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Biostratigraphy and facies of the Late Eocene in the Upper Austrian Molasse Zone with special reference to the Larger Foraminifera

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5 Text-Figures, 5 Plates and 2 Tables

Molassezone
Obereozän
Priabonium
Oberösterreich
Biostratigraphie
Fazies
Nannoplankton
Nummulitidae
Orthophragminidae
Discocyclinidae

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Content

Abstract

A The current study provides modern biostratigraphical data of Late Eocene sandstones, algal limestones ("Lithothamnia limestones") and marls of the Upper Austrian Alpine Foreland Basin. Nannoplankton, nummulitidae and orthrophragminidae (discocyclinidae and orbitoclypeidae)

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show a middle Priabonian age (NP 19-20 and SBZ 19-20). Most important taxa are *Isthmolithus recurvus, Cribrocentrum reticulatum,* and *Pemma papillatum* among the nannoplankton, and *Discocyclina augustae augustae, Nummulites chavannesi,* and *N. stellatus* among the larger foraminifera. Six different facies with remarkable occurrences of foraminifera can be identified, which are mostly characterized by different foraminiferal associations: Nummulite sandstone, *Discocyclina* marl, bryozoa marl, coralline-quartz sandstone, coralline bindstone, and coralline rudstone. A new species, *Discocyclina ruppi,* is described.

Biostratigraphie und Fazies des Obereozäns der oberösterreichischen Molassezone unter besonderer Berücksichtigung der Großforaminiferen

Zusammenfassung

Die vorliegende Studie stellt eine moderne biostratigraphische Bearbeitung der obereozänen Sandsteine, Algenkalke ("Lithothamnienkalk") und Mergel des Alpenvorlandbeckens in Oberösterreich dar. Die Bearbeitung von Nannoplankton, Nummulitiden und Orthophragminiden (Discocyclinidae und Orbitoclypeidae) erlaubt eine Einstufung in das mittlere Priabonium (NP 19-20, bzw. SBZ 19-20). Die wichtigsten Taxa sind *Isthmolithus recurvus, Cribrocentrum reticulatum,* und *Pemma papillatum* unter dem Nannoplankton und *Discocyclina augustae augustae, Nummulites chavannesi* und *N. stellatus* unter den Großforaminiferen. Oligozänes Alter kann nun erstmals ausgeschlossen werden. Sechs unterschiedliche Faziesbereich mit bemerkenswerten Vorkommen von Foraminiferen können unterschieden werden, die auch meist unterschiedliche Foraminiferen-Assoziationen aufweisen: Nummuliten-Sandstein, Discocyclinen-Mergel, Bryozoen-Mergel, Corallinaceen-Quarz-Sandstein, Corallinaceen-Bindstone, Corallinaceen-Rudstone. Mit *Discocyclina ruppi* wird eine neue Art beschrieben.

1. Introduction

Late Eocene sediments of the Alpine Foreland Basin are laterally extensive and continue in Bavaria (Buchholz, 1989). They predominantly consist of sandstones, algal limestones ("Lithothamienkalk"), and *Discocyclina* marls (Wagner, 1980). These sediments pass into deep water deposits of the Helvetic Zone towards the south (Wagner, 1996a). Comparable sediments are also known from Hungary (Báldi, 1986; Zágoršek, 1995).

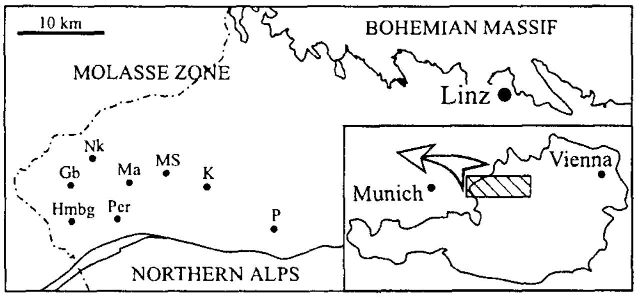
The red algal limestones of the Bavarian Molasse Zone are expected to be of Late Eocene age by the occurrence of *Gypsina linearis* and of *Discocyclina* sp. (Buchholz, 1984; 1989); the author argues, however, that the topmost parts of algal limestones may be of Oligocene age. In Austria, Papp (1957) was the first who studied the Late Eocene Larger Foraminifera. He mentions two nummulite species: *Nummulites bouillei* and *N. variolarius* ssp. 2. The question, whether topmost parts of the algal limestones may pass into the Oligocene has, however, not yet been solved.

The present study aims (1) to provide first biostratigraphic nannoplankton-data and a modern biostratigraphic study of larger foraminifera, (2) to give a systematic description of the Nummulitidae and Orthophragminidae, (3) to document the sedimentary facies and the distribution of foraminifera.

A description of facies and carbonate components and of the facies distribution is given; the nummulites and discocyclinids, including a new species, are described; and the biostratigraphy using nannoplankton and larger foraminifers is presented. Finally, we discuss the palecological implications.

2. Study area

The Austrian Molasse Zone of Upper Austria and Salzburg is part of the Alpine-Carpathian foreland basin (Wagner, 1980; 1996a; 1996b). The Cenozoic basin of the study area has a geometry of an asymmetrical, south-dipping, 30–55 km wide trough. Its northern margin is formed by the outcropping basement of the Bohemian Massif while its southern margin corresponds to the Alpine thrust front (Text-Fig. 1). In this basin the thickness of the Cenozoic series ranges from a few meters along its northern margin to over 3000 m along the Alpine deformation front. The crust of the European foreland today extends as a monoclinal ramp at least some 50 km southward from the Alpine deformation front under the Alpine-Carpathian nappe complexes (Wessely, 1987). The pre-Cenozoic underground and the studied Late Eocene algal limestones are only known from deep wells of the Rohöl AG Vienna. Ca. 200 deep wells were drilled in Upper Austria and Salzburg. Most studied samples come from the Autochthonous Molasse Zone, only the deep well Perwang 1 contains both autochthonous and allochthonous parts. A detailed study on the facies and paleontology of the algal limestones is in preparation by M. Rasser.



Text-Fig. 1
Study Area with the locations of studied deep wells. For abbreviations see text.

3. Material and methods

Ten deep wells of the Rohöl AG Vienna, stored in Pettenbach, Upper Austria, were sampled and studied. The cores of Helmberg 1 (Hmbg) Mattighofen 1 (Ma), and Neukirchen 1 (Nk) were studied and sampled completely; only the second and the third thrust sheets were sampled from Perwang 1 (Per); cores of Maria Schmolln 1 (MS), Geretsberg 1 (Gb), Kohleck 1 (K), Mühlleiten 1 (Ml), Puchkirchen 1 and 3 (P) were sampled randomly (text-fig. 1).

The second author (GyL) collected fourteen samples with C. Rupp from the bore holes Perwang 1 and Helmberg 1 in

August 1997 that were perspective to extract isolated foraminifera. Additionally, the fauna was determined from thin-sections. All of the fourteen samples that were collected from soft material contained isolated specimens. In eight samples the chambers of Larger Foraminifera were filled with pyrite which highly increased their preservation. Therefore, it was possible to split them by pliers along their equatorial plane (this method is described in LESS (1981) and COSOVIC (1990)), to determine them.

Washable material from the bore holes Helmberg 1 and Perwang 1 was used for nannoplankton studies. The preparation of nannoplankton and the taxonomy used in this study are the same as described by BÁLDI-BEKE (1984).

The figured specimens of nannoplankton and isolated larger foraminifers are stored at the Museum of Natural History, Vienna. Illustrated thin sections with sample numbers MOL# are stored at the Institute of Paleontology, University of Vienna.

4. Geological background

The Austrian Molasse Zone is part of the Alpine-Carpathian Foreland Basin (STEININGER et al., 1986). The Molasse sedimentation started during the Oligocene with the input of clastic sediments from the uplifted Alpine thrust front. Late Eocene sediments only contain clastic sediments coming from the Bohemian Massif and therefore belong to the Molasse underground or "Premolasse".

The sedimentological history of the Alpine Foreland Basin started in the Palaeozoic. Permo-Carboniferous continental sediments were deposited on the crystalline basement of the Bohemian Massif (WAGNER, 1996). During the Mesozoic the Alpine Foreland Basin belonged to the Epicontinental platform of the European plate. Deep karstifications occurred during the Lower Cretaceous which can be correlated with inversion movements of the western margin of the Bohemian Massif (SCHRÖDER, 1987) and crustal extensions in the Northern Atlantic and Norwegian-Greenland Sea areas (ZIEGLER, 1982; 1987). The combination of the Mid-Paleocene eustatic lowstand in sea level and the latest Cretaceous and earliest Cenozoic foreland deformation induced a major erosional phase in the Alpine-Carpathian foreland basin (BACHMANN et al., 1987). The subduction of the European plate caused an asymmetric subsidence of the Alpine foreland basin, of which the area of Upper Austria formed the northern margin during the Late Eocene and Oligocene (NACHTMANN and WAGNER, 1987). This subsidence is expressed by the transgression of the studied Late Eocene sediments on this tectonically structured and deeply eroded platform from the south to the north (WAGNER, 1980; 1996a; 1996b).

By the end of the Eocene, the Rhenodanubic Flysch Zone and the Helvetic Zone were subducted by the advancing Alpine nappe system. During the Oligocene, the Molasse basin replaced the Rhenodanubic Flysch zone by accumulating debris from the uplifting alpine orogenic system; this was the beginning of the Molasse sedimentation. During the Oligocene and Miocene the nappe systems of the alpine orogeny advanced northwards, which was accompanied by the northward migration of the axis of the Molasse Basin (WESSELY, 1987) and deposition of deep water sediments. At the end of the Ottnangian an uplift of the southern tip of the Bohemian Massif disconnected the western Molasse Basin from the eastern one (STEININGER et al., 1986). While the western Molasse zone shows a continental development, the eastern Molasse showed a last marine development between the Karpathian and the Badenian.

5. Results

5.1. Facies

5.1.1. Components

Nannoplankton is mostly preserved in *Discocyclina*- and bryozoa marls. Claystone layers within the algal limestones, which are supposed to be residual sediments formed by pressure solution, lack nannoplankton.

The most prominent components are the **coralline algae** (Corallinaceae, Rhodophyta; see WOELKERLING, 1988). They occur as isolated branches, rhodoliths, or they form crusts (bindstones sensu EMBRY and KLOVAN (1972)). The diversity of coralline algae is low. There are five genera with eight species (RASSER and PILLER, in press). About 90 % of the total coralline algae are represented by only two species: *Phymatolithon* sp. and *Neogoniolithon* sp. Another representative of the calcareous red algae, *Polystrata alba,* belongs to the **Peyssonneliaceae** (Rhodophyta; see BASSI, 1997). It forms crusts within rhodoliths as well as monospecific rudstones. The latter does not contain larger foraminfera or nannoplankton and is therefore not regarded here.

Foraminifera are mostly represented by nummulitids and orthophragminids. Miliolid smaller foraminifers can be prominent in some samples. Encrusting foraminifers do not occur in the studied material. Nummulitids predominantly occur in coarse quartz sandstones and in algal limestones. In one case they form an accumulation within a coralline algal bindstone. Orthophragminids mainly occur in fine grained sediments and may be rock-forming.

Scleractinian corals are represented by encrusting hermatypic and by erect non-hermatypic forms. Encrusting forms occur together with coralline algal crusts forming bindstones. Erect corals are supposed to have formed coral biostromes. They are mostly encrusted by coralline algae.

Molluscs are predominantly represented by large pectinid and ostreid bivalves. Owing to the strong cementation and the small diameter of deep well cores, the bivalves cannot be isolated and identified.

Brachiopoda are rare, they usually occur together with erect scleractinian corals. They are represented by small (about 10 mm) terebratulids.

Bryozoa are usually abundant in marls and even may be rock-forming. They also may occur together with coralline algae. Erect growth forms predominantly occur in the Bryozoa marls, encrusting forms are dominant in coralline algal limestones.

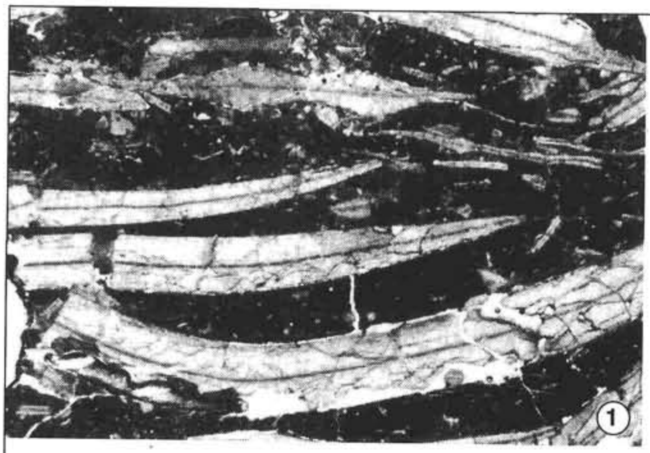
Quartz grains occur in all sizes, from fine to coarse sand. In the studied material, they are usually poorly rounded. Other terrigenous material is rare. The origin the of the fine-grained matrix has not yet been studied.

5.1.2. Facies descriptions

There are six facies with remarkable occurrences of foraminifers. Nannoplankton was only found in marly facies and in one sample of the fine-grained nummulite sandstone.

Nummulite Sandstone (Pl. 1, Fig. 2)

Nummulite sandstones are formed above the terrigenous basis series. Main components are quartz grains and nummulitids. Clastic sediments are usually poorly rounded and sorted. Nummulitids are usually not orientated and rarely fragmented, but affected by pressure solution. Mostly thick-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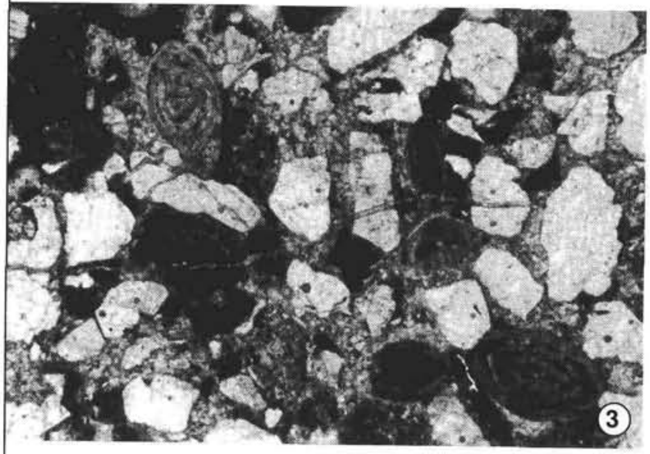
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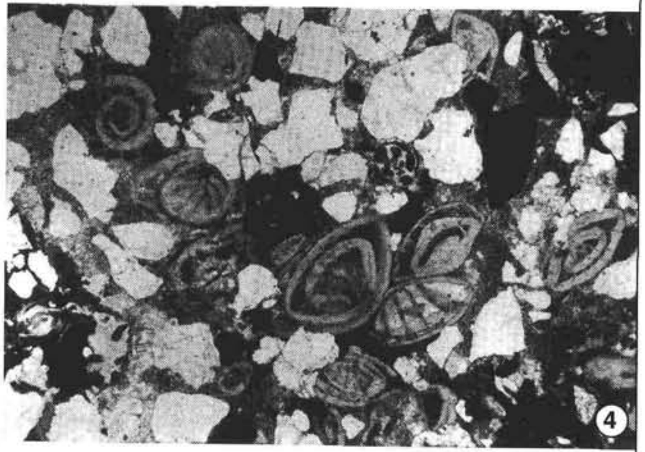
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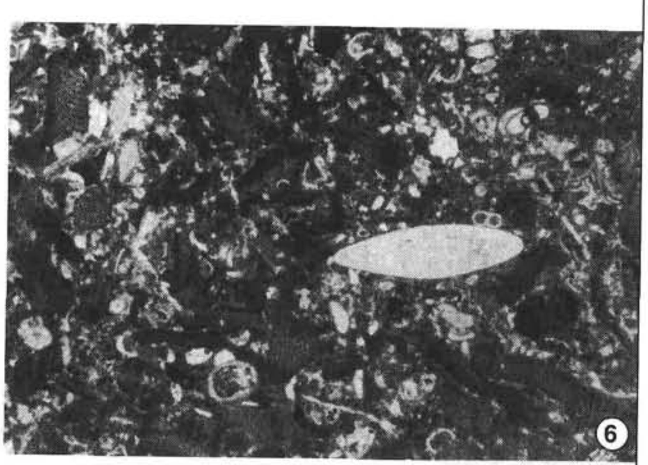
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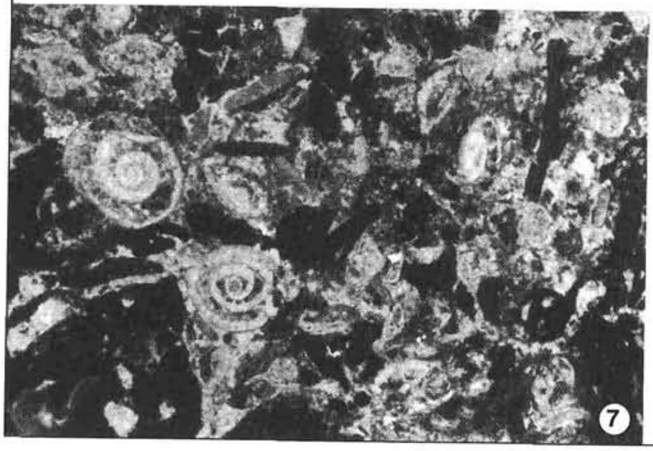
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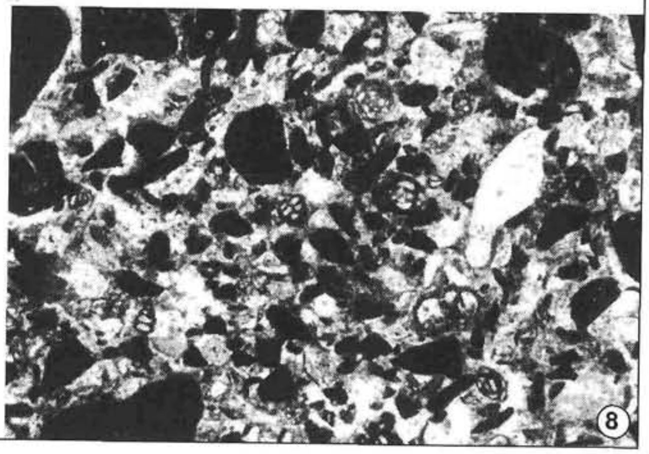
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walled rounded specimens occur. Additionally, orthophragminids may occur in finer grained sediments. Molluscs may occur. In the studied deep wells this facies is restricted to Helmberg 1 between -3217 and -3209 m.

Discocyclina Marl (Pl. 1, Fig. 1)

Orthophragminids, which are the dominant components of this facies, are mostly densely packed and orientated horizontally. They are rarely fragmented. In the deep well Helmberg 1, Nummulite sandstones gradually pass into *Discocyclina* Marls. Discocyclinids may be accompanied by erect bryozoans. This facies is abundant in the deep wells Perwang 1 and Helmberg 1 of the southern regions (see facies distribution).

Bryozoa Marls

Bryozoa marls are predominantly formed by densely packed erect bryozoans. Other components are rare. Orthophragminids may occur. In the studied deep wells this facies is restricted to Helmberg 1 (-3193 m).

Coralline-Quartz Sandstone (Pl. 1, Figs. 3, 4)

Main components are moderately sorted, but poorly rounded, quartz grains. Coralline algae are represented by isolated branches and small rhodoliths. Coralline algae are affected by pressure solution, but they are rarely fragmented. Nummulitids may be abundant. This facies occurs in deep wells of the northern region (see facies distribution): Neukirchen 1 (-1889 m) and Maria Schmolln 1.

Coralline Bindstone

Coralline algal bindstones are characterized by crust forming coralline algae; quartz grains may occur, the matrix is usually micritic. Encrusting corals may also contribute to the bindstone. Small rhodoliths may occur. Nummulitids usually occur randomly. Only in one sample there is a distinct layer of horizontally orientated nummulitids within a coralline bindstone. In the studied deep wells, this facies is restricted to the deep well Mattighofen 1 (-1952 to -1954 m).

Coralline Rudstone (Pl. 1, Figs. 5–8)

This is the most common facies. Coralline Rudstones are predominantly composed of coralline algal branches and partially of rhodoliths. Coralline algae may be fragmented or not. A micritic matrix may occur or not. All kinds of foraminifers may occur, but orthophragminids are rare. Few amounts of clastic components may occur. Peyssonneliacean algae may occur.

5.1.3. Facies Distribution

The Late Eocene of the Upper Austrian Molasse Zone transgrades from SW to NE onto a morphologically highly structured underground. The most important morphological high is the Central Swell Zone (WAGNER, 1996a; 1996b), which forms the continuation of the Landshut-Neuötting High of Bavaria (LEMCKE, 1984). A study about the underground relief is in preparation by M. RASSER. First results showed that several E–W trending swells occur in addition to the Central Swell Zone.

The basal Late Eocene transgression is represented by an up to 35 m thick terrigenous series consisting of shallow marine siliciclastic sandstones and lacustrine claystones (WAGNER, 1980). Considerable lateral changes in thickness are related to the morphology: While lowest thicknesses occur on top of the swells and isolated morphological highs, highest thicknesses occur in troughs between morphological high zones. Facies development of the overlying sediments allows a differentiation into a northern and a southern facies region, which are separated by the Central Swell Zone (WAGNER, 1980).

In the northern region, red algal limestones (mostly coralline rudstones) with a thickness of up to 80 m overlie the basal terrigenous series. Following the direction of the transgression, general sediment thickness decreases from SW to NE. As in the terrigenous series, the highest sediment accumulations occur in the troughs.

The top of the terrigenous series in the northern region usually consists of quartz sandstones which gradually pass into coralline-quartz sandstones and finally into red algal limestones (mostly coralline rudstones). In the lower part of red algal limestones, 0.2 to 1 m thick sandstone beds are intercalated. Sandstone intercalations are generally most abundant in troughs and on swell slopes. Only in the trough of the deep well Mattighofen 1, terrigenous influence is rare. The highest thickness of these terrigenously influenced red algal sediments occur in the troughs. The uppermost 10 to 60 m of the red algal limestones (increasing from N to S) show a lack of terrigenous influence (Text-fig. 4). *Polystrata alba* may be dominant in the top-most parts.

Sediments of the southern region are characterized by a terrigenous basal series passing into nummulite sandstones. The overlying sediments are characterized by *Discocyclina* marls followed by bryozoan marls. The topmost facies in the deep well Helmberg 1 is formed by a 2 m thick coralline rudstone. Further to the south, the *Discocyclina* marls are overlain by *"Globigerina marls"* of uncertain age. The deep well Perwang 1 contains a basal autochthonous series and five thrust sheets of the Allochthonous Molasse. *Discocyclina* marls are up to 40 m thick and are overlain by up to 50 m thick algal limestones (Text-fig. 3). This is in opposition to comparable occurrences of Hungary (BÁLDI, 1986; ZÁGORŠEK, 1995),

Plate 1

Microfacies

Fig. 1. *Discocyclina* marl with *Discocyclina augustae augustae, D. ruppi* and *Asterocyclina priabonensis,* X10 (Helmberg 1, -3199 m, sample: MOL 326).

Fig. 2. Nummulite sandstone with *Nummulites chavannesi* and *Discocyclina augustae augustae,* X10 (Helmberg 1, -3211 m, sample: MOL 80057).

Fig. 3. Coralline-Quartz sandstone with *Nummulites* cf. *stellatus* and *Asterigerina* sp., X10 (Maria Schmolln 1, -2147 m, sample: MOL 262).

Fig. 4. Coralline-Quartz sandstone with *Nummulites* cf. *stellatus* and *Asterigerina* sp., X10 (Neukirchen 1, -1889 m, sample: MOL 80031).

Fig. 5. Coralline rudstone with *Assilina* ex. gr. *gomezi,* X10 (Perwang 1, -2066 m, sample: MOL 80065).

Fig. 6. Coralline rudstone with *Nummulites* cf. *cunialensis,* X10 (Mattighofen 1, -2318 m, sample: MOL 80020).

Fig. 7. Coralline rudstone with *Asterigerina* sp., X10 (Mattighofen 1, -1968 m, sample: MOL 223).

Fig. 8. Coralline rudstone with *Miliolina* and *Nummulites* cf. *stellatus,* X10 (Mattighofen 1, -1930 m, sample: MOL 222).


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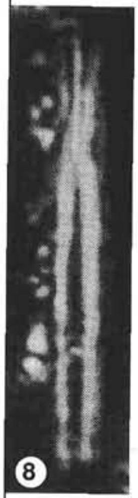
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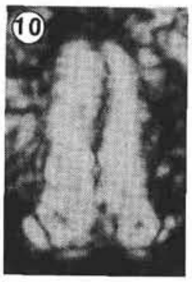
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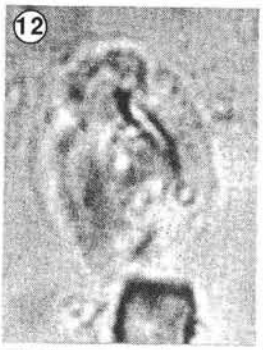
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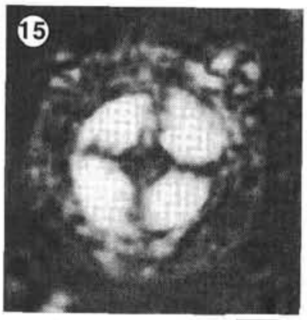
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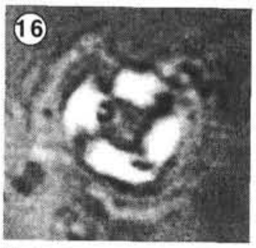
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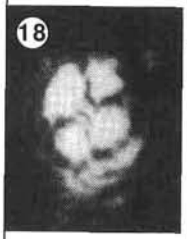
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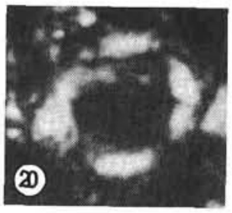
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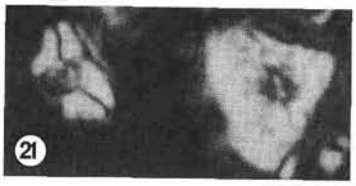
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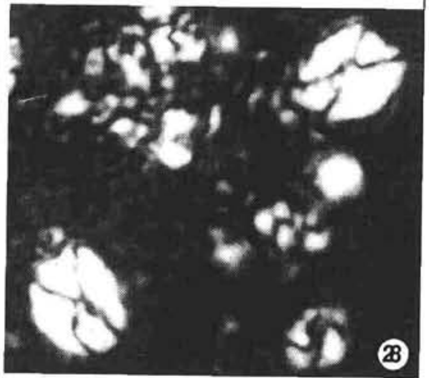
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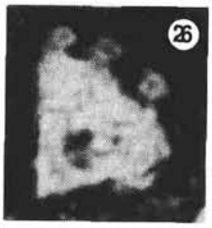
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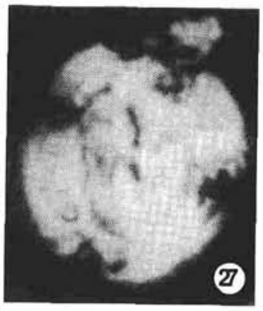
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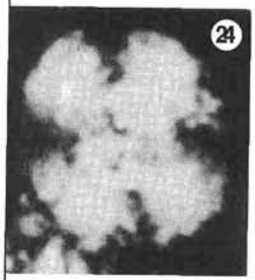
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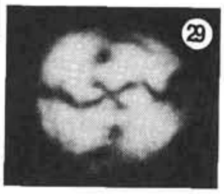
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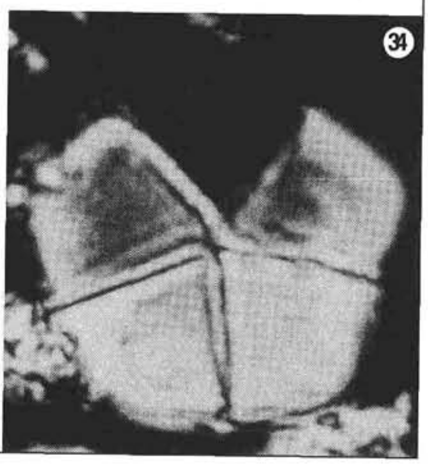
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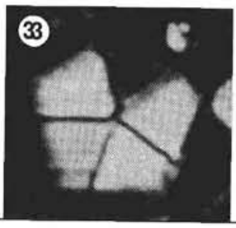
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where the *Discocyclina* marls terminate the Late Eocene successions.

5.2. Nannoplankton

Nannoplankton was studied to obtain biostratigraphical data. Only marly facies (*Discocylina* marls and bryozoa marls), and fine-grained nummulite sandstones from deep wells of the southern region contained nannoplankton. The studied nannofossil assemblages are similar in all samples, there are no characteristic differences. In the facies with a higher carbonate content, there are less nannofossils than in the more clayey ones. The preservation of nannoplankton is better in the carbonate-rich samples. The poorest and the worst preserved assemblage comes from Helmberg 1 (-3193 m).

The whole material is autochthonous, there are only 1–2 specimens of Cretaceous forms in some samples. Mostly, complete coccosphaeres are preserved. Text-fig. 3 shows the distribution of taxa.

22 species could be identified (compare BÁLDI-BEKE, 1984):
Isthmolithus recurvus DEFLANDRE
Transversopontis pulcher (DEFLANDRE) HAY, MOHLER and WADE
Discolithina multipora (KAMPTNER) MARTINI
Helicosphaera bramlettei (MÜLLER) JAFAR and MARTINI
Helicosphaera euphratis HAQ
Blackites sp.
Zygrhablithus bijugatus (DEFLANDRE) DEFLANDRE
Lanternithus minutus STRADNER
Coccolithus pelagicus (WALLICH) SCHILLER
Cyclococcolithus formosus KAMPTNER
Cribrocentrum reticulatum (GARTNER and SMITH) PERCH-NIELSEN
Cyclicargolithus floridanus (ROTH and HAY) BUKRY
Coronocyclus nitescens (KAMPTNER) BRAMLETTE and WILCOXON
Reticulofenestra placomorpha (KAMPTNER) STRADNER
Reticulofenestra bisecta (HAY, MOHLER and WADE) ROTH
Reticulofenestra callida (PERCH-NIELSEN) BYBELL
Discoaster nodifer (BRAMLETTE and RIEDEL) BUKRY
Braarudosphaera bigelowi (GRAN and BRAARUD) DEFLANDRE
Micrantholithus vesper DEFLANDRE
Micrantholithus procerus BUKRY and BRAMLETTE
Pemma papillatum MARTINI
Sphenolithus moriformis (BRÖNNIMANN and STRADNER) BRAMLETTE and WILCOXON

5.3. Larger Foraminifera

In this chapter we give a short description of those forms that were determined with enough certainty. With one exception *(Nummulites budensis)* isolated specimens occur in samples from the *Discocyclina* marl and the nummulite sandstone. Their distribution is listed in Tab. 1 with statistical data on the embryon size of the A-form (see also the table

Plate 2

Nannoplankton. Magnification: 3000 x. Mostly between crossed nicols, exceptions are given below.

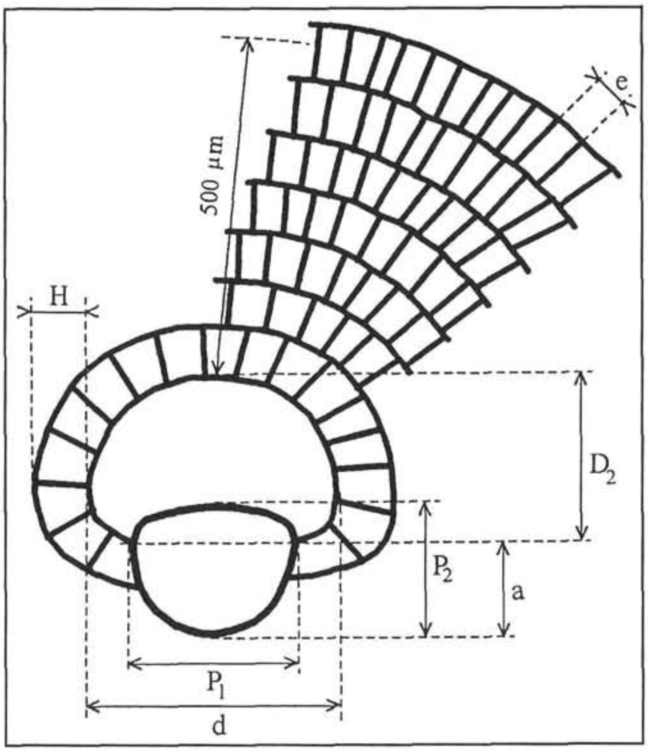
Figs. 1–3. *Isthmolithus recurvus* DEFLANDRE (normal light) (1–2: Helmberg 1, -3209 m, sample: 1998Z-0097/0007; 3: Perwang 1, -2323 m, sample: 1998Z-0097/0001).
Figs. 4, 5. *Transversopontis pulcher* (DEFLANDRE) HAY, MOHLER and WADE (Perwang 1, -2323 m, sample: 1998Z-0097/0001).
Fig. 6. *Discolithina multipora* (KAMPTNER) MARTINI (Perwang 1, -2323 m, sample: 1998Z-0097/0001).
Fig. 7. *Helicosphaera bramlettei* (MÜLLER) JAFAR et MARTINI (Perwang 1, -2323 m, sample: 1998Z-0097/0001).
Fig. 8. *Blackites* sp. (Perwang 1, -2323 m, sample: 1998Z-0097/0001).
Fig. 9. *Zygrhablithus bijugatus* DEFLANDRE) DEFLANDRE and *Lanternithus minutus* STRADNER (Helmberg 1, -3209 m, sample: 1998Z-0097/0007).
Fig. 10. *Zygrhablithus bijugatus* (DEFLANDRE) DEFLANDRE (Perwang 1, -2323 m, sample: 1998Z-0097/0001).
Fig. 11. *Discolithina multipora* (KAMPTNER) MARTINI (Perwang 1, -2323 m, sample: 1998Z-0097/0001).
Figs. 12, 13. *Helicosphaera euphratis* HAQ (same specimen, Fig. 12. with parallel nicols) (Perwang 1, -2323 m, sample: 1998Z-0097/0001).
Fig. 14. *Lanternithus minutus* STRADNER (Helmberg 1, -3209 m, sample: 1998Z-0097/0007).
Figs. 15, 16. *Cyclococcolithus formosus* KAMPTNER (with nicols near to parallel) (15: Perwang 1, -2323 m, 16: Helmberg 1, -3209 m, sample: 1998Z-0097/0007)
Fig. 17. *Reticulofenestra bisecta* (HAY, MOLER and WADE) ROTH and *Cyclicargolithus floridanus* (ROTH et HAY) BUKRY (Perwang 1, -2323 m, sample: 1998Z-0097/0001).
Fig. 18. *Coccolithus pelagicus* (WALLICH) SCHILLER (Helmberg 1, -3209 m, sample: 1998Z-0097/0007).
Fig. 19. *Zygrhablithus bijugatus* (DEFLANDRE) DEFLANDRE (Perwang 1, -2323 m, sample: 1998Z-0097/0001).
Fig. 20. *Coronocyclus nitescens* (KAMPTNER) BRAMLETTE and WILCOXON (Helmberg 1, -3209 m, sample: 1998Z-0097/0007).
Fig. 21. *Pemma papillatum* MARTINI and *Lanternithus minutus* STRADNER (Helmberg 1, -3209 m, sample: 1998Z-0097/0007).
Fig. 22. *Reticulofenestra callida* (PERCH-NIELSEN) BYBELL (Helmberg 1, -3209 m, sample: 1998Z-0097/0007).
Fig. 23. *Sphenolithus moriformis* (BRÖNNIMAMM and STRADNER) BRAMLETTE and WILCOXON (Perwang 1, -2323 m, sample: 1998Z-0097/0001).
Fig. 24. *Reticulofenestra bisecta* (HAY, MOLER and WADE) ROTH (Helmberg 1, -3209 m, sample: 1998Z-0097/0007).
Fig. 25. *Cyclicargolithus floridanus* (ROTH et HAY) BUKRY (Perwang 1, -2323 m, sample: 1998Z-0097/0001).
Fig. 26. *Pemma papillatum* MARTINI (Perwang 1, -2323 m, sample: 1998Z-0097/0001).
Fig. 27. *Reticulofenestra bisecta* (HAY, MOLER and WADE) ROTH (Helmberg 1, -3209 m, sample: 1998Z-0097/0007).
Fig. 28. *Lanternithus minutus* STRADNER (two specimens) and *Cyclicargolithus floridanus* (ROTH et HAY) BUKRY (small specimen right down) (Perwang 1, -2323 m, sample: 1998Z-0097/0001).
Fig. 29. *Cribrocentrum reticulatum* (GARTNER and SMITH) PERCH-NIELSEN (Perwang 1, -2323 m, sample: 1998Z-0097/0001).
Fig. 30. *Reticulofenestra calida* (PERCH-NIELSEN) BYBELL (Perwang 1, -2323 m, sample: 1998Z-0097/0001).
Fig. 31. *Reticulofenestra placomorpha* (KAMPTNER) STRADNER (Perwang 1, -2323 m, sample: 1998Z-0097/0001).
Fig. 32. *Reticulofenestra placomorpha* (KAMPTNER) STRADNER and *Lanternithus minutus* STRADNER (Helmberg 1, -3209 m, sample: 1998Z-0097/0007).
Fig. 33, 34. *Braarudosphaera bigelowi* (GRAN and BRAARUD) DEFLANDRE (33: Helmberg 1, -3209 m, sample: 1998Z-0097/0007; 34: Perwang 1, -2323 m, sample: 1998Z-0097/0001).

caption) and in text-figs. 3, 4.

Two main groups of larger foraminifera can be found in the *Discocyclina* Marls: The orthophragminids and the nummulitids. Orthophragminids (for details see e.g. LESS 1987, 1993, 1998 and FERRANDEZ, 1998) are mostly represented by *Discocyclina* (Discocyclinidae); the genus *Asterocyclina* (Orbitoclypeidae) was only found in three samples. Orthophragminid taxa are listed in Tab. 1 and text-figs. 3, 4. The most dominant taxon is the unribbed *Discocyclina augustae augustae,* which is a very common taxon in the Tethyan Priabonian. Other unribbed Discocyclinae, like *D. trabayensis* n. ssp. Mossano (see systematic description) and *D. dispansa* cf. *umbilicata* (both of them are also characteristic Tethyan forms) are only accessorial. Ribbed forms of the Discocyclinae (formerly grouped into the genus *Aktinocyclina*) are also relatively frequent, but their abundance is much lower than that of the unribbed *D. augustae augustae.* Their most frequent form is the new taxon, *D. ruppi* n. sp. This species is supposed to be the ribbed variant of the unribbed *D. trabayensis.* Two other ribbed Discocyclinae (*D. radians labatlanensis* and *D. samantai,* both are typical Tethyan forms) are also present but very rare in our samples. The other genus of the family Discocyclinidae, *Nemkovella,* is absent like the *Orbitoclypeus* belonging to the Orbitoclypeidae. The latter family is only represented by rare specimens of *Asterocyclina priabonensis,* which is well known from Priabona and Lâbatlan (Hungary) (LESS, 1987).

Nummulitidae are less frequent than the orthophragminids (they occur in only five of the eight samples). They are represented by the genera *Nummulites* (three species) and *Assilina* (one species). The distribution of Nummulites is rather interesting: In three samples (see text-figs. 3, 4 and tab. 1) *N. chavannesi* is the dominant form, but in the other two it is missing or very rare. In these samples *N. stellatus* and *N. cunialensis* are represented in almost equal quantity. *Assilina alpina* (formerly *Operculina alpina*) was found in three samples. All the nummulitids are typical Tethyan forms.

In thin-sections from the harder layers of the *Discocyclina* marls (deep well Helmberg 1, samples MOL 329 (-3199 m) and MOL 330 (-3197 m) approximately the same fauna of orthophragminids could be identified, whereas nummulitids are represented only by *N. chavannesi.* This species is characteristic for the nummulite sandstone too (deep well Helmberg 1. samples MOL 321 (-3214 m) to MOL 325 (-3209 m)), but in sample Helmberg 1, at -3215 m we have found a nearly equatorial section of *N. budensis* as well.



Text-Fig. 2
The measurement system for the A-forms of orthophragminids. See explanations in the text.

In the lower red algal limestone (deep well Mattighofen 1, samples MOL 202 (-1954 m) to MOL 212 (-1944 m) and deep well Neukirchen 1, samples MOL 377 (-1889 m) and MOL 380 (-1888 m) nummulitids are the dominant larger foraminifera, orthophragminids (most probably *Discocyclina augustae augustae*) were found only in one single sample (MOL 205 (-1952 m)). A rather inflated radiate form, identified as *Nummulites* cf. *stellatus* is the most frequent representative of its genus. Additionally, another radiate but less inflated form, identified as *N.* cf. *cunialensis* may be abundant. In three samples reticulate forms belonging to the *N. fabianii*-

Table 1.
Statistical data for the embryon size of populations of nummulitids and orthophragminids measured on split specimens. For nummulitids the data of the inner cross protoconch diameter, for orthophragminids those of the outer cross deuteroconch diameter (both in µm) are given. Abbreviations for taxa: nucha: *Nummulites chavannesi*, nucun: *N. cunialensis*, nuste: *N. stellatus*, asalp: *Assilina alpina*, diaug: *Discocyclina augustae augustae*, didsp: *D. dispansa* cf. *umbilicata*, ditrb: *D. trabayensis* cf. n. ssp. Mossano, disam: *D. samantai*, dirad: *D. radians labatlanensis*, dirup: *D. ruppi*, aspri: *Asterocyclina priabonensis*. n°: number of specimens, s.e.: standard error.

Borehole	Perwang 1.															Helmberg 1.								
Sample	2083 m			2311 m			2317 m			2323 m			2379 m			3193 m			3208 m			3209 m		
Taxa	n°	mean	s.e.	n°	mean	s.e.	n°	mean	s.e.	n°	mean	s.e.	n°	mean	s.e.	n°	mean	s.e.	n°	mean	s.e.	n°	mean	s.e.
nucha	1	140	–	22	191	6	1	230	–										8	151	8	12	181	7
nucun							8	121	8	6	86	7												
nuste							7	84	3	6	78	6							1	100	–			
asalp				2	115	4	4	135	15													2	105	18
diaug	9	234	10	13	240	5	13	252	10	10	262	15	4	224	12	2	315	18	10	274	15	17	275	7
didsp	1	600	–																					
ditrb	1	133	–																			1	156	–
disam	2	1110	134																					
dirad	2	440	14							1	390	–	7	370	17	2	372	34						
dirup										8	178	8										2	158	2
aspri	2	199	6				1	225	–				3	179	9									

group (represented by one single specimen in each of the samples) could be identified. In the deep well Perwang 1, at -2064 m, the involute *Assilina* cf. *gomezi* is present. Among other genera, *Asterigerina* is sometimes very frequent and single specimens of *Sphaerogypsina* and *Gypsina* were found in two samples. In one sample from the top-most algal limestone of Mattighofen 1 (MOL 260 (-1883 m), the genus *Nummulites* is still present and represented by *N.* cf. *cunialensis.*

5.3.1. Biometry

A detailed biometrical study was only made for *Discocyclina ruppi* n. sp. LESS. Text-fig. 2 shows the measurement system of orthophragminids introduced by LESS (1987, 1993). It contains nine dimensions (in µm) and countings:

P_1 and **P_2**: outer width and height of the protoconch.
d and **D_2**: outer width and height of the deuteroconch.
a: distance from the sole of the deuteroconch to the sole of the protoconch upwards (in text-fig. 2. "a" is negative!).
N: number of the adauxiliary chamberlets (in text-fig. 2 N=15).
H: average height of the adauxiliary chamberlets.
e: average width of the equatorial chamberlets.
n: number of equatorial annuli in the first 500 µm from the embryon's rim (in text-fig. 2 n~6.6).

Using these measurements, ten parameters are used for biometrical characterisation of particular populations. Five measured parameters (d, N, H, e and n) are used directly while five others are calculated:

P: medium diameter of the protoconch (in µm), calculated as $\mathbf{P=(P_1XP_2)^{1/2}}$.
Z: evolutionary index of the embryon (LESS, 1992), calculated as $\mathbf{Z=100X(0.5+[P_2+2Xa]/[2XD_2-P_2-2Xa+abs(P_2+2Xa)])}$.
L: average width of the adauxiliary chamberlets (in µm), calculated as $\mathbf{L=(D_2/c)X\pi X([(d+H)2+(D_2+H)2]/2)1/2/(N+1)}$, where $c=D_2-a$ if $a<0$, otherwise $c=D_2$.
F: isometry index of the adauxiliary chamberlets, calculated as $\mathbf{F=100XH/(H+L)}$.
G: isometry index of the equatorial chamberlets, calculated as $\mathbf{G=100X[(500-H)/(n-1)]/[(500-H)/(n-1)+e]}$.

The statistical data for *Discocyclina ruppi* by populations are tabulated in Table 2. In its description we use the terminology of LESS (1987).

5.3.2. Systematic Description

Order FORAMINIFERIDA EICHWALD, 1830
Family NUMMULITIDAE DE BLAINVILLE, 1827
Genus *Nummulites* LAMARCK, 1801

Nummulites chavannesi DE LA HARPE, 1878

Pl. 3, Figs. 1–3, 5–7

Nummulites chavannesi DE LA HARPE – DE LA HARPE, 1883, pl. 6, figs. 22–41.
Nummulites chavannesi DE LA HARPE – HERB and HEKEL, 1975, pl. 2, figs. 1–3, text-figs. 14–21.
Remarks: This taxon is the most important species of *Nummulites* in all facies. *N. cunialensis* is the closest taxon to it, however *N. chavannesi* has a considerably larger protoconch.
Facies: *Discocyclina* marl (rare to abundant); Nummulite sandstone (abundant); coralline bindstone (abundant in one sample).

Nummulites cunialensis HERB and HEKEL, 1975

Pl. 3, figs. 4, 8, 12, 16

Nummulites cunialensis n. sp. – HERB and HEKEL, 1975, pp. 122–123, pl. 1, figs. 5–8, text-figs. 9–13.
Remarks: This taxon substitutes *N. chavannesi* in two samples of the deep well Perwang 1. The main difference between them is the size of the protoconch. It is worth noting that in the sample from -2323 m the mean protoconch-size is considerably larger than that of the sample from -2317 m.
Facies: *Discocyclina* marl (rare to common); coralline-quartz sandstone (common); coralline bindstone (common); coralline rudstone (common).

Nummulites stellatus ROVEDA, 1961

Pl. 3, Figs. 9–11, 13–15

Nummulites stellatus n. sp. – ROVEDA, 1961, p. 181, pl. 15, figs. 1–14, pl. 17, figs. 7, 11, text-figs. 12–13.
Nummulites stellatus ROVEDA – HERB and HEKEL, 1975, pp. 127–128, pl. 1, figs. 12–16, text-figs. 33–37.
Remarks: This taxon is well distinguishable from the two previous ones by its strongly inclined and arcuated septa. As it can be identified from the thin-sections, we think that this is the most widespread *Nummulites* in the red algal limestones.
Facies: *Discocyclina* marl (rare to common); algal limestone (not differentiated) (rare); coralline rudstone (abundant); coralline-quartz sandstone (abundant); coralline bindstone (abundant)

Nummulites budensis HANTKEN, 1875

Pl. 3, Fig. 19

Nummulites budensis n. sp. – HANTKEN, 1875, pp. 74–75, pl. 12, fig. 4.
Nummulites bouillei DE LA HARPE (partim) – HERB and HEKEL, 1975, pp. 125–126, pl. 1., figs. 9–11, text-figs. 22–24 (non 25!).
Nummulites budensis HANTKEN - JÁMBOR-KNESS, 1988, pp. 258–259, pl. 15, figs. 229–237.
Remarks: One single specimen of this taxon could be identified from the nearly perfectly oriented equatorial section figured in pl. 3. It differs from the other Priabonian radiate *Nummulites* by a very small protoconch and a very loose spire. *N. budensis* was misidentified for a long time as *N. bouillei.* Our recent studies on topotypical material (LESS, 1999) made it clear that the Lower Oligocene *N. bouillei* is quite different from the Upper Eocene *N. budensis.*
Facies: Nummulite sandstone (one specimen)

Genus *Assilina* D'ORBIGNY, 1839

Assilina alpina (DOUVILLÉ), 1916

Pl. 4, figs. 1–3

Operculina alpina n. sp. – DOUVILLÉ, 1916, p. 329, text-fig. 1.
Operculina alpina DOUVILLÉ – HOTTINGER, 1977, pp. 85–87, pl. 38, figs. 4–6, text-figs. 33–34.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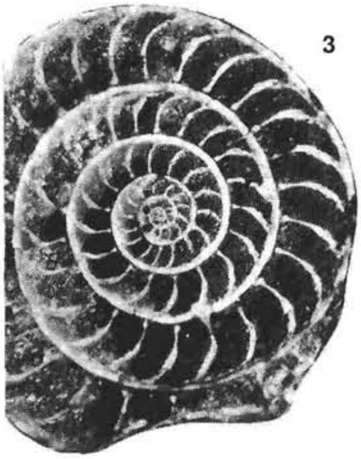
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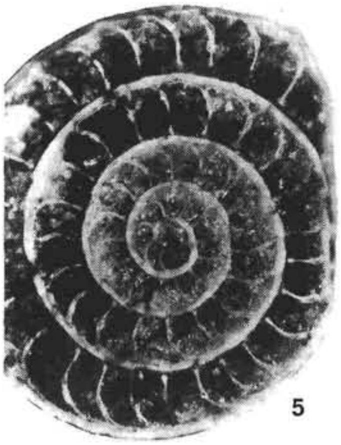
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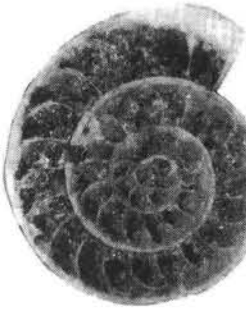
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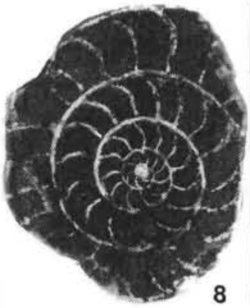
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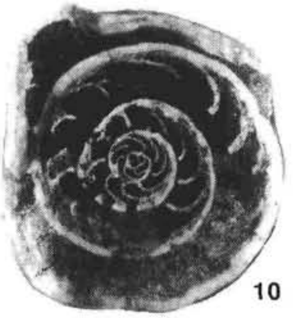
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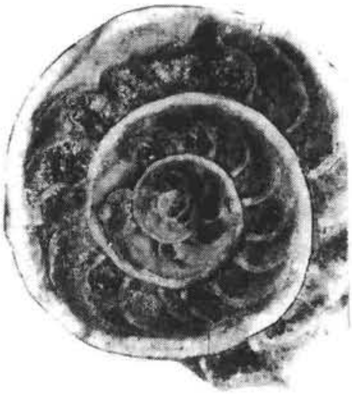
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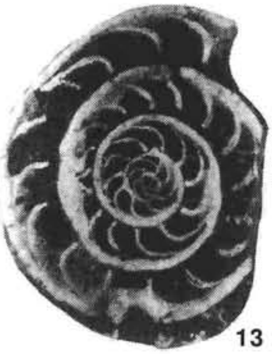
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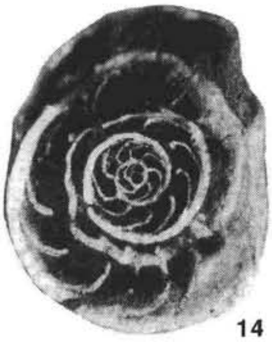
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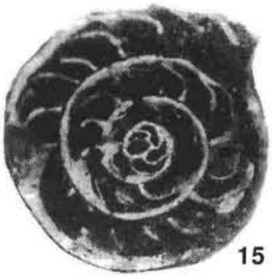
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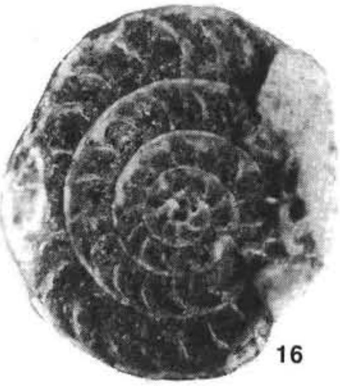
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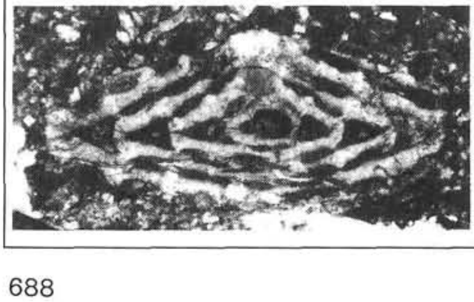
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Remarks: The embryon-size in our Austrian populations can be compared with those of Papazzoni (1998) from Spain, Italy and Romania and of Less (1999) from Hungary. It can be stated that our data (with the mean of 100–140 µm) are much closer to those coming from the Upper Bartonian (SBZ 18 zone) and Lower-Middle Priabonian (SBZ 19 zone) beds (mean=100–150 µm) than to those of the Upper Priabonian (SBZ 20 zone) populations (mean=160–190 µm).
Facies: *Discocyclina* marl (common); nummulite sandstone (rare)

Family Discocyclinidae Galloway, 1928

Genus *Discocyclina* Gümbel, 1868

Discocyclina augustae augustae Van Der Weijden, 1940

Pl. 4, figs. 5–11

Discocyclina (Discocyclina) augustae n. sp. – Van Der Weijden, 1940, pp. 23–26, pl. 1, figs. 4, 5, 7, 8, pl. 2, figs. 1, 2, 11.
Discocyclina augustae augustae Van Der Weijden – Less, 1987, pp. 155–156, pl. 10, figs. 5–6, 8–12, pl. 11, figs. 1–4.
Remarks: This taxon is the most widespread orthophragminid in the wash-residues. The populations of deep well Helmberg 1 have larger embryons than those of Perwang 1.
Facies: *Discocyclina* marl (abundant); nummulite sandstone (rare to abundant); coralline bindstone (common).

Discocyclina dispansa (Sowerby), 1840 cf. *umbilicata* (Deprat), 1905

Pl. 5, Fig. 2

Orthophragmina umbilicata n. sp. – Deprat, 1905, pp. 497–501, pl. 15, figs. 2–11, text-figs. A–E.
Discocyclina dispansa (Sowerby) *umbilicata* (Deprat) – Less, 1987, pp. 164–165, pl. 14, figs. 4–5, 7–8.
Remarks: One single isolated specimen of this taxon could be identified. However, we have also found some oblique sections of *Discocyclina* with considerably larger embryon than that of the *D. augustae augustae*. These forms can also be ranged conditionally to this taxon.
Facies: Discocyclina marl (rare)

Discocyclina trabayensis Neumann, 1955 cf. n. ssp. Mossano in Less, 1998

Discocyclina trabayensis vicenzensis n. ssp. (partim) – 1987, pp. 172–173, pl. 18, figs. 3–4
Remarks: We have found only two poorly preserved, not figurable specimens belonging to the *Discocyclina trabayensis*-lineage. Their mean deuteroconch-size is very likely less than 170 µm. Recently, Less (1998) subdivided the former (Less, 1987) *D. trabayensis vicenzensis* into two by this limit leaving the name for the Upper Priabonian (SBZ 20 zone) populations with mean deuteroconch-size exceeding 170 µm. Until the formal description of the forms belonging to the *D. trabayensis*-lineage with mean deuteroconch-size between 125 and 170 µm and characteristic for the Lower-Middle Priabonian (SBZ 19 zone) we use the name of *D. trabayensis* n. ssp. Mossano for them.
Facies: Nummulite sandstone (rare); Discocyclina marl (rare).

Discocyclina samantai Less, 1987

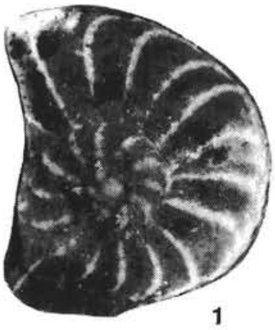
Pl. 5, Fig. 11

Discocyclina samantai n. sp. – Less, 1987, pp. 180–181, pl. 21, figs. 4–6.
Remarks: Until this finding this taxon, the ribbed variety of *Discocyclina pratti,* was known only from Hungary (Lábatlan, Less, 1987) and from Priabona (identified by Less in the Setiawan, 1983 material in Utrecht). All the three localities mark the Middle Priabonian (the O.15 orthophragminid biozone by Less, 1998).
Facies: Discocyclina marl (rare).

Plate 3

Foraminifera

Figs. 1–3, 5–7.	*Nummulites chavannesi* De La Harpe.
Fig. 1.	B-form, external view, X10 (Perwang 1, -2311 m, specimen: 2K2).
Fig. 2.	B-form, external view, X10 (Perwang 1, -2311 m, specimen: 2K3).
Fig. 3.	B-form, equatorial section, X20 (Perwang 1, -2311 m, specimen: 2K2).
Fig. 5.	A-form, equatorial section, X20 (Perwang 1, -2311 m, specimen: 2K1).
Fig. 6.	A-form, equatorial section, X20 (Helmberg 1, -3208 m, specimen: 2M4).
Fig. 7.	A-form, equatorial section, X20 (Helmberg 1, -3209 m, specimen: 2P0).
Figs. 4, 8, 12, 16.	*Nummulites cunialensis* Herb and Hekel.
Fig. 4.	B-form, external view, X10 (Perwang 1, -2317 m, specimen: 2L4).
Fig. 8.	A-form, equatorial section, X20 (Perwang 1, -2323 m, specimen: 2L7).
Fig. 12.	B-form, equatorial section, X20 (Perwang 1, -2317 m, specimen: 2L4).
Fig. 16.	A-form, equatorial section, X20 (Perwang 1, -2317 m, specimen: 2P2).
Figs. 9–11, 13–15.	*Nummulites stellatus* Roveda, A-form.
Fig. 9.	External view, X10 (Perwang 1, -2317 m, specimen: 2N9).
Fig. 10.	Equatorial section, X20 (Perwang 1, -2323 m, specimen: 2L6).
Fig. 11.	Equatorial section, X20 (Helmberg 1, -3208 m, specimen: 2L1).
Fig. 13.	Equatorial section, X20 (Perwang 1, -2317 m, specimen: 2N7).
Fig. 14.	Equatorial section, X20 (Perwang 1, -2323 m, specimen: 2L3).
Fig. 15.	Equatorial section, X20 (Perwang 1, -2317 m, specimen: 2N8).
Figs. 17–18.	*Nummulites* ex. gr. *fabianii* (Prever in Fabiani), A-form, nearly axial section, X20.
Fig. 17.	Helmberg 1, -3211 m, thin-section: MOL 323.
Fig. 18.	Mattighofen 1, -2387 m, thin-section: MOL 205.
Fig. 19.	*Nummulites budensis* Hantken, A-form, nearly equatorial section, X40 (Helmberg 1, -3215 m, thin-section MOL 80051).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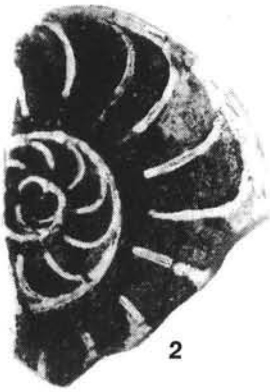
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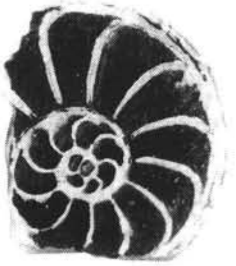
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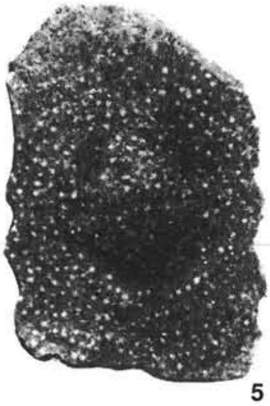
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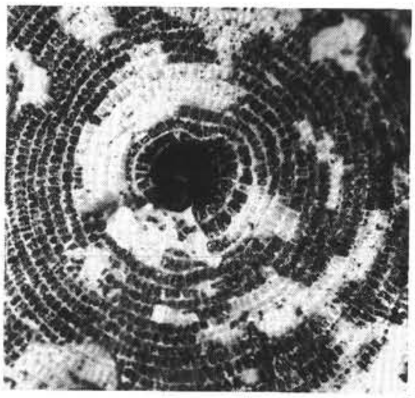
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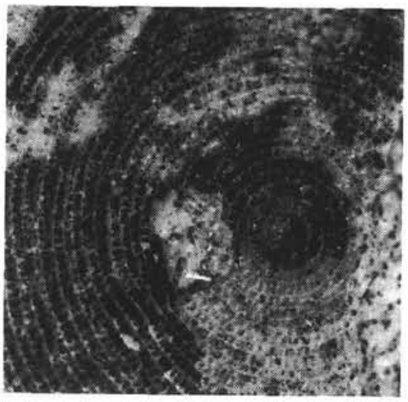
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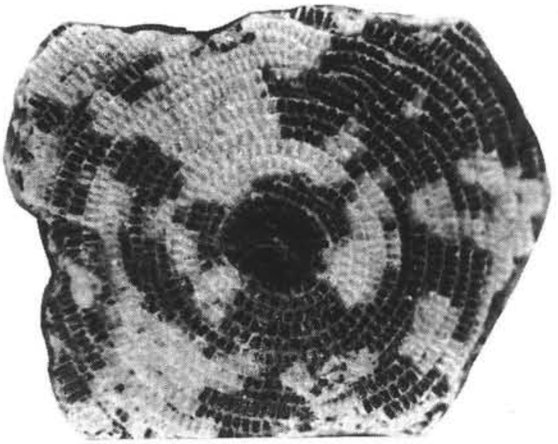
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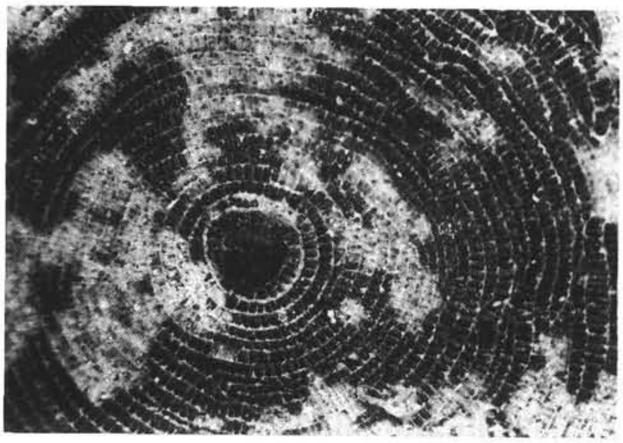
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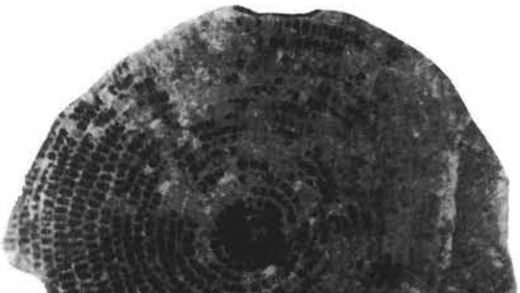
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Discocyclina radians (D'ARCHIAC, 1850) *labatlanensis* LESS, 1987

Discocyclina radians (D'ARCHIAC) *labatlanensis* n. ssp. – LESS, 1987, pp. 168–169, pl. 16, figs. 6–7.
Remarks: All our specimens from Austria are poorly preserved and not suitable for photo-documentation.
Facies: *Discocyclina* marl (rare), bryozoa marl (rare)

Discocyclina ruppi n. sp. LESS

Pl. 5, Figs. 3–4, 6–8

Derivatio nominis: In honour of Dr. Christian RUPP, the Austrian micropaleontologist from the Geological Survey of Vienna, who initiated the current study.
Holotype: Preparate 2M0, pl. 3, fig. 4.
Type locality: Deep well Perwang 1, at -2323 m below NN, of the Rohöl-AG Vienna; stored in Pettenbach, Upper Austria.
Type level: Middle Priabonian, upper part of the SBZ 19 biozone (SERRA-KIEL et al., 1998), O.15 orthophragminid biozone (LESS, 1998).
Diagnosis: Small- and medium-sized, flattened forms with 10 to 14 radial ribs. The embryon is nephrodiscodine, the two chambers are small. The few adauxiliary chambers are of the *"varians"* type, small and nearly isometric. The equatorial chamberlets are very narrow but rather high, especially near the peripheries. The growth pattern of the annuli is the *"trabayensis"* type.
Description: External morphology: Small- and medium-sized (3–6 mm), always flat forms. The umbo is max. 1 mm in diameter, strongly protruding. From here 7 to 10 thin radial ribs start. Between these ribs new ones may start from the middle of the collar. *"Discocyclina"* type rosette, tiny granules (30 to 50 μm in diameter). The size ratio of forms "A" and "B" is unknown, as the latter have not yet been found.
Internal morphology: The equatorial section of forms "A" (for quantitative characteristics see Table 2): Small nephrodiscodine embryon. Few, narrow, nearly isometric *"varians"* type (with arcuated outer wall) adauxiliary chamberlets. Narrow but rather high (especially towards the peripheries) equatorial chamberlets. *"Trabayensis"* type growth pattern of the annuli.
The equatorial section of forms "B": Microsphaeric specimens were not found in the examined populations.
Axial section: For the time being the new taxon has no perfectly oriented axial section.
Remarks: Ribbed forms with similar internal morphology were not known; this is why this new species has to be established. By its internal characteristics the closest unribbed taxon to *Discocyclina ruppi* is *D. trabayensis*. Therefore, the latter is thought to be the ancestor of the new species. Discoidal, ribbed forms were formerly ranged into the genus of *Aktinocyclina*. However, ribbed forms can be developed from different unribbed forms, even belonging to different genera (see LESS, 1987 and FERRÁNDEZ-CAÑADELL, 1997). Therefore, *Aktinocyclina* as a genus name has to be abandoned.

Table 2.
Statistical data for populations of *Discocyclina ruppi* n. sp. LESS. More details about the abbreviations of the parameters see in the text. n°: number of specimens, min.: minimum, max.: maximum, s.e.: standard error.

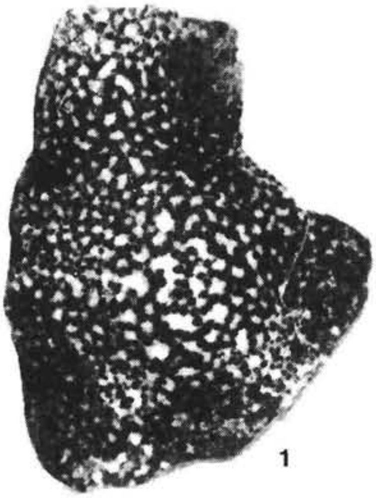
Sample	Perwang 1, 2323 m					Helmberg 1, 3209 m			
Parameters	n°	min.	max.	mean	s.e.	n°	min.	max.	mean
P (μm)	7	72	135	99.5	7.2	2	80	95	87.4
d (μm)	8	150	210	178.5	8.4	2	155	160	157.5
Z	7	46.9	57.7	54.3	1.4	2	51.6	55.4	53.5
N	7	12	16	14.0	0.6	2	14	14	14.0
H (μm)	8	35	50	42.8	2.0	2	40	40	40.0
L (μm)	7	28.0	39.5	35.4	1.4	2	32.1	32.4	32.2
F	7	47.8	57.9	54.6	1.2	2	55.3	55.5	55.4
e (μm)	8	20	25	23.9	0.7	2	20	22	21.0
n	8	12.0	14.6	12.8	0.4	2	11.0	11.5	11.2
G	8	60.0	64.3	62.1	0.5	2	66.6	69.7	68.1

It is worth noting that a slight intraspecific variability can be recognised between our two populations: The equatorial chamberlets of the two specimens from the deep well Helmberg 1, -3209 m are more elongated than those of the specimens from Perwang 1, -2323 m.
Comparison: Among the ribbed *Discocyclinae* only the Lutetian-Bartonian *D. knessae* (see in LESS, 1987) has similar-sized nephrodiscodine embryon. However, the outer wall of the adauxiliary chamberlets of *D. knessae* is straight, the chamberlets are of the *"archaici"* type instead of the *"varians"* type adauxiliary chamberlets of the *D. ruppi* with arcuate outer wall. Also, the equatorial chamberlets are more elongated (especially towards the peripheries) in the case of the *D. ruppi* than at *D. knessae*. These differences reflect the different origin of the two taxa: *D. knessae* derives from the unribbed *D. augustae* while the unribbed ancestor of *D. ruppi* is the *D. trabayensis*. The distinction from the Priabonian *D. nandori* is even easier, the latter has a bit larger and - what is more important - a semi-nephro- to trybliodiscodine type embryon. The adauxiliary chamberlets are also different: *D. nandori* has them more and they are of the *"pratti"* type.
Range: The Middle Priabonian (the upper part of the SBZ 20 biozone and the O.15 Orthophragminid biozone).

Plate 4

Foraminifera

Figs.1–3.	*Assilina alpina* (DOUVILLÉ).
Fig. 1.	External view, X10 (Perwang 1, -2311 m, specimen: 2K0).
Fig. 2.	A-form, equatorial section, X20 (Perwang 1, -2317 m, specimen: 2L0).
Fig. 3.	A-form, equatorial section, X20 (Perwang 1, -2317 m, specimen: 2K9).
Fig. 4.	*Assilina* cf. *gomezi* (COLOM and BAUZÁ), nearly axial section, X20 (Perwang 1, -2066 m, thin-section MOL 80065).
Figs. 5–11.	*Discocyclina augustae augustae* VAN DER WEIJDEN.
Fig. 5.	A-form, external view, X10 (Helmberg 1, -3209 m, specimen I).
Fig. 6.	A-form, equatorial section, X40 (Perwang 1, -2323 m, specimen: 2N6).
Fig. 7.	A-form, equatorial section, X40 (Perwang 1, -2317 m, specimen: 2M7).
Fig. 8.	A-form, equatorial section, X40 (Helmberg 1, -3209 m, specimen: 2N0).
Fig. 9.	A-form, equatorial section, X40 (Helmberg 1, -3208 m, specimen: 2N2).
Fig. 10.	A-form, equatorial section, X40 (Helmberg 1, -3209 m, specimen: 2M9).
Fig. 11.	A-form, equatorial section, X40 (Perwang 1, -2379 m, specimen: 2J9).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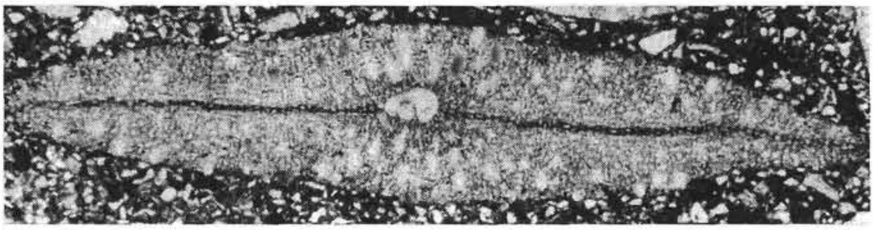
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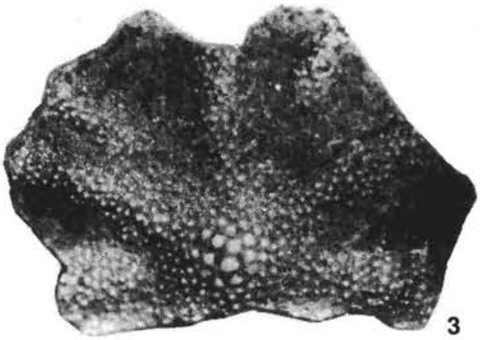
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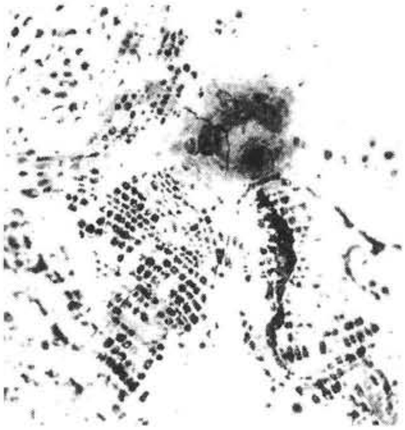
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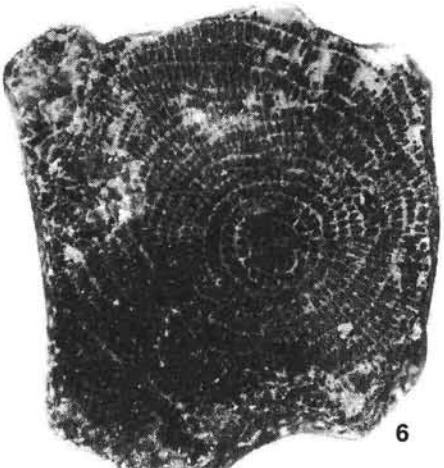
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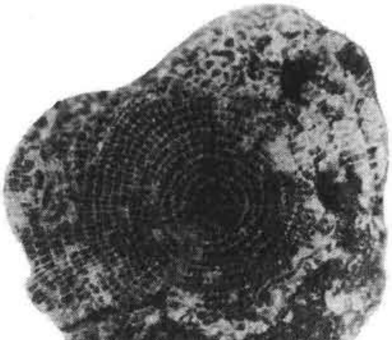
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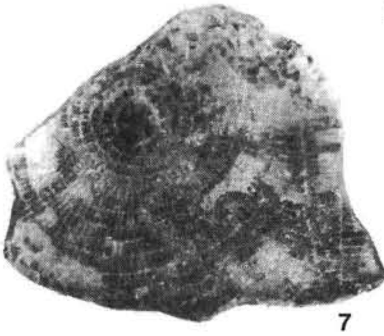
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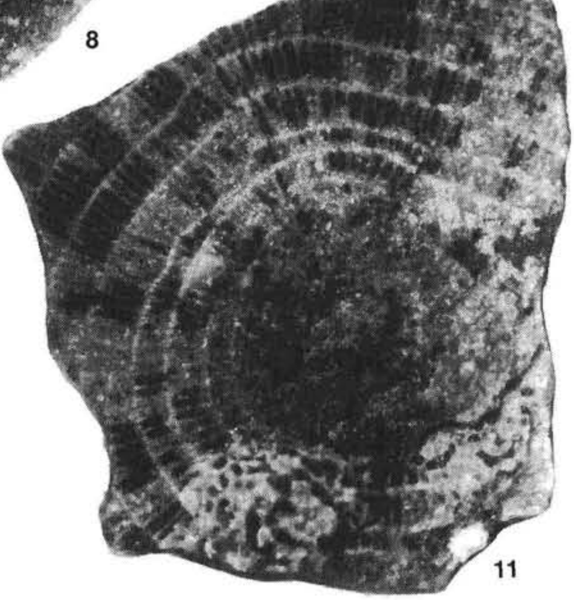
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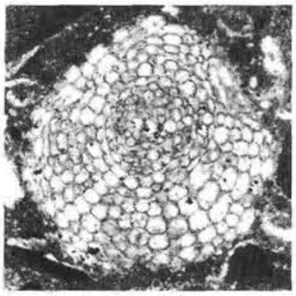
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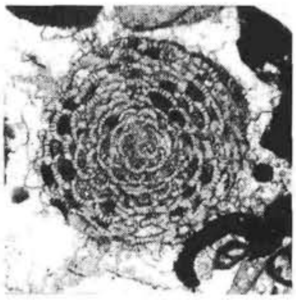
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Very likely an endemic form in the *Discocyclina* Marls of the basal layers of the Upper Austrian Molasse (deep well Perwang 1, -2323 m; deep well Helmberg 1, -3209 m).
Facies: *Discocyclina* marl (common); nummulite sandstone (rare); coralline bindstone (rare)

Family ORBITOCLYPEIDAE BRÖNNIMANN, 1946

Genus *Asterocyclina* GÜMBEL, 1868

***Asterocyclina priabonensis* GÜMBEL, 1868**

Pl. 5, Figs. 1, 5

Orbitoides (Asterocyclina) priabonensis n. sp. – GÜMBEL, 1868, pp. 715–716, pl. 4, figs. 36–41.
Asterocyclina priabonensis GÜMBEL – LESS, 1987, pp. 238–239, pl. 41, figs. 7–8.
Remarks: Our rather ill-preserved Austrian specimens show transitional character between *Asterocyclina stellata* (the ancestor) and *A. priabonensis.* This later taxon is not known before the Middle Priabonian.
Facies: Discocyclina marl (rare).

6. Discussion

6.1. Biostratigraphy

6.1.1. Nannoplankton

The biostratigraphic evaluation is the same for both deep wells. In MARTINI's zonation (1971) the studied assemblages belong to the NP 19-20 zones (text-fig. 5). The reasons for giving this stratigraphic position are based on the following arguments in detail:

The lower boundary of NP 19 is marked by the first appearance of *Isthmolithus recurvus,* which is present in almost all of the studied samples. That means, our assemblage is not older than NP 19. For the separation of NP 19 and NP 20 there is no marker at all. The only one which was given by MARTINI (1971) *(Sphenolithus pseudoradians)* already occurred even in the Middle Eocene (BÁLDI-BEKE, 1984; PERCH-NIELSEN, 1985). This species does not occur in the studied material.

The upper boundary of NP 20 is marked by the last occurrences of *Discoaster barbadiensis* and *Discoaster saipanensis* (rosette-shaped forms), but unfortunately they are totally missing in the studied material. Based on the following data – in spite of the absence of the zone markers – the assemblage can not be younger than NP 20:

1. The presence of *Cribrocentrum reticulatum:* The last occurrence of the species is suggested as a secondary marker for NP 20-21 boundary by C. MÜLLER (1978) and AUBRY (1986), and given the range by PERCH-NIELSEN (1985) for NP 16-19.

2. The presence of *Pemma papillatum:* even the genus is restricted to the Eocene; it is well known from Middle Eocene near-shore facies (BÁLDI-BEKE, 1984).

3. The *Lanternithus minutus* and *Zygrhablithus bijugatus* species are common to abundant in NP 21-22 throughout the Alps and Carpathians (BÁLDI-BEKE, 1984; CICHA, HAGN and MARTINI, 1971). In the studied material these two species are rare enough for an age older than Lowermost Oligocene.

The studied nannofossil assemblage is rather similar to that of the Priabonian in the Italian stratotype area (VERHALLEN and ROMEIN, 1983; PROTO-DECIMA, ROTH and TODESCI, 1975; BARBIN, 1989) and the Buda Marl, in and around Budapest (BÁLDI-BEKE, 1972). All the species from Upper Austria are present in these localities. The frequency of the species is rather similar among these: Assemblages are dominated by placoliths (genera *Coccolithus, Cyclococcolithus, Cyclicargolithus, Reticulofenestra*) and holococcoliths *(Zygrhablithus bijugatus, Lanternithus minutus),* which marks an inner shelf marine environment (BARBIN, 1989; BÁLDI-BEKE, 1984).

6.1.2. Larger Foraminifera

The age of the *Discocyclina* Marls can be determined quite precisely by using the recent data of SERRA-KIEL et al. (1998) and LESS (1998): *Discocyclina augustae augustae, Nummulites chavannesi* and *N. stellatus* are characteristic for the whole Priabonian. However, *Nummulites cunialensis, Discocyclina samantai* and *D. trabayensis* n. ssp. MOSSANO are more characteristic to its lower part, while *Asterocyclina priabonensis* is rather common in the upper two-third of this stage (text-fig. 5). These data together mark the upper part of the SBZ (shallow benthic zonation) 19 biozone of SERRA-KIEL et al. (1998) or the O.15 orthophragminid biozone of LESS (1998) and give a Middle Priabonian age. This is not at all contradicting to the calcareous nannoplankton data (NP 19-20 biozone). This age probably suits for the nummulitic sandstone, too. The age of the red algal limestone cannot be determined as precisely but it contains still distinct Eocene forms and on this base it can be tentatively put into the SBZ 20 (Upper Priabonian) biozone.

One of the most important findings is the occurrence of *N.* cf. *cunialensis* at the top of deep well Mattighofen 1. This points to the fact, that the uppermost parts of the algal limestones also belong to the Late Eocene; Oligocene age, as it

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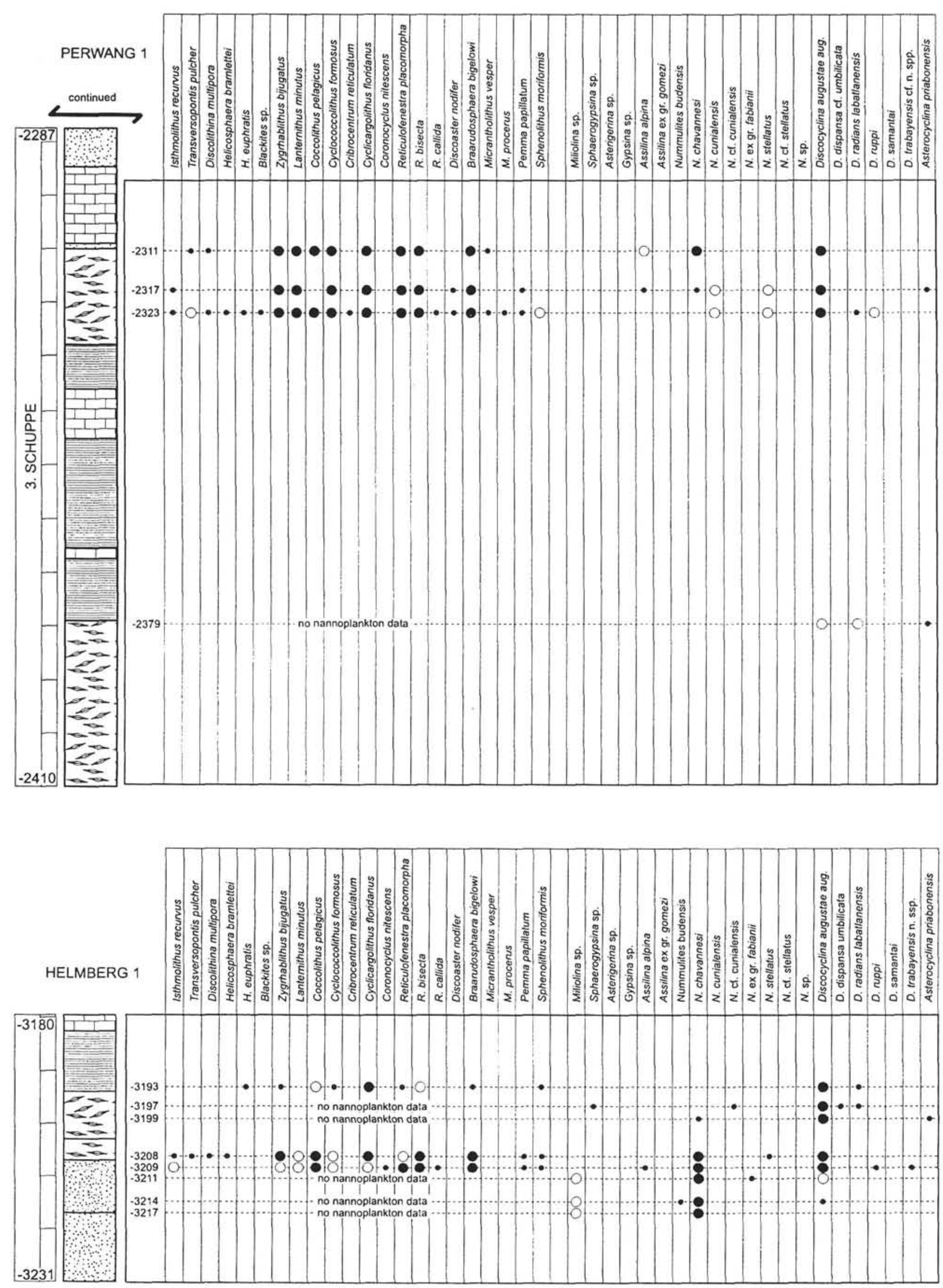
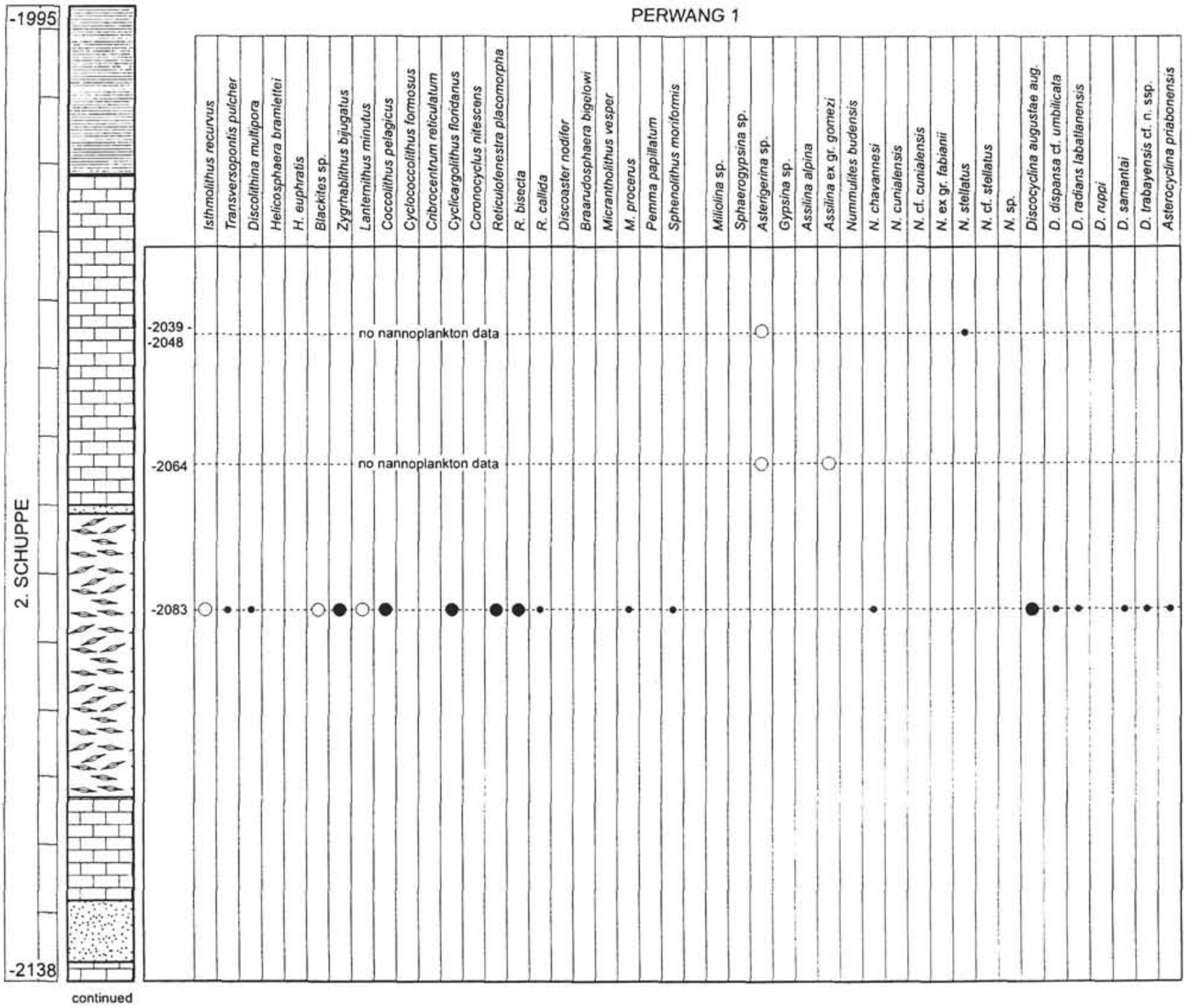
Plate 5

Foraminifera

Figs. 1, 5.	*Asterocyclina priabonensis* GÜMBEL.
Fig. 1.	A-form, external view, X20 (Perwang 1, -2323 m, specimen: 2L9).
Fig. 5.	A-form, equatorial section, X40 (Perwang 1, -2323 m, specimen: 2L9).
Fig. 2.	*Discocyclina dispansa* cf. *umbilicata* (DEPRAT), A-form, oblique section, X20 (Helmberg 1, -3211 m, thin-section MOL 80046).
Figs. 3–4, 6–8.	*Discocyclina ruppi* n. sp. LESS.
Fig. 3.	A-form, external view, X20 (Perwang 1, -2323 m, specimen: 2L9).
Fig. 4.	A-form equatorial section, X40 (Perwang 1, -2323 m holotype, specimen: 2M0).
Fig. 6.	A-form equatorial section, X40 (Perwang 1, -2323 m specimen: 2M2).
Fig. 7.	A-form (Helmberg 1, -3209 m sample: 2K5).
Fig. 8.	A-form equatorial section, X40 (Perwang 1, -2323 m specimen: 2M1).
Fig. 9.	*Sphaerogypsina* sp. , X40 (Mattighofen 1, -2318 m, thin-section MOL 80020).
Fig. 10.	*Gypsina* sp., X40 (Neukirchen 1, -1889 m, thin-section MOL 80029).
Fig. 11.	*Discocyclina samantai* LESS, A-form, equatorial section, X40 (Perwang 1, 2083 m, specimen: 2K8).

Text-Figure 3
Deep wells Helmberg 1 and Perwang 1: Geological columns and distribution of nannoplankton and foraminifera. Numbers mark the depths below NN. Intervals: 10 m. Legend: see text-fig. 4.





was expected (but not proved) for the topmost parts of the adjacent red algal limestones of Bavaria (BUCHHOLZ, 1984) can be excluded.

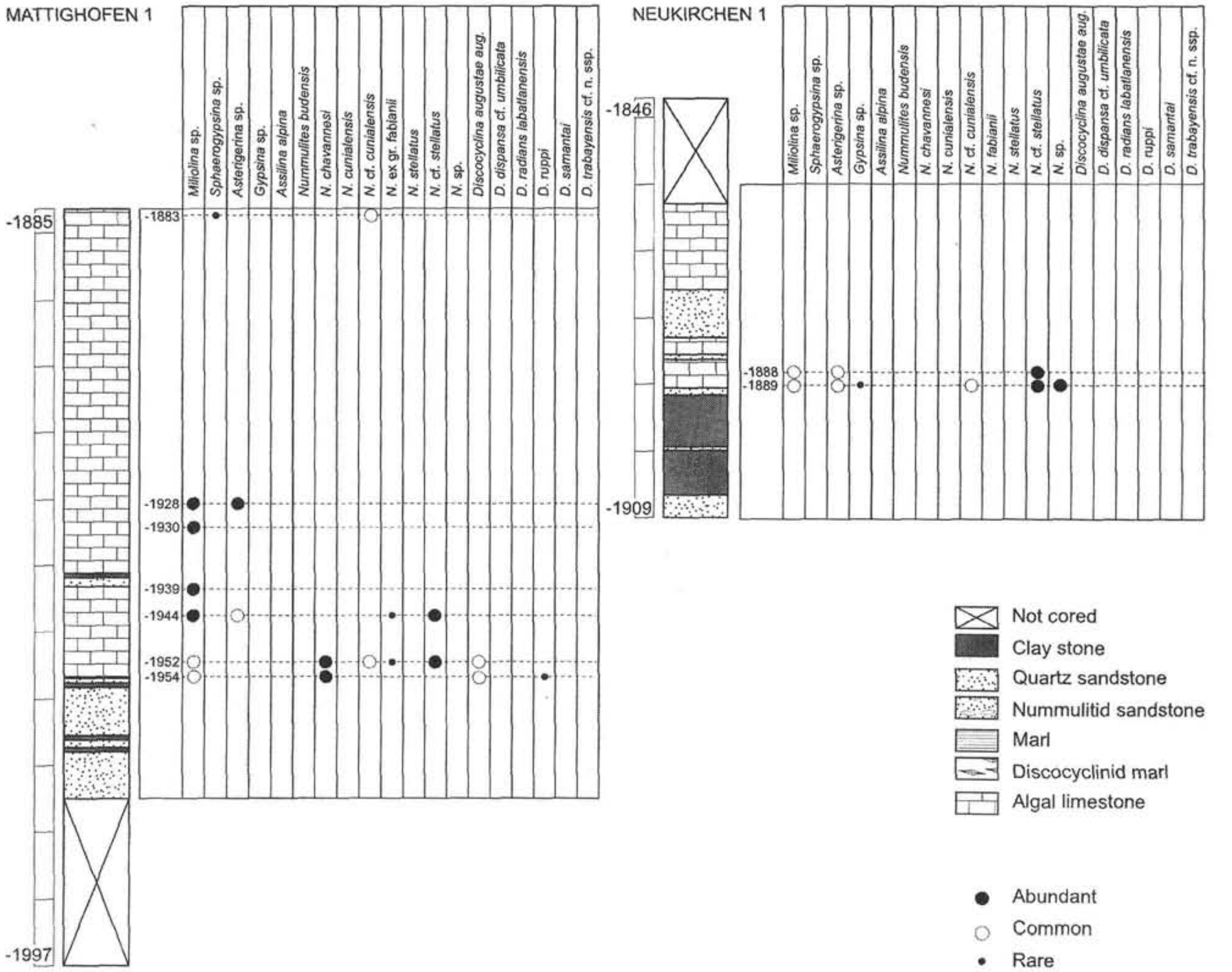
6.2. Palecology and Facies

The **nummulite sandstone** of Helmberg 1, which gradually develops from quartz sandstone, is interpreted as having formed in a higher energetic, maybe near-shore, environment. It is clearly dominated by *N. chavannesi; A. alpina* and *N.* ex gr. *fabianii* are rare; *N. budensis* and *N. stellatus* do not occur. Additionally, *Miliolina* sp. is common. Text-fig. 3 shows that the abundance of *D. augustae augustae* increases upsection, when the facies grades into the overlying *Discocyclina* marl.

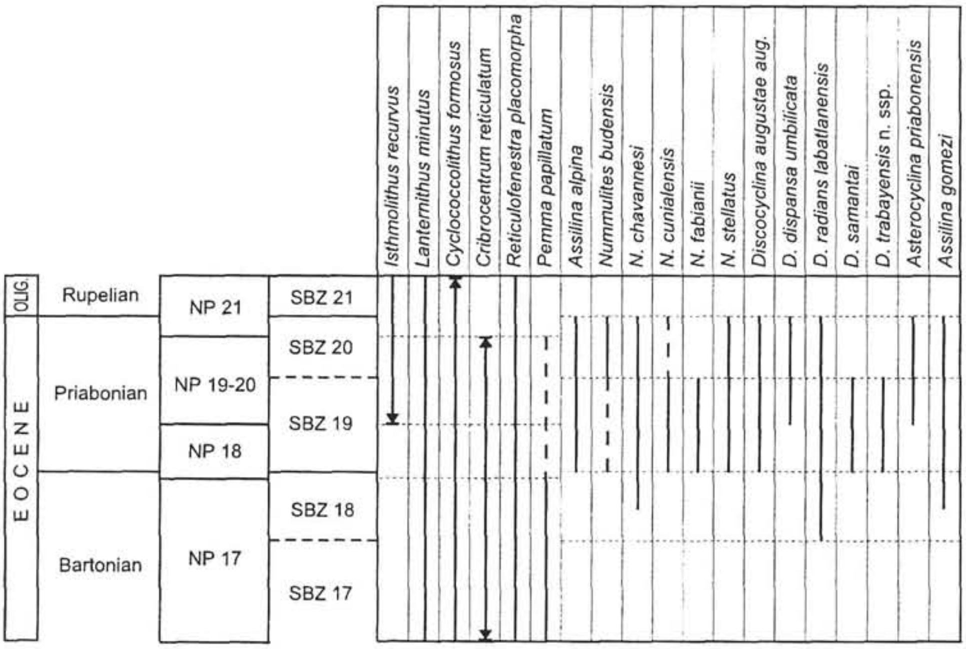
As the facies characteristics of the **Discocyclina marl** (grain size, low fragmentation of orthophragminids and occurrence of whole coccosphaeres) point to a lower energy environment, the succession from the nummulite sandstone, dominated by *N. chavannesi*, to the *Discocyclina* marl, dominated by *D. augustae augustae* can be interpreted as a deepening upward. This interpretation fits with the general geological situation of the Alpine Foreland Basin (WAGNER, 1996a; 1996b). Beside this species, only *D. ruppi* is common; all other orthophragminids are rare. Nummulitids are rare in the *Discocyclina* marl. *N. cunialensis* and *N. stellatus* are common only in the third thrust sheet of Perwang 1.

Additionally, the permanent but rare occurrence of *Isthmolithus recurvus* (frequent in high latitudes) in the *Discocyclina* marls marks a mid latitude assemblage, while the absence or scarcity of the genus *Discoaster* can be connected more probably with the near-shore character of the nannoplankton than the temperature, as it is explained by BARBIN (1989).

The **Bryozoa marl,** which follows above the Discocyclina marl in Helmberg 1, is represented in only one sample. In respect to the foraminiferal assemblages this facies corresponds to the *Discocyclina* marl. The facies succession can be interpreted as an ongoing deepening upward from the nummulite sandstone to the *Discocyclina* marl and finally to the Bryozoa marl. It can be expected that the distribution of larger foraminifera in the described succession does not only depend on the light availability, which is thought to be one of the most important factors influencing the distribution and morphology of orthophragminids (FERRANDEZ-CANADELL and SERRA-KIEL, 1992). Moreover, this group prefers quiet water conditions, while the mostly robust and inflated Nummulites were more tolerant to the higher energy level. Also, orthophragminids preferred soft substrate, while Nummulites could live on a sandy bottom.



Text-Figure 4
Deep wells Mattighofen 1 and Neukirchen 1: Geological columns and distribution of nannoplankton and foraminifera.



Text-Figure 5
Chronostratigraphy and correlation of SBZ and NP Zones with the range of nannoplankton and foraminifera. For details see text.

The **coralline-quartz sandstone** gradually develops from quartz sandstones in the "northern region" and shows characteristics of a higher energetic, maybe near-shore, environment - like the nummulite sandstone. However, in opposite to the latter, this facies completely lacks *N. chavannesi*. On the other side, *N.* cf. *stellatus* is abundant, which does not occur in the nummulite sandstone. Additionally, no orthophragminids occur in this facies.

The foraminiferal assemblage of the **coralline bindstone** facies shows components of both the nummulite sandstone and the coralline-quartz sandstone. It is the only facies in which *N. chavannesi* and *N.* cf. *stellatus* occur together in high abundance. Additionally, it is the only algal dominate facies in which *D. augustae augustae* is common. This combination may be caused be an allochthonous occurrence of the larger foraminifera.

The only abundant larger foraminifera in **coralline rudstones** is *N.* cf. *stellatus*. Additionally, *N.* ex gr. *fabianii* occurs in one sample. Orthophragminids do not occur. *Miliolina* sp. and *Asterigerina* sp. may be abundant.

The studied larger foraminiferal fauna of the Upper Austrian Alpine Foreland Basin was originated from the Tethys: All of them but the endemic *Discocyclina ruppi* n. sp. are well known from the classical localities of N Italy (Priabona, Mossano, Possagno, see PAPAZZONI and SIROTTI, 1995; HERB and HEKEL, 1975, and LESS, 1998) and also from the recently described locality of the Bükk Mts. (NE Hungary, LESS, 1999).

The studied fauna is rather restricted: Characteristic Tethyan genera *(Spiroclypeus, Heterostegina, Pellatispira, Orbitoclypeus)* are completely absent, *Assilina* and *Asterocyclina* are very scarce. Moreover, the specific content of the two most characteristic genera (*Discocyclina* and *Nummulites*) is much poorer than in typical Tethyan faunas (e.g. *Discocyclina augustae augustae* is almost monospecific, the other taxa are very scarce while *Nummulites incrassatus* and *N. pulchellus* are completely absent and *N. fabianii* is extremely rare).

7. Conclusion

The studied nannoplankton-assemblages belong to the NP 19-20 zones (Priabonian - Late Eocene). This can be shown by *Isthmolithus recurvus,* defining the lower boarder of NP 19, and by *Cribrocentrum reticulatum,* defining the upper boarder of NP 20, as well as by *Pemma papillatum.*

Using larger foraminifers, the *Discocyclina* marls, and probably also the nummulite sandstones, can be distinctively determined with the upper part of SBZ 19 (Middle Priabonian – Late Eocene). The algal limestones can tentatively put into the SBZ 20 (Upper Priabonian). Late Oligocene age can be excluded for the studied sediments.

The Larger Foraminiferal fauna of the Upper Austrian Alpine foreland Basin is a restricted Tethyan one and it is non-boreal. Some typical Tethyan genera do not occur. The new species *Discocyclina ruppi* is endemic in the study area.

The distribution of larger foraminifera can be summarised as follows: (1) Orthophragminidae are most abundant in fine-grained sediments; only *Discocyclina augustae augustae,* which is the dominant species of this group, may also be common in an algae-dominated facies (coralline bindstone); (2) *Nummulites* (cf.) *stellatus* is typical for sediments dominated by coralline algal branches and rhodoliths, *Nummulites chavannesis* for the nummulite sandstone; (3) only in the coralline bindstone, both *D. augustae augustae,* *N.* cf. *stellatus,* and *N. chavannesi* occur together in higher abundance.

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