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# Biostratigraphy and Facies of selected Exposures in the Grünbach-Neue Welt Gosau-Group (Coal-Bearing Series, Inoceramus-Marl and Zweiersdorf-Formation, Late Cretaceous and Paleocene, Lower Austria)

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5 Text-Figures, 5 Tables and 7 Plates

*This paper is dedicated to Benno Plöchinger*

*Österreichische Karte 1:50.000*
*Blätter 75, 76*

*Northern Calcareous Alps*
*Upper Gosau-Group*
*Late Cretaceous*
*Paleocene*
*Biostratigraphy*
*Facies*
*Foraminifera*
*Nannofossils*
*Palynomorpha*
*Mineral Analysis*

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**Biostratigraphie und Fazies einiger Aufschlüsse in der Grünbach-Neue Welt Gosau-Gruppe (Kohleflözführende Serie, Inoceramenmergel und Zweiersdorf-Formation, Oberkreide und Paleozän, Niederösterreich)**


## Zusammenfassung

Die verfeinerten Möglichkeiten der Foraminiferen- und Nannoplankton-Stratigraphie ließen es wünschenswert erscheinen, die stratigraphischen Pionierstudien von OBERHAUSER (Foraminiferen) und STRADNER (Nannoplankton), die diese im Zuge der Neukartierung des Gosau-Vorkommens von Grünbach-Neue Welt durch PLÖCHINGER (1961, 1967) durchführten, zu revidieren. Auch eine palynologische und mineralogische Bearbeitung einiger ausgewählter Proben wurde durchgeführt. Folgende vorläufige Ergebnisse zeichnen sich ab, wobei zu bemerken ist, daß bislang lediglich vergleichsweise wenige Proben bearbeitet wurden:

Eine Probe aus der Kohleflözführenden Serie von Maiersdorf entspricht der Globotruncana elevata Foraminiferenzone sensu ROBASZYNSKI & CARON (1995), d. h. frühes Campan. Die bislang untersuchten Inoceramenmergel-Proben des Bereichs westlich der Bahnstation Grünbach Schule zeigen ein spätcampanes Alter (Nannozonen UC15d, UC16 sensu BURNETT, 1998) bzw. entsprechen mit Nannozone UC17 dem Campan/Maastricht-Grenzbereich. Dies entspricht den planktonischen Foraminiferenzonen der Globotruncana ventricosa bzw. Globotruncana havanensis-Gansserina gansseri z. T. Hingegen zeigen die bisher untersuchten Proben von Inoceramenmergeln östlich von Grünbach Schule sowie auch in der Umgebung von Dörfles und Zweiersdorf frühes Maastricht-Alter (Nannozonen UC18-?UC19 bzw. Gansserina gansseri Foraminiferenzone), wobei auch frühes Spät-Maastricht nicht ausgeschlossen werden kann. Alle unsere Proben aus den Zweiersdorfer Schichten entsprechen der Nannozone NNTp4 des Dan. Die Palynomorphen-Spektren werden von Angiospermen-Pollen dominiert. Im Vergleich zu den Inoceramenmergeln des Campan zeigt die Probe aus der Kohleflözführenden Serie geringere Gehalte an Smektit und anderen Schichtsilikaten, während der Illit-Anteil etwas höher ist. Alle kretazischen Proben zeichnen sich durch hohen Kalzit-Gehalt aus; auch Dolomit ist häufig auffällig. In den spätcampanen Inoceramenmergeln sind die Smektitgehalte im Vergleich zu denen des Maastricht erhöht, hingegen sind die Gehalte an Kaolinit und Chlorit in den Inoceramenmergeln des Maastricht etwas erhöht. Das Mineralspektrum der Zweiersdorfer Schichten ist deutlich verschieden: Der Kalzitgehalt ist wesentlich niedriger, Dolomit fehlt. Hingegen stehen die Gehalte an Feldspat, Schichtsilikaten, Muskowit sowie Paragonit stark im Vordergrund; auch Smektit ist auffällig, während Illit zurücktritt.



## Abstract

Refined foraminifera- and nannoplankton-zonations triggered the start of an interdisciplinary study of selective fine-clastic outcrops in the Grünbach-Neue Welt Gosau-Group.

The Coal-Bearing Series at Maiersdorf can be assigned to the Globotruncana elevata planktonic foraminifera zone, i. e. late Early Campanian. Coarsly speaking, the Inoceramus-Marl of the western part of the Grünbach Gosau shows Late Campanian age (nannozones UC15d, UC16 sensu BURNETT, 1998), while in the area east of Grünbach Schule railway station (surroundings of Dörfles and Zweiersdorf) Early Maastrichtian ages prevail (nannofossil zones UC18-?UC19, respectively Gansserina gansseri planktonic foraminifera zone); also Late Maastrichtian parts of the Inoceramus-Marl are likely to occur. The palynomorpha are dominated by angiosperm pollen. All our samples from the Zweiersdorf-Formation can be assigned to the nannoplankton zone NNTp4 of Danian age.

All Late Cretaceous fine clastic samples are characterized by high contents of calcite, also dolomite is conspicuous. In the Zweiersdorf-Formation, however, the calcite content is low and dolomite is missing. In the latter muscovite, feldspar, phyllosilicates and paragonite are dominating, also smectite is common, whereas illite is rare. Within the Inoceramus-Marl the smectite content is elevated in the Late Campanian samples compared to the Early Maastrichtian ones, where the contents of kaolinite and chlorite are more conspicuous. The Coal-Bearing Series show only relatively small amounts of smectite and phyllosilicates, while the illite content is relatively higher.


## 1. Introduction

The classical area of Grünbach-Neue Welt Gosau-Group (PLÖCHINGER, 1961) is situated south, respectively east of the Hohe Wand mountain range, close to the eastern end of the Northern Calcareous Alps. WAGREICH & MARSCHALKO (1995) point out, that the approximately 20 km long and SW–NE striking sediment belt of the Grünbach-Neue Welt Gosau-Group continues subsurface below the Vienna Basin and maybe the Brezova-Group in the Little Carpathians in Slovakia represent its emerged NE-end. Tectonically the Gosau-Group of Grünbach-Neue Welt is interpreted as a syncline with an overturned NW limb, however, internal imbrications combined with a poor outcrop situation create a complex structure, which still requires further investigations. According to present knowledge the sequence comprises sediments from the Santonian to the Paleocene. Coarsly speaking the sequence starts with the basal conglomerate (Kreuzgraben-Formation) of (?)Santonian (?Turonian; see discussion in chapter 6.2.) age, rarely overlain by relict rudistid limestones of probable Santonian age. Outside of the area investigated by us, in the Scharrergraben North of Piesting, fine-clastic sedimentation is supposed to start already in the Santonian. The Coal-Bearing Series comprise sandstones and marls of the Early Campanian. The Inoceramus-Beds according to PLÖCHINGER (1961) comprise the Inoceramus-Marls and the Orbitoides-Sandstone of Late Campanian/Maastrichtian age. The cyclic clastic sediment sequences of the "flyschoid" Gosau of Danian/Paleocene age are here locally called Zweiersdorf-Formation.

The present paper deals with selective outcrops in the Coal-Bearing Series, the Inoceramus-Marls and the Zweiersdorf-Formation. The goal of our study is a first step to update the stratigraphic position of these formations and to interprete their palaeoenvironment by means of interdisciplinary study, comprising mineralogical analysis and the study of foraminifers, nannoplankton and palynomorphs. In the future we intend to concentrate sampling also to other outcrop regions, respectively profiles in the Grünbach-Neue Welt Gosau-Group in order to better understand the tectonics (repeated imbrications?) and the onset of marine sedimentation in various regions of this complex area.

## 2. Previous studies

The coal-bearing fossiliferous strata of Grünbach-Neue Welt Gosau-Group attracted already very early the interest of naturalists. A concise review on the history of geological research in this region was given by PLÖCHINGER (1961). Based on former studies by STÜTZ, KEFERSTEIN, MÜNSTER and his own extensive field work, Ami BOUÉ (1832) was in the position to establish the stratigraphic sequence of the region between Dreistätten and Hohe Wand. He recognized already the basal position of the Coal-Bearing Series. Finally in 1851 the synclinal character of the Grünbach-Neue Welt Gosau-"Mulde" (=syncline) has been described by CZJZEK.

In his famous "Geology of Styria" STUR (1871) summarizes the state of knowledge in Gosau research and compares the Gosau of "Neue Welt" with the Gosau locus classicus in Salzkammergut and other Gosau occurrences. Besides about 500 faunal elements, a rich and well preserved, however, almost undescribed flora was already known to STUR. Furthermore STUR refers to ZITTEL and stresses that a mountain barrier – comprising parts of the Carpathians and the Bohemian Massif – was responsible for the completely different development of the Late Cretaceous in southern Europe (abundant rudists) from that in northern Europe. In other words, the similarities and differences between "Alpine" respectively "Mediterranean" and "Boreal" bioprovinces claimed already attention 130 years ago!

In more recent times KOLLMANN & SUMMESBERGER (1982) and SUMMESBERGER (1997) described attractive excursion points in the Grünbach-Neue Welt Gosau region. In 1991, the geological map-sheet 1:50.000 No. 75 Puchberg am Schneeberg (redactor SUMMESBERGER) appeared in print, which comprises the Grünbach Gosau area and a large part of the Neue Welt Gosau outcrops. In this map the Gosau-Group of the Grünbach region is differentiated into 10 mappable units, among them the Campanian Coal-Bearing Series, the "Inoceramenmergel" of Late Campanian to Maastrichtian age and the Zweiersdorf-Formation of Danian-Paleocene age. The geological map-sheet 1:50.000 No. 76 Wiener Neustadt borders to the east of the aforementioned map (BRIX & PLÖCHINGER, 1982; explanatory text 1988). This map-sheet comprises the eastern end of this Gosau area, i.e. the main part of the Neue Welt Gosau outcrops. In both these map-sheets the "Inoceramenmergel" are considered to be of Late Campanian/Maastrichtian age.

Several profound papers by FAUPL et al. (e.g. 1987, 1996) and WAGREICH & FAUPL (1994) deal with the facies development, respectively basin analysis, palaeogeography and geodynamic evolution of various Gosau regions in the Northern Calcareous Alps, including the Grünbach-Neue Welt Gosau-Group. Also the biostratigraphic dating of fine clastic sediments has been considerably improved due to new findings of ammonites and due to revision of historic material (SUMMESBERGER et al., several papers). The same is especially true also for the foraminifera and nannofossils (cf. BUTT, 1981; WAGREICH, 1988, 1992).

The presence of foraminifera claimed already early attention. The foraminifer species *Spirolina grandis* was described by REUSS (1854) from Gosau marls of Grünbach and SCHLÖNBACH (1867) refers to the occurrence of *Haplophragmium* grande REUSS. In the context of this paper it is important to mention that REUSS (l.c.) lists 34 foraminiferal taxa from Austrian Gosau occurrences. Among them 17 species were already known to occur also in the Bohemian "Pläner"-Limestone and Marl! PETRASCHECK (1941) mentiones, that *Haplophragmium grande* REUSS is especially common in the top layers of the "Orbitoides-Sandstone", while KÜHN (1947) points also to the frequent occurrence of this taxon in the lowermost layers of the Inoceramus-Marl. Further on KÜHN (1947) reports on a foraminifera assemblage from the environs of Grünbach (det. P. MARIE, Paris), which represents a mixture of Santonian and Maastrichtian taxa, while Campanian elements according to this study are completely missing. However, it is important to note, that KÜHN's biostratigraphy was mostly based on rudist bivalves which – due to insufficient stratigraphic interpretations – subsequently caused fatal errors and in part also influenced a misinterpretation of palynostratigraphy (e.g. GÓCZÁN, 1964, 1973 ff.). Late Cretaceous foraminifers from the Inoceramus-Marls of Grünbach Gosau area were described in the sixties by OBERHAUSER (in PLÖCHINGER et al., 1961, 1967; in KÜPPER et al., 1963) and by OBERHAUSER (1963). The foraminifera of the "Inoceramenmergel" of Neue Welt Gosau-Group are mentioned in BRIX & PLÖCHINGER (1988), det. OBERHAUSER. Large foraminifers (Orbitoids) from this area were also studied by PAPP (in PLÖCHINGER, 1961). Since then no foraminiferal research was conducted here.

STRADNER (in PLÖCHINGER, 1961) provided the first record on nannofossil findings in the Zweiersdorf-Formation and in the Inoceramus-Marls (in PLÖCHINGER, 1967). Calcareous nannofossils from the "Inoceramenmergel" of Neue Welt Gosau area were determined by STRADNER (in BRIX & PLÖCHINGER, 1988). Calcareous nannoplankton from sediments of other localities of the Upper Gosau-Subgroup (sensu WAGREICH & FAUPL, 1994) was described by WAGREICH in many papers, such as WAGREICH (1986) or WAGREICH & KRENMAYR (1993). Coccoliths from the Cretaceous/Tertiary boundary sediments of Elendgraben in Gosau Basin were studied by STRADNER (in PREISINGER et al., 1986).

So far only a few papers deal with the Late Cretaceous palynofloras of the Gosau-Group. Papers reporting assemblages comparable with those of the Grünbach and Maiersdorf localities are those by FECHNER & SALOMON (1989) on the Late Campanian microflora of the Klein Walsertal, respectively by SIEGL-FARKAS (1994) and SIEGL-FARKAS, EBNER & LOBITZER (1994) on the palynology of the Kainach Gosau. SIEGL-FARKAS & WAGREICH (1996a) comment on the correlation of palynoflora with calcareous nannofossils of the Late Cretaceous of the Northern Calcareous Alps and the Transdanubian Central Range in Hungary. Pollen and dinoflagellate spectra from Grünbach and Maiersdorf localities resemble in many aspects those reported by SIEGL-FARKAS & WAGREICH (1996b) from the Late Cretaceous of the Polány Marl-Formation of Hungary. A preliminary report on palynomorph assemblages of the Coal-Bearing Series at Grünbach was given by DRAXLER (in SUMMESBERGER, 1997).

Additional background information on Late Cretaceous palynofloras can be found in the papers of GÓCZÁN (1964), KRUTZSCH (1973), GÓCZÁN & SIEGL-FARKAS (1990), SIEGL-FARKAS (1994), LANTOS et al. (1996) and SIEGL-FARKAS (in HRADECKÁ et al., 1999).

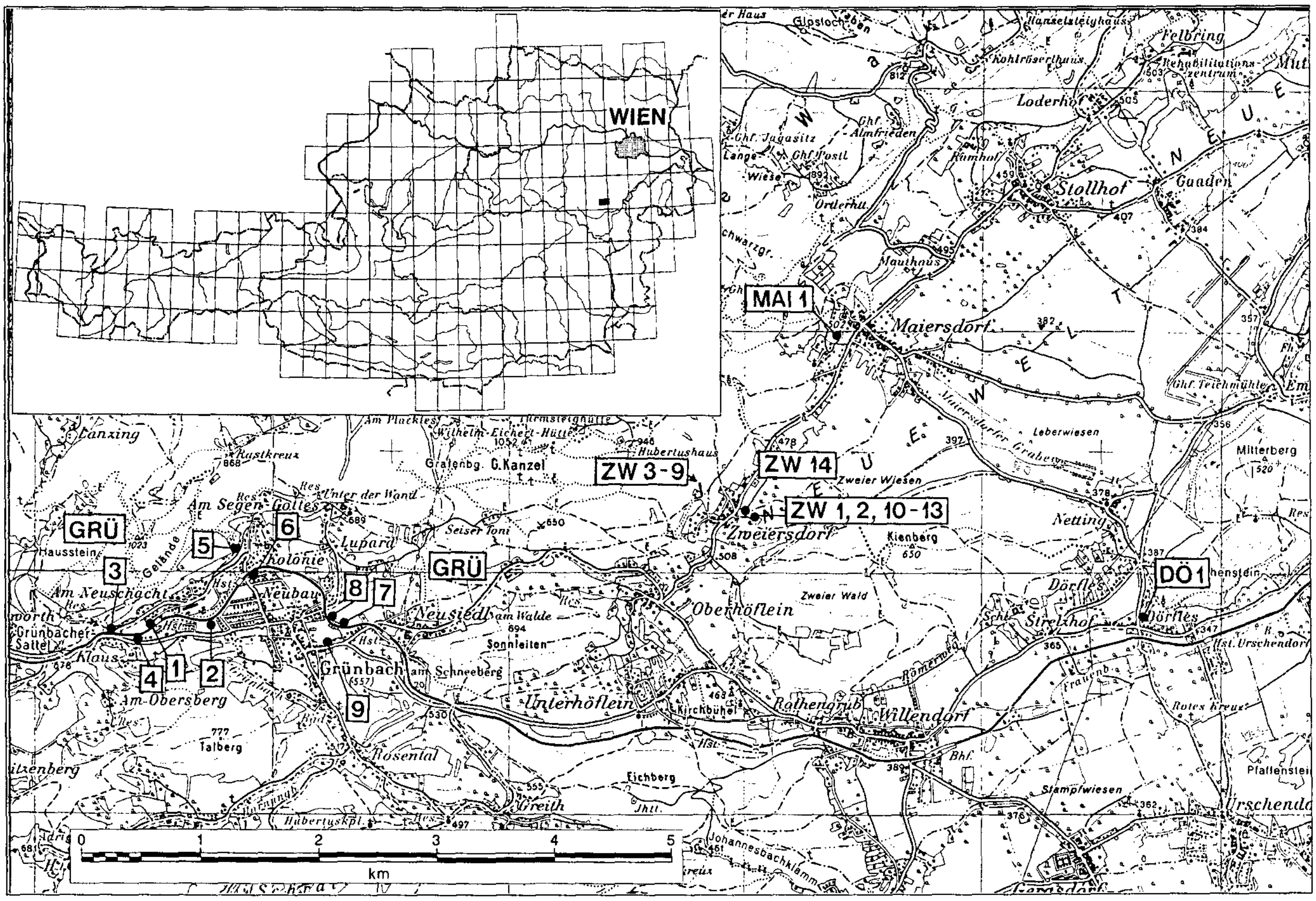
## 3. List of Samples

It is important to note, that only isolated samples have been collected and no continuous profiles have been studied so far by our working group. For topographic situation of samples refer to Text-Fig. 1.

Sample GRÜ1: Fresh light greyish green marls (Inoceramus-Marls) were temporarily exposed in a 1,5 m deep trench at Grünbach Kohlenwerk railway station, 3 m north of the railroad tracks.

Sample GRÜ2: Greenish soft marls (Inoceramus-Marls) on southern slope of railroad cut at railway-km 22,6.

Sample GRÜ3: Weathered greyish green marls (Inoceramus-Marls) between railway-kms 23,4 and 23,5, i.e. between Grünbacher Sattel and Grünbach Kohlenwerk railway station; sample point N' of railway lines (Plate 1, Fig. 2)




Text–Fig. 1.
Location of the marl outcrops sampled in the Grünbach-Neue Welt Gosau-Group.

Sample GRÜ4: Soft greenish marls (Inoceramus-Marls) from outcrop along mainroad leading from Grünbach to Puchberg am Schneeberg.

Sample GRÜ5: Slightly weathered greenish grey marls (Inoceramus-Marls) on northern slope of road from Grünbach Schule railway station to Bergbaumuseum.

Sample GRÜ6: Greenish grey marls (Inoceramus-Marls) on southern slope of shallow railroad cut, immediately E of Grünbach Schule railway station.

Sample GRÜ7: Weathered greenish grey marls (Inoceramus-Marls) intercalated by sandstone layers (see Plate 1, Fig. 1) along railway lines, northern slope, approximately 350 m E of railway station Grünbach am Schneeberg; railway-km 21.

Sample GRÜ8: As before. Sample-point at railway-km 21,1.

Sample GRÜ9: Grey fresh marls (Inoceramus-Marls) at parking lot opposite to "Grünbacherhof" restaurant in Grünbach am Schneeberg. The outcrop was fresh in 1997 and is now covered by a concrete wall.

Sample DÖ1: Soft greyish-green micaceous silty marls, ~80 m N of railway lines on road to Netting. The road cuts the railway lines W of railway station Urschendorf. This is the only sample of Inoceramus-Marls taken on mapsheet 76 Wiener Neustadt.

Sample MAI1: Light grey, slightly micaceous marls, intercalating with sandstone beds. Roadcut on side road branch to church of Maiersdorf village (to the left this road continues to Pension Fink); Coal-Bearing Series.

Sample ZW1: Greyish marls, intercalating with sandstone beds. Hollow way profile in Zweiersdorf-Formation ESE Gasthof Mohr in Zweiersdorf. The sample originates from topographic lowermost outcrop, i.e. from the southern end of the profile. The hollow way starts at House-No. Bründlweg 1 in Zweiersdorf.

Sample ZW2: As before, however, sample comes from the NW end of the outcrop.

Samples ZW10-13: As before. Samples originate from various places in the profile, in between samples ZW1 and ZW2.

Sample ZW14: From the NW end of the hollow way profile a field-path branches in NE direction; Zweiersdorf-Formation.

Samples ZW3-9: Yellowish-grey marls, Inoceramus-Marls, from hollow way in forest N of Zweiersdorf village, close (E–NE) of house Forststraße 14.

## 4. Material and methods

### 4.1. Mineralogical analyses

The mineralogy of the samples was studied by means of X-ray diffraction (XRD) using a Philips 1710 diffractometer with automatic divergent slit, 0.1° receiving slit, Cu LFF tube 45 kV, 40 mA, and a single-crystal graphite monochromator. The measuring time was 1s in step-scan mode and stepsize of 0.02 °2θ. Bulk samples as well as the clay fractions (<2µm) were analysed.

Sample preparation generally followed the methods described by WHITTIG (1965) and TRIBUTH (1989). Dispersion of clay particles and destruction of organic matter was achieved by treatment with dilute hydrogen peroxide. Separation of clay fraction was carried out by using centrifugation methods. The exchange complex of each sample (<2µm) was saturated with Mg and K using chloride solutions by shaking. Similar to the methods of KINTER & DIAMOND (1956) the preferential orientation of the clay minerals was obtained by suction through a porous ceramic plate. To avoid disturbance of the orientation during drying, the samples were equilibrated during 7 days above saturated $NH_4NO_3$ solution. Afterwards expansion tests were made, using ethylenglycol, glycerol and DMSO as well contraction tests heating the samples up to 550 °C. After each step the samples were X-rayed from 2–40 °2θ.

The clay minerals were identified according to THOREZ (1975), BRINDLEY & BROWN (1980), MOORE & REYNOLDS (1997) and WILSON (1987). Semiquantitative estimations were carried out according to OTTNER et al. (1997) using the corrected intensities of characteristic X-ray peaks (RIEDMÜLLER, 1978). Semiquantitative mineral composition of the bulk samples was estimated using the method described by SCHULTZ (1964).

The illite crystallinity was measured on glycolated 2 µm samples, using the method described by KISH (1991).

## 4.2. Palaeontology

### 4.2.1. Foraminifera

Twenty samples, about 1 kg in weight , were collected in the marl and claystone beds from Grünbach, Maiersdorf, Dörfles and Zweiersdorf localities for study of Foraminifera. The samples were disintegrated in the Laboratory of Geologische Bundesanstalt in Vienna using standard washing methods. The washed material of >63µ, >125µ, >400µ particle size was available for the study of foraminiferal assemblages. Foraminifers were separated under binocular microscope and photographs of species were taken using scanning electron microscope in the Laboratory of the Czech Geological Survey in Prague. Planktonic zonation of CARON (1985) and ROBASZYNSKI & CARON (1995) was used for the correlation of the studied assemblages.

### 4.2.2. Calcareous nannofossils

Samples for nannofossil study were processed in the Laboratory of the Czech Geological Survey, Prague. Smear slides were prepared using a decantation method, inspected with Nikon light microscope at 1,000x magnification.

Cretaceous biostratigraphic data were correlated with the UC zones sensu BURNETT (1998), with the standard CC zones of SISSINGH (1977) and PERCH-NIELSEN (1985) and with modified nannofossil zonation for Gosau-Group proposed by WAGREICH (1992a). Tertiary biostratigraphic data were correlated with the NNTp zones by VAROL (1998) and with standard NP zones by MARTINI (1971).

The interpretation of the appurtenance of Cretaceous nannofossil species to provinces followed mainly WIND (1979), WATKINS (1992), WAGREICH (1992b), WATKINS et al. (1996) and BURNETT (1998).

### 4.2.3. Palynomorpha

Palynological extraction was carried out in the laboratories of the Czech Geological Survey in Barrandov and involved standard HCl-HF-HCl-$ZnCl_2$ treatment and some samples were sieved (10 µm). The slides were mounted in glycerine-jelly and the acid-resistant residue was analysed under the light and SEM microscopes.

# 5. Results

## 5.1. Mineralogical analyses

Macroscopically the Inoceramus-Marls consist of greyish or greenish-grey sandy and ± slightly micaceous marls, which often show a yellowish weathering colour. Intercalations of hard ±dm-thick sandy marlstones are typical. The sample from Maiersdorf (MAI1), which belongs to the underlying Coal-Bearing Series, is lithologically similar, however, already macroscopically a higher content of plant debris is conspicuous. Also the grey sandy marls of the Zweiersdorf-Formation show a similar lithofacies with frequent intercalations of dm-thick marlstone and sandstone layers, however, generally speaking,

Table 1.
Mineralogical composition of bulk samples (in mass %)

| Age | Sample | Quartz | Calcite | Dolomite | Feldspars | Phyllosilicates | Pyrite |
|---|---|---|---|---|---|---|---|
| Paleocene | ZW2 | 15 | 12 | - | 16 | 57 | - |
| | ZW1 | 15 | 14 | - | 19 | 52 | - |
| | ZW6 | 13 | 35 | 9 | 7 | 36 | - |
| | ZW5 | 13 | 43 | 8 | 5 | 31 | - |
| | ZW4 | 10 | 55 | 4 | 5 | 26 | - |
| | ZW3 | 11 | 42 | 4 | 5 | 38 | - |
| | DÖ1 | 14 | 38 | 6 | 5 | 37 | - |
| Maastrichtian | GRÜ9 | 11 | 38 | 7 | 4 | 39 | - |
| | GRÜ8 | 11 | 44 | 5 | 6 | 34 | - |
| | GRÜ7 | 11 | 36 | 5 | 6 | 42 | - |
| | GRÜ4 | 11 | 51 | 4 | 4 | 31 | - |
| | GRÜ6 | 13 | 44 | - | 3 | 39 | - |
| | GRÜ1 | 9 | 58 | 4 | 2 | 27 | - |
| Campanian | GRÜ3 | 17 | 44 | - | 4 | 35 | - |
| | GRÜ2 | 11 | 51 | 3 | 3 | 31 | 1 |
| | GRÜ5 | 12 | 65 | - | 1 | 22 | - |
| | MAI1 | 13 | 59 | 7 | 2 | 19 | - |

the mica-content is much more conspicuous, than in the previous mentioned formations. In places also plant debris occurs.

### 5.1.1. Mineralogical composition of bulk samples

The results of bulk sample analyses are listed in Table 1; results of clay mineral composition (fractions <2μm) in Table 2.

Generally speaking almost all Campanian and Maastrichtian samples from Grünbach, Zweiersdorf, Maiersdorf and Dörfles have a similar mineralogical composition. They consist of moderate amounts of quartz, some feldspar – mostly plagioclase – and large amounts of calcite plus some dolomite and various amounts of phyllosilicates.

The Campanian samples of the Inoceramus-Marls (GRÜ2, 3, 5) and of the Coal-Bearing Series (MAI1) are characterized by the highest calcite values up to 65%, and the lowest amounts of feldspars and phyllosilicates. Pyrite was only identified in one sample (GRÜ2).

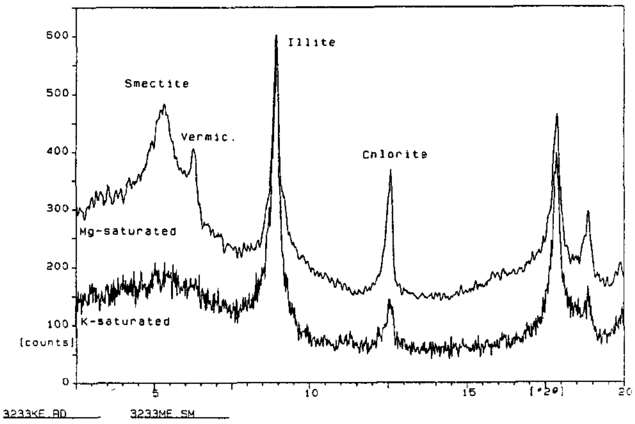
The Maastrichtian samples of the Inoceramus-Marls also contain high amounts of calcite and some dolomite too. The contents of dolomite and of phyllosilicates are somewhat higher than in the samples before.

The Paleocene samples (Zweiersdorf-Formation) differ by their mineralogical composition. The content of calcite is much lower than in the other samples, dolomite is not detectable, and the amount of feldspars and phyllosilicates is higher. These two samples ( ZW1,2) also contain high quantities of muscovite (in Table 1 included in "Phyllosilicates") and also another quite rare Na-mica mineral, called paragonite, which is typical for low metamorphic rocks of the epizone.

### 5.1.2. Clay mineral analysis

The Early Campanian sample MAI1 from the Coal-Bearing Series in comparison to the Late Campanian Inoceramus-Marls shows remarkably lower content of smectite and higher illite content (Tab. 2).

The Late Campanian Inoceramus-Marls (samples GRÜ2, 3, 5) are characterized by high smectite and mostly lower illite contents. Chlorite is present in all samples, kaolinite and vermiculite only in small amounts or traces.




Text–Fig. 2.
X-Ray-Diffractogram of sample GRÜ5, Late Campanian Inoceramus-Marls, <2μ fraction, glycolated.

The Maastrichtian samples of the Inoceramus-Marls show in general less smectite and more illite, as well as higher chlorite contents.

The youngest samples from the Paleocene Zweiersdorf-Formation contain the highest smectite values of all analysed samples, however, their content of illite is quite low.

The analysed smectites contain a high charged component that swells with ethylenglycol after Mg-saturation like smectites, but do not swell after treatment with K (like vermiculites; Text-Fig. 2). This high K-sensitivity is well known from clay minerals of soils in which strongly weathered vermiculite <2μm occurs. Such high charged clay minerals (sometimes called 18-Å-vermiculites) are typical for recent soils and paleosols too (SCHACHTSCHABEL et al., 1984). The occurrence of that less swelling 18-Å-clay mineral together with smectite is indicated with an asterisk (*) in Table 2.

Chlorite reacts quite sensitive against heat treatment. The 001 peaks disappear after two hours heating of the samples at 550°C. Detrital chlorites which originate from metamorphic rocks are different. Usually their 001 reflexions are reinforced by heat treatment. Neoformations of chlorites (from 2:1 layersilicates) in sediments or soils react in the same way as

Table 2.
Semiquantitative results of clay mineral analysis of fraction <2μm (in mass %). IC: Illite crystallinity (in °2θ). tr: Traces

| Age | Sample | Smectite | Illite | Kaolinite | Chlorite | Vermiculite | IC |
|---|---|---|---|---|---|---|---|
| Paleocene | ZW2 | 52* | 25 | 4 | 11 | 8 | 0,30 |
| | ZW1 | 50* | 21 | 6 | 19 | 4 | 0,30 |
| Maastrichtian | ZW6 | 29* | 43 | 8 | 15 | 5 | 0,25 |
| | ZW5 | 18* | 50 | 10 | 17 | 5 | 0,30 |
| | ZW4 | 30* | 35 | 10 | 18 | 7 | 0,25 |
| | ZW3 | 25* | 40 | 7 | 20 | 8 | 0,25 |
| | DÖ1 | 38* | 34 | 4 | 20 | 4 | 0,30 |
| | GRÜ9 | 25* | 52 | 3 | 16 | 4 | 0,30 |
| | GRÜ8 | 30* | 42 | 5 | 20 | 3 | 0,30 |
| | GRÜ7 | 30* | 52 | 6 | 12 | tr | 0,30 |
| | GRÜ4 | 39 | 48 | 2 | 11 | tr | 0,30 |
| | GRÜ6 | 24* | 47 | 2 | 18 | 9 | 0,20 |
| | GRÜ1 | 37 | 38 | 6 | 29 | tr | 0,25 |
| Campanian | GRÜ3 | 44 | 42 | 3 | 11 | tr | 0,30 |
| | GRÜ2 | 47 | 39 | 3 | 11 | tr | 0,30 |
| | GRÜ5 | 48* | 34 | tr | 12 | 6 | 0,30 |
| | MAI1 | 30 | 50 | tr | 14 | 6 | 0,30 |

in the analysed Gosau marls. That could indicate, that those chlorites are not of detrital, but of authigenetic or pedogenetic origin.

#### 5.1.3. Illite crystallinity (IC)

IC is the sharpness of the 001 illite peak and is expressed in °2θ. During increasing diagenesis the illites recrystallize and become more muscovitic. The peak form becomes more sharp, which results in lower °2θ values for higher IC. KÜBLER (1967) suggested 3 different zones of illite crystallinity: (1) diagenetic zone IC >0,42 °2θ, (2) anchizone 0,42–0,25 °2θ and (3) epizone < 0,25 °2θ.

In all analysed samples the 10 Å peaks of the illites are quite sharp. The measured values are between 0.20 and 0.30 °2θ, thus they all plot in the field of metamorphic alteration (Tab. 2). That indicates that the deposited illites could originate from micas of metamorphic rocks and had been only slightly weathered before sedimentation.

### 5.2. Palaeontology

#### 5.2.1. Foraminifera

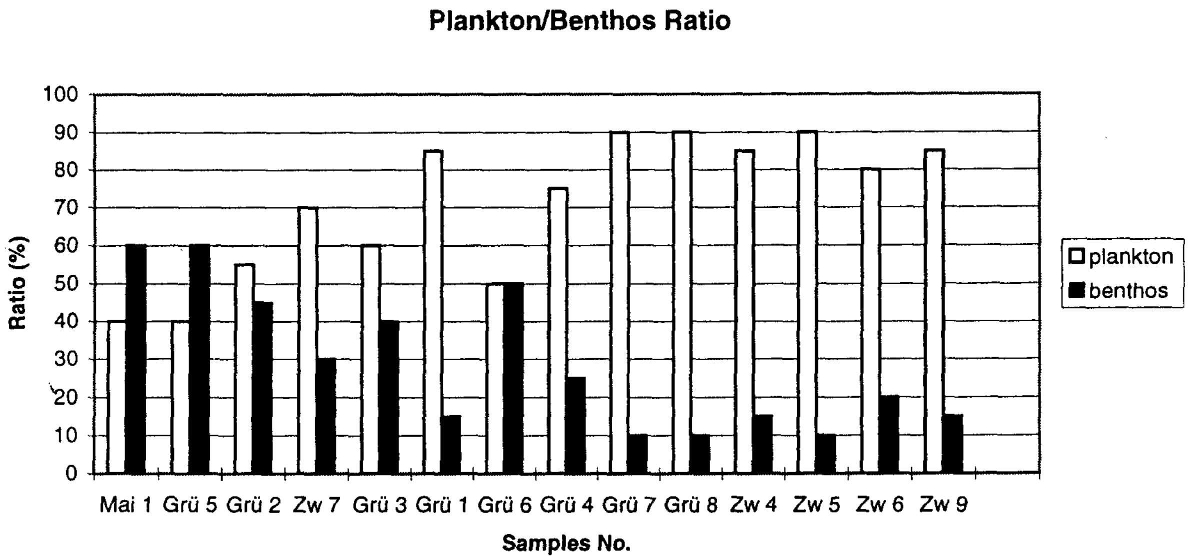
The studied sediments from the broader surroundings of Grünbach (Text-Fig. 1) contained rich but relatively poorly preserved Campanian and Maastrichtian foraminiferal assemblages (Table 3a, b).

The Campanian foraminiferal assemblages from samples of the Coal-Bearing Series at Maiersdorf (MAI1), and from part of the Inoceramus-Marls at Grünbach (GRÜ2, 3, 5) and Zweiersdorf (ZW7) were dominated by calcareous benthos, as *Gavelinella clementiana laevigata* (MARIE), *Gavelinella monterelensis* (MARIE), *Reussella szajnochae* (GRZYBOWSKI), *Bolivina incrassata* REUSS, *Vaginulina trilobata* (D'ORBIGNY) and *Lenticulina comptoni* (SOWERBY). Agglutinated species *Dorothia bulleta* (CARSEY), *Tritaxia trilatera* (CUSHMAN), *Tritaxia tricarinata* (REUSS) and *Spiroplectammina dentata* (ALTH) were present especially in the coarse fraction > 400 μ. Plankton was relatively abundant in these samples (about 60%; Tab. 3, Text-Fig. 5). The expressive and frequent tests of *R. szajnochae* and the presence of *Stensioeina exsculpta* (REUSS) evidenced the Campanian age (MARTIN, 1964; GASINSKI et al., 1999) of the sediments. According to the occurrence of *Globotruncanita elevata* (BROTZEN) in sample MAI1 and the absence of *Globotruncana ventricosa* (WHITE) this foraminiferal assemblage of the Coal-Bearing Series was attributed to the Globotruncana elevata Zone (Early Campanian) sensu ROBASZYNSKI & CARON (1995).

The appearance of *Globotruncana ventricosa* (WHITE) in sample GRÜ 5 indicated, together with *Globotruncanita stuarti* (DE LAPPARENT), *Globotruncanita subspinosa* (PESSAGNO), *Globotruncana falsostuarti* SIGAL, *Rosita fornicata* (PLUMMER) and rare occurrence of *Gansserina gansseri* (BOLLI), the lower part of the Late Campanian age of samples GRÜ 5, 2, 3 and ZW7 and the planktonic Globotruncana ventricosa and Globotruncanella havanensis – Gansserina gansseri Zones (ROBASZYNSKI & CARON, 1995).

The Maastrichtian age – Gansserina gansseri Zone – in samples Grünbach GRÜ 1, 6, 4, 7, 8, Dörfles DÖ1 and Zweiersdorf ZW3, 4, 5, 6, 9 was determined by the presence of benthic species *Bolivinoides draco* (MARSSON) and *Ventilabrella multicamerata* KLASZ. The first appearance of the characteristic Maastrichtian species *B. draco* (MARSSON) was recorded by KOCH (1977) in the upper part of the Early Maastrichtian. *V. multicamerata* KLASZ was reported by HANZLÍKOVÁ (1972) also from the uppermost part of the Early Maastrichtian. *Reussella szajnochae* (GRZYBOWSKI), a significant Campanian species, was found to be very rare in these samples. Planktic species dominated in the foraminiferal assemblages of this group of samples, especially *Rosita fornicata* (PLUMMER), *G. stuarti* (DE LAPPARENT), *Pseudotextularia elegans* (RZEHAK), *Rugoglobigerina rugosa* (PLUMMER), *Globotruncanita stuartiformis* (DALBIEZ), *G. falsostuarti* SIGAL and *Globotrucanella havanensis* (VOORWIJK) (Tab. 3a, b). The general character of foraminiferal assemblages and the presence of such species as *Rugoglobigerina hexacamerata* BRÖNNIMANN allowed to place these sediments to the upper part of Early Maastrichtian – Gansserina gansseri Zone sensu CARON (1985) and ROBASZYNSKI & CARON (1995).

The Paleocene foraminiferal assemblages, found in samples Zweiersdorf ZW1, 2, 11, 14, were very poor in abundance




Text–Fig. 3.
Plankton/benthos ratio of Late Cretaceous foraminiferal assemblages from Grünbach-Neue Welt Gosau-Group sediments. For stratigraphy of various samples see Tables 3a, b; 4a, b, c.

Tables 3a, b.
Distribution of Foraminifera in the studied samples from the Grünbach-Neue Welt Gosau-Group. • rare , O common, ● frequent, •R redeposition

| stratigraphy | E.C. | L.Campanian - Early Maastrichtian | | | | | | | | | | | | | | | Danian | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| planktic zonation | G.el | G.vent. | Globotruncanella havanensis-Gansserina gansseri | | | | | | | | | | | | | | ? | | | |
| species / samples | Mai 1 | Grü 5 | Grü 2 | Zw 7 | Gr 3 | Gr 1 | Grü 6 | Grü 4 | Grü 7 | Grü 8 | Dö 1 | Zw 3 | Zw 4 | Zw 5 | Zw 6 | Zw 9 | Zw 1 | Zw 2 | Zw 11 | Zw 14 |
| Marssonella oxycona | • | • | O | • | | | O | • | • | | • | | | O | | | | | | |
| Dorothia bulleta | • | ● | O | • | | | • | • | • | | | • | | | | • | | | | |
| Textularia sp. | • | | | | • | | | • | | | | | | | | | | | | |
| Bathysiphon sp. | • | | | | | | | | | | | | | | | • | | | | |
| Tritaxia trilatera | | ● | • | | | | O | • | • | • | | | | | | | | | | |
| Gaudryina pyramidata | • | • | | • | • | • | • | • | | | | | • | | | | | | | |
| Dorothia cf. pupa | | • | | | | | | • | • | • | | | | O | | | | | | |
| Haplophragmoides impensus | | | | | | | | | O | | | | | | | | | | | |
| Haplophragmoides eggeri | | | • | • | | | | | O | | • | | | | | | | | | |
| Recurvoides sp. | | | | | | | | | • | | | | | | | | | | | |
| Glomospira serpens | | | | • | | | | | • | | | | | | | | | | | |
| Ammodiscus cretaceus | | | | | | | | | • | | | | | | | | | | | |
| Spiroplectammina dentata | O | O | • | • | O | | | • | | | | | | | | | | | | |
| Marssonella rugosa | • | • | | | | | | | | | | • | | | | | | | | |
| Tritaxia tricarinata | O | O | | | • | | | • | | O | | | | | | | | | | |
| Gyroidinoides girardanus | | O | • | | | | | | | | | | | | | | | | | |
| Gyroidinoides nitida | | O | | | | | | | | | | | | | | | | | | |
| Clavulinopsis clavata | | • | | • | | | | | | | | | | | | | | | | |
| Gaudryina cretacea | | • | • | | | • | O | • | | | | | | | | | | | | |
| Heterostomella faveolata | | | • | | | | | | | | | | | | | | | | | |
| Bigenerina velascoensis | | | • | | | | • | | | | | | | | | | | | | |
| Ammobaculites alexanderi | | | • | | | | | | | | | | | | | | | | | |
| Gyroidinoides vortex | | | • | | | | | | | • | | | | | | | | | | |
| Rzehakina inclusa | | | | • | | | | | | | | • | | | | | | | | |
| Spiroplectammina semicomplanata | | | | | • | | • | | | | | | | | | | | | | |
| Gaudryina carinata | | | | | • | | | | | • | | | | | | | | | | |
| Ammobaculites coprolithiformis | | | | | | | • | | | | | | | | | | | | | |
| Plectina conversa | | | | | | | • | | | | | | | | | | | | | |
| Plectina watersi | | | | | | | | • | • | | | | | | | | | | | |
| Bolivinopsis anceps | | | | | | | | • | | | | | | | | | | | | |
| Thalmannamminina subturbinata | | | | | | | | | • | | | | | | | | | | | |
| Trochaminoides subcoronatus | | | | | | | | | O | | | | | | | | | | | |
| Spiroplectammina navarroana | | | | | | | | | | • | | | | | | | | | | |
| Glomospira irregularis | | | | | | | | | | • | • | | | | | • | | | | |
| Gyroidinoides sp. | | | | | | | | | | | | | | | | | •R | | | |
| Bolivinopsis spectabilis | | | | • | | | | | | • | • | | | | | | | | | |
| Trochammina sp. | | | | | | | | | | | | | | | | | •R | | | |
| Arenobulimina sp. | | | | | | | | | | • | | | | | | | | | | |
| Bolivina incrassata | ● | • | | | | • | | O | | | | | | | | O | | | | |
| Stensioeina exsculpta | O | • | • | | | | | | | | | | | | | | | | | |
| Gavelinella clementiana laevigata | ● | | ● | | | | O | O | O | | | | | | | • | | | | |
| Gavelinella monterelensis | ● | O | ● | | O | • | • | ● | | | | | | | | • | | | | |
| Nodosaria aspera | • | | • | | | | | | | | | | | | | | | | | |
| Praebulimina carseyae ? | • | | | | | | | | | | | | | | • | • | | | | |
| Globorotalites micheliniana | • | | | | | | • | | • | | | | | | | | | | | |
| Gavelinopsis bembix | • | | | | | | • | | | | | | | | | | | | | |
| Lenticulina comptoni | O | ● | | | | | | | | | | | | | | | | | | |
| Lenticulina sp. | | ● | | • | • | | | | | | | | | | | | | | | |
| Vaginulina trilobata | • | | ● | | | | • | | | | | | | | | | | | | |
| Saracenaria triangularis | • | | | | | | • | | | | | | | | | | | | | |
| Gavelinella clementiana convexa | | O | O | | | | | | | | | | | | | | | | | |
| Nodosaria monile | | • | • | | • | | | | | | | | | | | | | | | |
| Ramulina kittli | | • | | | | | | | | | | | | | • | | | | | |
| Marginulina curvatura | | | • | | | | | | | | | | | | | | | | | |
| Reussella szajnochae | | O | ● | O | O | • | | | | • | | | | | | | | | | |
| Stilostomella pseudoscripta | | | • | | | | | | | | | | | | | | | | | |
| Frondicularia angusta | | | • | | | | | | | | | | | | | | | | | |

| stratigraphy | E.C. | | L.Campanian - Early Maastrichtian | | | | | | | | | | | | | | Danian | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| planktic zonation | G.el | G.vent. | Globotruncanella havanenis-Gansserina gansseri | | | | | | | | | | | | | | ? | | | |
| species / samples | Mai 1 | Grü 5 | Grü 2 | Zw 7 | Gr 3 | Gr 1 | Gr 6 | Grü 4 | Gr 7 | Grü 8 | Dö 1 | Zw 3 | Zw 4 | Zw 5 | Zw 6 | Zw 9 | Zw 1 | Zw 2 | Zw 11 | Zw 14 |
| Gavelinella clementiana clementiana | | | | | • | • | | • | | | | • | • | • | | | | | | |
| Gavelinella pertusa | | | O | | | | | | | | | | | | | | | | | |
| Stensioeina pommerana | | | O | • | O | • | | | • | • | • | • | | | • | • | | | | |
| Fissurina alata | | | • | • | | | • | | • | | | | | • | | | | | | |
| Epistomina scalaris | | | • | • | | | | | • | | | | | ● | • | | | | | |
| Cibicides beaumontiana | | | • | | | | | | | | | | | | | | | | | |
| Dentalina catenula | | | • | • | | | | | | | | | | | | | | | | |
| Dentalina megapolitana | | | • | | | | | | | | | | | | | | | | | |
| Pullenia cretacea | | | | • | | • | O | | • | • | | | | | | • | | | | |
| Bolivinoides peterssoni | | | • | | | | | | • | | | | | | | | | | | |
| Dentalina gracilis | | | | | | • | • | | | | • | | | O | | | | | | |
| Bolivinoides draco | | | | | | • | • | • | | | • | | | | | | | | | |
| Vaginulina gosae | | | | | | | | | | | • | | | | • | | | | | |
| Neoflabellina leptodisca | | | | | | | • | | | | | | | | | | | | | |
| Bolivinoides decoratus | | | | | | | • | | • | • | | | | | | | | | | |
| Angulogavelinella bettenstaedti | | | | | | | • | | | | | | | | | | | | | |
| Lagena sulcatiformis | | | | | | | • | | | | | | | | | | | | | |
| Pyramidina sp. | | | | | | | • | | | | | | | | | | | | | |
| Reussella cimbrica | | | | | | | • | • | | | | • | | | | | | | | |
| Ellipsoglandulina subnodosa | | | | | | | | | • | | | | | | | | | | | |
| Bolivina incrassata crassa | | | | | O | | | | • | | • | | | | • | | | | | |
| Gublerina cuvillieri | | | | | | | | | | | | • | • | | | • | | | | |
| Osangularia sp. | | | | | | | | | | • | | • | | | | | | | | |
| Pseudoguembelina escolata | | | | | | | | | | | | | | | • | | | | | |
| Gavelinella thalmanni | | | | | | | | | | | | | | | | • | | | | |
| Quadrimorphina allomorphinoides | | | | | | | | | | | | | | | | | | •R | | |
| Globotruncana arca | O | • | O | | O | • | | • | | | | | | | | | | | | |
| Globotruncanita stuarti | | | | | | ● | | ● | ● | ● | ● | ● | O | | O | O | | | | |
| Pseudotextularia elegans | | | | | | O | • | • | O | | O | ● | ● | O | ● | ● | | | | |
| Globotruncanita subspinosa | | O | • | | | | | | O | O | | | | O | • | • | | | | |
| Globotruncana ventricosa | | O | O | • | • | | | | • | • | | | | | | | | | | |
| Heterohelix navarroensis | | | O | | | | • | | • | | | | • | | | | | | | |
| Rosita fornicata | | | ● | | ● | ● | ● | ● | ● | ● | ● | ● | • | | | ● | | | | |
| Archaeoglobigerina cretacea | | | O | | | | O | | | | | | | | | | | | | •R |
| Archaeoglobigerina blowi | | | • | | | | O | | | | | | | | | | | | | |
| Rugotruncana subcircumnodifer | | | • | | | | | | | | | | | | | | | | | |
| Rugoglobigerina rugosa | | | O | O | | O | ● | | • | • | • | O | | ● | ● | O | | | | |
| Globotruncana linneiana | | | • | | | O | • | • | | | | • | | | | | | | | |
| Ventilabrella multicamerata | | | | | | • | • | | • | • | | | | • | | • | | | | |
| Globotruncanita stuartiformis | ● | | | | • | O | | | ● | ● | O | O | ● | ● | • | | | | | |
| Globotruncanita elevata | O | • | | | | | | | | | | | | | | | | | | |
| Globotruncana falsostuarti | | | | ● | | ● | | | ● | ● | | O | ● | | O | ● | | | | |
| Heterohelix glabrans | | | | • | | | | | | | • | | | | | | | | | |
| Heterohelix striata | | | | • | | | | | | • | • | O | • | | ● | | | | | |
| Gansserina gansseri | | | | • | | | | | | • | | | • | | | | | | | |
| Globigerinelloides ultramicra | | | | | | • | | | | | | | | | | • | | | | |
| Globotruncanella havanensis | | | | • | | • | | | • | | • | O | O | | • | ● | | | | |
| Rugoglobigerina hexacamerata | | | | | | • | | | • | • | | • | | | • | | | | | |
| Heterohelix globulosa | | | • | | | | • | | | | | | | | • | | | | | |
| Heterohelix lata | | | | | | | • | | | | | | | | | | | | | |
| Ventilabrella glabrata | | | | | | | • | • | | | | | | | | | | | | |
| Rosita contusa | | | | | | | | | | • | | | O | | | O | | | | |
| Globorotalia angulata | | | | | | | | | | | | | | | | | | • | • | |
| Subbotina triloculinoides | | | | | | | | | | | | | | | | | • | • | | |
| Globorotalia pseudobulloides | | | | | | | | | | | | | | | | | | • | • | |
| Globigerina sp. | | | | | | | | | | | | | | | | | | | | • |

and preservation. Only a few specimens of planktic species of Danian age such as *Globigerina triloculinoides* PLUMMER, *Globigerina pseudobulloides* PLUMMER, *Globigerina angulata* (WHITE) were recognized in the studied sediments. Other taxa such as *Trochammina* sp., *Quadrimorphina allomorphinoides* (REUSS), were redeposited from the Late Cretaceous sediments ( see Tab. 3a, b).

### 5.2.2. Calcareous nannofossils

Relative abundances within samples were variable and coccoliths were moderately well preserved both in the Cretaceous and Tertiary assemblages (see Table 4). Outcrops in Grünbach (samples GRÜ1-8), Dörfles, Maiersdorf and Zweiersdorf in part provided nannofossils of the Late Cretaceous age,

Tables 4a, b, c.
Distribution of calcareous nannofossils in the sediments of the Grünbach-Neue Welt Gosau-Group. * Cretaceous nannofossil zones, ** Tertiary nannofossil zones; Relative sample abundance: ■ abundant (>20 specimens/1 field of view), ● less abundant (10-20 specimens/1 field of view), O common (1-10 specimens/1 field of view), • – rare (<10 specimens/10 fields of view); Relative species abundance: ● abundant (>5%), O common (5-1%), • rare (<1%), cf. – compare, R – reworked species, F – fragments; Nannofossil preservation: W – well preserved, M – moderately well preserved, P – poorly preserved; Localities: MAI – Maiersdorf, GRÜ – Grünbach, ZW – Zweiersdorf, DÖ – Dörfles.

| **GRÜNBACH GOSAU BASIN** | **CRETACEOUS** | | | | | | | | | | | | | | | | **TERTIARY** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **CAMPANIAN** | | | | | | | | **MAASTRICHTIAN** | | | | | | | | **DANIAN** | | | |
| **CC zones (Sissingh, 1977; Perch-Nielsen, 1985)*** | CC19 - CC22 | | | | | CC23 | | | CC24 - CC25a | | | | | | | | NP3 | | | |
| **NP zones (Martini, 1971)**** | | | | | | a | | b | | | | | | | | | | | | |
| **UC zones (Burnett, 1998)*** | UC15 | | | | | UC16 | | UC 17 | UC18 - ?UC19 | | | | | | | | NNTp4 | | | |
| **NNTp zones (Varol, 1998)**** | b | d | | | | | | | | | | | | | | | B - C | | | |
| **sample Nos.** | MAI 1 | GRÜ 5 | GRÜ 2 | ZW 7 | GRÜ 3 | GRÜ 1 | GRÜ 6 | GRÜ 4 | GRÜ 7 | GRÜ 8 | DÖ 1 | ZW 3 | ZW 4 | ZW 5 | ZW 6 | ZW 9 | ZW 1 | ZW 2 | ZW 11 | ZW 14 |
| **Relative sample abundance** | ○ | • | ● | ● | • | ● | ○ | • | ○ | ○ | ○ | ● | ● | ● | ■ | ■ | ○ | ● | ○ | ● |
| **Nannofossil preservation** | P | P | P | P | P | M | P | P | P | P | P | P | M | M | P | W | M | W | M | W |
| *Ahmuellerella regularis* | • | | • | • | • | • | | • | • | ○ | • | | • | | ○ | ○ | | R | R | |
| *Amphizygus brooksii* | • | | • | | • | ○ | | | | | | | | | | | | | | |
| *Arkhangelskiella cymbiformis* | ○ | • | ○ | ● | • | ○ | ○ | • | ● | ○ | ○ | ○ | ○ | ● | ● | ● | R | R | | R |
| *Biscutum coronum* | • | | | • | • | | | | | | | | | | • | ○ | | | | |
| *Biscutum ellipticum* | ○ | • | ○ | ○ | ○ | ○ | • | • | | • | • | | • | ○ | | | | | R | R |
| *Biscutum hattneri* | ○ | | • | | ○ | • | ○ | | • | | | • | | | • | | | | | |
| *Biscutum melaniae* | • | | • | ○ | | • | ○ | | • | | | • | • | | ○ | • | | | | |
| *Braarudosphaera bigelowii* | • | • | | | • | • | | • | | | | | | • | | | | • | • | • |
| *Broinsonia enormis* | ○ | | | • | | • | ○ | | ○ | • | | | • | ○ | ○ | ● | | R | | |
| *Broinsonia parca constricta* | ○ | • | • | • | • | ○ | ○ | | | | | | | | | | | R | R | R |
| *Calculites obscurus* | ○ | ● | ○ | ○ | ○ | | ○ | • | | | | | | | • | • | | | | |
| *Ceratolithoides aculeus* | ○ | • | ○ | • | • | ○ | • | | ○ | ○ | ○ | • | • | • | • | | | | | R |
| *Chiastozygus litterarius* | ○ | ○ | ○ | ○ | ○ | ○ | • | ○ | • | ○ | ○ | ○ | • | ○ | ○ | ○ | | | R | |
| *Cretarhabdus conicus* | ○ | • | ○ | • | | | ○ | • | ○ | ○ | • | • | • | • | ○ | ○ | R | R | R | |
| *Cribrosphaerella ehrenbergii* | ● | ● | ● | ● | ● | ○ | ● | ○ | ● | ○ | ○ | ○ | ○ | ● | ● | ● | R | R | R | R |
| *Cyclagelosphaera reinhardtii* | • | | • | • | | • | • | | | • | | • | | • | • | • | | | | |
| *Cylindralithus sculptus* | • | | • | | | | • | | | | | | • | • | | • | | | | |
| *Eiffellithus eximius* | • | • | | | • | | | | | | | | | | | | R | | | |
| *Eiffellithus gorkae* | ○ | | ○ | ○ | • | ○ | | | | | ○ | ○ | ○ | ○ | ● | ○ | R | R | R | |
| *Eiffellithus turriseiffelii* | ○ | ○ | ○ | ○ | ○ | ● | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | | | R | |
| *Gartnerago obliquum* | • | | ○ | | | • | ○ | | | | | | • | | | | | | | |
| *Kamptnerius magnificus* | • | | | • | • | • | | • | | | | | • | | | • | | | | |
| *Lithraphidites carniolensis* | • | | | ○ | | • | • | | | • | • | | | ○ | ○ | • | | | | |
| *Lithraphidites praequadratus* | • | | • | | | | | | | | | | | | | • | | | | R |
| *Lucianorhabdus cayeuxii* | ○ | ○ | | • | ○ | • | • | | | • | | | | | | | | | | |
| *Lucianorhabdus inflatus* | • | • | | | | | | • | | | | | | | | | | | | |
| *Manivitella pemmatoidea* | | | • | • | • | • | • | ○ | ○ | • | • | • | • | | | • | | | | |
| *Microrhabdulus attenuatus* | • | | | • | | | | | | | | | | | | | | | | |
| *Microrhabdulus decoratus* | • | | ○ | ○ | • | ○ | ○ | • | ○ | ○ | ○ | • | ○ | ○ | ○ | ○ | | | R | |
| *Micula staurophora* | ○ | ○ | • | ● | ○ | ● | ○ | ○ | ○ | ○ | ○ | • | ○ | ○ | ○ | ○ | R | R | R | R |
| *?Neocrepidolithus* sp. (rim) | ○ | | | | | | | | | | | | | | | | | | | |
| *Octolithus multiplus* | • | | | | | | | | | | | | | | | | | | | |
| *Placozygus fibuliformis* | ○ | | ○ | ○ | | • | • | ○ | ○ | ○ | ○ | • | • | ○ | ○ | ○ | | | | |
| *Prediscosphaera arkhangelskyi* | • | | • | | | • | | • | | | | | | | • | | | | | |
| *Prediscosphaera cretacea* | ● | ● | ● | ● | ● | ● | ● | ○ | ○ | ○ | ● | ○ | ○ | ● | ● | ● | R | R | R | R |
| *Prediscosphaera spinosa* | ○ | | • | ○ | | • | • | | • | • | • | • | • | | ○ | • | | | | R |
| *Psyktosphaera firthii* | cf. | | | • | | | | | | | | | | | • | | | | | |
| *Reinhardtites anthophorus* | • | | | | | | | | | | | | | | | | | | | |
| *Reinhardtites levis* | ○ | • | • | • | • | • | ○ | | | | | • | | | • | | | R | | |
| *Retacapsa angustiforata* | ○ | • | • | | ○ | ○ | • | • | • | • | ○ | | • | • | ○ | | R | R | | |
| *Retacapsa crenulata* | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | • | • | ○ | ○ | ○ | | | | |
| *Rotelapillus crenulatus* | ○ | | | | | ○ | ○ | | | | | | • | ○ | | | | | | |
| *Rucinolithus magnus* | • | • | | | • | | | | | | | | | | | | | | | |
| *Rucinolithus wisei* | • | | | | | | | | | | | | | | | | | | | |
| *Sollasites horticus* | • | | | | | | | | | | | | | • | | | | | | |
| *Staurolithites crux* | ○ | | • | | | • | | | • | | | | | | | | | | | |
| *Staurolithites mielnicensis* | ○ | | • | | | | • | | | | | | | | | | | | | |
| *Tegumentum stradneri* | • | | | | | • | | | | | | | | | | | | | | |
| *Uniplanarius gothicus* | • | | | | | • | | | | | | | | | | | | | | R |
| *Watznaueria barnesae* | ○ | ● | ● | ○ | ● | ● | ● | ○ | ● | ○ | ○ | ○ | ○ | ● | ○ | ● | | R | | R |

| GRÜNBACH GOSAU BASIN | CRETACEOUS | | | | | | | | | | | | | | | | TERTIARY | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CAMPANIAN | | | | | | | | MAASTRICHTIAN | | | | | | | | DANIAN | | | |
| CC zones (Sissingh, 1977; Perch-Nielsen, 1985)* | CC19 - CC22 | | | | | CC23 | | | CC24 - CC25a | | | | | | | | NP3 | | | |
| NP zones (Martini, 1971)** | | | | | | a | | b | | | | | | | | | | | | |
| UC zones (Burnett, 1998)* | UC15 | | | | | UC16 | | UC | UC18 - ?UC19 | | | | | | | | NNTp4 | | | |
| NNTp zones (Varol, 1998)** | h | d | | | | | | 17 | | | | | | | | | B - C | | | |
| sample Nos. | MAI 1 | GRÜ 5 | GRÜ 2 | ZW 7 | GRÜ 3 | GRÜ 1 | GRÜ 6 | GRÜ 4 | GRÜ 7 | GRÜ 8 | DÖ 1 | ZW 3 | ZW 4 | ZW 5 | ZW 6 | ZW 9 | ZW 1 | ZW 2 | ZW 11 | ZW 14 |
| **Relative sample abundance** | ○ | • | ● | ● | • | ● | ○ | • | ○ | ○ | ○ | ● | ● | ● | ■ | ■ | ○ | ● | ○ | ● |
| **Nannofossil preservation** | P | P | P | P | P | M | P | P | P | P | P | P | M | M | P | W | M | W | M | W |
| *Watznaueria biporta* | • | | | | | • | | | | | | | | | • | • | | | | |
| *Zeugrhabdotus bicrescenticus* | ○ | • | ○ | • | ○ | • | • | • | • | | | • | • | • | • | • | | | R | |
| *Zeugrhabdotus diplogrammus* | • | • | • | | • | • | | | | | | | | | | | | | | |
| *Zeugrhabdotus embergeri* | • | | | • | • | | • | | | • | | • | | | | • | R | | | |
| *Zeugrhabdotus praesigmoides* | • | | | | | | | | | | | | | | | | | | | |
| *Thoracosphaera* sp. (fragments) | • | | | | | • | | | | | | | | | | | | | | |
| *Bukrylithus ambiguus* | | • | | | • | | | • | | | | | | | | | | | | |
| *Tranolithus orionatus* | | • | ○ | | • | | • | | | | | | | | | | | | | |
| *Uniplanarius trifidus* | | • | | | | | ○ | • | | | | | | | | | | | | |
| *Ahmuellerella octoradiata* | | | • | | | • | • | • | • | • | | | | | | • | | | | |
| *Cylindralithus biarcus* | | | • | | | | | | • | | | | | | | | | | | |
| *Micula swastica* | | | • | • | • | | | | • | | | | | | | | | | | |
| *Ottavianus giannus* | | | • | | | | | | | | | | | | | | | | | |
| *Prediscosphaera grandis* | | | • | ○ | | F | • | | | F | F | | F | F | | • | | | | |
| *Prediscosphaera stoveri* | | | ○ | • | • | • | | • | • | • | | • | | | | • | | | R | |
| *Rhagodiscus angustus* | | | • | | | • | • | | • | | • | | | | | | | | | |
| *Rhagodiscus eboracensis* | | | • | | | | | | • | • | | | | | | • | | | | |
| *Tranolithus minimus* | | | • | • | | • | | • | | | • | | | | • | | | | | |
| *Watznaueria britannica* | | | • | | | • | | • | | | | • | | | | • | | | | |
| *Ceratolithoides amplector* | | | | • | | | | | | | | | | | | | | | | |
| *Ceratolithoides quasiarcuatus* | | | | • | | | | | • | | | | | | | | | | | |
| *Cribrosphaerella daniae* | | | | • | | | | | • | | | | | • | | ○ | | | | |
| *Cyclagelosphaera argoensis* | | | | ○ | | | | | | | | | | | | | | | | |
| *Cyclagelosphaera margerelii* | | | | ○ | | | | | | | | | | | | | | | | |
| *Gorkaea obliqueclausus* | | | | • | | | | | | | | | | | | | | | | |
| *Petrarhabdus* cf. *vietus* | | | | • | | | | | | | | | | | | | | | | |
| *Rucinolithus ?magnus* | | | | • | | | | | | | | | | | | | | | | |
| *Prediscosphaera majungae* | | | | • | | | | | | | | | | | | | | | | |
| *Prediscosphaera ponticula* | | | | • | | • | | | | • | • | | | | • | | | | | |
| *Uniplanarius sissinghii* | | | | cf. | | | • | | | | | | | | | | | | | |
| *Quadrum gartneri* | | | | | • | • | • | • | | | | | | | | | | | | |
| *Biscutum notacalum* | | | | | | • | | | | | | | | | | | | | | |
| *Corollithion signum* | | | | | | • | • | | | | | | | | | | | | | |
| *Lapideacassis* cf. *bispinosa* | | | | | | • | | | | | | | | | | | | | | |
| *Petrarhabdus copulatus* | | | | | | • | | | | | | | | | | | | | | |
| *Rhagodiscus asper* | | | | | | • | • | | • | | | | • | • | | • | | | | |
| *Corollithion ?madagaskarensis* | | | | | | | • | | | | | • | | | | • | | | | |
| *Helicolithus trabeculatus* | | | | | | | • | | | | | | | | | | | | | |
| *Microrhabdulus belgicus* | | | | | | | • | | • | | | | | | | • | | | | |
| *Staurolithites imbricatus* | | | | | | | • | | | | | | | | | • | | | | |
| *?Zeugrhabdotus sigmoides* | | | | | | | • | | | | | | | | | | | | | |
| *Lapideacassis cornuta* | | | | | | | | | | • | | | | | | | | | | |
| *Neocrepidolithus cohenii* | | | | | | | | | | | • | | | | | | | | | |
| *Markalius inversus* | | | | | | | | | | | | | • | • | • | • | | • | | |
| *Biscutum boletum* | | | | | | | | | | | | | • | | • | • | | | R | |
| *Biscutum magnum* | | | | | | | | | | | | | | | | • | | | R | |
| *Ceratolithoides* cf. *sesquipedalis* | | | | | | | | | | | | | | | | • | | | | |
| *Watznaueria fossacincta* | | | | | | | | | | | | | | | | • | | | | |
| *Biscutum harrisonii* | | | | | | | | | | | | | | | | | • | • | | |
| *Coccolithus pelagicus* | | | | | | | | | | | | | | | | | ○ | ● | ○ | ○ |

| GRÜNBACH GOSAU BASIN | CRETACEOUS | | | | | | | | | | | | | | | | TERTIARY | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CAMPANIAN | | | | | | | | MAASTRICHTIAN | | | | | | | | DANIAN | | | |
| CC zones (Sissingh, 1977; Perch-Nielsen, 1985)* / NP zones (Martini, 1971)** | CC19 - CC22 | | | | | CC23 | | | CC24 - CC25a | | | | | | | | NP3 | | | |
| | | | | | | a | | b | | | | | | | | | | | | |
| UC zones (Burnett, 1998)* | UC15 | | | | | UC16 | | UC 17 | UC18 - ?UC19 | | | | | | | | NNTp4 | | | |
| NNTp zones (Varol, 1998)** | b | d | | | | | | | | | | | | | | | B - C | | | |
| sample Nos. | MAI 1 | GRÜ 5 | GRÜ 2 | ZW 7 | GRÜ 3 | GRÜ 1 | GRÜ 6 | GRÜ 4 | GRÜ 7 | GRÜ 8 | DÖ 1 | ZW 3 | ZW 4 | ZW 5 | ZW 6 | ZW 9 | ZW 1 | ZW 2 | ZW 11 | ZW 14 |
| **Relative sample abundance** | ○ | • | ● | ● | • | ● | ○ | • | ○ | ○ | ○ | ● | ● | ● | ■ | ■ | ○ | ● | ○ | ● |
| **Nannofossil preservation** | P | P | P | P | P | M | P | P | P | P | P | P | M | M | P | W | M | W | M | W |
| *Cruciplacolithus asymmetricus* | | | | | | | | | | | | | | | | | • | ○ | • | • |
| *Cruciplacolithus intermedius* | | | | | | | | | | | | | | | | | ○ | • | • | |
| *Cruciplacolithus latipons* | | | | | | | | | | | | | | | | | • | • | • | • |
| *Cruciplacolithus primus* | | | | | | | | | | | | | | | | | ○ | ○ | ○ | ○ |
| *Cruciplacolithus tenuis* | | | | | | | | | | | | | | | | | ○ | ● | ○ | ● |
| *Ellipsilithus bollii* | | | | | | | | | | | | | | | | | • | • | • | • |
| *Ericsonia subpertusa* | | | | | | | | | | | | | | | | | ○ | ○ | ○ | ○ |
| *Ericsonia robusta* | | | | | | | | | | | | | | | | | • | ○ | | • |
| *Neochiastozygus modestus* | | | | | | | | | | | | | | | | | • | ○ | ○ | |
| *Neochiastozygus saepes* | | | | | | | | | | | | | | | | | • | • | ○ | ○ |
| *Prinsius martinii* | | | | | | | | | | | | | | | | | ○ | • | | • |
| *Sullivanica danica* | | | | | | | | | | | | | | | | | • | • | | • |
| *Thoracosphaera crassa* | | | | | | | | | | | | | | | | | • | • | • | ○ |
| *Thoracosphaera* sp. | | | | | | | | | | | | | | | | | • | ○ | • | ○ |
| *Toweius pertusus* | | | | | | | | | | | | | | | | | • | • | • | |
| *Toweius sellandianus* | | | | | | | | | | | | | | | | | • | • | • | • |
| *Zeugrhabdotus sigmoides* | | | | | | | | | | | | | | | | | ○ | ○ | ● | ○ |
| *Braarudosphaera* cf. *B. africana* | | | | | | | | | | | | | | | | | | • | • | • |
| *Ellipsolithus* sp. 1 | | | | | | | | | | | | | | | | | | • | | • |
| *Cruciplacolithus subrotundus* | | | | | | | | | | | | | | | | | | ○ | • | |
| *Ericsonia cava* | | | | | | | | | | | | | | | | | | • | | • |
| *Lanternithus duocavus* | | | | | | | | | | | | | | | | | | • | • | • |
| *Neocrepidolithus dirimosus* | | | | | | | | | | | | | | | | | | • | • | |
| *Markalius apertus* | | | | | | | | | | | | | | | | | | • | • | |
| *Markalius astroporus* | | | | | | | | | | | | | | | | | | • | • | • |
| ? *Biantholithus hughesii* | | | | | | | | | | | | | | | | | | | • | • |
| *Hornibrookina edwardsii* (rim) | | | | | | | | | | | | | | | | | | | • | • |
| *Neochiastozygus* cf. *N. eosaepes* | | | | | | | | | | | | | | | | | | | • | ○ |
| *Goniolithus fluckigeri* | | | | | | | | | | | | | | | | | | | | • |
| *Neochiastozygus* cf. *N. perfectus* | | | | | | | | | | | | | | | | | | | | • |
| *Eprolithus moratus* | | | | | | | | | | | | | | | | | R | | | |
| *Lithraphidites quadratus* | | | | | | | | | | | | | | | | | | R | | |
| *Micula murus-prinsii* | | | | | | | | | | | | | | | | | | | R | |

whereas locality Zweiersdorf, samples ZW 1, 2, 11, 14 yielded Tertiary species (sample points see Text-Fig. 1).

### Coal-Bearing Series and Inoceramus-Marls (Campanian-Maastrichtian)

The following groups of stratigraphically important nannofossil species were recognized within the Coal-Bearing Series (association 1) and Inoceramus-Marls (associations 2, 3, 4; see Table 4).

1. association with *Broinsonia parca constricta, Eiffellithus eximius, Lucianorhabdus* spp., rare *Prediscosphaera stoveri, Uniplanarius sissinghii* and *U. trifidus,* which gives evidence for the UC15 Zone sensu BURNETT (1998), i.e. Early-Late Campanian,
2. association with *Broinsonia parca constricta, Uniplanarius* spp. and *Reinhardtites levis; Eiffellithus eximius* is missing. It gives evidence for the UC16 Zone (Late Campanian),
3. association where *Uniplanarius trifidus* is present but *Broinsonia parca constricta* is already absent, giving evidence for the UC17 Zone (latest Campanian-Early Maastrichtian),
4. low-diversity nannoplankton assemblages with relatively common *Arkhangelskiella cymbiformis* and rare *Biscutum coronum, B. dissimilis* and *Reinhardtites levis,* which can be compared with the UC18-?UC19 zones interval (Early Maastrichtian-?lowermost Late Maastrichtian).

### Zweiersdorf-Formation (Danian)

Early Paleocene (Danian) calcareous nannofossil assemblages are characterized by the following features:

The associations comprise a high number of *Cruciplacolithus* spp., *Neochiastozygus saepes,* rare *Sullivania danica* and *Ellipsolithus bollii,* which gives evidence for the Danian Stage, NNTp4 Zone.

*Cruciplacolithus* spp. numerically dominate over *Coccolithus* sp. and *Ericsonia* spp. High species diversity of genus *Cruciplacolithus* (see Table 4c and Plate 6, Figs. 25-42) is characteristic. Rare presence of *Biantholithus hughesii* (a form having

Table 5: Distribution of dinocysts, spores, pollen and other organic-walled microfosssils in samples from Grünbach-Neue Welt Gosau-Group. * .... present, ** ..... 2-5 specimens *R .... redeposition

| Taxa locality | Grü 2 | Grü 3 | Grü 4 | Grü 6 | Mai 1 | Zw 2 | Dö 1 |
|---|---|---|---|---|---|---|---|
| **Dinoflagellate cysts and acritarchs** | | | | | | | |
| *Canningia* sp. | | | | | * | | |
| *Dinogymnium* sp. | | * | | | | | |
| aff. *Dinogymnium* sp. | | | | | * | | |
| *Exochosphaeridium* sp. | | | | | | | * |
| *Isabelidinium* sp. | | | | | * | | |
| *Oligosphaeridium* sp. | | | | * | | | |
| *Pyxidinopsis bakonyensis* (GÓCZÁN) | | | | | * | | |
| *Spinidinium* sp. | | | * | | | | |
| *Micrhystridium* sp. | | * | | | * | | * |
| **Non-marine microplankton** | | | | | | | |
| *Schizocystia* sp. | | * | | | | | |
| **Annelida-Polychaeta -scolecodonts** | | * | | | | | |
| **chitinous linings of foraminifers** | | * | * | | | | |
| **Pteridophyte spores** | | | | | | | |
| *Appendicisporites* sp. | | | | | * | | |
| aff. *Converrucosisporites* sp. | | * | | | | | |
| aff. *Dictyophyllidites* sp. | | | * | | | | |
| **Gymnosperm pollen** | | | | | | | |
| *Corollina torosus* (MALJAVKINA) | | | | | | *R | |
| *Callialasporites dampieri* (BALME)DEV | | | | | *R | | |
| **Angiosperm pollen** | | | | | | | |
| *Heidelbergipollis* cf. *tilioides* KRUTZSCH | | * | | | | | |
| *Oculopollis* sp. | | | * | * | | | |
| *Pseudopapillopollis praesubhercynicus* | * | * | | | | | |
| *Pseudopapillopollis* sp. | | | * | | | | |
| *Suemegipollis germanicus* KRUTZSCH | | * | * | | | | |
| *Suemegipollis* sp. | | * | | | | | |
| *Interporopollenites* sp. | | | * | | | | |
| *Pseudoplicapollis peneserta* PFLUG | | * | ** | | | | |
| *Trudopollis minimus* GÓCZÁN | | | | | ** | | |
| *Vacuopollis* cf. *minor* PACLT. & W.KR. | | | | | ** | | |
| *Minorpollis* sp. | | * | * | | * | | |

six elements) which was described by VAROL (1989) from the earliest Danian was recorded here. The presence of *Ellipsolithus bollii* and *Ellipsolithus* sp. 1 (see Plate 6, Figs. 23, 24) and the absence of the marker species *Ellipsolithus macellus* were observed.

Assemblages are formed by "survivor" taxa crossing the K/T boundary and by species the first appearances of which are observed in the Tertiary. Survivor nannofossils are represented by species *Cyclagelosphaera margerelii, Zeugrhabdothus sigmoides, Markalius apertus, Thoracosphaera* spp., and *Braarudosphaera bigelowii.*

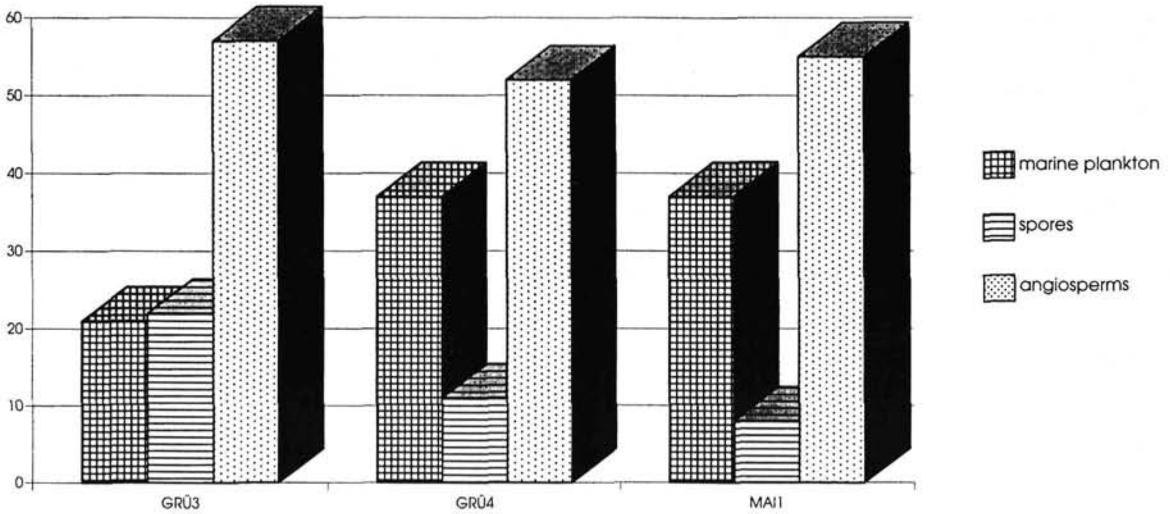
The Danian assemblages also contain reworked Cretaceous nannofossil species which give evidence for the following stratigraphical horizons: Turonian-Coniacian (sensu BURNETT, 1998) in sample ZW1 with *Eprolithus moratus;* Campanian with *Broinsonia parca constricta* in samples ZW2, ZW11 and ZW14, *Eiffellithus eximius* in sample ZW1; Late Maastrichtian with *Lithraphidites quadratus* in sample ZW2 and *Micula murusprinsii* in sample ZW11.

### 5.2.3. Palynomorpha

Seventeen samples from Grünbach (GRÜ1-9), Zweiersdorf (ZW1-6), Maiersdorf (MAI1) and Dörfles (DÖ1) were examined for palynological content. Seven of these contained palynomorphs (Tab. 5). The terrestrial flora, especially triporate angiosperm pollen of the Normapolles group, is the most abundant and diverse in the Grünbach and Maiersdorf sections (Tab. 5). The presence of dinoflagellate cysts and acritarchs, together with faunal remains of scolecodonts, indicates a marine environment of deposition.

The overall quality of preservation and recovery of palynomorphs, especially dinocysts (see Plate 7, Fig. 21) at Grünbach is poor (marine microplankton is broken, corroded or "pyrite pitted"), whereas the preservation of the angiosperm pollen (Text-Fig. 5) and/or some pteridophyte spores (due to a thicker exine) is relatively better. The presence of acritarchs of *Micrhystridium* type and higher terrestrial flora input may reflect a closer proximity to shallow-marine conditions during deposition. Non-marine microplankton (e.g. *Schizocystia* sp.) appears in sample GRÜ3 (Late Campanian Inoceramus-Marls), which otherwise shows an outer neritic depositional enviroment (see chapter 6.3.). Microbial activity associated with weathering may explain the scarcity and poor preservation of dinoflagellate cysts.

Angiosperm pollen dominate in five samples (GRÜ2, GRÜ3, GRÜ4, GRÜ6 and MAI1). Dominant species are *Pseudopapillopollis praesubhercynicus, Oculopollis* sp. and *Suemegipollis germanicus* in the samples from the Inoceramus-Marls in the




Text–Fig 4.
Distribution of major pollen, spores and marine plankton groups in samples from the Early Campanian Coal-Bearing Series (MAI1) and from the Late Campanian (GRÜ3) and Early Maastrichtian (GRÜ4) Inoceramus-Marls.

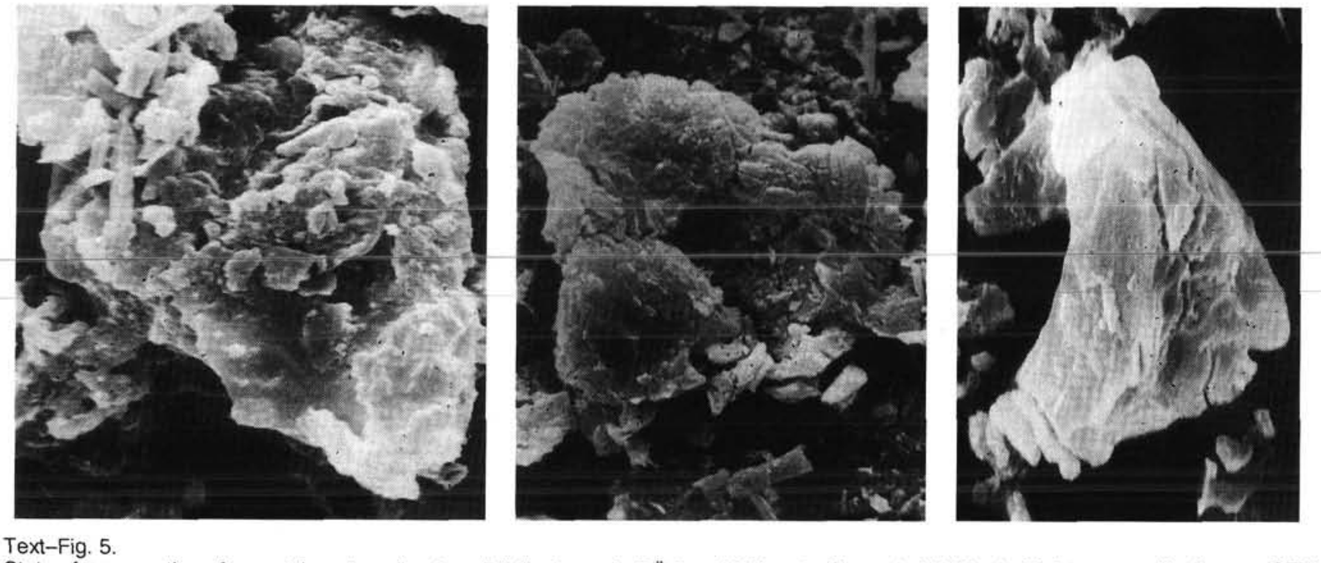
surroundings of Grünbach and *Pseudopapillopollis praesubhercynicus, Pseudopapillopollis* sp., *Trudopollis minimus* and *Vacuopollis* cf. *minor* in the sample MAI1 from the Coal-Bearing Series of Maiersdorf. Accessory species include rare miospores of ferns (e.g. *Appendicisporites* sp.). Angiosperm pollen comprise 80 % of the total assemblage at Grünbach and 60 % at Maiersdorf (Text-Fig. 4).

Biostratigraphically important species, such as *Pyxidinopsis bakonyensis*, characterize the deposits as lying within the Palaeostomocystis bakonyensis-Pseudopapillopollis praesubhercynicus Zone (GÓCZÁN & SIEGL-FARKAS, 1990). This species was found only in the sample of the Coal-Bearing Series at Maiersdorf (for details see Table 5).

Only two specimens of gymnosperm pollen were recorded in the studied samples. One of them, *Corollina torosus* (family Cheirolepidiaceae, which characterizes marsh environment), appears in sample ZW2 from the Zweiersdorf-Formation. It may have been redeposited from older sediments (Late Triassic-Cretaceous). The other one, *Callialasporites dampieri,* characteristic for Early Cretaceous sediments, appears in sample MAI1 from the Coal-Bearing Series of Maiersdorf.

The dinoflagellates are poorly preserved in the samples investigated. They are light in colour and commonly with rhomboidal pyrite in its molds. The assemblage displays a low species diversity. Most species are rare and occur sporadically in the studied samples. Only *Dinogymnium* spp. is consistently present in both the Grünbach and Maiersdorf samples. Other forms, very often corroded or broken, are of the genera *Spinidinium, Isabelidinium* and *Oligosphaeridium* (Tab. 5). No large cavate forms of *Chatangiella* appear. The assemblage corresponds to that reported by SIEGL-FARKAS & WAGREICH (1996b) and characterizes shallow-marine to neritic sediments.

Organic matter of the sample from the Coal-Bearing Series at Maiersdorf (sample MAI1) is composed of abundant black particles and amorphous matter with fecal pellets and rare tissues of vascular plants. Sporomorphs are often



Text–Fig. 5.
State of preservation of some triporate pollen from Dörfles (sample DÖ1) and Maiersdorf (sample MAI1). a) aff. *Interporopollenites* sp., SEM x 4000, Dörfles, b) *Oculopollis* sp., SEM x 2000, Maiersdorf, c) aff. *Pseudoplicapollis peneserta* W. KRUTZSCH, SEM x 4000, Dörfles.

dark brown in colour, indicating that organic matter has been subjected to thermal alteration (Text-Fig. 5).

The presence of rhomboidal pyrite, scolecodonts and chitinous linings of foraminifers in palynological preparations of the Inoceramus-Marl in Grünbach (samples GRÜ3,4) may indicate an environment with lower oxygen content.

More or less well-structured wood fragments, epidermal tissues, rare cuticles associated with small amounts of black granular amorphous detritus, appear in samples belonging to the Late Campanian Inoceramus-Marls (GRÜ2, 3).

Grey to black, finely particulate to granular amorphous matter associated with very rare palynomorphs characterizes sample GRÜ6 (Late Campanian Inoceramus-Marls). This is considered to be mainly algal matter bacterially degraded under dysaerobic conditions.

## 6. Discussion

### 6.1. Mineralogy

Most clay minerals of marine sediments are inherited from former exposed land masses. For that, clay mineral assemblages can express the intensity of weathering of the land masses adjacent to sedimentary basins (CHAMLEY, 1989).

So far only sample MAI1 from the Early Campanian Coal-Bearing Series at Maiersdorf has been investigated. In comparison to the Late Campanian Inoceramus-Marls a lower content of smectite and other phyllosilicates is evident, while the illite content is higher. The organic matter is dominated by black particles and amorphous matter, while the sporomorphs are often dark brown in colour, indicating thermal alteration.

From the mineralogical point of view, all samples of the Inoceramus-Marls show a high content of calcite. Also dolomite is conspicuous in most samples. In the Late Campanian samples the smectite content is elevated in comparison to the Maastrichtian ones. However, the content of illite, kaolinite and chlorite is slightly higher in the Maastrichtian sample set. The same is true for the content of feldspar and for the phyllosilicates.

The analysed high smectite contents in the Gosau marls correlate quite well with previous studies of Late Cretaceous marine sediments. POBER (1984) analysed higher amounts of smectite and illite/smectite mixed layer minerals in some samples from the "Upper Gosau-Subgroup" of Wörschach. The high smectite content can be a result of erosion of thick pedogenic blankets developed under high temperature and seasonally contrasted humidity (CHAMLEY, 1989). The existence of pedogenic minerals (soil vermiculite as well as soil chlorite) supports that theory. Short uplifting events before subsidence (WAGREICH, 1995) are in favour for intense soil erosion processes.

From the mineralogical point of view the samples of Danian age from the Zweiersdorf-Formation differ considerably from the Late Cretaceous marly sediments. In the Zweiersdorf-Formation the calcite content is much lower and dolomite is not present. On the contrary, the content of feldspar and of phyllosilicates is much higher. The same is true for muscovite and the rare mica mineral paragonite. The smectite content is also elevated, however, the illite content is lower than in the Late Cretaceous samples.

SAUER (1980) also found high amounts of smectite in four samples from Zweiersdorf and compared them with clay mineralogical results from the "Upper Gießhübl-Formation". In that marls he found higher smectite contents only in the diagenetically unaltered parts, but less or no smectite in the "Lower Gießhübl-Formation" (especially from deep drilling cores down to 4000m) which were altered by higher diagenesis to illite/smectite mixed layers and chlorite. Such transformations couldn't be found in the analysed samples in this study although according to WAGREICH (1991, 1995) also the most south-eastern parts of the Gosau sea show a very rapid subsidence during the Maastrichtian and Early Tertiary.

The moderate values of IC and the occurrence of paragonite in the Danian samples from Zweiersdorf-Formation (ZW1 and ZW2) indicate metamorphic rocks as parent materials for the weathering products transported into the Gosau basin.

### 6.2. Biostratigraphy and Palaeoecology of foraminifera and nannofossils

Stratigraphic determination of the Late Cretaceous and Paleocene sediments from the Grünbach-Neue Welt Gosau region was refined on the basis of foraminifers and calcareous nannofossils.

Complete foraminiferal, nannofossil and palynomorph lists for each studied sample are shown together with the distribution of species in Tables 3a, b; 4a, b, c; 5.

OBERHAUSER (in PLÖCHINGER et al., 1961, 1967 and in BRIX & PLÖCHINGER, 1988) and OBERHAUSER (1963) recorded many benthonic and planktic foraminifera taxa from the Campanian-Maastrichtian sediments of Grünbach-Neue Welt Upper Gosau-Group. Most of them were recognized also in our material. Nevertheless, the taxa have now a new systematic range sensu LOEBLICH & TAPPAN (1988) and several new species of the genera *Gavelinella* and *Gaudryina* could be determined by using systematic descriptions of HERCOGOVÁ (1984), HRADECKÁ (1996) and EDWARDS (1981). The new foraminiferal research (GASINSKI et al., 1999; CARON, 1985; ROBASZYNSKI & CARON, 1995; ALEKSEEV & KOPAEVICH, 1997; ROBASZYNSKI & CHRISTENSEN, 1989 etc.) allowed the present authors to formulate a more detailed stratigraphic subdivision of Late Cretaceous sediments from this area.

The following foraminiferal planktic zones (sensu ROBASZYNSKI & CARON, 1995) were recognized in the sample set of the Coal-Bearing Series and Inoceramus-Marls (Campanian, Maastrichtian):

1. Globotruncana elevata Zone which corresponds to the lower part of the UC15 Nannoplankton Zone sensu BURNETT (1998) and can be correlated with the upper part of the Early Campanian (sample MAI1 only – Coal-Bearing Series).
2. Interval of Globotruncanella havanensis – Gansserina gansseri Zones which corresponds to the UC15-?UC19 Nannoplankton Zone interval sensu BURNETT (1998) and can be correlated with the Late Campanian and Early Maastrichtian. According to the results of nannofossil study, it is possible to subdivide this interval into the upper part of UC15 Zone and UC16 Zone attributed to the Late Campanian, the UC17 Zone characterizes the Campanian/Maastrichtian boundary interval and the UC18-?UC19 Zone is attributed to the Early Maastrichtian. All samples represented by the Gansserina gansseri Zone belong to the Inoceramus-Marls.

Our set of samples from the Zweiersdorf-Formation (Danian) provided only scarce and poorly preserved foraminifers of no stratigraphic significance. The relative age of these sediments was determined from nannofossils which can be correlated with the lower part of the NNTp4 Zone, the middle part of the Danian.

Two palaeobathymetric zones were determined on the basis of foraminiferal plankton/benthos ratio (Text-Fig. 3) in the Late Cretaceous samples:

1. Outer neritic of Early Campanian age – sample MAI1, Coal-Bearing Series – and samples GRÜ2, 3, 5 and ZW7, Inoceramus-Marl of Late Campanian age.

Upper-middle bathyal in the Late Campanian-Early Maastrichtian interval. These facies belong to the transition between shelf marls and bathyal hemipelagites and turbidites. The character of microfossil assemblages presents a mixture of cold water and warm water preferring elements.

In the foraminiferal assemblage of the Coal-Bearing Series in Maiersdorf (sample MAI1) benthic species of *Gavelinella, Lenticulina, Stensioeina* and agglutinated species *Spiroplectammina dentata* (ALTH) and *Tritaxia tricarinata* (REUSS) prevailed. The ratio plankton/benthos was 40/60 (Text-Fig. 3). Palaeobathymetry based on plankton/benthos ratio (BUTT, 1981; KUHNT & OBERT, 1989) indicates water depth of about 200 m, which implies outer neritic environment. The Late Campanian and Early Maastrichtian sediments were probably deposited in deeper marine environment (upper-middle bathyal) dominated by keeled planktic species of genera *Globotruncana, Globotruncanita, Globotruncanella* and *Rosita* (80–90%). Benthonic foraminifers were represented by deep-water agglutinated species such as *Bathysiphon, Tritaxia tricarinata* (REUSS), *Dorothia bulleta* (CARSEY), *Recurvoides* sp., *Spiroplectammina dentata* (ALTH) and others (PERYT et al., 1997). The studied sediments of the Grünbach-Neue Welt Gosau-Group belong to the Upper Gosau-Subgroup with facies association F (shelf/slope transitional deposits) sensu WAGREICH & FAUPL (1994). This facies exhibits the transition from shelf marls with storm beds to bathyal hemipelagites and turbidites.

From the palaeogeographic point of view the character of foraminiferal assemblages represents a mixture of Boreal and Tethyan elements. *Reussella szajnochae* is a typical Tethyan species. The presence of cold water-preferring taxa such as *Gavelinopsis, Gaudryina,* etc. suggests an influence of cold water currents in deeper water environment. SUMMESBERGER (1997) also refers to the Late Campanian belemnite *Belemnitella hoeferi* (SCHLOENBACH) from Grünbach as an indicator of cooler environment. Also the occurrence of the cold-water planktonic taxon *Globigerinelloides ultramicra* (SUBBOTINA) in the Early Maastrichtian Inoceramus-Marls indicates a change in water temperatures from warm to cool-temperate during the Campanian, which corresponds to a global climatic event (LOMMERZHEIM, 1991). Late Maastrichtian assemblages of the Abathomphalus mayaroensis Zone were not encountered in the studied sediments.

Mixing of low- and high-latitude nannofossil taxa is evident especially in the Campanian assemblages. Warm water-preferring (Tethyan) taxa are present here in relatively low numbers, represented by genera *Uniplanarius* and *Ceratolithoides.* Cold water-preferring species (Boreal) are represented here by rare *Prediscosphaera stoveri, Biscutum coronum* and *B. dissimilis.*

Surprisingly, low-latitude nannofossils represented by genera *Ceratolithoides* and *Uniplanarius* form only a negligible proportion of the assemblages relative to the Late Campanian nannofossils from the Waschberg Zone and Ždánice Unit of the Outer West Carpathians (ŠVÁBENICKÁ, 1995, 1998 and ŠVÁBENICKÁ in SUMMESBERGER et al., 1999). This phenomenon can be explained not only by different palaeogeographic positions of the depositional areas but also by specific palaeoenvironmental conditions. The Upper Gosau-Subgroup (in the sense of WAGREICH & FAUPL, 1994) comprises deep-water hemipelagic and turbiditic deposits. This was also reflected in the character of nannofossil assemblages.

The present study did not confirm the existence of field outcrops showing a Cretaceous/Tertiary boundary in the Zweiersdorf section. The "youngest" Cretaceous nannofossil association encountered in our samples belongs to the UC18-?UC19 zones interval which is correlated with the Early Maastrichtian, whereas the "oldest" Tertiary coccoliths were correlated with the NNTp4 Zone, middle part of Danian.

Our small set of samples from the locus classicus of the Zweiersdorf-Formation can be assigned by nannoplankton to the Danian stage (NNTp4 Zone). The nannofossil species *Ellipsolithus bollii* is mentioned by PERCH-NIELSEN (1985) after the first occurrence of *Ellipsolithus macellus* which marks the base of NP4 Zone and NNTp4D Zone, respectively. Nevertheless, *E. macellus* was not found in the studied material. Position of the stratigraphical horizon within the NNTp4C Zone is also supported by numerical dominance of *Cruciplacolithus* spp. over *Coccolithus* spp. which was described by VAROL (1998) and is characteristic of the NNTp4C Zone.

An interesting aspect is the redeposition of Late Cretaceous nannofossils – including also Turonian/?Coniacian elements (sensu BURNETT, 1998) – in the Zweiersdorf-Formation. The provenance of these Turonian/?Coniacian nannofloral elements is not clear. According to the present state of knowledge marine sedimentation commenced in the Grünbach-Neue Welt Gosau region in the Santonian, however, in the nearby Gosau outcrops of Furth-Gemeindeberg, sedimentation is supposed to start already in the (?)Turonian.

### 6.3. Palynomorpha

Most of the studied samples were barren or yielded extremely poor palynomorpha assemblages. Yet, the presence of some dinoflagellate cysts (e.g. *Pyxidinopsis bakonyensis*) and triporate angiosperm pollen of the Normapolles group (*Pseudopapillopollis praesubhercynicus, Heidelbergipollis* cf. *tilioides, Suemegipollis germanicus*) allows a good biostratigraphic identification of the samples. The palynological analysis shows that the assemblages of samples GRÜ2, GRÜ3 and probably MAI1 are very similar to the assemblages from the Polány Marl-Formation of Hungary and can be assigned to the Palaeostomocystis bakonyensis-Pseudopapillopollis praesubhercynicus Zone of GÓCZÁN & SIEGL-FARKAS (1990). This zone represents the uppermost Cretaceous in the Hungarian palynostratigraphical zonation. GÓCZÁN & SIEGL-FARKAS (1990) placed this zone within the Late Maastrichtian. According to the foraminifers (SIDÓ in GÓCZÁN, 1973), the upper part of the Polány Marl-Formation is placed near the Campanian-Maastrichtian boundary. Using both palynomorphs and nannoplankton, SIEGL-FARKAS & WAGREICH (1996b) assigned the Polány Marl-Formation to the end of the Late Campanian.

### 6.4. Spatial stratigraphic distribution of the Inoceramus-Marls

PLÖCHINGER (1967) assumes, that the Inoceramus-Marls of the Grünbach syncline and of the NE limb of the Neue Welt Gosau exposures are predominantly of Early Maastrichtian age, while the Inoceramus-Marls of the SW limb of the Neue Welt, of the Fischauer Berge and along the edge to the Vienna Basin, are most probably of Late Campanian age. Inoceramus-Marls of Late Maastrichtian age were encountered by PLÖCHINGER (1961, 1967) only in the surroundings of Oberhöflein. Based on these stratigraphic data PLÖCHINGER (1967) deduces a transgressive trend from E to W. However, the evaluation of our still small and therefore not really representative set of samples seems to contradict this model. The cluster of our samples (Text-Fig. 1; Tables 3, 4) from the region between the railway station Grünbach Schule and Grünbacher Sattel (samples GRÜ1-6) comprise the Late Campanian (Nannozones UC15d, UC16, sensu BURNETT, 1998) and sample GRÜ4 shows a nannoplankton assemblage of Nannozone UC17, indicating the Campanian/ Maastrichtian boundary interval. Our samples taken further to the East, i. e. samples GRÜ7,8, DÖ1 and the sample-set taken NW of Zweiersdorf show Inoceramus-Marl of Early Maastrichtian age (Nannozones UC18-?UC19). Lowermost Late Maastrichtian age cannot be ruled out for samples ZW6 and ZW9.

A much denser sample grid and above all further detailed biostratigraphic study of profiles is still necessary for a better understanding of the transgressive trends in the Grünbach-Neue Welt Gosau region.

## 7. Conclusions

An interdisciplinary study of the Late Cretaceous and Early Paleocene (Danian) marly sediments of the Grünbach-Neue Welt Gosau region – comprising mineralogical and palaeontological aspects – has been started. The goal of our study was a more detailed, updated analysis of the biostratigraphy and palaeoenvironment, including also aspects of palaeogeography respectively bioprovinces, by comparison of the assemblages of foraminifera, nannoplankton and palynomorpha.

So far only one sample from the Coal-Bearing Series at Maiersdorf has been investigated. It can be assigned to the Early Campanian Nannozone UC15b sensu BURNETT (1998), respectively to the *Globotruncana elevata* Zone. The foraminiferal plankton/benthos ratio indicated an outer neritic environment of this deposition (Text-Fig. 3). In comparison to the Late Campanian Inoceramus-Marls a lower content of smectite and of phyllosilicates is evident in the Coal-Bearing Series, while the illite content is higher. The organic matter is dominated by black particles and amorphous matter, while the sporomorphs are often dark brown in colour, indicating thermal alteration.

Our sample set of the Inoceramus-Marls shows a Late Campanian to Early Maastrichtian age (Globotruncana ventricosa Zone and Globotruncanella havanensis-Gansserina gansseri Zones, respectively Nannozones UC15d-?UC19). From the mineralogical point of view, all samples of the Inoceramus-Marl show a high content of calcite. Also dolomite is conspicuous in most samples. In the Late Campanian samples the smectite content is elevated in comparison to the Maastrichtian ones. However, the content of illite, kaolinite and chlorite is slightly higher in the Maastrichtian sample set. The same is true for the content of feldspar and for the phyllosilicates. The Inoceramus-Marl in the surroundings of Grünbach mainly show a Late Campanian age, while in the region of Dörfles and Zweiersdorf the Early Maastrichtian predominates. The foraminifera assemblages indicate deposition of the Inoceramus-Marl in an upper-middle bathyal environment. A mixture of Boreal and Tethyan nannoplankton, foraminifera and also palynomorpha taxa is evident.

From the mineralogical point of view the Zweiersdorf-Formation differs considerably from the Late Cretaceous marly sediments. In the Zweiersdorf-Formation the calcite content is much lower and dolomite is not present. On the contrary, the content of feldspar and of phyllosilicates is much higher. The same is true for muscovite and the rare mica mineral paragonite. The smectite content is also elevated, however, the illite content is lower than in the Late Cretaceous samples.

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## Appendix

### List of calcareous nannofossils mentioned in this paper, in the alphabetical order of generic epithets:

### Cretaceous taxa

*Ahmuellerella octoradiata* (GÓRKA, 1957) REINHARDT, 1966
*Ahmuellerella regularis* (GÓRKA, 1957) REINHARDT & GÓRKA, 1967
*Amphizygus brooksii* BUKRY, 1969
*Arkhangelskiella cymbiformis* VEKSHINA, 1959
*Biscutum constans* (GÓRKA, 1957) BLACK in BLACK & BARNES, 1959
*Biscutum coronum* WIND & WISE in WISE & WIND, 1977
*Biscutum hattneri* WISE, 1983
*Biscutum magnum* WIND & WISE in WISE & WIND, 1977
*Biscutum melaniae* (GÓRKA, 1957) BURNETT, 1997
*Biscutum notacalum* WIND & WISE in WISE & WIND, 1977
*Broinsonia parca constricta* HATTNER et al., 1980
*Broinsonia enormis* (SHUMENKO, 1968) MANIVIT, 1971
*Braarudosphaera africana* STRADNER, 1961
*Braarudosphaera bigelowii* (GRAN & BRAARUD, 1935) DEFLANDRE, 1947
*Bukrylithus ambiguus* BLACK, 1971
*Calculites obscurus* (DEFLANDRE, 1959) PRINS & SISSINGH in SISSINGH, 1977
*Ceratolithoides amplector* BURNETT, 1998
*Ceratolithoides sesquipedalis* BURNETT, 1998
*Chiastozygus litterarius* (GÓRKA, 1957) MANIVIT, 1971
*Corollithion ?madagaskarensis* PERCH-NIELSEN, 1973
*Corollithion signum* STRADNER, 1963
*Cretarhabdus conicus* BRAMLETTE & MARTINI, 1964
*Cribrosphaerella daniae* PERCH-NIELSEN, 1973
*Cribrosphaerella ehrenbergii* (ARKHANGELSKY, 1912) DEFLANDRE in PIVETEAU, 1952
*Cyclagelosphaera argoensis* BOWN, 1992
*Cyclagelosphaera reinhardtii* (PERCH-NIELSEN, 1968) ROMEIN, 1977
*Cylindralithus biarcus* BUKRY, 1969
*Cylindralithus sculptus* BUKRY, 1969
*Eiffellithus eximius* (STOVER, 1966) PERCH-NIELSEN, 1968
*Eiffellithus gorkae* REINHARDT, 1965
*Eiffellithus turriseiffelii* (DEFLANDRE in DEFLANDRE & FERT, 1954) REINHARDT, 1965
*Eprolithus moratus* (STOVER, 1966) BURNETT, 1998
*Gartnerago obliquum* (STRADNER, 1963) NOËL, 1970
*Gorkaea obliqueclausus* (VAROL, 1991) VAROL & GIRGIS, 1994
*Helicolithus trabeculatus* (GÓRKA, 1957) VERBEEK, 1977
*Kamptnerius magnificus* DEFLANDRE, 1959
*Lapideacassis* cf. *L. bispinosa* (PERCH-NIELSEN in PERCH-NIELSEN & FRANZ, 1977) BURNETT, 1998
*Lapideacassis cornuta* (FORCHHEIMER & STRADNER, 1973) WIND & WISE in WISE & WIND, 1977
*Lithraphidites carniolensis* DEFLANDRE, 1963

*Lithraphidites praequadratus* ROTH, 1978
*Lithraphidites quadratus* BRAMLETTE & MARTINI, 1964
*Lucianorhabdus cayeuxii* DEFLANDRE, 1959
*Lucianorhabdus inflatus* PERCH-NIELSEN & FEINBERG in PERCH-NIELSEN, 1986
*Manivitella pemmatoidea* (DEFLANDRE in MANIVIT, 1965) THIERSTEIN, 1971
*Microrhabdulus attenuatus* (DEFLANDRE, 1959) DEFLANDRE, 1963
*Microrhabdulus belgicus* HAY & TOWE, 1963
*Microrhabdulus decoratus* DEFLANDRE, 1959
*Micula murus-prinsii*
*Micula staurophora* (GARDET, 1955) STRADNER, 1963
*Micula swastica* STRADNER & STEINMETZ, 1984
*Octolithus multiplus* (PERCH-NIELSEN, 1973) ROMEIN, 1979
*Ottavianus giannus* RISATTI, 1973
*Placozygus fibuliformis* (REINHARDT, 1964) HOFFMANN, 1970
*Petrarhabdus copulatus* (DEFLANDRE, 1959) WIND & WISE in WISE, 1983
*Petrarhabdus vietus* BURNETT, 1998
*Prediscosphaera arkhangelskyi* (REINHARDT, 1965) PERCH-NIELSEN, 1984
*Prediscosphaera cretacea* (ARKHANGELSKY, 1912) GARTNER, 1968
*Prediscosphaera grandis* PERCH-NIELSEN, 1979
*Prediscosphaera majungae* PERCH-NIELSEN, 1973
*Prediscosphaera ponticula* (BUKRY, 1969) PERCH-NIELSEN, 1984
*Prediscosphaera spinosa* (BRAMLETTE & MARTINI, 1964) GARTNER, 1968
*Prediscosphaera stoveri* (PERCH-NIELSEN, 1968) SHAFIK & STRADNER, 1971
*Psyktosphaera firthii* POSPICHAL & WISE, 1990
*Quadrum gartneri* PRINS & PERCH-NIELSEN in MANIVIT et al., 1977
*Reinhardtites anthophorus* (DEFLANDRE, 1959) PERCH-NIELSEN, 1968
*Reinhardtites levis* PRINS & SISSINGH in SISSINGH, 1977
*Retacapsa angustiforata* BLACK, 1971
*Retacapsa crenulata* (BRAMLETTE & MARTINI, 1964) GRÜN in GRÜN & ALLEMANN, 1975
*Rhagodiscus angustus* (STRADNER, 1963) REINHARDT, 1971
*Rhagodiscus asper* (STRADNER, 1963) REINHARDT, 1967
*Rhagodiscus eboracensis* BLACK, 1971
*Sollasites horticus* (STRADNER et al. in STRADNER & ADAMIKER, 1966) (ČEPEK & HAY, 1969
*Staurolithites crux* (DEFLANDRE & FERT, 1954) CARATINI, 1963
*Staurolithites imbricatus* (GARTNER, 1968) BURNETT, 1998
*Staurolithites mielnicensis* (GÓRKA, 1957) PERCH-NIELSEN, 1968
*Tranolithus minimus* (BUKRY, 1969) PERCH-NIELSEN, 1984
*Tranolithus orionatus* (REINHARDT, 1966) REINHARDT, 1966
*Uniplanarius gothicus* (DEFLANDRE, 1959) HATTNER & WISE, 1980
*Uniplanarius sissinghii* PERCH-NIELSEN, 1986
*Uniplanarius trifidus* (STRADNER in STRADNER & PAPP, 1961) HATTNER & WISE, 1980
*Watznaueria barnesae* (BLACK, 1959) PERCH-NIELSEN, 1968
*Watznaueria biporta* BUKRY, 1969
*Watznaueria britannica* (STRADNER, 1963) REINHARDT, 1964
*Watznaueria fossacincta* (BLACK, 1971) BOWN in BOWN & COOPER, 1989
*Zeugrhabdotus bicrescenticus* (STOVER, 1966) BURNETT in GALE et al., 1996
*Zeugrhabdotus diplogrammus* (DEFLANDRE in DEFLANDRE & FERT, 1954) BURNETT in GALE et al., 1996

### Cretaceous/Tertiary boundary transitional taxa sensu POSPICHAL & BRALOWER (1992) and BURNETT (1998)

*Braarudosphaera bigelowii* (GRAN & BRAARUD, 1935) DEFLANDRE, 1947
*Cyclagelosphaera margerelii* NOËL, 1965
*Goniolithus fluckigeri* DEFLANDRE, 1957
*Markalius apertus* PERCH-NIELSEN, 1979
*Markalius inversus* (DEFLANDRE in DEFLANDRE & FERT, 1954) BRAMLETTE & MARTINI, 1964
*Thoracosphaera* spp.
*Zeugrhabdotus sigmoides* (BRAMLETTE & SULLIVAN, 1961) BOWN & YOUNG, 1997

### Tertiary taxa

*Biantholithus hughesi* VAROL, 1989
*Biscutum harrisonii* VAROL, 1989
*Coccolithus pelagicus* (WALLICH, 1871) SCHILLER, 1930
*Cruciplacolithus assymetricus* van HECK & PRINS, 1987
*Cruciplacolithus intermedius* van HECK & PRINS, 1987
*Cruciplacolithus latipons* ROMEIN, 1979
*Cruciplacolithus primus* PERCH-NIELSEN, 1977
*Cruciplacolithus subrotundus* PERCH-NIELSEN, 1969
*Cruciplacolithus tenuis* (STRADNER, 1961) HAY & MOHLER in HAY et al., 1967
*Ellipsollithus bollii* PERCH-NIELSEN, 1977
*Ellipsolithus macellus* (BRAMLETTE & SULLIVAN, 1961) SULLIVAN, 1964
*Ericsonia robusta* (BRAMLETTE & SULLIVAN, 1961) PERCH-NIELSEN (1985)
*Ericsonia subpertusa* HAY & MOHLER, 1967
*Hornibrookina edwardsii* PERCH-NIELSEN, 1977
*Lanternithus duocavus* LOCKER, 1967
*Markalius astroporus* (STRADNER, 1963) HAY & MOHLER in HAY et al., 1967
*Neochiastozygus* cf. *N. eosaepes* PERCH-NIELSEN, 1981
*Neochiastozygus modestus* PERCH-NIELSEN, 1971
*Neochiastozygus* cf. *N. perfectus* PERCH-NIELSEN, 1981
*Neochiastozygus saepes* PERCH-NIELSEN, 1971
*Prinsius martinii* (PERCH-NIELSEN, 1969) HAQ, 1971
*Sullivania danica* (BROTZEN, 1959) VAROL, 1992
*Thoracosphaera crassa* van HECK & PRINS, 1987
*Toweius pertusus* (SULLIVAN, 1965) ROMEIN, 1979
*Toweius selandianus* PERCH-NIELSEN, 1979






## Plate 1

Fig. 1: Outcrop of Inoceramus-Marl at railway-km 21, W of Grünbach railway station. Sample point No. GRÜ7. Weathered marls with some sandstone intercalations.

Fig. 2: Outcrop of Inoceramus-Marl between railway-kms 23.4 and 23.5, i.e. between Grünbacher Sattel and Grünbach Kohlenwerk rail-way station. Sample point No. GRÜ3 exposes weathered marls. The sample was taken right hand from the sign-point "5".

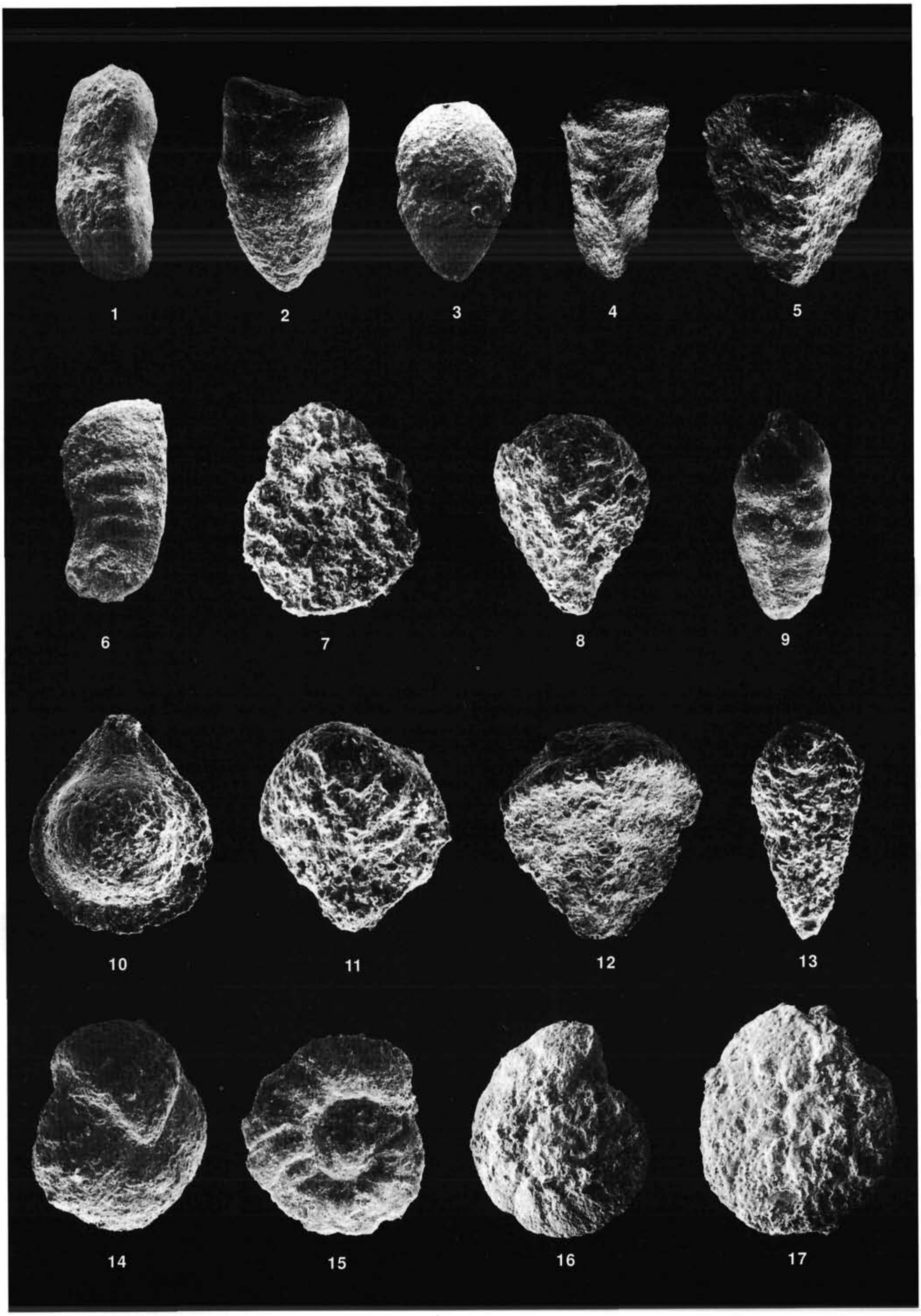
Fig. 3: Outcrop of Zweiersdorf-Formation, located approximately 200 m ESE Gasthof Mohr. Sample point No. ZW1 shows a tectonically disturbed flysch-like sequence of marls and sandstones. Our sample point No. ZW1 most probably is equivalent to sample point Z7 by PLÖCHINGER et al. (1961).

Fig. 4: *Gastropod creeping trail Subphyllochorda*, typical trace fossil of Zweiersdorf-Formation (sandy micaceous marls). Width of trail 25 mm.

Fig. 5: Basal breccia ("Kreuzgraben-Formation"), along railway line at Grünbacher Sattel. Red matrix did not contain any biota.

**Plate 2**

Fig. 1: *Tritaxia tricarinata* (REUSS); Grünbach, sample GRÜ 8, x 60
Fig. 2: *Marssonella oxycona* (REUSS); Grünbach, sample GRÜ 1, x 60
Fig. 3: *Dorothia bulleta* (CARSEY); Grünbach, sample GRÜ 8, x 40
Fig. 4: *Gaudryina carinata* FRANKE; Grünbach, sample GRÜ 1, x 27
Fig. 5: *Gaudryina pyramidata* CUSHMAN; Grünbach, sample GRÜ 1, x 60
Fig. 6: *Vaginulina trilobata* (D'ORBIGNY); Grünbach, sample GRÜ 1, x 40
Fig. 7: *Stensioeina exsculpta* (REUSS); Maiersdorf, sample MAI 1, x 110
Fig. 8: *Bolivinoides peterssoni* BROTZEN; Grünbach, sample GRÜ 7, x 100
Fig. 9: *Bolivina incrassata* REUSS; Grünbach, sample GRÜ 1, x 30
Fig. 10: *Fissurina alata* REUSS; Grünbach, sample GRÜ 6, x 80
Fig. 11: *Bolivinoides draco* (MARSSON); Dörfles, sample DÖ 1, x 110
Fig. 12: *Spiroplectammina dentata* (ALTH); Maiersdorf, sample MAI 1, x 80
Fig. 13: *Bolivinoides decoratus* (JONES); Grünbach, sample GRÜ 6, x 140
Fig. 14: *Pullenia cretacea* CUSHMAN; Grünbach, GRÜ 6, x 80
Fig. 15: *Gavelinella monterelensis* (MARIE); Maiersdorf, sample MAI 1, x 43
Fig. 16: *Gavelinella clementiana convexa* EDWARDS; Grünbach, sample GRÜ 5, x 44
Fig. 17: *Gavelinella clementiana laevigata* (MARIE); Grünbach, sample GRÜ 6, x 80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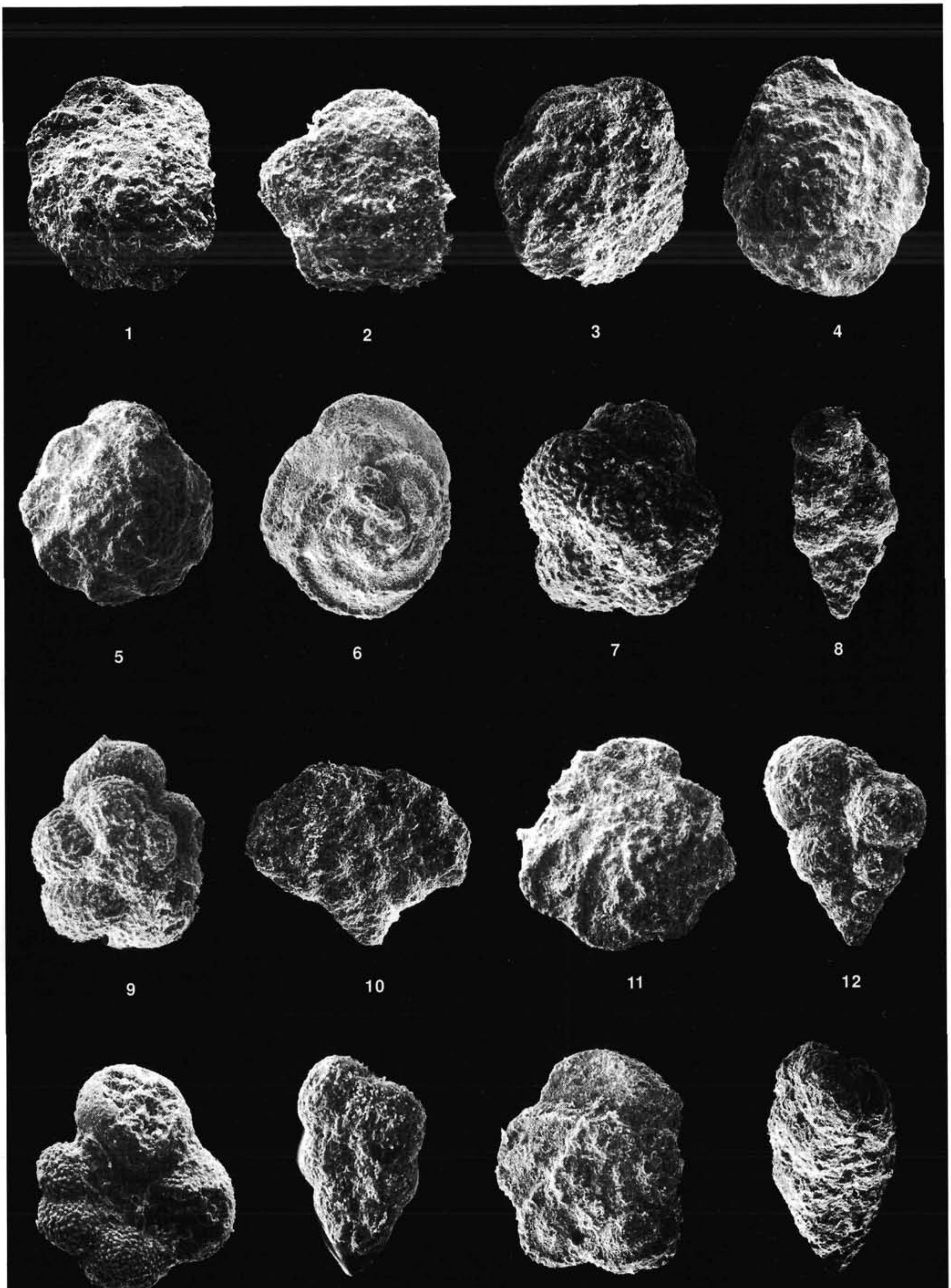
## Plate 3

Fig. 1: *Globotruncana falsostuarti* SIGAL; Grünbach, sample GRÜ 7, x 70
Fig. 2: *Globotruncana linneiana* (D'ORBIGNY); Grünbach, sample GRÜ 6, x 130
Fig. 3: *Globotruncana ventricosa* (WHITE); Grünbach, sample GRÜ 2, x 70
Fig. 4: *Rosita contusa* (CUSHMAN); Grünbach, sample GRÜ 8, x 60
Fig. 5: *Globotruncanita stuarti* (LAPPARENT); Grünbach, sample GRÜ 2, x 50
Fig. 6: *Rosita fornicata* (PLUMMER); Grünbach, sample GRÜ 6, x 90
Fig. 7: *Rugoglobigerina rugosa* (PLUMMER); Grünbach, sample GRÜ 6, x 100
Fig. 8: *Heterohelix navarroensis* LOEBLICH; Grünbach, sample GRÜ 6, x 110
Fig. 9: *Rugoglobigerina hexacamerata* BRÖNNIMANN; Grünbach, sample GRÜ 6, x 100
Fig. 10: *Ventilabrella multicamerata* KLASZ; Grünbach, sample GRÜ 1, x 60
Fig. 11: *Globotruncanita stuartiformis* (DALBIEZ); Grünbach, sample GRÜ 6, x 50
Fig. 12: *Heterohelix globulosa* (EHRENBERG); Grünbach, sample GRÜ 6, x 120
Fig. 13: *Rugoglobigerina rugosa* (PLUMMER); Grünbach, sample GRÜ 6, x 120
Fig. 14: *Pseudotextularia elegans* (RZEHAK); Grünbach, sample GRÜ 6,x 100
Fig. 15: *Globotruncana arca* (CUSHMAN); Grünbach, sample GRÜ 6, x 90
Fig: 16: *Pseudotextularia elegans* (RZEHAK); Grünbach, sample GRÜ 6, x 90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## Plate 4

Figs. 1-2: *Amphizygus brooksii* BUKRY; Grünbach, sample GRÜ 1
Figs. 3-4: *Ahmuellerella regularis* (GÓRKA) REINHARDT & GÓRKA; Zweiersdorf, sample ZW 9
Fig. 5: *Ahmuellerella octoradiata* (GÓRKA) REINHARDT; Grünbach, sample GRÜ 1
Fig. 6: *Calculites obscurus* (DEFLANDRE) PRINS & SISSINGH; Grünbach, sample GRÜ 5
Figs. 7-10: *Biscutum ellipticum* (GÓRKA) GRÜN; 7, 8 – Zweiersdorf, sample ZW 9; 9, 10 – Zweiersdorf, sample ZW 6
Figs. 11-12: *Biscutum dissimilis* WIND & WISE; Zweiersdorf, sample ZW 9
Figs. 13-14: *Biscutum melaniae* (GÓRKA) BURNETT; Zweiersdorf, sample ZW 6
Figs. 15-16: *Placozygus fibuliformis* (Reinhardt) Hoffmann; Zweiersdorf, sample ZW 9
Fig. 17: *Zeugrhabdotus praesigmoides* BURNETT; Maiersdorf, sample MAI 1
Fig. 18: *Zeugrhabdotus embergeri* (NOËL,) PERCH-NIELSEN; Maiersdorf, sample MAI 1
Figs. 19-20: *Eiffellithus eximius* (STOVER) PERCH-NIELSEN; Maiersdorf, sample MAI 1
Figs. 21-24: *Eiffellithus gorkae* REINHARDT; Zweiersdorf, sample ZW 9
Figs. 25-26: *Prediscosphaera stoveri* (PERCH-NIELSEN) SHAFIK & STRADNER; Grünbach, sample GRÜ 1
Figs. 27-28: *Staurolithites mielnicensis* (GÓRKA) PERCH-NIELSEN; Zweiersdorf, sample ZW 9
Figs. 29-30: *Staurolithites* cf. *crux* (DEFLANDRE & FERT) CARATINI; Maiersdorf, sample MAI 1
Figs. 31-32: *Lapideacassis* cf. *L. bispinosa* (PERCH-NIELSEN) BURNETT; Grünbach, sample GRÜ 1
Figs. 33-34: *Cribrosphaerella ehrenbergii* (ARKHANGELSKY) DEFLANDRE; Grünbach, sample GRÜ 1
Figs. 35-36: *Psyktosphaera firthii* POSPICHAL & WISE, Zweiersdorf, sample ZW 6
Figs. 37-38: *Reinhardtites levis* PRINS & SISSINGH; Grünbach, sample GRÜ 2
Figs. 39-40: *Arkhangelskiella cymbiformis* VEKSHINA; Zweiersdorf, sample ZW 6
Figs. 41-42: *Broinsonia parca constricta* HATTNER et al.; Maiersdorf, sample MAI 1

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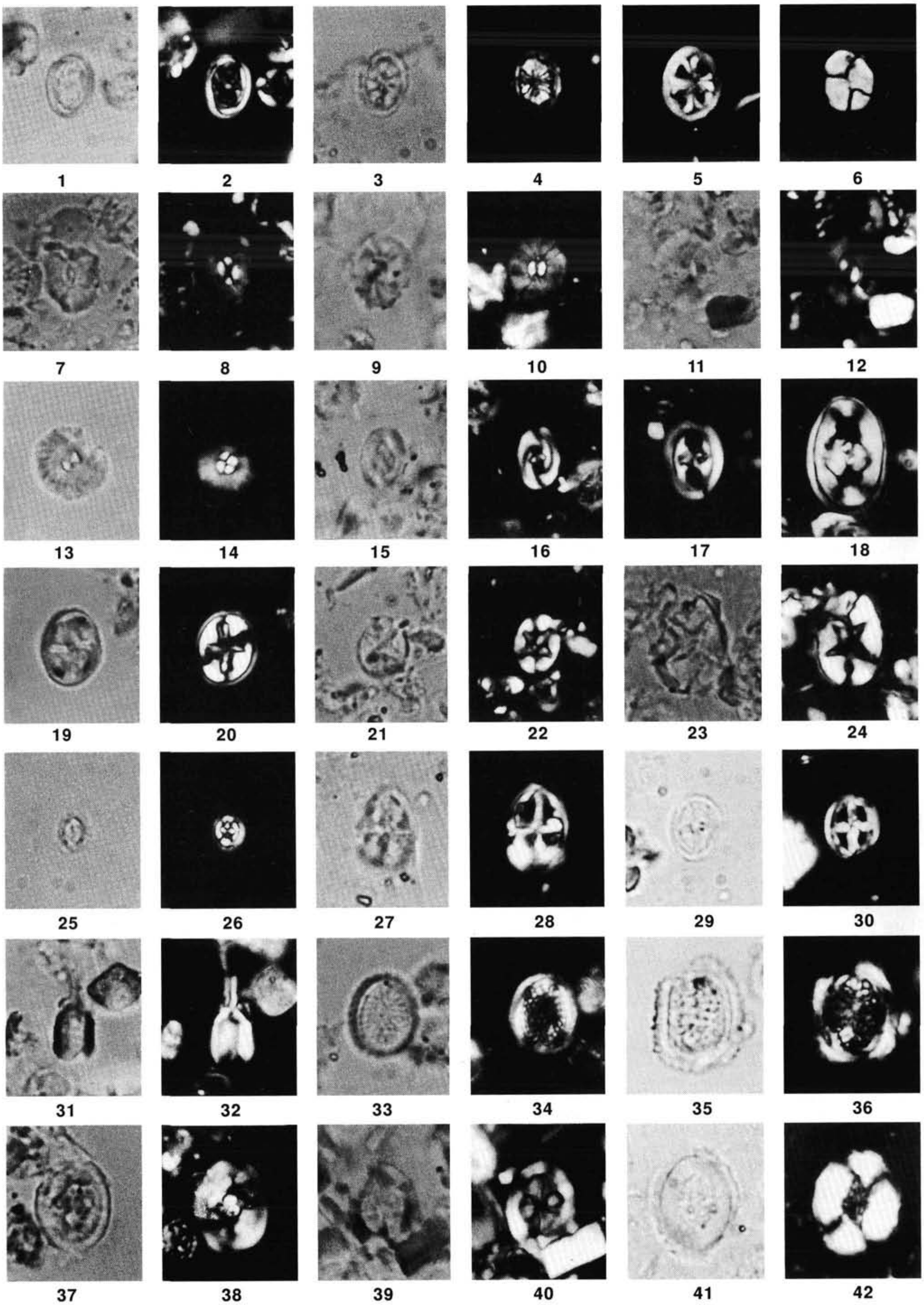
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## Plate 5

Fig. 1: *Petrarhabdus copulatus* (DEFLANDRE) WIND & WISE; Grünbach, sample GRÜ 1
Figs. 2, 3: *Ceratolithoides amplector* BURNETT; Zweiersdorf, sample ZW 7
Figs. 4, 5: *Ceratolithoides sesquipedalis* BURNETT; Zweiersdorf, sample ZW 9
Fig. 6: *Ceratolithoides aculeus* (STRADNER) PRINS & SISSINGH; Grünbach, sample GRÜ 2
Figs. 7-8: *Watznaueria barnesae* (BLACK) PERCH-NIELSEN; Zweiersdorf, sample ZW 9
Figs. 9-12: *Lithraphidites praequadratus* ROTH; Zweiersdorf, sample ZW 9
Figs. 13-14: *Cyclagelosphaera reinhardtii* (PERCH-NIELSEN) ROMEIN; Zweiersdorf, sample ZW 9
Figs. 15-16: *Micula staurophora* (GARDET) STRADNER; Zweiersdorf, sample ZW 6
Figs. 17-18: ?*Quadrum* sp., ?*Micula* sp., Zweiersdorf, sample ZW 6
Figs. 19-20: *Cyclagelosphaera argoensis* BOWN; Zweiersdorf, sample ZW 6
Figs. 21-24: *Zeugrhabdotus sigmoides* (BRAMLETTE & SULLIVAN) BOWN & YOUNG; Zweiersdorf, sample ZW 1
Figs. 25-26: *Markalius apertus* PERCH-NIELSEN; Zweiersdorf, sample ZW 2
Figs. 27-30: *Markalius astroporus* (STRADNER) HAY & MOHLER; Zweiersdorf, sample ZW 2
Figs. 31-32: *Biscutum harrisonii* VAROL; Zweiersdorf, sample ZW 2
Figs. 33-34: *Toweius selandianus* PERCH-NIELSEN; Zweiersdorf, sample ZW 2
Figs. 35-36: *Prinsius martinii* (PERCH-NIELSEN) HAQ; Zweiersdorf, sample ZW 1
Figs. 37-38: *Zeugrhabdotus* sp.; Zweiersdorf, sample ZW 2
Figs. 39-41: *Thoracosphaera crassa* HECK & PRINS; Zweiersdorf, sample ZW 2
Fig. 42: *Thoracosphaera* sp.; Zweiersdorf, sample ZW 2

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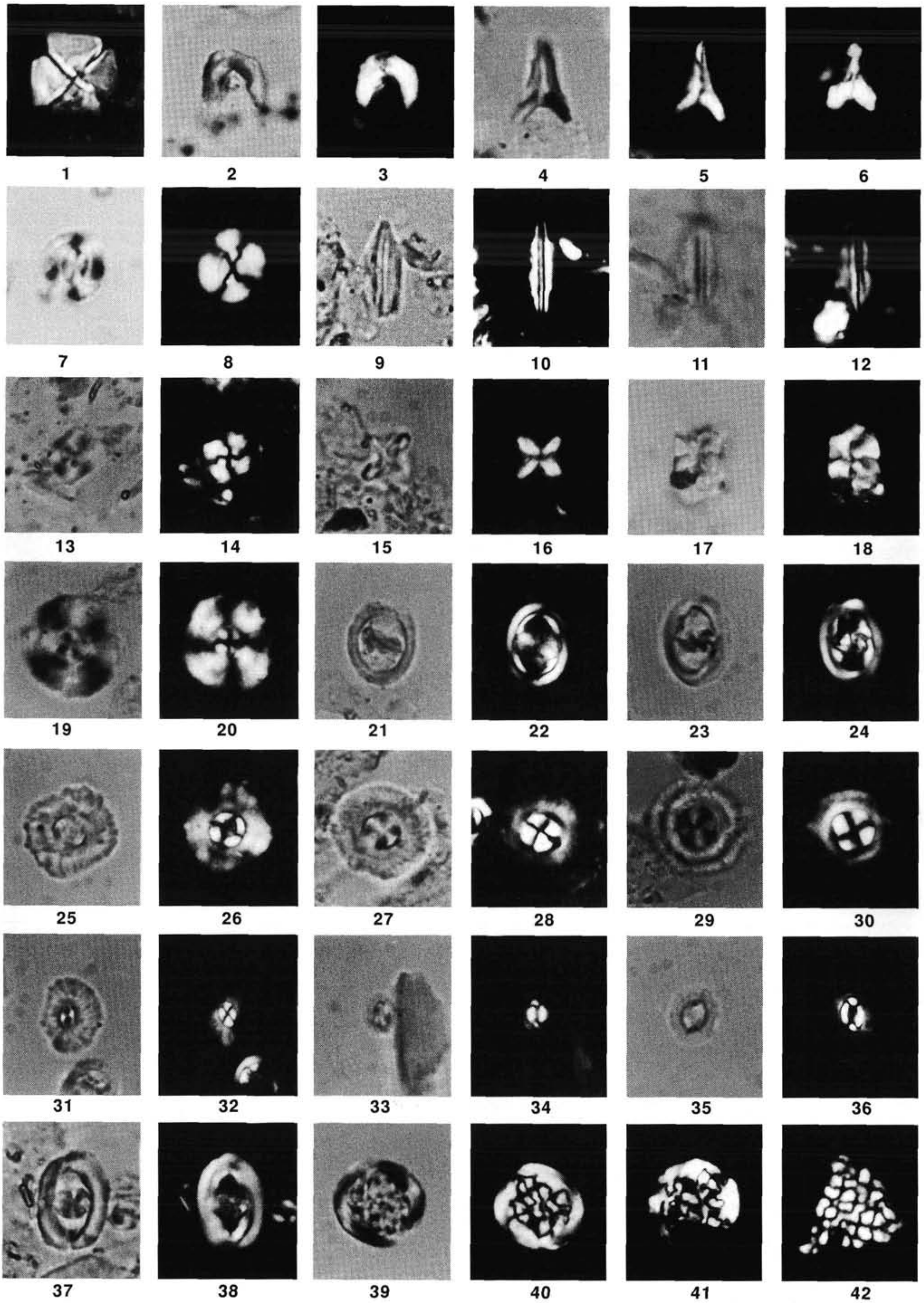
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## Plate 6

Figs. 1-2: *Coccolithus pelagicus* (WALLICH) SCHILLER; Zweiersdorf, sample ZW 2
Figs. 3-4: Placolith; Zweiersdorf, sample ZW 2
Figs. 5-6: *Ericsonia cava* (HAY & MOHLER) PERCH-NIELSEN, Zweiersdorf, sample ZW 2
Figs. 7-8: *Ericsonia subpertusa* HAY & MOHLER; Zweiersdorf, sample ZW 2
Figs. 9-10: *Ericsonia robusta* (BRAMLETTE & SULLIVAN) PERCH-NIELSEN; Zweiersdorf, sample ZW 2
Figs. 11-12: *Braarudosphaera* cf. *B. africana* STRADNER; Zweiersdorf, sample ZW 2 (?reworked species from the Albian-Cenomanian interval or autochthonous component of Danian association).
Figs. 13-14: *Neochiastozygus saepes* PERCH-NIELSEN; Zweiersdorf, sample ZW 2
Figs. 15-18: *Neochiastozygus modestus* PERCH-NIELSEN; Zweiersdorf; Figs. 15, 16: sample ZW 2; Figs. 17, 18: sample ZW 1
Figs. 19-20: *Ellipsolithus bollii* PERCH-NIELSEN; Zweiersdorf, sample ZW 2
Figs. 21-22: *Ellipsolithus* cf. *bollii* PERCH-NIELSEN; Zweiersdorf, sample ZW 2
Figs. 23-24: *Ellipsolithus* sp. 1; Zweiersdorf, sample ZW 2
Figs. 25-26: *Cruciplacolithus subrotundus* PERCH-NIELSEN; Zweiersdorf, sample ZW 2
Figs. 27-28: *Cruciplacolithus latipons* ROMEIN, Zweiersdorf, sample ZW 1
Figs. 29-30: *Cruciplacolithus primus* PERCH-NIELSEN; Zweiersdorf, sample ZW 2
Figs. 31-32: *Cruciplacolithus intermedius* van HECK & PRINS; Zweiersdorf, sample ZW 2
Figs. 33-34, 37-42: *Cruciplacolithus tenuis* (STRADNER) HAY & MOHLER; Zweiersdorf; Figs. 33, 34, 41, 42: sample ZW 2; Figs. 37-40: sample ZW 1
Figs. 35-36: *Cruciplacolithus asymmetricus* HECK & PRINS; Zweiersdorf, sample ZW2

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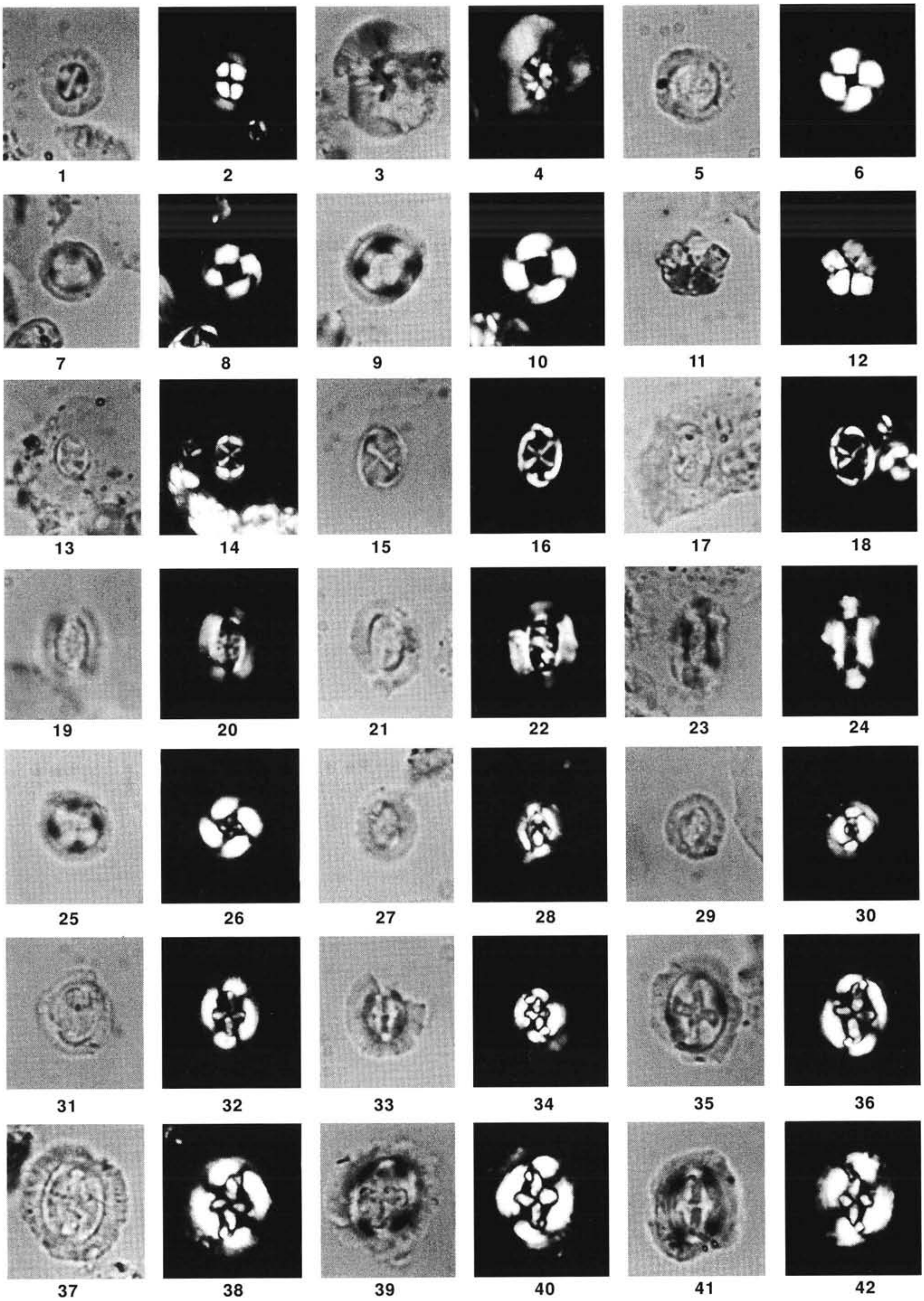
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## Plate 7

Fig. 1: *Oculopollis* sp., Grünbach, sample GRÜ 4, 95 /1
Fig. 2: *Oculopollis* sp., Grünbach, sample GRÜ 6, 960/2
Fig. 3: *Pseudopapillopollis praesubhercynicus* Góczán, Grünbach, sample GRÜ 3, 957/3
Fig. 4: *Corollina torosus* (Malj.), Zweiersdorf, sample ZW 2, redeposition
Fig. 5: *Suemegipollis* cf. germanicus Krutzsch, Grünbach, sample GRÜ 3, 957/2
Fig. 6: *Suemegipollis* sp., Grünbach, sample GRÜ 3, 957/1
Fig. 7: *Suemegipollis germanicus* Krutzsch, Grünbach, sample GRÜ 4, 958/1
Fig. 8: *Plicapollis pseudoexcelsus* Greifeld, Grünbach, sample GRÜ 3, 957/1
Fig. 9: *Pseudoplicapollis peneserta* Pflug, Grünbach, sample GRÜ 3, 957/2
Fig. 10: *Micrhystridium* sp., Grünbach, sample GRÜ 3, 957/1
Fig. 11: *Trudopollis minimus* Góczán, Maiersdorf, sample MAI 1, 954/2
Fig. 12: *Trudopollis minimus* Góczán, Maiersdorf, sample MAI 1, 954/1
Fig. 13: *Vacuopollis* cf. *minor,* Pacltová & Krutzsch, Maiersdorf, sample MAI 1, 954/1
Fig. 14: *Vacuopollis* cf. *minor* Pacltová & Krutzsch, Maiersdorf, sample MAI 1, 954/2
Fig. 15: aff. *Converrucosisporites* sp., Grünbach, sample GRÜ 3, 957/3
Fig. 16: aff. *Dictyophyllidites* sp., Grünbach, sample GRÜ 4, 958/2
Fig. 17: *Pyxidinopsis bakonyensis* (Góczán) Stover & Evitt, Maiersdorf, sample MAI 1, 954/2
Fig. 18: *Appendicisporites* sp., Maiersdorf, sample MAI 1, 954/2
Fig. 19: Scolecodonts of worms of the Annelida-Polychaeta group, Grünbach, sample GRÜ 3, 957/1
Fig. 20: aff. *Dinogymnium* sp., Maiersdorf, sample MAI 1, 954/3
Fig. 21: *Dinogymnium* sp., Grünbach, sample GRÜ 3, 957/1

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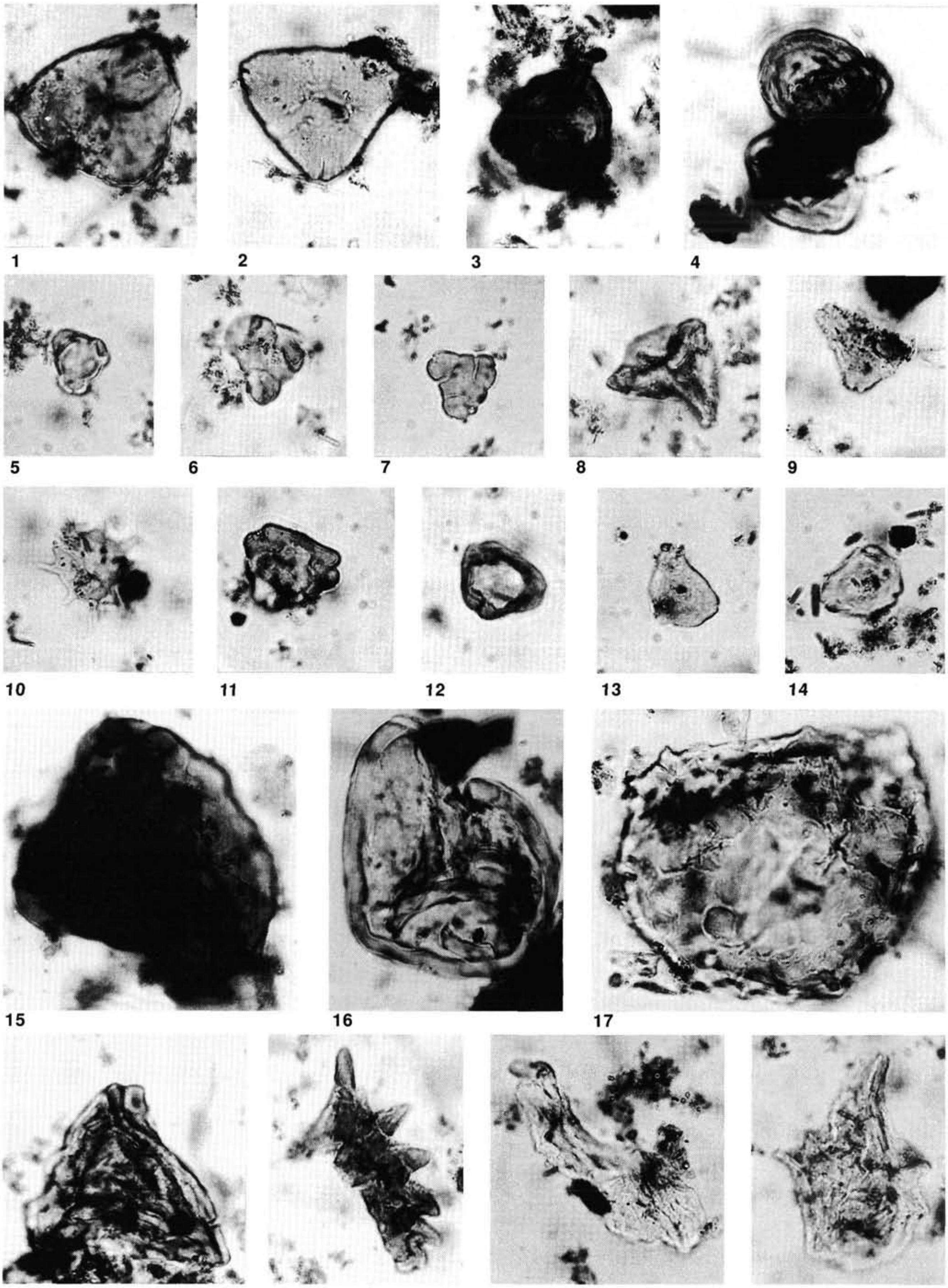

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