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EARLY CRETACEOUS AGGLUTINATED FORAMINIFERA FROM LIMESTONE - MARL RHYTHMITES OF THE GRESTEN KLIPPEN BELT, EASTERN ALPS (AUSTRIA)

by

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With 10 figures and 3 plates

ZUSAMMENFASSUNG

In der Grestener Klippenzone (Österreich) wurden die Kalk-Mergel-Rhythmite der Oberen Blassenstein Schichten untersucht. Unterschiede in der Lithologie, Ichnofazies und im Gehalt an organischem Kohlenstoff demonstrieren zwei Sedimentationstypen, die vor allem mit einer unterschiedlichen Durchlüftung des Bodenwassers zusammenhängen. Generell handelt es sich um graue Nannomikrite mit dunklen Bioturbationen.

Den Mineralbestand bilden 75-95% Karbonat, etwas Quarz, Plagioklas und Tonmineralien. Die durchschnittliche Bankmächtigkeit beträgt 15-20 cm. Dazwischen eingeschaltet sind dunkelgraue bis schwarze Mergel und Tonmergel mit etwa 5 cm Mächtigkeit. Deren Karbonatgehalt schwankt zwischen 10 und 70%; der unlösliche Rückstand besteht aus Tonmineralien (Glimmer, Chlorit, Smektit), Quarz und Plagioklas.

Der Litho-Typ I zeigt zwischen Kalk- und Mergellagen scharfe Kontakte und deutliche Änderungen im Karbonatgehalt. Der Gehalt an C_{org} erreicht bis 2,39%. In den Kalken kommt nur *Chondrites* als Spurenfossil vor, die Mergel sind nicht bioturbat. Der Litho-Typ II zeigt graduelle Übergänge zwischen Kalken und Mergeln, der C_{org} -Gehalt ist geringer. Die Spurenfossilien sind divers, dominiert von *Chondrites*, *Planolites* und *Zoophycos*. Kalke und Mergel sind gleicherweise bioturbat.

Die kleinwüchsige Foraminiferenfauna läßt nicht immer eine direkte Korrelation zu den Litho-Thypen zu, da aus den Kalken nur Lösungsrückstände vorliegen. Man kann jedoch drei ökologische Vergesellschaftungen unterscheiden, die von Ablagerungstiefe und Durchlüftung des Bodenwassers beeinflußt sind:

1) *Dorothia haueriviana* Vergesellschaftung. Dominierend sind agglutinierte Arten mit *D. haueriviana*, *Glomospirella gaultina*, *Rhizammina*, *Hyperammina* und *Reophax*. Diese Vergesellschaftung tritt in beiden Litho-Typen auf. Im weltweiten Vergleich ist sie an offene, produktive Karbonatschelfbereiche gebunden, bei denen vom inneren Schelf bis zum tieferen Kontinentalabhang der Anteil der Kalkschaler kontinuierlich abnimmt. 2) *Ammobaculoides carpathicus* Vergesellschaftung. Wahrscheinlich eine laterale Vertretung der *Dorothia* Vergesellschaftung, mit dominierend *A. carpathicus*, *Bigenerina? gracilis*, *Haplophragmoides* und *Trochammina*; Kalkschaler sind selten. Diese Fauna wurde nur in Litho-Typ II bei den geringsten Gehalten von organischem Kohlenstoff gefunden und lebte wahrscheinlich in einem Bereich besserer Durchlüftung. Sie ist bisher nur aus dem Flysch der polnischen Karpaten bekannt. 3) *Lenticulina eichenbergi* Vergesellschaftung. Verschiedene Lenticulinen, *Nodosaria*, *Dentalina*, *Marginulinopsis*, *Vaginulinopsis* und *Spirillina neocomiana* kennzeichnen diese Faunengemeinschaft. Agglutinierte Arten sind selten. Ähnliche Faunen werden als charakteristisch für den Ablagerungsbereich des mittleren Schelfs interpretiert.

Zusammenfassend lassen sich für die Oberen Blassenstein Schichten Ablagerungsbedingungen im Bereich mittlerer Schelf bis Bathyal, oberhalb der CCD (Auflösungstiefe für Kalziumkarbonat), annehmen. Schwankende Durchlüftungsbedingungen des Bodenwassers führten teilweise zu dysaeroben Bedingungen, die sich in Lithofazies und agglutinierte Foraminiferenfauna widerspiegeln. Nach kalkigem Nannoplankton und Foraminiferen sind die Schichten in die Unterkreide (Hauterivien - ?Barremien) einzustufen.

ABSTRACT

The lithology and micropaleontology of limestone-marl rhythmites have been investigated from the Early Cretaceous Upper Blassenstein member of the Gresten Klippen Belt (Austria). Differences in lithology, ichnofacies and C_{org} -content allow to distinguish two different sedimentary environments, which correspond to well-oxygenated and dysaerobic conditions. The deposition of nannomicrites and black pelites is probably related to climatic cycles. Sedimentary features do not indicate turbiditic sedimentation. Nannoplankton assemblages consist of low-latitude species (tropical/subtropical).

The foraminifera fauna exhibits mainly dwarfed agglutinated forms which reflect a deep-water, low oxygen environment. Three foraminiferal assemblages have been distinguished: (1) *Dorothia hauteriviana* assemblage, corresponding to bathyal deposition environments in the North Atlantic off Morocco; (2) *Ammobaculoides carpathicus* assemblage, dominated by the nominate species and *Bigenerina gracilis*, a fauna explained as an ecological substitution of the *D. hauteriviana* assemblage, which has equivalents only in the Polish Carpathian flysch; (3) *Lenticulina eichenbergi* assemblage, a fauna of lenticulinas and other nodosariids, indicative of a shelf environment.

Based on the biostratigraphy of nannoplankton and foraminifera, the investigated sections are assigned to the Hauterivian-?Barremian.

INTRODUCTION

The present paper deals with the micropaleontology of Early Cretaceous limestone-marl rhythmites from an external tectonic unit of the Eastern Alps. Geographically, the sections are situated near Waidhofen an der Ybbs, in western Lower Austria.

Previous work on the geology of this area has been done by Trauth (1950, 1954), Schnabel (1970) and others (see Tollmann 1985, p. 321 for a review of literature), but little attention has been paid to the micropaleontology of the Early Cretaceous formations. Thus, this article provides the first detailed work on microfossils and facies of the Neocomian of the Gresten Klippen Belt.

One of the specific goals of the work is to correlate the foraminiferal fauna to a certain paleoenvironment. For this reason, detailed studies of the sedimentology (e.g., including determinations of C_{org} -contents) were carried out, and samples were collected from five sections for a concurrent study of microfaunal assemblages and ichnofacies. The stratigraphic correlation of these sections was done by nannofossil biostratigraphy.

Foraminiferal faunas are dominated by agglutinated forms. Therefore washed marl samples and samples from micritic limestones, dissolved in acetic acid, were investigated. As a larger part of the fauna consists of calcareous agglutinated species, an ecological comparison of the different residues was not possible. For paleoecological and biostratigraphic interpretations, similar faunas from the western Tethys, the Carpathians, Northern Germany and the North Atlantic have been taken in consideration.

Investigated samples and figured specimens are deposited in the Micropaleontological Collection of the Museum of Natural History in Vienna.

GEOLOGIC SETTING

The Gresten Klippen Belt is an external tectonic unit of the Eastern Alps. Today it is intercalated within the nappes of the Rhenodanubian Flysch, all overthrust by the Northern Calcareous Alps (figure 1).

The sedimentary sequence of the Gresten Klippen Belt was deposited originally on a granitic crystalline basement comparable to the eastern part

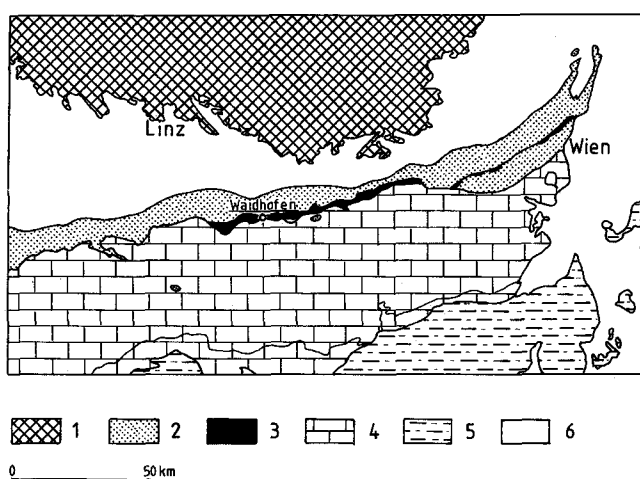


Fig. 1.
Tectonic sketch map of the northeastern Alps with the position of the Gresten Klippen Belt, after BECK-MANNAGETTA & MATURA (1980).
1 = Crystalline of the Bohemian Massif; 2 = Rhenodanubian Flysch Zone; 3 = Gresten Klippen Belt; 4 = Northern Calcareous Alps and Grauwacken-zone; 5 = Central Alps units; 6 = Tertiary Basins.

of the Bohemian Massif (Faupl 1975; unit 1 in figure 1), far south of its recent position. Sedimentation started in the Lias with fluvial deposits developing into shallow-water marine and paralic facies with coal formation. This sequence is overlain by marine sediments of increasing depth, reaching a maximum subsidence with the deposition of carbonate-free cherts in the Late Dogger. In the Malm, a turbiditic sequence of pelagic and (in the Late Malm) calcareous turbidites developed. These clastics were deposited in a slope to basinal position. In the Tithonian, the turbidites grade laterally into non-clastic micritic *Aptychus*-limestones of the Blassenstein formation (Lower Blassenstein member). Superimposed on the turbiditic and non-turbiditic units are the uniform limestone-marl rhythmites of the Neocomian Upper Blassenstein member.

The sedimentary sequence of the Gresten Klippen Belt can be explained as a transgressive series overlying a subsiding passive continental margin adjacent to the Bohemian Massif, which formed the northern margin of the Tethys in Jurassic time. In the Tertiary, the sediments of the Gresten Klippen Belt were scraped off from basement, moved northwards and overthrust by the nappes of the Rhenodanubian Flysch and Northern Calcareous Alps. Included in the tectonic of the Flysch, the Gresten Klippen appear today in small isolated intensively tectonized units within the Rhenodanubian Flysch.

LOCALITIES

All investigated samples are from limestone-marl rhythmites of the Upper Blassenstein member (Gresten Klippen Belt). The sections are situated near Waidhofen an der Ybbs, in western Lower Austria (figure 2).

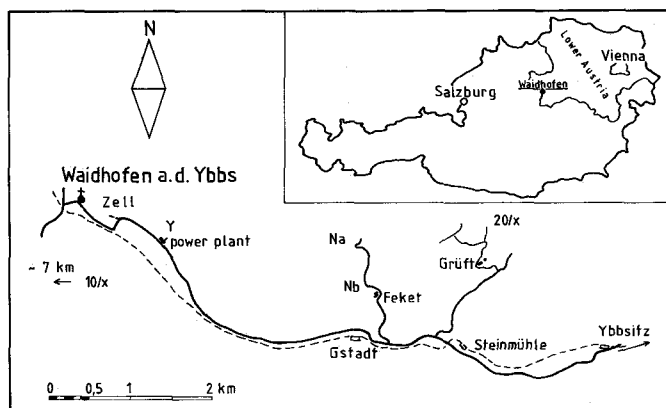


Fig. 2.

Location of the investigated sections of the Upper Blassenstein Member near Waidhofen an der Ybbs, western Lower Austria (Austrian Map 1:50.000, sheets 70 Waidhofen an der Ybbs, 71 Ybbsitz).

Section Na: Arzberggraben 3.5 km E of Waidhofen, roadcut 650 m NNW of the Feket farm. A detailed profile of the section is given in figure 3.

Section Nb: Arzberggraben 3.75 km ESE Waidhofen, roadcut 150 m W of the Feket farm. Profile Nb in figure 3.

Section Y: Waidhofen an der Ybbs, suburb Zell, outcrop on the northern bank of the Ybbs river next to the electric power station. See figure 3 for the detailed profile of the section.

Hochkogel: 7 km W of Waidhofen, northwestern flank of the hillside, roadcut 200 m WNW of the Pichl farm. All samples (10/12, 10/13, 10/14) are from a 2 m thick section.

Ybbsitz-Schwarzenberg: 5 km E Waidhofen, a little quarry 500 m N of the Gräft farm. The samples 20/7, 20/8 and 20/9 were taken from a 2 m thick section.

LITHOLOGY

Sediments of the Upper Blassenstein member are typical limestone-marl rhythmites. Mudstones are gray nannomicrites, mottled black by bioturbation, with an average bed thickness of 15 to 20 cm. The macrofossil content shows common occurrences of calcitic *aptychi* but only sporadic preservation of aragonitic ammonites. Carbonate content varies from 75 to 95%. The insoluble residue consists of quartz, clay minerals (mainly micas) and some plagioclase feldspar. The organic carbon content (C_{org}) varies between 0.24 and 0.55%, with an mean value of 0.35.

These values have to be interpreted with some caution, as outcrop samples have been analyzed, which may have lost up to 50% of their C_{org} by weathering (Clayton and Swetland 1978; Leythaeuser 1973). The percentages therefore must be regarded rather as minimum contents.

Intercalated pelites are gray to almost black marls with carbonate contents between 10 and 70% and an average thickness of about 5 cm. Clay minerals (micas, chlorite and smectite), quartz and plagioclase form the insoluble residue. C_{org} -contents of the pelites are distinctly higher than those of limestones (up to 2.39%; 0.80% on average).

According to the development of limestone-marl contacts, two types of rhythmites can be distinguished (figure 4).

Litho-type I: The first type is characterized by distinct limestone-marl intercalations, e.g. section

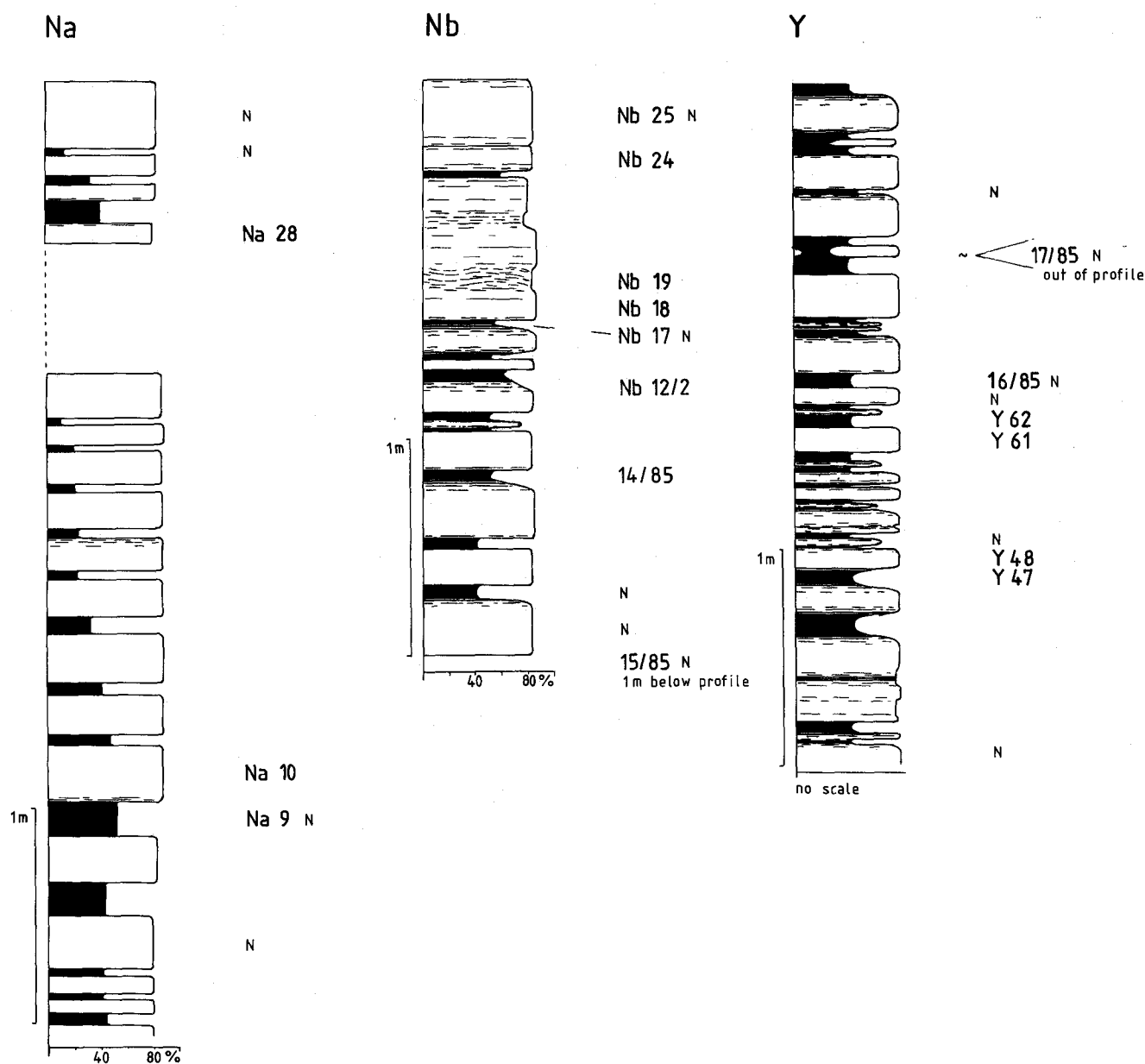
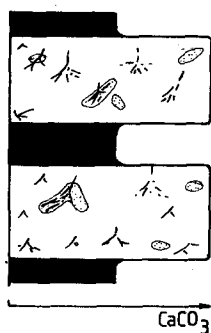


Fig. 3.
Lithological profiles of the main sections of the Upper Blassenstein member and position of samples.
Na = Arzberggraben, section A; Nb = Arzberggraben, section B; Y = Waidhofen - Zell, section at the Ybbs river.

Litho-type I



Litho-type II

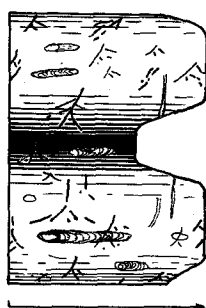


Fig. 4.
Rhythmite facies of the Upper Blassenstein member.
Litho-type I with sharp limestone-marl contacts; small and large *Chondrites* are the only trace fossils occurring in limestones.
Litho-type II displaying gradational limestone-marl contacts and a diverse trace fossil assemblage, both limestones and marls are burrowed.

Na, with sharp contacts and abrupt changes in carbonate contents. The limestone-marl ratio is about 3 to 4. Marls have C_{org} -contents up to 2.39%. As *Chondrites* is the only trace fossil occurring in the limestones and as marls are not burrowed, this type also differs from litho-type II by the ichnofacies.

Litho-type II: The most conspicuous characteristics of this sediment type are gradational contacts of limestones and marls with gradual changes in carbonate contents. The limestone-marl ratio is about 4 to 5, and C_{org} -contents are somewhat lower than in litho-type I sediments. Trace fossil assemblages, which are dominated by *Chondrites*, *Planolites* and *Zoophycos*, are more diverse. Both limestones and marls are bioturbated.

SEDIMENTOLOGY OF LIMESTONE-MARL RHYTHMITES

The formation of limestone-marl rhythmmites can be caused by an interplay of periodic changes in carbonate supply, e.g. calcareous nannoplankton productivity, changes in the supply of terrigenous clay and possibly by changes in carbonate solution (Einsele 1982).

In the Neocomian Blassenstein formation, these periodic changes are accompanied by changes in the oxygenation of bottom waters. In litho-type I sequences, low oxygen conditions coincide with the deposition of clay-rich sediments, producing black marls with high contents of organic carbon (figure 5), lacking any bioturbation. Climatic periodicities have been considered a cause of these continuous fluctuations (Arthur 1979; Weissert *et al.* 1979), affecting plankton productivity as well as the supply of siliciclastic detritus, and the exchange of oceanic bottom waters, thereby governing the oxygen content of the water.

Section	Limestones Sample C _{org}		Marls Sample C _{org}		Rhythmite facies
Na	28	0.41	29	2.39	Litho-type I
	10	0.27	9	0.63	
	6	0.41	5	0.52	
Nb top	19	0.55	17	0.67	Litho-type II
	18	0.34	13	0.50	
	base	1	0.35	2	Litho-type I
Y	78	0.29	77	0.32	Litho-type II
	61	0.29	62	0.47	
	48	0.26	47	0.44	
	42	0.24	41	0.14	

Fig. 5.
Percentages of organic carbon contents in the Neocomian Blassenstein formation.
Note differences between litho-type I and II rhythmmites and low values in section Y.

Another model for the deposition of limestone-marl interlayers are turbiditic redepositions of lime mud (Hesse 1975; Kelts and Arthur 1981). As these "pelagic" turbidities are difficult to recognize, redeposition cannot be ruled out with certainty, especially in litho-type I sequences with sharp lithological contacts. Otherwise, there are no indications for resedimentation like tiering of burrows or traces which are frequently associated with turbidites, e.g. escape burrows. Sediment deformation structures like those reported from allochthonous chalks by Watts *et al.* (1980) or deformed traces are absent in the sections investigated, therefore turbiditic redeposition of lime mud is not likely.

ICHNOFACIES

Two types of ichnofacies can be discerned in the rhythmmites, differing both in diversity and intensity of bioturbation: a *Chondrites* assemblage (I), which is bound to the litho-type I rhythmmites and a diverse assemblage (II), occurring in litho-type II sequences.

I. *Chondrites* assemblage: The only trace fossils occurring are large burrows, 5 to 10 mm in diameter, and two groups of smaller *Chondrites* (2 mm and 0.5 to 1 mm in diameter). Intensity of bioturbation is low. Cross-cutting relations show that the smallest *Chondrites* are the youngest burrows. They preferentially follow older burrows (composite burrows). All traces are sharply defined and were emplaced in already consolidated sediment (soft to firm ground; plate 3, figure 10).

II. *Chondrites-Zoophycos-Trichichnus-Planolites* assemblage: In this facies burrowing of the sediment starts soon after the deposition of carbonate mud in an unconsolidated substrate ("soupground" environment), therefore the oldest traces are poorly defined. The above listed assemblage was emplaced later in soft to firm sediment. Different size *Chondrites* types are distinguished (8 to 15 mm, 2 mm and 0.5 to 1 mm in diameter). The smallest type cuts all other traces and is the youngest of the assemblage. *Zoophycos* traces are small, and vary between 6 and 8 mm in diameter. Linear or slightly curved walled-burrows normal to the sediment surface are assigned to *Trichichnus*. The walls of these burrows are pyritized. *Planolites* burrows are unbranched, mostly linear parallel to the sedimentary surface, with diameters of 3 to 6 mm (plate 3, figure 11).

The trace fossil assemblages described above are typical for pelagic micritic limestones. Similar assemblages have been reported both from micritic shelf-sea chalks of shallow paleodepths of a few hundred meters (e.g. the North Sea chalk: Ekdale *et al.* 1984) and from deep-sea carbonate micrites deposited in a few thousand meters depth (e.g. from the Atlantic Ocean: Ekdale 1980; Ekdale *et al.* 1984). The distribution of traces therefore seems to respond to other environmental parameters rather than to paleodepth. Accordingly, paleobathymetric interpretations of trace fossil assemblages are difficult.

Still, comparative studies of trace fossil assemblages in shelf-sea and deep-sea chalks show some differences of ichnofacies, like different abundances of *Thalassionides* burrows, which are much more prominent in shelf-sea chalks than in deep-water micrites (Ekdale and Bromley 1984; Ekdale *et al.* 1984; Warme *et al.* 1973). As *Thalassionides* burrows are almost absent from the Neocomian part

of the Blassenstein formation, these micrites seem to be of deep-water origin.

Diversity of trace fossils and intensity of bioturbation correspond to oxygenation of the environment rather than to paleodepth (Ekdale 1985; Ekdale *et al.* 1984; Saverda and Bottjer 1986). Diverse assemblages and intensive bioturbation like in the second ichnofacies (*Chondrites-Zoophycos-Trichichnus-Planolites* assemblage) correspond to a well-oxygenated environment. The low-diversity *Chondrites* assemblage indicates poor oxygenation or dysaerobic conditions. Higher C_{org} -contents in sections with the *Chondrites* assemblage (e.g. section Na; figure 5) support this interpretation.

The trace producers, especially those of *Chondrites* burrows lived in sediments some tens of centimeters below the sediment-water interface (Berger *et al.* 1979; Bromley and Ekdale 1986). Sharply defined and well contrasted burrows, which were emplaced in already consolidated sediments, show that this is also true for the micrites of the Upper Blassenstein member.

Some of the poorly defined traces in the unconsolidated sediment may be caused by agglutinated foraminifera. The infaunal habitat (comp. Jones and Charnock 1986) and the producing of traces in the upper layers of soft sediments by agglutinated foraminifera is reported by Kaminski *et al.* (this volume) from the deep sea.

NANNOFOSSIL BIOSTRATIGRAPHY

Rich nannofloras from marls and mudstones of the Upper Blassenstein member allow a fairly good stratigraphical correlation of the sections. The specimens were determined by light microscopy. REM examinations showed poor preservation of coccoliths due to overgrowth and carbonate solution, which is also evidenced by the dominance of solution resistant forms as *Watznaueria* in all samples (Roth and Bowdler 1981). The nannoflora contains low-latitude species, indicative for tropical to subtropical conditions (Thierstein 1976). A stratigraphical distribution of the most important coccoliths and nannoconids is given in figure 6.

The age of sections Nb and Y is determined as Valanginian/Hauterivian (zones CC 3-4 after Sissingh 1977) by the co-occurrence of *Calcicalathina oblongata* and *Cruciellipsis cuvillieri*. The species *C. oblongata* restricts the age of the Hochkogel section to zones CC 3-5. A Late Hauterivian/Early Barremian age (zones CC 4b-5) is indicated for the Ybbsitz-Schwarzenberg section by the co-occurrence of *Eprolithus antiquus* with *C.*

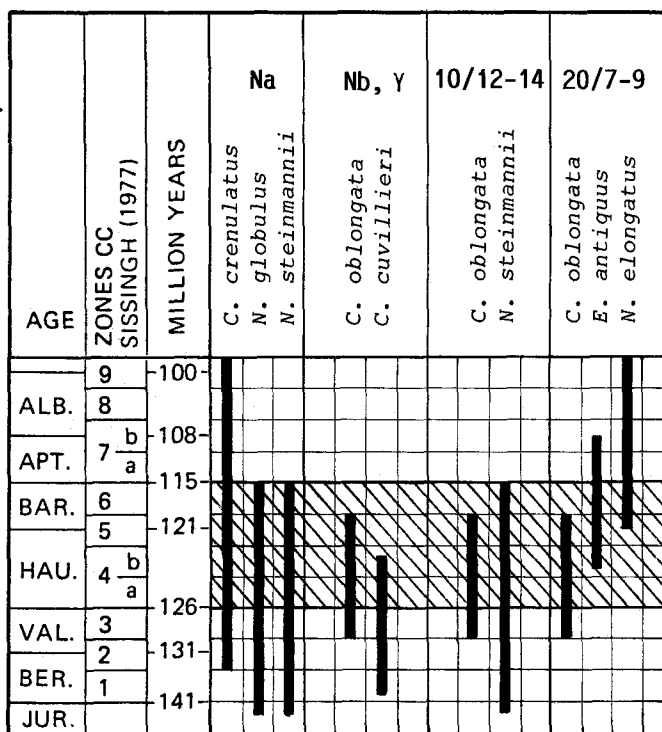


Fig. 6. Stratigraphical ranges of nannofossil species observed in the sections of the Upper Blassenstein member. Timescale and ranges according to DERES & ACHERITEGUY (1980), PERCH-NIELSEN (1986), SISSINGH (1977).

	Na	Nb	Y	10/x	20/x
Braarudosphaera bigelowii		•	•		
Calcicalathina oblongata		•	○	•	•
Conusphaera mexicana			•	•	•
Cretarhabdus crenulatus	○	○	○	○	•
Cretarhabdus div. spec.		○	○		•
Cruciellipsis cuvillieri		•	○		
Cyclagelosphaera margareli	•	○	○	•	•
Ellipsagelosphaera britannica	○	○	○	•	
Eprolithus antiquus					•
Lithrathidites carniolensis		•		○	•
Micrantholithus hoschulzii	•	•	○	○	
Micrantholithus obtusus	•	•	○		•
Nannoconus bermudezii					•
Nannoconus colomii			○		
Nannoconus elongatus					•
Nannoconus globulus	•				•
Nannoconus kamptneri					•
Nannoconus steinmannii	•	•	○	○	○
Parhabdolitus asper	•	•			
Rucinolithus heyii	•				•
Rucinolithus wiseii	○	•			
Rotelapillus laffittei		•			
Tranolithus salillum		•	•		
Watznaueria barnesae	●	●	●	●	○
Zeugrhabdus antophorus	•				•
Zeugrhabdus embergeri	○	○	○	○	○
Zeugrhabdus noeliae	•				•
Coccosphaera	•	•	○	•	•

Fig. 7. Calcareous nannofossil occurrences in the sections of the Upper Blassenstein member (Gresten Klippen Belt). Estimated frequencies from rare, rare to frequent, abundant to dominant.

oblongata and *Lithraphidites bollii*. Rarely occurring *Nannoconus elongatus* may restrict this age to Early Barremian (Deres and Acheriteguy 1980). A list of nannofossil species of the different sections is given in figure 7.

BIOSTRATIGRAPHY AND PALEOECOLOGY OF FORAMINIFERA

The investigation of Early Cretaceous microfaunas from the Gresten Klippen Belt was initiated to reveal a deposition model for the upper part of the Blassenstein formation. The assemblages are dominated by agglutinated foraminifera and radiolaria. The species composition of foraminifera fauna differs distinctly in some of the investigated sections. The sections themselves comprise lithological sequences from isolated tectonical klippen.

The interpretation of the ecology and stratigraphy of acid-dissolved limestone residues is not without difficulties. Calcareous forms and most of the multiserial genera of agglutinated foraminifera with calcareous wall material or cement, such as *Dorothia* and *Bigenerina* are strongly affected by dissolution during processing. This has been shown by comparison of the residues of washed and acid-processed samples. Planktonic foraminifera are absent in washed samples and thin-sections. The foraminifera fauna in general is of small size, between 63-160 µm fraction. The multiserial agglutinated species have an average length of 0.5-0.6 mm whereas lenticulinas are of larger sizes up to >1 mm. The preservation of the fauna is rather poor, strongly recrystallized and partly crushed.

The species distribution in the different sections is given in figures 8 and 9. The dark shales interbedded in the limestones contain a fauna dominated by *Dorothia hauteriviana* (Moullade). Less common are *Rhizammina algaeformis* Brady, *Hyperammina gaultina* Ten Dam, *Ammodiscus*, *Glomospira*, *Glomospirella gaultina* (Berthelin), *Reophax*, *Haplophragmoides*, and *Trochammina*. The calcareous benthics have a dominance of *Nodosaria* and *Dentalina*, *Lenticulina* and *Vaginulinopsis* are present. Because of the poor preservation, the species of calcareous benthics have not been determined in detail.

In the acid residues, the balance is shifted to *Rhizammina algaeformis* Brady and *Hyperammina gaultina* Ten Dam. Some rare species are enriched, as *Ammodiscus cretaceus* (Reuss), *A. tenuissimus* (Guembel), *Glomospira charoides* (Jones and Parker), *G. irregularis* (Grzybowski), *Kalamopsis grzybowskii* (Dylazanka), *Reophax minutus* Tappan,

R. nodulosus Brady, and *Gaudryina filiformis* Berthelin.

Another fauna type is developed in one section only. Dominant species is *Ammobaculoides carpathicus* Geroch, followed by *Bigeneria ? gracilis* Antonova. *Dorothia hauteriviana* (Moullade) is virtually absent. The other accompanying fauna compares to the *Dorothia* assemblage.

In the same locality, but tectonically displaced, a third fauna differs by the dominance of calcareous species. The assemblage has a normal growth size and contains numerous lenticulinas, e.g. *Lenticulina eichenbergi* Bartenstein and Brand, *L. ouachensis* (Sigal). From the group *Marginulinopsis/Vaginulinopsis*, only *M. schloenbachii* (Reuss) and *V. incurvata* (Reuss) have been determined. *Spirillina neocomiana* Moullade is rather common in this place, as there are also *Nodosaria* and *Dentalina*. The poor agglutinated fauna consists of *Rhizammina*, *Trochammina* and few *Dorothia*.

Compared with the different types of lithology and ichnofacies, there exists no direct relation with the foraminiferal assemblages in the different sections:

Arzberggraben, section Na: Litho-type I, with sharp changes of shales and limestones and low intensity of bioturbation. The section contains a rather poor fauna, predominantly tubular agglutinated species. Calcareous species are rare and represented mainly by *Nodosaria* and *Dentalina*. Important agglutinated species are *Dorothia hauteriviana* (Moullade) and *Glomospirella gaultina* (Berthelin). Pyritized radiolaria are fairly common.

Arzberggraben, section Nb: Litho-type II, with gradational sedimentological contacts and strong bioturbation. The foraminifera fauna contains the same assemblage in section Na, but is richer and more diversified, particularly in agglutinated tubular species and *Dorothia hauteriviana* (Moullade). Calcareous benthics are comprised of *Nodosaria*, *Dentalina* and occasionally *Epistomina caracolla* (Roemer). Pyritized and calcified radiolaria are common.

Ybbsitz-Schwarzenberg section: Lithology and facies of type I. A rich fauna of *Dorothia hauteriviana* (Moullade) is present, with less common *Nodosaria*, *Dentalina* and *Lenticulina*. Pyritized radiolaria are common.

Hochkogel section: Because of outcrop conditions, the type of lithology is not defined. The fauna is dominated by *Dorothia hauteriviana* (Moullade) and some radiolaria.

GRESTEN KLIPPEN BELT Eastern Alps, Austria Upper Blassenstein Member Early Cretaceous	
ARZBERGGRABEN Section Na: Na 28 insoluble residue Na 10 insoluble residue Na 9 washed sample ARZBERGGRABEN Section Nb: Nb 25 insoluble residue Nb 24 insoluble residue Nb 19 insoluble residue Nb 18 insoluble residue Nb 17 washed sample Nb 12/2 insoluble residue 14-85 insoluble residue 14-85 washed sample 15-85 insoluble residue 15-85 washed sample	Ammobaculites goodlandensis CUSHM. & ALEXANDER Ammobaculites cf. reophacoides BARTENSTEIN Ammobaculites subcretaceus CUSHM. & ALEXANDER Ammobaculoides carpathicus GEROCH Ammodiscus cretaceus (REUSS) Ammodiscus tenuissimus (GUEMBEL) Arenobulimina sp. Bigenerina cf. jurassica (HAEUSLER) Bigenerina ? gracilis ANTONOVA Bolivinopsis sp. Dorothia hauteriviana (MOULLADE) Dorothia cf. kummi (ZEDLER) Dorothia subtrochus (BARTENSTEIN) Gaudryina filiformis BERTHELIN Glomospira charoides (JONES & PARKER) Glomospira gordialis (JONES & PARKER) Glomospira irregularis (GRZYBOWSKI) Glomospirella gaultina (BERTHELIN) Haplophragmoides concavus (CHAPMAN) Haplophragmoides nonionoides (REUSS) Hyperammina gaultina TEN DAM Kalamopsis grzybowski (DYLAZANKA) Pelosina lagenoides CRESPI Psammosiphonella alexanderi (CUSHMAN) Psammosphaera fusca SCHULZE Pseudobolivina sp. Recurvoides sp. Reophax minutissimus BARTENSTEIN & BRAND Reophax minutus TAPPAN Reophax nodulosus BRADY Reophax pilulifer BRADY Reophax scorpiurus MONTFORT Rhizammina algaeformis BRADY Saccammina placenta (GRZYBOWSKI) Spiroplectinata ? Tolypammina ? Trochammina cf. depressa LOZO Trochammina cf. minuta CRESPI Trochammina sp. Trochamminoides sp. Dentalina spp. Epistomina sp. Epistomina caracolla caracolla (ROEMER) Fronicularia inversa REUSS Glandulina / Globulina / Guttulina spp. Lenticulina eichenbergi BARTENSTEIN & BRAND Lenticulina ouachensis (SIGAL) Lenticulina spp. Marginulinopsis schloenbachi (REUSS) Nodosaria spp. Ramulina sp. Spirillina neocomiana MOULLADE Vaginulinopsis incurvatus (REUSS) Vaginulinopsis / Marginulinopsis spp.

Fig. 8.
Distribution of benthic foraminifera in the investigated sections of the Early Cretaceous Upper Blassenstein member.
Sections Arzberggraben Na and Nb.

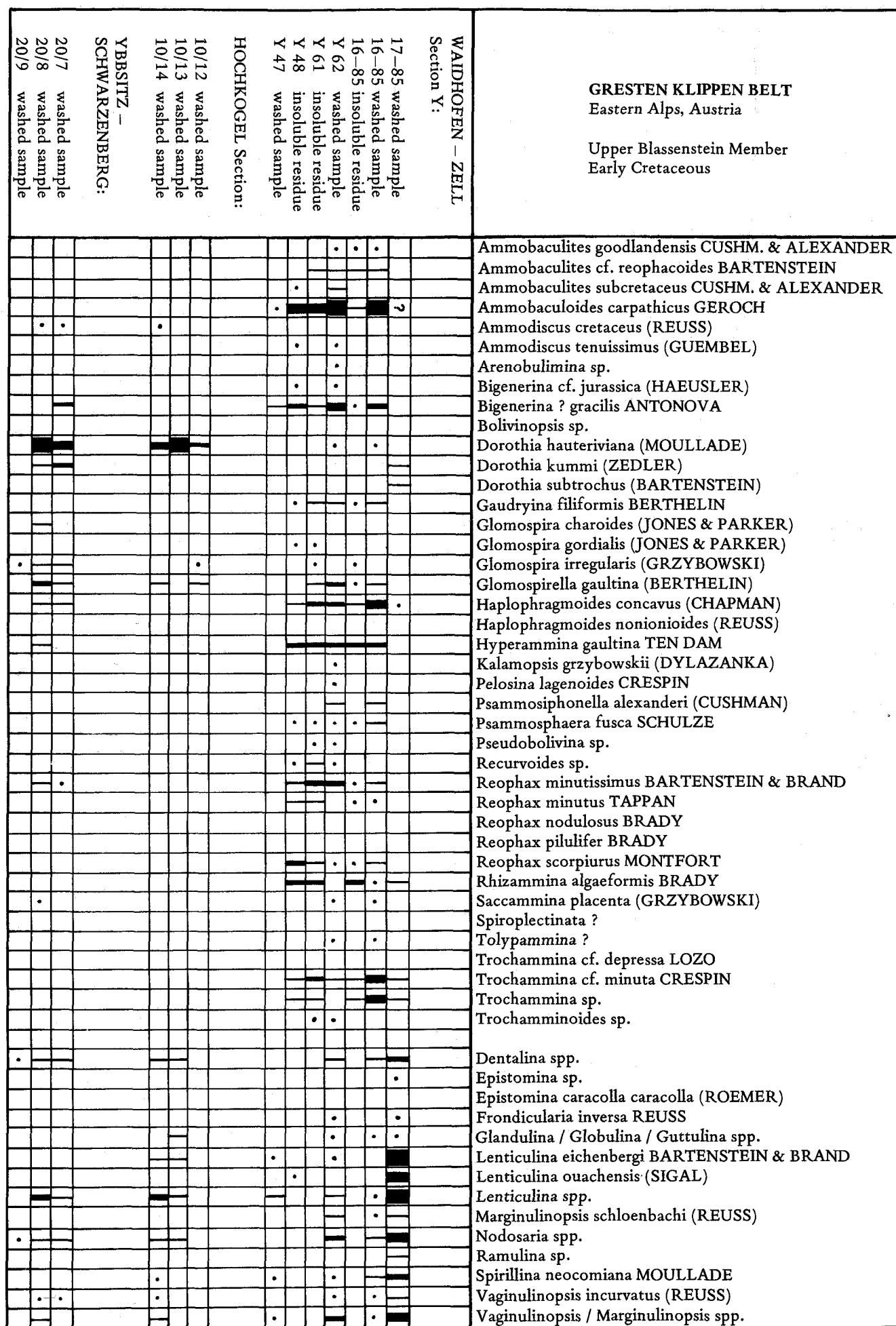


Fig. 9.
Distribution of benthic foraminifera in the investigated sections of the Early Cretaceous Upper Blassenstein member.
Sections Waidhofen - Zell, Hochkogel, and Ybbsitz - Schwarzenberg.

Waidhofen-Zell section at the power station: The sequence comprises the litho-type II, with strong bioturbation. It contains a distinctly different foraminifera assemblage. This fauna is dominated by *Ammobaculoides carpathicus* Geroch, *Bigenerina* ? *gracilis* Antonova and different species of *Trochammina*. In contrast, one sample (17-85) outside of this section contains abundant calcareous benthic species, mainly lenticulinas, and biogenic detritus (fragments of aptychi, echinoids, inoceramids), few glauconitic pellets and some radiolaria.

Stratigraphy: The stratigraphic interpretation of the foraminifera fauna is not very precise owing to the presence of long ranging species. Some of the biostratigraphic ranges reported from continuous sections of the time range in question are compared in figure 10. All the investigated sections of the Blassenstein formation exhibit a biostratigraphic range of Hauterivian to Barremian, compared to the last and first occurrences of species referred to by different authors. Some restrictions to the time span are possible as the stratigraphic correlations in the southern USSR demonstrate the first appearance of *Dorothia kummi* (Zedler) and common occurrences of *Lenticulina eichenbergi* Bartenstein and Brand in the Hauterivian (Drushtchitz and Gorbatschik 1979). This would agree with the absence of planktonic foraminifera. Planktonic species in the Early Cretaceous are generally absent before Late

Hauterivian (Van Hinte 1976) and are also not reported with certainty from the earliest Cretaceous of the Alpine-Carpathian realm before Barremian.

Paleoecology: The investigation of the foraminifera in the different sections resulted in a subdivision of three different ecological assemblages. The interpretation of the paleoecological significance of these assemblages is still tentative. However, a comparison with other faunas from different regions has been attempted.

(1) *Dorothia hauteriviana* assemblage: This comprises a common occurrence of the nominate taxon together with *Glomospirella gaultina* (Berthelin), *Rhizammina*, *Hyperammina*, *Reophax*, and rare calcareous benthics such as *Nodosaria*, *Dentalina*, *Lenticulina*. This assemblage occurs in the following sections: Arzberggraben Na and Nb; Hochkogel; Ybbsitz-Schwarzenberg.

(2) *Ammobaculoides carpathicus* assemblage: The nominate species together with *Bigenerina* ? *gracilis* Antonova replace laterally (?) the *Dorothia* assemblage. Species of *Haplophragmoides* and *Trochammina* are common; tubular agglutinates are less important. The poorly represented calcareous benthics correspond to the *Dorothia* assemblage. This assemblage has been found in Waidhofen-Zell, section Y.

(3) *Lenticulina eichenbergi* assemblage: This fauna is dominated by different lenticulinas, characterized by *Lenticulina eichenbergi* Bartenstein and Brand, together with *Nodosaria*, *Dentalina*, *Marginulinopsis* and *Vaginulinopsis*. The species *Spirillina neocomiana* Moullade is an important species in this fauna. The assemblage occurs in Waidhofen-Zell (sample 17-85) in a different tectonical position to the section Y.

The dwarfed size of the foraminifera is remarkable. The multiserial agglutinated species are predominantly minute and their size seems to be related, with a scarce fauna of calcareous benthics, to low oxygen conditions connected with high organic surface productivity (Phleger and Soutar 1973; Hart and Bigg 1981). Dysaerobic bottom conditions and sluggish circulation during deposition of the dark shales are in agreement with the results of trace fossil studies (see above).

In a worldwide pattern, the distribution of similar foraminifera faunas as the *Dorothia* assemblage has been reported by Haig (1979) for the Mid-Cretaceous. His *Marssonella* assemblages associated with carbonate productive open continental shelves occur with distinct associations in different regions from the inner shelf to the deeper slope. At the

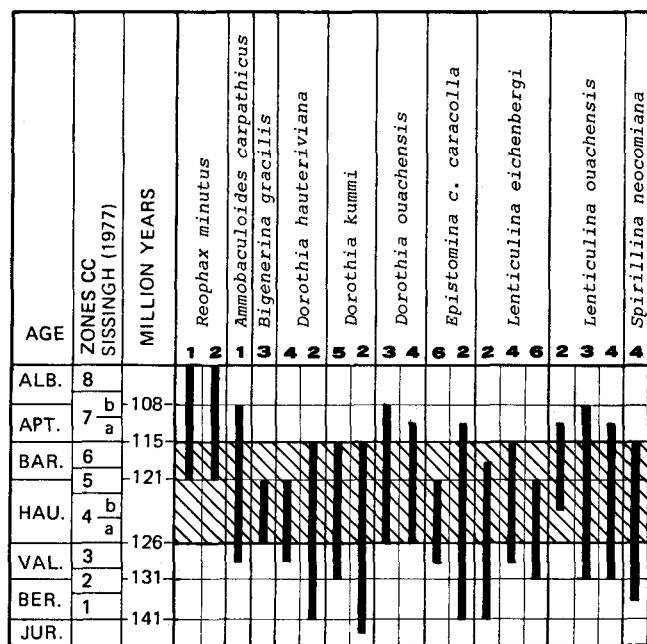


Fig. 10. Stratigraphic ranges of some agglutinated foraminifera in the Early Cretaceous according to
 1) GEROCH & NOWAK (1984)
 2) BARTENSTEIN (1978, 1979)
 3) SIGAL (1979)
 4) MOULLADE (1966)
 5) ZEDLER (1961)
 6) BARTENSTEIN & BRAND (1951).

deeper slope, agglutinated species of *Bathysiphon*, *Hyperammina*, *Pelosina*, *Hormosina*, *Glomospira*, and *Haplophragmoides* are dominant together with "*Marssonella*". This is in good agreement with the assemblage reported here. The area of the Early Cretaceous warm water, carbonate belt in the Atlantic is yielding such *Dorothia hauteriviana* or *praehauteriviana* assemblages in many DSDP sites from the western Atlantic Blake Plateau and the Blake-Bahama Abyssal Plain in the west (Sites 99-101 and 390-392; Luterbacher 1972; Gradstein 1979) and off Africa. There are many sites from Cape Bojador (Site 397; Butt 1979), the Iberia Abyssal Plain (Site 398; Sigal 1979; Basov *et al.* 1979), along the coast of Morocco (Site 370, 415-416; Kuznetsova and Seibold 1978; Gradstein 1978; Sliter 1980; Butt 1982) to the Cape Verde Basin (Site 367; Krasheninnikov and Pflaumann 1977; Kuznetsova and Seibold 1978). Depending on the water depth, the *Dorothia* assemblage is associated with calcareous benthics as *Epistomina* and *Lenticulina* at shallower depths, with *Nodosaria*, *Dentalina*, *Marginulinopsis*, and some agglutinates along the slope, and together with many "primitive" agglutinates around the CCD. Radiolaria are common in all depth ranges. The most comparable description of the corresponding *Dorothia hauteriviana* assemblage is given by Butt (1982, p. 239, plate 6c) from the Early Cretaceous of Site 370. The fauna is associated with dwarfed and thin-walled specimens of *Lenticulina*, *Citharina*, *Marginulina*, *Dentalina*, *Ammodiscus*, *Glomospira* and *Reophax*.

Out of the investigated sections, the *Ammobaculoides carpathicus* assemblage occurs in the sequence containing the lowest organic carbon content. This could reflect stronger ventilation of bottom water. This is in agreement with the ichnofacies (*Chondrites-Zoophycos-Trichichnus-Planolites* assemblage) too. A regional comparison of this assemblage is more problematic. In the Silesian unit of the Polish Carpathians, the nominate species occurs in a *Dorothia hauteriviana* assemblage together with trochamminids, ataxophragmiids and nodosariids in the Hauterivian of flysch deposits (Geroch 1966). A deep-water environment of this assemblage is therefore reliable.

The *Lenticulina eichenbergi* assemblage derived from a tectonically emplaced slice of dark gray marls, from the same locality as the *A. carpathicus* assemblage. Sedimentation in a shallower environment seems possible considering the absence of a well-developed agglutinated fauna. Some sediment transport from shallower depth occurred, as is evidenced by biogenic detritus of shell fragments. In comparison with the Early Cretaceous of Morocco, a similar association was reported from

the Agadir region (Butt 1982). The fauna with *Lenticulina eichenbergi* Bartenstein and Brand, *L. ouachensis* (Sigal), *Epistomina caracolla* (Reuss), and *Spirillina neocomiana* Moullade was interpreted as mid-shelf environment, and corresponds well with the investigated assemblage.

There exists no well-developed foraminifera fauna in the Early Cretaceous of the Eastern Alps before Barremian. Short faunal lists are published (e.g. Plöschinger and Oberhauser 1956; Oberhauser 1963; Barth 1968; Tollman 1976; Felber and Wyssling 1979). The only Neocomian/Hauterivian faunas described in more detail are: (1) from the external Waschberg unit, displaced autochthonous Mesozoic of the Molasse Basin (Noth 1951); (2) from Aptychus limestones of the Northern Calcareous Alps, only from acid residues (Holzer 1969); (3) from the clastic Rossfeld formation of the Northern Calcareous Alps (Faupl and Tollmann 1971). In contrast, rich microfaunas are present in the Barremian (e.g. W. Fuchs 1971).

Summarizing the results of the foraminifera investigation, it can be assumed that the deposition of the Upper Blassenstein rhythmites took place in the highly productive carbonate belt of Tethys in a (only local) mid-shelf to mainly bathyal environment, above the CCD. The minute size of foraminifera and the faunal composition agree with the ichnofacies investigation, and demonstrate dysaerobic conditions with changing oxygen contents of bottom waters. The biostratigraphic evaluations of the foraminifera point to a Hauterivian age.

CONCLUSIONS

The subsidence of the northern margin of the Tethys in the Gresten Klippen Belt caused a development from continental and near-shore facies to depths below the CCD during Jurassic time. Turbiditic sedimentation of the Upper Jurassic is replaced by uniform limestone-marl rhythmites of the Upper Blassenstein member in the Early Cretaceous. Nannoplankton and foraminifera restrict the age of these sediments to Hauterivian-?Early Barremian.

Based on sedimentology, ichnofacies and organic carbon contents, the changing deposition of nannoozes and black clays, probably caused by climatic changes, coincides with varying oxygenation of bottom waters. The fauna of agglutinated foraminifera dominated by dwarfed species is in agreement with the interpretation of oxygen depletion in bottom waters.

The foraminifera assemblages co-occur with rich pyritized and calcified radiolaria faunas and are interpreted as bathyal accordingly. Only one calcareous benthic foraminiferal assemblage was observed. It is indicative of a mid-shelf environment, but the tectonic and paleogeographic relationship of the section delivering this fauna to the other sections is not clear.

Contents of organic carbon are reasonably high in the investigated Neocomian rhythmites. Therefore, these sediments could be considered as possible source rocks for hydrocarbon prospecting in the Alpine realm.

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PLATE 1

- Figures 1-2 *Rhizammina algaeformis* Brady, 1884; irregular tubes exhibiting distinct variations in size.
 Waidhofen-Zell (sample 15-85)
- Figure 3 *Tolypammina*?; large irregular tubes of continuous diameter with some constrictions.
 Waidhofen-Zell (sample Y 62 P)
- Figure 4 *Psammosiphonella alexanderi* (Cushman, 1933); straight tubes with circular cross sections.
 Arzberggraben, section Nb (sample 15-85)
- Figure 5 *Hyperammina gaultina* Ten Dam, 1950; tubes, closed at one end, with fine-grained translucent walls.
 Waidhofen-Zell (sample Y 62 P)
- Figure 6 *Psammosphaera fusca* Schulze, 1875; spheres mainly compressed by fossilization, coarse-grained walls.
 Waidhofen-Zell (sample 16-85)
- Figure 7 *Saccammina placenta* (Grzybowski, 1898); spheres compressed by fossilization, fine-grained walls, aperture often obscured.
 Waidhofen-Zell (sample 16-85)
- Figure 8 *Pelosina lagenoides* Crespin, 1953; small elongate spheres with aperture on a neck.
 Arzberggraben, section Nb (sample 14-85)
- Figure 9 *Kalamopsis grzybowskii* (Dylazanka, 1923); chamber-like inflated tubes, normally broken at constrictions; fine-grained, translucent walls.
 Arzberggraben, section Nb (sample 15-85)
- Figure 10 *Ammodiscus tenuissimus* (Guembel, 1862).
 Waidhofen-Zell (sample Y 62 P)
- Figure 11 *Glomospira irregularis* (Grzybowski, 1897).
 Arzberggraben, section Nb (sample 15-85)
- Figures 12-13 *Glomospirella gaultina* (Berthelin, 1880); initial coiling irregular, later few whorls planispirally overlapping.
 Figure 12: Arzberggraben, section Nb (sample 15-85)
 Figure 13: Waidhofen-Zell (sample Y 62 P)
- Figure 14 *Reophax minutissimus* Bartenstein and Brand, 1951; small, globular chambers of similar size.
 Arzberggraben, section Nb (sample 15-85)
- Figure 15 *Reophax minutus* Tappan, 1940; chambers globular, gradually increasing in size.
 Waidhofen-Zell (sample 16-85)
- Figure 16 *Ammobaculites* cf. *reophacoides* Bartenstein, 1952; small coiled initial part, sutures indistinct.
 Waidhofen-Zell (sample 16-85)
- Figure 17 *Ammobaculites goodlandensis* Cushman and Alexander, 1930; large coiled initial part, coarse-grained wall.
 Waidhofen-Zell (sample 16-85)

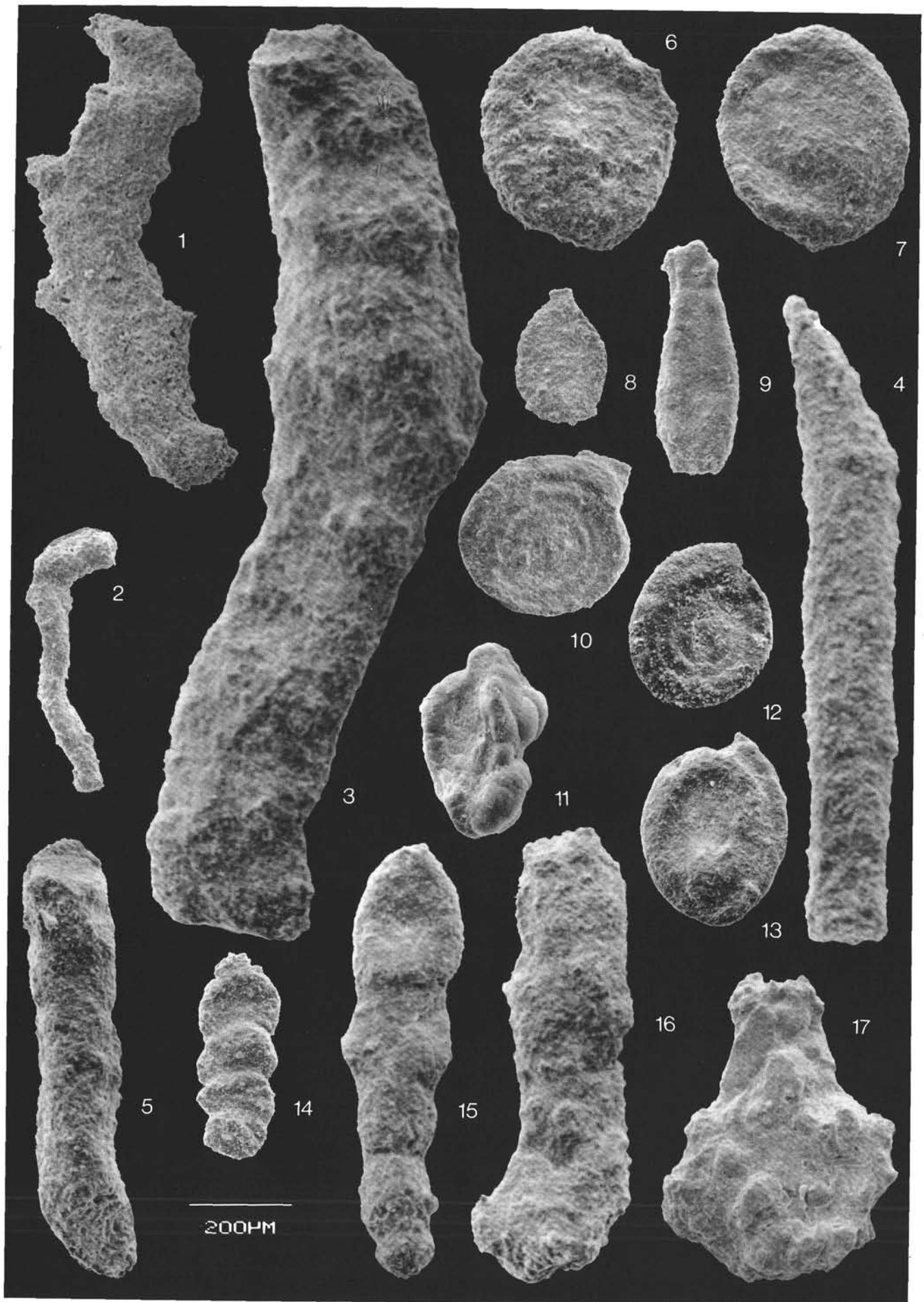


PLATE 2

- Figures 1-2 *Ammobaculoides carpathicus* Geroch, 1966; initial part irregularly coiled, often compressed, then follows a short biserial and a long straight uniserial chamber arrangement; sutures indistinct.
Waidhofen-Zell, section Y (sample 16-85)
- Figures 3-6 *Bigennerina ? gracilis* Antonova, 1964; short biserial part, followed by cuneate chambers in a loose biserial series similar to *Haeuslerella*; aperture terminal and central on a short neck; distinct micro- and megalospheric generations.
Waidhofen-Zell, section Y (figures 3-5: sample Y 62 P; figures 4-6: sample 16-85)
- Figures 7-8 *Gaudryina filiformis* Berthelin, 1880; small slender test with numerous low chambers in the biserial part.
Waidhofen-Zell, section Y (sample 16-85)
- Figures 9-10 *Dorothia hauteriviana* (Moullade, 1961); fairly long, slender test with approximately parallel sides in the biserial part; sutures indistinct, moderately incised and therefore faint lobate outline; apertural face inclined, strongly concave bordered by an elevated shoulder of the chamber rim.
Arzberggraben, section Nb (figure 9: sample 14-85; figure 10: sample 15-85)
- Figure 11 *Dorothia cf. ouachensis* (Sigal, 1952); small test with conical outline, laterally somewhat compressed, sutures indistinct.
Arzberggraben, section Nb (sample 14-85)
- Figure 12 *Dorothia kummi* (Zedler, 1961); small conical test with circular cross-section, sutures indistinct.
Arzberggraben, section Nb (sample 15-85)
- Figures 13-14 *Haplophragmoides concavus* (Chapman, 1892); all specimens deformed by diagenesis; nevertheless distinct umbilical cavity and chamber arrangement visible.
Waidhofen-Zell, section Y (sample 16-85)
- Figure 15 *Recurvoides* sp.; small globular chambers in a distinct streptospiral coiling, aperture obscured.
Waidhofen-Zell, section Y (sample 16-85)
- Figure 16 *Trochammina cf. minuta* Crespin, 1953; small form with a rounded, somewhat lobate outline and 4-5 chambers in the final whorl.
Arzberggraben, section Nb (sample 14-85)
- Figures 17-18 *Trochammina* sp.; fairly large form with a raised but flattened, multichambered initial coil; last two whorls with few large chambers; normally deformed by diagenesis.
Waidhofen-Zell, section Y (sample 16-85)
Figure 17: umbilical side, Figure 18: spiral side

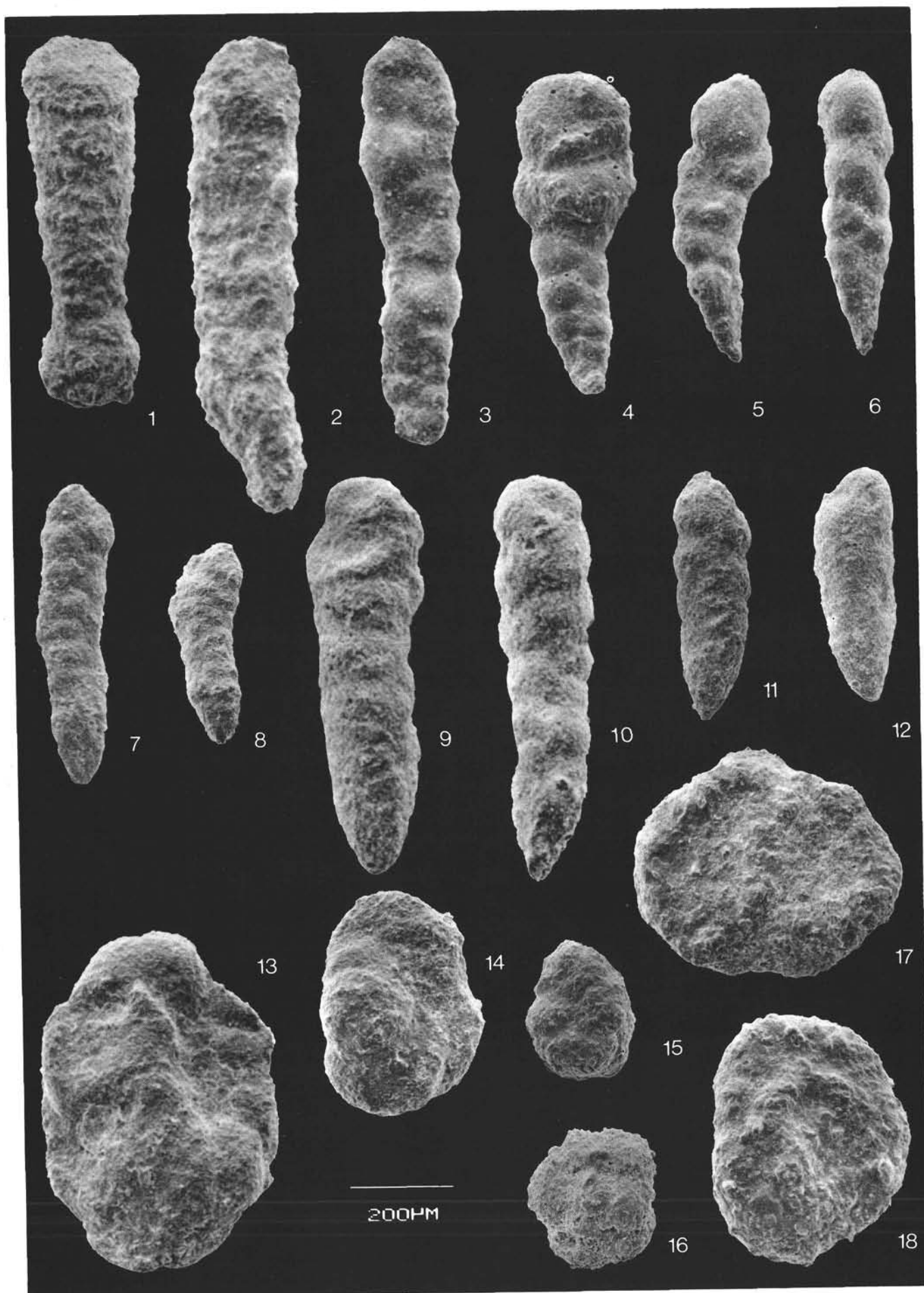


PLATE 3

- Figure 1 *Lenticulina eichenbergi* Bartenstein and Brand, 1951.
Waidhofen-Zell (sample 17-85)
- Figure 2 *Lenticulina ouachensis* (Sigal, 1952).
Waidhofen-Zell (sample 17-85)
- Figure 3 *Spirillina neocomiana* Moullade, 1961.
Waidhofen-Zell, section Y (sample 16-85)
- Figure 4 *Ramulina* sp.
Waidhofen-Zell (sample 17-85)
- Figures 5-8 Pyritized radiolaria
Figure 5: Waidhofen-Zell (sample 17-85)
Figures 6-8: Arzberggraben, section Nb (sample 14-85)
- Figure 9 Calcified radiolaria; all specimens are compressed, no detailed structures of the surface observable.
Arzberggraben, section Nb (sample 14-85)
- Figure 10 Trace fossils. *Chondrites* assemblage. Group of composite burrows and isolated small chondrites. Lithologic sequence of litho-type I, Arzberggraben (section Na). Cut parallel to the sedimentary surface; natural size.
- Figure 11 Trace fossils. *Chondrites-Zoophycos-Trichichnus-Planolites* assemblage. Substrate indistinctly mottled by early bioturbation, well defined traces of *Zoophycos* and composite burrows. Lithologic sequence of type II, Arzberggraben (section Nb). Cut parallel to the sedimentary surface; natural size.

