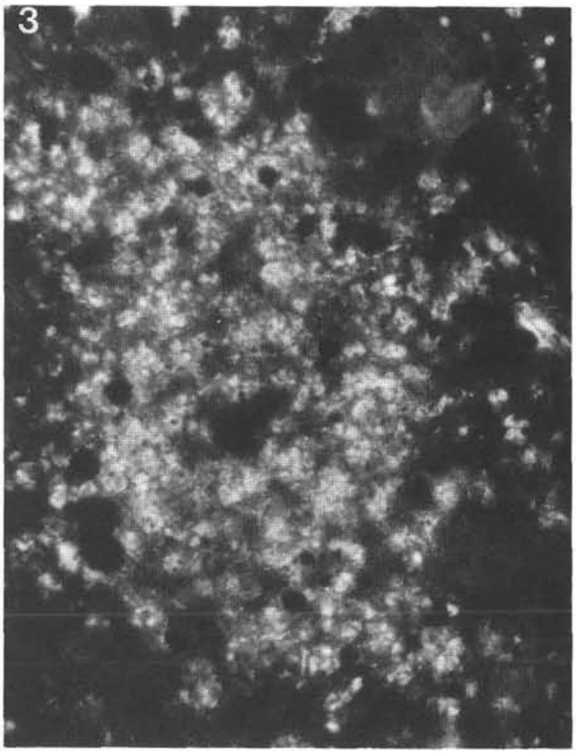

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Plate 2

Calcareous nannofossils from the Hauptblätterton (Lower Barremian) of Moorberg, Aegi, Letter (NW-Germany)

Figs. 1,2: *Micrantholithus obtusus*.
Hauptblätterton (Lower Barremian), Aegi section, sample no. Aegi 46/2/I.
1: LM, Ph, neg. no. 40/22, ×1400.
2: LM, ×-nicols, neg. no. 40/20, ×1400.

Figs. 3,4: *Nannoconus abundans*.
Hauptblätterton (Lower Barremian), Letter section, sample no. Letter 98/2/I.
3: LM, Ph, neg. no. 43/15, ×3000.
4: LM, ×-nicols, neg. no. 43/13, ×3000.

Fig. 5: *Nannoconus* sp.
Hauptblätterton (Lower Barremian), Aegi section, sample no. Aegi 46/3/I.
LM, Ph, neg. no. 41/9, ×1500.

Figs. 6,7: *Nannoconus borealis*.
Blätterton (bed 52), Aegi section, sample no. Aegi 52/1/I.
6: LM, Ph, neg. no. 42/21, ×1500.
7: LM, ×-nicols, neg. no. 42/19, ×1500.

Fig. 8: *Nannoconus elongatus*.
Blätterton (bed 52), Aegi section, sample no. Aegi 52/1/I.
LM, Ph, neg. no. 38/8, ×1500.

Fig. 9: *Nannoconus elongatus*.
Blätterton (bed 52), Aegi section, sample no. Aegi 52/1/I.
LM, Ph, neg. no. 38/18, ×1500.

Figs. 10,11: *Nannoconus abundans*.
Blätterton (bed 60), Aegi section, sample no. Aegi 60/1/I.
10: LM, Ph, neg. no. 43/3, ×2050.
11: LM, ×-nicols, neg. no. 43/1, ×2050.

Figs. 12,13: *Conusphaera mexicana*.
Hauptblätterton (Lower Barremian), Aegi section, sample no. Aegi 46/2/I.
12: LM, Ph, neg. no. 40/13, ×3000.
13: LM, ×-nicols, neg. no. 40/13, ×3000.

Figs. 14,15: *Nannoconus globulus*.
Hauptblätterton (Lower Barremian), Aegi section, sample no. Aegi 46/3/I.
14: LM, Ph, neg. no. 40/25, ×1600.
15: LM, ×-nicols, neg. no. 40/23, ×1600.

Figs. 16,17: *Conusphaera mexicana*.
Blätterton (bed 60), Aegi section, sample no. Aegi 60/1/I.
16: LM, ×-nicols, neg. no. 43/9, ×3300.
17: LM, ×-nicols, neg. no. 43/7, ×3300.

Fig. 18: *Diadorhombus rectus*.
Blätterton (bed 60), Aegi section, sample no. Aegi 60/1/I.
LM, Ph, neg. no. 42/27, ×3000.

Fig. 19: *Lithastrinus septentrionalis*.
Hauptblätterton, Moorberg section, sample no. Moorberg 50/1/I.
LM, ×-nicols, neg. no. 46/11, ×2400.

Figs. 20,21: *Lithastrinus septentrionalis*.
Hauptblätterton, Letter section, sample no. Letter 98/2/I.
20: LM, Ph, neg. no. 43/18, ×2500.
21: LM, ×-nicols, neg. no. 43/16, ×2500.

Figs. 22,23: *Lithraphidites carniolensis*.
Blätterton (bed 52), Aegi section, sample no. Aegi 52/1/I.
22: LM, Ph, neg. no. 38/4, ×1000.
23: LM, ×-nicols, neg. no. 38/2, ×1000.

Figs. 24,25: *Zygodiscus* cf. *elegans*.
Blätterton (bed 58), Aegi section, sample no. Aegi 52/1/II.
24: LM, Ph, neg. no. 36/28, ×3050.
25: LM, ×-nicols, neg. no. 36/25, ×3050.

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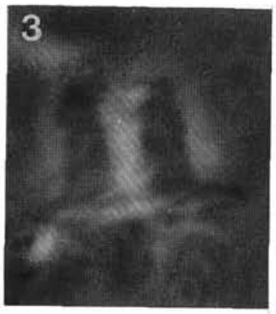

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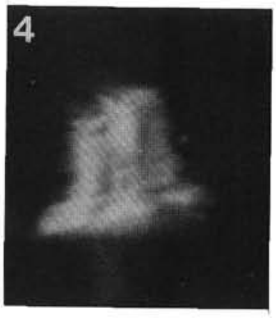

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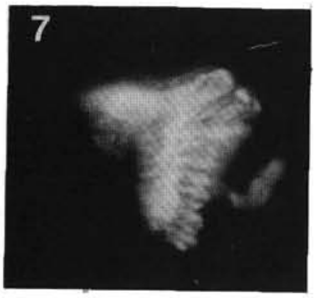

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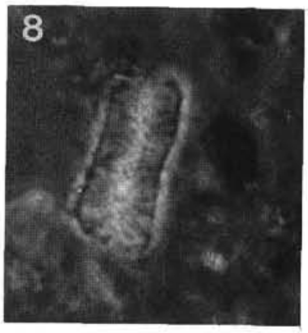

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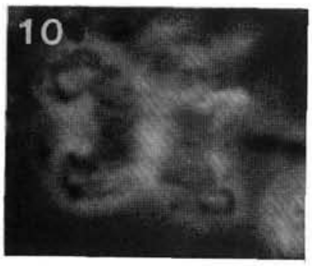

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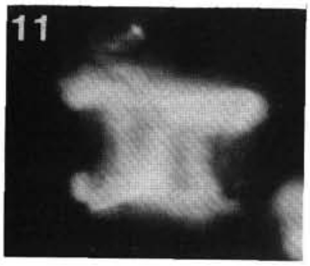

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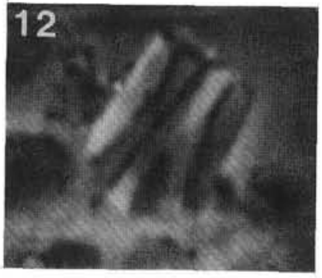

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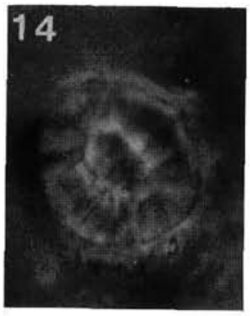

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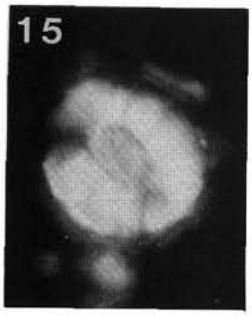

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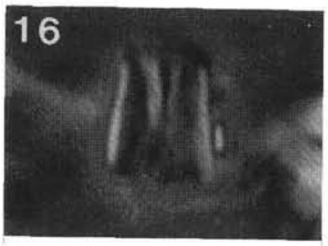

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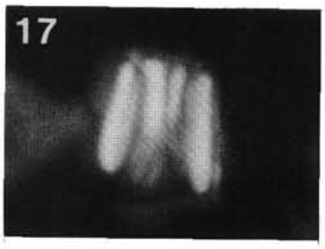

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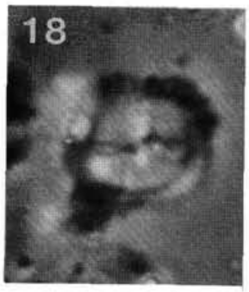

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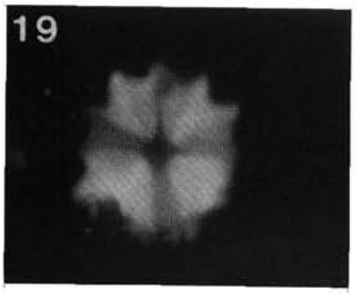

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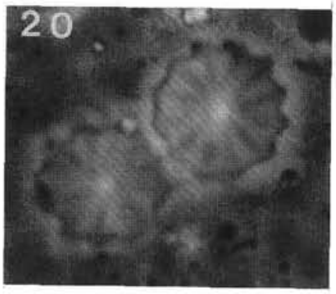

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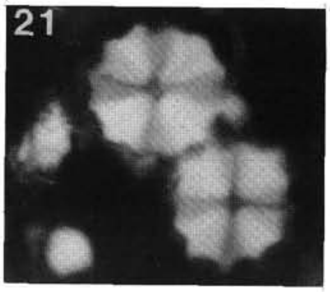

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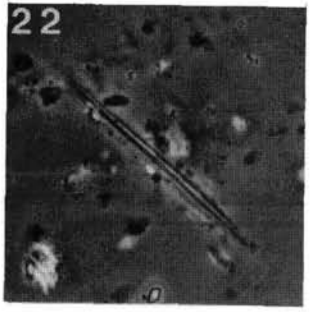

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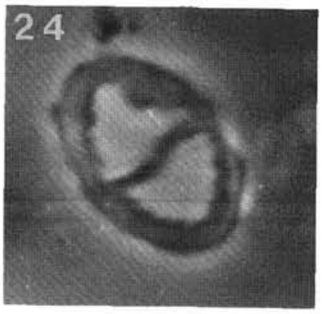

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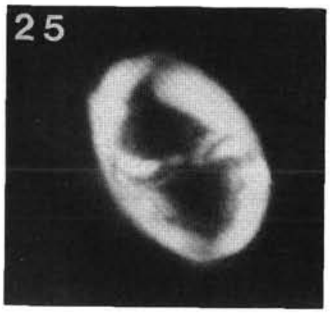

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Plate Explanations for Plates 3 and 4

The following samples (Gott-), residues (CH-, Z- or Davey) and SEM tubs (IC-) were used in the preparation of these plates:

Gott 50/1/79, Z223, IC328 (Pl. 3, fig. 9);
Gott 100/1/83, CH189, IC320 (Pl. 4, fig. 9);
Gott 100/5/83, CH097, IC282 (Pl. 4, figs. 5,10,12);
IC283 (Pl. 3, fig. 12);
IC284 (Pl. 3, fig. 1);
Gott 100/6/83, Davey prep., IC265 (Pl. 3, figs. 2,5,11,13,14; Pl. 4, fig. 1);
Gott 100/7/83, CH099, IC178 (Pl. 3, fig. 7; Pl. 4, figs. 2,6);
Gott 100/8/83, CH100, IC297 (Pl. 4, figs. 8,11);
IC299 (Pl. 3, fig. 10);
IC300 (Pl. 3, fig. 4);
Gott 100/9/83, CH101, IC303 (Pl. 3, figs. 6,8);
Gott 100/11/83, CH103, IC309 (Pl. 3, fig. 3);
IC310 (Pl. 4, fig. 3);
IC311 (Pl. 4, fig. 4);
Gott 100/12/83, CH104, IC314 (Pl. 4, fig. 7).

Plate 3

Dinocysts from the Hauptblätterton (Lower Barremian) of Gott (NW-Germany)

Fig. 1: *Gonyaulacysta fastigiata.*
Ventral view. Film 181/32. Grid. ref. 203/772. ×800.

Figs. 2,9,10: *Gonyaulacysta exsanguia.*
2: Ventral view. Film 174/25a. Grid. ref. 299/739. ×800.
9: Detail of acanthate parasutural crests. Film 244/17. Grid. ref. 342/754. ×3200.
10: Detail of undulate parasutural crests showing characteristic perforations. Film 202/25. Grid. ref. 328/758. ×3200.

Fig. 3: *Rhynchodiniopsis fimbriata.*
Ventral view. Film 211/05a. Grid. ref. 239/736. ×400.

Figs. 4,8: *Pseudoceratium pelliferum.*
4: Long-horned morph, dorsal view. Film 204/01. Grid. ref. 255/847. ×400.
8: Short-horned morph, dorsal view. Film 200/17. Grid. ref. 221/724. ×400.

Figs. 5,6: *Cleistosphaeridium* sp. nov.
5: Showing apical archaeopyle, operculum still attached. Film 176/37. Grid. ref. 325/825. ×800.
6: Detail of processes and wall ornamentation. Film 200/10. Grid. ref. 185/806. ×3200.

Fig. 7: *Meiourogonyaulax amalsis.*
Ventral view. Film 188/04. Grid. ref. 328/883. ×800.

Fig. 11: Dinocyst gen. nov., sp. nov.
Showing characteristic tapering blade-like processes. Film 172/24. Grid. ref. 252/863. × 800.

Fig. 12: *Trichodinium 'castanea'.*
Dorsal view showing 3″ archaeopyle. Film 184/02. Grid. ref. 268/806. ×800.

Figs. 13,14: *Trichodinium speetonensis.*
13: Dorsal view showing 3″ archaeopyle. Film 173/11. Grid. ref. 318/893. ×800.
14: Ventral view showing "flagellar markings". Film 177/20b. Grid. ref. 305/764. ×720.

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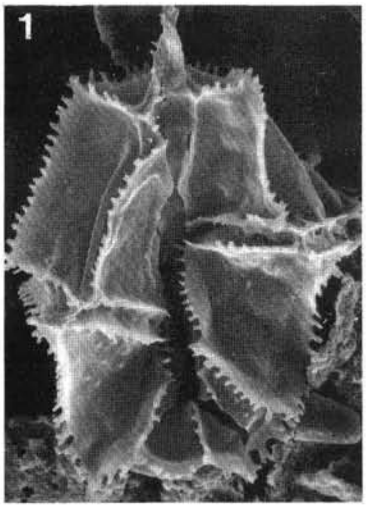
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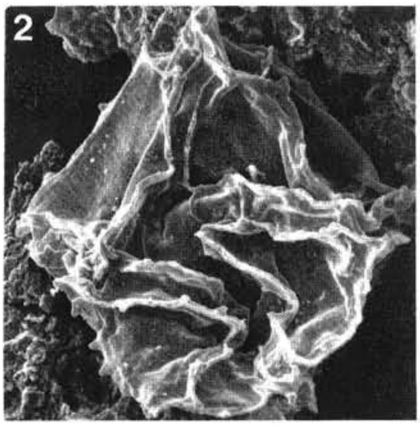
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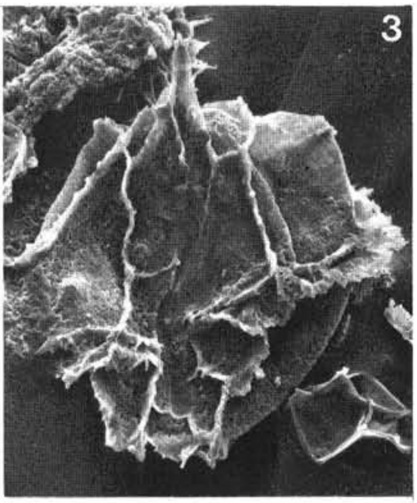
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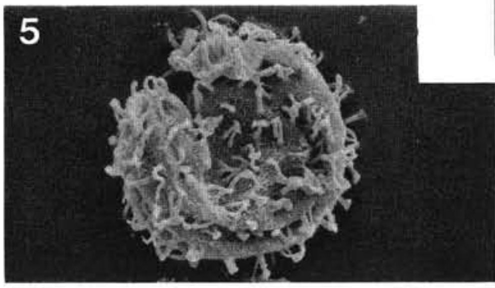
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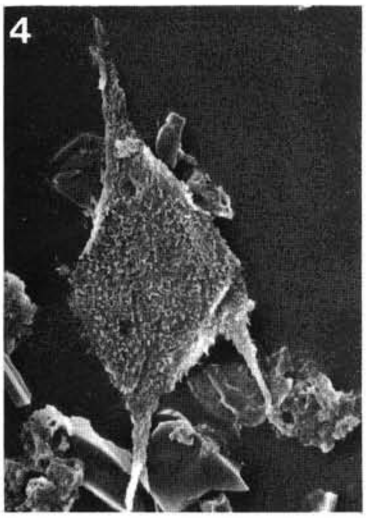
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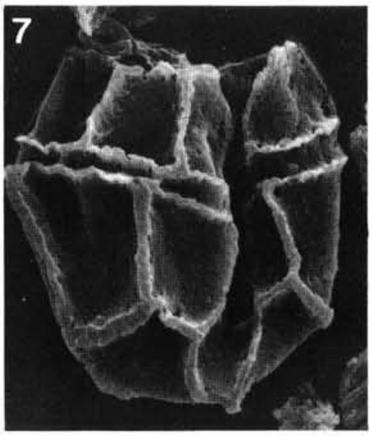
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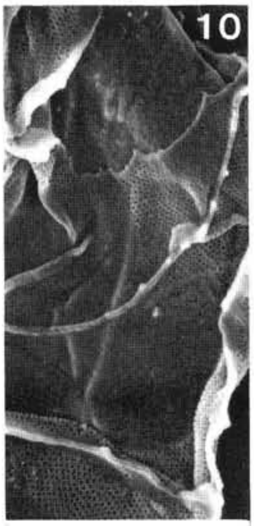
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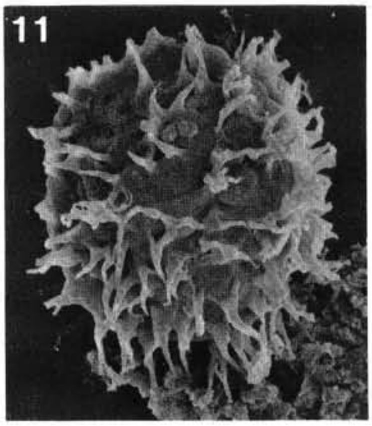
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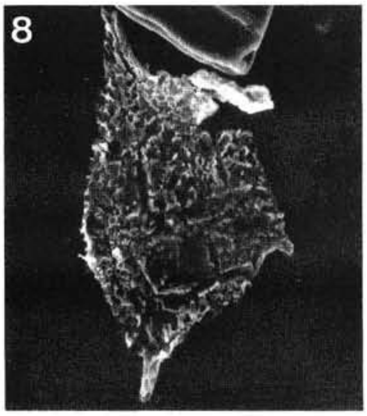
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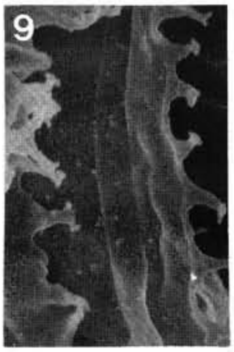
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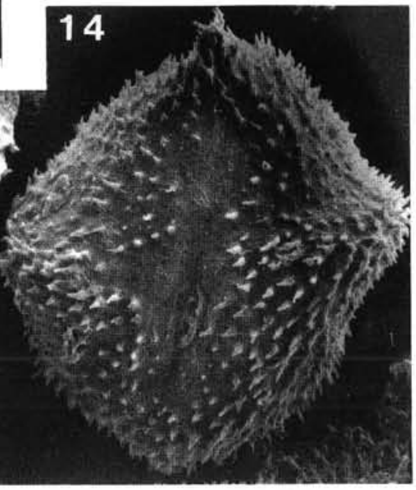
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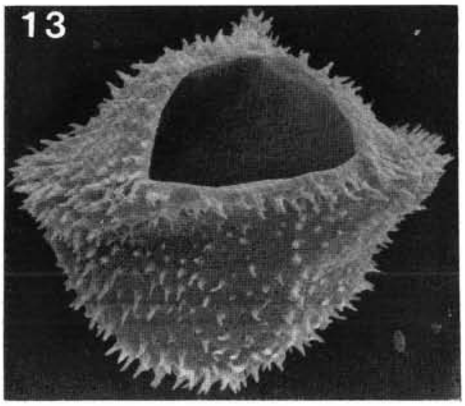
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Plate 4

Palynomorphs from the Hauptblätterton (Lower Barremian) of Gott (NW-Germany)

Figs. 1,2: *Aptea anaphrissa*.
Two specimens illustrating the range of morphological variation.
1: Dorsal view. Film 172/01. Grid. ref. 293/910. ×400.
2: Ventral view. Film 191/31. Grid. ref. 232/877. ×400.

Fig. 3: *Cyclonephelium distinctum*.
Showing attached apical operculum. Film 217/10. Grid. ref. 298/833. ×800.

Figs. 4,5: *Oligosphaeridium abaculum*.
4: Complete specimen, dorsal view, apical archaeopyle suture visible. Film 213/13. Grid. ref. 300/829. ×400.
5: Detail of periphragmal surface sculpture. Broken process base revealing less pronounced sculpture of endophragm. Film 183/03. Grid. ref. 225/755. ×3200.

Fig. 6: *Hystrichosphaeridium arborispinum*.
Apical archaeopyle suture displayed. Film 190/33. Grid. ref. 230/788. ×800.

Fig. 7: *Subtilisphaera terrula*.
Dorsal view. Film 212/11. Grid. ref. 322/855. ×800.

Fig. 8: *Druggidium augustum*.
Ventral view showing spatulate parasulcus. Film 206/08. Grid. ref. 305/774. ×1600.

Fig. 9: *Druggidium jubatum*.
Ventral view showing typical high parasutural crests. Film 218/04. Grid. ref. 228/874. ×1600.

Fig. 10: *Batiacasphaera* sp. nov.
Dorsal view with displaced operculum. Film 183/05. Grid. ref. 238/718. ×1600.

Fig. 11: Acritarch, gen. nov., sp, nov.
Showing distinctive ornamentation. Film 271/09. Grid. ref. 204/793. ×3200.

Fig. 12: *Cymatiosphaera* sp. nov.
Polygonal fields bordered by rings of tubercles. Film 182/33. Grid. ref. 188/848. ×1600.

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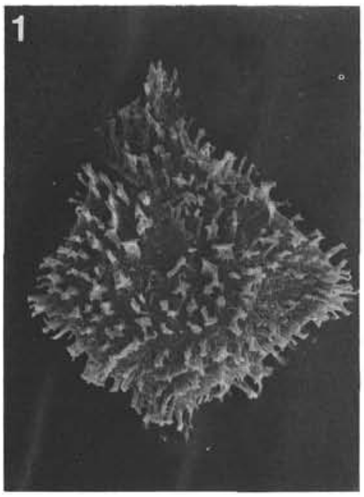
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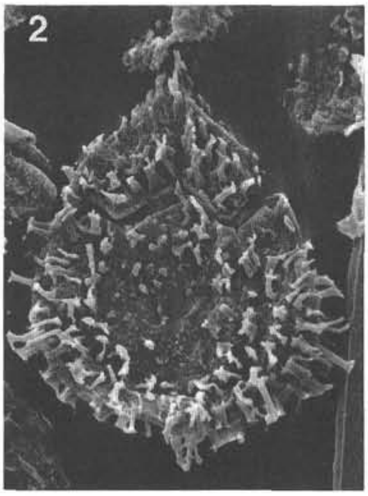
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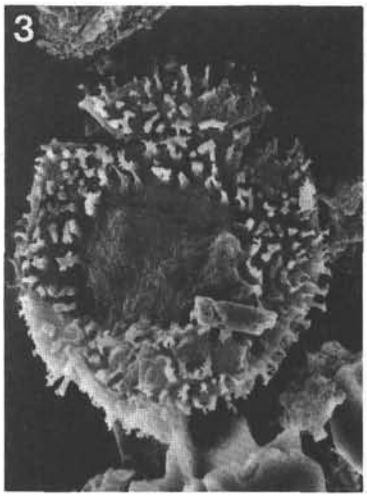
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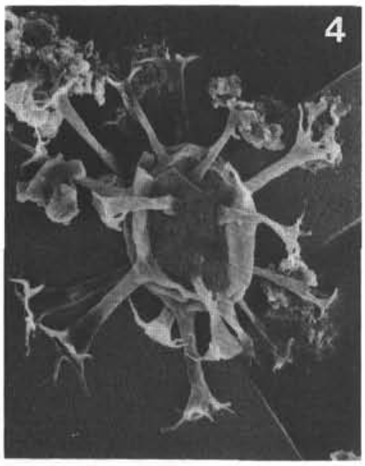
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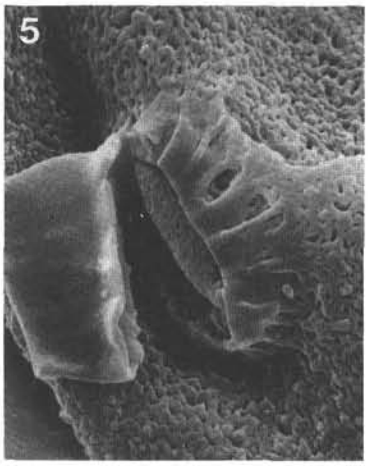
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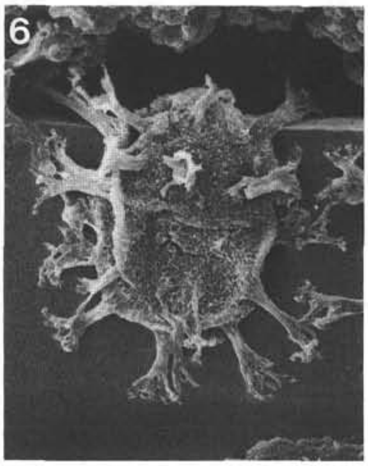
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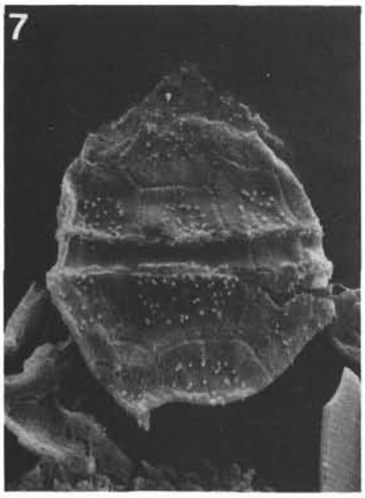
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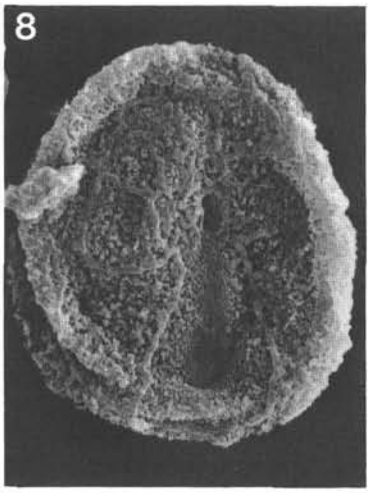
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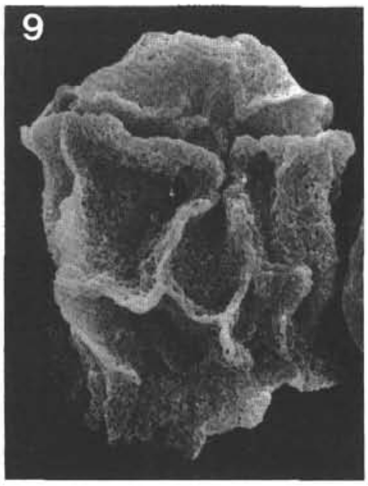
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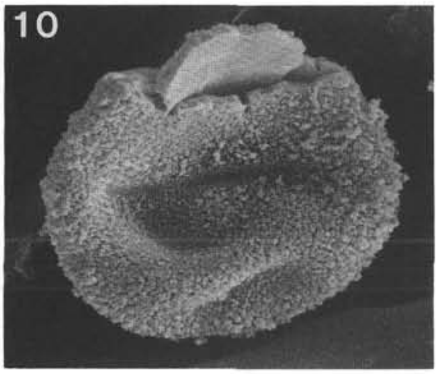
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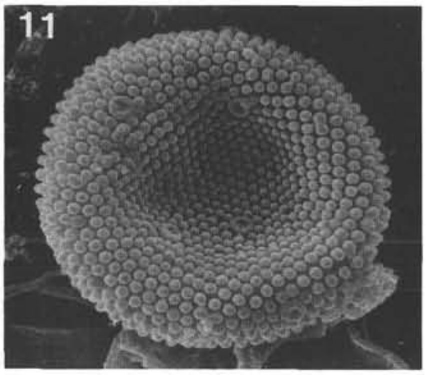
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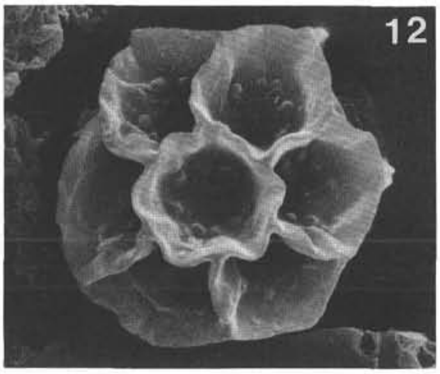
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Zoologisch-Botanische Datenbank/Zoological-Botanical Database

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