Zitteliana	20	Hagn/Herm-Festschrift	67–77	München, 31. 12. 1993	ISSN 0373-9627

Nannofossil biostratigraphy of the Late Cretaceous Nierental Formation, Northern Calcareous Alps (Bavaria, Austria)

By

MICHAEL WAGREICH & HANS-GEORG KRENMAYR*)

With 6 Text-figures and 1 Plate

KURZFASSUNG

Die biostratigraphische Gliederung des Campan-Maastrichts der Nierentaler Schichten (Gosau-Gruppe, Nördliche Kalkalpen) wurde mit Hilfe von Nannofossilien an den Lokalitäten Lattengebirge bei Bad Reichenhall, Gosau (Oberösterreich) und Gams (Steiermark) untersucht. Trotz Wiederaufarbeitungen älterer Nannofloren in turbiditischen Mergeln, konnte die Nannofossil-Standardzonierung der tethyalen Oberkreide angewendet werden. Die Basis des Maastrichts im Sinne der tethyalen Planktonforaminiferengliederung, definiert mit dem Aussterben von *Globotruncanita calcarata*, liegt sowohl im Profil von Gams als auch in Gosau innerhalb der Nannofossilzone CC22ab, unterhalb des letzten Auftretens der Nannofossilien *Eiffellithus eximius* und *Reinhardtites anthophorus*.

ABSTRACT

The nannofossil biostratigraphy of the Campanian-Maastrichtian of the Nierental Fm. (Gosau Group, Northern Calcareous Alps) is investigated within the localities Lattengebirge/Bavaria, Gosau/Upper Austria, and Gams/Styria. Although reworking of older sediments is partly observed, especially within turbiditic marlstones, standard nannofossil zonations for the Late Cretaceous of the low-latitude Tethyan realm can be applied. The base of the Maastrichtian, drawn at the level of the last occurrence of the planktonic foraminifera *Globotruncanita calcarata*, corresponds to a horizon within the nannofossil zone CC22ab, below the last occurrence of *Eiffellithus eximius* and *Reinhardtites anthophorus*, both in the Gosau and the Gams sections.

1. INTRODUCTION

The term „Nierentaler Schichten" has been commonly used as a lithostratigraphic term for varicoloured, deep-water marly limestones and marls of the Late Cretaceous and Early Tertiary Gosau Group of the Northern Calcareous Alps (NCA) (e. g. HAGN 1955, 1957; HERM 1962a, b; OBERHAUSER 1963; FAUPL et al. 1987). The biostratigraphy of this upper part of the Gosau basins fillings of the NCA has been investigated in detail with planktonic and, to a lesser degree, benthonic foraminifera (e. g. WICHER 1956; GANSS & KNIPSCHEER 1954, 1956; HAGN 1955, 1957, 1981; KUPPER 1956; HERM 1962a, b; OBERHAUSER 1963; KOLLMANN 1964; WILLE-JANOSCHEK 1966; BUTT 1981). The results of these microfossil studies indicated a considerable diachronism of the base and the top of the plankton-rich marls and marly limestones referred to as „Nierentaler Schichten"

*) Univ. Ass. Dr. MICHAEL WAGREICH, Institut für Geologie, Universität Wien, Universitätsstraße 7, A-1010 Wien; Dr. HANS-GEORG KRENMAYR, Geologische Bundesanstalt, Rasumovskygasse 23, A-1031 Wien.

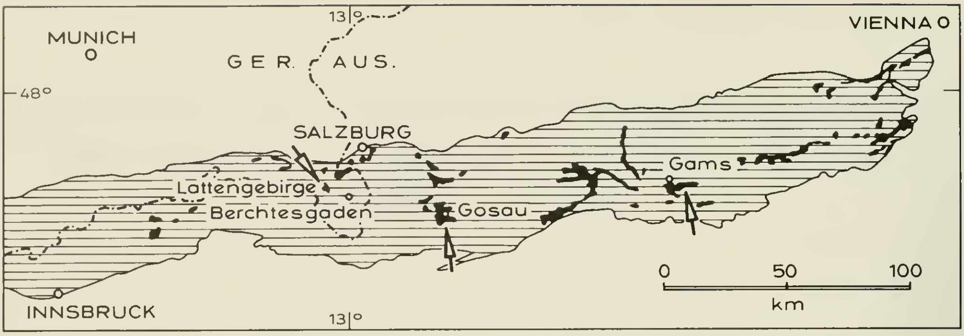


Fig. 1: Sketch map of the Northern Calcareous Alps of Austria and Bavaria together with the 3 localities mentioned in the text.

between major localities. This diachronism resulted in the usage of the broader term „Nierental facies" for red and grey marls and marly limestones of the Upper Gosau Complex according to Herm (1962a) and Oberhauser (1963).

A recent detailed sedimentological analysis by Krenmayr (in prep.) based on earlier facies analysis work by Butt (1981) and paleogeographical reconstructions by Faupl et al. (1987) helped towards a better definition and understanding of the lithofacies of the „Nierental Formation" as a formal lithostratigraphic subunit of the Gosau Group of the NCA. In accordance with most of the previous authors (e. g. Herm 1962b) we suggest to use the lithostratigraphic term Nierental Fm. only for sediments of the Late Cretaceous and Early Tertiary filling of the Gosau basins of the NCA. The lithofacial characteristics, such as the significance of red coloured pelites and distinctive pelitic intervals interpreted as hemipelagites between turbiditic sandstones and marls, are described in detail in Krenmayr (in prep.) and Krenmayr et al. (in prep.). In general, the facies of the Nierental Fm. is interpreted as a series of marl-rich turbidites of various thicknesses, interstratified with hemipelagites of high carbonate contents, deposited in a slope environment. Depositional depths of the upper to lower bathyal are interpreted from the foraminiferal assemblages of the hemipelagites (e. g. Butt & Herm 1978; Butt 1981).

This paper deals with the biostratigraphy of the Nierental Formation based on calcareous nannofossils, which are correlated with the existing zonations of planktonic foraminifera. Nannofossil investigations were performed on smear slides and slightly concentrated samples under the light microscope. Three major localities of the Gosau Group of the NCA were investigated (fig. 1): the Lattengebirge area; the type area of the Gosau Group, the Gosau Valley; and the Gams area north of Hieflau/Styria.

ACKNOWLEDGEMENTS

The authors acknowledge the financial support of the Austrian Science Foundation, Project P7462 under the guidance of Prof. P. Faupl (University of Vienna), and a grant from the Austrian Academy of Science to M. Wagreich as a contribution to IGCP Project 262 (Tethyan Cretaceous Correlations). We thank M. Jarnik for improving the English.

2. SAMPLING STRATEGY IN TURBIDITE-HEMIPELAGITE COUPLETS

Deep-water turbidites interbedded with calcareous hemipelagites are a common feature of the Nierental Fm. of the NCA (Butt 1981). The sediment-gravity flow deposits of the Nierental Fm. have a great facies variability, ranging from coarse grained debris flow/grain flow deposits and classical turbidites with complete or incomplete Bouma sequences to silt-mud-turbidites. The thicknesses of the pelitic Bouma-Te-divisions also show a great variability from marlstones only a few centimeters thin in the Lattengebirge section (Butt 1981) or parts of the Gams-Kohlhuber section, to abnormal thick pelitic intervals of a few meters above relatively thin turbidites, e. g. in the lower part of the Rote Wand section in the Gosau Valley area (Krenmayr, in prep.). The carbonate content of these turbiditic pelites, generally ranging between 22 and 65%, decreases slightly from the base to the top, which is a mirror of the grain size grading and increasing clay content of the turbidite Te-division.

The hemipelagic intervals of the investigated sections have higher carbonate contents (55 to 85%) than the Te-intervals, resulting in a significant higher resistivity against weathering of the hemipelagic marly limestones. Hemipelagic intervals have thicknesses of 2 cm to more than 50 cm in the Lattengebirge section, 2 to more than 60 cm in the Gosau sections and 5 to 30 cm in the Gams sections. Light grey, brownish and red colours are typical for the hemipelagites.

Nannofossil sampling of sections with turbidites interbedded with carbonate-rich hemipelagites is faced with a twofold dilemma. On the one hand sampling of turbiditic marls should be avoided because of the great probability of erosion and mixing with reworked, older nannofossil assemblages. On the other hand the carbonate content of the turbiditic marls is more suitable for the preservation of the nannofossils than the hemipelagic layers - carbonate contents of about 40 to 50% supply the best preservation conditions in the studied samples, limiting both dissolution and diagenetic overgrowths of nannofossils.

The effect of reworking in nannofossil samples of turbiditic marl layers can be classified broadly according to the scale and age of eroded sediments: (1) Erosion of significant older (> 1-2 nannofossil zones), mainly lithified strata in the hinterland of the turbidite basin, resulting in a mixing of nannofossils of different ages, and (2) subaquaeous erosion and incorporation of shelf or slope pelites by individual turbidite flows, leading to the mixing of slightly older (< 1-2 zone) nannofossils with an autochthonous assemblage.

Within the studied sections of the Late Cretaceous, type 1 reworking is clearly a secondary phenomena, although extensive reworking of Late Cretaceous sediments is known from overlying Paleocene turbidites of the Gams basin (e. g. KOLLMANN 1964; LAHODYNSKY 1988). Typical nannofossils of the lower part of the Gosau sequences (Coniacian-Santonian) are missing almost completely in assemblages of turbiditic marls of the Nierental Fm. of the three investigated sections, although erosion of these sediments has been proven by the occurrence of some blocks of older sediments within debris flows and slump masses in the lower part of the Nierental Fm. in the Gams basin (e. g. KRISTAN-TOLLMANN & TOLLMANN 1976). The scarcity of significant erosion of older sediments during the Campanian-Maastrichtian compared with Paleocene sediments is probably not only a consequence of the local paleogeographic situation of flooding and subsidence of the NCA (FAUPL et al. 1987; WAGREICH 1991), but may also be related to a global sea level highstand during this time (e. g. HAQ et al. 1987), resulting in worldwide general decrease of the erosional gradient and trapping of the eroded sediments on wide shelf areas.

Erosion of type 2 may be ubiquitous within turbiditic deep-water sections resulting in imprecise dating of zonal boundaries and nannofossil events, especially those which rely on the last occurrence of a marker species. Sometimes reworking of slightly older assemblages is indicated by a sudden decrease in abundances and the exclusive appearence of broken specimen (e. g. samples 44 and 45 of the Lattengebirge section, comp. fig. 2). Zonal boundaries which may be strongly influenced by reworking are especially concentrated in the Latest Campanian - Early Maastrichtian, where the last occurences of marker species like *Eiffellithus eximius*, *Reinhardtites anthophorus*, *Broinsonia (Aspidolithus) parca* group, *Quadrum* group, *Tranolithus orionatus*, and *Reinhardtites levis* define the lower boundaries of the nannofossil zones CC22c to CC25a in the standard zonation of SISSINGH (1977) and PERCH-NIELSEN (1979, 1985).

Bearing in mind these effects of reworking within the turbiditic marls, hemipelagic intervals of the Nierental Fm. were preferentially sampled. Effects of reworking should be minimized in these layers although the action of bottom currents or dilute „tails" of turbidity currents during the deposition of these „hemipelagic" layers cannot be excluded (BUTT 1981). However, the high carbonate contents of these hemipelagitic intervals result in stronger diagenetic overgrowths and recrystallizations. Therefore, samples of the hemipelagic intervals sometimes show a bad preservation potential with delicate forms strongly recrystallized to the extent that they cannot be identified safely any longer. On the other hand a double sampling test of turbidite-hemipelagite couplets within small intervals of the sections did not result in a significant higher biostratigraphic resolution. Despite the preservational effects reported above, the nannofossil assemblages of turbiditic marls and hemipelagic intervals were very similar.

Another problem for sampling work arises if the bioturbation of the hemipelagic layers and the uppermost part of the turbiditic marlstone packages is very strong. This can lead to nearly complete mixing of the different sediment types, especially in the case of thinly bedded turbidite-hemipelagite couplets. Differential nannofossil sampling of hemipelagic and turbiditic layers is nearly impossible under such circumstances, as happened for example in parts of the Gams area sections.

3. NANNOFOSSIL BIOSTRATIGRAPHY

In general the preservation of the nannofossil assemblages is bad, although the diversities are rather high; nannofossil abundances were sometimes higher in hemipelagic layers because of relatively less admixture of silt and clay fragments compared with the turbiditic marls. The nannofossil zonations can be compared with the standard nannofossil zonation scheme for the Late Cretaceous of SISSINGH (1977) and PERCH-NIELSEN (1979, 1985), with some modifications at the subzone level for the Santonian-Campanian boundary interval by WAGREICH (1988, 1992) and for the Campanian-Maastrichtian boundary interval by SCHONFELD & BURNETT (1991) and BURNETT et al. (1992). This low latitude nannofossil zonation of the Late Cretaceous is correlated with the standard plankton foraminiferal zonation of the Tethyan realm (e. g. BUTT 1981; MARKS 1984; ROBASZYNSKI et al. 1984; CARON 1985).

3.1 LATTENGEBIRGE SECTION

The Lattengebirge composite section (HERM 1962; BUTT 1981; HAGN 1981; RISCH 1988) includes the Dalsenalm section at the eastern bank of the Röthelbach, the Taucherholzstubenweg section, and the Wasserfallgraben section. Due to faulting in the lower part of the Wasserfallgraben, a considerable part of the Late Campanian part of the section may be strongly reduced in thickness or even missing. The biostratigraphy of the Cretaceous part of the Lattengebirge was dealt with in detail by HERM (1962a, b, 1981), BUTT (1981), and RISCH (1988), based on planktonic foraminifera.

The section starts at the Dalsenalm locality with Santonian shelf marls, according to the foraminiferal faunas reported by BUTT (1981) and own investigations. The partly covered section of the Taucherholzstubenweg (*elevata* zone, BUTT 1981) and the Wasserfallgraben (*calcarata* to *mayaorensis* zone) make up the upper part of the composite section and show the typical lithology of the Nierental Fm. described above. In the uppermost part of the Wasserfallgraben a detailed Cretaceous-Tertiary boundary section with nannofossil and foraminiferal zonations was described by HERM et al. (1981).

Within the Lattengebirge composite section 31 samples were examined for their nannofossil content (fig. 2). Some samples were also checked for planktonic foraminifera, especially around the Santonian-Campanian and Campanian-Maastrichtian boundary.

The section of the Dalsenalm starts with grey shelf marls incorporating sandstone tempestites of the Lower Gosau Complex (FAUPL et al., 1987) lying slightly discordantly over sandy limestones of probably Early Santonian age. A Santonian age of the shelf sediments is proven by the presence of nannofossils indicative of the nannofossil zones CC16 and CC17a, together with the planktonic foraminifera *Dicarinella*

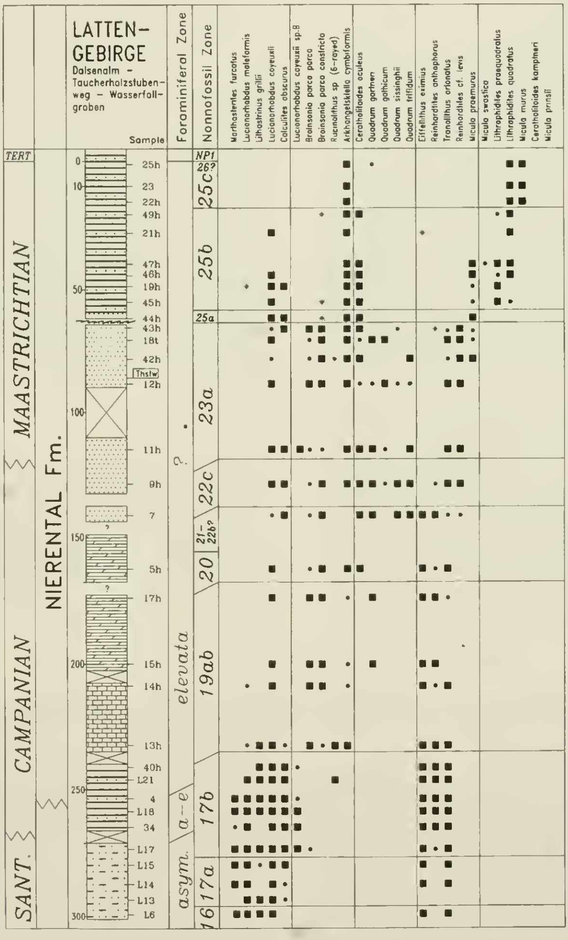


Fig. 2: Distribution of marker species in the Lattengebirge composite section. "Thstw" denotes bridge of Taucherholzstubenweg. Sample numbers and sample positions indicated on the right side of the lithologic column; Samples: h = hemipelagic pelite, t = turbiditic pelite; lithology and symbols see fig. 3.

asymetrica and *Sigalia decoratissima* (BUTT 1981). The lower boundary of the Campanian can be recognized with the help of the first occurrence (FO) of the planktonic foraminifera *Globotruncanita elevata*, still associated with *Dicarinella asymetrica*, in gray marls about 35 m above the indurated limestones. As in the section of Gosau (WAGREICH 1988, 1992) the FO of *G. elevata* is recognized within the nannofossil subzone CC17b, a few meters above the first occurrence of curved morphotypes of *Lucianorhabdus cayeuxii*. The following Campanian part of the section (Taucherholzstubenweg, base of Wasserfallgraben) is strongly covered and disturbed by faulting. No detailed investigations were made within that part, although zones CC19 to CC20 have been found. The top of the Campanian is taken at the level of the last occurrence (LO) of the planktonic foraminifera *Globotruncanita calcarata* (e. g. MARKS 1984; ROBASZYNSKY et al. 1984). This event falls within nannofossil zone CC22. Above this, a succession of nannofossil zones CC22c to CC23a was recognized up to 60 m below the top of the Maastrichtian. Here, the top of zone CC25a follows immediately above zone CC23a - zone CC24 is missing completely, probably due to normal faults running oblique to the sampled section. Above the faults the section continues up to the Cretaceous/Tertiary boundary as it was described by HERM et al. (1981). Due to the rather long sampling interval, the topmost nannofossil zones of the Maastrichtian (CC26a, b) were not found during our study.

3.2 GOSAU SECTIONS

Published nannofossil investigations in the Gosau area are concentrated on the Lower Gosau Complex up to the Early Campanian (WAGREICH 1988, 1992) and the Cretaceous-Tertiary boundary interval in the Elendgraben SW Russbach (PREISINGER et al. 1986; LAHODYNSKY 1988). KUPPER (1956) and WILLE-JANOSCHECK (1966) indicated a Campanian to Maastrichtian age for the Nierental Fm. in the Gosau area by means of planktonic foraminifera. Two sections were chosen for nannofossil sampling: the Elendgraben section southwest of Rußbach (WILLE-JANOSCHEK 1966; LAHODYNSKY 1988) and the Rote Wand section 1.5 km E of the Zwieselalm (KÜPPER 1956). Detailed nannofossil sampling in the lower part of the Elendgraben section resulted in the recognition of several major faults. Therefore, only the upper part of the Elendgraben (starting 1140 m above sea level) below the K/T-boundary site could be used for biostratigraphic zonation and is reported here. The most complete section of the Campanian *elevata*

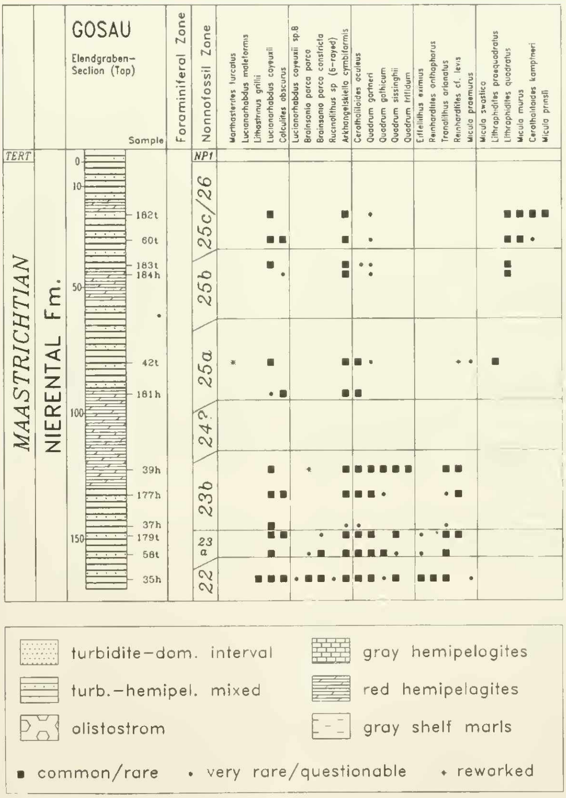


Fig. 3: Distribution of nannofossil marker species in the Nierental Fm. of the Elendgraben section of the Gosau Valley. Explanations see fig. 2.

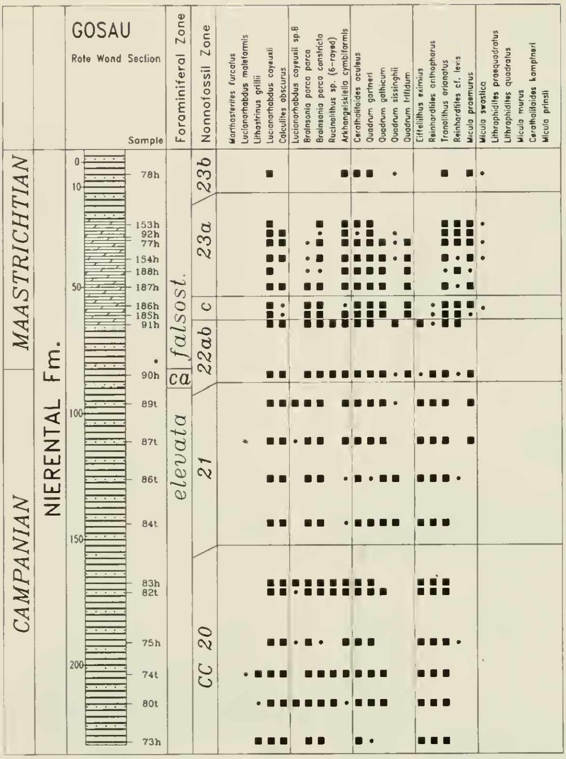


Fig. 4: Distribution of nannofossil marker species in the Rote Wand section W of the Gosau Valley. Explanations see fig. 2; lithology and symbols see fig. 3.

zone to the "middle" Maastrichtian is situated in the gorge of the Rote Wand, where KUPPER (1956) has already found the Late Campanian *calcarata* zone. The section up to the K/T boundary in the Rote Wand gorge described by LAHODYNSKY (1988) was not sampled due to faulting.

The Elendgraben section (fig. 3) starts about 170 m below the K/T-boundary within zone CC22c?, indicative of the Campanian-Maastrichtian boundary interval and the Early Maastrichtian (SCHONFELD & BURNETT 1991). However, *Eiffellithus eximius*, whose LO defines the base of CC22b, is still present in these samples, ranging well above the LO of *Reinhardtites anthophorus*. This anomalous distribution of *E. eximius* was only observed within the Elendgraben section and may be due to reworking. A distinct, about 40 m thick, red-coloured interval, dominated by hemipelagic sedimentation, is present from the top of CC23b to the base of CC25a, about 95 m below the K/T boundary.

The Rote Wand section (Fig. 4) begins with gray marls of the Early to Mid-Campanian zone CC20 and was sampled up to 230 m above the base, which is Early Maastrichtian according to markers indicative of the nannofossil zone CC23b. *G. calcarata* has been found 145 m above the base, which corresponds to the nannofossil zone CC22ab. A red hemipelagic interval, about 50 m thick, very similar to the red hemipelagites of the nearby Elendgraben section, starts in the upper part of CC22ab. The top of this distinct lithological unit, regarded as a lithostratigraphic marker horizon within the Nierental Fm., is already documented in zone CC23a in the Rote Wand section, 2 nannozones below the top of the red interval in the Elendgraben section. This points to the existence of highly diachronous (about 1-2 Ma) lithofacies boundaries within the Nierental Fm. of the Gosau area.

3.3 GAMS SECTIONS

In the Gams area the second Cretaceous-Tertiary boundary site was found within the Gosau localities of Austria (LAHODYNSKY 1988). The sections investigated during this study are situated in the west of the K/T site in northern tributaries of the Gamsbach: the Schweinbach section (gorge E of farming house "Sommerauer" of KOLLMANN 1964, KRISTAN-TOLLMANN & TOLLMANN 1976, 1991), and the Kohlhuber section (gorge and western tributaries east of farming house "Kohlhuber" of KOLLMANN (1964); W of farming house "Sattelbauer"). The Schweinbach tributary provides a continuous, although partly covered section within basal hemipelagites and following thin turbidites interbedded with hemipelagites of the Campanian *elevata* zone to the Late Maastrichtian *mayaorensis* zone of the planktonic fora-

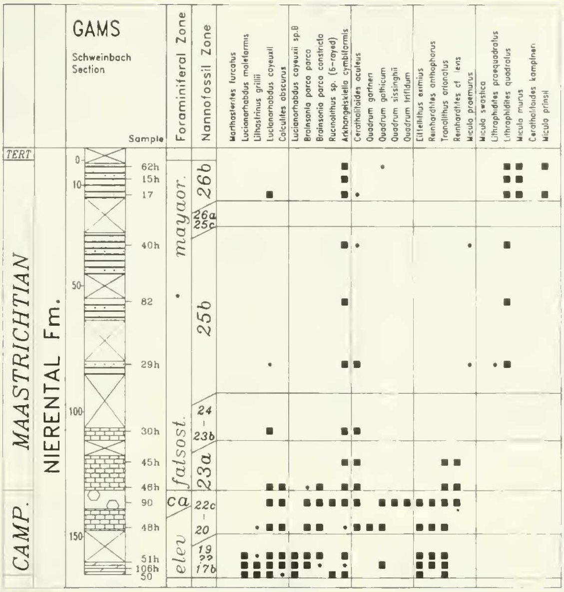


Fig. 5: Distribution of marker species in the Schweinbach section E of Gams/Styria. Explanations see fig. 2; lithology and symbols see fig. 3.

miniferal zonation of Kollmann (1964). A distinctive slumping mass with large olistolits of a Late Santonian/Early Campanian age occurs within the *calcarata* zone according to Kristan-Tollmann & Tollmann (1976). Due to the high sedimentation rates of turbidites the Kohlhuber section provides a very detailed zonation of the Early to Late Maastrichtian above the *calcarata* zone of the uppermost Campanian.

Within both sections the LO of *G. calcarata* can be recognized in the nannofossil zone CC22, characterized by the presence of both *Eiffellithus eximius* and *Reinhardtites anthophorus* together with *Quadrum trifidum* and *Reinhardtites* cf. *levis.* In the Schweinbach section a detailed subdivision of the nannofossil zone CC22 is impossible due to reworking within a slump. The extended Kohlhuber section (fig. 6) indicates a succession of LO of zonal markers in accordance to the standard zonal scheme of Sissingh (1977) and Perch-Nielsen (1979, 1985) with the exception of *Tranolithus orionatus*, which disappears below the LO of the *Broinsonia parca* group. Minor reworking of type 2 can be observed by the presence of some broken specimens of slightly older species of the former zone. Nevertheless, e. g. the lower boundary of CC24, defined by the LO of *B.* (*Aspidolithus*) *parca constricta*, could be recognized by a sudden decrease in the abundance of the marker species to the sole presence of broken specimen. The top of the „Kohlhuber" section can be dated as "middle" Maastrichtian (zone CC25a), below the FO of *Lithraphidites quadratus.* The Schweinbach section was sampled up to the topmost zone of the Maastrichtian (CC26b), defined by the presence of *Micula prinsii* together with *Micula murus.*

4. DISCUSSION

Recent investigations on the Campanian-Maastrichtian boundary indicated a strong diachronity between the definition of the base of the Maastrichtian in the Tethyan realm (LO of the planktonic foraminifera *Globotruncanita calcarata*), and the definition of the lower boundary of the Maastrichtian in the Boreal realm (FO of belemnites of the *Belemnella lanceolata* lineage). It has been shown, that the level of extinction of *G. calcarata* can be correlated with the subzone CC22c of the *Quadrum trifidum* nannofossil zone, whereas the base of the Maastrichtian according to the Boreal zonation scheme is already in the nannofossil zone CC23a (Schonfeld & Burnett, 1991). During our study we found approximately the same position of the LO of *G. calcarata* within the CC22 *Quadrum trifidum* zone, although within the two Gams sections and the Rote Wand section of the Gosau Valley, samples with *G. calcarata* are still characterized by the presence of *Eiffelithus eximius*, indicative of CC22ab below subzone CC22c. On the other hand, an influence of reworking cannot be ruled out - *E. eximius* is a very common nannofossil in the Campanian assemblages of the Gosau sections, and an anomalous range of this species with a LO well above the LO of *Reinhardtites anthophorus* can be proven in the Elendgraben section. In the Lattengebirge section, the exact position of the LO of *G. calcarata* could not be proven, probably due to faulting in this part of the section. According to BUTT (1981), *G. calcarata* has been found at the base of the turbidite-dominated part of the section, which can probably be correlated with our samples No. Lg7 or 9h. Sample Lg7 (nannofossil zone CC22b?) still contains a Late Campanian foraminiferal assemblage with *Globotruncanita subspinosa*, whereas Lg9h is already characterized by an Early Maastrichtian assemblage of Rugoglobigerinas without *G. subspinosa* and nannofossils indicative of zone CC22c.

A detailed correlation within the latest Campanian to Early Maastrichtian subzones of CC22 is also hindered by the fact that the FO of *Reinhardtites levis*, defining the base of CC22b, could not be precisely dated, due to overgrowth and recrystallisation processes in carbonate-rich samples, which make the differentiation of *R. anthophorus* and *R. levis* very difficult. Only large (> 10 µm) *Reinhardtites* with a completely closed central area were grouped into *R.* cf. *levis*. As *R. levis* evolves out of *R. anthophorus* by an increase in the size of the elements which subsequently close the central area (e. g. PRINS & SISSINGH in SISSINGH 1977), this definition is quite arbitrary and the FO of *R. levis* is not used as a reliable marker event during this study. That is why the subzones CC22a and CC22b are grouped together.

Plate 1 Nannofossil marker species of the Campanian – Maastrichtian of the Gosau Group
All figures with crossed nicols, except Fig. 1 with 80° crossed nicols

Fig. 1 *Marthasterites furcatus* (DEFLANDRE, in DEFLANDRE & FERT 1954) DEFLANDRE, 1959. Probe L18, Lattengebirge.

Fig. 2 *Lucianorhabdus maleformis* REINHARDT, 1966. Probe L18, Lattengebirge.

Fig. 3 *Lithastrinus* cf. *grillii* STRADNER, 1962. Probe EG35h, Elendgraben, Gosau.

Fig. 4 *Lucianorhabdus cayeuxii* DEFLANDRE, 1959. Probe L18, Lattengebirge.

Fig. 5 *Calculites obscurus* (DEFLANDRE, 1959) PRINS & SISSINGH, 1977. Probe GAM131 (*calcarata* horizon), "Kohlhuber" section, Gams.

Fig. 6 *Lucianorhabdus cayeuxii* DEFLANDRE, 1959 (ssp. B of WAGREICH 1988). Probe L18, Lattengebirge.

Fig. 7 *Broinsonia (Aspidolithus)* cf. *parca parca* (STRADNER, 1963) BUKRY, 1969. Probe EG35h, Elendgraben, Gosau.

Fig. 8 *Broinsonia (Aspidolithus) parca constricta* HATTNER, WIND & WISE, 1980. Probe GAM131 (*calcarata* horizon), "Kohlhuber" section, Gams.

Fig. 9 *Broinsonia (Aspidolithus) parca constricta* HATTNER, WIND & WISE, 1980. Probe EG 90h (*calcarata* horizon), Rote Wand section, Gosau.

Fig. 10 *Rucinolithus* sp. Probe EG 186h, Rote Wand section, Gosau.

Fig. 11 *Arkhangelskiella cymbiformis* VEKSHINA, 1959 (small specimen). Probe LG43h, Lattengebirge.

Fig. 12 *Arkhangelskiella cymbiformis* VEKSHINA, 1959 (large specimen). Probe GA17, Schweinbach section, Gams.

Fig. 13 *Ceratolithoides aculeus* (STRADNER, 1961) PRINS & SISSINGH, in SISSINGH 1977. Probe EG35h, Elendgraben, Gosau.

Fig. 14 *Quadrum gartneri* PRINS & PERCH-NIELSEN, in MANIVIT et al. 1977. Probe EG 186h, Rote Wand section, Gosau.

Fig. 15 Transitional form between *Qu. gartneri* and *Quadrum gothicum* (DEFLANDRE, 1959) PRINS & PERCH-NIELSEN, in MANIVIT et al. 1977. Probe EG77h, Rote Wand section, Gosau.

Fig. 16 *Quadrum sissinghii* PERCH-NIELSEN, 1986. Probe EG35h, Elendgraben, Gosau.

Fig. 17 *Quadrum trifidum* (STRADNER, in STRADNER & PAPP 1961) PRINS & PERCH-NIELSEN, in MANIVIT et al. 1977. Probe EG 90h (*calcarata* horizon), Rote Wand section, Gosau.

Fig. 18 *Eiffellithus eximius* (STOVER, 1966) PERCH-NIELSEN, 1968. Probe L6, Lattengebirge.

Fig. 19 *Reinhardtites anthophorus* (DEFLANDRE, 1959) PERCH-NIELSEN, 1968. Probe EG35h, Elendgraben, Gosau.

Fig. 20 *Reinhardtites* cf. *anthophorus* (DEFLANDRE, 1959) PERCH-NIELSEN, 1968. Probe L18, Lattengebirge.

Fig. 21 *Tranolithus orionatus* (REINHARDT, 1966) PERCH-NIELSEN, 1968. Probe EG 186h, Rote Wand section, Gosau.

Fig. 22 *Reinhardtites levis* PRINS & SISSINGH, in SISSINGH 1977. Probe EG 90h (*calcarata* horizon), Rote Wand section, Gosau.

Fig. 23 *Micula* cf. *praemurus* (BUKRY, 1973) STRADNER & STEINMETZ, 1984. Probe LG43h, Lattengebirge.

Fig. 24 *Micula swastica* STRADNER & STEINMETZ, 1984. Probe EG77h, Rote Wand section, Gosau.

Fig. 25 *Lithraphidites praequadratus* ROTH, 1978. Probe EG42t, Elendgraben, Gosau.

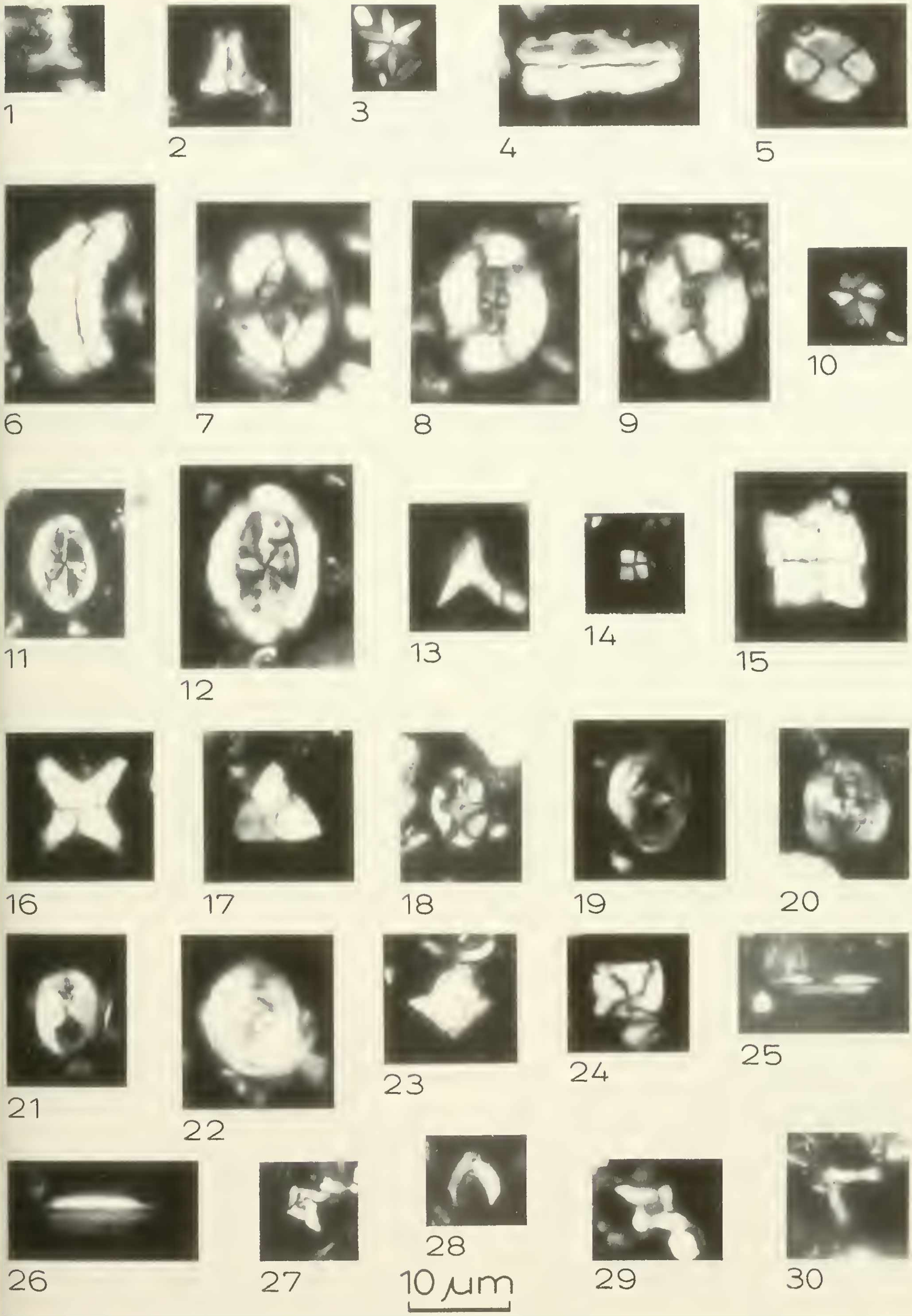
Fig. 26 *Lithraphidites quadratus* BRAMLETTE & MARTINI, 1964. Probe GA17, Schweinbach section, Gams.

Fig. 27 *Micula murus* (MARTINI, 1961) BUKRY, 1973. Probe GA17, Schweinbach section, Gams.

Fig. 28 *Ceratolithoides kamptneri* BRAMLETTE & MARTINI, 1964. Probe EG182t, Rote Wand section, Gosau.

Fig. 29 Transitional form between *M. murus* and *Micula prinsii* PERCH-NIELSEN, 1979. Probe GA17, Schweinbach section, Gams.

Fig. 30 Broken specimen of *Micula prinsii* PERCH-NIELSEN, 1979. Probe EG182t, Rote Wand section, Gosau.



WAGREICH, M. & KRENMAYR H.-G.: Nannofossils of the Nierental Formation

Tafel 1

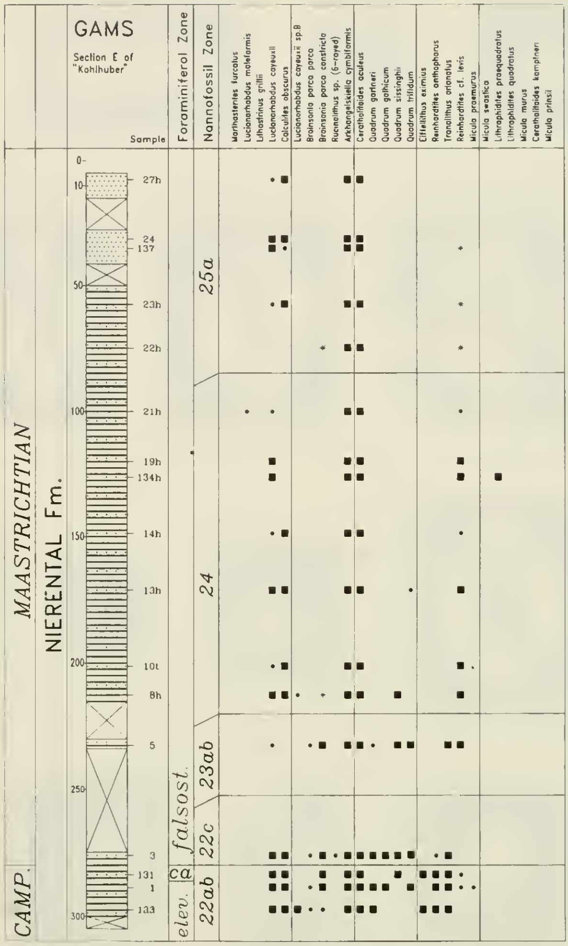


Fig. 6: Distribution of marker species in the section E of farming house "Kohlhuber", E of Gams/Styria. Explanations see fig. 2; lithology and symbols see fig. 3.

REFERENCES

BURNETT, J. A., KENNEDY, W. J. & WARD, P. D. (1992): Maastrichtian nannofossil biostratigraphy in the Biscaya region (south-western France, northern Spain). - Newsl. Stratigr., 26: 145-155, 5 figs.; Berlin, Stuttgart.

BUTT, A. (1981): Depositional environments of the Upper Cretaceous rocks in the Northern part of the Eastern Alps. - Cushman Found. Foram. Res., Spec. Publ., 20: 1-81, 33 figs., 9 tab., 20 pls.; Washington.

BUTT, A. & HERM, D. (1978): Palaeo-oceanographic aspects of the Upper Createceous geosynclinal sediments of the Eastern Alps. - In: CLOSS, H., ROEDER, D. & SCHMIDT, K. (eds.), Alps, Apennines, Hellenides; Int. Union Comm. Geodyn. Sci Rep., 38: 87-95, 2 figs.; Stuttgart.

CARON, M. (1985): Cretaceous planktic Foraminifera. - In: BOLLI, H. M., SAUNDERS, J. B. & PERCH-NIELSEN, K. (eds.), Plankton Stratigraphy, 17-86, 37 figs.; Cambridge (Cambridge Univ. Press).

FAUPL, P., POBER, E. & WAGREICH, M. (1987): Facies development of the Gosau Group of the Eastern Parts of the Northern Calcareous Alps during the Cretaceous and Paleogene. - In: FLUGEL, H. W. & FAUPL, P. (eds.), Geodynamics of the Eastern Alps, 142-155, 4 figs., 1 tab.; Wien (Deuticke).

GANSS, O. & KNIPSCHEER, H. C. G. (1954): Das Alter der Nierentaler und Zwieselalmschichten des Beckens von Gosau. - N. Jb. Geol. Paläont. Abh., 99: 361-378, 2 pls.; Stuttgart.

GANSS, O. & KNIPSCHEER, H. C. G. (1956): Nochmals: Zur Altersstellung der Nierentaler Schichten. - N. Jb. Geol. Paläont. Mh., 1956: 290-297; Stuttgart.

HAGN, H. (1955): Zur Altersfrage der Nierentaler Schichten im Bekken von Gosau. - N. Jb. Geol. Paläont. Mh., 1955: 16-30; Stuttgart.

HAGN, H. (1957): Das Profil des Beckens von Gosau (österreichische Kalkalpen) in mikropaläontologischer Sicht. - Anz. Österr. Akad. Wiss., math.-naturwiss. Kl., 1957: 31-67; Wien.

HAGN, H. (Hrsg.) (1981): Die Bayerischen Alpen und ihr Vorland in mikropaläontologischer Sicht. - Geol. Bavarica, 82: 408 pp., 70 figs., 7 tab., 13 pls.; München.

HAQ, B., HARDENBOL, J. & VAIL, P. (1987): Chronology of fluctuating sea levels since the Triassic. - Science, 235: 1156-1166; New York.

HERM, D. (1962a): Die Schichten der Oberkreide (Untere, Mittlere und Obere Gosau) im Becken von Reichenhall (Bayerische/Salzburger Alpen). - Z. dt. geol. Ges.: 113, 320-338, 4 figs.; Hannover.

HERM, D. (1962b): Stratigraphische und mikropaläontologische Untersuchungen der Oberkreide im Lattengebirge und Nierental (Gosaubecken von Reichenhall und Salzburg). - Abh. Bayer. Akad. Wiss., math.-naturwiss. Kl., N. F., 104: 1-119, 9 figs., 11 pls.; München.

HERM, D., HILLEBRANDT, A. VON & PERCH-NIELSEN, K. (1981): Die Kreide/Tertiär-Grenze im Lattengebirge (Nördliche Kalkalpen) in mikropaläontologischer Sicht. - Geol. Bavarica, 82: 319-344, 3 figs., 2 tab., 4 pls.; München.

KOLLMANN, H. A. (1964): Stratigraphie und Tektonik des Gosaubeckens von Gams (Steiermark, Österreich). - Jb. Geol. Bundesanst., 107: 71-159, 5 figs., 4 pls.; Wien.

KRISTAN-TOLLMANN, E. & TOLLMANN, A. (1976): Neue Neoflabellinen (Foraminifera) aus dem Senon der Gamser Gosau, Österreich. - Sitzber. Österr. Akad. Wiss., math.-naturwiss. Kl., Abt. I, 185: 307-321, 5 figs.; Wien.

KRISTAN-TOLLMANN, E. & TOLLMANN, A. (1991): Neoflabellinen aus der Oberkreide beidseits des Atlantiks. - Mitt. österr. geol. Ges., 82: 135-171, 5 figs., 8 pls.; Wien.

KUPPER, K. (1956): Stratigraphische Verbreitung der Foraminiferen in einem Profil aus dem Becken von Gosau. - Jb. Geol. Bundesanst., 99: 273-320, 1 tab., 2 pls.; Wien.

LAHODYNSKY, R. (1988): Lithostratigraphy and sedimentology across the Cretaceous/Tertiary boundary in the Flyschgosau (Eastern Alps, Austria). - Rev. Espanola Paleont., Extraord., 1988: 73-82, 4 figs.; Madrid.

MARKS, P. (1984): Proposal for the recognition of boundaries between Cretaceous stages by means of planktonic foraminiferal biostratigraphy. - Bull. geol. Soc. Denmark, 33: 163-169; Kopenhagen.

OBERHAUSER, R. (1963): Die Kreide im Ostalpenraum Osterreichs in mikropaläontologischer Sicht. - Jb. Geol. Bundesanst., 106: 1-88; Wien.

PERCH-NIELSEN, K. (1979): Calcareous nannofossils from the Cretaceous between the North Sea and the Mediterranean. - In: WIEDMANN, J. (Ed.), Aspekte der Kreide Europas, Int. Union Comm. Geodyn. Sci Rep., Ser. A, 6: 223-272; Stuttgart.

PERCH-NIELSEN, K. (1985): Mesozoic calcareous nannofossils. - In: BOLLI, H. M., SAUNDERS, J. B. & PERCH-NIELSEN, K. (eds.), Plankton Stratigraphy, 329-426, 92 figs.; Cambridge (Cambridge Univ. Press).

PREISINGER, A., ZOBETZ, E., GRATZ, A. J., LAHODYNSKY, R., BECKE, M., MAURITSCH, H. J., EDER, G., GRASS, F., ROGL, F., STRADNER, H. & SURENIAN, R. (1986): The Cretaceous/Tertiary boundary in the Gosau Basin, Austria. - Nature, 322: 794-799, 6 figs.; London.

RISCH, H. (1988): Zur Sedimentationsabfolge und Tektogenese der Gosaukreide im Reichenhaller Becken. - N. Jb. Geol. Paläont. Mh., 1988: 293-310, 3 figs.; Stuttgart.

ROBASZYNSKI, F., CARON, M., GONZALES DONOSO, J. M. & WONDERS, A. A. H. (eds.) (1984): Atlas of Late Cretaceous Globotruncanids. - Rev. Micropaléont., 26: 145-305, 11 figs., 54 pls.; Paris.

SCHONFELD, S. & BURNETT, J. (1991): Biostratigraphical correlation of the Campanian-Maastrichtian boundary: Lägersdorf-Hemmoor (northwestern Germany), DSDP Sites 548A, 549, and 551 (eastern North Atlantic) with paleobiogeographical and paleoceanographical implications. - Geol. Mag., 128: 479-503, 11 figs., 2 tab.; London.

SISSINGH, W. 1977. Biostratigraphy of Cretaceous calcareous nanno_plankton. - Geol. Mijnbouw, 56: 37-56; Amsterdam.

WAGREICH, M. (1988): Nannoplankton- und Foraminiferen-Feinstratigraphie des Santon-Untercampans der Gosauschichtgruppe von Gosau-Rußbach (Oberösterr.-Salzburg). - Mitt. Ges. Geol. Bergbaustud. Österr., 34/35: 279-294, 3 figs.; Wien.

WAGREICH, M. (1991): Subsidenzanalyse an kalkalpinen Oberkreideserien der Gosau-Gruppe (Österreich). - Zbl. Geol. Paläont. Teil I, 1990: 1645-1657, 2 figs.; Stuttgart.

WAGREICH, M. (1992): Correlation of Late Cretaceous nannofossil zones with ammonite zones and planktonik Foraminifera: the Austrian Gosau sections. - Cretaceous Res., 13: 505-516, 5 figs.; London.

WICHER, C. A. (1956): Die Gosau-Schichten im Becken von Gams (Österreich) und die Foraminiferengliederung der höheren Oberkreide in der Tethys. - Paläont. Z., Sh., 30: 87-136, 7 figs., 2 pls.; Stuttgart.

WILLE-JANOSCHEK, U. (1966): Stratigraphie und Tektonik der Schichten der Oberkreide und des Alttertiärs im Raume von Gosau und Abtenau (Salzburg). - Jb. geol. Bundesanst., 109: 91-172, 3 figs., 11 pls.; Wien.