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Calcareous nannofossil assemblages from Upper Cretaceous to Paleocene deep-water deposits of the Muttekopf area (Gosau Group, Northern Calcareous Alps, Austria)

HANS EGGER*

4 Text-Figures, 1 Table

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Eastern Alps
Gosau Group
Cretaceous
Paleocene
Calcareous nannoplankton

Contents

Abstract

With an erosional unconformity at the base, the Gosau Group (upper Turonian to lower Lutetian) overlies the previously formed nappe stack of the Northern Calcareous Alps. In the Muttekopf area (Tyrol), more than one kilometre thick deposits of the Gosau Group are magnificently exposed, however, micro- and nannofossils are exceedingly rare in this succession. This is probably an effect of a high grade of diagenesis. Previously measured vitrinite reflectance values range between 1.03 %R at the base of the succession and 0.59 %R at its top and suggest burial depths between 3 km and 4 km. Due to strong recrystallization of the marlstone most of the now studied smear slides were devoid of identifiable nannofossils. Nonetheless, a few better preserved samples give the first evidence for uppermost Santonian to Middle Campanian, uppermost Maastrichtian and Danian nannoplankton assemblages in the Muttekopf area.

Kalkiges Nannoplankton aus oberkretazischen bis paleozänen Tiefwasserablagerungen des Muttekopf-Gebietes (Gosau-Gruppe, Nördliche Kalkalpen, Österreich)

Zusammenfassung

Die Gosau-Gruppe (oberes Turonium bis unteres Lutetium) liegt mit einer Erosionsdiskordanz auf dem Deckenstapel der Nördlichen Kalkalpen. Die mehr als 1 km mächtigen Gosauablagerungen des Muttekopf-Gebiets (Tirol) sind hervorragend aufgeschlossen, haben aber dennoch bislang kaum Mikro- oder Nannofossilien geliefert. Die Ursache dafür liegt vermutlich in dem hohen Diagenesegrad der Ablagerungen. Zuvor gemessene Vitrinitreflexionsdaten liegen zwischen 1,03 %R an der Basis und 0,59 %R in den höchsten Anteilen der Abfolge und deuten auf eine Versenkungstiefe von 3 km bis 4 km hin. Wegen der starken Rekristallisation der Mergelproben waren in den meisten der jetzt untersuchten Nannoplanktonpräparate keine Fossilien identifizierbar. Einige besser erhaltene Proben lieferten aber für das Muttekopf-Gebiet die ersten Nachweise für Nannoplanktonvergesellschaftungen des Ober-Santoniums bis Mittel-Campaniums, des obersten Maastrichtiums und des Daniums.

* HANS EGGER: Geological Survey of Austria, Neulinggasse 38, 1030 Vienna, Austria. hans.egger@geologie.ac.at

Introduction

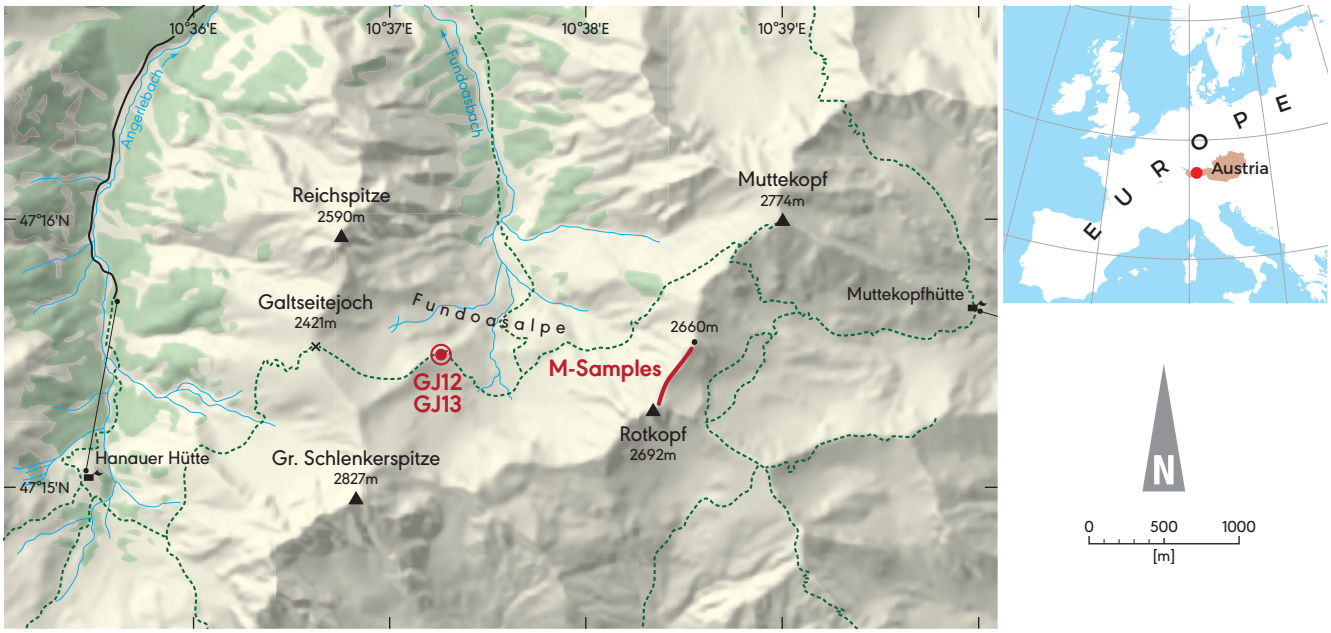
Due to sparse vegetation in altitudes above 2,000 m, the best exposed outcrops of the Gosau Group in the Northern Calcareous Alps occur in the Muttekopf area (Text-Fig. 1), which is located about 50 km to the west of the Tyrolean capital Innsbruck. However, contrary to other occurrences of this group (Turonian–Lutetian), fossils are scarce there. GÜMBEL (1861) was the first to assume a Cretaceous age of these deposits, but since he only found biostratigraphically insignificant trace fossils, this age assignment solely based on lithostratigraphic correlations. The first marker fossil was discovered by AMPFERER (1912), who reported on *Cladoceramus undulatoplicatus* (ROEMER) from the lower part of the succession in the Muttekopf area. The stratigraphic range of this inoceramid is restricted to the *C. undulatoplicatus* Zone of the uppermost Coniacian to lowermost Santonian (GRADSTEIN et al., 2012). At the same location, LEISS (1990) found the ammonite *Gaudryceras mite* (HAUER), which has a stratigraphic range from the Coniacian to the Maastrichtian (KENNEDY & SUMMESBERGER, 1979). Co-occurring planktonic foraminifera species (*Globotruncana linneiana* (D'ORBIGNY), *Globotruncana bulloides* VOGLER und *Marginotruncana pseudolinneiana* PESSAGNO) give more precise age constraints and indicate a chronostratigraphic assignment of this outcrop to the Santonian part of the *C. undulatoplicatus* Zone.

Despite extensive sampling all over the area, OBERHAUSER (1963) could find foraminifera only at the Rotkopf Mt. (Text-Figs. 1, 3), where *Orbitoides* sp. was previously described by WOPFNER (1954). Beside other planktonic species, OBERHAUSER (1963) identified *Gansserina gansseri* (BOLLI), which is a marker fossil for the upper Maastrichtian. He assumed that the succession near Rotkopf Mt. might reach into the Danian but subsequent re-sampling of the section by LAHODYNSKY (1988) did not give evidence for this. ORTNER (1990) reported on four calcareous nannoplankton species from other sites of the Muttekopf area, which were determined by Herbert Stradner (Vienna): *Watznaueria barnesae* (BLACK), *Retecapsa crenulata* (BRAMLETTE & MARTINI), *Eiffellithus turriseiffeli* (DEFLANDRE) and *Eiffellithus eximius* (STOVER). The stratigraphic range of the latter species is from the Turonian to the top of the Campanian. More precise chronostratigraphic assignments were not possible with this poor assemblage because the other recognized species have more extended ranges.

For this paper, smear slides from newly collected samples from different outcrops of the Muttekopf area were investigated for calcareous nannoplankton. Additionally, well documented samples from this area, which are stored in the collections of the Geological Survey of Austria were re-examined for the same purpose. This paper records the first evidences of Upper Santonian–Campanian, Maastrichtian and Danian calcareous nannoplankton assemblages from the Muttekopf area.

Geological setting

The Muttekopf area belongs to the 500 km long fold and thrust belt of the Northern Calcareous Alps (NCA), which are a detached part of the Adriatic Plate. In the Cretaceous, deposition occurred at the northern active continental margin of this plate, which was located at a paleolatitude of 20° to 30° N (PUEYO et al., 2007). After an episode of strong deformation and erosion in the Albian and Cenomanian, a transgression in the Turonian heralds the onset of the deposition of the mainly siliciclastic and mixed siliciclastic-carbonate strata of the Gosau Group. The formation of this new sedimentary basin is still discussed and several basin types were interpreted, e.g. compressional piggy back and synthrust basin models or extensional and pull-apart basin models (e.g. WAGREICH & DECKER, 2001).The lower part of the Gosau Group (Lower Gosau Subgroup) consists of terrestrial to shallow marine deposits. A strong pulse of subsidence in the Santonian caused the establishment of deep marine conditions in the western part of the NCA in the Middle Santonian (EGGER



Text-Fig. 1.
Position of the Muttekopf area.

Text-Fig. 2.
Sample point 750 m eastward of Galtseitejoch.

et al., 2013 and references therein). Sedimentation was terminated by the collision of the Adriatic and European continental plates in the late Lutetian, 42 million years ago (EGGER et al., 2017).

In the Muttekopf area, the base of the Gosau Group is resting on Upper Triassic lagoonal dolomite (Hauptdolomit) and consists of braided river and alluvial fan deposits. These are overlain by the above mentioned neritic silty to sandy marlstone containing inoceramids and planktonic foraminifera of the Lower Santonian. The whole succession of the Lower Gosau Subgroup is about 300 m thick and was designated as Plattein Formation by HAAS (1991).

Further up-section, the succession is dominated by gravity flow deposits indicating substantial subsidence of the basin. Deposition of this 850 m thick deep marine succession (Muttekopf Formation, HAAS, 1991) took place in a submarine slope environment and was affected by synsedimentary deformation, which is reflected by two major unconformities. ORTNER et al. (2015 and references therein) interpreted these unconformities as connected to tear faults during transpressive fold growth. These unconformities subdivide the Upper Gosau Subgroup into three parts. Each of them is dominated by laterally continuous siliciclastic turbiditic sandstone and siltstone and resedimented unchannelized conglomerates showing predominant carbonate clasts. Within the middle part a 50 m thick slump with megaclasts of Triassic limestone occur.

Material and methods

For calcareous nannofossil investigations, smear-slides were prepared from a suspension of unprocessed material in distilled water of pH 7 without applying concentration techniques. Fifty smear slides were studied with a Zeiss Axioplan light microscope using crossed and parallel polarization filters at a magnification of 1,000 x. For chronostratigraphic assignments the zonal schemes of SISSINGH (1977) and MARTINI (1971) have been used for the Cretaceous and Paleogene deposits, respectively.

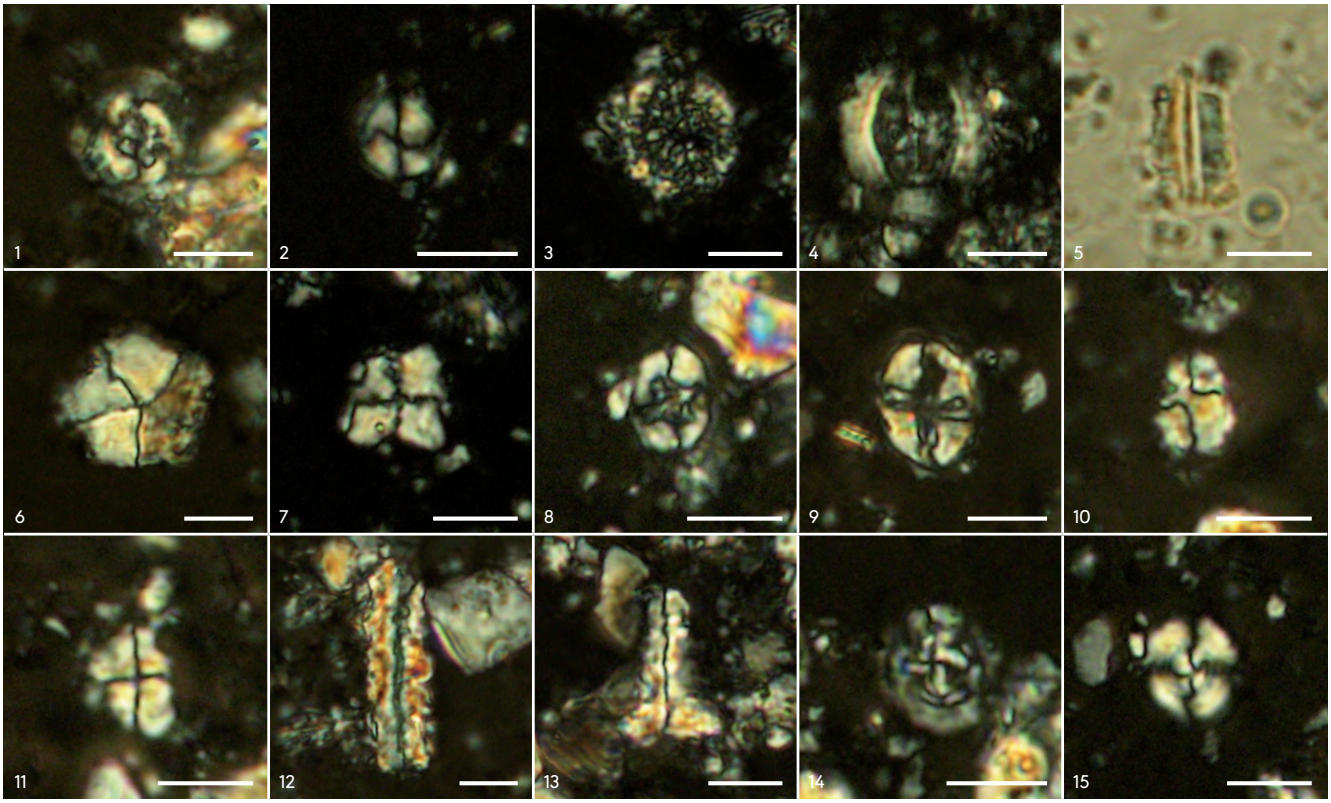
During a field trip in 2015 samples were collected along the track from the Hanau hut to the Fundoas Valley (Text-Fig. 1) and along the track leading from the Muttekopf hut eastward to Platteinwiesen. Due to strong recrystallization most of these samples do not contain identifiable calcareous nannoplankton. In a few samples *Watznaueria barnesae* BLACK is the only species sporadically occurring, which has a stratigraphic range from the Jurassic to the end of the Cretaceous. Stratigraphically important nannoplankton assemblages were found in two samples taken to the east of the Galtseitejoch (Text-Fig. 1). The nannoplankton assemblages of these samples are poorly preserved and consist essentially of deeply etched and fragmented specimens. Per field of view one to five specimens occur. Thirteen species were identified.

Additionally, nine smear slides of samples from the Rotkopf area were investigated (Text-Figs. 1, 4). These samples from the uppermost part of the Muttekopf Gosau succession were collected by Roman Lahodynsky in the year 1987 and are stored in the collections of the Geological Survey of Austria. These nannoplankton assemblages also display poor preservation and low diversity. Seventeen species were identified including reworked taxa, which form the majority of encountered species.

Results

Upper Santonian to Middle Campanian

Only two out of 24 samples, which were taken along the track from the Hanau hut to the Fundoas valley (Text-Fig. 1), contain stratigraphically valuable nannofossils. These fossiliferous samples originate from the same location (47°15´29” N, 010°37´15” E), which is situated about



Text-Fig. 3.
Light microscope images of calcareous nannoplankton species from the Muttekopf area. (1) *Cruciplacolithus tenuis* – sample M41, (2) *Coccolithus pelagicus* – M9, (3) *Operculodinella operculata* – M9, (4) *Arkhangelskiella cymbiformis* – M9, (5) *Lithraphidites quadratus* – M32, (6) *Braarudosphaera bigelowii* – M41, (7) *Uniplanarius gothicus* – M25, (8) *Eiffellithus turriseiffeli* – GJ12, (9) *Eiffellithus eximius* – GJ12, (10) *Calculites obscurus* – GJ12, (11) *Calculites ovalis* – GJ12, (12) *Lucianorhabdus cayeuxii* – GJ12, (13) *Lucianorhabdus maleformis* – GJ12, (14) *Prediscosphaera cretacea* – GJ12, (15) *Watznaueria barnesae* – GJ12. Scale bar: 5 µm.

750 m to the east of the Galtseitejoch in an altitude of 2,300 m (Text-Figs. 1, 2). The sampled rock is light grey marlstone, which alternate with brownish weathering turbiditic sandstone. Single marlstone layers are up to 1 m thick, the sandstone beds can obtain thicknesses up to 0.5 m. Sandstone beds often display the lower parts of the Bouma cycle (T_{abc}), the marlstone is interpreted to be part T_d of this cycle.

The nannoplankton assemblage of the two samples (GJ12, GJ13) is strongly recrystallized (Text-Fig. 3). Only 12 species could be determined with certainty: *Broinsonia enormis* (SHUMENKO), *Calculites obscurus* (DEFLANDRE), *Calculites ovalis* (STRADNER), *Eiffellithus eximius* (STOVER), *Eiffellithus turriseiffeli* (DEFLANDRE), *Lucianorhabdus cayeuxii* DEFLANDRE, *Microrhabdulus decoratus* DEFLANDRE, *Micula staurophora* (GARDET), *Prediscosphaera cretacea* (ARKHANGELSKI), *Retecapsa crenulata* (BRAMLETTE and MARTINI), *Watznaueria barnesae* (BLACK), *Zeugrhabdotus embergeri* (NOËL).

All encountered species are from the Cretaceous, most of them have their first occurrences (FO) in the Upper Cretaceous. Among this assemblage, *Lucianorhabdus cayeuxii* is the second most common species after *Watznaueria barnesae*. In the zonation scheme of SISSINGH (1977) the first occurrence (FO) of *L. cayeuxii* indicates the base of the Santonian Zone CC16 and the FO of *Calculites obscurus* is the marker for the base of Zone CC17 (*Calculites obscurus* Zone), which comprises the uppermost Santonian and lowermost Campanian (see GRADSTEIN et al., 2012). The zonal marker for Zone CC18 (*Broinsonia parca* Zone) was not found. However, it cannot be ruled out that the absence of this species is due to the poor preservation of the assemblage. A stratigraphic age not younger as Middle Campanian is indicated by several specimens of *Eiffellithus eximius*, a species which has its last occurrence (LO) in the lower Upper Campanian. Hence, if the composition of this assemblage is not an effect of heterochronous reworking, the samples can be assigned to the Upper Santonian to Middle Campanian.

Maastrichtian

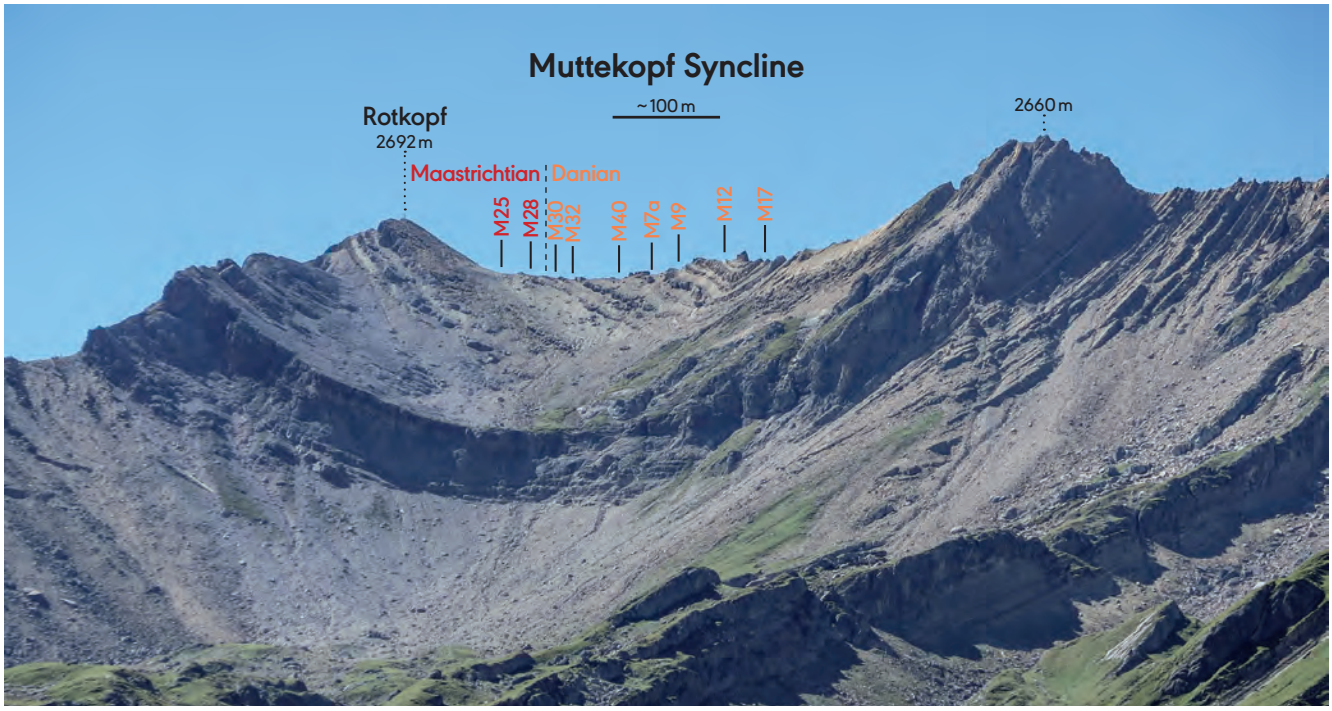
Maastrichtian nannoplankton assemblages (Text-Figs. 3, 4) occur in samples collected by Roman Lahodynsky at the ridge to the northeast of the Rotkopf Mt. (2,692 m). The chronostratigraphic assignment is based on findings of *Lithraphidites quadratus* BRAMLETTE & MARTINI, whose FO is about at the base of the Upper Maastrichtian (GRADSTEIN et al., 2012). *L. quadratus* co-occurs with fragments of large specimens (> 10 µm) of *Arkhangelskiella cymbiformis* VEKSHINA, which is also indicative for the Upper Maastrichtian. Beside these two stratigraphically important species, *Calculites obscurus* (DEFLANDRE), *Cribrosphaerella ehrenbergii* (ARKHANGELSKI), *Eiffellithus turriseiffeli* (DEFLANDRE), *Micula staurophora* (GARDET), *Uniplanarius gothicus* (DEFLANDRE) and *Watznaueria barnesae* (BLACK) were observed. In the zonation scheme of SISSINGH (1977) the assemblage can be attributed to Zone CC25 (*Lithraphidites quadratus* Zone). The close spacial proximity to Paleocene deposits described below suggests that the absence of markers for Zone CC26 (*Micula prinsii*, *Nephrolithus frequens*) might be due to the poor preservation of the assemblage.

AGE	SAMPLE	*Arkhangelskiella cymbiformis*	*Braarudosphaera bigelowii*	*Broinsonia enormis*	*Broinsonia parca parca*	*Calculites ovalis*	*Calculites obscurus*	*Coccolithus pelagicus*	*Cribrosphaerella ehrenbergii*	*Cruciplacolithus tenuis*	*Cyclagelosphaera reinhardtii*	*Eiffellithus eximius*	*Eiffellithus turriseiffeli*	*Ericsonia* sp.	*Lithraphidites quadratus*	*Lithraphidites* sp.	*Lucianorhabdus cayeuxii*	*Lucianorhabdus maleformis*	*Markalius inversus*	*Microrhabdulus decoratus*	*Micula staurophora*	*Operculodinella operculata*	*Placozygus spiralis*	*Prediscosphaera cretacea*	*Retecapsa crenulata*	*Uniplanarius gothicus*	*Watznaueria barnesae*
Paleocene	M17	•					•			•				•			•		•		•	•		•			•
	M12	•					•		•	•	•		•	•	•							•		•			•
	M9	•	•				•	•		•				•			•				•	•					•
	M7a		•		•		•		•	•			•	•			•				•	•					•
	M41	•	•		•					•				•			•				•	•			•		•
	M32	•	•		•		•		•			•	•		•		•				•	•		•			•
	M30	•	•									•	•								•	•					•
Cret.	M28	•							•				•		•						•			•			•
	M25	•			•				•				•		•		•				•			•		•	•
	GF13			•		•						•					•				•				•		•
	GJ12			•		•	•					•	•			•	•	•		•				•			•

Tab. 1.
Distribution of calcareous nannoplankton species in the samples from the Muttekopf area.

Danian

The Cretaceous/Paleogene-boundary (K/Pg-boundary) has been discovered at five sites within the Nierental Formation (Gosau Group) of the Eastern Alps (see EGGER et al., 2009, for a review). At all sections, the lowermost Paleocene is characterized by massive reworking of Cretaceous species, which prevents unequivocal differentiation between survivors and victims of the ecological disaster at the end of the Mesozoic. Good indicators for survivorship of taxa are atypical abundances of species, reflecting the ecological stress after the rapid environmental changes at the K/Pg-boundary (PERCH-NIELSEN, 1985). Albeit scarcely, the calcareous dinoflagellate cyst *Operculodinella (Thoracosphaera) operculata* appears regularly in the Maastrichtian samples but exhibits an unprecedented increase in abundance immediately following the K/Pg-event. This corre-



Text-Fig. 4.
Sample points at the ridge to the northeast of Rotkopf.

sponds to the "*Thoracosphaera*" bloom, which was recorded in many K/Pg-boundary sites because the cyst-producing genus *Operculodinella* was apparently well adapted to the environmental conditions at and just above the boundary (HILDEBRAND-HABEL et al., 1999).

In the samples collected by Roman Lahodynsky at the Rotkopf ridge (Text-Figs. 3, 4), the onset of the Danian is indicated by common fragments of *Operculodinella ("Thoracosphaera") operculata* (BRAMLETTE & MARTINI), which occur regularly from sample M30 up-section (Tab. 1). In all of these samples *Braarudosphaera bigelowii* (GRAN & BRAARUD) was found, a species which was encountered in the Maastrichtian samples of the Muttekopf area (Tab. 1). High abundances of this latter species are recorded in a number of K/Pg-boundary sections (e.g. PERCH-NIELSEN, 1985; GARDIN & MONECHI, 1998; TANTAWY, 2003). Both species occur already in the Maastrichtian but appear in large numbers only within the *Markalius inversus* Zone (Zone NP1) after the impact event at the K/Pg-boundary.

Cruciplacolithus tenuis (STRADNER), *Coccolithus pelagicus* (WALLICH), and *Ericsonia* sp. were found further up-section at the Rotkopf ridge. These species have their FO in the Danian *Cruciplacolithus tenuis* Zone (Zone NP2), which is the highest zone preserved in the Muttekopf area. Additionally, *Arkhangelskiella cymbiformis* VEKSHINA, *Broinsonia parca parca* (STRADNER), *Calculites obscurus* (DEFLANDRE), *Cribrosphaerella ehrenbergii* (ARKHANGELSKI), *Eiffellithus turriseiffeli* (DEFLANDRE), *Lithraphidites quadratus* BRAMLETTE & MARTINI, *Micula staurophora* (GARDET), *Placozygus spiralis* (BRAMLETTE & MARTINI), *Prediscosphaera cretacea* (ARKHANGELSKI), *Retecapsa crenulata* (BRAMLETTE & MARTINI), *Uniplanarius gothicus* (DEFLANDRE), and *Watznaueria barnesae* (BLACK) occur as reworked species.

Discussion

Taking into account the thickness of the Paleogene in other areas of the Northern Calcareous Alps, particularly of the stratigraphically most complete succession in the Reichenhall Basin near Salzburg (EGGER et al., 2017), it can be assumed that about 1,000 m thick Paleocene and Eocene deposits were eroded in the Muttekopf area. Nonetheless, this original sedimentary coverage cannot explain the high grade of diagenesis of the Gosau Group there. PETSCHICK (1989) reported on vitrinite reflectance values between 1.03 %R at the base of the succession and 0.59 %R at its top. These values suggest burial depths between 3 and 4 km and give evidence that the Gosau deposits were overthrusted by structurally higher units, which were almost totally removed by erosion. Small relics of these units are the Krabachjoch and Larsenn klippen in the proximity of the Muttekopf area, which are also part of the Northern Calcareous Alps.

Due to this deep burial of Cretaceous and Paleogene deposits nannoplankton assemblages are destroyed or strongly damaged. If calcareous nannoplankton is preserved the diversity is low and the specimens are deeply etched, centreless, and fragmented. Consequently, the identity of specimens is often questionable. These assemblages originate from samples showing vitrinite reflectance values between 0.6 %R and 0.8 %R. Samples with a higher degree in diagenesis do not contain identifiable nannofossils with the exception of sporadically occurring specimens of *Watznaueria barnesae*, which usually is the most common species in Cretaceous deposits of the Eastern Alps.

The biostratigraphic interpretation of calcareous nannoplankton assemblages is not only hampered by poor nannofossil preservation due to diagenetic alteration but also by synsedimentary substantial reworking of older species. Particularly the Paleocene assemblages can contain substantial admixtures of species (*Broinsonia parca parca, Eiffellithus eximius, Calculites obscurus, Lucianorhabdus cayeuxii*, *Lithraphidites quadratus*, large specimens of *Arkhangelskiella cymbiformis*), which indicate the erosion of Campanian and Maastrichtian strata in the earliest Paleocene.

Conclusion

Before continental collision in the Lutetian, deposits of the Gosau Group (Turonian–Lutetian) accumulated on the part of the active continental margin, which later became the Northern Calcareous Alps. Associated with the uplift of the Eastern Alps, the vast majority of the sedimentary rocks of the Gosau Group was removed by erosion and only small relics of the former extensive coverage are preserved in areas of tectonic subsidence. The only known exception of this distribution pattern is the Muttekopf area, where enhanced tectonic uplift can be implied from vitrinite reflectance data. It is assumed that at least 1 km of Paleogene deposits and c. 3 km of overlying tectonic units became eroded. Today, the only existing Paleogene deposits in the Muttekopf area are c. 100 m thick Paleocene strata, which reach into the *Cruciplacolithus tenuis* Zone (Zone NP2) of the lower Danian.

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