GEOLOGICA CARPATHICA, 53, 3, BRATISLAVA, JUNE 2002
197–210

CALCAREOUS NANNOFOSSILS OF THE UPPER KARPATIAN AND LOWER BADENIAN DEPOSITS IN THE CARPATHIAN FOREDEEP, MORAVIA (CZECH REPUBLIC)

LILIAN ŠVÁBENICKÁ

Czech Geological Survey, Klárov 131/3, 118 21 Prague, Czech Republic; svab@cgu.cz

(Manuscript received November 13, 2001; accepted in revised form March 19, 2002)

Abstract: Calcareous nannofossils were studied in the Karpatian and Lower Badenian deposits of the Carpathian Foredeep, Moravia in view of their use in biostratigraphy. The following nannofossil horizons were recognized: 1. "helicolith" horizon with common *Helicosphaera ampliaperta* in sandy clays ("schlier") of the Laa Formation, 2. Helicosphaera waltrans horizon in clays and siliciclastic sediments of the Grund Formation and in the basal siliciclastic sediments of the Lower Badenian, and 3. Sphenolithus heteromorphus horizon in clays ("tegel") of Lower Badenian (Moravian) age. In its upper part, oval forms of *Coronocyclus nitescens* and 5-rayed symmetrical discoasters appear. The occurrence of species *H. waltrans* is limited to a short stratigraphic interval approximately corresponding to the range of planktonic foraminiferal species *Globigerinoides bisphericus* and includes the first appearances of *Praeorbulina* ssp. and *Orbulina suturalis.* The dominance of helicoliths in the Laa and Grund formations and in the basal siliciclastic sediments of the Lower Badenian gives evidence for a shallow epicontinental sea. Nannofossil enrichment above the Helicosphaera waltrans horizon evidences deepening of depositional area, open-sea conditions, and reflects the Lower Badenian transgression. The problem of correlation of the Central Paratethys regional stages either with the Mediterranean chronostratigraphic scale or with NN zones was discussed.

Key words: Carpathian Foredeep, Miocene, Karpatian, Badenian, calcareous nannofossils, biostratigraphy, paleoecology.

Introduction

The Carpathian Foredeep is a foreland basin bordering the West-Carpathian arch along its distal periphery. Paleogeographically, it is included into the intercontinental basins of the Central Paratethys. In the Oligocene and Miocene, this area was a region of shallow, variable-salinity basins with specific macrofauna, microfauna and nannoflora. The complicated paleogeographical development of the Central Paratethys influenced mainly by the terminal phases of the Alpine Orogeny has been broadly studied, recently by Rögl (1998), Kováč et al. (1998), Jarosiński & Krzywiec (2001) and others.

Biostratigraphic evaluation based on calcareous nannofossils was carried out for the Lower to Middle Miocene deposits of the Carpathian Foredeep, southern and central Moravia, Czech Republic (Fig. 1). Attention was focused on the Karpatian-Badenian strata where foraminifers with species *Globigerinoides bisphericus* and genera *Praeorbulina* and *Orbulina* appear for the first time, and on the overlying Lower Badenian deposits.

Nannofossil species *Helicosphaera waltrans* was found to be a significant marker for biostratigraphic subdivision of the Karpatian and Badenian sediments within the NN4/NN5 zone boundary. Its occurrence forms a significant interval with probably short stratigraphic range.

The aim of the present study was to analyse nannofossil assemblage with *H. waltrans* and the assemblages below and above the occurrences of this species and to test the eligibility of *H. waltrans* as a zonal marker in the Carpathian Foredeep.

Previous studies

Biostratigraphic evaluation of the Karpatian and Badenian deposits of the Carpathian Foredeep in Moravia was largely based on foraminifers, especially in the papers by Vašíček (1949) and Molčíková (1967). Attention was focused on Karpatian foraminifers by Cicha & Zapletalová (1967) and Papp et al. (1978). Modern biostratigraphic interpretations are presented in the works of Cicha (1995, 1999, 2001), Cicha et al. (1998), Pálenský & Čtyroká (1994), Cicha & Čtyroká (1995), Čtyroká et al. (1995) and Čtyroká & Pálenský (1997).

Calcareous nannofossils were studied by Molčíková (1974, 1978, 1983). She distinguished the Karpatian Stage from the Badenian one within zone NN5, according to the first occurrence of the species *Discoaster variabilis*. Lehotayová & Molčíková (1978) presented an overview on Badenian nannofossil assemblages in the territory of former Czechoslovakia. The first comparisons of nannofossil biostratigraphy with foraminiferal data have been carried out by Čtyroká & Švábenická (1997, 2000) and Švábenická & Čtyroká (1998, 1999).

In the Polish part of the Carpathian Foredeep, Middle Miocene nannofossils were described by Martini (1977), Gonera & Slezak (in Cieszkowski et al. 1988) and Dudziak & Łaptaś (1991). In the Outer Western Carpathians, Slezak et al. (1995) attributed the terminal flysch deposits of the Skole Nappe to the early Lower Badenian, zone NN5. The correlation of nannofossils with foraminiferal microfauna in the Polish part of Central Paratethys was presented by Dudziak & Łuczkowska (1991) and in the Outer Carpathians and its foredeep by Garecka & Olszewska (1998).

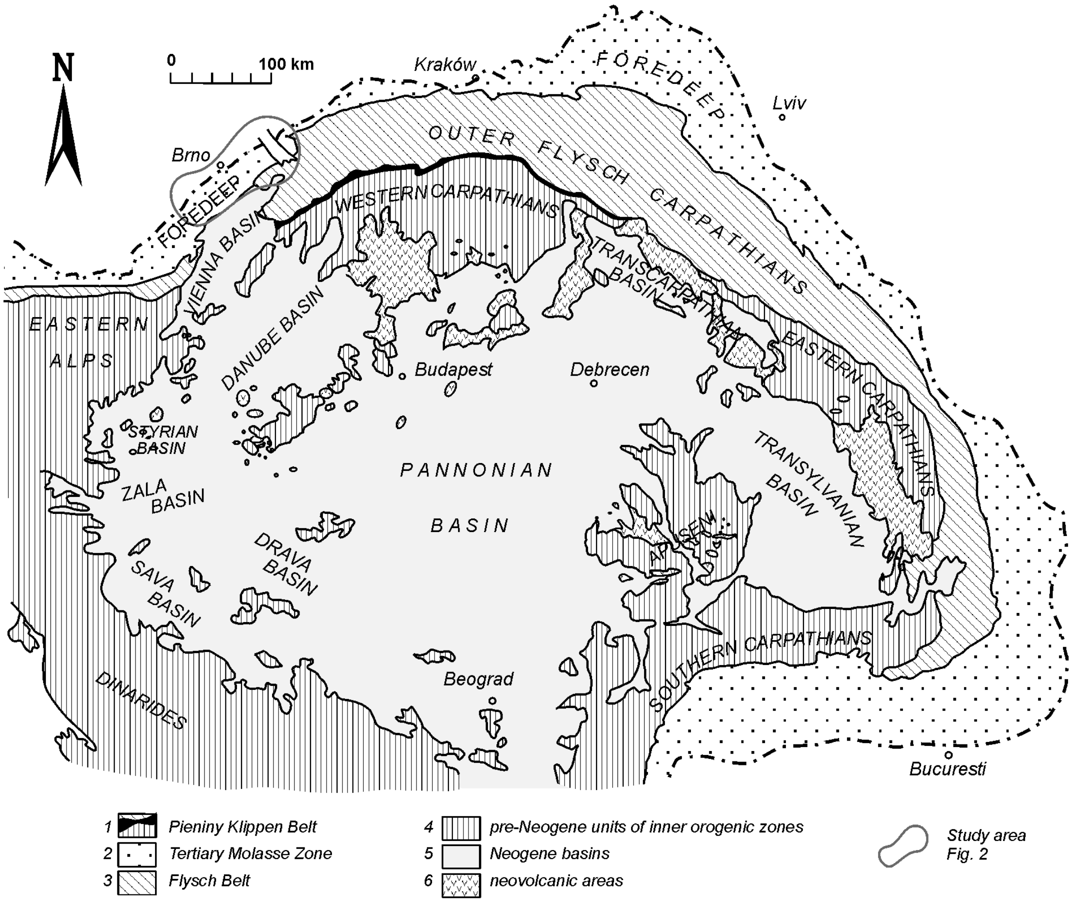


Fig. 1. Schematic geological map of the western part of the Western Carpathians, and the location of the study area.

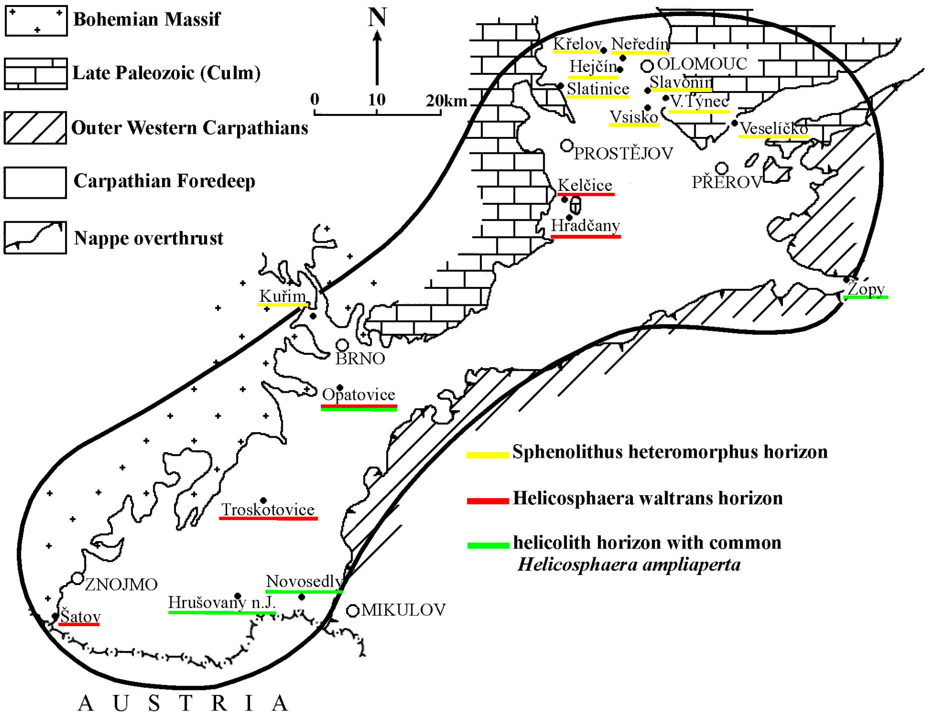


Fig. 2. A sketch map of the Carpathian Foredeep, southern and central Moravia, Czech Republic, showing the location of the studied localities and major cities (in capitals). Nannofossil horizons are marked in colours.

Nannofossil associations from the lower part of the Badenian were described by Lehotayová (1975) in the Danube Lowland. A comparison of the Karpatian nannofossil assemblages (zones NN4 and NN5) in the Intra-Carpathian basins of Slovakia with those of the same age from the Carpathian Foredeep in Moravia was worked out by Lehotayová (1984). The nannoplankton biostratigraphy of the Lower and Middle Miocene deposits of the Vienna Basin, Slovak Republic and its comparison with the Mediterranean and Paratethyan zonations was presented by Andreyeva-Grigorovich et al. (2001). In this paper, the short stratigraphic range of *Helicosphaera waltrans* is correlated within the midle part of Badenian.

Fuchs & Stradner (1977) combined foraminiferal and nannofossil data in the study of Badenian sediments of the Vienna Basin, Austria. Nannofossil assemblages of zone NN5 with *Sphenolithus heteromorphus* and discoasters were correlated with the "Untere Lageniden-Zone" where planktonic foraminifers *Globigerinoides bisphericus* and *Praeorbulina glomerosa* s.l. appear for the first time. Stradner & Fuchs (1978) presented an overview of nannoplankton in the Badenian strata (zones NN5 and NN6/7) of Austria. Švábenická (1993, 2000) focused on the species *Helicosphaera waltrans* as a significant marker in the Karpatian-Badenian boundary strata of the Alpine-Carpathian Foredeep, Lower Austria.

Lower and Middle Miocene nannofossils in the Hungarian territory of the Paratethys were broadly studied by Báldi-Beke & Nagymarosy (1979), Báldi-Beke (1980, 1982) and Nagymarosy (1985). In Romania, Mărunţeanu (1992, 1993, 1999) reported the occurrence of index nannofossil species in the Miocene deposits of Intra- and Extra-Carpathian basins, and compared it with the Mediterranean and Paratethyan areas. The Karpatian/Badenian boundary is placed here within the Langhian Stage of the general stratigraphic classification.

As concerns the Eastern Paratethys, Andreyeva-Grigorovich & Savytskaya (2000) worked out a nannofossil stratigraphy within zone NN5 (Tarkhanian/Langhian) and correlated it with the Central Paratethys and Mediterranean stages.

Material

Calcareous nannofossils were studied from the Lower-Middle Miocene boundary deposits of Carpathian Foredeep in the area of southern and central Moravia, Czech Republic (Fig. 2).

Localities	Sample No.	preservation of nannofossils	abundance of nannofossils	% of reworked specimens (estimate)	*Braarudosphaera bigelowii*	*Calcidiscus leptoporus*	*Calcidiscus macintyrei*	*Calcidiscus premacintyrei*	*?Catinaster* sp.	*Coccolithus miopelagicus*	*Coronocyclus nitescens* (circular forms)	*Coronocyclus nitescens* (oval forms)	*Discoaster adamanteus*	*Discoaster deflandrei*	*Discoaster exilis*	*Discoaster variabilis*	*Discoaster* sp. (5-rayed forms)	*Helicosphaera ampliaperta*	*Helicosphaera carteri*	*Helicosphaera mediterranea*	*Helicosphaera scissura*	*Helicosphaera vedderi*	*Helicosphaera walbersdorfensis*	*Helicosphaera waltrans*	*Pontosphaera discopora*	*Pontosphaera multipora*	*Reticulofenestra haqii*	*Reticulofenestra minuta*	*Reticulofenestra pseudoumbilicus* (<7 µm)	*Reticulofenestra pseudoumbilicus* (>7 µm)	*Rhabdosphaera sicca*	*Rhabdosphaera* sp.	*Sphenolithus heteromorphus*	*Syracosphaera* sp.	*Triquetrorhabdulus* sp.	*Umbilicosphaera rotula*
Novosedly	A	M	L	98														R	VR							VR		R	R							
	B	M	L	98														R		R	R					VR			VR							
Hrušovany n. J.	1	P	M	98														R	VR		R					VR		VR	VR				?		VR	
	2	M	M	95														R	F	VR	F	VR				VR										
Žopy	224	P	VL	90							VR							F	VR		VR				VR	VR										
Opatovice HJ-103	301 m	P	L	90														C									VR		R							
	287 m	P	L	90	VR			VR		VR				VR				R	F		VR	R				VR	R	R	F	VR			VR	VR		
	238 m	M	VH	75	VR	R	VR	F		VR			R		VR	VR			C			F		F		F		C	F	R			F	F		R
	210 m	M	L	80						R			VR			VR		R	C	VR	VR			F		R	R	R	F				VR			VR
Šatov	1	P	L	95														R	R		VR			VR		VR	VR	R	VR					VR		
	3	P	L	95	R					VR								R	R			VR		R				VR	R				VR			
	6	P	L	99												VR			VR					VR					VR							
	7	M	M	95	VR			VR		R	VR					VR						R		F				R	R				VR			
	8	P	L	99						VR						VR		VR	VR		VR			VR	VR	VR			VR							
	9	P	L	95	VR														F		VR			F		VR	VR	VR	R				R			
Troskotovice		P	L	95						VR								VR	F		R			F			VR	R	R							
Hradčany	14	M	VH	90			?			R	VR				VR	VR		R	F	VR				F		R	R	R	R	VR			VR	R		
Kelčice	K1	M	H	90				VR		R	VR				R	VR			F		R		VR	F		VR		R	R		R		R			R
Veselíčko	31	M	H	85	R	R				R	VR		VR	R	R	VR		VR	F	VR	R					R	VR	R	R	VR	R		R	VR		
Velký Týnec	4	M	VH	60			R	R		F			VR		F	F		VR	R				F			R		R	R	R		R	F	R		
	23	M	M	90	VR					R			VR		R				VR		R		R			R	VR		VR	VR	R	R	R			
Slatinice	A	M	H	75	R	R	R	R		F					VR				F		VR		R			R		R	VR	R	R		C			R
Slavonín	5	M	M	40			R			F					C	C			F				R			R	R	F	R	R			C	R		F
	6	M	H	50						R	R	R			C	C		VR	F				F		R	F	F	F	C	F			R	R		F
	7	M	H	60					?	F			R		C	C			F				F			F	F	R	C	C	R		VR			R
	8	M	H	50			R	F	?	F	R	F			C	C	R		C				F			C	R	F	C	C	F		R	R		F
	9	M	H	50				F		F	F	F		R	C	C			F				F		R	F	R	C	F	F	F		F			C
	S2	M	M	30	R					F	F			R	C	C		VR	C		VR		F			F	R	F	C	F	F		R			
Vsisko	6	M	VH	70					?	C	F								C				C			C	R	F	F	F			C	F		F
Hejčín	H1	M	VH	90						C					R	R		VR	C		VR					F	R	R	R	F	F		R			
Neředín	2	M	VH	80			R			R	R			R	C	C			F	VR					R	F		F	R	F			C			F
	3	M	M	80				VR		R								VR	C	VR						R		F	R	R	F		C			
Křelov	K2	M	M	60	R	R	R	R		F			R	R		F			C				R			F	R	C	C	F	R	R	R			F
	2	M	H	50		R	F	C		F	C				F	F			F				F			F		F	C	F			F	F		C
Kuřim-Pod Jánečkem		M	H	60	R	R		F		C				R	R				C				C		R	C	F	F	F	F	F		F	F		C
Kuřim	V101	M	VH	40				F	?	C			R	R	C	C	R	VR	C				F			C	F	F	C	C	F	R	F			F

Fig. 3. Carpathian Foredeep, southern and central Moravia, Czech Republic. Distribution of calcareous nannofossil taxa the first occurrence of which is mostly known in the Miocene. *Abundance of nannofossil taxa:* **C** — common (>1 specimen per field of view), **F** — few (1–10 specimens per 10 fields of view), **R** — rare (1–10 specimens per 20 fields of view), **VR** — very rare (<1 specimen per 20 fields of view). *Preservation of nannofossils:* **M** — moderate (etching or mechanical damage is apparent but majority of specimens are easily identifiable), **P**— poor (etching and especially mechanical damage is intensive making identification of some specimens difficult). *Estimates of the abundance of nannofossils in samples:* VH = very high (>20 specimens per field of view), **H** — high (10–20 specimens per field of view), **M** — moderate (5–10 specimens per field of view), **L** — low (1–5 specimens per field of view), **VL** — very low (<1 specimen per field of view).

The deposits comprise Karpatian sandy clays ("schlier") of the Laa Formation and Karpatian-Badenian siliciclastic sediments and clays of the Grund Formation (sensu Cicha 2001). Above, Lower Badenian basal and marginal siliciclastic sediments, clays ("tegel") and Lithothamnion Limestone were deposited. Lower Badenian clays ("tegel") are characterized by the presence of benthic Lanzendorf microfauna (Cicha & Tejkal 1965).

Material was sampled during mapping and other geological works. This contribution gives an overview of all available data. The results are considered to be state-of-the-art. Precise correlation remains obscure because no continuous section crossing the Karpatian/Badenian boundary and overlying Lower Badenian strata has been made yet.

Methods

Suspension slides were prepared using a decantation method (separated fraction of 3–30 μm in the following procedure: the heavy fraction was allowed to settle for 3 minutes in a 45-mm water column, the fine fraction for 45 minutes). Slides were inspected with a Nikon light-microscope at 1000× magnification.

Quantitative data on Miocene taxa mentioned in this study were obtained by counting the number of specimens per field of view under the microscope. This method was chosen because of the presence of a high number of reworked nannofossils in taphocoenoses.

Biostratigraphic conclusions were based exclusively on species whose first appearance is known from the Miocene. Biostratigraphic data were compared with the standard nannoplankton NN zones of Martini (1971) and Young (1998), and MNN (Mediterranean Neogene Nannoplankton) zones of Fornaciari et al. (1996).

Results

Samples provided moderately well or poorly preserved calcareous nannofossils (Fig. 3). Large placoliths and helicoliths (>10 μm in long axis) occur mostly in fragments and the distal rays of discoasters are broken or strongly etched especially in deposits with an admixture of sand and silt.

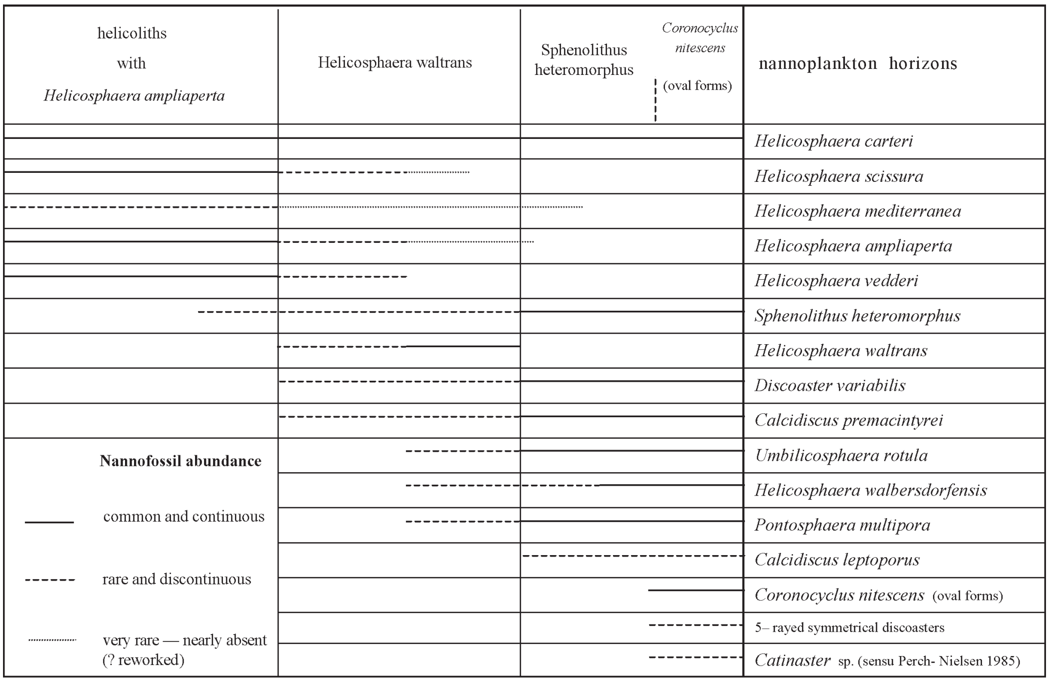
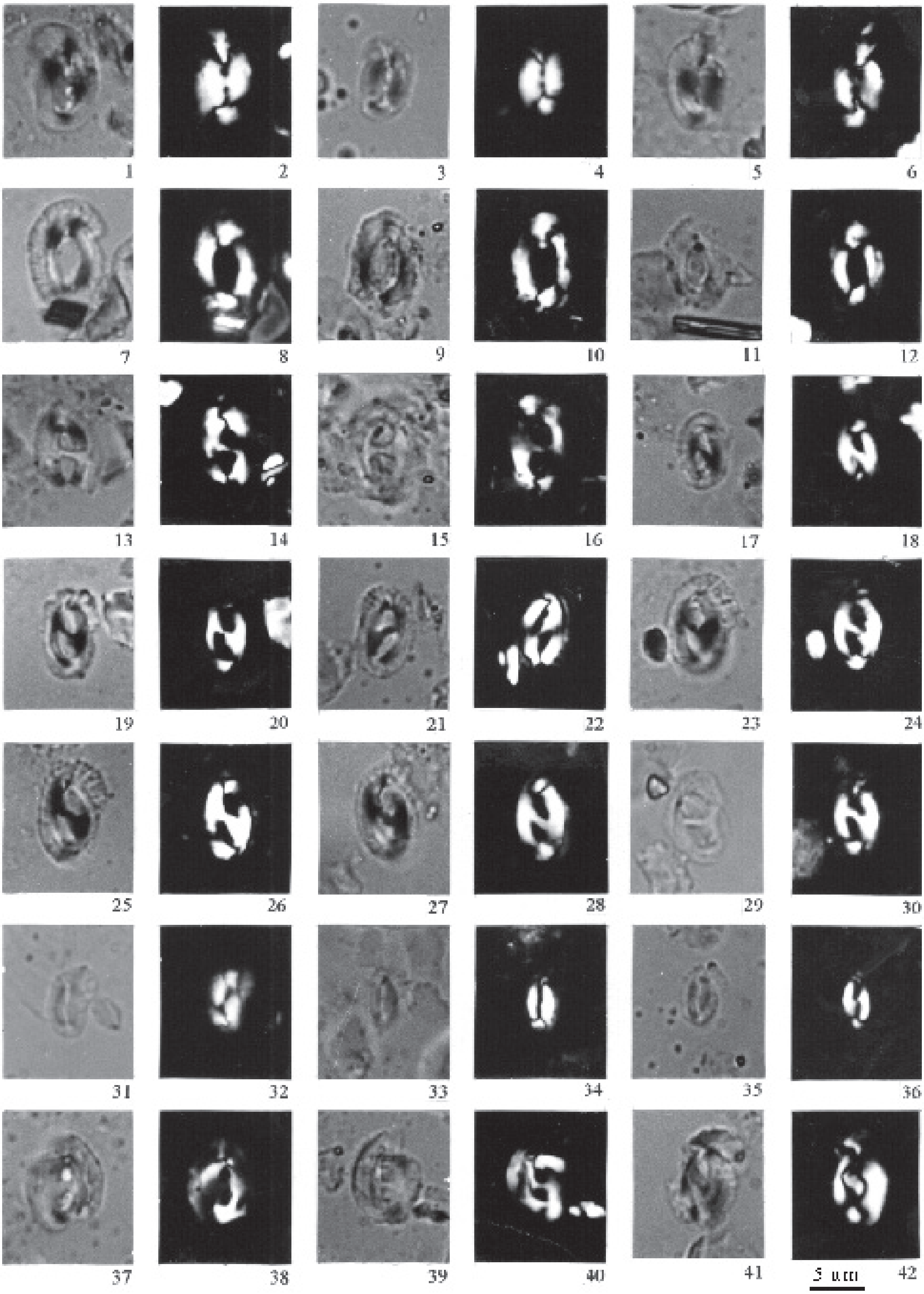
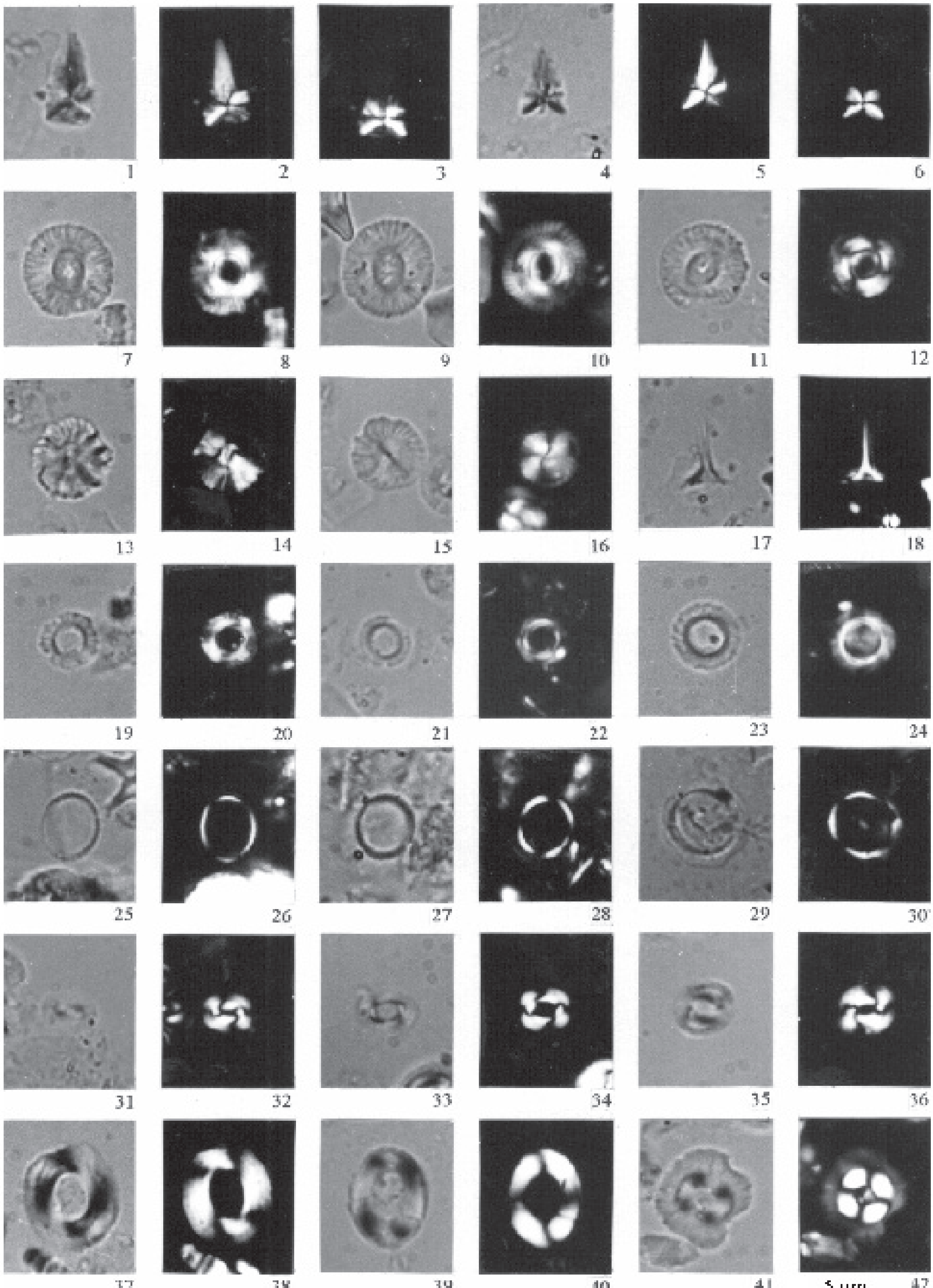


Fig. 4. Carpathian Foredeep, southern and central Moravia, Czech Republic. Distribution of stratigraphically significant calcareous nannofossils in the Karpatian and Lower Badenian deposits and delimination of nannoplankton horizons.

Fig. 5. Miocene calcareous nannofossils of the Karpatian and Lower Badenian deposits in the Carpathian Foredeep, Moravia (Czech Republic). **PPL** — plane-polarized light, **XPL** — cross-polarized light. **1–6** — *Helicosphaera carteri* (Wallich) Kamptner. 1, 2 — Lower Badenian clays, Vsisko No. 71; 1: PPL, 2: XPL; 3, 4 — Lower Badenian clays, Hejčín No. 28; 3: PPL, 4: XPL; 5, 6 — Laa Formation, Novosedly No. 2; 5: PPL, 6: XPL. **7–12** — *Helicosphaera ampliaperta* Bramlette et Wilcoxon, Laa Formation. 7, 8 — Novosedly No. 2; 7: PPL, 8: XPL; 9–12 — Opatovice HJ103 (301.7 m); 9,11: PPL, 10,12: XPL. **13–16** — *Helicosphaera mediterranea* Müller, Laa Formation. 13, 14 — Hrušovany; 13: PPL, 14: XPL; 15, 16 — Novosedly No. 2; 15: PPL, 16: XPL. **17–30** — *Helicosphaera waltrans* Theodoridis. 17–20 — basal siliciclastic sediments of the Lower Badenian, Hradčany No. 14/1; 17,19: PPL, 18,20: XPL; 21–24 — Grund Formation, Šatov No. 7; 21,23: PPL, 22,24: XPL; 25–28 — Grund Formation, Opatovice HJ103 (210.6 m); 25,27: PPL, 26,28: XPL; 29, 30 — basal siliciclastic sediments of the Lower Badenian, Kelčice No. K1; 29: PPL, 30: XPL. **31–36** — *Helicosphaera walbersdorfensis* (Müller) Theodoridis, Lower Badenian clays. 31,32: Slatinice No. A; 31: PPL, 32: XPL; 33–36 — Velký Týnec No. 75; 33,35: PPL, 34,36: XPL. Reworked nannofossil specimens (helicoliths) from the Eocene and Oligocene sediments. **37–38** — *Helicosphaera compacta* Bramlette et Wilcoxon, Lower Badenian clays. Vsisko No. 71; 37: PPL, 38: XPL. **39–40** — *Helicosphaera recta* (Haq) Jafar et Martini, Lower Badenian clays. Vsisko No. 71; 39: PPL, 40: XPL. **41–42** — *Helicosphaera intermedia* Martini, Lower Badenian clays. Hejčín No. 28; 41: PPL, 42: XPL. Microphotographs by L. Švábenická.


5 μm


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
5 µm

Three horizons of calcareous nannofossils were observed (Fig. 4):

— "helicolith" horizon with *Helicosphaera ampliaperta* accompanied by other species of the genus *Helicosphaera: H. carteri, H. vedderi, H. scissura, H. euphratis* and rare *H. mediterranea* (Fig. 5). Helicoliths are rarely complemented by small placoliths of genus *Reticulofenestra*. Miocene specimens form about 5–10 % of the taphocoenoses.

The horizon is characteristically developed in sandy clays of the Laa Formation. On rare occasions, nearly monospecific assemblage with *H. ampliaperta* is observed. Extreme enrichment (bloom) was recored in the Opatovice HJ-103 borehole (301.7 m) where the Miocene assemblage and about 26 % of taphocoenoses are almost exclusively formed by *H. ampliaperta* (see Fig. 3).

— horizon with *Helicosphaera waltrans.* Abundance of helicoliths is slightly decreasing; they are complemented by a low number of genera *Discoaster, Calcidiscus, Umbilicosphaera*, etc. The species *Sphenolithus heteromorphus* appears discontinuously and is present in very low numbers. Miocene specimens form about 10–20 % of the taphocoenoses. The horizon was observed in clays and siliciclastic sediments of the Grund Formation and in the basal siliciclastic sediments of the Lower Badenian (sensu Cicha 2001). The horizon can be subdivided into two parts :

The lower part is characterized by helicoliths with rare presence of *H. waltrans* (1–2 specimens/20 fields of view) and *H. ampliaperta* (about 1 specimen/20–30 fields of view), and by a discontinuous presence of *H. mediterranea* complemented by rare *Sphenolithus heteromorphus* (1 specimen/10–20 fields of view), *Discoaster variabilis* and *Calcidiscus premacintyrei.*

The upper part is characterized by common occurrence of *H. waltrans* (5–10 specimens/10 fields of view) in association with *Helicosphaera carteri,* rare *H. walbersdorfensis*, *Reticulofenestra pseudoumbilicus* (< 7 μm), *Calcidiscus premacintyrei, Discoaster variabilis, Pontosphaera multipora* and *Umbilicosphaera rotula*, and by rare presence/absence of *S. heteromorphus* (Figs. 6 and 7).

— horizon with *Sphenolithus heteromorphus* (1–5 specimens/10 fields of view). The assemblage includes species of *Helicosphaera walbersdorfensis, H. carteri, Pontosphaera multipora, Umbilicosphaera rotula, Calcidiscus premacintyrei, C. macintyrei, C. leptoporus, Discoaster exilis, D. variabilis,* a high number of small placoliths of genus *Reticulofenestra,* large forms of *Coccolithus miopelagicus* (>10 μm in size), *Rhabdosphaera* ssp. (sensu Young 1998) including *R. sicca*, etc. Within the upper part of the interval, oval forms of species *Coronocyclus nitescens* appear (localities Slavonín and Vsisko), along with 5-rayed symmetrical discoasters (localities Slavonín and Kuřim), and enigmatic specimens of genus ?*Catinaster* (or central part of discoaster?, localities Slavonín, Vsisko and Kuřim — see Fig. 7.25,26). On rare occasions, *H. mediterranea* was observed. Miocene species form about 50–70 % of the taphocoenoses.

The assemblage was observed in Lower Badenian clays ("tegel"), and silty and sandy clays.

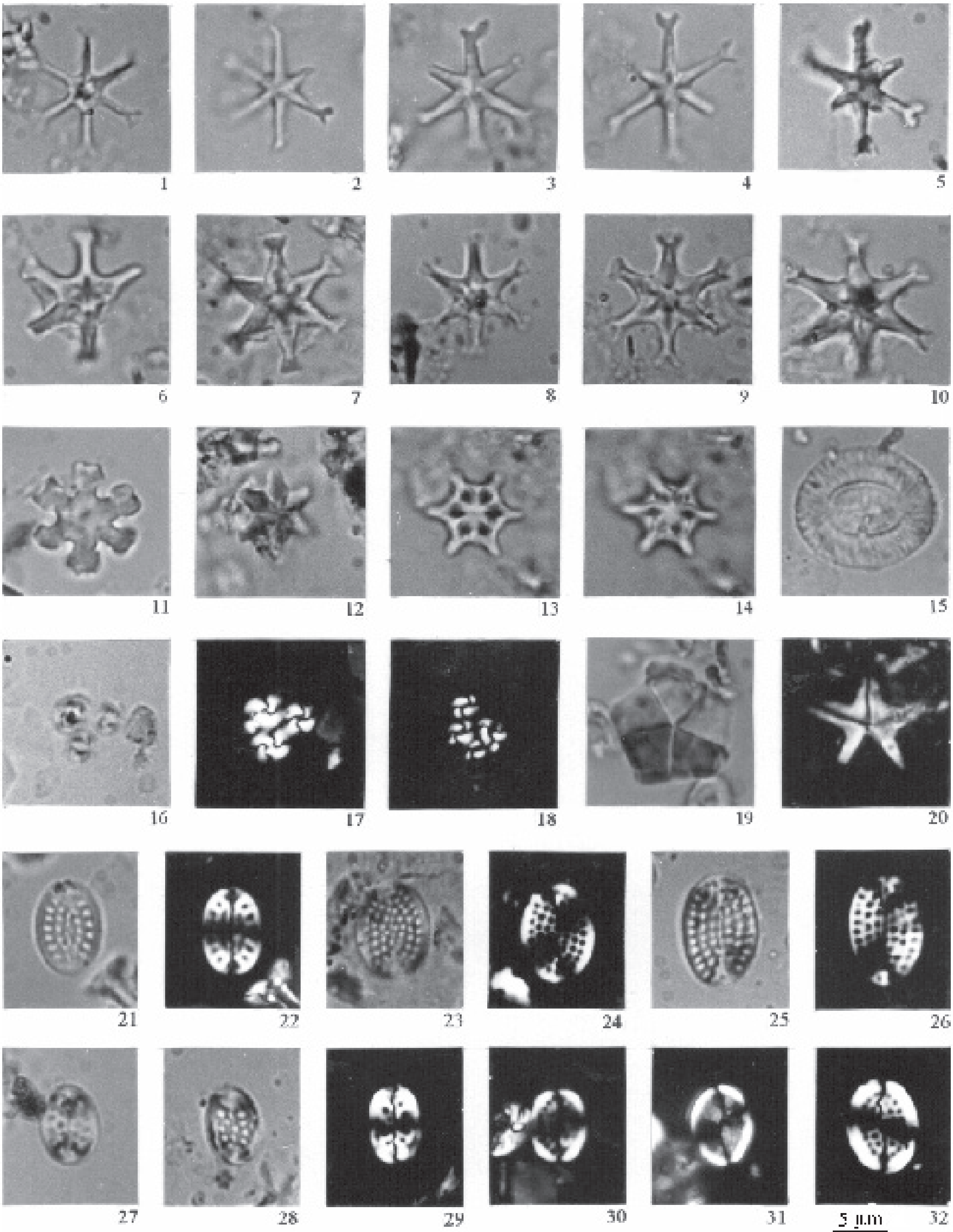
Miocene assemblages are complemented by a high number of reworked species, mostly from the Campanian, Maastrichtian and Middle Eocene sediments. Reworked coccoliths and discoasters from the Lower Cretaceous, Turonian–Coniacian interval, Lower Paleocene (within NP2–NP3 Zones), Early and Late Eocene, Eocene/Oligocene boundary and Oligomiocene were observed in lower numbers. The quantity of reworked nannofossil specimens varies. Generally, taphocoenoses of both horizons with *Helicosphaera ampliaperta* and *Helicosphaera waltrans* contain about 80–95 % of reworked nannofossils whereas the proportion of reworked specimens is distinctly decreasing in the overlying horizon with *Sphenolithus heteromorphus*, forming about 30–50 % of the taphocoenoses.

Discussion

The presence or absence of some stratigraphically important forms in the Miocene sediments of the Central Paratethys is probably controlled ecologically. According to Báldi-Beke (1982), helicoliths are neither purely oceanic nor typical nearshore forms. This fact influenced their expansion in the unstable paleoenvironmental conditions of the Carpathian Foredeep and increases their significance in biostratigraphy. In the Karpatian and Karpatian/Badenian boundary deposits, nannofossil assemblages are represented predominantly by helicoliths and nearly lack specimens of other genera such as *Discoaster, Umbilicosphaera* or *Sphenolithus,* otherwise forming a usual component of the assemblages.

Nannofossil species *Helicosphaera waltrans* was described by Theodoridis from Gozo, Italy in 1984. This species has

Fig. 6. Miocene calcareous nannofossils of the Karpatian and Lower Badenian deposits in the Carpathian Foredeep, Moravia (Czech Republic). **PPL** — plane-polarized light, **XPL** — cross-polarized light. **1–6** — *Sphenolithus heteromorphus* Deflandre, Lower Badenian clays. 1–3 — Neředín No. 74; 1: PPL, 2,3: XPL at 0° and 45°; 4–6 — Hejčín, No. 28; 4: PPL, 5,6: XPL at 0° and 45°. **7–10** — *Calcidiscus premacintyrei* Theodoridis, Lower Badenian clays. 7, 8 — Křelov No. K2; 7: PPL, 8: XPL; 9, 10 — Slavonín No. 50/9; 9: PPL, 10: XPL. **11, 12** — *Calcidiscus* cf. *macintyrei* (Bukry et Bramlette) Loeblich et Tappan, Lower Badenian clays. Křelov No. K2; 11: PPL, 12: XPL. **13–16** — *Calcidiscus leptoporus* (Murray et Blackman) Loeblich et Tappan, Lower Badenian clays. 13, 14 — Hejčín No. 28; 13: PPL, 14: XPL; 15, 16 — Křelov K2; 15: PPL, 16: XPL. **17, 18** — *Rhabdosphaera sicca* Stradner, Lower Badenian clays. Velký Týnec No. 75; 17: PPL, 18: XPL. **19–24** — *Umbilicosphaera rotula* (Kamptner) Varol, Lower Badenian clays. 19–22 — Hejčín No. 28; 19,21: PPL, 20,22: XPL; 23, 24 — Slavonín No. 50/9; 23: PPL, 24: XPL. **25–30** — *Coronocyclus nitescens* (Kamptner) Bramlette et Wilcoxon, oval forms, Lower Badenian clays. 25–28 Slavonín No. 50/8; 25,27: PPL, 26,28: XPL; 29, 30 — Vsisko No. 71; 29: PPL, 30: XPL. **31, 32** — *Reticulofenestra haqii* Backman, basal siliciclastic sediments of the Lower Badenian. Hradčany; 31: PPL, 32: XPL. **33–36** — *Reticulofenestra pseudoumbilicus* (Gartner) Gartner, Lower Badenian clays. 33, 34 — Slavonín No. 50/7; 33: PPL, 34: XP; 35, 36 — Hejčín No. 28; 35: PPL, 36: XPL. Reworked specimens from the Eocene and Oligocene sediments. **37, 38** — *Reticulofenestra umbilicus* (Levin) Martini et Ritzkowski, Lower Badenian clays. Slavonín No. 50/9; 37: PPL, 38: XPL. **39, 40** — *Pontosphaera latelliptica* (Báldi-Beke) Perch-Nielsen, Lower Badenian clays. Hejčín No. 28; 39: PPL, 40: XPL. **41, 42** — *Ericsonia formosa* (Kamptner) Haq, Lower Badenian clays. Slavonín No. 50/7; 41: PPL, 42: XPL. Microphotographs by L. Švábenická.



been mentioned rarely from the Miocene deposits of the Mediterranean and Atlantic areas only. Fornaciari et al. (1996, 1997) placed its short stratigraphic range within the middle part of zone MNN5 (approximately middle part of Langhian), above the Sphenolithus heteromorphus paracme/low abundance interval. Young (1998: Fig. 8.2) diagrammatically expressed its short range, approximately within the middle part of zone NN5 and correlated it with the uppermost Langhian and lower part of the Serravalian. On the basis of quantitative analyses, Fornaciari et al. (1996) correlated the range of *H. waltrans* with the upper part of subzone MNN5a and lower part of subzone MNN5b. According to Berggren et al. (1995), the lower part of zone NN5 can be correlated within the "transitional" planktonic foraminiferal subzone Mt5b Praeorbulina glomerosa/Orbulina suturalis and its middle part with zone Mt6 Orbulina suturalis/Globorotalia peripheroronda.

In the Paratethys, *H. waltrans* was reported from the Lower-Middle Miocene boundary deposits of the western part of the Carpathian Foredeep in the area of Moravia, Czech Republic (Švábenická & Čtyroká 1998, 1999; Čtyroká & Švábenická 1997, 2000) and Lower Austria (Švábenická 1993, 2000). *H. waltrans* in rare association with *Sphenolithus heteromorphus* was mentioned from the Middle Miocene sediments SE of Kraków by Gonera & Slezak (in Ciezskowski et al. 1988; without photodocumentation of species). In the Vienna Basin, this species was found at the locality of Sedlecký Mlýn (E of Mikulov, Czech Republic) by the present author, in the Slovak part of basin by Andreyeva-Grigorovich et al. (2001) and in the Austrian part of the basin by Coric (pers. commun.). In the Eastern Paratethys (Crimea, Kerch Peninsula and Ukraine), *H. waltrans* was recorded in a short interval of zone NN5 by Andreyeva-Grigorovich & Savytskaya (2000). *H. waltrans* has not been mentioned from the Miocene deposits of Romania yet, such as from the Badenian deposits of the Outer Moldavides (see Mărunţeanu 1999). Nevertheless, the specimen presented on Fig. 5.6 is very similar in shape to *H. waltrans* (see taxonomic notes in Appendix No. 1).

H. waltrans was present in the clays and coarse clastics of the Grund Formation and in the Lower Badenian clastics of the Carpathian Foredeep. This species was observed mostly in the absence of *Sphenolithus heteromorphus.* The first occurrence of *H. waltrans* associated with rare *H. ampliaperta* probably coincidies with the paracme of Sphenolithus heteromorphus that is correlated with zone MNN4b (Fornaciari et al. 1996). The co-existence of the both species may be also explained by reworking of *H. ampliaperta* from the older Miocene strata. In view of the above mentioned data, *H. waltrans* appears in stratigraphically older deposits of the Carpathian Foredeep than mentioned by Fornaciari et al. (1996, 1997) and Young (1998). The absence or rare presence of *S. heteromorphus* may also be explained ecologically. The sandy clays of the Laa Formation, coarse clastics and clays of the Grund Formation and basal clastics of Lower Badenian were deposited in temperate shallow waters, that is under conditions not favourable for the life of sphenolith-producing Coccolithophores.

Comparative studies (Čtyroká & Švábenická 1997 and Švábenická & Čtyroká 1998, 1999) point out that the occurrence of *H. waltrans* is limited to a short stratigraphic interval approximately corresponding to the stratigraphic range of foraminiferal species *Globigerinoides bisphericus* Todd, and including the first appearance of *Orbulina suturalis* Brönnimann in its upper part. This interval can be correlated with nannoplankton zones NN4 (upper part) and NN5 (lower part), that is MNN4b and MNN5a (part) respectively (Fig. 8). Čtyroká & Švábenická (2000) emphasized that the last occurrence of *H. waltrans* precedes the last occurrence of *Globigerinoides bisphericus*. In the Alpine-Carpathian Foredeep, Lower Austria, *H. waltrans* appears before the first occurrence of *G. bisphericus*, in association with foraminiferal microfauna *Uvigerina graciliformis* Papp et Turn., *Pappina parkeri breviformis* (Papp et Turn.) and rare specimens of *Globorotalia* (Švábenická 2000).

Correlation of the first and last occurrence data of *H. waltrans* in the Carpathian Foredeep remains obscured because no consensus exists on the correlation of the Central Paratethys regional stages either with the Miocene standard (Mediterranean) chronostratigraphic scale or with the standard nannoplankton NN zones (Fig. 9). The NN4/NN5 zone boundary is attributed to the Lower/Middle Miocene (Serravalian/Langhian) boundary, and to the Karpatian/Badenian boundary of regional division in the Central Paratethys by Spiegler & Rögl (1992: Table 1). Nevertheless, Rögl (1998: Table 1) and Garecka & Olszewska (1998: Fig. 3) placed the NN4/NN5 boundary within the Langhian and the lower part of Badenian respectively and Andreyeva-Grigorovich et al. (2001: Fig. 2)

Fig. 7. Miocene calcareous nannofossils of the Karpatian and Lower Badenian deposits in the Carpathian Foredeep, Moravia (Czech Republic). **PPL** — plane-polarized light, **XPL** — cross-polarized light. **1–5** — *Discoaster exilis* Martini et Bramlette, Lower Badenian clays. PPL; 1 — Slavonín No. 50/7; 2, 3 — Slavonín No. 50/9; 4, 5 — Neředín No. 74. **6–10** — *Discoaster variabilis* Martini et Bramtette, Lower Badenian clay. PPL; 6 — Neředín No. 74; 7, 8 — Slavonín No. 50/8; 9, 10 — Křelov No. K2. **11** — *Discoaster deflandrei* Bramlette et Riedel, Laa Formation. Opatovice HJ-103 (287.3 m); PPL. **12** — *Discoaster* ex gr. *adamanteus* Bramlette et Wilcoxon, Lower Badenian clays. Hejčín No. 28; PPL. **13, 14** — *Catinaster* sp. sensu Perch-Nielsen (1985), Lower Badenian clays. Vsisko; PPL. **15** — *Coccolithus miopelagicus* Bukry, Lower Badenian clays. Slavonín No. 50/8; PPL. **16–18** — *Reticulofenestra minuta* Roth. 16, 17 — Lower Badenian clays, Neředín No. 74; 16: PPL, 17: XPL; 18 — Grund Formation, Šatov No. 7; XPL. **19** — *Braarudosphaera bigelowii* (Gran et Braarud) Deflandre, Lower Badenian clays. Křelov K2; PPL; specimen may be reworked from the Upper Cretaceous or Paleogene sediments. **20** — *Micrantholithus vesper* Deflandre, Grund Formation. Opatovice HJ-103 (213.3 m); XPL. **21–26** — *Pontosphaera multipora* (Kamptner) Roth; Lower Badenian clays. 21, 22 — Slavonín No. 50/8; 21: PPL, 22: XPL; 23–26 — Vsisko No. 71; 23,25: PPL, 24,26: XPL. **27–29** — *Pontosphaera* cf. *enormis* (Locker) Perch-Nielsen, Lower Badenian clays. Vsisko No. 71; 27,28: PPL, 29: XPL; probably reworked specimen from the Oligocene sediments. **30–32** — *Pontosphaera discopora* Schiller, Lower Badenian clays. XPL; 30 — Slavonín 50/8; 31, 32 — Neředín No. 74. Microphotographs by L. Švábenická.

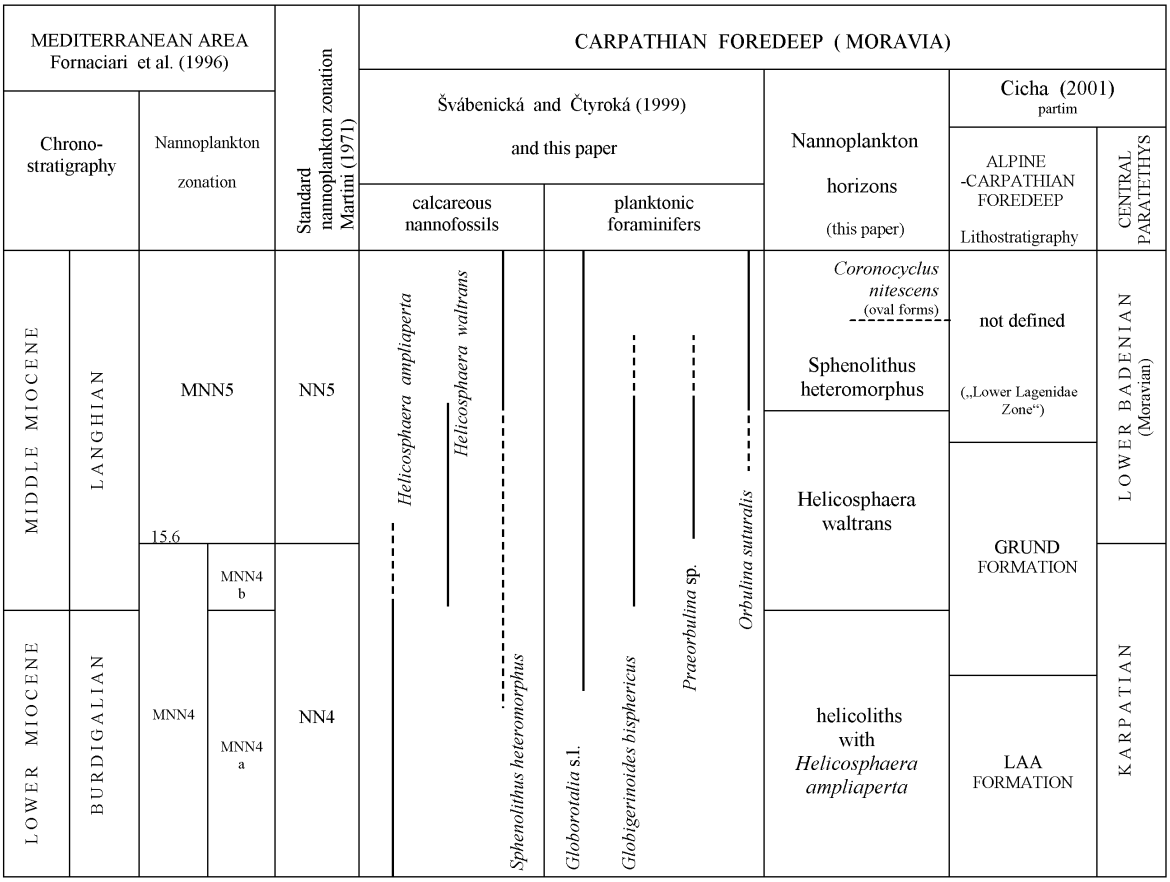


Fig. 8. Comparison of nannoplankton zonation in the Mediterranean area proposed by Fornaciari et al. (1996), standard nannoplankton zonation (Martini 1971), chronostratigraphy in the Central Paratethys and lithostratigraphy in the Carpathian Foredeep (Cicha 2001), distribution of stratigraphically significant species of planktonic foraminifers and calcareous nannofossils (Švábenická & Čtyroká 1999) and nannoplankton horizons in the Carpathian Foredeep, Moravia (this paper).

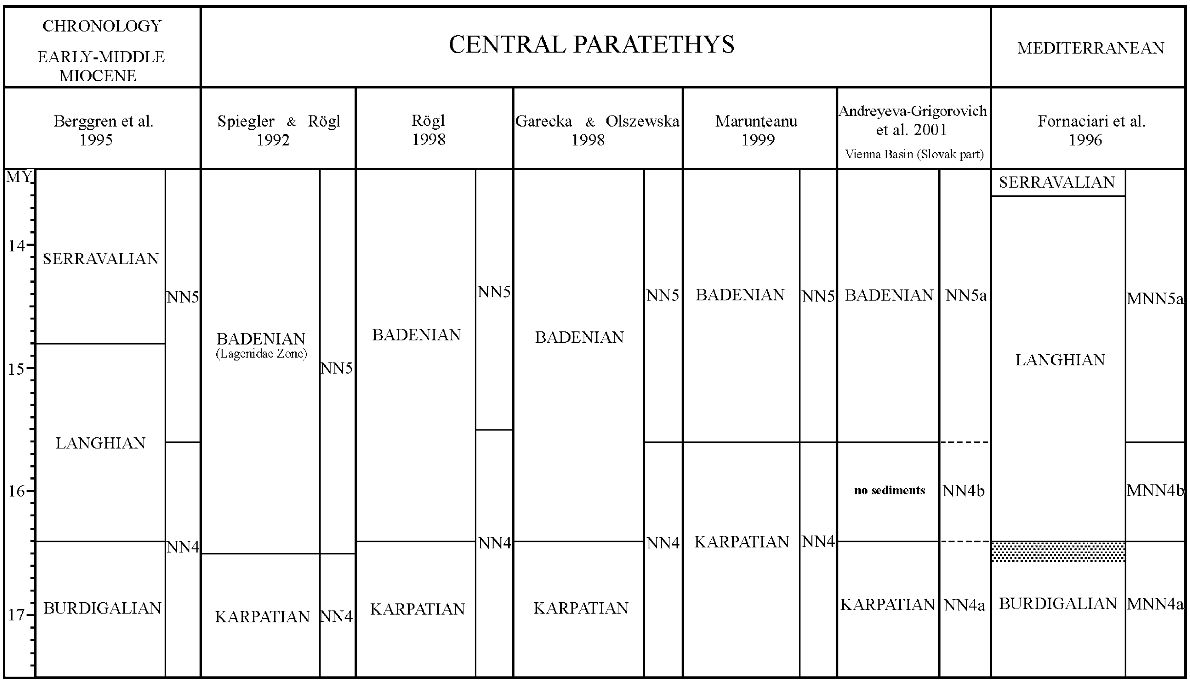


Fig. 9. Correlation of standard chronology with the Central Paratethys and Mediterranean.

correlated it within the Langhian and with the Karpatian/Badenian boundary. In the Mediterranean, Fornaciari et al. (1996: Text-Fig. 17) placed the NN4/NN5 boundary within the lower part of the Middle Miocene (lower part of the Langhian), and a similar opinion was expressed by Berggren et al. (1995: Fig. 4) in a revised chronology of the Miocene — see Fig. 9.

H. waltrans is rarely mentioned in literature, although its size (large helicolith about 10 μm in length), morphology (asymmetrically elliptical outline and two triangular openings in central area well visible under light microscope), and a short stratigraphic range are optimum conditions for its use in biostratigraphy. This "puzzle" may be caused by: 1 — The very short stratigraphic interval where *H. waltrans* is available. This is documented by Theodoridis (1984) who described the Helicosphaera waltrans Subzone from the D.S.D.P. Site 372, Sierra Leone Rise, Atlantic Ocean, in thickness of 6.7 m. 2 — A taxonomic problem: in papers published before 1984, specimens of *H. waltrans* could have been considered to be a different, then already described species, for instance varieties of *H. mediterranea* or *H. sellii.* This assumption is confirmed by the study of Nagymarosy (1985: p. 78, Pl. 5, Figs. 3–6; manuscript received in 1984) who presented specimens of *H. waltrans* under the name *Helicopontosphaera* cf. *sellii*.

The rare occurrence of *H. mediterranea* in association with *H. waltrans* and *S. heteromorphus* can by explained either by reworking of the older Miocene strata or being a component of the autochthonous assemblage. Báldi-Beke & Nagymarosy (1979) and Báldi-Beke (1980) mentioned species *Helicopontosphaera* cf. *sellii* (syn. *Helicosphaera mediterranea* — see Appendix No. 1) in association with *S. heteromorphus* from the Karpatian and Badenian deposits of Central Paratethys, Hungary. Báldi-Beke (1982) found that the stratigraph-

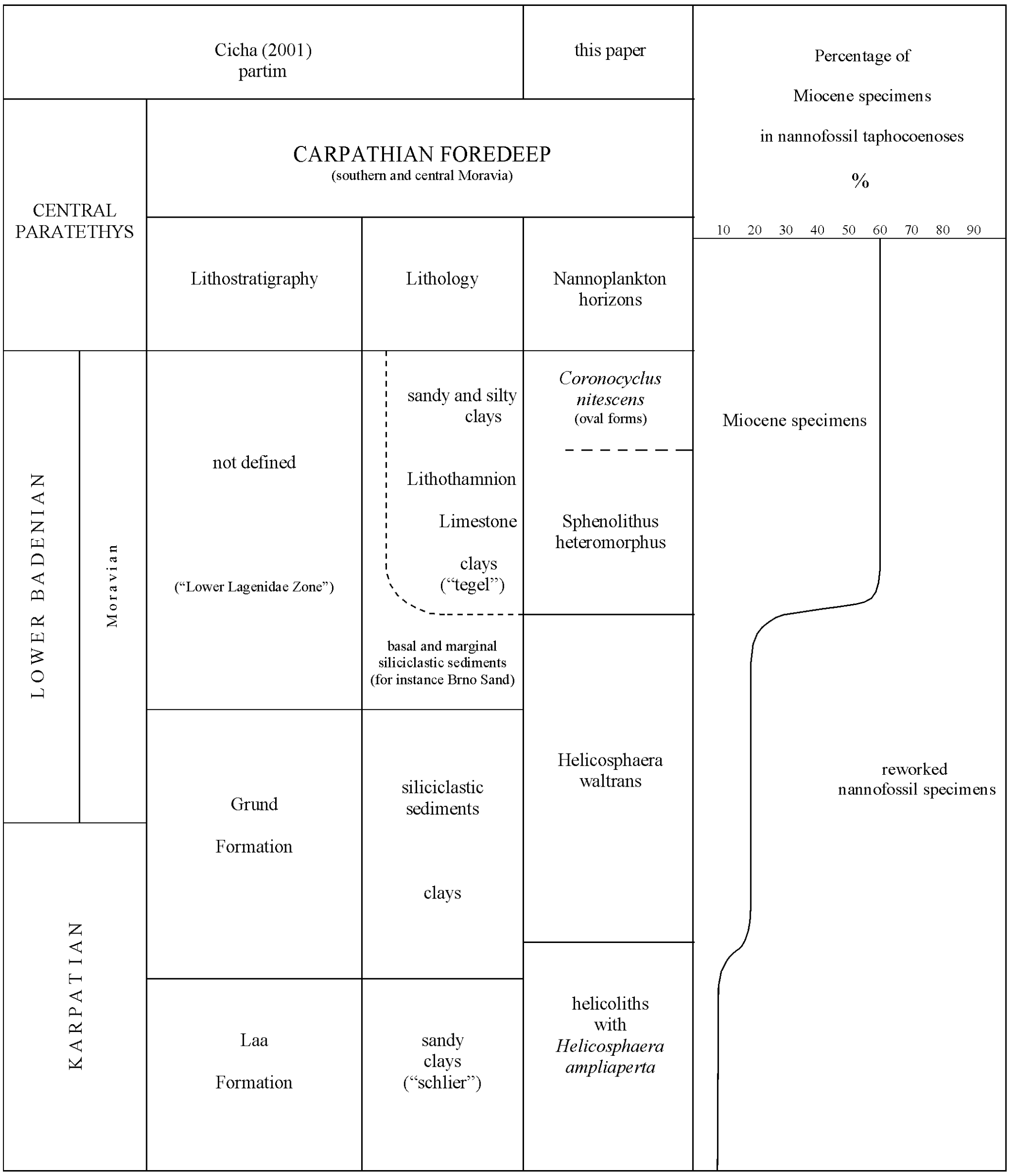


Fig. 10. Carpathian Foredeep, southern and central Moravia. Nannopankton horizons in the Karpatian and Lower Badenian deposits shown against NN Zones of Martini (1971) and lithology and lithostratigraphy of Cicha (2001) including the proportions of Miocene autochthonous specimens against reworked ones in nannofossils taphocoenoses.

ic range of *H. mediterranea* in the Carpathian Basin reaches considerably higher than that in the Mediterranean or Pacific regions, up to zone NN7. Nevertheless, *H. mediterranea* was observed by Andreyeva-Grigorovich (2001) in the Vienna Basin only up to zone NN4 inclusive.

On the basis of the above mentioned observations it is possible to assume that the first occurrence of *H. waltrans* in the Carpathian Foredeep probably precedes this event in the Tethys, and that its original area of distribution was in the Central Paratethys. This species probably migrated through the "Trans-Tethyan-Trench-Corridor" to the Mediterranean. As supposed by Rögl (1998) this seaway connected the Pannonian, Styrian and Vienna basins and a part of the Carpathian Foredeep. Intermittent seaways and regional closure of basins with endemic development are supposed to occur here in the period from the Karpatian (Late Burdigalian) to Early Badenian (Langhian).

The presence of some nannofossil genera may be an important phenomenon for the paleoclimatic and paleobathymetric interpretations of the studied area. Aubry (1990) mentioned *Discoaster variabilis* as a temperate form and *D. exilis* and *D. deflandrei* as species that either tolerate, or exhibit preference for colder waters. In epicontinental marine sediments, discoasters are never abundant and are usually smaller in size than in sediments deposited under oceanic conditions. In contrast, helicoliths are indicative for hemipelagic deposition and they are common in shallow oceanic or epicontinental marine deposits. Such observations can be applied also to the Carpathian Foredeep: a "helicolith" assemblage is observed in sandy clays of the Laa Formation. This phenomenon indicates a shallow epicontinental sea. Helicoliths complemented by a low number of discoasters and coccoliths of genera *Umbilicosphaera* and *Calcidiscus* in clays and siliciclastic sediments of Grund Formation and basal siliciclastic sediments of the Lower Badenian may indicate an incipient transgression. Higher numbers of discoasters and coccoliths recorded in the Lower Badenian clays reflect the deepening of the depositional area and open ocean conditions. Similar observations were presented by Báldi-Beke (1980) and Nagymarosy (1985) from the Karpatian and Badenian deposits of northern Hungary.

Conclusion

Three nannoplankton horizons were recognized in the Karpatian/Badenian boundary strata and in the Lower Badenian deposits of the Carpathian Foredeep, Moravia (Fig. 10):

1. "helicolith" horizon with *Helicosphaera ampliaperta*, correlated with the upper part of the Laa Formation,

2. horizon with *Helicosphaera waltrans*, correlated with the Grund Formation and basal siliciclastic sediments of the Lower Badenian,

3. horizon with *Sphenolithus heteromorphus*, observed in the Lower Badenian deposits.

The species *Helicosphaera waltrans* is present in a significant horizon that is suitable for biostratigraphic use in the Carpathian Foredeep. The horizon is limited to a short stratigraphic interval which approximately corresponds to the stratigraphic range of foraminiferal species *Globigerinoides bispheric*us and includes the first appearance of *Orbulina suturalis* in its upper part (Švábenická & Čtyroká 1999). This interval may be correlated with the nannoplankton zones NN4 (upper part) and NN5 (lower part), that is MNN4b and the lower part of MNN5 respectively.

The short stratigraphic range of *H. waltrans* seems to be diachronous, first occurring in the Central Paratethys. This phenomenon has to be considered carefully because no consensus exists on the correlation of Central Paratethys regional stages either with the Miocene standard chronostratigraphic scale or with the nannoplankton NN zones.

The dominant occurrence of helicoliths in sandy clays of the Laa Formation gives evidence for a shallow epicontinental sea. The high number of helicoliths complemented by rare discoasters and other coccoliths in clays and siliciclastic sediments of the Grund Formation and basal siliciclastic sediments of the Lower Badenian may indicate a beginning of transgression.

The change in quality and quantity of Miocene nannofossil assemblages, that is enrichment in discoasters and coccoliths is evidence of open-sea conditions and reflects transgression in the Lower Badenian.

Acknowledgment: This study is a contribution to the projects "Biostratigraphy and sedimentology of the Lower and Middle Miocene in the Alpine-Carpathian Foredeep (Lower Austria, Moravia)" (Grant No. 205/98/0694) and "Reedition of the Karpatian stratotype" (Grant No. 205/01/0085), supported by the Grant Agency of the Czech Republic. The author thanks Assoc. Prof. Dr. Ivan Cicha (Czech Geological Survey) for his critical comments to stratigraphy in the Central Paratethys and Dr. Eva Halásová and Prof. Dr. Aida S. Andreyeva-Grigorovich (Faculty of Science, Comenius University Bratislava) for fruitful discussions.

Appendix No. 1

Taxonomic notes

Helicosphaera mediterranea Müller

Fig. 5.13–16

Helicoponthosphaera cf. *sellii* Bukry et Bramlette — Báldi-Beke (1980), p. 174, Plate IV, Figs. 17–20.

Helicosphaera mediterranea n.sp. — Müller (1981), p. 428, Pl. 1, Figs. 13,14.

Helicosphaera mediterranea Müller — Theodoridis (1984), Pl. 20, Figs. 5–9.

Helicosphaera mediterranea Müller — Fornaciari & Rio (1996), Pl. 1, Fig. 15.

Helicosphaera mediterranea Müller — Mărunţeanu (1999), Pl. IA, Fig. 4a,b, non Pl. IB, Fig. 6.

Helicosphaera cf. *waltrans* Theodoridis — Andreyeva-Grigorovich & Savytskaya (2000), Pl. I, Fig. 4.

Helicosphaera mediterranea Müller — Andreyeva-Grigorovich et al. (2001), Fig. 4/6.

Remark: In the Carpathian Foredeep, this species was recorded up to the lower part of zone NN5. Nevertheless, in the Grund Formation and the overlying Lower Badenian strata, *H. mediterranea* occurs very rarely or is absent.

Aubry (1990) drew attention to the broad geographical distribution of *H. mediterranea* and to the fact that its stratigraphic range changes depending on the specific location: this species is present in zones NN2 and NN3 in the Mediterranean, in the range of NN3–NN5 in the Pacific and in zones NN1–NN7 in the Carpathian basins (according to the observations of Báldi-Beke 1982).

Helicosphaera waltrans Theodoridis
Fig. 5.19–30

Helicosphaera waltrans n.sp. — Theodoridis (1984), p. 124, Pl. 13, Fig. 2, Pl. 20, Figs. 5–9, Pl. 26, Fig. 2.
Helicopontosphaera cf. *sellii* Bukry et Bramlette — Nagymarosy (1985), Pl. 5, Figs. 3–6.
Helicosphaera waltrans Theodoridis — Fornaciari et al. (1996), Pl. 2, Figs. 11, 12.
Helicosphaera waltrans Theodoridis — Young (1998), Pl. 8.1, Fig. 18.
?*Helicosphaera mediterranea* Müller — Mărunţeanu (1999), Pl. IB, Fig. 6.
Helicosphaera waltrans Theodoridis — Andreyeva-Grigorovich & Savytskaya (2000), Pl. II, Fig. 3.

Remark: In the Carpathian Foredeep, this species occurs in a stratigraphically short interval probably correlated with zones MNN4b and a lower part of MNN5. It forms a significant horizon that includes the Grund Formation and the basal siliciclastic sediments of the Lower Badenian. This species has not been observed in the overlying Lower Badenian clays ("tegel") yet.

Although Mărunţeanu (1999) did not mention *H. waltrans* from the Outer Moldavides, East Carpathians, the specimen depicted on the Fig. 5.6 looks similar to *H. waltrans* by its elliptical outline, size and central area where two triangular central openings are separated by the inclined bridge.

Appendix No. 2

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

Calcidiscus leptoporus (Murray et Blackman) Loeblich et Tappan
Calcidiscus premacintyrei Theodoridis
Coccolithus miopelagicus Bukry
Coronocyclus nitescens (Kamptner) Bramlette et Wilcoxon
Discoaster adamanteus Bramlette et Wilcoxon
Discoaster deflandrei Bramlette et Riedel
Discoaster exilis Martini et Bramlette
Discoaster variabilis Martini et Bramlette
Helicosphaera ampliaperta Bramlette et Wilcoxon
Helicosphaera carteri (Wallich) Kamptner
Helicosphaera mediterranea Müller
Helicosphaera scissura Müller
Helicosphaera vedderi Bukry
Helicosphaera walbersdorfensis (Müller) Theodoridis
Helicosphaera waltrans Theodoridis
Pontosphaera multipora (Kamptner) Roth
Reticulofenestra haqii Backman
Reticulofenestra minuta Roth
Reticulofenestra pseudoumbilicus (Gartner) Gartner
Rhabdosphaera sicca Stradner
Sphenolithus heteromorphus Deflandre
Umbilicosphaera rotula (Kamtner) Varol

References

Andreyeva-Grigorovich A.S. & Savytskaya N.A. 2000: Nannoplankton of the Tarkhanian deposits of the Kerch Peninsula (Crimea). *Geol. Carpathica* 51, 6, 399–406.

Andreyeva-Grigorovich A.S., Kováč M., Halásová E. & Hudáčková N. 2001: Litho- and biostratigraphy of the Lower and Middle Miocene sediments of the Vienna basin (NE part) on the basis of calcareous nannoplankton and foraminifers. *Scr. Fac. Sci. Nat. Univ. Masaryk. Brun., Geol.* 30, 2000 27–40.

Aubry M.P. 1990: Handbook of Cenozoic Calcareous Nannoplankton. Book 4: Heliolithae (Helioliths, Cribriliths, Lopadoliths and others). *Micropaleontology Press,* 1–381.

Báldi-Beke M. 1980: The nannoplankton of the Oligocene-Miocene sediments underlying the Börzsöny Mts. (Northern Hungary) andesites. *Földt. Közl., Bull. Hung. Geol. Soc*. 110, 159–179 (in Hungarian with English abstract).

Báldi-Beke M. 1982: *Helicosphaera mediterranea* Müller 1981, and its stratigraphical importance in the Lower Miocene. *INA Newslett.* 4, 2, 104–106.

Báldi-Beke M. & Nagymarosy A. 1979: On the position of the Ottnangian and Karpatian regional stages in the Tertiary nannoplankton zonation. *7th International Congress on Mediterranean Neogene*, *Athens*, *Ann. Géol. Pays Hellén., Hors Sér. Fasc.* 1, 51–59.

Berggren W.A., Kent D.V., Swisher C.C. & Aubry M.P. 1995: A revised Cenozoic geochronology and chronostratigraphy. *Geochronology Time Scales and Global Stratigraphic Correlation, SEPM Spec. Publ.* 54, 129–212.

Cicha I. 1995: Development of the Neogene deposits in Central Paratethys, new results. *Knihovnička ZPN* 16, 67–71 (in Czech).

Cicha I. 1999: Beitrag zur Auswertung der miozänen Foraminiferenfaunen im westlichen Weinviertel auf Blatt 22 Hollabrunn. In: Geologische Karten ÖK 9 Retz und ÖK 22 Hollabrunn — Neogenes Naturraumpotential der Bezirke Horn und Hollabrunn. *Geol. Bundesanstalt Wien* 55–59.

Cicha I. 2001: Outline of the stratigraphy of the Middle Miocene in the Alpine-Carpathian foredeep (Lower Austria, Moravia). *Scr. Fac. Sci. Nat. Univ. Masaryk. Brun., Geol.* 30, 2000, 23–26.

Cicha I. & Čtyroká J. 1995: Stratigraphy problems of the boundary members of the Karpatian and Early Badenian in the Southern Carpathian Foredeep. *Zpr. Geol. Výzk. v roce 1994* 20–21.

Cicha I. & Tejkal J. 1965: Zum Problem des sogenante Torton in den westkarpatischen Becken (Mittelmiozän). *Geol. Práce, Zpr.* 36, 115–121.

Cicha I. & Zapletalová I. 1967: Die Foraminiferen der Karpatischen Serie. In: Cicha I., Seneš J. & Tejkal J. (Eds.): Chronostratigraphie und Neostratotypen, I, M3 Karpatien. *Veda,* 104–148.

Cicha I., Rögl F., Rupp C. & Čtyroká J. 1998: Oligocene-Miocene foraminifera of the Central Paratethys. *Abh. Senckenberg. Naturforsch. Gesell.* 549, 1–325.

Cieszkowski M., Gonera M., Oszczypko N., Slezak J. & Zuchiewicz W. 1988: Lithostratigraphy and age of Upper Miocene deposits at Iwkowa, Polish West Carpathians. *Bull. Pol. Acad. Sci., Earth Sci.* 36, 3–4, 309–329.

Čtyroká J., Havlíček P., Hradecká L. & Švábenická L. 1995: Research of the Lower Badenian bazal and border clastic sediments near Novosedly village. *Zpr. Geol. Výzk. v roce 1994* 27–28 (in Czech).

Čtyroká J. & Švábenická L. 1997: Foraminiferal and nannofossil stratigraphic correlation of the Miocene sediments, south of Šatov (Carpathian Foredeep). *Zpr. Geol. Výzk. v roce 1996* 70–71 (in Czech).

Čtyroká J. & Švábenická L. 2000: Biostratigraphic evaluation of

Badenian deposits on the Olomouc map-sheet (Foraminifers and Calcareous nannofossils). *Zpr. Geol. Výzk. v roce 1999* 17–20 (in Czech with English abstract).

Dudziak J. & Łaptaś A. 1991: Stratigraphic position of Miocene carbonate-siliciclastic deposits near Chmielnik (Świetokrzyskie Mountains Area, Central Poland) based on calcareous nannofossils. *Bull. Pol. Acad. Sci., Earth Sci.* 39, 1, 55–66.

Dudziak J. & Łuczkowska E. 1991: Biostratigraphic correlation of foraminiferal and calcareous nannoplankton zones, Early-Middle Badenian (Miocene), Southern Poland. *Bull. Pol. Acad. Sci., Earth Sci.* 39, 3, 199–214.

Fornaciari E., Di Stefano A., Rio D. & Negri A. 1996: Middle Miocene quantitative calcareous nannofossil biostratigraphy in the Mediterranean region. *Micropaleontology* 42, 1, 37–63.

Fornaciari E. & Rio D. 1996: Latest Oligocene to early middle Miocene quantitative calcareous nannofossil biostratigraphy in the Mediterranean region. *Micropaleontology* 42, 1, 1–36.

Fornaciari E., Rio D., Ghibaudo G., Massari F. & Iaccarino S. 1997: Calcareous plankton biostratigraphy of the Serravallian (Middle Miocene) stratotype section (Piedmont Tertiary Basin, NW Italy). *Mem. Sci. Geol.* 49, 127–144.

Fuchs R. & Stradner H. 1977: Über Nannofossilien im Badenien (Mittelmiozän) der Zentralen Paratethys. *Beitr. Paläont. Österr.* 2, 1–58.

Garecka M. & Olszewska B. 1998: Biostratigraphy of the Early Miocene of the Southern Poland based on planktic foraminifera and calcareous nannoplankton. *Przegl. Geol.* 46, 8/2, 712–721.

Jarosiński M. & Krzywiec P. 2001: Neogene collision of the Carpathians and its influence on the Carpathian foreland plate: integration of seismic and outcrop data from the Polish Carpathian Foredeep basin. In: Ádám A., Szarka L. & Szendröi J. (Eds.): Pancardi 2001, Abstracts. *Geodetic and Geophysical Research Institute of the Hungarian Academy of Siences*, CO-7.

Kováč M., Nagymarosy A., Oszczypko N., Csontos L., Ślączka A., Mărunţeanu M., Matenco L. & Márton E. 1998: Palinspastic reconstruction of the Carpathian-Pannonian region during Miocene. In: Rakús M. (Ed): Geodynamic development of the Western Carpathians. *Geol. Survey of Slovak Republic,* Bratislava, 189–217.

Lehotayová R. 1975: Calcareous nannoflora of a Badenian Preorbulina-Orbulina horizon. *Západ. Karpaty, Sér. Paleont.* 1, 25–38.

Lehotayová R. 1984: Lower Miocene calcareous nannoflora of the West Carpathians. *Západ. Karpaty, Sér. Paleont.* 9, 99–109.

Lehotayová R. & Molčíková V. 1978: Das Nannoplankton in der Tschechoslowakei. In: Papp A., Cicha I., Seneš J. & Steininger F. (Eds.): Chronostratigraphie und Neostratotypen, Miozän der Zentralen Paratethys, M4 Badenien (Moravien, Wielicien, Kosovien). *Veda*, Bratislava, 481–486.

Martini E. 1971: Standard Tertiary and Quaternary calcareous nannoplankton zonation. In: Farinacci A. (Ed.): Proceedings II. Planktonic Conference, Roma 1970. *Edizioni Tecnoscienza,* 2, 739–785.

Martini E. 1977: Calcareous nannoplankton from the Korytnica basin (Middle Miocene, Holy Cross Mountains, Poland). *Acta Geol. Pol.* 27, 125–133.

Mărunţeanu M. 1992: Distribution of the Miocene calcareous nannofossils in the Intra- and Extra-Carpathian areas of Rumania. In: Hamršmíd B. & Young J. (Eds.): Nannoplankton Research, Vol. II: Tertairy Biostratigraphy and Paleoecology; Quaternary coccoliths. Proceedings of the 4th INA Conf. *Knihovnička ZPN* 14b, 2, 247–261.

Mărunţeanu M. 1993: Contents in calcareous nannoplankton of the marine Lower and Middle Miocene beds, East and North-East of Zalău. *Rom. J. Stratigraphy* 75, 99–103.

Mărunţeanu M. 1999: Litho- and biostratigraphy (calcareous nannoplankton) of the Miocene deposits from the Outer Moldavides. *Geol. Carpathica* 50, 4, 313–325.

Molčíková V. 1974: Nannoplankton of the Karpatian and of variegated Neogene beds in the Carpathian foredeep. *Věst. Ústř. Úst. Geol.* 49, 83–88.

Molčíková V. 1978: Calcareous nannoplankton in the Karpatian deposits of Carpathian Foredeep, Moravia. *Geol. Práce, Spr.* 70, 143–157.

Molčíková V. 1983: The Karpatian and Lower Badenian calcareous nannoflora of the Carpathian Foredeep in Moravia. *Miscellanea Micropalaeont., Knihovnička ZPN* 4, I, 283–304.

Müller C. 1981: Beschreibung neuer *Helicosphaera*-Arten aus dem Miozän un Revision biostratigraphischer Reichweiten einiger neogener Nannoplankton-Arten. *Senckenberg. Lethea* 61, 3/6, 427–435.

Nagymarosy A. 1985: The correlation of the Badenian in Hungary based of nannofloras. *Ann. Univ. Sci. Budapest, Geol.* 25, 33–86.

Pálenský P. & Čtyroká J. 1994: Notice to age of Miocene sediments in Moravské Bránice environs. *Zpr. Geol. Výzk. v roce 1993* 67–69 (in Czech).

Papp A., Cicha I. & Čtyroká J. 1978: Allgemeine Charakteristik Foraminiferenfauna im Badenien. In: Papp A., Cicha I., Seneš J. & Steininger F. (Eds.): Chronostratigraphie und Neostratotypen, Miozän der Zentralen Paratethys, VI, M4 Badenien (Moravien, Wielicien, Kosovien). *Veda*, Bratislava, 263–268.

Rögl F. 1998: Palaeogeographic Considerations for Mediterranean and Paratethys Seaways (Oligocene to Miocene). *Ann. Naturhist. Mus. Wien* 99A, 279–310.

Slezak J.A., Koszarski A. & Koszarski L. 1995: Calcareous nannoplankton stratigraphy of the terminal flysch deposits from the Skole Nappe (Oligocene–Miocene, Polish Carpathians, Krosno Beds). In: Flores J.A. & Sierro F.J. (Eds.): 5th INA Conference in Salamanca Proceedings. *Universidad de Salamanca*, 267–277.

Spiegler D. & Rögl F. 1992: *Bolboforma* (Protophyta, incertae sedis) im Oligozän und Miozän des Mediterran und Zentralen Paratethys. *Ann. Naturhist. Mus. Wien* 94, A, 59–95.

Stradner H. & Fuchs R. 1978: Das Nannoplankton in Österreich. In: Papp A., Cicha I., Seneš J. & Steininger F. (Eds.): Chronostratigraphie und Neostratotypen, Miozän der Zentralen Paratethys, M4 Badenien (Moravien, Wielicien, Kosovien). *Veda*, Bratislava, 489–498.

Švábenická L. 1993: Bericht 1992 über die biostratigraphische Bearbeitung von kalkigem Nannoplankton auf Blatt 22 Hollabrunn. *Jb. Geol. B.-A.* 136, 2, 639–640.

Švábenická L. & Čtyroká J. 1998: Foraminifera and nannofossil biostratigraphic correlation of the Karpatian and Lower Badenian sediments in the Carpathian Foredeep of Moravia (Preliminary results). *Zpr. Geol. Výzk. 1997* 166–169 (in Czech).

Švábenická L. & Čtyroká J. 1999: Biostratigraphic correlation (Foraminifers and Nannofossils) of the Karpatian and Lower Badenian sediments in the Alpine-Carpathian Foredeep (Moravia and Lower Austria). *Geol. Carpathica, Spec. Issue* 55, 79–80.

Švábenická L. 2000: Bericht 1999 über Untersuchungen an kalkigem Nannoplankton auf den Blättern 22 Hollabrunn und 23 Hadres. *Jb. Geol. B.-A.* 142, 3, 388–389.

Theodoridis S. 1984: Calcareous Nannofossil Biozonation of the Helicoliths and Discoasters. *Utrecht Micropaleont. Bull.* 32, 1–271.

Vašíček M. 1949: Moravian Neogene representatives of the genus Vaginulina legumen (Linné), 1758. *Sbor. Stát. Geol. Úst. ČSR* 16, 329–399 (in Czech).

Young J.R. 1998: Neogene. In: Bown P.R. (Ed.): Calcareous Nannofossil Biostratigraphy. *Cambridge University Press*, 225–265.