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LATE CAMPANIAN/LATE MAASTRICHTIAN PENETRATION OF HIGH-LATITUDE CALCAREOUS NANNOFLORA TO THE OUTER WESTERN CARPATHIAN DEPOSITIONAL AREA

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Abstract: A joint occurrence of high-latitude "boreal" and low-latitude "tethyan" calcareous nannofossil taxa has been observed in sediments of Late Campanian and Late Maastrichtian age, in the Outer (Menilite-Krosno) group of nappes (Waschberg Zone and Ždánice Unit) and Magura group of nappes (Rača and Bílé Karpaty units) of the Outer Western Carpathians. The degree of influence of the "boreal" province was a function of the paleogeographical position of basins and geological time: the depositional area of the Outer (Menilite-Krosno) group of nappes was probably situated on the SE passive margin of the West European Platform. The calcareous nannofossils include both high-latitude species (*Monomarginatus quaternarius*, *Neocrepidolithus watkinsii*) and low-latitude ones (genera *Ceratolithoides* and *Quadrum*) in Late Campanian times. In Maastrichtian times the high-latitude phenomena dominates (common *Psyktosphaera firthii,* absence of *Ceratolithoides kamptneri, Watznaueria : Micula* ratio = 1 : 3). In the Magura group of nappes the depositional area of which is considered to be a high activity terrane of the Tethyan mobile Realm, the Late Campanian nannoflora is characterized by the presence of low-latitude species. The influx of high-latitude species is evident here especially in the Late Maastrichtian (higher numbers of *Prediscosphaera stoveri* and *Nephrolithus frequens*). A migration path can be supposed between the northern part of the Tethys and North European basins through the Peri-Tethyan basins (Polish Trough). In contrast, the Late Campanian section of the Münsterland Basin, which is included into the "boreal" province, yielded exclusively cosmopolitan and boreal nannofossils including *Heteromarginatus bugensis*.

Key words: Outer Western Carpathians, Münsterland Basin, Campanian, Maastrichtian, calcareous nannofossils, biostratigraphy, bioprovinces.

Introduction

Bioprovincialism was increasing during the Late Cretaceous due to gradual global cooling, resulting in the coexistence of typical Tethyan/tropical and Boreal or Austral fauna. According to Burnett (1998), paleobiogeographical separation of calcareous nannofloras became increasingly apparent through the Campanian and into the Maastrichtian. This paleobiogeographic separation allows for the differentiation of three distinctive biogeographical regions: the "boreal" province (broadly, northern high paleolatitudes), the intermediate- "tethyan" province (broadly, moderate to low paleolatitudes), and the "austral" province (southern high paleolatitudes).

A joint occurrence of low-latitude "tethyan" and high-latitude "boreal" calcareous nannofossil taxa was observed in Late Cretaceous sediments of the Outer Western Carpathians (Figs. 1 and 2), particularly in the Outer (Menilite-Krosno) group of nappes (Waschberg Zone and Ždánice Unit) and in the Magura group of nappes (Rača and Bílé Karpaty units). The depositional areas of these geological units are supposed to have originated south-east of their present locations and, as a whole, they may be included in the warm-temperate realm of the Tethys. According to Stráník et al. (1996) the depositional area of the Outer (Menilite-Krosno) group of nappes was situated about 100 km from its present location, on the southeastern passive margin of the European Platform which is believed to be a northern margin of the Tethys. Stráník (in Švábenická et al. 1997) regards the Magura group of nappes depositional area as a high activity terrane of the Tethyan mobile Realm, situated a few hundreds km from its present location, partially on the territory of the present Central Carpathians and touching the southeastern rim of European Platform.

Fig. 1. A sketch map showing the locations of studied areas (marked by hatched areas).

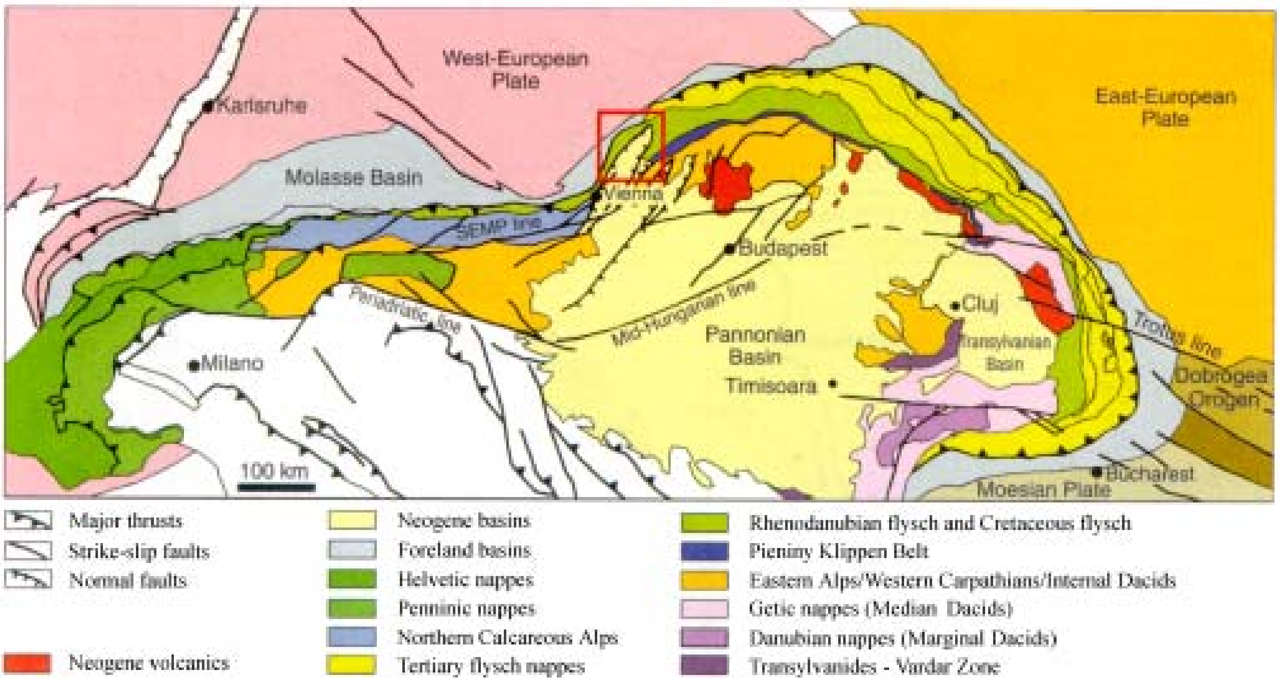


Fig. 2. Schematic geological map of the Alps, Carpathians, Dinarides and the Pannonian Basin, and the location of the study area. From Linzer (in Tomek 1996), modified.

Autochthonous epicontinental Cretaceous sediments of the cool to temperate "boreal" realm, that is the chalk shelf depositional area of North European basins, occur farther to the north and northwest in the European Platform.

The aim of this work was to study the migration of high-latitude calcareous nannoflora to the depositional area of the northern margin of Tethys during the Campanian and Maastrichtian, and influence of the "boreal" province in the particular depositional areas in the framework of the present Outer Western Carpathians.

Previous studies

The presence of distinctive latitude-restricted nannoplankton species was first reported by Worsley & Martini (1970) in the Maastrichtian, who noted the bipolar distribution of *Nephrolithus frequens* and a coeval concentration of *Micula murus* in lower latitudes. Bukry (1973) proposed low-latitude nannoplankton biostratigraphic zonation for the Upper Cretaceous. Latitude and paleoclimatic distribution patterns of Maastrichtian nannoflora were discussed by Worsley (1974). Thierstein (1976) noted that some nannofossil species display high abundances with increasing paleolatitude, and Thierstein & Haq (1977) presented a systematic analysis of the Upper Cretaceous nannoplankton biogeography. Many later publications discussed latitude-restricted nannofossils and their affinities to provinces during the Upper Cretaceous: Wind (1979), Perch-Nielsen (1985), Burnett (1990, 1998), Watkins (1992), Watkins et al. (1996), and others.

The coexistence of low-latitude and high-latitude nannofossils in the Western Carpathians was first observed by Švábenická (1992) in Campanian sediments of the Pavlov-5 borehole (see Fig. 3) in the Ždánice Unit, Outer (Menilite-Krosno) group of nappes. Later, this phenomenon was also observed in the Campanian and Maastrichtian flysch deposits of the Magura group of nappes in the Rača and Bílé Karpaty units (Švábenická et al. 1997; Švábenická in Bubík et al. 1999). The significant penetration of high-latitude nannoflora to the depositional area of the Outer (Menilite-Krosno) group of nappes (Waschberg Zone and Ždánice Unit) in the Turonian–Maastrichtian interval was broadly described by Švábenická (in Stráník et al. 1996; in Summesberger et al. 1999; in Hofmann et al. 1999). A stratigraphic correlation of the latitude-restricted nannofossils in the Campanian of the Outer Western Carpathians was presented by Švábenická (1995 and 1998). High-latitude "boreal" species were found to be more frequent in the Outer group of nappes than in the Magura group of nappes (Švábenická 1999). An overview of the occurrences of high- and low-latitude species in nannofossil assemblages within the depositional area of the Late Cretaceous northern margin of the Tethys was presented by Švábenická et al. (in print).

Material

Material was collected in the Outer Western Carpathians in the territory of the Czech Republic, Slovakia and Austria (Figs. 3 and 4). Data presented here were obtained mostly during geological research in this area and are mostly published. This work summarizes all available observations.

Samples were taken from outcrops: from flysch sediments s.s. (interval T_e sensu Bouma 1962) in the Rača and Bílé

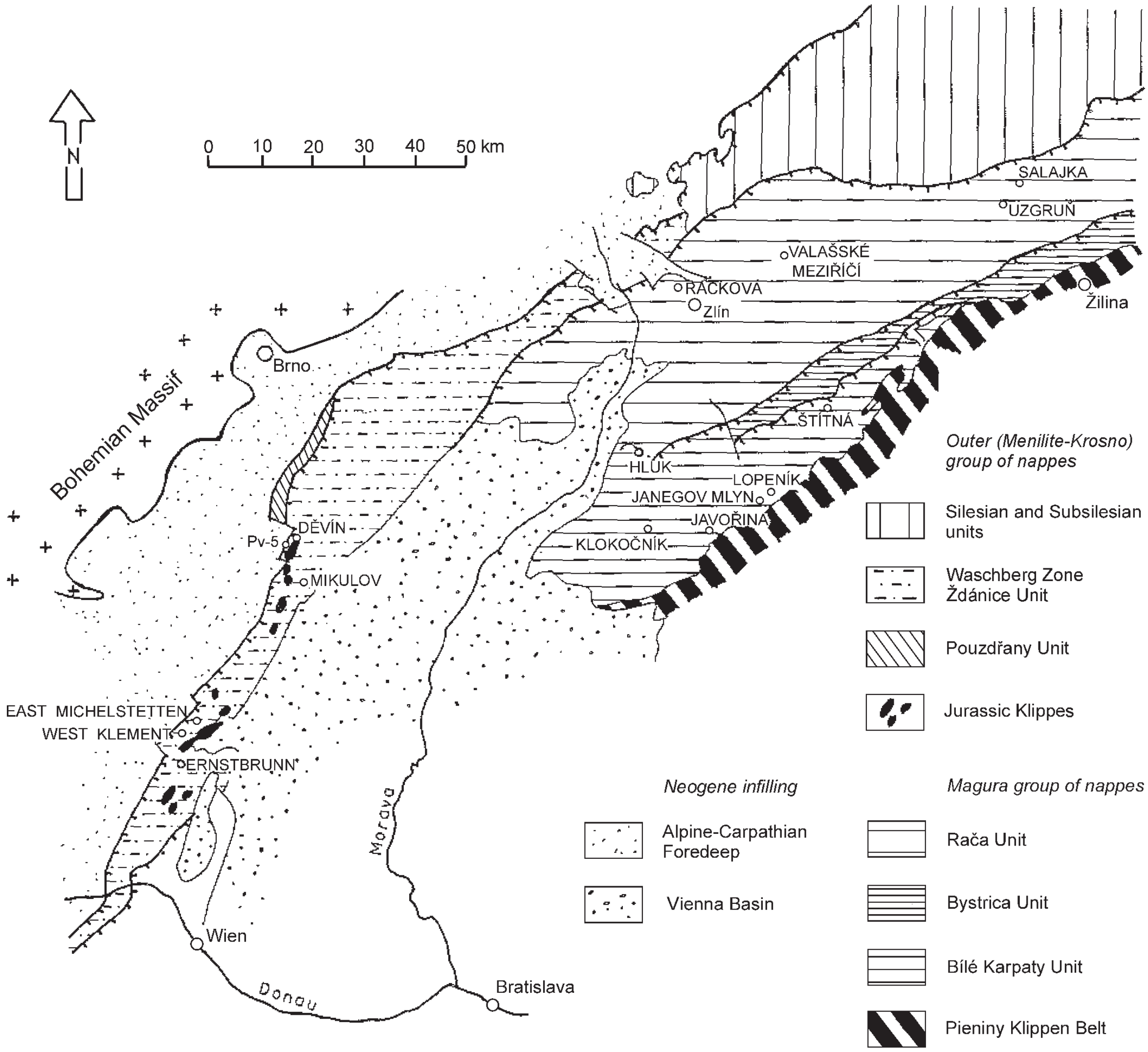


Fig. 3. A sketch map of the western part of the Outer Western Carpathians showing the locations of studied sections (in capitals) and major cities. Pv-5: Pavlov-5 borehole.

Karpaty units, Magura group of nappes, and from claystones and marlstones in the Waschberg Zone and Ždánice Unit, Outer (Menilite-Krosno) group of nappes. In addition, tectonic slices of the Púchov Marl in the front of the Magura group of nappes were studied. These sediments are believed to have originated in the depositional area of the Pieniny Klippen Belt (Švábenická et al. 1997).

Outer Western Carpathians

Outer (Menilite-Krosno) group of nappes

Waschberg Zone and Ždánice Unit

Pálava Formation (Stráník et al. 1996): grey and brownish-grey calcareous claystones with a variable amount of silt. Nannofossils were studied in the Pavlov-5 borehole (Švábenická 1992) and at the localities of Mikulov and Děvín (Stráník et al. 1996), Ernstbrunn (Hofmann et al. 1999), East Michelstetten and West Klement (Summesberger et al. 1999). In total, 60 samples were studied.

Magura group of nappes (western part)

Rača Unit

Kaumberg Formation: the upper part is formed by medium- to thin-bedded flysch with sporadic layers of red-brown calcareous claystones to marlstones. Nannofossils were studied at the locality of Salajka (Švábenická et al. 1997). Four samples were studied.

Soláň Formation (Matějka & Roth 1948): medium- to thick-bedded flysch. Its Cretaceous sediments are represented by blue-grey, fine- to coarse-grained sandstones prevailing over grey and dark grey-green claystones. Nannofossils were studied at the localities of Valašské Meziříčí (Švábenická et al. 1997 and see Appendix 1.4), Racková (see Appendix 1.3) and Uzgruň (Bubík et al. 1999). In total, 22 samples were studied.

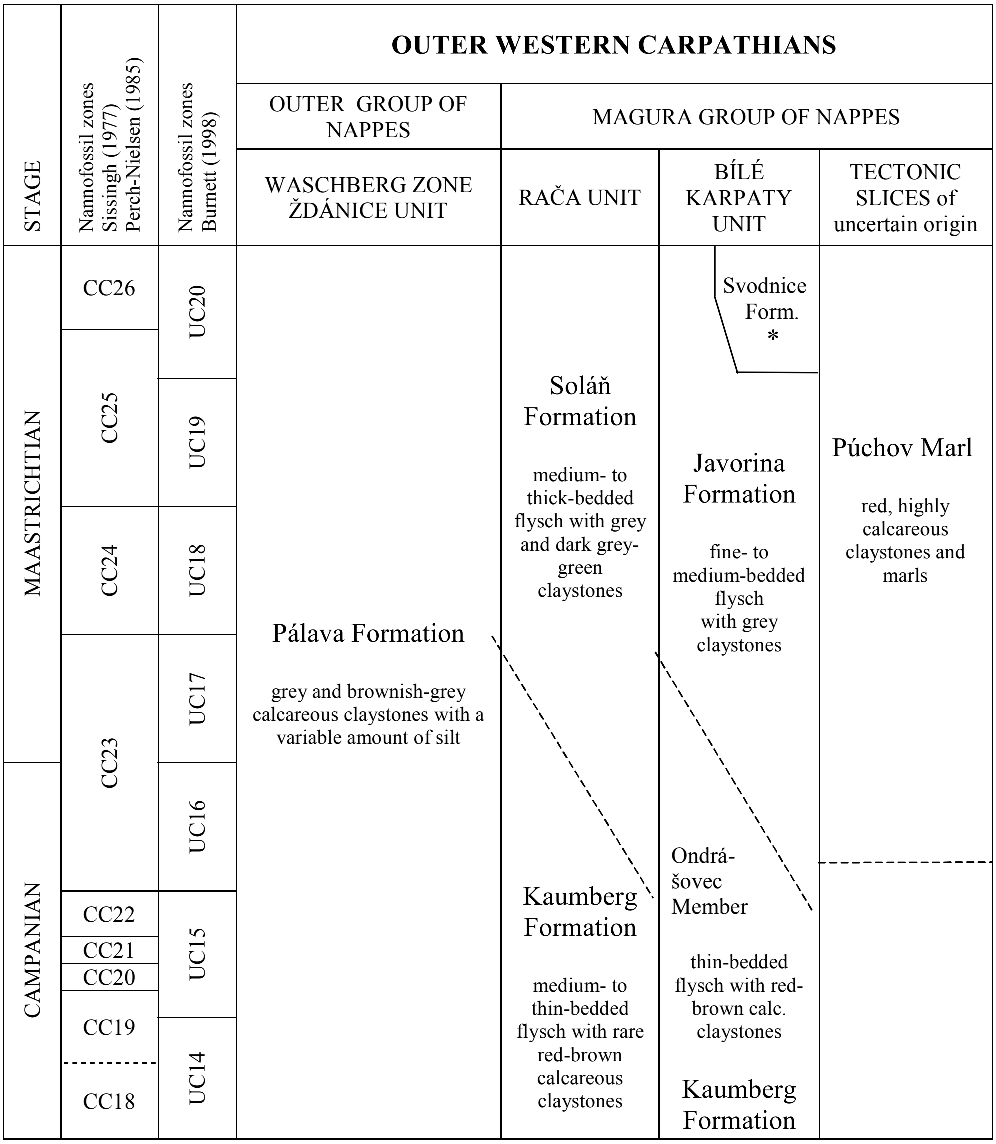


Fig. 4. Chronostratigraphic correlation chart of the lithostratigraphic units of the Outer Western Carpathians mentioned in the text. * Svodnice Formation: medium- to thick-bedded flysch with grey calcareous claystones.

Bílé Karpaty Unit

Ondrášovec Member (Potfaj 1993) of the Kaumberg Formation: thin-bedded flysch with red-brown calcareous claystones. This lithofacies is developed in the upper part of the Kaumberg Formation. Nannofossils were studied at the localities of Janegov Mlyn and Velký Lopeník. In total, 13 samples were studied.

Javorina Formation (Stráník et al. 1989): fine- to medium-bedded flysch contains fine- to medium-grained greywacke sandstones, mostly non-calcareous grey claystones and sporadically intercalations of turbidity limestones. Nannofossils were studied at the localities of Klokočník (Švábenická & Bubík 1992) and Javořina (see Apendix 1.2). In total, 30 samples were studied.

Svodnice Formation (Pesl 1968): medium- to thick-bedded flysch with grey calcareous claystones prevailing over greywacke sandstones. Nannofossils were studied at the locality of Štítná (Švábenická et al. 1997). Twenty samples were studied.

A tectonic slice (Púchov Marl) in the front of the Bílé Karpaty Unit is characterized by red, highly calcareous claystones and marls. Sediments were studied at the locality of Hluk (see Appendix 1.1). Five samples were studied.

Münsterland Basin, NW Germany

Upper Campanian nannofossil associations from the boreholes of Oberdarfeld-1 (Švábenická in Kaever & Lommerzheim 1995) and Longinusturm-1 (Lommerzheim 1995) were included in this study to provide a comparison with coeval associations from sediments deposited on the West European Platform. This depositional area is included within the "boreal" province (Figs. 1 and 5). In total, 150 samples were studied.

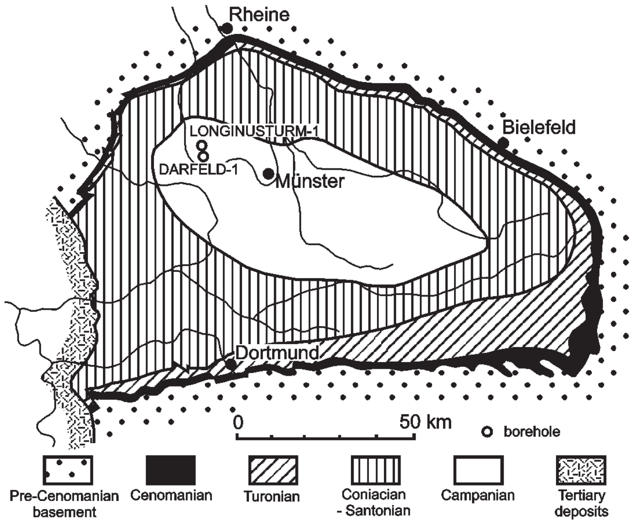


Fig. 5. A sketch map of the Münsterland Basin, NW Germany, and locations of boreholes (in capitals). After Kaever (1980), modified.

Nannofossils in the flysch sediments were generally poorly to moderately well preserved and this is believed to have resulted in reduced assemblage diversity in samples. The mechanical damage to nannofossil species is explained here as resulting from the specific genesis of turbidites: all the components are allochthonous in fact. The significance of calcareous nannofossils as a tool for stratigraphic conclusions in flysch sequences was already discussed by Švábenická & Bubík (1992). Generally, no macrofossils are available in the above mentioned flysch sediments.

Well or moderately preserved nannofossils were obtained from the claystones and marlstones of the Waschberg Zone

Stage	CAMPANIAN			
Nannofossil zones (Burnett 1998)	UC15b-c^{TP}			
Sample	$13B_1$	$13B_2$	$13C_1$	$13C_2$
Preservation	P	P	P	P
Abundance	H	H	H	H
Ahmuellerella octoradiata	F	R	F	R
Amphizygus brooksii	R	R	R	R
Arkhangelskiella cymbiformis	R	R		R
Arkhangelskiella specillata	R	R		R
Biscutum ellipticum	F	F	F	F
Braarudosphaera bigelowii			R	
Broinsonia parca constricta	R	R	R	R
Broinsonia parca parca				R
Calculites obscurus	F	F		R
Ceratolithoides aculeus	F	F	F	F
Ceratolithoides arcuatus	R			F
Chiastozygus litterarius	F	F		F
Cretarhabdus conicus	F	F		F
Cribrosphaerella ehrenbergii	F	F	F	F
Cyclagelosphaera sp.	F			
Cylindralithus biarcus			R	
Eiffellithus eximius	F	R	R	R
Eiffellithus gorkae	F	R	R	R
Eiffellithus turrisieffelii	F	F	F	F
Gartnerago obliquum	F	F	F	F
Haqius circumradiatus			R	
Kamptnerius magnificus	F	F	R	F
Lapideacassis sp.			R	
Lithraphidites carniolensis				R
Lucianorhabdus cayeuxii (curved form)		R	R	
Lucianorhabdus inflatus	F	F	R	F
Manivitella pemmatoidea	R	F	R	R
Microrhabdulus attenuatus	F	F	R	

Stage	CAMPANIAN			
Nannofossil zones (Burnett 1998)	UC15b-c^{TP}			
Sample	$13B_1$	$13B_2$	$13C_1$	$13C_2$
Preservation	P	P	P	P
Abundance	H	H	H	H
Microrhabdulus decoratus	R			R
Micula staurophora	C	C	F	F
Micula swastica		R	R	
Placozygus fibuliformis	F	F	F	
Prediscosphaera arkhangelskyi	R	R		R
Prediscosphaera cretacea	C	F	C	C
Prediscosphaera grandis (fragments)	R			
Prediscosphaera ponticula				R
Prediscosphaera spinosa				R
Prediscosphaera stoveri	R	R		
Quadrum gartneri	R	R		
Quadrum-Uniplanarius		R		
Reinhardtites anthophorus	F	F	F	F
Reinhardtites cf. *R. levis*		R	R	R
Retacapsa crenulata	F	F	F	F
Retacapsa ficula	R			
Retacapsa schizobrachiata	R			
Rhagodiscus angustus			R	
Rhagodiscus asper		R		
Tranolithus minimus			R	
Tranolithus phacelosus	F	F		R
Uniplanarius gothicus	R			
Watznaueria barnesae	C	C	C	C
Watznaueria biporta		R		R
Zeugrhabdotus bicrescenticus	F	F	F	F
Zeugrhabdotus diplogrammus	F	R	F	
Zeugrhabdotus embergeri	R	R	R	F
Zeugrhabdotus praesigmoides	R	R		R

Fig. 6. Calcareous nannofossil distribution at the locality of Salajka, Outer Western Carpathians (Rača Unit, Soláň Formation). Estimated abundance of nannofossil taxa: **C** = common (>1 specimens per field of view), **F** = few (>1 specimen per 10 fields of view), **R** = rare (<1 specimen per 10 fields of view). Preservation of nannofossils: **P** = poor (etching and mechanical damage is intensive). Estimates of the abundance of nannofossils in samples: **H** = relative high (>3 nannofossils per field of view). Categories after Burnett & Whitham (1999), modified.

Stage	CAMPANIAN												
Nannofossil zones Burnett (1998)	$UC15b^{TP}$			$UC15c^{TP}$						$UC15d^{TP}$ – ?UC16			
Locality	Janegov Mlyn					Velký Lopeník							
Sample	16A	16E	16G	17A	18A	$15C_2$	$15C_1$	15B	15A	14A	13E	13E	13B
Preservation	P	M	P	M	VP	P	M	M	VP	VP	M	P	P
Abundance	H	M	M	H	L	M	H	H	L	L	H	M	H
Ahmuellerella octoradiata	R	R	R				F	R			F		
Ahmellerella regularis							R			R	R	R	
Amphizygus brooksii		R	R										
Arkhangelskiella cymbiformis	F	F	F	F			R	R			R	R	
Arkhangelskiella specillata											R		
Biscutum coronum				F							R		
Biscutum ellipticum	F	F	F	F			F	F			F	F	F
Biscutum magnum						R	R	R					
Biscutum notacalum							R				R		
Braarudosphaera bigelowii							R	R			F	R	
Braarudosphaera cf. *B. turbinea*											R	R	
Broinsonia enormis	R	R						F			R	F	R
Broinsonia matalosa	R	R											
Broinsonia parca constricta	F	F	F	F		R	F	F	F	R	F	F	F
Calculites obscurus		F	F	F	R		R	R			F	R	
Calculites ovalis					R	R			R				
Ceratolithoides aculeus	F	F	F	F			F	F	F	R	F	F	F
Ceratolithoides arcuatus			R	R				R	R		R	R	R
Chiastozygus litterarius	F	F	C	F		R	F	F				F	
Corollithion signum	R			R									
Cretarhabdus conicus									R			R	
Cribrosphaerella ehrenbergii	C	C	F	C			F	F	R	R	R	F	F
Cruciellipsis cuvillieri											r		
Cyclagelosphaera sp.	R									R		R	R
Cylindralithus biarcus		F	R								R		
Cylindralithus sp.	R						R	R				R	
Eiffellithus eximius	F	F	F	F		R	F	F	R				
Eiffellithus turriseiffelii	F	F	F	F		F	F	F	R		F	R	R
Eprolithus floralis	R						R	R					
Gartnerago obliquum	F	F	F	F			F	R				F	
Helicolithus trabeculatus	R			R				R					
Kamptnerius magnificus	F	R	R	R			R	R			R	R	
Lithastrinus septenarius											R		
Lithraphidites carniolensis		F		R			R	R					
Lithraphidites praequadratus													R
Lucianorhabdus ex gr. *cayeuxii*									R		F	F	
Lucianorhabdus inflatus		F		F			F	F		R	F	R	R
Manivitella pemmatoidea	R	F	F	F		R	R	F				R	R
Markalius cf. *M. apertus*				R									
Marthasterites furcatus						R		R					

Stage	CAMPANIAN												
Nannofossil zones Burnett (1998)	$UC15b^{TP}$			$UC15c^{TP}$						$UC15d^{TP}$ – ?UC16			
Locality	Janegov Mlyn					Velký Lopeník							
Sample	16A	16E	16G	17A	18A	$15C_2$	$15C_1$	15B	15A	14A	13E	13E	13B
Preservation	P	M	P	M	VP	P	M	M	VP	VP	M	P	P
Abundance	H	M	M	H	L	M	H	H	L	L	H	M	H
Microrhabdulus attenuatus	F	F	F	F			R	R			R	R	
Microrhabdulus decoratus	F					R	R	F	R	R	C	R	R
Micula cf. *M. concava*		F	R	F	R	R		R	R			R	R
Micula starophora	C	F	F	F	F	F	F	F	C	F	C	F	C
Nannoconus sp.											R		
Orastrum campanensis			R										
Petrarhabdus copulatus								R				R	R
Placozygus fibuliformis	R	R	R	R			R	R			F		
Prediscosphaera arkhangelskyi	R		F	R			R						
Prediscosphaera cretacea	C	C	C	C	F	F	F	F	R	F	C	F	F
Prediscosphaera cf. *P. grandis*				R								R	f
Prediscosphaera ponticula	R	R					R	R				F	
Prediscosphaera spinosa	R	R						R			R		
Prediscosphaera stoveri	?	?					R	R			R		
Quadrum gartneri		R					R	R	R		R		
Quadrum-Uniplanarius					R		R				R		
Reinhardtites anthophorus		F	F	F			R	R	R				R
Reinhardtites cf. *R. levis*												F	F
Reinhardtites levis								R			F	R	R
Retacapsa angustiforata		R											R
Retacapsa crenulata	C	F	F	C	F	R	F	F	F		R	F	F
Rhagodiscus angustus				R				R					
Rhagodiscus asper		R						R					
Rotelapillus crenulatus			F				F	F					F
Rucinolithus ?magnus	R			F			R	F			F		
Rucinolithus sp.				R			R					R	
Rucinolithus wissei													
Staurolithites mielnicensis		R									R		
Tranolithus gabalus								R					
Tranolithus phacelosus	F			R			R	R					R
Uniplanarius gothicus							R		R	R	R	R	R
Uniplanarius sissinghii				R		F	F	F	F	F			R
Uniplanarius trifidus										F	F	R	R
Watznaueria barnesae	C	C	A	A	C	C	C	C	C	C	A	A	C
Watznaueria biporta								R				R	
Watznaueria britannica			R					R					R
Zeugrhabdotus bicrescenticus	C	F	F	F			F	F	R		C	F	F
Zeugrhabdotus diplogrammus		R							R			R	
Zeugrhabdotus embergerii	R		R			R	R	R	R		F	R	R
Zeugrhabdotus praesigmoides								R				R	R

Fig. 7. Calcareous nannofossil distribution at the localities of Janegov Mlyn and Velký Lopeník, Outer Western Carpathians (Bílé Karpaty Unit, Ondrášovec Member of the Kaumberg Formation). Estimated abundance of nannofossil taxa: **A** = abundant (>5 specimens per field of view), **C** = common (5–1 specimens per field of view), **F** = few (>1 specimen per 10 field of view), **R** = (<1 specimen per 10 fields of view), **r** = reworked species, **f** = fragments. Preservation of nannofossils: **M** = moderate (overgrowth, etching or mechanical damage is apparent but majority of specimens are easily identifiable), **P** = poor (etching and mechanical damage is intensive making identification of some specimes difficult), **VP** = very poor (some specimens cannot be identified). Estimates of the abundance of nannofossils in samples: **H** = high (>5 nannofossils per field of view), **M** = moderate (1–5 nannofossils per field of view), **L** = low (<1 nannofossil per field of view). Categories after Burnett & Whitham (1999), modified.

and Ždánice Unit. The specimens were slightly etched and broken only rarely, and therefore easily identifiable.

The abundance, species diversity and preservation of nannofossil assemblages in the Longinusturm-1 borehole depend on the lithological character of the sediment. Specimens from sandstones and limestone intercalations were poorly preserved, broken, etched or overgrown with calcite; identification of some specimens was therefore difficult. Marlstones and claystones provided moderately well preserved, easily identifiable specimens.

Methods

Suspension slides were prepared using a decantation method. The 3–30 μm fraction was separated in the following way:

Stage	MAASTRICHTIAN							
Nannofossil zones (Burnett 1998)	UC20b^{TP}	UC20c^{TP}						UC20d^{TP}
Sample	29R	29A	29B	29C	29D	29E	29F	35C
Preservation	M	P	P	M	VP	P	M	M
Abundance	H	L	M	H	L	M	H	H
Acuturris scotus	R						R	F
Ahmuellerella octoradiata	F					R	F	F
Ahmuellerella regularis	R			R		F	F	F
Amphizygus brooksii	R							R
Arkhangelskiella cymbiformis	C	C	C	C	C	C	C	C
Biscutum coronum	F	R		R		R	F	F
Biscutum ellipticum	F	F	F	F	R		F	F
Biscutum melaniae								R
Biscutum notacalum	R							R
Braarudosphaera bigelowii	F		R	R		F		F
Braarudosphaera turbinea							R	
Broinsonia enormis	F		F				F	F
Broinsonia parca constricta			R					
Calculites obscurus	F			F		R		R
Ceratolithoides aculeus			R					
Ceratolithoides kamptneri		R	F	R	F		F	F
Chiastozygus antiquus	F		R	F		R	F	F
Chiastozygus litterarius	F	F	F	R	F	R	F	F
Cretarhabdus conicus	F		R	R		R		
Corollithion exiguum	R							
Corollithion ?madagaskarensis	R			R			R	R
Cribrocorona gallica							R	R
Cribrosphaerella cf. *C. daniae*	R	R		R			F	F
Cribrosphaerella ehrenbergii	F	F	C	F	F	F	F	F
Cyclagelosphaera sp.			R	R		R		
Cylindralithus biarcus				R				
Eiffellithus gorkae	F	F	F	F	F	F	F	F
Eiffellithus parallelus	F	R	F	F	R	R	R	F
Eiffellithus turriseiffelii	F	F	F	F	F	F	F	F
Gartnerago obliquum	F	R					F	F
Helicolithus trabeculatus	R			R				
Kamptnerius magnificus	F	F	R	R		F	F	F
Lithraphidites carniolensis	R			R		R	F	R
Lithraphidites praequadratus						R	R	
Lithraphidites quadratus	F	F	F	F			C	F
Lucianorhabdus cayeuxii	R	R	R	R		R	R	R
Lucianorhabdus inflatus		R		R		R		
Lucianorhabdus ex gr. *maleformis*				R			R	
Manivitella pemmatoidea	R	R	R	R				
Markalius apertus	R	R						R

Stage	MAASTRICHTIAN							
Nannofossil zones (Burnett 1998)	UC20b^{TP}	UC20c^{TP}						UC20d^{TP}
Sample	29R	29A	29B	29C	29D	29E	29F	35C
Preservation	M	P	P	M	VP	P	M	M
Abundance	H	L	M	H	L	M	H	H
Markalius inversus	R			R			R	R
Microrhabdulus attenuatus	R		R	R			F	
Microrhabdulus decoratus	F		F	F		F	F	R
Micula cf. *M. concava*	R	R	R	R		R	R	R
Micula murus	R	R	R	R			R	
Micula murus-prinsii			R				R	
Micula prinsii								R
Micula staurophora	C	C	F	C	C	C	C	C
Micula swastica				R				?
Neocrepidolithus cohenii	R							R
Neocrepidolithus watkinsii						R		R
Nephrolithus frequens	R						R	F
Placozygus fibuliformis	F	F		F		F	F	F
Podorhabdus ?elkefensis	R							R
Prediscosphaera arkhangelskyi	F	R		R			R	R
Prediscosphaera cretacea	C	C	C	C	C	C	C	C
Prediscosphaera grandis	R	R	F	R		R	F	F
Prediscosphaera majungae	F							
Prediscosphaera ponticula		R	R	R		R	R	
Prediscosphaera spinosa	R	R		R	R	R	R	R
Prediscosphaera stoveri	F	R				F	R	F
Psyktosphaera firthii				?				?
Rhagodiscus angustus	R						F	R
Rhagodiscus asper		R				R	R	R
Reinhardtites anthophorus		R	R			R	R	
Reinhardtites levis	F					F		F
Retacapsa crenulata		R	R	F			R	
Retacapsa schizobrachiata			R				R	R
Staurolithites ellipticus	F						F	F
Staurolithites mielnicensis	F						R	F
Thoracosphaera sp.		R	R	R		R	R	
Tranolithus minimus	R							R
Tranolithus phacelosus	F					F	R	
Watznaueria barnesae	F	F	F	F	C	F	F	F
Watznaueria biporta		R	F	R		R		
Watznaueria britannica	R			R		R	R	R
Watznaueria fossacincta			R	R				
Zeugrhabdotus embergeri	R			R			R	
Zeugrhabdotus praesigmoides	F	F	F				F	F
Zeugrhabdotus sp.	R					R	F	F

Fig. 8. Calcareous nannofossil distribution at the locality of Štítná, Outer Western Carpathians (Bílé Karpaty Unit, Svodnice Formation). Estimated abundance of nannofossil taxa: **C** = common (5–1 specimens per field of view), **F** = few (>1 specimen per 10 fields of view), **R** = (<1 specimen per 10 fields of view), ? = questionable species. Preservation of nannofossils: **M** = moderate (overgrowth, etching or mechanical damage is apparent but majority of specimens are easily identifiable), **P** = poor (etching and mechanical damage is intensive making identification of some specimens difficult), **VP** = very poor (some specimens cannot be identified). Estimates of the abundance of nannofossils in samples: **H** = high (>5 nannofossils per field of view), **M** = moderate (1–5 nannofossils per field of view), **L** = low (<1 nannofossil per field of view). Categories after Burnett & Whitham (1999), modified.

the heavy-fraction was allowed to settle for 3 minutes in a 45 mm water column and removed, the fine-fraction was saved for slide preparation after 45 minutes. The slides were studied using a Nikon light-microscope at 1000× magnification.

Quantitative and other data of the nannofossil taxa mentioned in this study were collected using the method of Burnett & Whitham (1999) and slightly modified. The calculation of relative abundances of nannofossil taxa was based on ca. 300–500 specimens. Biostratigraphic data were correlated with the UC zones introduced by Burnett (1998) and compared with the standard nannoplankton CC zones by Sissingh (1977) and Perch-Nielsen (1985). Interpretations of provincial preferences of nannofossil species were based on Wind (1979), Watkins et al. (1996) and Burnett (1998). The herein used terms “boreal” and “tethyan” follow Burnett (1998).

Stage	UPPER CAMPANIAN																											
Nannofossil zones (Burnett 1998)	$UC15d^{BP}$																				$UC15e^{BP}$							
Sample (m)	101.20	100.30	98.60	95.40	91.30	88.40	86.30	81.30	79.70	72.60	69.10	65.20	59.50	51.80	45.35	38.55	37.80	37.00	31.70	28.60	23.40	19.40	17.40	13.20	9.00	6.60	4.20	2.50
Lithology	CM+G	CM+G	L+G	SM+G	CM	L+G	L+G	SM+G	MC	SM	SM	SM	CM	L	CM	MC+G	L+G	MC+G	SM+G	SM+G	SM+G	SM+G	SM+G	SM+G	SM+G	SM+G	SM	SM
Preservation	M	M	VP	VP	VP	M	P	VP	P	P	VP	VP	M	VP	M	M	M	M	M	P	P	VP	VP	VP	M	P	VP	VP
Abundance	H	H	L	L	L	M	M	L	M	M	L	L	M	L	H	H	H	H	H	H	M	L	M	L	H	M	M	L
Acuturris scotus	F	R	R						R				F			R	R		F								R	
Ahmuellerella octoradiata	F	F	F			F			R		R	R	F			F	R	R	R		R					R		R
Ahmuellerella regularis	R		R			R			R								R		R	R								
Angulofenestrelithus snyderi	R												R		R													
Arkhangelskiella confusa	F	R				R							R	R			F								R			
Arkhangelskiella cymbiformis	F	F	F	R	F	F	F	F	F	F	F	F	F	F	F	F	C	F	F	F	F	R	F	R	C	F	R	R
Biscutum coronum	F	R				R	R		R				F		R		F				R				F			
Biscutum dissimilis	R								R		R																	
Biscutum ellipticum	C	C	F			F			R	R		R	R	R	R	F	F	F	F	R			R		F		R	
Biscutum magnum	F	F	R			R			F	R	R		F		R	F	F	R	F				R		R	R	R	R
Biscutum melaniae	F	R				R										F	F	F	F	R	R		R					
Braarudosphaera bigelowii	F	F							R	R	R		R		R	F	F	R	F	R	R		R					
Broinsonia enormis	R	R			R				R	R			F						R		R			R	R		R	
Broinsonia parca constricta	R	F	F	R	R	F	F	F	F	F	F	R	F	F	F	F	F	F	F	F	F	R	F	R	F	F	F	F
Broinsonia matalosa	R												R		R	R												
Broinsonia signata	F	R	R					R	R				R		R		R						R		R			
?Bukrylithus ambiguus	R																		R									
Calculites obscurus	F	C	F	F		F	R	R	F	F	R	F	F	F	R	C	C	F	F		F	F	F	F	F	F	F	R
Chiastozygus litterarius	R		R			F			R	R	R	R	F	R	R	F	R	R	F	R	R	R		R	F		R	
Cretarhabdus conicus	R	F	F		R	F	R	R	F	F	R	R	F	R	R	R	F	F	F	F	R	R	F		F		R	
Cribrosphaerella ehrenbergii	R	F	F		R	F	F	R	F	R	F	R	F		F	R	F	F	F	F	F			R	F	R	F	
Cyclagelosphaera reinhardtii	F	R	R			F				R	R	R	F	R	F	F	F	R	F	R	R	R					F	R
Dodekapodorhabdus noeliae	R									R		R			R	R	R		R	R				f				
Eiffellithus eximius	F	R	R			R	R		R		F		R	R	F	F	F	F	F	F	R		R					R
Eiffellithus gorkae	F	F	R		R	F	R	F	F	R	F	F	F	F	R	F	F	F	F		R			R	F			
Eiffellithus cf. *E. pospichalii*	R																											
Eiffellithus turriseiffelii	F	F	F	F	F	F	F	F	C	F	F	F	F	F	F	C	C	C	C	C	F	C	C	F	C	F	F	F
Eprolithus floralis	R	F		R			R		F			R	F		F	R	F	R	R	F	R	R	R	R				R
Gartnerago obliquum	F	F	F		R	F	R	R	R		R	F	F	R	F	F	F	F	F		R		R	R	R	R	R	R
Grantarhabdus coronadventis	F	R							R	R	R									R			R		R			
Helicolithus trabeculatus	R	R	R			R			R				R	R		R	R			R			R					
Heteromarginatus bugensis	R					R												R										
Kamptnerius magnificus	F	F	F	R	F	F	F	F	F	F	F	R	F	F	F	C	C	C	C		F	R	F	F	F	F	F	F
Lithraphidites carniolensis	R					R																						
Lucianorhabdus cayeuxii	F	F			R	F	R	F	F	F	F		F	F	F	C	C	C	C	R	C	R	F	R	F	F	R	R
Lucianorhabdus cayeuxii (curved forms)	F								F	R	R		R		R	R			F			R	R		R			
Lucianorhabdus inflatus	F	C	F	R		F	R	F	F	F	R	R	C	F	F	F	C	C	C	F	F		R	F	F	R	R	
Manivitella pemmatoidea	R												R		R	R	R		R	R	R						R	
Microrhabdulus decoratus	R																		R									
Micula cf. *M. concava*	F	R	R					R	R	R		R		R	R	R	R	F		F	R							
Micula staurophora	C	C	F	R	F	C	C	C	C	C	C	F	F	C	C	C	C	A	C	A	C	F	F	C	C	F	C	F
Micula swastica	R					R			R										R						R			
Monomarginatus quaternarius	R	R		R	R	F	R	R	R	R	R		f	R		R	R	R	R		R					R		
Neocrepidolithus watkinsii	F					R							R				R											
Orastrum campanensis	F	F	R			R	F	R	F	R	F	R	F	R	F	R	F		R	R								
Placozygus fibuliformis	F	R				F						R	F		R			R	F							R		
Prediscosphaera arkhangelskyi	F	F	R			R					R		R			R	R		R	R								
Prediscosphaera cretacea	C	C	F	R	F	F	F	F	C	F	F	F	C	F	F	A	C	C	C	F		R	F	F	C	F	F	F
Prediscosphaera ponticula	F	R	R			R				R	R	R	R		R	F						R				R		R
Prediscosphaera spinosa	R	R	R			F			R			R	F			R	R	R	R						R			

Fig. 9. Calcareous nannofossil distribution in the Longinusturm-1 borehole, Münsterland Basin (NW Germany). Lithology: **SM** = sandy marlstone, **CM** = clayey marlstone, **MC** = marly claystone, **L** = limestone, **+ G** = with glauconite. Estimated abundance of nannofossil taxa: **A** = abundant (>5 specimens per field of view), **C** = common (5–1 specimens per field of view), **F** = few (>1 specimen per 10 fields of view), **R** = (<1 specimen per 10 fields of view), ? = questionable species, **f** = fragments, **r** = reworked specimens. Preservation of nannofossils: **M** = moderate (overgrowth, etching or mechanical damage is apparent but the majority of specimens are easily identifiable), **P** = poor (overgrowth and etching is intensive making identification of some specimens difficult), **VP** = very poor (some specimens cannot be identified). Estimates of the abundance of nannofossils in samples: **H** = high (>5 nannofossils per field of view), **M** = moderate (1–5 nannofossils per field of view), **L** = low (<1 nannofossil per field of view). Categories after Burnett & Whitham (1999), modified.

Stage	UPPER CAMPANIAN																											
Nannofossil zones (Burnett 1998)	$UC15d^{BP}$																				$UC15e^{BP}$							
Sample (m)	101.20	100.30	98.60	95.40	91.30	88.40	86.30	81.30	79.70	72.60	69.10	65.20	59.50	51.80	45.35	38.55	37.80	37.00	31.70	28.60	23.40	19.40	17.40	13.20	9.00	6.60	4.20	2.50
Lithology	CM+G	CM+G	L+G	SM+G	CM	L+G	L+G	SM+G	MC	SM	SM	SM	CM	L	CM	MC+G	L+G	MC+G	SM+G	SM+G	SM+G	SM+G	SM+G	SM+G	SM+G	SM+G	SM	SM
Preservation	M	M	VP	VP	VP	M	P	VP	P	P	VP	VP	M	VP	M	M	M	M	M	P	P	VP	VP	VP	M	P	VP	VP
Abundance	H	H	L	L	L	M	M	L	M	M	L	L	M	L	H	H	H	H	H	H	M	L	M	L	H	M	M	L
Prediscosphaera stoveri	F	R				R							F						R									
Quadrum gartneri	R										R				R		R											
Quadrum svabenickae	F	R								R							R		R									
Reinhardtites anthophorus	C	C	C		F	F	F	F	C	F	C	C	C	F	F	C	C	F	A	C	C	F	F	F	C	C	F	F
Reinhardtites levis	F	F	R			R	R	F	F		F	F	F	F		C	F	F	F	F	F		F	F	F	F	F	F
Retacapsa angustiforata	F	F					R		R				F															
Retacapsa crenulata	F	F			R	F			R	R					R	F	F	R	F	R			R	R	F		R	
Rhagodiscus angustus	R																											
Rotelapillus crenulatus	F	R											R															
Seribiscutum primitivum	R		R									R					R											
Sollasites horticus	R																											
Staurolithites cf. *S. ellipticus*	F					R		R																				
Staurolithites imbricatus	F					R													F									
Staurolithites laffittei	R					F							F				R		R						R			
Thoracosphaera cf. *T. operculata*	R															R	R	R			R							
Tranolithus orionatus	R	F	R					R	R					R	R	F	R	F								R		
Tranolithus phacelosus	F	F	R			F	R	R	R	R	R	F	F	R	R	F	R	F	F	F	F	R	F	F	F	F	R	
Watznaueria barnesae	A	C	C	F	C	C	C	F	F	C	C	C	C	F	C	A	A	C	C	C	C	F	C	F	C	F	C	F
Watznaueria biporta	R									R		R	R	R		F	R			R					R		R	
Zeugrhabdothus bicrescenticus	F	R	F			F	R					R	F		R	R		F	R		R	R		R	R			
Zeugrhabdothus diplogrammus	F	R	R		R	R	R		R	R	R	F					R	R	F	R	R			R		R		
Zeugrhabdothus praesigmoides	R					R				R			F		R		R						R		F			
Zeugrhabdothus sp.	R	F		R		R	R			R	R		F	R			R	F	F	R	R		R			R	R	R
Lucianorhabdus maleformis		R		R		R							R															
Watznaueria britannica		R															R								R			
Radiolithus sp. (>11 elements)		R	R																R						R			
?*Podorhabdus* sp.		R				R										R												
Arkhangelskiella specillata			R	R						R	R		F												R			R
Staurolithites aachenus			R			R				?			R											R				
Helicolithus cf. *H. turonicus*						r							r															
Lithraphidites praequadratus						R																						
Microrhabdulus attenuatus						R					R								F		R							
?*Misceomarginatus pleniporus*						R																						
Petrorhabdus copulatus						R			R				R		R		R											
Prediscosphaera grandis						R							f			R	R								R			
?*Rhagodiscus infinitus*						R													R									
Staurolithites mielnicensis						R					R		R						R									
Octocyclus reinhardtii									R				R															
Rucinolithus cf. *R. wissei*									F									R										
Zeugrhabdotus embergeri									R	R		R					R		R								R	
Cylindralithus biarcus										R										R								
Cylindralithus serratus													R															
Lapideacassis cf. *L. bispinosa*													R															
Uniplanarius trifidus													R															
Zeugrhabdotus sp.													R				R				R	R	R					
Rhagodiscus asper															R	R	R		R									
Lithastrinus grillii																R												
Lithastrinus septenarius																R			R									
Braarudosphaera cf. *B. turbinea*																					R							
Eprolithus moratus																												R

Continuation of Fig. 9

Results

Outer Western Carpathians

Outer (Menilite-Krosno) group of nappes, Waschberg Zone and Ždánice Unit

Campanian, zones UC15c^{TP}–UC15d^{TP}; UC15d^{BP} (CC21–CC22)

Nannofossil associations are characterized by high species diversity and by the presence of both low- and high-latitude species. Low-latitude nannofossils are represented by genera *Uniplanarius* and *Ceratolithoides,* high-latitude species by genera *Biscutum* (small and large species), *Monomarginatus*, and species *Neocrepidolithus watkinsii* and *Acuturris scotus*. Specimens of genus *Lucianorhabdus* and species *Kamptnerius magnificus* represent up to 5 % of the assemblages. *Watznaueria barnesae* quantitatively prevails over *Micula staurophora* in the approximate ratio 2 : 1.

Upper Maastrichtian, zone UC20d^{TP} (CC26)

The highly diversified assemblage is characterized by high numbers of species *Arkhangelskiella cymbiformis*, *Micula staurophora* (*Watznaueria : Micula* ratio = 1 : 3), *Prediscosphaera* ex gr. *cretacea,* and *Cribrosphaerella ehrenbergii* forming 5–10 % of the assemblages, and by common (1–5 %) *Lithraphidites quadratus, Prediscosphaera majungae,* and *Ahmuellerella regularis.* Low-latitude "tethyan" species are represented by rare *Micula murus* and *M. prinsii,* high-latitude species by *Nephrolithus frequens, Prediscosphaera stoveri* and common *Psyktosphaera firthii*. Moreover, *Biantholithus sparsus* was recorded here on rare occasion. Specimens of genus *Ceratolithoides* were not observed.

Magura group of nappes, Rača and Bílé Karpaty units

Campanian and basal Maastrichtian, zones UC15b^{TB}–UC16 (CC20–CC23a)

Nannofossil assemblages are rather of "tethyan" affinity, with only minor amounts of high-latitude species (Figs. 6 and 7). The associations are characterized by higher numbers of *Watznaueria barnesae*, *Cribrosphaerella ehrenbergii* and *Prediscosphaera cretacea*. A usual component of the assemblages are low-latitude taxa including *Ceratolithoides* (*C. aculeus* prevails), and *Uniplanarius sissinghii* and *U. trifidus*. Though infrequent, high-latitude species, such as *Biscutum coronum* and *Prediscosphaera stoveri*, are also present. *Neocrepidolithus watkinsii* was recorded in the Rača Unit (Valašské Meziříčí locality — see Appendix 1), in the assemblage where *Watznaueria* : *Micula* ratio was observed of approx. 1 : 1.

A tectonic slice in the front of the Bílé Karpaty Unit (Púchov Marl) was studied at Hluk locality (see Appendix 1). The nannofossil assemblage consists of high numbers (5–10 %) of *Watznaueria barnesae* and *Cribrosphaerella ehrenbergii; Lucianorhabdus* is absent. *Uniplanarius trifidus, U. sissinghii, Ceratolithoides aculeus, Micula staurophora* and *Reinhardtites levis* are relatively common, representing ca. 1–3 % of the assemblages. *Biscutum coronum, B. ellipticum, Prediscosphaera stoveri, Kamptnerius magnificus, Petrarhabdus copulatus* and *Tortolithus* cf. *hallii* were recorded in very low numbers (< 0.1 %).

Upper Maastrichtian, zone UC20 (CC26)

Nannofossil assemblages of relatively high species diversity (Fig. 8) include *Lithraphidites quadratus, Eiffellithus paralleus, Markalius apertus* and *Corollithion ?madagaskarensis.* The assemblages are generally characterized by higher numbers of the species *Arkhangelskiella cymbiformis, Watznaueria barnesae* and *Micula staurophora* (forming about 5 %), and by the influx of high-latitude species. This is confirmed by the presence of *Prediscosphaera stoveri, Biscutum coronum*, fragments of *Cribrosphaerella* cf. *daniae*, rare *Acuturris scotus* and very rare *Psyktosphaera firthii.* Low-latitude species are represented by *Ceratolithoides kamptneri, Micula murus* and *M. prinsii.* The *Watznaueria : Micula* ratio is ca. 1 : 2. *Biantholithus sparsus* was also recorded here on rare occasion.

Münsterland Basin

Sediments of the Longinusturm-1 borehole provided nannofossil assemblages of cosmopolitan and high-latitudinal affinities (Fig. 9) indicating a Late Campanian age (zone UC15d-e^{BP}). An exception is sample 59.50 m where one specimen of *Uniplanarius trifidus* (see Fig. 12.36) and rare *Cylindralithus serratus* (see Fig. 12.29,30) were found. Assemblages are characterized by a high number of *Lucianorhabdus,* and a low number of *Cribrosphaerella ehrenbergii*. This phenomenon was especially evident in the interval of 31–38 m.

The whole section contains species *Eiffellithus eximius, Broinsonia parca constricta* and relative common *Reinhardtites anthophorus* and *R. levis*. Small specimens of *Prediscosphaera stoveri* were recorded already in the lowermost part of the section, in association with *Orastrum campanensis, Heteromarginatus bugensis, Neocrepidolithus watkinsii, Biscutum coronum, B. dissimilis*, *Acuturris scotus* and rare *Quadrum svabenickae.* Rare occurrences of *Petrarhabdus copulatus* were observed only occasionally, in the interval of 37.80–88.40 m. Nannofossil associations of the Upper Campanian sediments in the borehole Oberdarfeld-1 provided similar data; no "tethyan" nannofossils were recorded here (Švábenická in Kaever & Lommerzheim 1995).

The occurrences of latitude-restricted nannofossil species in the above mentioned geological units are presented in Figs. 10 and 11.

Discussion

According to Kaever & Lommerzheim (1995), the Münsterland Basin had a transitional position between the Boreal and Tethyan realms in the Late Campanian. This is supported by

UPPER CAMPANIAN –?BASAL MAASTRICHTIAN

taxon considered to be high-latitude
⊕ Watkins et al. (1996), ⊗ Wind (1979)
* taxon strictly limited to one realm (Burnett 1998)
• taxon although globally distributed shows preference for particular province by displaying high abundances (Burnett 1998)
† zonal marker used for European "boreal" and "intermediate", and "austral" provices (Burnett 1998)
# taxon shows preference for low-latitudes (Thierstein 1981)

		Outer Western Carpathians			
		Outer group of nappes	Magura group of nappes		
	Münsterland Basin Longinusturm-1 UC15d-e^{BP}	Waschberg-Ždánice Unit Ernstbrunn, Michelstet., Děvín, UC15d^{TP}-?UC16	Rača Unit Salajka, (UC15b^{TP}) Valašské Meziříčí	Bílé Karpaty Unit Javořina, Lopeník UC15c^{TP}-?UC16	Tectonic slice Púchov Marl Hluk, UC15d^{TP}-UC16
taxa considered to be high-latitude					
Acuturris scotus ⊕⊗	F	R	-	-	-
Biscutum coronum ⊕⊗	F	F	R	R	VR
Biscutum magnum ⊕⊗	F	F	-	-	-
Heteromarginatus bugensis *	R	-	-	-	-
Kamptnerius magnificus •	F	F	R	R	R
Monomarginatus quaternarius ⊕⊗	R	F	-	-	-
Neocrepidolithus watkinsii * ⊕	R	R	VR	-	-
Prediscosphaera stoveri †	F	R	-	VR	VR
Seribiscutum primitivum ⊕	VR	-	-	-	-
Staurolithites aachenus ⊕	F	R	-	-	-
taxa considered to be low-latitude					
Bukryaster hayi *	-	VR	-	-	-
Ceratolithoides aculeus *	-	F	F	F	F
Ceratolithoides arcuatus *	-	R	R	F	-
Ceratolithoides sesquipedalis *	-	F	-	-	-
Cylindralithus serratus #	VR	R	VR	-	R
Uniplanarius sissinghii *	-	F	-	F	F
Uniplanarius trifidus *	-	F	-	F	F-C
taxa of local biostratigraphic or other interest					
Cribrosphaerella ehrenbergii	R	F	F	F	C
Orastrum campanensis	F	F	-	-	?
Petrarhabdus copulatus	VR	R	-	VR	R

Fig. 10. Upper Campanian. Occurrence of latitude-restricted nannofossils in the Outer Western Carpathians and the Münsterland Basin. **C** = common (>1 specimens per field of view), **F** = few (>1 specimen per 10 fields of view), **R** = rare (<1 specimen per 10 fields of view), **VR** = specimen recorded on very rare occasions, **-** = specimen not recorded.

the occurrence of rare "tethyan" and cosmopolitan taxa and demonstrated by the Late Campanian sequence of the Oberdarfeld section. It has important implications for the stratigraphical correlation between the Boreal Realm and the Tethys: cephalopods *Nostoceras polyplocum*, *Trochoceramus* aff. *helveticus* and *Belemnitella mucronata minor* coexist here, nevertheless, nannofloras include "boreal" index species only. Similar nannofossil associations were observed in the Longinusturm-1 borehole. The absence of typical "tethyan" nannofossils, such as *Ceratolithoides* and *Uniplanarius*, within zone UC15d-e^{BP} supports the idea that nannofloras from the Tethys did not penetrate into this depositional area. The only minor influx of low-latitude nannoflora into the NW part of the Münsterland Basin was recorded at a depth of 59.50 m where rare *Cylindralithus serratus* and a single specimen of *Uniplanarius trifidus* were observed. The absence of low-latitude nannofossil species does not allow us to use the nannoplankton biozonation for the "tethyan-intermediate province" sensu Burnett (1998) for the Upper Campanian sediments in the Münsterland Basin.

Burnett (1998) presented *Heteromarginatus bugensis* and *Neocrepidolithus watkinsii* as apparently endemic taxa restricted to high paleolatitudes, and *Kamptnerius, Nephrolithus* and large *Biscutums* as taxa which, although globally distributed, become more abundant in high latitudes. The presence and higher numbers of the above mentioned nannofossils are clear evidence of some influence of the "boreal" province in the Waschberg Zone and Ždánice Unit during the Campanian and Maastrichtian. According to Stráník et al. (1996) this depositional area was situated on the SE passive margin of West European Platform and belonged to the Boreal-Tethyan transitional area. *Heteromarginatus bugensis* has not been observed in the Outer Western Carpathians and was recorded in the Münsterland Basin only.

The gradual change in the character of nannoplankton assemblages is apparent especially in the Outer (Menilite-Krosno) group of nappes (Waschberg Zone and Ždánice Unit) from the Campanian to Maastrichtian. The co-occurrence of low- and high-latitude nannofossils is obvious in the Late Campanian whereas high-latitude taxa become more abundant and low-latitude taxa nearly disappear in the Late Maastrichtian (absence of *Ceratolithoides* during the Maastrichtian). These data may indicate gradual cooling within this depositional area, probably caused by both the increasing dominance of

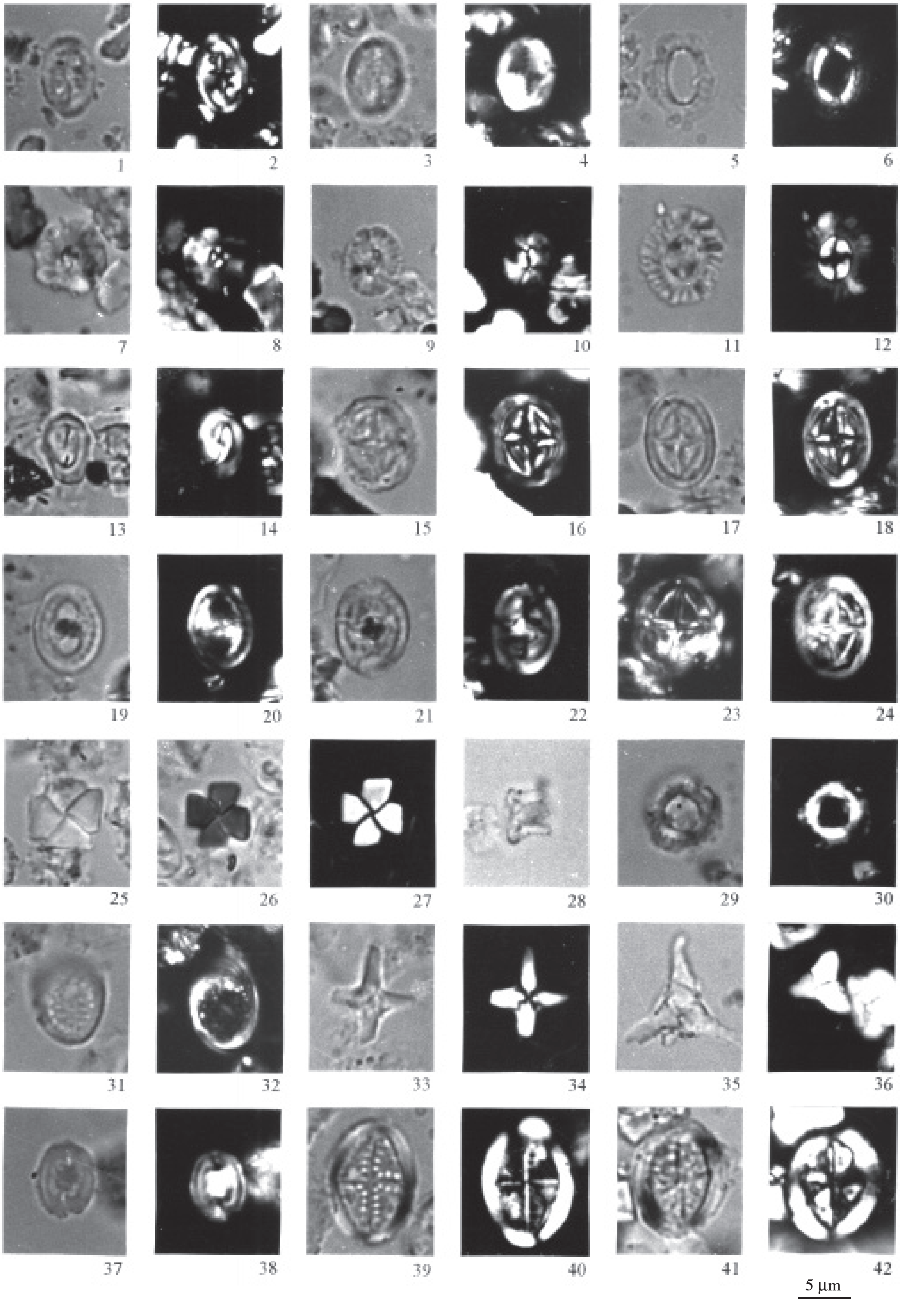
UPPER MAASTRICHTIAN	Outer Western Carpathians		
		Magura group of nappes	
taxon considered to be high-latitude ⊕ Watkins et al. (1996), ⊗ Wind (1979) * taxon strictly limited to one realm (Burnett 1998) • taxon although globally distributed shows preference for particular province by displaying high abundances (Burnett 1998) † zonal marker used for European "boreal" and "intermediate", and "austral" provices (Burnett 1998) ϶ zonal marker used for "tethyan-intermediate" province (Burnett 1998)	Outer group of nappes Waschberg-Ždánice Unit West Klement UC20d^{TP}	Rača Unit Uzgruň UC20	Bílé Karpaty Unit Štítná UC20
taxa considered to be high-latitude			
Acuturris scotus ⊕⊗	F	-	VR
Biscutum coronum ⊕⊗	F	F	F
Cribrosphaerella daniae ⊕⊗	R	VR	VR
Kamptnerius magnificus •	F	F	F
Nephrolithus frequens ⊕	F	F	F
Prediscosphaera stoveri †	F	F	F
Psyktosphaera firthii * ⊕	C	VR	VR
taxa considered to be low-latitude			
Ceratolithoides kamptneri *	-	F	F
Micula murus •	R	F	F
Micula prinsii ϶	F	F	R
taxa of local biostratigraphic or other interest			
Biantholithus sparsus	VR	VR	-
Cribrocorona gallica	R	R	R
Eiffellithus parallelus	F	F	F
Prediscosphaera majungae	C	F	F

Fig. 11. Upper Maastrichtian. Occurrence of latitude-restricted nannofossils in the Outer Western Carpathians. For quantitative explanations see Fig. 10.

southerly paleocurrents from the North European basins and the global cooling during the Late Cretaceous. In addition, the detrital and nutrient input and other factors have to be also taken into account.

The joint occurrence of latitude-restricted nannofossils in the Outer (Menilite-Krosno) group of nappes (Waschberg Zone and Ždánice Unit) documents that the depositional area of the northern margin of the Tethys was influenced by the

Fig. 12. Stratigraphically significant calcareous nannofossils from the Outer Western Carpathians and Münsterland Basin. **PPL:** plane-polarized light, **XPL:** cross-polarized light. **1, 2.** *Heteromarginatus bugensis* (Górka) Crux; Upper Campanian, Münsterland Basin, Longinusturm-1, 88.40 m; 1, PPL; 2, XPL. **3, 4.** *Orastrum campanensis* (Čepek) Wind & Wise; Upper Campanian, Outer Western Carpathians, Waschberg Zone, Ernstbrunn No. 6064; 3, PPL; 4, XPL. **5, 6.** *Biscutum magnum* Wind & Wise; Upper Campanian, Outer Western Carpathians, Waschberg Zone, Ernstbrunn No. 6064; 5, PPL; 6, XPL. **7, 8.** *Biscutum melaniae* (Górka) Burnett; Upper Campanian, Münsterland Basin, Longinusturm-1, 37.80 m; 7, PPL; 8, XPL. **9, 10.** *Biscutum ellipticum* (Górka) Grün; Upper Campanian, Münsterland Basin, Longinusturm-1, 88.40 m; 9, PPL; 10, XPL. **11, 12.** *Biscutum coronum* Wind & Wise; Upper Campanian, Münsterland Basin, Longinusturm-1, 37.80 m; 11, PPL; 12, XPL. **13, 14.** *Neocrepidolithus cohenii* (Perch-Nielsen) Perch-Nielsen; Upper Maastrichtian, Outer Western Carpathians, Magura group of nappes, Uzgruň No. 21A; 13, PPL; 14, XPL. **15–18.** *Neocrepidolithus watkinsii* Pospichal & Wise; Upper Campanian; 15,16: Münsterland Basin, Longinusturm-1, 31.70 m. 17, 18: Outer Western Carpathians, Waschberg Zone, Ernstbrunn No. 6064; 15,17, PPL; 16, 18, XPL. **19, 20.** *Reinhardtites anthophorus* (Deflandre) Perch-Nielsen; Upper Campanian, Outer Western Carpathians, Waschberg Zone, Ernstbrunn No. 6064; 19, PPL; 20, XPL. **21, 22.** *Reinhardtites levis* Prins & Sissingh; Upper Campanian, Münsterland Basin, Longinusturm-1, 88.40 m; 21, PPL; 22, XPL. **23, 24.** *Monomarginatus quaternarius* Wind & Wise; Upper Campanian, Outer Western Carpathians, Waschberg Zone; 23: Děvín; 24: Ernstbrunn No. 6064; XPL. **25–27.** *Petrarhabdus copulatus* (Deflandre) Wind & Wise; Upper Campanian, Outer Western Carpathians; 25: tectonic slice, Púchov Marl, Hluk; 26, 27: Wachberg Zone, Ernstbrunn No. 6064; 25, 26, PPL; 27, XPL. **28–30.** *Cylindralithus serratus* Bramlette & Martini; Upper Campanian; 28: side view, Outer Western Carpathians, Púchov Marl (tectonic slice in the Magura group of nappes), Hluk; 29, 30: Münsterland Basin, Longinusturm-1, 31.70 m; 28, 29, PPL; 30, XPL. **31, 32.** *Angulofenestrellithus snyderi* Bukry; Upper Campanian, Outer Western Carpathians, Waschberg Zone, Ernstbrunn No. 6064; 31, PPL; 32, XPL. **33, 34.** *Uniplanarius sissinghii* Perch-Nielsen; Upper Campanian, Outer Western Carpathians, Waschberg Zone, Ernstbrunn No. 6064; 33, PPL; 34, XPL. **35, 36.** *Uniplanarius trifidus* (Stradner) Hattner & Wise; Upper Campanian; 35: Outer Western Carpathians, Waschberg Zone, Ernstbrunn No. 6064; 36: Münster Basin, Longinusturm-1, 59.50 m; 35, PPL; 36, XPL. **37, 38.** *Podorhabdus*? *elkefensis* Perch-Nielsen; Upper Maastrichtian, Outer Western Carpathians, Štítná No. 35C; 37, PPL; 38, XPL. **39–42.** *Arkhangelskiella cymbiformis* Vekshina; Outer Western Carpathians; 39–40: Upper Campanian, Waschberg Zone, Ernstbrunn No. 6064; 41–42: Upper Maastrichtian, Magura group of nappes, Uzgruň No. 26A$_1$; 39, 41, PPL; 40, 42, XPL. Microphotographs by L. Švábenická.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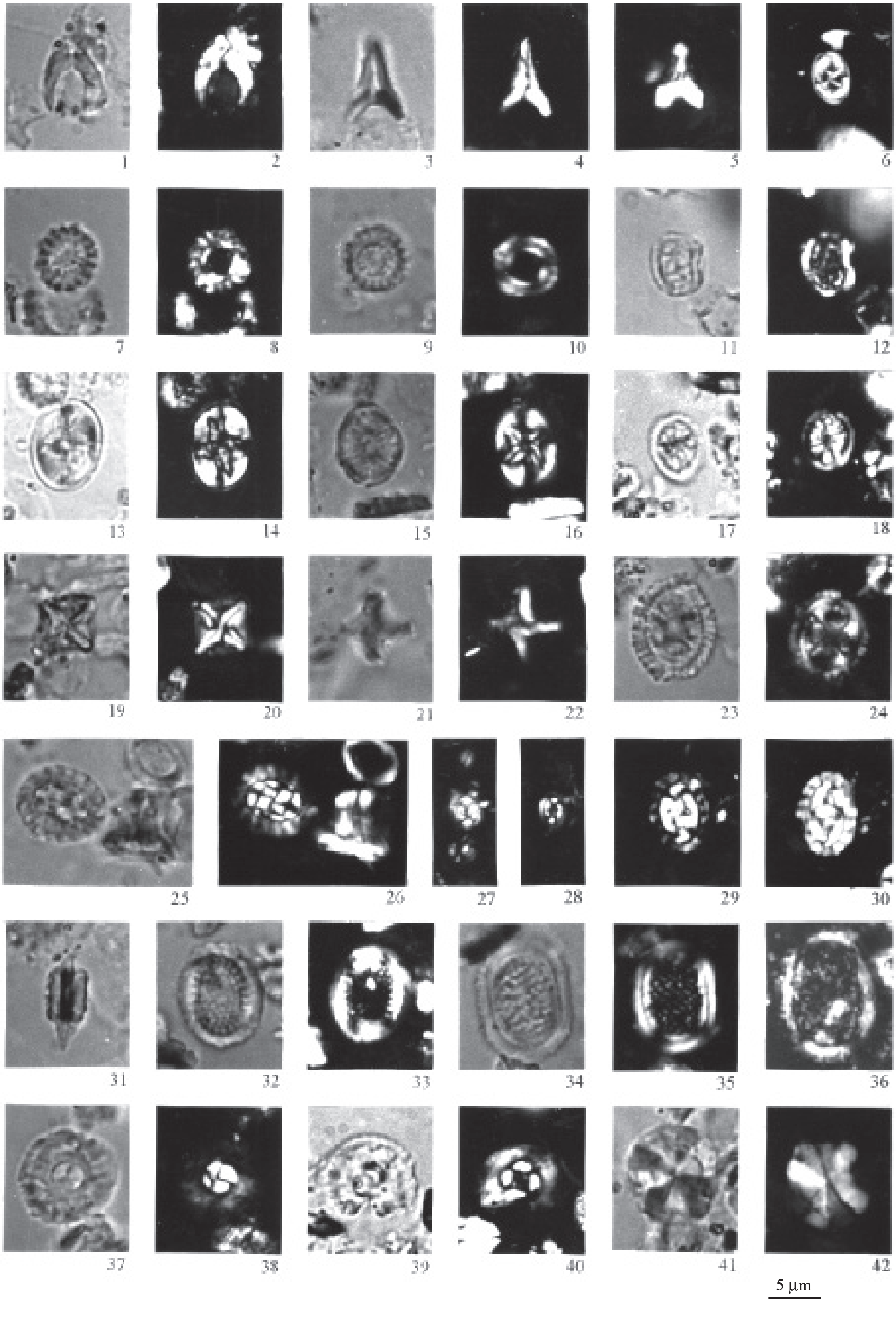
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Boreal region in the Late Cretaceous. The existence of a corridor can be supposed across the Peri-Tethyan basins (Polish Trough) probably connecting the northern Tethyan basins with North European basins from the Turonian–Coniacian until the Maastrichtian–Paleocene (Malata & Poprawa 1997). This path could have caused the migration of high-latitude "boreal" nannoflora into depositional areas of the Outer Western Carpathians during the Campanian–Maastrichtian interval. The abundance of low-latitude taxa and the different character of nannofossil assemblages in the Magura group of nappes document, that its depositional area was located far to the south and was separated from those of the Waschberg-Ždánice Unit by the Silesian Basin and Silesian Cordillera (Potfaj 1998).

The presence of the Paleogene marker species *Biantholithus sparsus* in nannofossil assemblages otherwise Late Maastrichtian in age is mentioned from time to time, for instance by Heck & Prins (1987) and Pospichal & Wise (1990). This species is occasionally observed in small numbers in the Maastrichtian sediments of the Outer Western Carpathians, in the Pálava Formation of the Waschberg Zone, Austria (Summesberger et al. 1999) and the Soláň Formation of the Magura group of nappes (Bubík et al. 1999). The stratigraphic significance of *B. sparsus* seems to be therefore arguable and should be subject to a detailed revision.

Conclusions

The common occurrence of high- and low-latitude nannofossils in the Outer (Menilite-Krosno) group of nappes (Waschberg Zone and Ždánice Unit) documents that the depositional area of the northern margin of the Tethys was connected with the North European basins in the Campanian and Maastrichtian, probably through a corridor of Peri-Tethyan basins, Polish Trough.

The degree of influence by "tethyan" and "boreal" bioprovinces was a function of both the geographical positions of the basins and time:

In the Upper Campanian, "boreal" species (*Neocrepidolithus watkinsii, Monomarginatus quaternarius, Acuturris scotus, Biscutum coronum*) form a significant component of the nannofossil assemblages in the Outer (Menilite-Krosno) group of nappes (Waschberg Zone and Ždánice Unit). In contrast, they are observed in small numbers or are absent in the Magura group of nappes.

In the Upper Maastrichtian, a significant input of high-latitude nannoflora is evident in the Outer (Menilite-Krosno) group of nappes (Waschberg Zone and Ždánice Unit). As concerns the Magura group of nappes, gradual "boreal" influence was recorded here, nevertheless, the nannoflora retains its "tethyan" character.

In the Upper Campanian, similar cosmopolitan and high-latitude nannofossil species occur in the Outer (Menilite-Krosno) group of nappes (Waschberg Zone and Ždánice Unit) and Münsterland Basin. An exception is the species *Heteromarginatus bugensis* which was observed exclusively in the Münsterland Basin.

Low-latitude nannofossil species are nearly absent from the Upper Campanian sediments of the Münsterland Basin.

By virtue of the common occurrence of high- and low-latitude nannofossil species, both "boreal" and "tethyan" zonations sensu Burnett (1998) can be applied to biostratigraphic correlations of the Campanian and Maastrichtian deposits in

Fig. 13: Stratigraphically significant calcareous nannofossils from the Outer Western Carpathians and Münsterland Basin. **PPL:** plane-polarized light, **XPL:** cross-polarized light. **1, 2.** *Ceratolithoides kamptneri* Bramlette & Martini; Upper Maastrichtian, Outer Western Carpathians, Magura group of nappes, Uzgruň 26A$_1$; 1, PPL; 2, XPL. **3, 4.** *Ceratolithoides sesquipedalis* Burnett; Upper Campanian, Outer Western Carpathians, Waschberg Zone, Ernstbrunn No. 6064; 3, PPL; 4, XPL. **5.** *Ceratolithoides aculeus* (Stradner) Prins & Sissingh; Upper Campanian–?basal Maastrichtian, Outer Western Carpathians, Púchov Marl (tectonic slice in the Magura group of nappes), Hluk; XPL. **6.** *Corollithion ?madagaskarensis* Perch-Nielsen; Upper Maastrichtian, Outer Western Carpathians, Magura group of nappes, Štítná No. 35C; XPL. **7–10.** *Cribrocorona gallica* (Stradner) Perch-Nielsen; Upper Maastrichtian, Outer Western Carpathians; 7, 8: Magura group of nappes, Štítná No. 29F; 9, 10: Waschberg Zone, West Klement; 7, 9, PPL; 8, 10, XPL. **11, 12.** *Nephrolithus frequens* Górka; Upper Maastrichtian, Outer Western Carpathians, Magura group of nappes, Uzgruň 21; 11, PPL; 12, XPL. **13, 14.** *Eiffellithus eximius* (Stover) Perch-Nielsen; Upper Campanian, Outer Western Carpathians, Waschberg Zone, Michelstetten; 13, PPL; 14, XPL. **15, 16.** *Eiffellithus parallelus* Perch-Nielsen; Upper Maastrichtian, Outer Western Carpathians, Waschberg Zone, West Klement, 15, PPL; 16, XPL. **17, 18.** *Ahmuellerella regularis* (Górka) Reinhardt & Górka; Upper Maastrichtian, Outer Western Carpathians, Magura group of nappes, Uzgruň No. 26A$_2$; 17, PPL; 18, XPL. **19, 20.** *Micula staurophora* (Gardet) Stradner; Upper Maastrichtian, Outer Western Carpathians, Magura group of nappes, Štítná No. 35C; 19, PPL; 20, XPL. **21, 22.** *Micula prinsii* Perch-Nielsen; Upper Maastrichtian Outer Western Carpathians, Waschberg Zone, West Klement; 21, PPL; 22, XPL. **23, 24.** *Tetrapodorhabdus decorus* (Deflandre) Wind & Wise; Upper Maastrichtian, Outer Western Carpathians, Waschberg Zone, West Klement; 23, PPL; 24, XPL. **25, 26.** *Prediscosphaera majungae* Perch-Nielsen (proximal shield and side view); Upper Maastrichtian, Outer Western Carpathians, Waschberg Zone, West Klement; 25, PPL; 26, XPL. **27, 28.** *Prediscosphaera stoveri* (Perch-Nielsen) Shafik & Stradner; Upper Maastrichtian, Outer Western Carpathians; 27: Waschberg Zone, West Klement; 28: Magura group of nappes, Uzgruň No. 20B; XPL. **29, 30.** *Prediscosphaera arkhangelskyi* (Reinhardt) Perch-Nielsen; Upper Campanian, Outer Western Carpathians, Waschberg Zone, Michelstetten; XPL. **31.** *Lithraphidites quadratus* Bramlette & Martini; Upper Maastrichtian, Outer Western Carpathians, Magura group of nappes, Štítná No. 29F; PPL. **32, 33.** *Cribrosphaerella ehrenbergii* (Arkhangelsky) Deflandre; Münsterland Basin, Longinusturm-1, 37.80 m; 32, PPL; 33, XPL. **34–36.** *Psyktosphaera firthii* Pospichal & Wise; Upper Maastrichtian, Outer Western Carpathians, Waschberg Zone, West Klement; 34, PPL; 35, 36, XPL. **37, 38.** *Markalius inversus* (Deflandre) Bramlette & Martini; Upper Maastrichtian, Outer Western Carpathians, Magura group of nappes, Štítná No. 29F; 37, PPL; 38, XPL. **39, 40.** *Markalius apertus* Perch-Nielsen; Upper Maastrichtian, Outer Western Carpathians, Magura group of nappes, Uzgruň No. 21; 39, PPL; 40, XPL. **41, 42.** *Biantholithus sparsus* Bramlette & Martini; Upper Maastrichtian, Outer Western Carpathians, Magura group of nappes, Uzgruň No. 20; 41, PPL; 42, XPL. Microphotographs by L. Švábenická.

the Outer (Menilite-Krosno) group of nappes of the Outer Western Carpathians.

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References

Bouma A.H. 1962: Sedimentology of some flysch deposits; a graphic approach to facies interpretation. *Elsevier*, 1–168.

Bubík M., Bąk M. & Švábenická L. 1999: Biostratigraphy of the Maastrichtian to Paleocene distal flysch sediments of the Rača Unit in the Uzgruň Section (Magura group of nappes, Czech Republic). *Geol. Carpathica* 50, 1, 33–48.

Bukry D. 1973: Low-latitude coccolith biostratigraphic zonation. *Init. Rep. DSDP* 15, 685–703.

Burnett J.A. 1990: A new nannofossil zonation scheme for the Boreal Campanian. *INA Newsletter* 12, 67–70.

Burnett J.A. 1997: New species and new combinations of Cretaceous nannofossils, and a note on the origin of *Petrarhabdus* (Deflandre) Wind & Wise. *J. Nannoplankton Res.* 19, 2, 133–146.

Burnett J.A. 1998: Upper Cretaceous. In: Bown P.R. (Ed.): Calcareous Nannofossil Biostratigraphy. *Cambridge University Press*, 132–199.

Burnett J.A. & Whitham F. 1999: Correlation between the nannofossil and macrofossil biostratigraphies and the lithostratigraphy of the Upper Cretaceous of NE England. *Proc. Yorkshire Geol. Soc.* 52, 4, 371–381.

Heck S.E.v. & Prins B. 1987: Refined Nannoplankton Zonation for the Danian of the Central North Sea. In: Stradner H. & Perch-Nielsen K. (Eds.): International Nannoplankton Association, Vienna Meeting 1985, Proceeding. *Abh. Geol. Bundesanst.* 39, 285–303.

Hofmann T., Švábenická L. & Hradecká L. 1999: Biostratigraphy of Fissure Fillings in the Ernstbrunn Limestone of the Waschberg Zone (Lower Austria). *Abh. Geol. B.-A.* 56/2, 465–474.

Kaever M. 1980: Geologie des westlichen Münsterlandes. *Führer zu vor- und frühgeschichtlichen Denkmälern,* Mainz, 45, 20–39.

Kaever M. & Lommerzheim A. 1995: The highest Campanian in the transitional area between the boreal and the Tethyan realms in NW-Germany: Implications for stratigraphy, facies, palaeoceanography and palaeoclimatology. *Münstersche Forsch. Geol. Paläont*. 77, 293–327.

Lommerzheim A.J. 1995: Stratigraphie und Ammonitenfaunen des Santons und Campans im Münsterländer Becken (NW-Deutschland). *Geol. Paläont. Westf.* 40, 3–97.

Malata T. & Poprawa P. 1997: Subsidence and uplift analysis of the Polish part of Outer Carpathian basins — backstripping of reconstructed profiles of the basin-fill. In: Krobicki M. & Zuchiewicz W. (Eds.): Dynamics of the Pannonian-Carpathian-Dinaride System. *Przegl. Geol.* 45, 10, 1088–1089.

Matějka A. & Roth Z. 1948: Report of map sheet Vsetín. *Věst. Stát. Geol. Úst*. 23, 133–136 (in Czech).

Perch-Nielsen K. 1985: Mesozoic calcareous nannofossils. In: Bolli H.M., Saunders J.B. & Perch-Nielsen K. (Eds.): Plankton Stratigraphy. *Cambridge University Press*, 329–426.

Pesl V. 1968: Lithofacies of Paleogene in the Magura Unit of the Outer Carpathian Flysch on the territory of Czechoslovakia and Poland. *Sbor. Geol. Vied, Rad ZK* 9, 71–117 (in Czech, English summary).

Pospichal J.J. & Wise W.W. 1990: Maastrichtian calcareous nannofossil biostratigraphy of maud Rise ODP Leg 113 Sites 689 and 690, Weddell Sea. *Proc. ODP, Sci. Results* 113, 465–487.

Potfaj M. 1993: Position and role of the Biele Karpaty Unit in the Flysch Zone of the West Carpathians. *Geol. Práce, Spr*. 98, 55–78 (in Slovak, English summary).

Potfaj M. 1998: Geodynamics of the Klippen Belt and Flysch Belt of the Western Carpathians. In: Rakús M. (Ed.): Geodynamic development of the Western Carpathians. *Geol. Survey of Slovak Republic,* 143–154.

Sissingh W. 1977: Biostratigraphy of Cretaceous nannoplankton, with appendix by Prins B. & Sissingh W. *Geol. en Mijnb.* 56, 37–65.

Stráník Z., Krejčí O. & Menčík E. 1989: Contribution to the geology of the Biele Karpaty Unit. *Zpr. Geol. Výzk. v Roce 1986* 143–147 (in Czech).

Stráník Z., Bubík M., Čech S. & Švábenická L. 1996: The Upper Cretaceous in South Moravia. *Věst. Čes. Geol. Úst*. 71, 1, 1–30.

Summesberger H., Švábenická L., Čech S., Hradecká L. & Hofmann T. 1999: New palaeontological and biostratigraphical data on the Klement and Pálava Formations (Upper Cretaceous) in Austria (Waschberg-Ždánice Unit). *Ann. Naturhist. Mus. Wien* 100A, 39–79.

Švábenická L. 1992: Upper Cretaceous nannofossils from the Klement Formation (Flysch Belt of the West Carpathians, Czechoslovakia). *Proceedings of the 4th INA Conf., Knih. ZPN* 14a, 189–205.

Švábenická L. 1995: The stratigraphical corellation of the Campanian low- and high-latitude calcareous nannofossils in Southern Moravia (Western Carpathians). *Geol. Carpathica* 46, 297–302.

Švábenická L. 1998: Occurrence of *Petrarhabdus copulatus* (Deflandre) Wind and Wise in the Outer Western Carpathians. *Věst. Čes. Geol. Úst.* 73, 2, 89–98.

Švábenická L. 1999: Penetration of high-latitude nannoflora to the depositional area of the Outer Western Carpathians in the Turonian-Maastrichtian. *Geol. Carpathica* 50, Spec. Issue, 77–79.

Švábenická L. & Bubík M. 1992: The fossil record (calcareous nannofossils and foraminifers) in single intervals of the Upper Cretaceous flysch sequence of the West Carpathians, Czechoslovakia. *Cretaceous Research* 13, 583–590.

Švábenická L., Bubík M., Krejčí O. & Stráník Z. 1997: Stratigraphy of Cretaceous sediments of the Magura group of nappes in Moravia. *Geol. Carpathica* 48, 3, 179–191.

Švábenická L., Wagreich M. & Egger H. in press: Late Cretaceous nannofossil assemblages at a transect from the northern Tethys to the temperate realm in Central Europe. In: Michalík J. (Ed.): Tethyan/Boreal Cretaceous Correlation. *Veda,* Bratislava.

Thierstein H. 1976: Mesozoic calcareous nannoplankton biostratigraphy of marine sediments. *Mar. Micropaleont.* 1, 325–362.

Thierstein H.R. 1981: Late Cretaceous nannoplankton and the change at the Cretaceous-Tertiary boundary. *Soc. Econ. Paleont. Min. Spec. Publ.* 32, 355–394.

Thierstein H. & Haq B.U. 1977: Maastrichtian/Danian biogeographic variations in calcareous nannoplankton (Abstr.). *J. Paleontology* 51, Suppl., 28–29.

Tomek Č. 1996: PANCARDI — Dynamics of Ongoing Orogeny. In: Gee D.G. & Zeyen H.J. (Eds.): EUROPROBE 1996 — Lithosphere Dynamics: Origin and Evolution of Continents. *Uppsala University*, 15–26.

Watkins D.K. 1992: Upper Cretaceous nannofossils from Leg 120, Kerguelen Plateau, Southern Ocean. *Proc. ODP, Sci. Results* 120, 343–370.

Watkins D.K., Wise S.W., Pospichal J.J. & Crux J. 1996: Upper Cretaceous calcareous nannofossil biostratigraphy and paleoceanography of the Southern Ocean. In: Moguilevsky A. & Whatley R. (Eds.): Microfossils and Oceanic Environments. *University of Wales*, *Aberystwyth Press*, 355–381.

Wind F.H. 1979: Maastrichtian-Campanian nannofloral provinces of the Southern Atlantic and Indian oceans. In: Talwani M. & Hay W. et al. (Eds.): Deep Sea Drilling Results in the Atlantic Ocean: Continental Margins and Paleoenvironment. *Amer. Geophys. Union* 123–127.

Wise S.W. Jr. 1993: Mesozoic and Cenozoic calcareous nannofossils recovered by Deep Sea Drilling Project Leg 71 in the Falkland Plateau region, Southwest Ocean. *Init. Rep., Deep Sea Drilling Project* 71, 481–550.

Worsley T.R. 1974: The Cretaceous-Tertiary boundary event in the ocean. *SEPM Spec. Publ.* 20, 94–125.

Worsley T.R. & Martini E. 1970: Late Maastrichtian nannoplankton provinces. *Nature* 225, 1242–1243.

Appendix 1

Nannofossil taxa identified at the localities mentioned in text:

1.1 — Hluk (Púchov Marl, tectonic slice in the front of the Bílé Karpaty Unit, Magura group of nappes); Late Campanian–?basal Maastrichtian, zone UC15d^{TP}–UC16.
Ahmuellerella octoradiata, A. regularis, Arkhangelskiella cymbiformis, Biscutum coronum, B. ellipticum, Broinsonia enormis, Broinsonia parca constricta, B. p. parca, Ceratolithoides aculeus, Cretarhabdus conicus, Cribrosphaerella ehrenbergii, Cyclagelosphaera sp., *Cylindralithus serratus, Eiffellithus gorkae, E. parallelus* (one badly preserved specimen), *E. turriseiffelii, Gartnerago obliquum, Kamptnerius magnificus, Lithraphidites carniolensis, Manivitella pemmatoidea, Markalius inversus, Microrhabdulus attenuatus, M. decoratus, Micula staurophora, M. swastica, Petrarhabdus copulatus, Placozygus fibuliformis, Prediscosphaera cretacea, P. grandis, P. majungae, P. ponticula, P. spinosa, P. stoveri, Quadrum gartneri, Reinhardtites levis, Retacapsa angustiforata, R. schizobrachiata, Rotelapillus crenulatus, Rucinolithus wisei, Staurolithites mielnicensis, Tranolithus phacelosus, Uniplanarius gothicus, U. sissinghii, U. trifidus, Watznaueria barnesae, W. biporta, Zeugrhabdothus bicrescenticus, Z. diplogrammus, Z. embergeri, Z. sigmoides,* curved spines (sensu Burnett 1997, p. 145. Plate 1: Fig. 27).

1.2 — Javořina 42D$_1$/95 (Javorina Formation, Bílé Karpaty Unit, Magura group of nappes); Early/Late Campanian boundary, zone UC15c^{TP}.
Arkhangelskiella cymbiformis, Biscutum melaniae, Braarudosphaera bigelowii, Broinsonia parca constricta, Ceratolithoides aculeus, Cretarhabdus conicus, Cribrosphaerella ehrenbergii, Cyclagelosphaera sp., *Eiffellithus eximius, E. gorkae, E. pospichalii, Eprolithus floralis, Glaukolithus compactus, Kamptnerius magnificus, Manivitella pemmatoidea, Micula staurophora, Microrhabdulus attenuatus, M. decoratus, Petrarhabdus copulatus, Placozygus* cf. *sigmoides, Prediscosphaera cretacea, P. grandis* (fragments), *P. spinosa, Reinhardtites anthophorus, Retacapsa crenulata, Thoracosphaera* sp., *Tranolithus phacelosus, Uniplanarius sissinghii, Watznaueria barnesae, W. biporta, W. quadriradiata, Zeugrhabdotus embergeri*.

1.3 — Racková 60B (Soláň Formation, Rača Unit, Magura group of nappes); Late Maastrichtian, zone UC20.
Acuturris scotus, Ahmuellerella octoradiata, A. regularis, Arkhangelskiella cymbiformis, A. cf. *maastrichtiana, Biantholithus sparsus, Biscutum coronum, Braarudosphaera bigelowii, Chiastozygus antiquus, C. litterarius, Corollithion exiguum, C. ?madagaskarensis, Cribrosphaerella ehrenbergii, Eiffellithus gorkae, E. parallelus, E. pospichalii, Gartnerago obliquum, Helicolithus trabeculatus, Kamptnerius magnificus, Lithraphidites carniolensis, L. praequadratus-quadratus, L. quadratus, Lucianorhabdus inflatus, Micula staurophora, Microrhabdulus attenuatus, M. decoratus, Neocrepidolithus cohenii, Octolithus multiplus, Placozygus fibuliformis, P. sigmoides, Prediscosphaera arkhangelskyi, P. cretacea, P. grandis, P.* cf. *majungae, P. spinosa, P. stoveri, Psyktosphaera* cf. *firthii, Retacapsa crenulata, Rhagodiscus angustus, R. asper, Staurolithites mielnicensis, Tegumentum stradneri, Watznaueria barnesae, Zeugrhabdotus bicrescenticus, Z. embergerii, Z.* cf. *trivectis.*

1.4 — Valašské Meziříčí (Soláň Formation, Rača Unit, Magura group of nappes); upper part of Early Campanian, zone UC15b^{TP}.
Arkhangelskiella cymbiformis, A. specillata, Biscutum coronum, B. ellipticum, B. melaniae, Broinsonia enormis, Calculites obscurus, Ceratolithoides aculeus, Chiastozygus litterarius, Cretarhabdus conicus, Cribrosphaerella ehrenbergii, Cyclagelosphaera sp., *Eiffellithus eximius, E. gorkae, Gartnerago obliquum, Kamptnerius magnificus, K. punctatus, Lithastrinus grillii, Lucianorhabdus* ex gr. *cayeuxii, L. inflatus, L. maleformis, Manivitella pemmatoidea, Markalius inversus, Microrhabdulus decoratus, Micula staurophora, Micula swastica, Neocrepidolithus watkinsii, Placozygus fibuliformis, Prediscosphaera cretacea, P. grandis* (fragments), *P. ponticula, P. spinosa, ?Quadrum svabenickae, Reinhardtites anthophorus, R.* cf. *R. levis, Retacapsa angustiforata, R. schizobrachiata, Rucinolithus* sp., *Staurolithites* cf. *S. mielnicensis, Tranolithus phacelosus, Uniplanarius gothicus, Watznaueria barnesae, W. biporta, W. britannica, Zeugrhabdotus bicrescenticus, Z. embergeri, Z. praesigmoides*.

Appendix 2

Nannofossil taxa mentioned in the text, in alphabetical order of genera epithets.

Acuturris scotus (Risatti 1973) Wind & Wise in Wise & Wind 1977
Ahmuellerella octoradiata (Górka 1957) Reinhardt 1966
Ahmuellerella regularis (Górka 1957) Reinhardt & Górka 1967
Amphizygus brooksii Bukry 1969
Angulofenestrelithus snyderi Bukry 1969
Arkhangelskiella confusa Burnett 1998
Arkhangelskiella cymbiformis Vekshina 1959
Arkhangelskiella maastrichtiana Burnett 1998
Arkhangelskiella specillata Vekshina 1959
Biantholithus sparsus Bramlette & Martini 1964
Biscutum coronum Wind & Wise in Wise & Wind 1977
Biscutum dissimilis Wind & Wise in Wise & Wind 1977
Biscutum ellipticum (Górka 1957) Grün & Alleman 1975
Biscutum magnum Wind & Wise in Wise & Wind 1977
Biscutum melaniae (Górka 1957) Burnett 1997
Biscutum notacalum Wind & Wise in Wise & Wind 1977
Braarudosphaera bigelowii (Gran & Braarud 1935) Deflandre 1947
Braarudosphaera turbinea Stradner 1963
Broinsonia enormis (Shumenko 1968) Manivit 1971
Broinsonia matalosa (Stover 1966) Burnett in Gale et al. 1996
Broinsonia parca constricta Hattner et al. 1980
Broinsonia parca parca (Stradner 1963) Bukry 1969
Broinsonia signata (Noël 1969) Noël 1970
?*Bukrylithus ambiguus* Black 1971
Calculites obscurus (Deflandre 1959) Prins & Sissingh in Sissingh 1977
Calculites ovalis (Stradner 1963) Prins & Sissingh in Sissingh 1977
Ceratolithoides aculeus (Stradner 1961) Prins & Sissingh in Sissingh 1977
Ceratolithoides arcuatus Prins & Sissingh in Sissingh 1977
Ceratolithoides kamptneri Bramlette & Martini 1964
Chiastozygus antiquus (Perch-Nielsen 1973) Burnett 1998
Chiastozygus litterarius (Górka 1957) Manivit 1971
Corollithion exiguum Stradner 1961
Corollithion ?madagaskarensis Perch-Nielsen 1973
Corollithion signum Stradner 1963
Cretarhabdus conicus Bramlette & Martini 1964

Cribrocorona gallica (Stradner 1963) Perch-Nielsen 1973
Cribrosphaerella daniae Perch-Nielsen 1973
Cribrosphaerella ehrenbergii (Arkhangelsky 1912) Deflandre in Piveteau 1952
Cruciellipsis cuvillieri (Manivit 1966) Thierstein 1971
Cyclagelosphaera reinhardtii (Perch-Nielsen 1968) Romein 1977
Cylindralithus biarcus Bukry 1969
Cylindralithus serratus Bramlette & Martini 1964
Dodekapodorhabdus noeliae Perch-Nielsen 1968
Eiffellithus eximius (Stover 1966) Perch-Nielsen 1968
Eiffellithus gorkae Reinhardt 1965
Eiffellithus parallelus Perch-Nielsen 1973
Eiffellithus pospichalii Burnett 1998
Eiffellithus turriseiffelii (Deflandre in Deflandre & Fert 1954) Reinhardt 1965
Eprolithus moratus (Stover 1966) Burnett 1998
Eprolithus floralis (Stradner 1962) Stover 1966
Gartnerago obliquum (Stradner 1963) Noël 1970
Grantarhabdus coronadventis (Reinhardt 1966) Grün in Grün & Allemann 1975
Haqius circumradiatus (Stover 1966) Roth 1978
Helicolithus trabeculatus (Górka 1957) Verbeek 1977
Helicolithus turonicus Varol & Girgis 1994
Heteromarginatus bugensis (Górka 1957) Crux in Crux et al. 1982
Kamptnerius magnificus Deflandre 1959
Kamptnerius punctatus Stradner 1963
Lapideacassis cf. *L. bispinosa* (Perch-Nielsen in Perch-Nielsen & Franz 1977) Burnett 1998
Lithastrinus grillii Stradner 1962
Lithastrinus septenarius Forchheimer 1972
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
Lucianorhabdus maleformis Reinhardt 1966
Manivitella pemmatoidea (Deflandre in Manivit 1965) Thierstein 1971
Markalius apertus Perch-Nielsen 1979
Markalius inversus (Deflandre in Deflandre & Fert 1954) Bramlette & Martini 1964
Marthasterites furcatus (Deflandre in Deflandre & Fert 1954) Deflandre 1959
Microrhabdulus attenuatus (Deflandre 1959) Deflandre 1963
Microrhabdulus decoratus Deflandre 1959
Micula concava (Stradner in Martini & Stradner 1960) Verbeek 1976
Micula murus (Martini 1961) Bukry 1973
Micula prinsii Perch-Nielsen 1979
Micula staurophora (Gardet 1955) Stradner 1963
Micula swastica Stradner & Steinmetz 1984
Misceomarginatus pleniporus Wind & Wise in Wise & Wind 1977
Monomarginatus pectinatus Wind & Wise in Wise & Wind 1977
Monomarginatus quaternarius Wind & Wise in Wise & Wind 1977
Nannoconus sp.
Neocrepidolithus cohenii (Perch-Nielsen 1968) Perch-Nielsen 1984
Neocrepidolithus watkinsii Pospichal & Wise 1990
Nephrolithus frequens Górka 1957
Octocyclus reinhardtii (Bukry 1969) Wind & Wise in Wise & Wind 1977
Octolithus multiplus (Perch-Nielsen 1973) Romein 1979
Orastrum campanensis (Cepek 1970) Wind & Wise in Wise & Wind 1977
Petrarhabdus copulatus (Deflandre 1959) Wind & Wise in Wise 1983
Placozygus fibuliformis (Reinhardt 1964) Hoffmann 1970
Podorhabdus? *elkefensis* Perch-Nielsen 1981
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
Quadrum svabenickae Burnett 1998
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
Retacapsa ficula (Stover 1966) Burnett 1998
Retacapsa schizobrachiata (Gartner 1968) Grün in Grün & Allemann 1975
Rhagodiscus angustus (Stradner 1963) Reinhardt 1971
Rhagodiscus asper (Stradner 1963) Reinhardt 1967
Rhagodiscus infinitus (Worsley 1971) Applegate et al. in Covington & Wise 1987
Rotelapillus crenulatus (Stover 1966) Perch-Nielsen 1984
Rucinolithus ? *magnus* Bukry 1975
Rucinolithus wisei Thierstein 1971
Seribiscutum primitivum (Thierstein 1974) Filewicz et al. in Wise & Wind 1977
Sollasites horticus (Stradner et al. in Stradner & Adamiker 1966) Cepek & Hay 1969
Staurolithites aachenus (Bukry 1969) Burnett 1998
Staurolithites ellipticus (Gartner 1968) Lambert 1987
Staurolithites imbricatus (Gartner 1968) Burnett 1998
Staurolithites laffittei Caratini 1963
Staurolithites mielnicensis (Górka 1957) Perch-Nielsen 1968
Thoracosphaera operculata Bramlette & Martini 1964
Tortolithus hallii (Bukry 1969) Crux in Crux et al. 1982
Tranolithus gabalus Stover 1966
Tranolithus minimus (Bukry 1969) Perch-Nielsen 1984
Tranolithus orionatus (Reinhardt 1966) Reinhardt 1966
Tranolithus phacelosus Stover 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 Wind & Cepek 1979
Watznaueria quadriradiata Bukry 1969
Zeugrhabdotus bicrescenticus (Stover 1966) Burnett in Gale et al. 1996
Zeugrhabdotus diplogrammus (Deflandre in Deflandre & Fert 1954) Burnett in Gale et al. 1996
Zeugrhabdotus embergeri (Noël 1958) Perch-Nielsen 1984
Zeugrhabdotus praesigmoides Burnett 1998
Zeugrhabdotus sisyphus (Gartner 1968) Crux 1989
Zeugrhabdotus trivectis Bergen 1994