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Biostratigraphy and paleoenvironmental changes on the transition from the Menilite to Krosno lithofacies (Western Carpathians, Czech Republic)

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Abstract: Study of microfossils and calcareous nannofossils confirmed the diachronous onset of the Krosno lithofacies. In the Fore-Magura Unit the *Reticulofenestra ornata* bloom correlated with NP24 Zone (lower Upper Oligocene) was recognized within this facies while in the Ždánice-Subsilesian Unit in the underlying Menilite lithofacies. Onset of the Krosno lithofacies in the external Pouzdřany Unit is attributed to the Lower Miocene, NN3 Zone. The Zagórz Limestone intercalations were found as an important biostratigraphic horizon for the lower part of the Krosno lithofacies in the Ždánice-Subsilesian Unit and is attributed to NP25 Zone. Microplankton blooms (*Limacina* sp., bivalve juveniles, clavate planktonic foraminifers *Beella* and *Bolliella*, radiolarians, prasinophyte cysts, planktonic diatoms) and calcareous nannoplankton blooms (*Cyclicargolithus* spp., *R. ornata*) or abundances of some taxa (*Pontosphaera* spp., *Reticulofenestra minuta*, *Syracosphaera* sp.) are characteristic of the upper Menilite and lower Krosno lithofacies and reflect rearrangement of Carpathian orogenic zone, isolation of foreland basins and development of "Protoparatethys".

Key words: Oligocene, Lower Miocene, Outer Flysch Carpathians, biostratigraphy, paleoenvironment, plankton blooms, foraminifers, calcareous nannofossil.

Introduction

The Krosno lithofacies represents the youngest synorogenic turbiditic sediments gradually terminating the last depositional episode in the flysch basins of the Western Carpathians. Its development responded to the integrated effects of the Neoalpine orogenic movements and eustatic changes in the Oligocene. The aim of this study is to give the biostratigraphic data around the onset of the Krosno lithofacies in tectonic units of the Outer (Menilite-Krosno) Group of Nappes in the territory of the Czech Republic. Moreover, the relation between the Krosno lithofacies deposition and the underlying Menilite Formation was studied from the biostratigraphic and paleoenvironmental points of view.

Geological setting

The study area is a part of the Outer Flysch Carpathians — Neoalpine structure in the foreland of Paleoalpine Carpathian Centralides. The Krosno lithofacies is widespread through the Outer Group of Nappes called also the Menilite-Krosno Group and it is missing in the Inner (Magura) Group of Nappes except its eastern extension in Poland (Świdziński 1961) and Slovak Republic (Potfaj 1983) where the deposition persisted for a longer time.

The Krosno lithofacies, besides the succession of regional "Menilite" facies in the Oligocene, is a characteristic feature of the group of nappes in the Flysch Carpathians. The onset of the Krosno lithofacies was triggered by the beginning of tectonic movements that rebuilt the deep-sea basins with predominantly pelagic sedimentation to much shallower relic molasse basins. The Krosno lithofacies itself can be regarded as an accumulation of turbidites controlled by the Neoalpine orogenetic activity (Picha et al. 2006). The typical development of this lithofacies is light grey mostly calcareous mudstone and clay interbedded with fine-grained sandstone with calcareous cement and clastic garnets.

The Krosno lithofacies overlay the Menilite Formation, which can be characterized as a succession of several regional facies reflecting the isolation of basins (Krhovský et al. 1992). The basal Sub-Chert Member of Menilite Formation consists of bioturbated light marls interbedded with dark laminated shales and documents stepwise isolation of the depositional area from the World Ocean. Higher, the Chert Member usually in facies of "Menilite" cherts and non-calcareous siliceous shales, represents period of widespread anoxia, water stratification, freshwater surface waters and high biosiliceous productivity. Above, the blooms of nannofossil *Reticulofenestra ornata* formed the Dynów Marlstone — a horizon of bioturbated nannofossil marlstones that were accumulated under similar settings to the underlying cherts but with slightly increased surface salinity.

The terminal member of the Menilite Formation is the Šitbořice Member that reflects the restoration of normal marine conditions in the surface waters but anoxia still persisted alternating with oxic episodes (Krhovský et al. 1992). Typically brown-grey laminated shales and marls interbedded with grey bioturbated shales prevail in lithology.

The onset of the Krosno lithofacies is usually a gradual transition with increased frequency of turbidites of typical lithology mentioned above. The maximum thickness of the Krosno lithofacies attains up to 1250 m at the Moravian territory according to the deep boreholes. In the Polish Outer Carpathians it may exceed 3000 m (Bak 2005).

The Krosno lithofacies has several local lithostratigraphic names along the Carpathian arc: the Křepice Formation in the Pouzdřany Unit, Ždánice-Hustopeče Formation in the Ždánice-Subsilesian Unit, and Krosno Formation in the Silesian and Fore-Magura Units (Fig. 1).

Previous studies

The diachronous onset of the Krosno lithofacies in the Western Carpathians was described by Koszarski & Żytko (1959, 1961), Jucha (1969), and Haczewski (1981, 1984) based on the occurrence of the Jaslo Limestone marker horizon in the different lithostratigraphic units (Menilite, Krosno, and Malcov Formations) from the Polish Flysch Carpathians. In the territory of the Czech Republic only incomplete information exists about the age of the Krosno lithofacies (Krhovský et al. 1995; Bubík & Švábenická 2000; Stráník & Švábenická 2004). The biostratigraphy of the Krosno lithofacies was studied mainly by microfossils and calcareous nannofossils (Molčíková & Stráník 1987; Stráník 2004; Švábenická & Stráník 2005; Švábenická et al. 2005). The position and stratigraphic validity of the Zagórz Limestone in the Krosno lithofacies has already been mentioned by Bubík & Švábenická (2000).

Material

The Stavěšice, Boleradice, Dolní Věstonice, and Chomýž sections were newly documented. The rock and fossil material is stored at the Czech Geological Survey. Archive rock material from the boreholes Křepice-5 and Slavkov-3, and test trenches Němčičky and Dolní Věstonice stored in the Czech Geological Survey, Brno was exploited for nannofossil study. The original microfossil slides from the same storage were available for the revision of foraminifers and other microfossils: diatoms, prasinophytes, radiolarians, pteropods, fish and shark remains, etc. For the location of all these sections see Fig. 1.

Methods

Samples disintegrated in solution of sodium bicarbonate were washed to obtain microfossils using sieves of mesh size 0.063 mm. The microfossils were manually picked under binocular microscope. Semiquantitative data

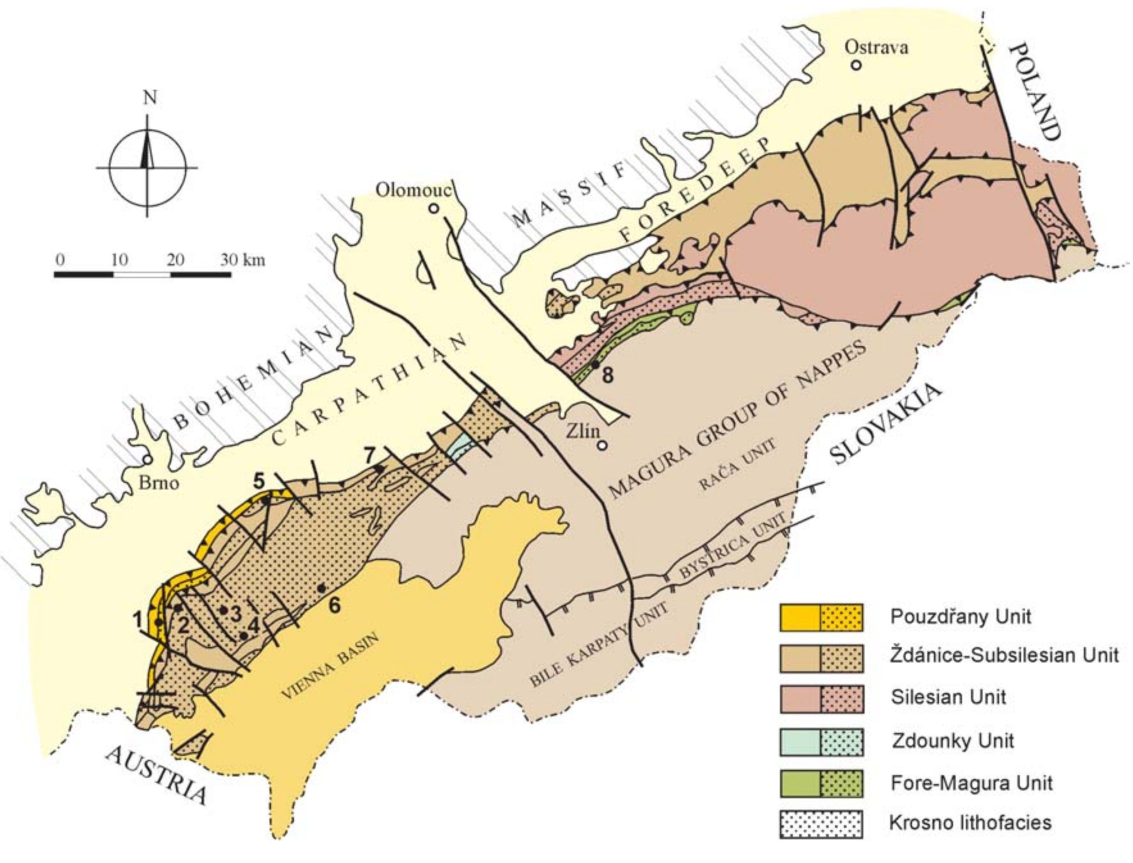


Fig. 1. Krosno lithofacies in the Outer (Menilite-Krosno) Group of Nappes, Outer Western Carpathians in the territory of the Czech Republic. Localities: **1** — Pouzdřany, **2** — Křepice-5, **3** — Boleradice, **4** — Němčičky, **5** — Slavkov-3, **6** — Stavěšice, **7** — Litenčice, **8** — Chomýž.

for microfossils are usually based on picks of 300 specimens at least. The counts were done separately for planktonic foraminiferal assemblage and benthic foraminiferal assemblage as separate sets from the same sample. Other microfossils were then counted from total taphocoenose (together with foraminifers). Smaller microfossil picks from poor samples were not counted and only a presence of microfossils was recorded.

Smear slides for calcareous nannofossils were prepared using a decantation method. The 3–30 μm fraction was separated in the following way: 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. Examination of the nannofossils was carried out using an oil-immersion-objective Nikon light-microscope at 1000 × magnification.

Biostratigraphic data were correlated with planktonic foraminiferal zones by Berggren et al. (1995) and nannoplankton standard NP and NN zones by Martini (1971) and NNT zones by Varol (1998). Central Paratethys regional stages and their comparison with nannoplankton NP and NN zones (Table 1) and biostratigraphic evaluation of planktonic foraminifers are done sensu Cicha et al. (1998).

Table 1: Correlation of Oligocene and Early Miocene with Central Paratethys stages by Cicha et al. (1998), modified. The informal substages of the Kiscellian after Báldi (1980) and Egerian by Báldi & Seneš (1978). **M.M.** — Middle Miocene, * — (partim).

Epoch	Age	Central Paratethys stages		Biozones (Berggren et al. 1995) Planktonic foraminifers	Biozones (Berggren et al. 1995) Calcareous nannoplankton
M.M.*	Langhian	Badenian (partim)		M6	NN5*
				M5	
Early Miocene	Burdigalian	Karpatian		M4	NN4
		Ottnangian		M3	
					NN3
		Eggenburgian		M2	NN2
	Aquitanian	Egerian	late	M1 b	
				M1 a	NN1
Oligocene	Chattian		early	P22	NP25
				P21 b	
	Rupelian	Kiscellian	late	P21 a	NP24
				P20	
			early	P19	NP23
				P18	NP22
					NP21*

Results

Křepice-5 Borehole

The borehole was drilled in 1981 and penetrated the Ždánice-Hustopeče Formation, reached the top of the Šitbořice Member at 25.4 m, and the top of the Dynów Marlstone at 95.15 m, both of the Menilite Formation (Stráník et al. 1981a; Jurášová 1987), Fig. 2.

The microfossil oryctocoenoses are composed of planktonic and benthic foraminifers (Fig. 3), abundant fish remnants (teeth, bones, scales), rare radiolarians, sponge spicules, juvenile bivalves, pteropods, diatoms, prasinophytes (Figs. 4, 5), etc. Benthic foraminifers are predominantly calcareous, mainly buliminids (Table 2). Some assemblages are dominated by agglutinated taxa (ammodiscids). Otherwise, agglutinated taxa represent a minor part of the highly diverse mixed assemblages. This fauna comprises *Glomospira gibbosa*, *G. charoides*, *Ammodiscus* sp., *Bathysiphon*? sp., *Haplophragmoides* spp., *Trochammina* spp., *Recurvoidella* sp. The lower part of the Šitbořice Member and the interval just below the onset of the Krosno lithofacies are characterized by frequent reworked planktonic foraminifers from the Middle–Upper Eocene (mostly *Subbotina* spp.) and less often the older taxa. The lowermost part of the Ždánice-Hustopeče Formation does not show any faunal turnover. It is a rather step-wise decrease in diversity with more frequent levels barren of foraminifers upwards.

Calcareous clays of the upper part of the Šitbořice Member were rich in moderately preserved nannofossils of very low diversity (Table 3). The assemblages are characterized by alternations of abundances of genus *Pontosphaera* (Fig. 6.21–36), or *Cyclicargolithus* spp., *Dictyococcites bisectus*, *Reticulofenestra lockeri*, *R. minuta*, and *Syracosphaera* sp. Specimens reworked from the older strata either occurred in very low numbers or were not encountered. Bloom *Reticulofenestra ornata* (Fig. 7.19–24) was recorded in the uppermost part of the formation. It is interrupted by a short interval of higher diversity where *R. ornata* disappears and *Helicosphaera obliqua* (Fig. 6.7–10) occurs for the first time.

The Krosno lithofacies yields poor and poorly preserved nannofossils. Rare specimens of *Helicosphaera recta* accompanied by *Cyclicargolithus* spp., *Pontosphaera multipora*, abundant *Reticulofenestra minuta*, and other species were found in the lowermost part of the section exclusively (see Table 3). The overlying sediments contain scarce autochthonous species complemented by more frequent reworked nannofossils. Some levels provided either poor reworked specimens exclusively or were barren of nannofossils.

Biostratigraphy: The first occurrence of *Helicosphaera obliqua* at 29.2–29.4 m proves the NP24 Zone (Aubry 1990). The base of the zone may, anyhow, be lower considering *H. recta* reported by Stráník et al. (1981a) from 64.0 m depth. At 28.9–29.0 m the significant planktonic foraminifer *Paragloborotalia opima* rarely occurs for the first time and formally delimits the base of the *P. opima*

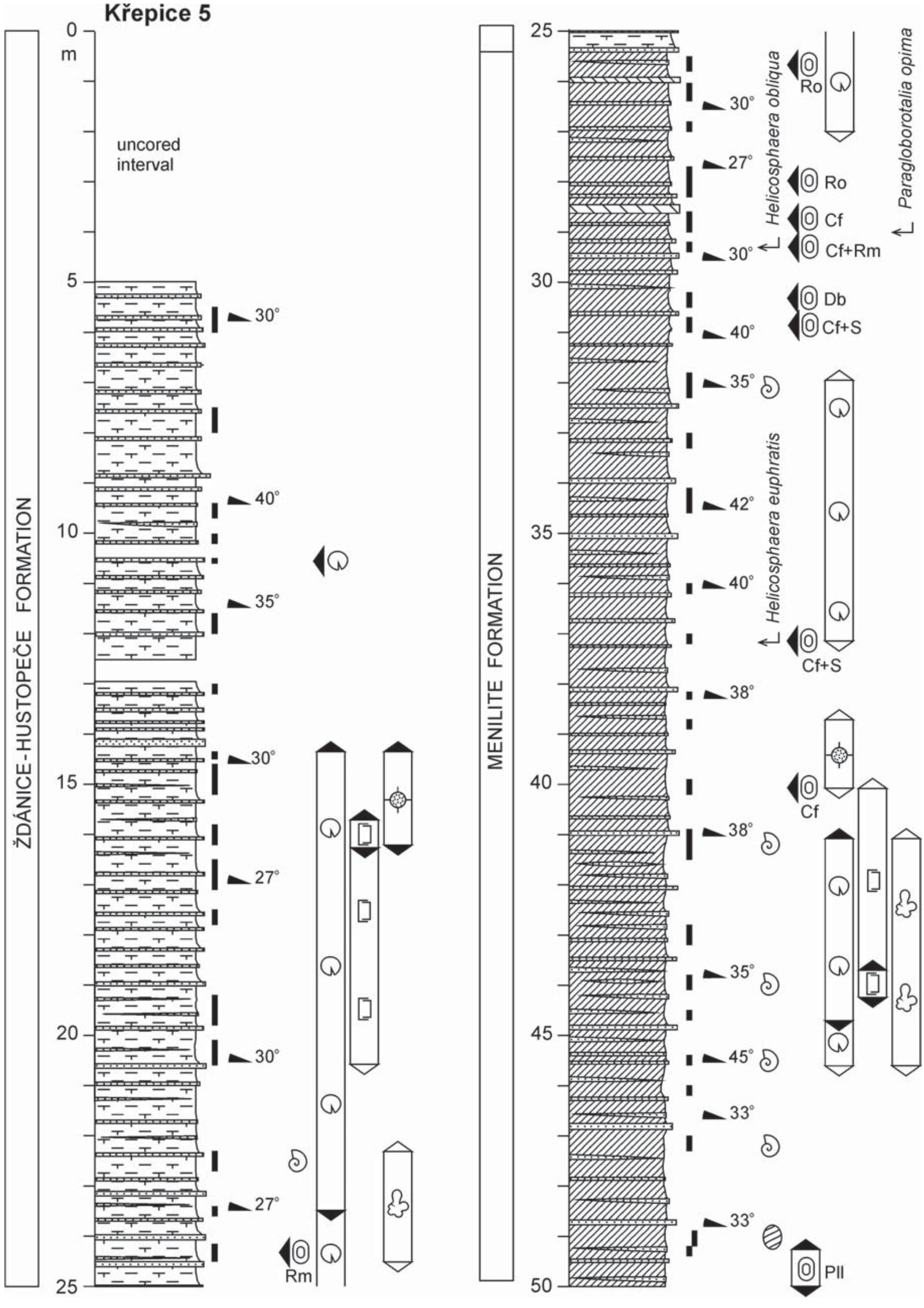


Fig. 2. Log of the Křepice-5 Borehole. **1** — brownish marlstone; **2** — brown grey non-calcareous shale; **3** — fine-grained sandstone; **4** — black grey laminated chert; **5** — greenish non-calcareous and brown calcareous shales; **6** — brown limestone; **7** — light grey, calcareous, light grey sideritic dolomite; **8** — grey marly shale; **9** — dip of beds; **10** — first occurrence of fossil; **11** — interval with occurrence; **12** — interval with acme; **13** — horizon with acme; **14** — nannofossils (Cp — *Coccolithus pelagicus*, Cy — *Cyclicargolithus* spp. *Continued on the next page.*

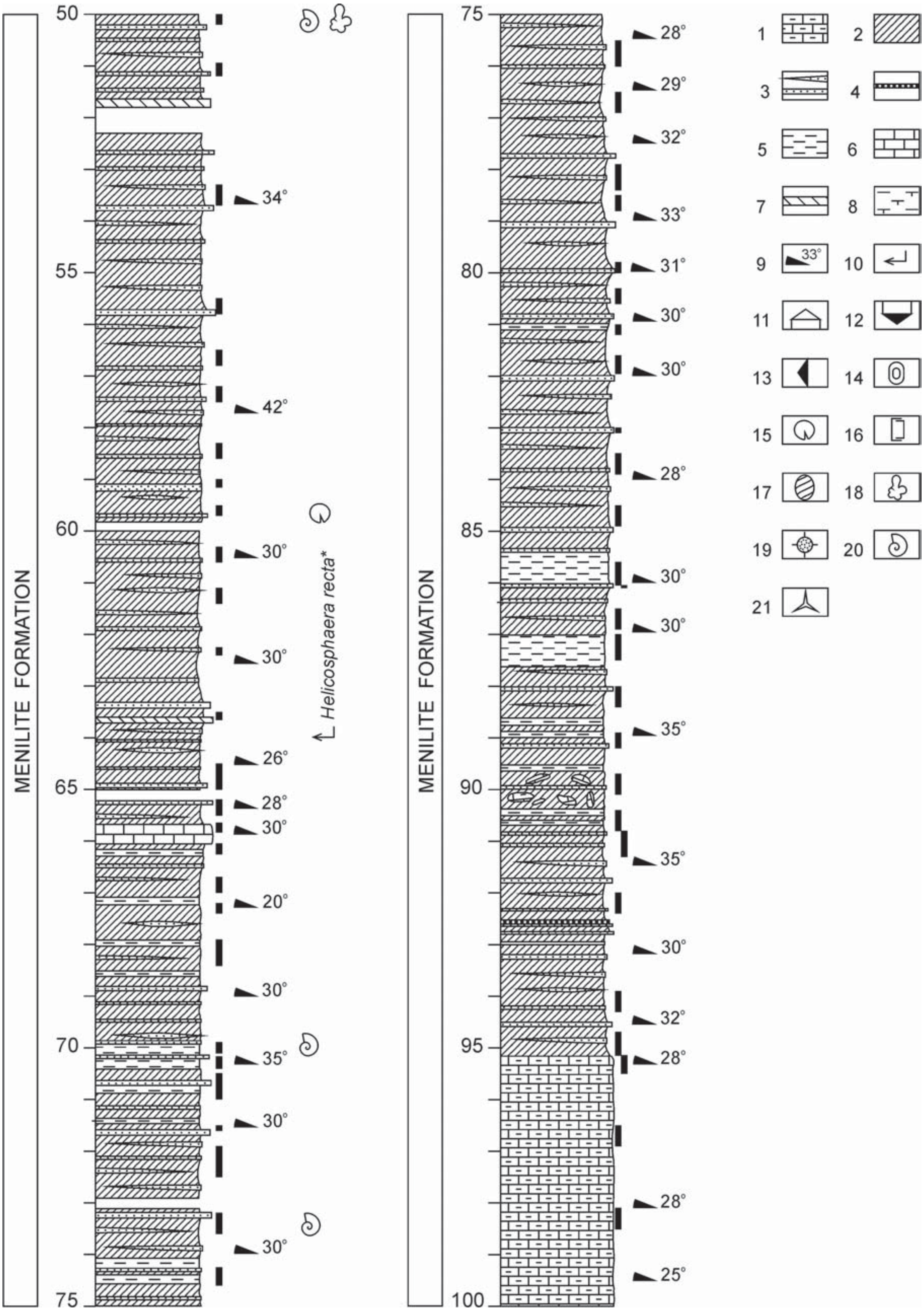


Fig. 2 continued from the previous page. Cf — *Cyclicargolithus floridanus*, Db — *Dictyococcites bisectus*, Pll — *Pontosphaera latelliptica, P. latoculata*, S — *Syracosphaera* sp., Rm — *Reticulofenestra minuta*, Ro — *Reticulofenestra ornata*); **15** — prasinophytes; **16** — diatoms; **17** — charophytes; 18 — clavate planktonic foraminifers (*Beella*, *Bolliella*); **19** — radiolarians; **20** — micromolluscs (pteropods, juvenile bivalves); **21** — sponge spicules. * — after Stráník et al. (1981).

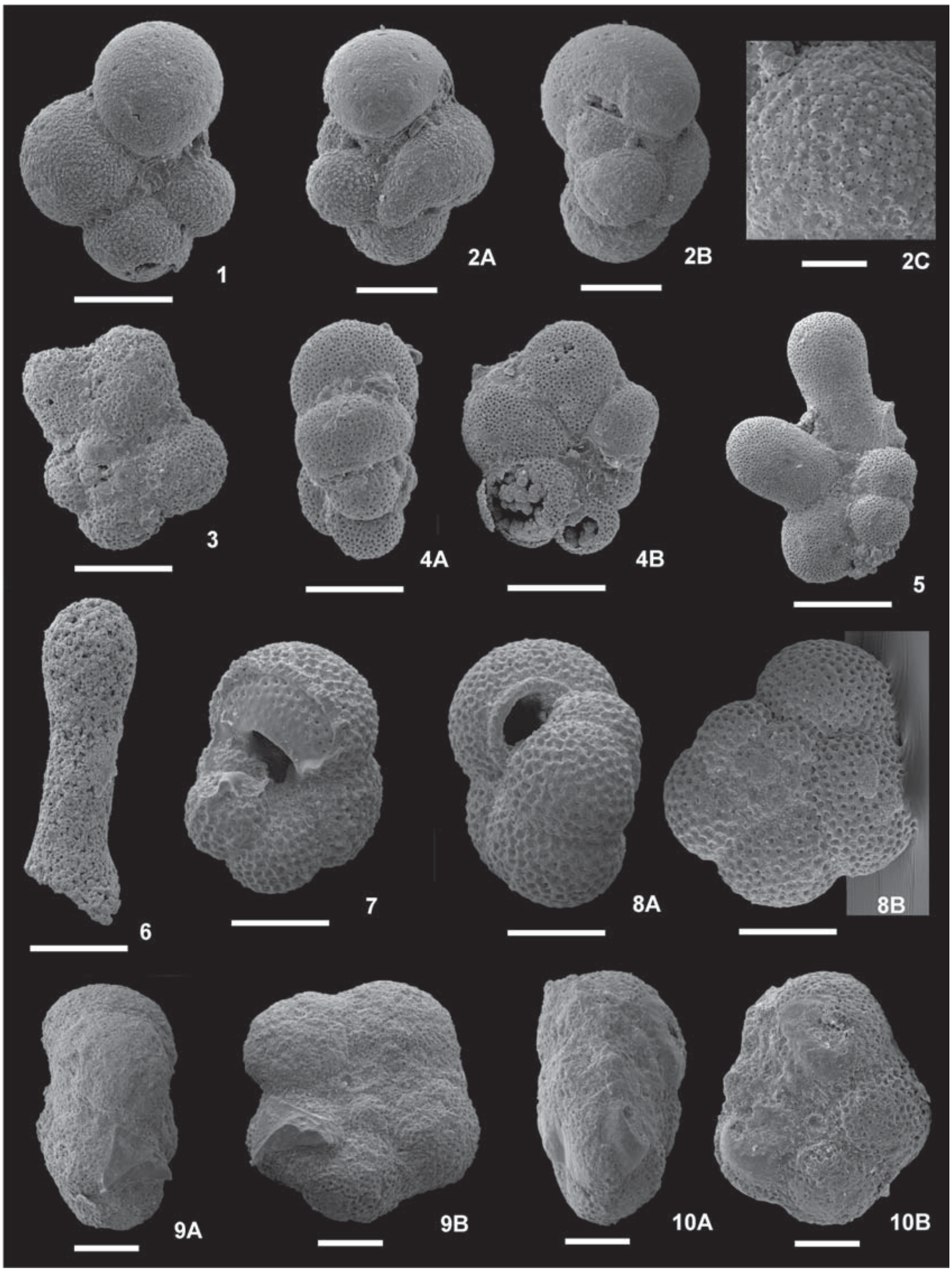


Fig. 3. Significant planktonic foraminifers near the Krosno lithofacies onset. **1, 2** — *Bolliella navazuelensis*, Křepice-5, 24.15–24.5 m. **3–6** — *Beella rohiensis*, Křepice-5; 3,4 — 24.15–24.5 m; 5,6 — 43.8–44.1 m. **7, 8** — *Paragloborotalia semivera*, Slavkov-3, 257.5–258.5 m. **9, 10** — *Paragloborotalia opima*; 9 — Boleradice, sample 69/05; 10 — Křepice-5, 28.6–29.0 m. Length of bar: 100 μm except 2C — 25 μm.

Zone. The surface sample collected from deluvium at the well site revealed *Helicosphaera ampliaperta* indicating NN2–NN4 zone interval, Lower Miocene.

Paleoecology and paleoenvironment: The foraminiferal taphocoenoses indicate fluctuations of paleoenvironment through the section from oxic to dysoxic and fully anoxic (benthic free). The benthic foraminiferal assemblages contain frequent to abundant taxa adapted well to hypoxic conditions: *Fursenkoina*, *Virgulinella*, *Bolivina*, *Caucasina*, *Chilostomella*, *Allomorphina*, *Nonionella* (SenGupta & Machain-Castillo 1993) and also to fluctuating salinity (*Protelphidium*). At the upper part of the Šit-

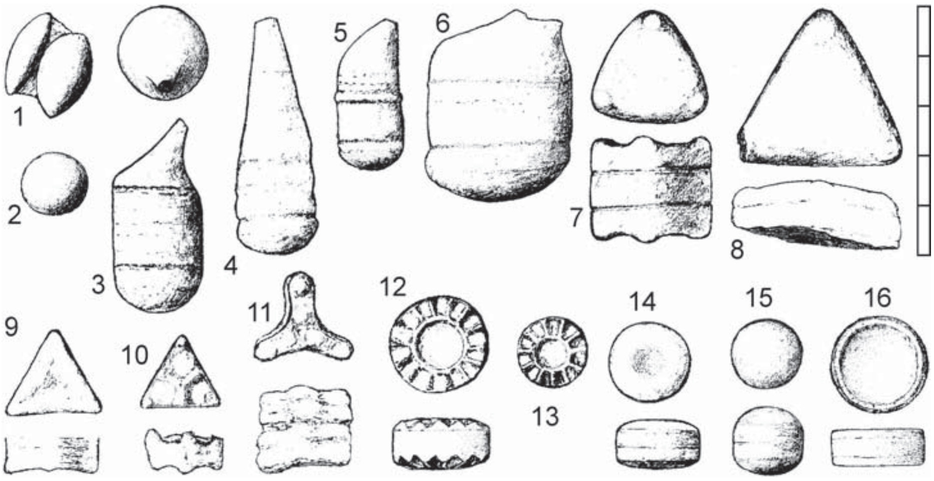


Fig. 4. Prasinophytes and diatoms preserved as pyrite casts. **1, 2** — leiospheres (Prasinophyta): 1 — cast of the specimen with ruptured cuticle, Křepice-5, 15.8–16.2 m. **3–6** — *Odontella* sp., Křepice-5, 43.8–44.1 m. **7–11** — *Triceratium* spp., Křepice-5; 7 — 15.8–16.2 m; 8–11 — 15.8–16.2 m. **12–13** — *Arachnodiscus indicus*, Křepice-5, 15.8–16.2 m. **14–16** — "*Coscinodiscus*" spp., Křepice-5, 15.8–16.2 m. Length of bar 0.5 mm.

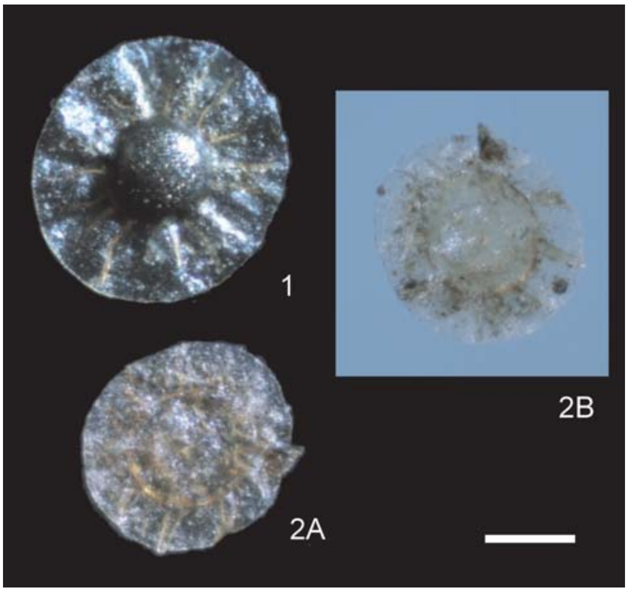


Fig. 5. *Pterospermella* spp. (Prasinophyta). **1** — specimen with 3D preservation filled by pyrite. **2** — compressed specimen, Křepice-5; 1 — 14.6–15.2 m; 2 — 15.8–16.2 m. Krosno lithofacies. Length of bar = 0.1 mm.

bořice Member (at about 38 m) the diversity of benthic foraminifers decreases. At the same level pyrite cores of *Limacina* and juvenile bivalves nearly disappear.

In the upper part of the studied section (32.0 to 23.6 m) unusual occurrences and blooms of microplankton were encountered. They are grouped into two intervals with the same succession:

1. prasinophytes + clavate planktonic foraminifers (*Beella*, *Bolliella*);
2. prasinophytes + diatoms (*Odontella*? sp., "*Coscinodiscus*" spp., *Triceratium* spp., *Arachnodiscus indicus*);
3. prasinophytes + radiolarians.

These intervals contain oligo-specific nannofossil assemblages and are separated by an interval with *Reticulofenestra ornata* bloom that is probably evidence of very low salinity and/or high nutrient levels (Krhovský et al. 1992). *R. ornata* blooms were reported by Stráník et al. (1981a) also from 63.5–64.0 m and 74.2–74.6 m of the Křepice-5.

Slavkov-3 Borehole

The borehole was drilled in 1965 as a fully cored reference section for intepretation of seismics. It penetrated clayey facies of the Ždánice-Hustopeče Formation and at 234.4 m reached the top of a sequence that may be either the reduced (hypoxic) facies of the same formation or the Šitbořice Member of the Menilite Formation (Fig. 8). Below, at 282.8 m a fault was encountered, with Eocene greenish clays below.

The microfossil taphocoenoses consist of planktonic and benthic foraminifers, frequent fish bit, sponge spicules, diatoms, radiolarians and limonite casts of narrow burrowings (*Trichichnus*?), Table 4. Burrowing casts are abundant below 193 m, siliceous microfossils (sponges, diatoms, radiolarians) occur frequently higher. Reworked foraminifers from Upper Cretaceous and older Paleogene strata were encountered at different depths of the section. Highest diversity of reworked forms occurred at 203–205 m: *Gyroidinoides nitidus*, *Globotruncanella petaloidea*, *Pseudohastigerina micra*, *Acarinina soldadoensis*, *A. broedermanni*, *Morozovella trichotrocha*, *M. aequa*.

The nannofossil assemblages below 234.4 m are abundant but of low diversity. High numbers of *Cyclicargolithus floridanus* and *Cyclicargolithus floridanus-abisectus* and/or *Reticulofenestra minuta* are typical for these strata (Table 5). Presence of *Helicosphaera recta* and *H. obliqua* were recorded in 267.0–268.0 m and common Pontosphaeraceae including *Pontosphaera enormis* (Fig. 6.24), *P. discopora* and *P. magna*, and *Helicosphaera euphratis* in 257.5–258.0 m. Reworked nannofossils were present on rare occasions. The sediments above 234.4 m contain mostly poor and poorly preserved nannoflora. Some intervals were barren of nannofossils or contained only reworked Paleogene and Upper Cretaceous specimens. On the other hand, the lowermost part of the section (234.0–225.0 m) yielded abundant and medium-well preserved nannofossils characterized by helicosphers (*Helicosphaera ampliaperta*, *H. scissura*, *H. mediterranea*, *H.* cf. *elongata* — see Fig. 6) accompanied by common *Coccolithus pelagicus* and *Cyclicargolithus floridanus-abisectus.* On rare occasions, *Sphenolithus* cf. *belemnos* and *S. delphix* were recorded in depth 225.0–226.0 m (Fig. 7.26–29). Reworked specimens form a common component of the oryctocoenosis.

Table 2: *Caption see on the next page.*

KŘEPICE-5			PLANKTONIC FORAMINIFERA																					BENTHIC FORAMINIFERA																				
Lithostratigraphy	Planktonic foraminiferal zones*	Sample (m)	*Globigerina postcretacea*	*Globigerina praebulloides*	*Globigerina ouachitaensis*	*Tenuitella brevispira*	*Globigerina wagneri*	*Globigerina euapertura*	*?Globigerina globularis*	*Tenuitellinata angustiumbilicata*	*Beella rohiensis*	*Globigerina lentiana*	*Globigerina officinalis*	*Globorotaloides suteri*	*Paragloborotalia nana*	*"Globigerina" ampliapertura*	*Chiloguembelina cubensis*	*Paragloborotalia opima*	*Tenuitella evoluta*	*Bolliella navazuelensis*	*Tenuitella munda*	upper Senonian plankton	Paleocene-Eocene plankton	*Glomospira gibbosa*	*Glomospira charoides*	*Glomospira gordialis*	*Ammodiscus* spp.	*Bathysiphon?* sp.	*Trochammina* spp.	*Trochamminoides* aff. *variolarius*	*Haplophragmoides* spp.	*Recurvoidella* sp.	*Recurvoides* sp.	*Semivulvulina pectinata*	*Quinqueloculina* spp.	*Amphicoryna* & "*Nodosaria*" spp.	*Lenticulina* spp.	*Plectofrondicularia* spp.	*Neugeborina longiscata*	*Globocassidulina subglobosa*	*Praeglobobulimina* spp.	*Caucasina* spp	*Fursenkoina* gr. *mustoni*	*Fursenkoina* gr. *schreibersiana*
Ždánice-Hustopeče Formation	G. opima	5.5–6.0	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
		7.5–8.0	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
		9.4–9.7	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
		10.0–10.2																						x																				
		10.6–11.0	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
		11.6–12.0			cf																																							
		13.0–13.2		D	R	R				cfR																																		
		14.35–14.6	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
		14.6–15.2	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
		15.8–16.2		A	cfF					R		R	R	R													F	A													R			
		16.5–17.1																						D								x												
		17.5–17.8																						x																				
		19.2–19.8	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
		20.1–20.6																											x		x													
		22.3–22.7		A	R		A				R	R	R	R		R					R																				x			
		23.4–23.6		F	cf		A					F								cfF				R								R					R					R		
		24.15–24.5		F	R	R	A			F	R				R				R	R				D													R					R		
Menilite Formation–Šitbořice Member		25.5–25.8		F			D					cfF											x				D	R				R												
		26.0–26.4		F			F					A		R													D																	
		26.8–27.0		x			x			cfx		x															x	x													x		x	
		27.7–28.3		x								x															x																	
		28.6–29.0		R			R					R	cf		F			R					F																					
	G. ampliapertura	29.2–29.4		A			F					A	R		R								x														R			R				
		30.2–30.5		F			F					A			R								A																					
		30.7–31.0		F			cf			R		D											F																					
		31.8–32.3		F		F	R			R		F	A														A																	
		31.8–32.3 B		R		R							A		A									A			A	R														R		
		33.0–33.3		A		F	F					F	R	R										D													R							
		34.1–34.6					x																	F			D	F																
		36.0–36.2			x																			x				x																
		37.0–37.2		F	R					R	cf	A	F		R		R																			x								
		38.15–38.3																						D	A																			
		38.7–39.0		cfA	R		R					R	R										x					R	R											R	R	R		
		39.9–40.2										cf											x								R										R	R		
		40.9–41.5		F							R	A	R																		R						R					R		
		42.8–43.2		F	R	R					cf	D	R	R										F	R		R		R		R						R			R	R	R	F	
		43.8–44.1		R			A				A	R												F	R			R	R		R			R	R						R	R	F	
		44.5–44.7		x																																	R					F		
		45.4–45.6		F	R	R	F		F		R	A												F			R		R	R					R		R			R	F	R	R	
		46.05–46.2		F	R		A					F										x		R	R		R				R			R	R	R	R	R		R	R	R		R
		47.0–47.3		D			R																R	F							F					R	R					R		R
		48.8–49.2		x																				F	A			F	R															
		49.2–49.4		x																			x	R	F																	R	F	
		49.9–50.2		F		R	A		R	R	F													R					R	R	R				R	R					F		F	
		50.95–51.2		cf	x	cf																		A				R												F	R	R		
		56.5–56.8		D	A		cfR					cfR	R											R				R													R		R	
		59.5–59.7	R	D		R	cfR						F										R						R		R							R		R		R	R	
		65.2–65.5		D			cfF					A	R																															
		69.9–70.1	F		R	F								R									R													R				R		R		
		73.2–73.6	A	F				cfR		F		R	R		R									R			R		R			R	R	R	R				R	R	R	F	R	R
		80.3–80.6																						D	R	A																		
		85.6–86.05		R	cfR								F										F	R								R			A			R				R		
		86.05–86.1	A	R		R		R				R	R	F												R		R				cf							R	R		R		
		90.4–90.8		R	R	cfF	R	R		R			R	A									R					R						R	cf				R	F		R		R
		90.4–90.8B			R							R		D	R	R							F												cf	R								R
		92.0–92.4				cf		cf																																				
		93.9–94.3	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
		94.7–95.15	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/

Table 2: Distribution of microfossils in the Křepice-5 Borehole. **R** — rare (approximately <5 %), **F** — frequent (approx. <10 %), **A** — abundant (approx. >5 %), **D** — dominant (>50 %), **cf** — uncertain determination, **/** — sample barren of foraminifers.

KŘEPICE-5			BENTHIC FORAMINIFERA															OTHER MICROFOSSILS																								
Lithostratigraphy	Planktonic foraminiferal zones*	Sample [m]	*Virgulinella chalkophila*	*Bolivina crenulata*	*Bolivina beyrichi beyrichi*	*Bolivina beyrichi carinata*	*Bolivina dilatata*	*Bulimina* gr. *elongata*	*Angulogerina* & *Euuvigerina* spp.	*Uvigerina moravia*	*Chilostomella* spp.	*Allomorphina* spp.	*Nonionella* spp.	*Epistominella* spp.	*Valvulineria* spp.	*Lobatula* spp.	*Cibicidoides* spp.	*Hanzawaia* spp.	*Escornebovina* spp.	*Gyroidinoides byramensis*	*Melonis affinis*	*Oridorsalis* spp.	*Cribroelphidium* gr. *granosum*	*Protelphidium* spp.	*Pterospermella* sp. (Prasinophyta)	leiospheres (Prasinophyta)	Charophyta (oogonia)	?megaspores	*Odontella*? sp.	"*Coscinodiscus*" spp.	*Triceratium* spp.	*Arachnodiscus indicus*	Spumellaria	Nasellaria	Porifera (spicules)	*Limacina* spp. (Pteropoda)	Bivalvia juv.	Ostracoda	Echinoidea (Irregularia)	Teleostei (bones, teeth)	Elasmobranchii	burrowing casts
Ždánice-Hustopeče Formation	*G. opima*	5.5–6.0	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/																D		
		7.5–8.0	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/																R		
		9.4–9.7	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/																		
		10.0–10.2																																						x		
		10.6–11.0	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	x	F									x							
		11.6–12.0																																						D		
		13.0–13.2		x			x																																	D		
		14.35–14.6	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/		F							D	R	R					A		
		14.6–15.2	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	R															D	R	
		15.8–16.2	F										R												R	F			F				A							A		
		16.5–17.1																								R			R											D		
		17.5–17.8																								D				R										A		
		19.2–19.8	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/		F				R										D		
		20.1–20.6																								R		R	R											D		
		22.3–22.7	x								x		x	x											R	R										R				D		
		23.4–23.6		R		F											R								R	A		R											R	D		
		24.15–24.5	R					R	R		R	R					R											R												D		
Menilite Formation–Šitbořice Member		25.5–25.8		R																		F																		D	R	R
		26.0–26.4															R											R												D		
		26.8–27.0							x		x								x			x		x		x		x												x	x	
		27.7–28.3																																						x		
		28.6–29.0																																						D	R	
	G. ampliapertura	29.2–29.4															R																		R					D	R	
		30.2–30.5																?																						A	R	
		30.7–31.0		R				R									?																							A		
		31.8–32.3	R	A					R						R		R	R																						D		
		31.8–32.3 B	R								R		R													R									R	R				D	R	
		33.0–33.3		R									R												R										R					A		
		34.1–34.6							R																			R							R					D		
		36.0–36.2																							R	R														D		
		37.0–37.2	x																							R														D		
		38.15–38.3																																	R					D		
		38.7–39.0	A		R				F		R	F					R	R		R						x							x							x		
		39.9–40.2	D	R					F		R	F																		R			R							D		
		40.9–41.5	R		R			R	R		R	R	R				R	R		R			R			F				R	R					R	R			D		
		42.8–43.2	A	F	R			R	R		A	R		R	R		R	R	R	R					R				R	R	R	R								A	R	
		43.8–44.1	A		R			F	R		A		R	R	R	R	F			R		R			R	F			F	R						R	F			R		
		44.5–44.7		A				R	F		R					R	R								R															D		
		45.4–45.6	R	R	F	R			R		F	R	R	R	F	R	R			R		R						R									R	R		F	R	
		46.05–46.2		F		F		R	A				R		R	R	F		R	R		R	R	R															R	F		
		47.0–47.3							A					R	R			R						R												R	R			D	R	
		48.8–49.2							A								R										R								R					D		
		49.2–49.4							R							F						R																		D		
		49.9–50.2	F						R		A									F		F															R			A		
		50.95–51.2							F							R							R																	D		R
		56.5–56.8	R						R		A	D																												D		
		59.5–59.7					R	R	F		R					R	R			cfR		D		R		R														D		
		65.2–65.5		x							x																													F		
		69.9–70.1		F					A							R	F	R				R		R												R		R		D		
		73.2–73.6		R		R			A		R	R	R		R		F	R	R																R	R			R	D		
		80.3–80.6																																						x	x	
		85.6–86.05		R					F							R	R																						A	A		
		86.05–86.1		R					R																															A		
		90.4–90.8		R				R	A		R			R		R	R			R	R														R					A		
		90.4–90.8B	R						R	R						R	R	R																	x			x		x		x
		92.0–92.4																																	R					D	R	
		93.9–94.3	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/																A		
		94.7–95.15	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/																R		

Table 3: Distribution of calcareous nannofossils in the Křepice-5 Borehole and biostratigraphic interpretation. * — zones (Martini 1971) attributed to interval upper Egerian-lower Lower Badenian of Central Paratethys stages (see Table 1). Abundance of Oligocene and Miocene nannofossil species: **A** — abundant (>10 specimens per 1 field of view of the microscope), **C** — common (10–5 specimens per 1 field of view), **F** — few (4–1 specimens per 1 field of view), **R** — rare (<10 specimen per 10 fields of view), **VR** — very rare (<1 specimens per 10 fields of view), **?** — questionable species, **f** — fragments, **r** — reworked from the older Oligocene strata. Preservation of calcareous 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 specimens difficult), **VP** — very poor (etching and mechanical damage is very intensive, specimens mostly in fragments). Estimates of the abundance of nannofossils in samples: **VH** — very high (>50 specimens per 1 field of view of the microscope), **H** — (50–30 specimens per 1 field of view), **M** — moderate (30–10 specimens per 1 field of view), **L** — low (10–1 specimens per 1 field of view), **VL** — very low (<10 specimens per 10 fields of view).

Křepice-5 borehole			Nannofossil zones																																					
Age		Lithostratigraphy	Martini (1971)	Varol (1998)	Depth (m)	nannofossil abundance	nannofossil preservation	*Coccolithus eopelagicus*	*Coccolithus pelagicus*	*Cyclicargolithus floridanus*	*Dictyococcites bisectus*	*Pontosphaera latelliptica*	*Pontosphaera latoculata*	*Reticulofenestra lockeri*	*Syracosphaera pulchra*	*Pontosphaera multipora*	*Pontosphaera* cf. *plana*	*Reticulofenestra minuta* (< 3 µm)	*Syracosphaera* sp. (2–3 µm)	*Transversopontis obliquipons*	*Zygrhablithus bijugatus*	*Sphenolithus moriformis*	*Reticulofenestra hillae*	*Cyclicargolithus floridanus-abisectus*	*Helicosphaera euphratis*	*Pontosphaera discopora*	*Braarudosphaera bigelowii*	*Coronocyclus nitescens*	*Helicosphaera bramlettei*	*Pontosphaera rothii*	*Reticulofenestra ornata*	*Cyclicargolithus abisectus*	*Helicosphaera intermedia*	*Helicosphaera obliqua*	*Sphenolithus dissimilis*	*Helicosohaera recta*	*Rhabdosphaera* sp. (fragments)	*Helicosphaera ampliaperta*	*Helicosphaera carteri*	reworked nannofossil specimens
Lower Miocene		Ždánice-Hustopeče Fm	NN2–NN4*		0.0	L	P		F	R	R	r	r	r		F		F	R		r	R	F	r					r	r				r				VR	R	VA
O l i g o c e n e	Kiscellian (upper part)		NP24	NNTo7C – NNTo8	13.0–13.2	barren of nannofossils																																		
					14.5–15.2																																			
					16.5–17.1	VL	VP	R	R		R		r											R																F
					17.5–17.8	barren of nannofossils																																		
					20.1–20.6																																			
					24.1–24.5	H	M		F	F	R		R	R		F		VA	F						F	R	VR					R	F		R	R	F			R
		Menilite Formation (Šitbořice Member)			25.5–25.8	VH	M	R	R	R	R													R							VA									VR
					26.0–26.4	barren of nannofossils																																		
					27.7–28.3	M	M	R	R	F	R																				C									F
					28.6–29.0	H	M			C		R				R					R	F	R		F	R					R				F					VR
					29.2–29.4	VH	M		F	VA	C		VR	R		F		VA				R	R	R	C					F		F	F	F						VR
			NP23 (upper part)	NNTo7A–B	30.2–30.5	H	M		F	F	A			F	R			R					R								F									VR
					30.7–31.0	VH	M			VA	C							R					R		VR						A									VR
					31.8–32.3	L	VP				F	R				VR					VR		R				VR			F	R									R
					33.0–33.3	VH	M		A	A	R	F	A	F	F	R		VA	VA		C	R		VR	R		VR	VR	R	R										R
					37.0–37.2	VH	M	VR	C	F	F	C	C		R	VR		A	A		F			VR	VR	VR														R
				NNTo7A	39.9–40.2	VH	M			VA	F	F	F	R		R			VR			VR	R																	VR
					40.9–41.5	barren of nannofossils																																		
					42.8–43.2																																			
					43.8–44.1	L	P				R	R	F										R																	
					44.5–44.7	H	M	R	VR	R	F	C	F	F	R	VR		C	F		F	VR																		VR
					49.2–49.4	VH	M		C	VR	F	A	C	F		F	R	C	F	VR	F																			
					49.9–50.2	M	M	VR	F	R	R	C	A	C	R																									
					50.9–51.2	barren of nannofossils																																		

Biostratigraphy: The Slavkov-3 Borehole section may be subdivided into two intervals:

1. 234–281 m with planktonic foraminifer *Paragloborotalia semivera* and nannofossil species *Pontosphaera enormis*;
2. above 234 m with foraminifer *Cassigerinella boudecensis* and nannofossil *Helicosphaera ampliaperta*.

The presence of *P. enormis* is evidence of the NP25 Zone (Aubry 1992), Upper Oligocene. The higher interval is the Lower Miocene according to nannofossils (NN2–NN4), more precisely the Eggenburgian on the basis of the foraminifers *Globigerina dubia*, *Globigerinoides trilobus*, and *Paragloborotalia* cf. *acrostoma*. These facts indicate a significant gap or tectonic interval around the depth of 234 m. The presence of *Sphenolithus belemnos* at 225–226 m indicates NN3 Zone correlated with the upper Eggenburgian to lower Ottnangian (see Table 1).

Paleoecology and paleoenvironment: The abundance of helicospheres and pontospheres below 234 m indicates shallow-marine settings. The influx of sphenoliths at 225–226 m reflects a temporary highstand. The overlying strata contain few Miocene specimens and reworked coccoliths predominate. This indicates a shallow-marine

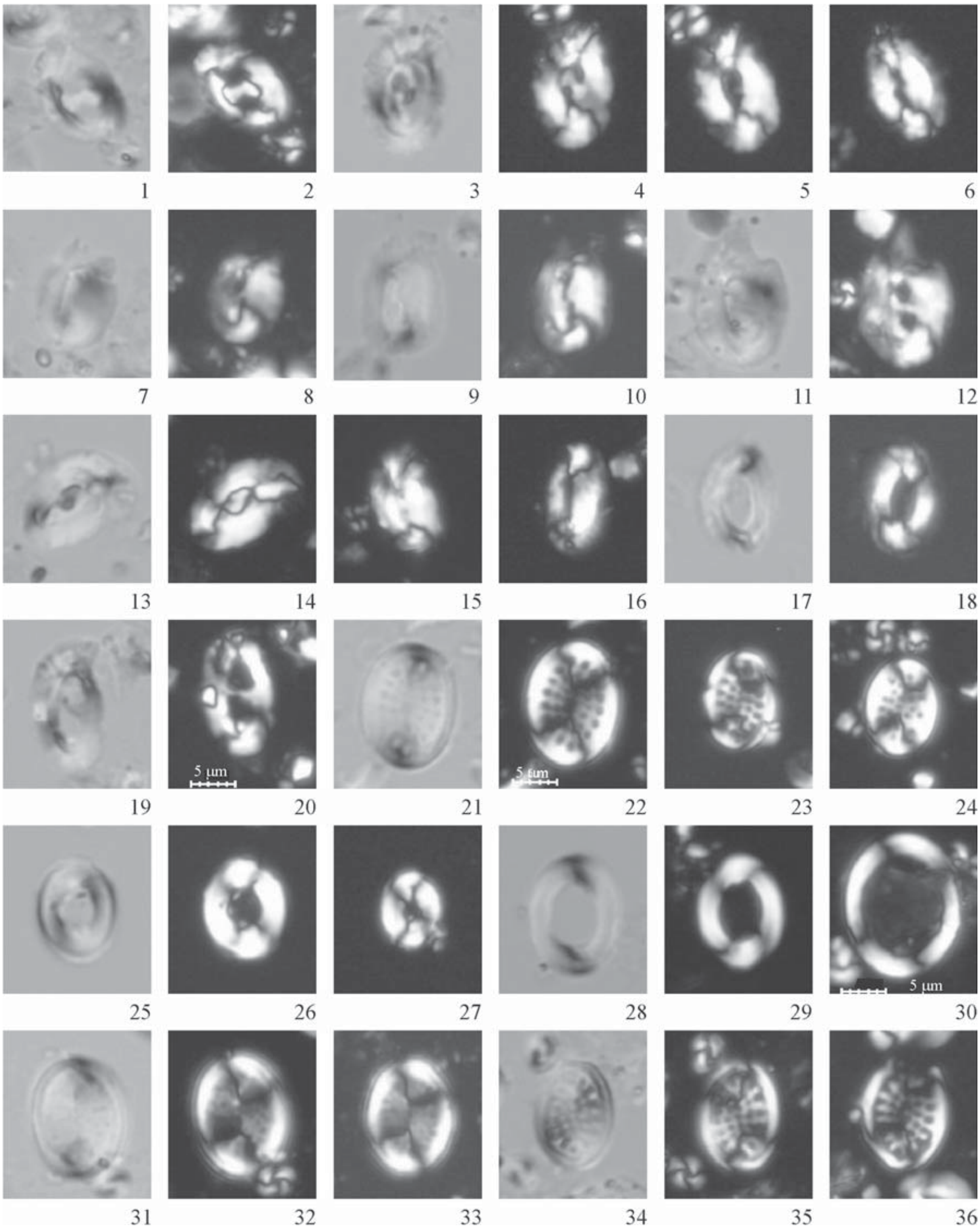


Fig. 6. Significant calcareous nannofossils in the Menilite and Krosno lithofacies. PPL — plane-polarized light, XPL — cross-polarized light. **1, 2** — *Helicosphaera bramlettei*, Křepice-5, 33.0–33.3 m; 1 — PPL; 2 — XPL. **3–5** — *Helicosphaera intermedia*, Křepice-5, 24.1–24.5 m; 3 — PPL; 4, 5 — XPL at 0° and 30°. **6** —*Helicosphaera* cf. *elongata*, Slavkov-3, 233.0–234.0 m; XPL. **7–10** — *Helicosphaera obliqua*, Křepice-5, 29.2–29.4 m; 7, 9 — PPL; 8, 10 — XPL. **11, 12** — *Helicosphaera recta*, Křepice-5, 24.1–24.5 m; 11 — PPL; 12 — XPL. **13, 14** — *Helicosphaera euphratis*, Křepice-5, 29.2–29.4 m; 13 — PPL; 14 — XPL. **15** — *Helicosphaera carteri*, Slavkov-3, 112.0–114.0 m, XPL. **16** — *Helicosphaera scissura*, Slavkov-3, 233.0–234.0 m, XPL. **17, 18** — *Helicosphaera ampliaperta*, Slavkov-3, 225.0–226.0 m; 17 — PPL; 18 — XPL. **19, 20** — *Helicosphaera mediterranea*, Slavkov-3, 225.0–226.0 m; 19 — PPL; 20 — XPL. **21–23** — *Pontosphaera multipora*, Křepice-5, 49.2–49.4 m; 21 — PPL; 22, 23 — XPL. **24** — *Pontosphaera enormis*, Slavkov-3, 257.5–258.0 m, XPL. **25–27** — *Pontosphaera latelliptica*, Křepice-5, 49.9–50.2 m; 25 — PPL; 26, 27 — XPL. **28, 29** — *Pontosphaera latoculata*, Křepice-5, 49.9–50.2 m; 28 — PPL; 29 — XPL. **30** — *Pontosphaera magna*, Slavkov-3, 257.5–258.0 m; XPL. **31–33** — *Pontosphaera discopora*, Slavkov-3, 257.5–258.0 m; 31 — PPL; 32, 33 — XPL. **34–36** —*Pontosphaera rothii*, Křepice-5, 31.8–32.3 m; 34 — PPL; 35, 36 — XPL. For figs. 1–29 and 31–36 see scale bar on fig. 20.

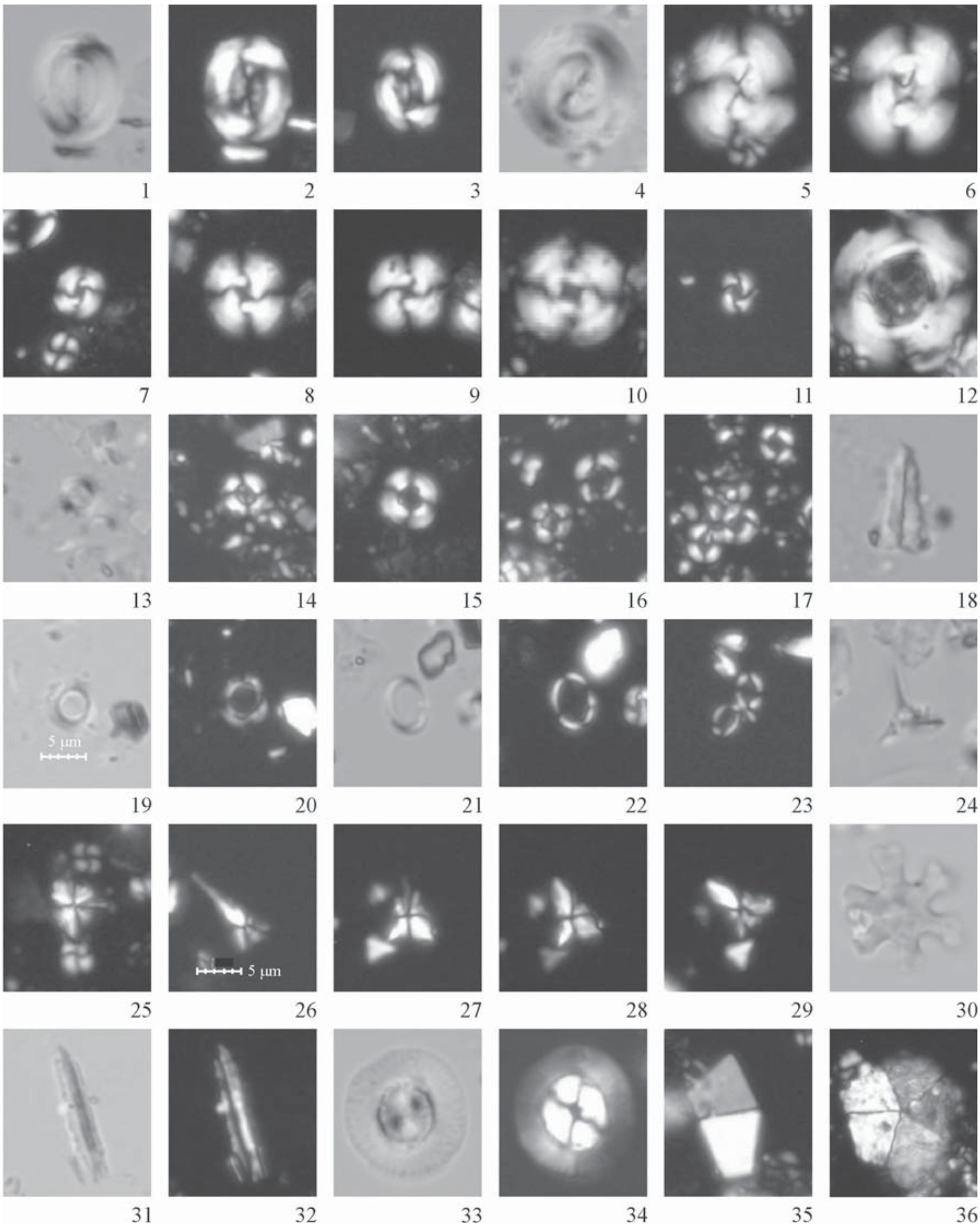


Fig. 7. Significant calcareous nannofossils in the Menilite and Krosno lithofacies. PPL — plane-polarized light, XPL — cross-polarized light. **1–3** — *Reticulofenestra lockeri*, Křepice-5; 1 — PPL; 2, 3 — XPL. **4–6** — *Dictyococcites bisectus*, Křepice-5, 29.2–29.4 m; 4 — PPL; 5, 6 — XPL. **7** — *Cyclicargolithus floridanus*, Křepice-5, 49.9–50.2 m, XPL. **8, 9** — *Cyclicargolithus floridanus-abisectus*, Stavěšice No. 2, XPL. **10** — *Cyclicargolithus abisectus*, Stavěšice No. 7, XPL. **11** — *Reticulofenestra minuta*, Křepice-5, 29.2–29.4 m, XPL. **12** — *Reticulofenestra hillae*, Křepice-5, 30.7–31.0 m, XPL. **13–17** — *Reticulofenestra ornata*, Křepice-5, 25.5–25.8 m; 13 — PPL; 14–17 — XPL. **18** — *Zygrhablithus bijugatus*, Křepice-5, 33.0–33.3 m, PPL. **19, 20** — *Umbilicosphaera rotula*, Slavkov-3, 225.0–226.0 m; 19 — PPL; 20 — XPL. **21, 22** — *Syracosphaera pulchra*, Křepice-5, 33.0–33.3 m; 21 — PPL; 22 — XPL. **23** — *Syracosphaera* sp., Křepice-5, 33.0–33.3 m, XPL. **24** — *Rhabdosphaera sicca,* Slavkov-3, 267.0–268.0 m, PPL. **25** — *Sphenolithus moriformis*, Křepice-5, 28.6–29.0 m, XPL. **26** — *Sphenolithus delphix*, Slavkov-3, 225.0–226.0 m, XPL. **27–29** — *Sphenolithus belemnos*, Slavkov-3, 225.0–226.0 m, XPL at 0°, 15° and 45°. **30** — *Discoaster deflandrei*, Slavkov-3, 225.0–226.0 m, PPL. **31, 32** — *Triquetrorhabdulus carinatus*, 257.7–258.0 m; 31 — PPL; 32 — XPL. **33, 34** — *Coccolithus eopelagicus*, Křepice-5, 44.5–44.7 m; 33 — PPL; 34 — XPL. **35, 36** — *Braarudosphaera bigelowii,* XPL; 35 — Stavěšice No. 4, fragment; 36 — Slavkov-3, 257.5–258.0 m. All figures the same size — for scale bar see fig. 26.

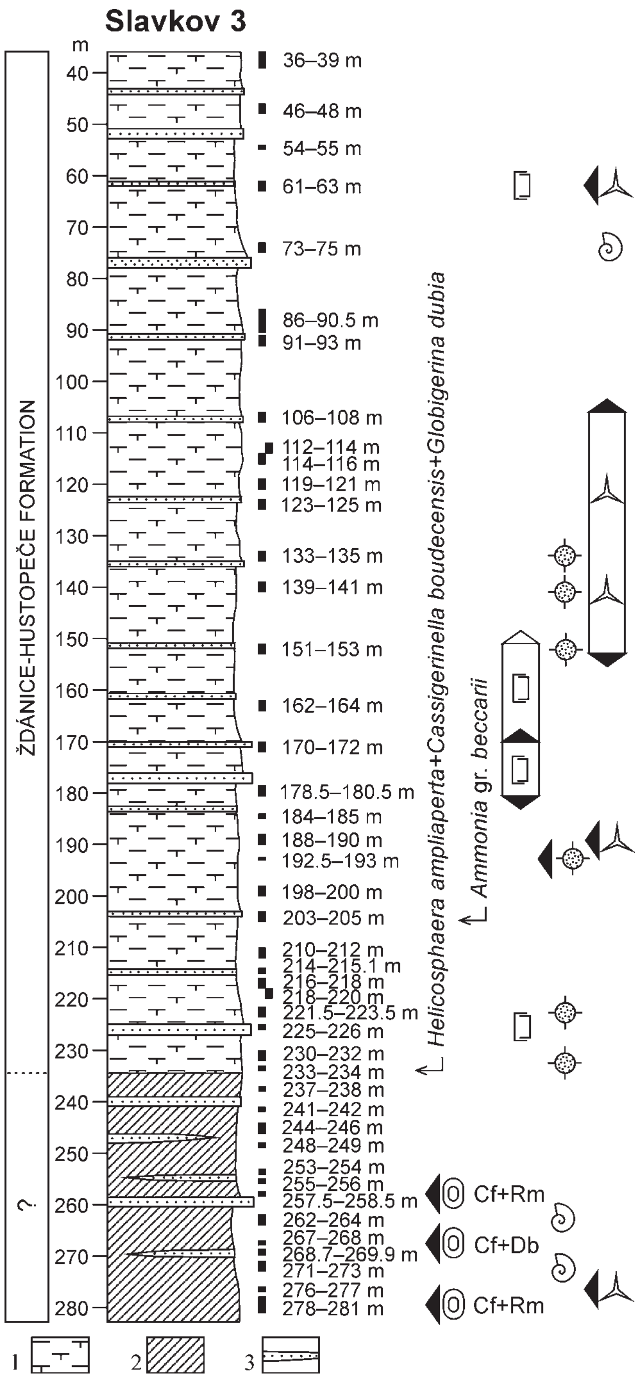


Fig. 8. Log of the Slavkov-3 Borehole. **1** — grey marly shale, **2** — dark greenish-grey shale, **3** — grey calcareous sandstone, for other symbols see abbreviations to Fig. 2.

environment, input of terrigenous material, and probably fluctuating salinity. Benthic foraminiferal assemblages are low in diversity. The assemblage with *Oridorsalis* spp. characterizes the older part of the section (except the barren interval at 205–220 m). Faunal turnover occurs approximately at 205 m depth where *Ammonia* gr. *beccarii* has its first occurrence. At 151 to 180 m frequent pyritized diatoms occur indicating nutrient influx and/or a preservation event.

Stavěšice

The site was studied in the 2.5 m long test trench excavated between Stavěšice and Nenkovice villages. The excavation reached 1.25 m of the Ždánice-Hustopeče Formation with an intercalation of whitish light brown nannofossil limestones of the Zagórz Horizon (Fig. 9).

Microfossil oryctocoenoses comprise planktonic and benthic foraminifers and rarely echinoid spines (Irregularia), pyritized diatoms ("*Coscinodiscus*" spp.), sponge spicules and diatoms. Foraminiferal benthos is solely calcareous, with abundant buliminids (*Fursenkoina*, *Bolivina*, *Caucasina*) but also some rotaliids and nodosariids. The Zagórz Limestone yields nearly monogeneric assemblage of *Cyclicargolithus* sp. The overlying sediments contain rich and moderately preserved nannofossils relatively low in diversity (Table 6). Abundant *Cyclicargolithus* is accompanied by *Zygrhablithus bijugatus*, *Braarudosphaera bigelowii*, pontospheres including common *Pontosphaera rothii*, rare *Helicosphaera recta*, and other species. The proportion of reworked nannofossils (Upper Cretaceous prevails) attains about 1–5 %.

Biostratigraphy: Joint presence of "*Globigerina*" *ampliapertura* and *Helicosphaera recta* indicates late Kiscellian age.

Paleoecology and paleoenvironment: Fairly-well diversified benthic foraminiferal assemblage with abundant *Bolivina* spp. (*B. dilatata*, *B. beyrichi*, *B.* gr. *crenulata*, *B.* gr. *budensis*, *B. semistriata nobilis*) and other calcareous taxa (*Fursenkoina mustoni*, *Caucasina tenebricosa*, *C. schisch-*

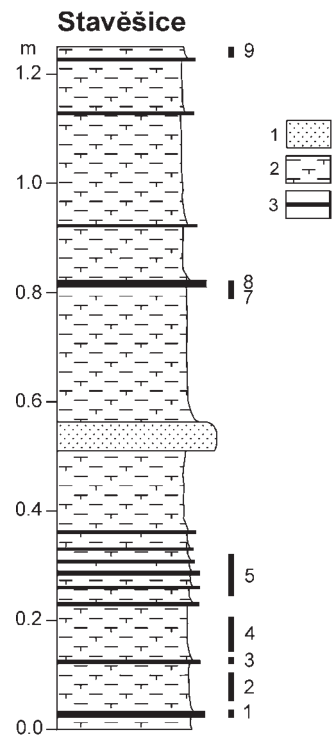


Fig. 9. Detail of the Zagórz Limestone Horizon in Stavěšice. **1** — ochry weathered calcareous sandstone, **2** — grey calcareous clay, **3** — light beige nannofossil limestone (Zagórz Limestone).

Table 4: Distribution of microfossils in Slavkov-3 Borehole. For used signs see Table 2. *Continued on the next page.*

SLAVKOV-3			PLANKTONIC FORAMINIFERA																													BENTHIC FORAMINIFERA										
Age	Lithostratigraphy	Samples [m]	*Globigerina praebulloides*	*Globigerina wagneri*	*Globoturborotalita woodi*	*Catapsydrax unicavus* (non-bullate)	*Paragloborotalia semivera*	*Globigerina ouachitaensis*	*Globigerina lentiana*	*Tenuitella brevispira*	*Globigerina euapertura*	*Catapsydrax dissimilis*	"*Globigerina*" *ampliapertura*	*Tenuitellinata angustiumbilicata*	*Globigerinoides primordius*	*Globigerina posteretacea*	*Globigerina officinalis*	*Globigerina ottnangiensis*	*Cassigerinella boudecensis*	*Globigerina dubia*	*Globigerina quinqueloba*	*Globigerina anguliofficinalis*	*Globigerinelloides trilobus*	*Globigerinella obesa*	*Paragloborotalia* cf. *acrostoma*	*Paragloborotalia nana*	*Tenuitellinata pseudoedita*	*Globorotaloides suteri*	*Paragloborotalia pseudocontinuosa*	U. Cretaceous plankton	Paleocene-Eocene plankton	*Lenticulina* spp.	*Euuvigerina germanica*	*Oridorsalis* sp.	*Gyroidinoides girardanus*	*Cibicides borislavensis*	*Karreriella* sp.	*Elphidium* gr. *subtypicum*	*Globocassidulina subglobosa*	*Almaena* sp.	*Bolivina crenulata*	*Angulogerina* spp.
Eggenburgian	Ždánice-Hustopeče Formation	46–48	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
		54–55																	x																							
		61–63																	x																							
		73–75																x											x		x											
		91–93																																								
		106–108								R						cfR			A																	R			R			
		114–116																																								
		123–125																	D																	R						
		133–135																																								
		139–141								R						R																										
		151–153																																								
		162–164												cfR					R		R																					
		170–172																													x											
		178.5–180.5												R		R			R																	R						
		188–190															R		D		R	R					cfR															R
		192.5–193	R													R	R		F									R			x	R										
		198–200																																								
		203–205										R																R		x	x											
		210–212																																								
		216–218	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
		218–220																												x												
		221.5–223.5	F						R	R				R		R						R												A								
		225–226	F											R		R		R	R			R				R	R			x				D								
		230–232	A	A					F			R	R	R				R					R	R	R						x											
		233–234	A	F			F		F					R	F	F	R	R	R	R	R	R												R								
Egerian	?	237–238	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
		244.1–246																																								
		248–249																																								
		253–254	A						R			F	R																		x	R		D					R			
		257.5–258.5					R		A	F	R																					R		R					R		F	R
		262–264	A	F			F	R																							x	R		A			R	R	R	R		
		271–273	D	R																											x											
		276–277																																		x						
		278–281	R	R	R	D	F																								x	R	R	R	R	cfR						

kinskayae, *Protelphidium* sp., *Nonion* sp., *Neugeborina longiscata*, *Stilostomella* spp., *Angulogerina* spp., *Epistominella* sp., *Escornebovina orthorapha*, *Gyroidinoides* sp., *Melonis affinis*, etc.) indicate oxic to slightly hypoxic normal-marine deeper sublitoral. Nannofossil assemblages with higher numbers of pontospheres, *Z. bijugatus*, and *B. bigelowii* are typical for near-shore environment.

Boleradice

The section is situated in the abandoned sandstone quarry in Boleradice village where the medium-rhythmic turbidite sediments of the Ždánice-Hustopeče Formation crop out (Fig. 10a). The turbidite sequence consists of mudstones, siltstones, and sandstones typical for the Krosno lithofacies (Fig. 11). Whitish nannofossil limestones in the upper part of the section represent the Zagórz Limestone Horizon (Fig. 10b).

Microfossil oryctocoenoses are rich in both planktonic and benthic foraminifers and locally in fish bones. Benthic foraminifers are mostly calcareous, less frequently agglutinated (Table 7). Prasinophyte cysts, diatoms, pteropods, and other microfossils are rather rare. Microfossils are often preserved as limonite casts (originally pyritized). Nannofossil assemblages are of moderate preservation and low in diversity. They contain high numbers of specimens of genera *Cyclicargolithus* and *Coccolithus*. The deposits from the lower part of the section are an exception (Table 8, samples B and E). As well as these genera, they provided *Reticulofenestra minuta*, rare helicospheres (*Helicosphaera euphratis* and *H. recta*) and pontospheres (*Pontosphaera multipora*, *P. latocullata*, and *P. enormis*). Reworked specimens are present scarcely. Some layers did not provide any nannofossils. The intercalations of the Zagórz Limestone yielded bloom of *Cyclicargolithus floridanus-abisectus* usually without any other specimens.

Table 4: *Continued.*

SLAVKOV-3			BENTHIC FORAMINIFERA																		OTHER MICROFOSSILS																								
Age	Lithostratigraphy	Samples [m]	*Escornebovina* sp.	*Cibicidoides* spp.	*Glomospira gibbosa*	*Cribroelphidium* gr. *granosum*	*Grigelis* sp.	*Ortomorphina* sp.	*Bolivina fastigia*	*Ammodiscus* sp.	*Karreriella postsiphonella*	*Sigmoilinita tenuis*	*Cibicidoides pachyderma*	*Hanzawaia* sp.	*Sigmoilopsis* sp.	*Lagnea* sp.	*Glomospira gordialis*	*Ammonia* gr. *beccarii*	*Nonion* sp.	*Elphidium* sp.	*Globocassidulina* cf. *oblonga*	*Uvigerina* cf. *semiornata*	*Globocassidulina globosa*	*Cassidulina laevigata*	*Caucasina schischkinskayae*	*Protelphidium* sp.	*Epistominella* sp.	*Bolivina hebes*	*Pullenia bulloides*	*Bolivina dilatata*	*Melonis pompilioides*	*Bulimina elongata*	*Valvulineria* sp.	Cretaceous-Eocene flysch benthos	"*Coscinodiscus*" sp.	Spummellaria	Nassellaria	Porifera (spicules)	*Limacina* sp. (Pteropoda)	*Bivalvia* juv.	Echinoidea (Irregularia)	Teleostei (bones. teeth)	Teleostei (otolites)	phosphatic pelets	burrowing casts
Eggenburgian	Ždánice-Hustopeče Formation	46–48	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/								R			
		54–55																R	R	cfF			A																						
		61–63																R		R			cfR										R		R	R		F							
		73–75				F																										R		x		R				R		R			
		91–93				x																																							
		106–108																R	F				F	R			R	cfR		R	R					R	R	F							
		114–116				x																																							
		123–125												R				F	F	F							R											A			R	R			
		133–135																R	R				R						R							R		R							
		139–141		R															R				F					R								R		F							
		151–153												R					R				R												R	R		F							
		162–164																R	R	R			F			cfR									R			R							
		170–172																					R												F			R				D			
		178.5–180.5												R				F					R	R		R	R								F			R				F			
		188–190		F														R					A	F	R													F				A			
		192.5–193																R																		A		R				F			
		198–200																				R																			R	R			A
		203–205		R														F	F	F	R																	R				R			R
		210–212															R																									D			
		216–218	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/								D			
		218–220																																				R				R			R
		221.5–223.5		R	R					R	R	R	F	F	R	R																				R						R			A
		225–226		R					cfR																										R	R									
		230–232																																											A
		233–234					R	R																												R						R	R		R
Egerian	?	237–238	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/								F			D
		244.1–246			D	R																																				R		R	D
		248–249			D																																					R			R
		253–254																																				R				R	R		A
		257.5–258.5	R	R																																					R	R			R
		262–264																																						R	R	F	R		A
		271–273																																x				R	R			R			R
		276–277																																				A				A			
		278–281																																								A			

Table 5: Distribution of calcareous nannofossils in the Slavkov-3 Borehole and biostratigraphic interpretation. For explanations see Table 3.

Slavkov-3

Age	Lithostratigraphy	Martini (1971)	Depth (m)	nannofossil abundance	nannofossil preservation	*Coccolithus pelagicus*	*Cyclicargolithus floridanus*	*Cyclicarg. Floridanus-abisectus*	*Dictyococcites bisectus*	*Reticulofenestra hillae*	*Reticulofenestra minuta*	*Reticulofenestra lockeri*	*Cyclicargolithus abisectus*	*Pontosphaera multipora*	*Rhabdosphaera sicca*	*Rhabdosphaera* sp. (fragments)	*Helicosphaera obliqua*	*Helicosphaera recta*	*Pontosphaera latoculata*	*Braarudosphaera bigelowii*	*Helicosphaera euphratis*	*Pontosphaera discopora*	*Pontosphaera enormis*	*Pontosphaera rothii*	*Pontosphaera* cf. *magna*	*Sphenolithus dissimilis*	*Sphenolithus moriformis*	*Triquetrorhabdus carinatus*	*Zygrhablithus bijugatus*	*Coronocyclus nitescens*	*Helicosphaera ampliaperta*	*Helicosphaera* cf. *elongata*	*Helicosphaera scissura*	*Reticulofenestra haqii*	*Syracosphaera pulchra*	*Helicosphaera mediterranea*	?*Sphenolithus belemnos*	*Sphenolithus delphix*	*Umbilicosphaera rotula*	*Discoaster deflandrei*	*Helicosphaera carteri*	*Helicosphaera intermedia*	reworked nannofossil specimens
Lower Miocene	Ždánice-Hustopeče Formation	NN2–NN4	54.0–55.0	VL	VP	VR			VR	f																				VR												R
			86.0–90.5	L	P	R			VR	f				VR													R				VR										VR		F
			106.0–108.0	L	VP	R																				R				F		VR							VR		F
			112.0–114.0	L	P	F	R		R	f																	VR				F										R		F
			119.0–121.0	VL	VP	F	R		R	r																					VR													VR
			123.0–125.0	L	P	F	R	r	R	r														r						R	R				R	VR					R	VR	F
			139.0–141.0	VL	VP	R	R																							R										VR		VR
			151.0–153.0	VL	VP	VR		VR	VR																	VR																VR
			162.0–164.0	VL	VP	R										R																											VR
			170.0–172.0	reworked specimens exclusively																																							
			178.0–180.5	barren of nannofossils																																							
			184.0–185.0	VL	VP	R	R		VR	f																					R												VR
			188.0–190.0	VL	VP	R	VR		VR	f																					VR												R
			192.5–193.0	barren of nannofossils																																							
			203.0–205.0	VL	VP	R														VR																						
			214.0–215.1	VL	P	R	R		R			R		R						R						cf.	R				R									VR			R
			218.0–220.0	barren of nannofossils																																							
			221.5–223.5	barren of nannofossils																																							
			225.0–226.0	VH	MW	A	F	F	R	F				R					R		R										C				R	R	R	R	F	R			C
			233.0–234.0	H	MW	C	F	F	R	F	F	F		F					R		R	R				R	R		VR	R	F	F	F	R	R								F
Oligocene	?	NP25	237.0–238.0	barren of nannofossils																																							
			241.0–242.0	barren of nannofossils																																							
			255.0–256.0	barren of nannofossils																																							
			257.5–258.0	VH	W		VA	C			VA	F	F	C	R	R			R	f	F	F	F	R	R	?	F	R	F														R
			267.0–268.0	H	P		A		A			R		F	F	F	F	VR	C																								VR
		?NP23–24	268.7–269.9	M	P	R	C	R		R		F	?	F																														VR
			271.0–273.0	barren of nannofossils																																							
			276.0–277.0	barren of nannofossils																																							
			280.0–281.0	VH	W	F	A	R	F	f	A	F																															

Table 6: Distribution of calcareous nannofossils in the Stavěšice section and biostratigraphic interpretation. For explanations see Table 3.

Age	Age	Lithostratigraphy	Nannofossil zones: Martini (1971)	Nannofossil zones: Varol (1998)	Sample No.	nannofossil abundance	nannofossil preservation	*Coccolithus pelagicus*	*Cyclicargolithus abisectus*	*Cyclicargolithus floridanus*	*Cyclicargolithus floridanus-abisectus*	*Reticulofenestra hillae*	*Clausicoccus subdistichus*	*Dictyococcites bisectus*	*Pontosphaera multipora*	*Pontosphaera rothii*	*Reticulofenestra minuta*	*Rhabdosphaera* sp. (fragments)	*Sphenolithus moriformis*	*Zygrhablithus bijugatus*	*Braarudosphaera bigelowii*	*Pontosphaera crucifera*	*Discoaster deflandrei*	*Pontosphaera latoculata*	*Reticulofenestra ornata*	*Helicosphaera euphratis*	*Pontosphaera enormis*	*Micrantholithus* sp.	*Pontosphaera discophora*	*Pontosphaera* ex gr. *plana*	*Reticulofenestra lockeri*	*Helicosphaera bramlettei*	*Helicosphaera recta*	*Pontosphaera latelliptica*	reworked nannofossil specimens
Oligocene	Kiscellian (upper part)	Ždánice-Hustopeče Fm	?NP23-NP24-25	?NNTo7B-NNTo10	8	M	P	R	F	C	C		VR	R	F	R	R			F	VR					VR					VR	VR	VR	VR	F
					7	VH	W	F	C	A	A			R		F	R			F		R								R					VR
					6	VH	M	F	F	A	A		R	R	R	C	R		R	C	f	?		R				f	R	R	?				F
					5	H	P	F	F	C	A	f	R	F	VR	C	R			F	F	R				R	?								F
					4	H	M	F	F	C	C	f		R		F	R	F		R	F		VR	R	?										R
					3	M	M	R	R	F	C	f	R	R	R	F				F	VR	R													R
					2	VH	M	F	F	A	A		R	VR	VR	C	R	F	VR	F															R
					1	M	M	R	?	C	C	f																							VR

Biostratigraphy: Early Egerian age is supported by the rare presence of *Pontosphaera enormis* and single *Paragloborotalia opima* (P21) at sample 69/05. Joint occurrence of both species delimits stratigraphic age in a short range within the lower part of the NP25 Zone.

Paleoecology and paleoenvironment: Dominance of low-oxygen specialists (*Fursenkoina mustoni*, *Virgulinella chalkophila*, *Bolivina crenulata*, *Chilostomella* spp., *Stainforthia* spp.) among the benthic foraminifers indicates hypoxic conditons at the bottom. Agglutinated taxa (*Bathysiphon*? sp., *Ammodiscus aequispiralis*, *Trochammina* spp., *Haplophragmoides* spp.) suggest upper bathyal depth, although typical shelf taxa also rarely occur (*Quinqueloculina* sp., *Guttulina* sp.). The abundance of genus *Cyclicargolithus* accompanied by *R. minuta* reflects highstand.

Němčičky

The section was studied using archive samples from 7 m long test trench Němčičky-I. Above the Chert Member of the Menilite Formation there was the strongly reduced sequence of the Šitbořice Member. Tectonic reduction of the thickness is probable. Above this sequence is the Ždánice-Hustopeče Formation (Fig. 12).

Microfossil assemblages at the base of the Šitbořice Member consists of reworked Upper Cretaceous foraminifers. Autochthonous foraminiferal microfauna (plankton and calcareous benthos) was recovered only from the sample 12b, in the Ždánice-Hustopeče Formation. The nannoflora contains common specimens of the genus *Cyclicargolithus* including *C. abisectus* and pontospheres with *Pontosphaera*

Fig. 10. Boleradice section (abandoned quarry). **a** — Krosno lithofacies, **b** — detail of the Zagórz Limestone Horizon.

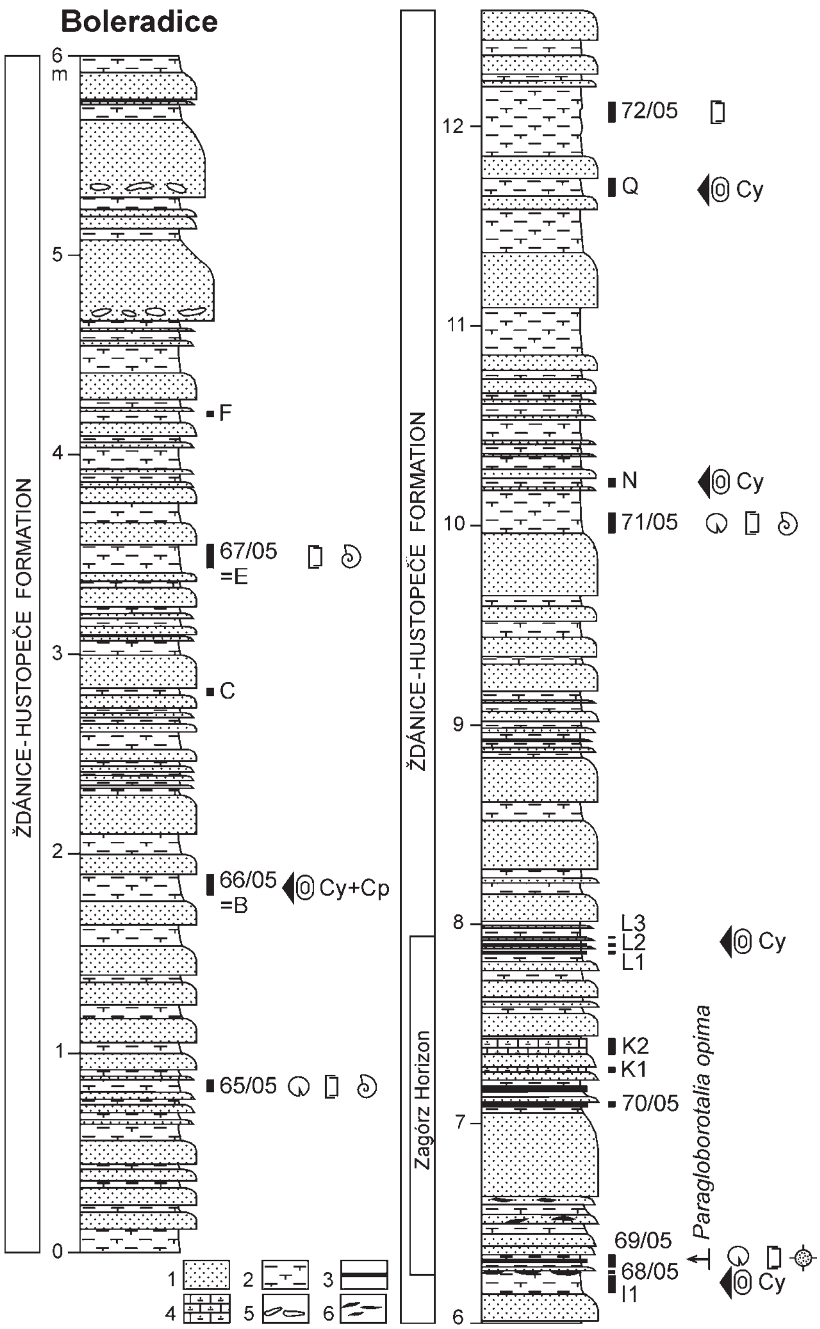


Fig. 11. Log of the Boleradice section (abandoned quarry). **1** — grey calcareous sandstone, **2** — brown grey and grey calcareous shale, **3** — whitish nannofossil limestone (Zagórz Limestone), **4** — grey silty marlstone, **5** — shaly intraclasts, **6** — nannofossil-limestone intraclasts. For other symbols see abbreviations to Fig. 2.

enormis (samples 12a and 13) and *P. rothii*. *Helicosphaera recta* was recorded in samples 12 and 13. Assemblages are accompanied by high numbers of reworked nannofossils from the Upper Cretaceous and older Paleogene strata.

Biostratigraphy: Presence of *Cassigerinella boudecensis* in the sample 12b indicates the Early Miocene age (Cicha et al. 1998) whereas calcareous nannofossils indicate the early Egerian.

Paleoecology and paleoenvironment: Only the sample 12b revealed autochthonous foraminiferal fauna. Benthic taxa represent mostly low-oxygen tolerant forms (*Bolivina* gr. *crenulata*, *Bulimina elongata*, *Caucasina coprolithoides*, *Fursenkoina* cf. *mustoni*). Normal salinity hypoxic conditions can be considered. The presence of pontospheres reflects a near-shore environment.

Chomýž

In the Fore-Magura Unit two composite sections near Chomýž village were studied. Both of them consist of isolated outcrops revealing the transition from the Menilite to Krosno lithofacies (Fig. 13).

The microfossil oryctocoenoses of the Šitbořice Member are extremely poor. Only single specimens of benthic foraminifers (*Pullenia*? sp., *Cibicidoides boryslavensis*) and rare pyritized diatoms, sponge spicules, echinoid spines, fish remains, and phosphatic pelets may be autochthonous. Massive redeposition of Eocene mixed foraminiferal fauna (predominantly agglutinated benthos) constitutes the major part of the oryctocoenoses. The same strata also yield poor nannofossils with *Reticulofenestra ornata* bloom accompanied by rare *Cyclicargolithus floridanus-abisectus* and *Transversopontis pax* (Table 9). A change in nannoflora was observed immediately below the onset of the Krosno lithofacies. *R. ornata* disappears and the autochthonous component is formed by *Helicosphaera euphratis*, *Pontosphaera multipora*, *P. latoculata,* and *Cyclicargolithus floridanus-abisectus*. Moreover, deposits contain fragments of mostly reworked specimens from the older flysch strata. Some levels were barren of calcareous nannofossils.

The Krosno lithofacies (Ždánice-Hustopeče Formation) contains for fewer of reworked flysch-type foraminifers. In the pseudoassociation of the Krosno Formation marsh-type agglutinated fauna newly appears. It is comparable with the fauna of the Cenomanian–Turonian of the Bohemian Cretaceous Basin (*Evolutinella* sp., *Trochammina* aff. *inflata*, *Glomospira* sp.). These redepositions were observed in the samples 5/05A and B. The lowermost part of the Krosno lithofacies provided rare nannofossils mostly reworked from the older strata accompanied by diatoms. Poor autochthonous nannoflora with *Helicosphaera obliqua*, *H.* cf. *carteri* and *H. intermedia* was recorded in sample No. 71A (see Fig. 13). A bloom of *Reticulofenestra ornata* with rare *Transversopontis obliquipons* was observed ap-

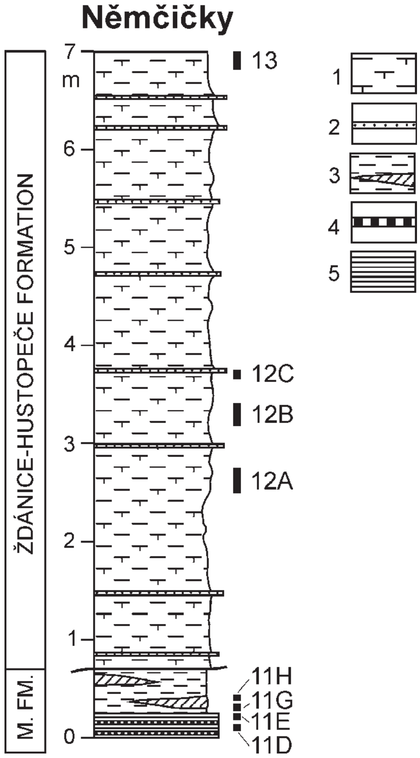


Fig. 12. Log of the Němčičky-I Test Trench. **1** — greenish-grey and brownish-grey calcareous shales, **2** — grey sandstone, **3** — green-grey and brown-grey non-calcareous shales with marly slices, **4** — chert, **5** — non-calcareous shale.

proximately 10 m above. In fact, no distinct change in nannoflora was observed in this transitional interval.

Biostratigraphy: The recovered microfauna is common in the Kiscellian–Egerian of the Central Paratethys. Nannofossil species *H. obliqua* indicates zone interval NP24–NP25, upper Kiscellian to lower Egerian. The occurrence of the diatom *Odontella* spp. is characteristic also for the upper Kiscellian and lower Egerian of the Ždánice Unit (Křepice-5, Boleradice).

Paleoecology and paleoenvironment: The absence of characteristic planktonic and benthic foraminiferal assemblages of the Menilite and Krosno Formations may be caused by dissolution during early diagenesis. It is anyhow not clear, why at least pyrite cores of foraminifers are not present as is the case for diatoms. The alternation of intervals with poor and mostly reworked nannoflora and *Reticulofenestra ornata* reflects eustatic fluctuation and periods of low salinity to fresh water conditions.

Summarizing remarks and discussion

Unconformities

Indices of possible unconformity were observed in the Slavkov-3 section. At 234 m the first occurrences of several marker taxa are accumulated although under normal superposition they would be apart (*Cassigerinella boudecensis*, *Glo-*

Table 7: Distribution of microfossils in the Boleradice section. For explanations see Table 2.

BOLERADICE			PLANKTONIC FORAMINIFERA											
Age	Lithostratigraphy	Sample	*Globigerina wagneri*	*Tenuitella brevispira*	*Tenuitellinata angustiumbilicata*	*Globigerina officinalis*	*Bolliella navazuelensis*	*Beella rohiensis*	*Globigerina leniana*	*Tenuitella denseconnexa*	*Tenuitella munda*	*Tenuitella liverovskae*	*Paragloborotalia opima*	*?Globigerina* spp.
Oligocene	Ždánice-Hustopeče Fm	72/05												
		71/05			cfR							cfR		F
		70/05	/	/	/	/	/	/	/	/	/	/	/	/
		69/05		A	R	R			cfR		R		R	
		68/05		D							R			
		67/05	R	A				F			R	cfR		
		66/05		R	R				A	R				
		65/05	R	F	F	R	cfR	F						

BOLERADICE			BENTHIC FORAMINIFERA																												
Age	Lithostratigraphy	Sample	*Fursenkoina* gr. *mustoni*	*Epistominella binominata*	*Epistominella typica*	*Epistominella* spp.	*Bolivina* gr. *crenulata*	*Bolivina fastigia*	*Angulogerina* & *Euuvigerina* spp.	*Amphimorphina* spp.	*Chilostomella* spp.	*Virgulinella chalkophila*	*Nonionella* sp.	*Biapertorbis alteconica*	*Protelphidium* spp.	*Bolivina dilatata*	*Stainforthia* spp.	*Bulimina elongata*	*Bathysiphon?* sp.	*Trochammina* spp.	*Haplophragmoides* spp.	*Ammodiscus aequispiralis*	*Stilostomella* spp.	*Quinqueloculina* sp.	*Cibicidoides borislavensis*	*Globocassidulina globosa*	*Guttulina* sp.	*Virgulopsis* sp.	*Caucasina* spp.	*Asterigerinoides* sp.	*Cibicidoides* spp.
Oligocene	Ždánice-Hustopeče Fm	72/05		A	R		F	R	F						R			R			R	R			R				R		R
		71/05	D	F	R		A		R			R		F	R					R	cfF	F								R	R
		70/05	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
		69/05	D	R	R		R		R		F	cfR					R		R											R	
		68/05	D						R		R		R						R												
		67/05	D		R		R		R		F	F	R				A			R	cfR	R		R					R		
		66/05		F		A	R	R	F						R				R		R	F			R	R	R	R	R		
		65/05	A	F			F		F	F	F	R	R	R	R	R	R	R	R	R	R	R	R	R							

BOLERADICE			OTHER MICROFOSSILS										
Age	Lithostratigraphy	Sample	*Pterospermella* sp. (Prasinophyta)	leiospheres (Prasinophyta)	*Odontella?* sp.	"*Coscinodiscus*" spp.	*Triceratium* spp.	*Nasellaria*	Porifera (spicules)	*Limacina* spp. (Pteropoda)	Bivalvia juv.	Echinoidea (Irregularia)	Teleostei (bones, teeth)
Oligocene	Ždánice-Hustopeče Fm	72/05				R							D
		71/05	R		R					R			R
		70/05											
		69/05		R	R			R					
		68/05										F	R
		67/05			R		R			R			
		66/05							R				R
		65/05	R		R	R	R				R		R

Table 8: Distribution of calcareous nannofossils in the Boleradice section and biostratigraphic interpretation. For explanations see Table 3.

Boleradice: Age		Lithostratigraphy	Nannofossil zones: Martini (1971)	Nannofossil zones: Varol (1998)	Sample No.	sample abundance	nannofossil preservation	*Coccolithus pelagicus*	*Cyclicargolithus floridanus*	*Cyclicargolithus floridanus-abisectus*	*Dictyococcites bisectus*	*Reticulofenestra minuta*	*Cyclicargolithus abisectus*	*Braarudosphaera bigelowii*	*Coccolithus eopelagicus*	*Helicosphaera compacta*	*Helicosphaera euphratis*	*Helicosphaera recta*	*Pontosphaera enormis*	*Pontosphaera latoculata*	*Pontosphaera multipora*	*Reticulofenestra lockeri*	*Reticulofenestra hillae*	*Rhabdosphaera* sp. (fragments)	*Sphenolithus dissimilis*	*Sphenolithus moriformis*	*Zygrhablithus bijugatus*	*Pontosphaera discophora*	*Syracosphaera pulchra*	*Pontosphaera rothii*	reworked nannofossil specimens
Oligocene	Lower Egerian	Ždánice-Hustopeče Formation	NP25	NNTo8–NNTo10	Q_3	H	M	C	C	C	R									VR		R	R						F	R	R
					Q_2	H	M	F		A	R		C						?				VR							VR	f
					Q_1	M	M	F		A			F																R		
					N	H	M	F		A	R		F		R						R		f						R		
					L_3	M	P	R	F	A	R				R								f			R					VR
					L_2	H	M	F		A			C																		
					L_1	M	M			C																					
					K_2	barren of nannofossils																									
					I_1	H	P	F		A			A																		
					F	M	M	A	F		R		F		R														F		VR
					E	H	M	A	R		R	C	F				R		VR	VR	VR		R	R				VR	C		R
					C	barren of nannofossils																									
					B	M	P	C	C	C	F	F	F	f	C	VR	VR	VR	?	VR	R	R	f	R	R	R	R				C

Table 9: Distribution of calcareous nannofossils in the Chomýž section and biostratigraphic interpretation. For explanations see Table 3.

Chomýž: Age		Lithostratigraphy		Martini (1971)	Sample No.	nannofossil abundance	nannofossil preservation	*Reticulofenestra ornata*	*Cyclicargolithus floridanus-abisectus*	*Transversopontis obliquipons*	*Coccolithus eopelagicus*	*Dictyococcites bisectus*	*Coccolithus pelagicus*	*Cyclicargolithus floridanus*	*Helicosphaera euphratis*	*Reticulofenestra hillae*	*Sphenolithus moriformis*	*Pontosphaera latoculata*	*Pontosphaera multipora*	*Zygrhablithus bijugatus*	*Helicosphaera* cf. *carteri*	*Helicosphaera* cf. *elongata*	*Helicosphaera intermedia*	*Helicosphaera obliqua*	*Pontosphaera latelliptica*	*Sphenolithus conicus*	reworked nannofossil specimens
Oligocene	Kiscellian to Egerian	Ždánice-Hustopeče Formation		NP24–NP25	71B	L	P	C		VR		VR															VR
					6B	barren of nannofossils																					
					5B	barren of nannofossils																					
					5A	VL	VP				VR	VR	VR														VR
					71A	L	VP	VR				R	F	F						R	VR	VR	VR	R	R	R	F
	?			?	185H	reworked specimens exclusively																					
					185G	barren of nannofossils																					
					185F	reworked specimens exclusively																					
	Kiscellian (upper part)	Menilite Formation	Šitbořice Meber	NP23	185E	L	VP		F		R	R				f	R	R	R	R							F
					185D	barren of nannofossils																					
					185B	L	VP		R		VR		R	R	R	f	VR										F
					185A	barren of nannofossils																					
					70/6	L	P	C																			
					70/5	L	VP	C		VR	f	VR															
					70/3	M		A	R	F																	
					70/2	M		A																			
					70/1	barren of nannofossils																					

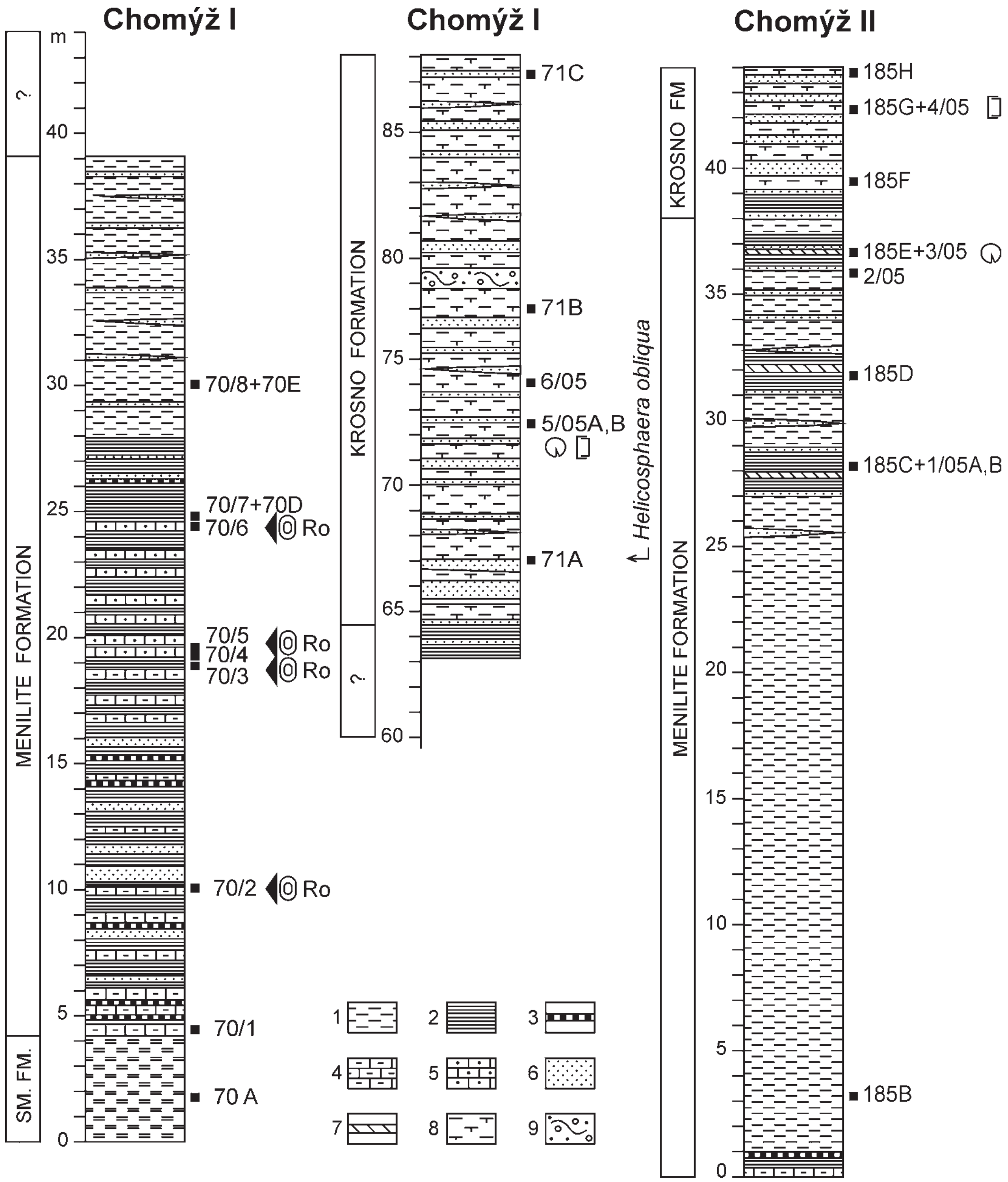


Fig. 13. Logs of the Chomýž I and II sections. **1** — green-grey and brown-grey shales, **2** — dark brown non-calcareous paper shale, **3** — dark chert, **4** — brownish marlstone to limestone, **5** — brownish sandy marlstone to limestone, **6** — sandstone, **7** — ochrous pelocarbonate and beige marl, **8** — grey calcareous shale, **9** — grey calcareous sandstone (slump), for other symbols see abbreviations to Fig. 2.

bigerina dubia, *Globigerinoides trilobus*, *Helicosphaera ampliaperta*). This cummulation reveals a stratigraphic gap comprising the upper Egerian at least. The first occurrence of *Sphenolithus belemnos* just 8 m higher (Fig. 7) indicates that even the lower part of the Eggenburgian may be missing. Another explanation of the gap is tectonic reduction. No additional indices of this possibility were recorded.

Paleobathymetry

A shallowing is indicated in the Slavkov-3 Borehole by benthic foraminiferal turnover from the *Oridorsalis* to *Ammonia* assemblage at 203–205 m. While *Oridorsalis* is stenohaline bathyal element, *Ammonia* is euryhaline and typical of inner shelf settings (Murray 1991). The turnover coincides with abundant redeposition from the Cretaceous and Paleogene at the same level. Associated poor nannofossils contain the shallow marine element *Braarudosphaera bigelowii*. The shallowing event may be related to sea-level fall during the late Eggenburgian (Krhovský et al. 1995). It may also reflect local tectonic event in the basin.

The presence of the isochronous Zagórz Limestone Horizon allowed interpretation of the paleobathymetric gradient between the Boleradice and Stavěšice sections. The benthic foraminiferal assemblage with agglutinated taxa at Boleradice suggests an upper bathyal habitat. The benthic assemblage at Stavěšice lacks agglutinated taxa, nannofossils contain high numbers of pontospheres and other shallow-water species (*Z. bijugatus*, *B. bigelowii*) and reflect a rather deeper sublittoral.

Plankton blooms

The blooms and occurrences of uncommon microplankton in the studied sections indicate paleoenvironmental perturbations. The recorded microplankton can be classified in the following ecological groups (niches):

1) *Limacina* sp. (Pteropoda) — fully marine epipelagic plankton. The tests are preserved solely as pyrite casts.

2) Bivalve juveniles. Just one tiny form, always articulated valves preserved as pyrite casts.

3) Clavate planktonic foraminifers — represented by the genera *Beella* and *Bolliella*. They may be specialists for hypoxic water masses analogically to Lower Cretaceous clavate genera specialized for global hypoxia of the Ocean of that period (Premoli Silva et al. 1999).

4) Radiolaria — fully marine siliceous microplankton. Radiolarians are preserved in silica. They are indicators of waters rich in nutrients (phosphorus) and silica.

5) Prasinophyta (*Pterospermella* spp., *Tasmanites* spp., leiospheres) — preserved as organic-walled cysts or pyrite casts. Prasinophyta are green microalgae that may indicate brackish water in shallow marine habitats.

6) Planktonic diatoms. Several different quite large forms (see Tables 2 and 7) are preserved as pyrite casts. They represent probably marine taxa.

7) Bloom taxa of calcareous nannofossils.

The taxonomic composition of blooms was controlled by nutrients, salinity (normal marine to pliohaline), and possibly other factors. Intervals of rare presence of pyritized pteropods and bivalve juveniles reflect rather preservation events then increased productivity. The aragonitic shell of pteropods is dissolved under the aragonitic lysocline. It means that the pyritization of shells took a very short time. The pyritized diatoms occur in some levels together with pteropods. The same forms of diatoms were recorded from the Krosno Formation of the Silesian Unit near the Jaslo and Zagórz Limestone Horizons (Bak 2005). The distribution of microplankton in the Křepice-5 borehole provokes many questions. The appearances of individual microplankton groups are organized in succession: clavate planktonic foraminifers > prasinophytes > diatoms > radiolarians, that repeats two time. The sequence of environmental changes may be considered based on the microplankton requirements mentioned above. Brackish-water elements (prasinophytes) should be explained by flood runoff from a continental source rather than by a bloom in the freshwater surface of a waterbed. Both intervals are accompanied by low-diversity nannofossil assemblages with abundances of:

— *Pontosphaera latoculata* and *P. latelliptica* accompanied by common *R. minuta* and few *Zygrhablithus bijugatus* and *Reticulofenestra lockeri*,

— *Pontosphaera latoculata* and *P. latelliptica* accompanied by common *Reticulofenestra lockeri*,

— *Reticulofenestra minuta*,

— *Reticulofenestra minuta* and *Syracosphaera* sp. accompanied by *Pontosphaera rothii*,

— *Dictyococcites bisectus*.

The two intervals are separated by nannofloral bloom of coccolithophore *Reticulofenestra ornata*. The endemic Paratethys species *R. ornata* and its explosive bloom have already been described in many works (Stráník et al. 1981a; Nagymarosy 1983; Báldi-Beke 1984; Krhovský et al. 1992; Melinte 2005, etc.). It is considered an important correlation event of high stratigraphic validity in the Oligocene of both the Central and Eastern Paratethys. This bloom is evidence of the extreme ecologic conditions, probably very low salinity and/or high nutrient levels (Krhovský et al. 1992). Nagymarosy & Voronina (1992) pointed out, that blooms of *R. ornata* were repeated within the zone interval NP22–NP24 and the last rare specimens were recorded in NP25. The youngest *R. ornata* bloom correlated with NP24 Zone was observed just before the onset of the Krosno lithofacies in Křepice-5 Borehole whereas in the Chomýž outcrop it occurs in the lower part of the Krosno lithofacies. In the Křepice-5, *R. ornata* bloom is intercalated by a short interval with *Helicosphaera obliqua* that indicates restored normal marine conditions (see Table 3).

Some nannoplankton blooms produced nannofossil limestone horizons. A *Cyclicargolithus* bloom was described from the Jaslo Limestone Horizon, Subsilesian Unit (Bubík 1987, 1992), where these placoliths are the main component of sediment. A monogeneric assemblage occasionally accompanied by rare other species (*Zygrhablithus bijugatus*, *Dictyococcites bisectus*, or genus *Pontosphaera*) documents an increase in nannoplankton productivity caused by ecological stress and may reflect fluctuation of salinity accompanied by an increase in nutrient content. It is correlated within the NP23 Biochron. A similar bloom was recorded also in Zagórz Limestone Horizon (Haczewski 1989; Bubík & Švábenická 2000) in the lower part of the Krosno lithofacies. This one probably corresponds to NP24 Zone according to the presence of *Helicosphaera recta* in close proximity to under- and overlying strata of this horizon. Moreover, a bloom of *C. floridanus* was recorded in dark calcareous clays of the Křepice-5 Borehole in 39.9–40.2 m (Švábenická et al. 2005).

Oligocene nannofloral fluctuation is mentioned from the whole Carpathian area (Nagymarosy 1991; Nagymarosy & Voronina 1992; Krhovský et al. 1992; Melinte 2005) and reflects environmental changes connected with the stepwise isolation of Paratethys (Rögl 1998).

Correlations

The result of this research is a stratigraphic framework of various events verified on reference sections (Table 10). This framework was finally used for age assignment and correlation of the studied sections. The Menilite Chert and the Zagórz Limestone Horizons are important for correlations. Unfortunately, the Jaslo Limestone Horizon was not found in the studied area and may be primarily missing. In

Table 10: Biostratigraphic range of the significant foraminifers and calcareous nannofossil marker species in the Menilite and Krosno Formations, Outer Western Carpathians, Czech Republic. **1** — last occurrence by Nagymarosy & Voronina (1992), **2** — first and **3** — last occurrences by Young (1998), **4** — first occurrence by Melinte (2005), **5** — first occurrence by Báldi-Beke (1982), **6** — sensu Aubry (1992).

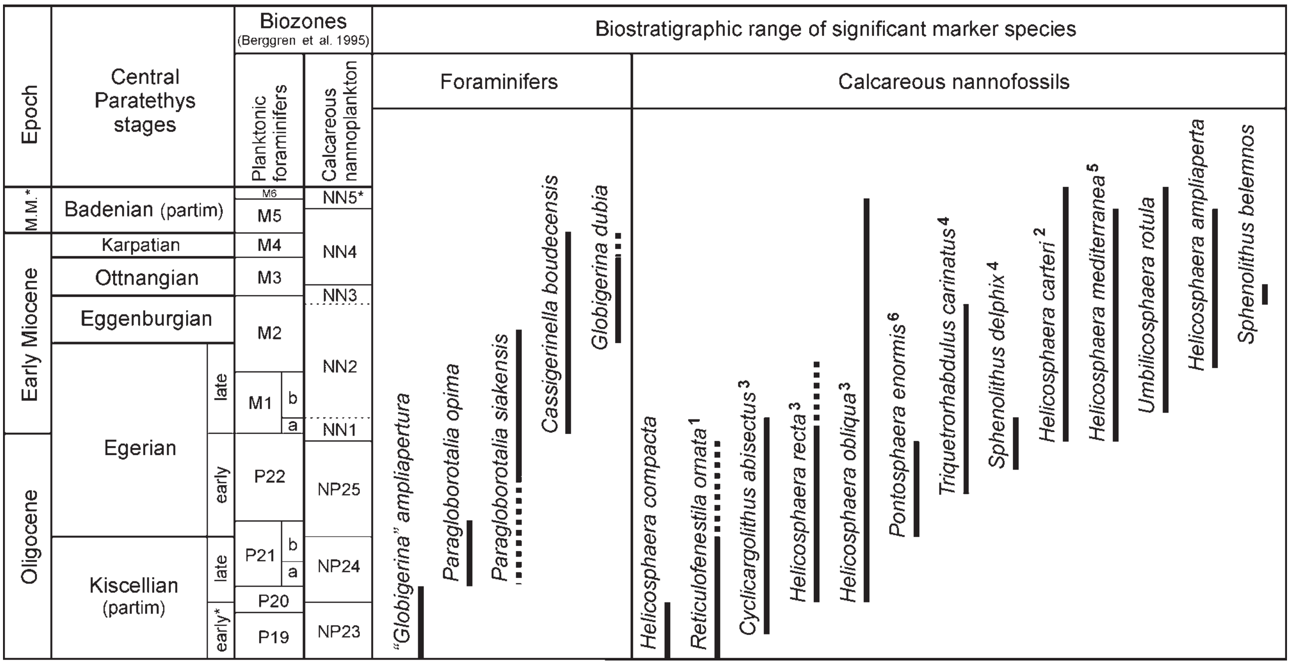
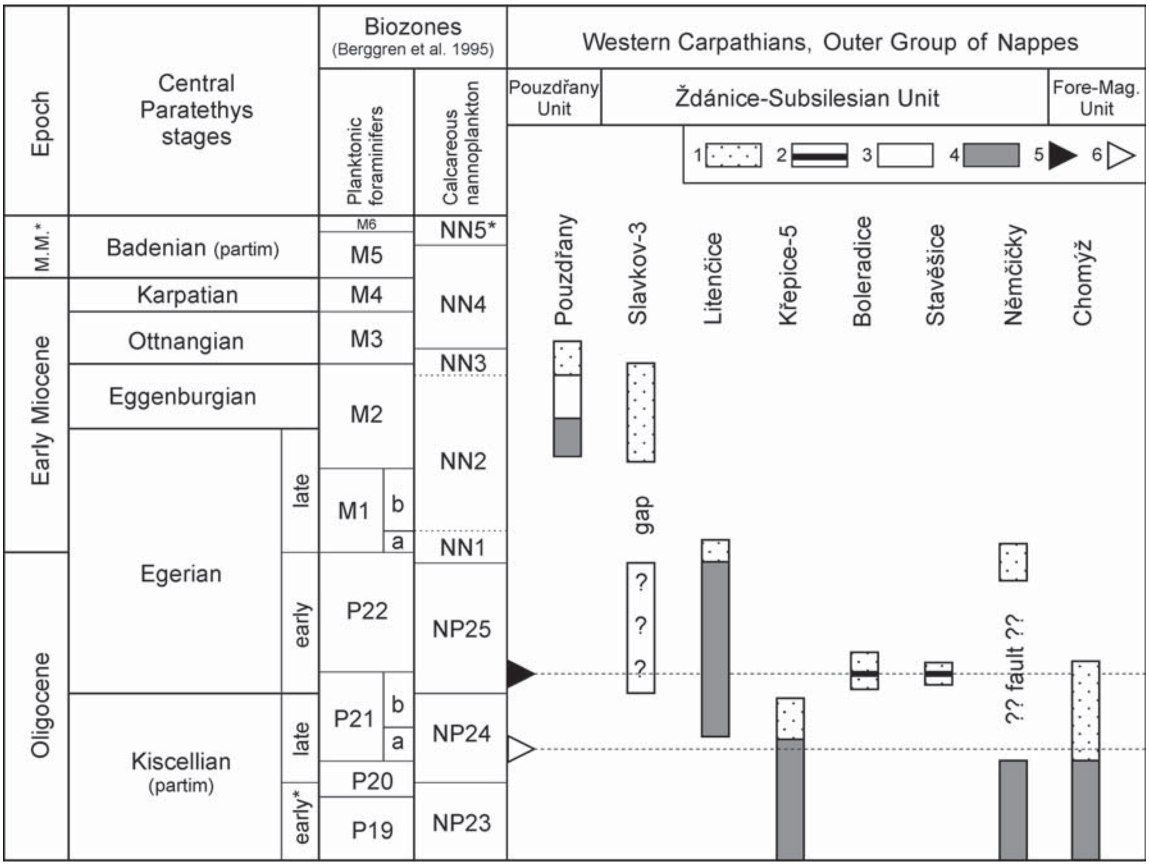


Table 11: Graphically expressed diachronous onset of the Krosno lithofacies in the Outer Group of Nappes, Western Carpathians, Czech Republic. **1** — Krosno lithofacies, **2** — Zagórz Limestone, **3** — hemipelagic light marls, **4** — hypoxic Menilite lithofacies, **5** — Zagórz Limestone Horizon, **6** — *Reticulofenestra ornata* bloom, **M.M.** — Middle Miocene, * — partim.



the upper part of the Šitbořice Member in the Křepice-5 Borehole no such lithology was encountered. The Jaslo Limestone Horizon was observed in the northern sector of the Ždánice-Subsilesian Unit (Bubík 1987, 1992). The nannofossil acmes of *Reticulofenestra ornata* are very useful (see "Plankton blooms" above). The upper acme served as new local event for correlation. As concerns foraminiferal biostratigraphy, the last occurrence of "*Globigerina*" *ampliapertura* and the first occurrence of *Paragloborotalia opima* are both important data within the upper Kiscellian, but their scarcity limits their practical use. Very useful marker species is *Cassigerinella boudecensis*. All observations until now confirm that the species appears at or close to the Oligocene/Miocene boundary within the Egerian (Table 10).

Final correlation of studied sections confirmed the diachronism of the Krosno lithofacies onset between the Pouzdřany Unit, Ždánice-Subsilesian Unit, and Fore-Magura Unit (Table 11). In the Pouzdřany Unit, onset of the Krosno lithofacies is near the Eggenburgian/Ottnangian boundary (Stráník et al. 1981b; Krhovský et al. 1995). In the Ždánice-Subsilesian Unit, the Krosno lithofacies onset varies within the late Kiscellian and early Egerian. In the case of the Němčičky section, there is doubt about completeness. It is possible that the lower part of Krosno lithofacies is tectonically reduced. Very distal lithofacies in the Slavkov-3 Borehole is difficult to correlate with other sections with the typical Menilite and Krosno facies. The whole section may be a part of the Krosno lithofacies. The Litenčice section has already been described by Jurášová & Bubík (1989). The onset of the Krosno lithofacies characterizes clavate planktonic foraminifer *Bolliella navazuelensis*. It is believed that it can be compared with one of the two horizons with clavate plankton in the Křepice-5 Borehole. The underlying Šitbořice Member at Litenčice contained *Helicosphaera recta* ca. 50 m below the onset.

The Fore-Magura Unit (Chomýž) shows the same age for the Krosno base in terms of biostratigraphy. The last *Reticulofenestra ornata* bloom, anyhow occurs within the lowermost Krosno lithofacies while in the Ždánice Unit it takes place in the uppermost part of the Menilite Formation (Křepice-5). The *R. ornata* bloom allows higher resolution correlation than biostratigraphy here.

Conclusions

The nannofossil blooms and the occurrence of prasinophytes and diatoms in the upper part of the Menilite Formation reflects paleoenvironmental perturbations, such as freshwater runoff (floods), decreased salinity, water stratification, high nutrient input, and sea-level fluctuations probably connected with climatic change and gradual isolation of the Protoparatethys during the Oligocene.

Micro- and nannofossils changed during the onset of the Krosno lithofacies. Autochthonous species occur in low numbers and reworked fossils from older Paleogene and Upper Cretaceous strata prevail. Autochthonous assemblages higher in diversity indicate restored contact with the open sea. Alpine orogenic movements supplied basins with high numbers of reworked fossils.

Correlation based on biostratigraphy and a set of events brought evidence for diachronism in the onset of the Krosno lithofacies. In the Pouzdřany Unit it appears at the top of the Eggenburgian — NN3 Zone, in the Ždánice-Subsilesian at the upper Kiscellian above the *R. ornata* bloom, and in Fore-Magura below the *R. ornata* bloom (see Table 11).

The Zagórz Limestone intercalations attributed to the NP25 Zone are important biostratigraphic horizons in the Krosno lithofacies of the Ždánice-Subsilesian Unit.

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Appendix 1

Calcareous nannofossil taxa mentioned in the text in alphabetical order of genera epithets
Braarudosphaera bigelowii (Gran et Braarud) Deflandre
Coccolithus pelagicus (Wallich) Schiller
Coccolithus eopelagicus (Bramlette et Riedel) Bramlette et Sullivan
Coronocyclus nitescens (Kamptner) Bramlette et Wilcoxon
Cyclicargolithus abisectus (Müller) Wise
Cyclicargolithus floridanus (Roth et Hay) Bukry
Dictyococcites bisectus (Hay, Mohler et Wade) Bukry et Percival
Discoaster deflandrei Bramlette et Riedel
Helicosphaera ampliaperta Bramlette et Wilcoxon
Helicosphaera bramlettei Müller
Helicosphaera carteri (Wallich) Kamptner
Helicosphaera compacta Bramlette et Wilcoxon
Helicosphaera elongata Theodoridis
Helicosphaera euphratis Haq
Helicosphaera intermedia Martini
Helicosphaera mediterranea Müller
Helicosphaera obliqua Bramlette et Wilcoxon
Helicosphaera recta (Haq) Jafar et Martini
Helicosphaera scissura Müller
Pontosphaera discopora Schiller
Pontosphaera enormis (Locker) Perch-Nielsen
Pontosphaera latelliptica (Báldi-Beke) Perch-Nielsen
Pontosphaera latoculata (Bukry et Percival) Perch-Nielsen
Pontosphaera magna Haq
Pontosphaera multipora (Kamptner) Roth
Pontosphaera obliquipons (Deflandre) Hay, Mohler et Wade
Pontosphaera plana (Bramlette et Sullivan) Haq
Pontosphaera rothii Haq
Reticulofenestra hillae Bukry et Percival
Reticulofenestra lockeri Müller
Reticulofenestra minuta Roth
Reticulofenestra ornata Müller
Rhabdosphaera sicca Stradner
Sphenolithus belemnos Bramlette et Wilcoxon
Sphenolithus delphix Bukry
Sphenolithus dissimilis Bukry et Percival
Sphenolithus moriformis (Brönnimann et Stradner) Bramlette et Wilcoxon
Syracosphaera pulchra Lohmann
Triquetrorhabdulus carinatus Martini
Umbilicosphaera rotula (Kamptner) Varol
Zygrhablithus bijugatus (Deflandre) Deflandre

Appendix 2

Foraminiferal taxa mentioned in the text and tables in alphabetical order of genera epithets
Acarinina broedermanni (Cushman)
Acarinina soldadoensis (Bronnimann)
Ammodiscus aequispiralis Subbotina
Ammonia beccarii (Linne)
Beella rohiensis (Popescu et Brotea)
Biapertorbis alteconica (Popescu et Brotea)
Bolivina beyrichi beyrichi Reuss
Bolivina beyrichi carinata Hantken
Bolivina budensis (Hantken)
Bolivina crenulata Cushman
Bolivina dilatata Reuss
Bolivina fastigia Cushman
Bolivina hebes Macfadyen
Bolivina semistriata nobilis Hantken
Bolliella navazuelensis (Molina)
Bulimina elongata d'Orbigny
Cassidulina laevigata d'Orbigny
Cassigerinella boudecensis Pokorny
Catapsydrax dissimilis (Cushman et Bermudez)
Catapsydrax unicavus Bolli, Loeblich et Tappan
Caucasina coprolithoides (Andreae)
Caucasina schischkinskayae (Samoilova)
Caucasina tenebricosa Pishvanova
Chiloguembelina cubensis (Palmer)
Cibicidoides borislavensis (Aisenstat)
Cibicidoides pachyderma (Rzehak)
Cribroelphidium granosum (d'Orbigny)
Elphidium subtypicum Papp
Epistominella binominata (Subbotina)
Epistominella typica (Subbotina)
Escornebovina orthorapha (Egger)
Euuvigerina germanica Cushman et Edwards
Fursenkoina mustoni (Andreae)
Fursenkoina schreibersiana (Czjzek)
"*Globigerina*" *ampliapertura* Bolli
Globigerina anguliofficinalis Blow
Globigerina dubia Egger
Globigerina euapertura Jenkins
?*Globigerina globularis* Roemer
Globigerina lentiana Roegl
Globigerina officinalis Subbotina
Globigerina ottnangiensis Roegl
Globigerina ouachitaensis Howe et Wallace
Globigerina praebulloides Blow
Globigerina postcretacea Mjatliuk
Globigerina quinqueloba Natland
Globigerina wagneri Roegl
Globigerinella obesa (Bolli)
Globigerinoides primordius Blow et Banner
Globigerinelloides trilobus (Reuss)
Globocassidulina globosa (Hantken)
Globocassidulina oblonga (Reuss)
Globocassidulina subglobosa (Brady)
Globorotaloides suteri Bolli
Globotruncanella petaloidea (Gandolfi)
Globoturborotalita woodi (Jenkins)
Glomospira charoides (Jones et Parker)
Glomospira gibbosa (Subbotina)
Glomospira gordialis (Jones et Parker)
Gyroidinoides byramensis (Cushman et Todd)
Gyroidinoides girardanus (Reuss)
Gyroidinoides nitidus (Reuss)
Karreriella postsiphonella (Spandel)
Melonis affinis (Reuss)
Melonis pompilioides (Fichtel et Moll)
Morozovella trichotrocha (Loeblich et Tappan)
Morozovella aequa (Cushman et Renz)
Neugeborina longiscata (d'Orbigny)
Paragloborotalia acrostoma (Wezel)
Paragloborotalia nana (Bolli)
Paragloborotalia opima (Bolli)
Paragloborotalia pseudocontinuosa (Jenkins)
Paragloborotalia semivera (Hornibrook)
Pseudohastigerina micra (Cole)
Pullenia bulloides (d'Orbigny)
Semivulvulina pectinata (Reuss)
Sigmoilinita tenuis (Czjzek)
Tenuitella brevispira (Subbotina)
Tenuitella evoluta (Subbotina)
Tenuitella munda (Jenkins)
Tenuitellinata angustiumbilicata (Bolli)
Tenuitellinata pseudoedita (Subbotina)
Trochammina inflata (Montagu)
Trochamminoides variolarius (Grzybowski)
Uvigerina moravia Boersma
Uvigerina semiornata d'Orbigny
Virgulinella chalkophila (Hagn)