JAHRBUCH DER GEOLOGISCHEN BUNDESANSTALT
Jb. Geol. B.-A. | ISSN 0016-7800 | Band 158 | Heft 1–4 | S. 65–72 | Wien, Dezember 2018

Planktic foraminiferal biostratigraphy and paleoecology of the "Buntmergelserie" (Ultrahelvetic Zone, Campanian to Maastrichtian) in Upper Austria (Magdalenaberg and Hochhub areas)

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4 Text-Figures, 3 Tables

Österreichische Karte 1:50.000
BMN / UTM
67 Grünau im Almtal
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Upper Austria
Ultrahelvetic Units
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Abstract

Early to Middle Campanian and Late Maastrichtian planktic foraminiferal assemblages provide new information on age and paleo-environments of the Ultrahelvetic Zone of Upper Austria. Index species indicate the *G. elevata, G. ventricosa*, and *A. mayaroensis* Zones. Quantitative analyses show that deposition took place at bathyal paleo-water depths of about 1,000 m or even at greater depths but above the carbonate compensation depth (CCD). Living conditions were generally stable and oligotrophic. Some exceptional assemblages point to increased mixed layer paleo-productivity indicated by reduced equilibrium species contents and increased contents of species with opportunistic reproductive strategy.

Biostratigrafie und Paläoökologie planktischer Foraminiferen aus der Buntmergelserie (Ultrahelvetikum, Campanium bis Maastrichtium) in Oberösterreich (Magdalenaberg und Hochhub)

Zusammenfassung

Planktische Foraminiferenassoziationen liefern neue Informationen über Alterseinstufungen und Umweltbedingungen im frühen bis mittleren Campanium und späten Maastrichtium des Ultrahelvetikums von Oberösterreich. Leitarten zeigen die *G. elevata-, G. ventricosa-* und *A. mayaroensis*-Zonen an. Auf Basis quantitativer Untersuchungen erfolgte die Ablagerung im bathyalen Bereich bei Wassertiefen um 1.000 m oder tiefer, jedoch oberhalb der Karbonat-Kompensationstiefe (CCD). Die Lebensbedingungen werden als allgemein stabil und oligotrophisch eingestuft. Davon abweichende Assoziationen deuten auf erhöhte Paläoproduktivität im Oberflächenwasser hin, die sich durch reduzierte Anteile von Gleichgewichtsarten und erhöhte Anteile von Arten mit opportunistischer Reproduktionsstrategie auszeichnen.

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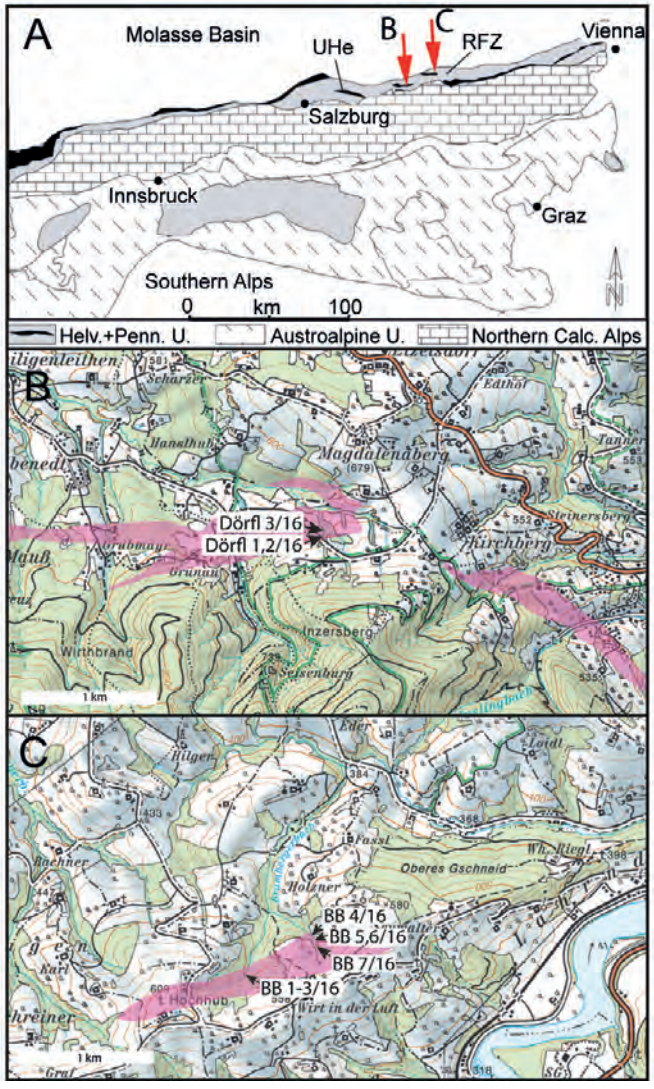
Introduction

The Ultrahelvetic tectonic unit is a stripped part of the passive continental margin in the south of the European Plate (Rupp et al., 2011). Its paleo-slope sediments are combined to the so-called "Buntmergelserie" (variegated marls) and show an intensive internal imbrication as well as a generally southward dip (Maurer, 1971; Braustingl, 1988; Egger et al., 2007a, b). Continuous sections within the "Buntmergelserie" are not known from Upper Austria. Ages of the "Buntmergelserie" reach from Early Cretaceous (Albian) to Eocene (Lutetian; Rupp et al., 2011). The occurrences of Ultrahelvetic units became exposed as tectonic slices along dextral strike-slip faults and are sometimes called "Fenster" (tectonic windows; Egger et al., 2007a, b; Rupp et al., 2011). Most of such slices are exposed within the Rhenodanubian Flysch-Zone (e.g., Rupp et al., 2011).

For many of the occurrences of Ultrahelvetic rocks (Text-Fig. 1A), the exact ages of their sediments are not well evaluated and allocations to the "Buntmergelserie" were based mainly on lithology. Biostratigraphic information is available only for a few tectonic slices, e.g., by one sample from the "Hochhub-Fenster" ("Brambergerbachschichten"; Braunstingl, 1988). Consequently, an extensive sampling and age determination of the rocks is needed. In this contribution we investigate grey and red marlstones from two of the tectonic slices in order to evaluate their depositional ages and paleo-environment based on its planktic foraminiferal assemblages.

Sturm (1969) published one of the first descriptions of Late Cretaceous planktic foraminifera including a biostratigraphic zonation for Ultrahelvetic strata from Upper Austria. Other (local or regional) zonations are sometimes based also on combinations of planktic and benthic foraminifera and were published from the Gosau Group of various areas such as Bavaria (Herm, 1962), Styria (Kollmann, 1963), and Salzburg state (Wille-Janoschek, 1966), or from Moravia (Hanzlíková, 1972). Recently, Wolfgring & Wagreich (2016) and Wolfgring et al. (2016) published modern foraminifera-based paleo-ecologic interpretations for Campanian strata of the Gosau Group.

In this contribution, we apply a modern global biostratigraphic concept (Premoli Silva & Verga, 2004). In addition to this, quantitative analyses of the planktic foraminiferal assemblages provide information on paleo-water depth, stability and trophic states of the paleo-environments.



Text-Fig. 1.
A: Location of the investigated occurrences (red arrows; B – Dörfl, Magdalenaberg area, C – Bramberger Bach, Hochhub area) and tectonic map of the Eastern Alps (UHe – Ultrahelvetic units; RFZ – Rhenodanubian Flysch Zone; Helv. + Penn. U. – Helvetic and Penninic Units). **B:** Location of samples collected near Dörfl (Magdalenaberg area). **C:** Locations of samples collected at Bramberger Bach near Hochhub (local hill). Pink marked areas in maps B and C represent occurrence of "Buntmergelserie" (variegated marls) of the Ultrahelvetic Unit (distribution according to Egger et al., 2007b (B) and Krenmayr et al., 2006, and this contribution (C)).

Material, methods, and concepts

200 g of dry sediment were disintegrated with 5 % hydrogen peroxide solution and washed over a 0.063 mm sieve. The residue was dried and dry sieved into 0.063 to 0.125 and 0.125 to 1 mm fractions. In order to prevent uncertain species identification of juvenile specimens, counts and classifications were performed with the 0.125 to 1 mm fraction only. The samples were split into manageable subsamples (aliquots) and completely picked for foraminifera (morphotype separation). Specimens of index species were identified also in the complete sample (Tab. 1). All sample material is stored in the collection of the Geologische Bundesanstalt (collection numbers GBA 2018/009/0001ff.). We applied the taxonomic or biostratigraphic concepts published in Caron (1985), Premoli Silva & Verga (2004) or Ogg et al. (2012).

Samples were collected by Hans Egger and Stjepan Ćorić (GBA) during fieldwork in 2016. Three samples from the Magdalenaberg area (samples Dörfl 1–3/16; Text-Fig. 1B, Tabs. 1, 2) include red as well as grey marlstones. From the Hochhub area, all seven samples consist of grey marlstones (samples Bramberger Bach 1–7/16; Text-Fig. 1C, Tab. 1). Exact locations of sampled outcrops are shown in Table 3.

The washed material (residue) yielded, although not completely disaggregated, high numbers of microfossils. Among those, planktic foraminifera are most frequent.

sample no./rock colour	Dörfl 1/16	Dörfl 2/16	Dörfl 3/16	BB 1/16	BB 2/16	BB 3/16	BB 4/16	BB 5/16	BB 6/16	BB 7/16
index species										
Abathomphalus mayaroensis				X	X	X	X	X	X	X
Contusotruncana contusa				X	X	X	X	X	X	X
Racemiguembelina fructicosa				X	X	X	X	X	X	X
Gansserina gansseri				X			X		X	
Globotruncana ventricosa			X							
Pseudotextularia elegans		X	X	X				X		
Contusotruncana patelliformis	X		X							
Globotruncanita elevata	X	X								
planktic morphotyes										
keeled planktic species	121	37	99	16	41	43	25	75	180	71
non-keeled planktic species	177	15	116	13	16	24	76	76	226	56
bi- or multiserial planktic species	295	55	124	25	91	94	206	181	306	121
sum	593	107	339	54	148	161	307	332	712	248
% planktic morphotyes										
keeled planktic species	20	35	29	30	28	27	8	23	25	29
non-keeled planktic species	30	14	34	24	11	15	25	23	32	23
bi- or multiserial planktic species	50	51	37	46	61	58	67	55	43	49
planktic foraminifera zone	*G. elevata*		*G. ventricosa*	*A. mayaroensis*						
Stage	early Campanian		m. Campanian	late Maastrichtian						

Tab. 1.
Distribution of planktic foraminiferal index species, planktic morphotypes, and planktic foraminiferal zonation of samples investigated. BB = Bramberger Bach.

Much less frequent are benthic foraminifera. Ostracods and radiolaria are scarce. Almost all foraminifera specimens are recrystallized and many are broken or crushed and covered with sediment particles. However, biostratigraphic index species of the Campanian to Maastrichtian interval are relatively large and easy to identify. Likewise, the distinction of the three main planktic morphotypes (keeled trochospiral, non-keeled trocho- or planispiral, bi- or multiserial) did not cause problems.

The morphotype concept applied here corresponds largely to the reproductive strategy concept of Equilibrium species (K-strategists, here keeled species, globotruncanids), intermediate species (non-keeled species), and opportunists (*r*-strategists, biserial species). This concept is explained in PREMOLI SILVA & SLITER (1999) and COCCIONI & LUCIANI (2004) and has been applied for various late Cretaceous intervals in the Alpine region (e.g., GEBHARDT et al., 2010; WOLFGRING & WAGREICH, 2016). Dominance of *K*-Strategists is indicative for stable, meso- to highly oligotrophic conditions (PREMOLI SILVA & SLITER, 1999; COCCIONI & LUCIANI, 2004; FRIEDRICH et al., 2008). On the other hand, biserial *Heterohelix* (most frequent *r*-strategists) dominate in nearshore assemblages or in unstable areas with salinity or oxygen fluctuations (e.g., NEDERBRAGT, 1991; NEDERBRAGT et al., 1998; PREMOLI SILVA & SLITER, 1999). In addition, massive productivity disturbances in upwelling areas such as at Tarfaya (Morocco) may lead to strong dominance of heterohelicids (KELLER et al., 2008). Therefore, dominance of Heterohelix can be seen as a good stress indicator. A list of genera is shown in Table 3. Large multi- and biserial *Racemiguembelina* and *Pseudotextularia* (here counted together with opportunistic Heterohelicids) are too rare as they have a significant influx on the results. The same is valid for rare Hedbergellids (opportunists) within the non-keeled morphogroup.

Stable oxygen and carbon isotope analyses of planktic foraminifera can provide depth rankings among the investigated species. Distinctions between mixed layer (surface, subsurface), thermocline, and sub-thermocline (deep) dwellers of the Campanian to Maastrichtian interval on species level were presented by e.g., ABRAMOVICH et al. (2003, 2010). We interpret the occurrence of species with known depth habitat.

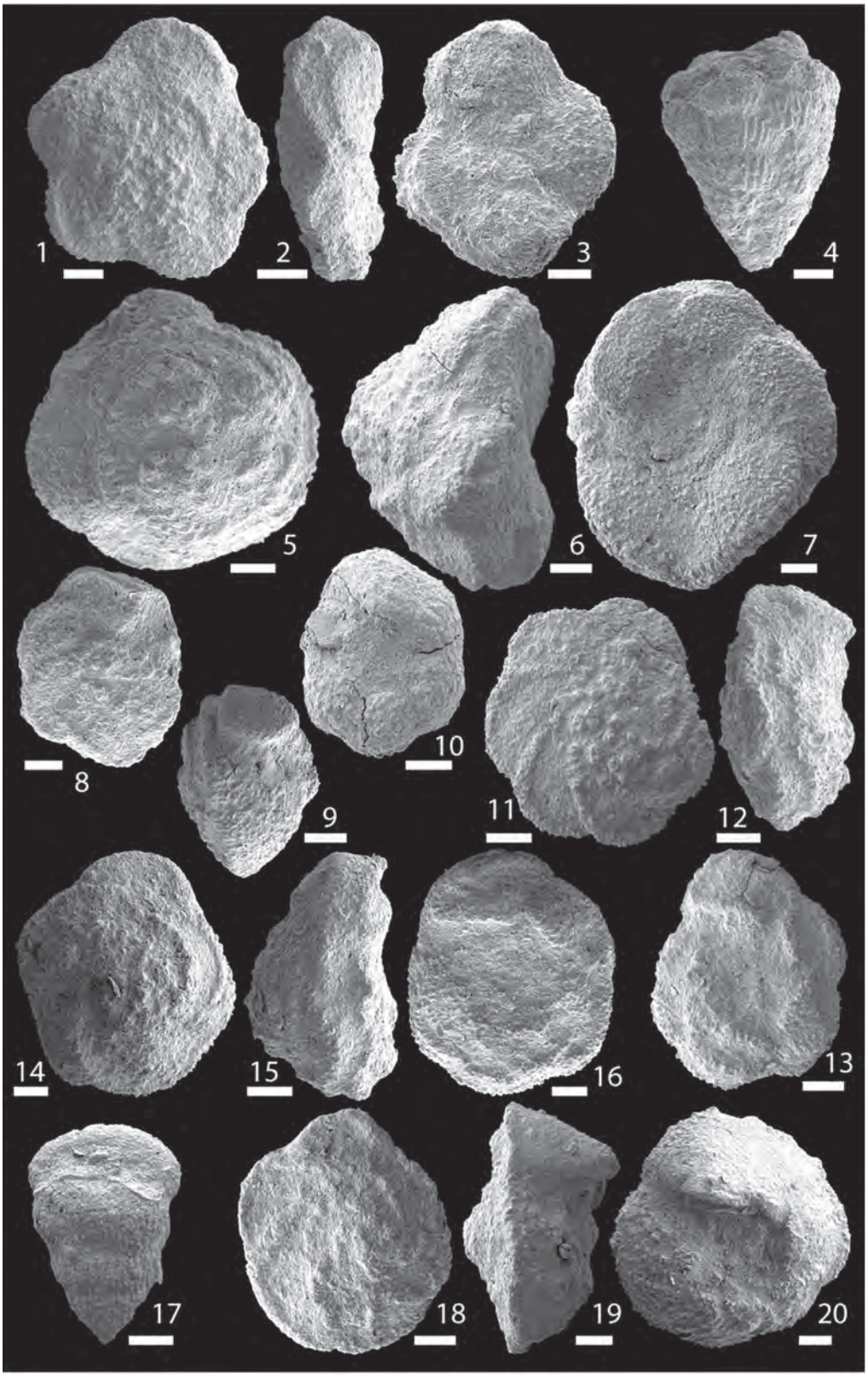
sample	latitude	longitude
Dörfl 1/16	47°56'00''N	14°02'35''E
Dörfl 2/16	47°56'00''N	14°02'35''E
Dörfl 3/16	47°56'01''N	14°02'36''E
BB 1/16	47°59'20''N	14°19'55''E
BB 2/16	47°59'20''N	14°19'55''E
BB 3/16	47°59'20''N	14°19'55''E
BB 4/16	47°59'29''N	14°20'19''E
BB 5/16	47°59'28''N	14°20'19''E
BB 6/16	47°59'28''N	14°20'19''E
BB 7/16	47°59'27''N	14°20'19''E

Tab. 2.
Geographic coordinates for the investigated samples. BB = Bramberger Bach.

Results

Biostratigraphy

Based on the presence of index species among the planktic foraminifera assemblages, we were able to distinguish three different biozones, two from the Campanian and one from the Maastrichtian Stage. We applied the zonal concept published in PREMOLI SILVA & VERGA (2004). The scheme published in the Geological Time Scale 2012 (GRADSTEIN et al., 2012) is based on some (in particular biserial) species that could not be found in the samples investigated, either because these species are very rare or because the preservational status is too poor (recrystallized or covering with sediment particles). The occurrences of index species are listed in Table 1. The species are figured in Text-Figure 2.



Text-Fig. 2.
1–3. *Abathomphalus mayaroensis*. 1. spiral view, 2. lateral view, 3. umbilical view. 1. sample BB 5/16, 2, 3. sample BB 6/16.
4. *Racemiguembelina fructicosa*. lateral view. sample BB 4/16.
5–7. *Contusotruncana contusa*. 5. spiral view, 6. lateral view, 7. umbilical view, all sample BB 4/16.
8–10. *Gansserina gansseri*. 8. spiral view, 9. lateral view, 10. umbilical view, all sample BB 4/16.
11–13. *Globotruncana ventricosa*. 11. spiral view, 12. lateral view, 13. umbilical view, all sample Dörfl 3/16.
14–16. *Contusotruncana patelliformis*. 14. spiral view, 15. lateral view, 16. umbilical view, all sample Dörfl 1/16.
17. *Pseudotextularia elegans*. lateral view, sample BB 4/16.
18–20. *Globotruncanita elevata*. 18. spiral view, 19. lateral view, 20. umbilical view, all sample Dörfl 1/16.

BB = Bramberger Bach.
All scale bars: 0.1 mm.

Text-Fig. 3.
Outcrop of samples Dörfl 1/16 (red marlstone) and 2/6 (grey marlstone). Hammer serves as scale. Photograph: Hans Egger (GBA).

***K*-strategists** equilibrium genera	*Abathomphalus* *Contusotruncana* *Ganserina* *Globotruncana* *Globotruncanita*
***r*/*K*-intermediates**	*Archaeoglobigerina* *Globotruncanella* *Macroglobigerinelloides* *Planoglobulina** *Plummerita* *Pseudoguembelina** *Pseudotextularia** *Racemioguembelina** *Rugoglobigerina* *Rugotruncana* *Ventilabrella**
***r*-strategists** opportunists	*Guembelitria* *Heterohelix* *Laeviheterohelix* *Muricohedbergella***

Tab. 3.
Planktic foraminiferal genera allocated to different life- and reproductive strategies.
* counted as bi- or multiserial, very rare. ** counted as non-keeled, very rare.

Magdalenaberg area, Campanian

The oldest planktic foraminiferal zone identified is the Early Campanian *G. elevate* Zone. Its base is marked by the last occurrence (LO) of all *Dicarinella* species. The top of this zone is defined by the first occurrence (FO) of *Globotruncana ventricosa*. It comprises, among other species, the FO of *Contusotruncana patelliformis*. *Pseudotextularia elegan*s is another prominent species occurring in the samples of this zone. Neither *Dicarinella* species nor *G. ventricosa* occur in samples Dörfl 1/16 and Dörfl 2/16 (Text-Fig. 3). Consequently, these samples were allocated to the *G. elevate* Zone. This age assignment corresponds to the results of the nannoplankton flora (CC19 for Dörfl 1/16 and Zone CC18 for Dörfl 2/16; HANS EGGER, personal communication).

The second identified Campanian zone is the Middle to Late Campanian *G. ventricosa* Zone. It is defined as the interval from the FO of *Globotruncana ventricosa* to the FO of *Radotruncana calcarata*. Beside the name giving species and many other globotruncanids, *C. patelliformis* and *P. elegans* were found, but no *R. calcarata*. Thus, sample Dörfl 3/16 points to a Middle to Late Campanian age (*G. ventricosa* Zone). This age assignment corresponds to the results of the nannoplankton flora (Zone CC22; HANS EGGER, personal communication).

The nannoplankton results as well as those for planktic foraminifera in combination with stratigraphic position of the three samples in the field (Text-Fig. 1B) and southward dipping of rocks suggests invers bedding in this part of the tectonic wedge. However, the generally intensive internal imbrication of the Helvetic wedges and the lack of continuous outcrops does not excludes tectonic faults between the sampling locations. Future investigations may confirm or disprove our finding at this position or at other locations.

Bramberger Bach near Hochhub, Maastrichtian

All samples taken in the Bramberger Bach (BB; Text-Fig. 1C) yielded *Abathomphalus mayaroensis* (Tab. 1). In samples BB 1/16 and BB 2/16, this index species is very rare but present. In the other BB-samples, it is rather frequent and can be found quickly within the assemblages. The *A. mayaroensis* Zone is defined by the interval from the FO of the nominate taxon to the extinction of almost all Cretaceous planktic foraminifera (i.e., the Cretaceous/Paleogene boundary). Therefore, all BB-samples were allocated to the late Maastrichtian *A. mayaroensis* Zone. This age assignment corresponds to the results for the nannoplankton flora (Zone CC25; HANS EGGER, personal communication). We could not find index species for younger zones (*P. hariaensis* or *P. hantkeninoides*) as proposed by e.g, HUBER et al. (2008) and OGG et al. (2012). The samples may therefore be merely assignable to the middle part of the Late Maastrichtian than to the late part. However, these species may be too rare in the area or its presence may be obscured by the poor preservation status of the assemblages. Other prominent species found in the Late Maastrichtian assemblages are *Contusotruncana contusa, Racemiguembelina fructicosa*, and only occasionally *Gansserina gansseri* (Tab. 1). Frequent large Heterohelicids are another remarkable constituent of the BB-samples.

Paleoecology

An overview of the results is presented in Table 1 and Text-Figure 4. The content of keeled (i.e., *K*-selected) species ranges between 20 and 30 % in most samples. Only in to outliers different contents occur: the highest percentage was found in the Early Campanian Dörfl 2/16 (35 %) and the lowest in BB 4/16 (8 %). Non-keeled (r/K-intermediates) vary from 11 to 34 %. Their maximum occurs in the Middle to Late Campanian sample Dörfl 3/16. The biserial (and multiserial) portions range between 37 and 67 % (samples Dörfl 3/16 and BB 4/16, respectively). The average content of the other samples is 52 %.

A first view on the washed residues show a strong dominance of planktic foraminifera in the assemblages. Benthic specimens are relatively rare although present. A rough estimate points to a proportion of more than 90 % planktic foraminifera, and samples BB 5/16, BB 6/16, and BB 7/16 contain 97 %, 96 %, and 97 % planktic foraminifera respectively.

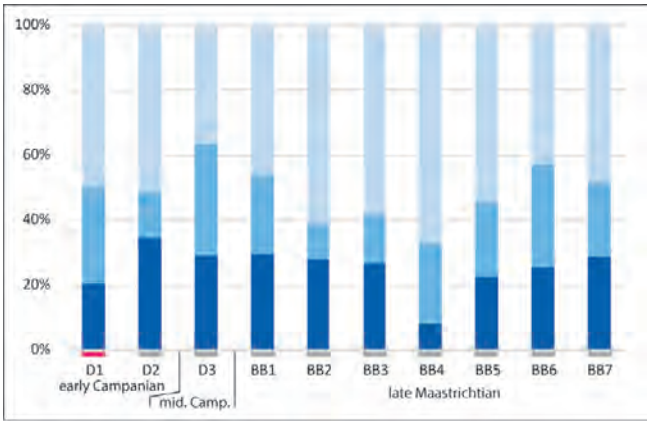
Deep dwelling (sub-thermocline) *A. mayaroensis* and some globotruncanids were found in all Maastrichtian samples. Thermocline (e.g., *G. ventricosa, R. fructicosa, G. gansseri*) and mixed layer (e.g., *P. elegans*) species occur in Campanian and Maastrichtian samples.

Discussion and interpretation

Although not directly comparable with modern faunas and ecological settings, planktic foraminiferal contents would point to bathyal paleo-water depths of about 1,000 m or even deeper (VAN DER ZWAAN et al., 1990, 1999). LECKIE et al. (1998) interpreted bathyal depths for Cenomanian–Turonian deposits with c. 90 % planktic foraminifera from the Western Interior Basin of North America. The deep depositional environment is confirmed by the presence of sub-thermocline dwellers (*Abathomphalus*) within the planktic assemblages at least for the Maastrichtian samples.

Within the found benthic foraminiferal assemblages, large agglutinated specimens are prominent. The observed genera include e.g., *Arenobulimina, Dorothia, Gaudryina, Hormosina, Marssonella, (Para-)trochaminoides*, or *Tritaxia*. This phenomenon may point to environmental conditions similar to those of the paleo-geographically adjacent flysch deposits (compare e.g., GRÜN, 1969; GRÜN et al., 1964; BUBÍK, 1995; GASINSKI & UCHMAN, 2009), at least in terms of food supply to the sea floor and to bottom water oxygenation. Benthic foraminiferal assemblages and very high percentages of planktic foraminifera indicate great paleo-water depths, possibly middle to lower bathyal. Due to the high carbonate content of the sediments, the depositional depth was however above the CCD (carbonate compensation depth).

No definite differences in the planktic foraminiferal assemblages were found between red and grey marlstones in the Magdalenaberg area (Text-Fig. 3). The preparation status of the washed tests seem to be slightly better in the red facies. The higher content of non-keeled forms might be significant but only one sample from red marls was investigated.



Text-Fig. 4.
Distribution (percentages) of planktic foraminiferal morphogroups in the investigated samples and sample ages. D = Dörfl, BB = Bramberger Bach. Columns: dark blue – keeled; middle blue – non-keeled; bright blue – bi- and multiserial. Rock colour is indicated by the bar above sample number.

The reduced content of *K*-selected species (i.e., keeled species; Text-Fig. 4) in sample Dörfl 1/16 resembles the assemblages described by WOLFGRING & WAGREICH (2016) from the Campanian Nierental Formation (Gosau Group). There, the strict association of Cretaceous Oceanic Red Beds (CORBs) with highly oxic bottom waters was disproved (WOLFGRING et al., 2016). We may therefore assume a slightly reduced bottom water oxygenation or even an increased surface productivity (higher food availability for planktic foraminifera) for the red layers of the Early Campanian of the Magdalenaberg area.

Similar to the paleo-ecological setting for the red marlstone of the Early Campanian, sample BB 4/16 from the Late Maastrichtian shows the lowest content of *K*-selected species and the highest of *r*-selected species. This is a distinct shift towards opportunistic life strategies if compared with the other samples. We therefore assume either increased food supply or ecologic stress (environmental instability) for the sedimentation period represented by this sample. Both factors would support reproductive rates of opportunistic *r*-strategists, or suppresses the reproduction of *K*-selected equilibrium species (here globotruncanids).

For the other Maastrichtian samples as well as for the Campanian grey marlstone samples, we interpret stable, most likely oligotrophic conditions for their sedimentation periods. This is indicated by the relatively high contents of globotruncanids (i.e., keeled morphotypes) and relatively low contents of heterohelicids (i.e., biserial morphotypes).

Conclusions

We investigated planktic foraminiferal assemblages of ten marlstone samples from two tectonic slices representing the Ultrahelvetic Zone at the northern margin of the Eastern Alps. The results show different ages for the two slices: 1. the Magdalenaberg/Dörfl-area samples show Early to Middle Campanian ages (*G. elevata* and *G. ventricosa* Zones); 2. the Hochhub/Bramberger Bach-area samples show uniformly Late Maastrichtian ages (*A. mayaroensis* Zone). Paleo-ecologically, most assemblages point to stable, oligotrophic conditions. Deposition took place at bathyal

paleo-water depths of about 1,000 m or even at greater depths but above CCD. Two assemblages, one from Early Campanian red beds, the second from the Late Maastrichtian and even more clearly, indicate increased paleo-productivity in the mixed layer of the Late Cretaceous sea by increased contents of opportunistic species (*r*-strategists) and decreased contents of equilibrium species (*K*-strategists).

Acknowledgements

HANS EGGER and STJEPAN ĆORIĆ (GBA) sampled the investigated rocks during fieldwork in 2016 and provided the sample material. We are grateful to SABINE GIESSWEIN and CHRISTIAN AUER for SEM micrographs, KATHARINA DANIS for sample preparation and GERLINDE POSCH-TRÖZMÜLLER (all GBA) for assistance with GIS-files.

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Received: 10. September 2018, accepted: 8. October 2018