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The stratigraphy of the Oligocene deposits from the Ropa tectonic window (Grybów Nappe, Western Carpathians, Poland)

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The Ropa tectonic window of the Magura Nappe is composed of Oligocene deposits that belong to the Grybów Nappe. The youngest deposits of the Ropa tectonic window are correlated with calcareous nannoplanton zones NP24 and NP25. The NP24 zone interval was determined in the Sub-Grybów Beds and in the Grybów Marl Formation, whereas the Krosno (Cergowa) Beds belong to zone NP25. This age determination corresponds well with that of other Magura Nappe tectonic windows and also with the southern part of the Silesian and Dukla nappes. The facies and age of the Krosno Beds from the Grybów succession record the termination of Fore-Magura basins. The Grybów Nappe deposits in the Ropa tectonic window are overthrust by Cretaceous–Eocene formations of the Magura Nappe.

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Key words: Western Carpathians, Grybów Nappe, Oligocene, calcareous nannoplancton.

INTRODUCTION

In the Polish part of the Magura Nappe eleven tectonic windows have been recognized (Fig. 1, see also Książkiewicz, 1972). These windows belong to the Fore-Magura Group of nappes (FMGN) and occupy an intermediate position between the Silesian and the Magura nappes. In the tectonic windows the Obidowa Unit is present, which is regarded as the western prolongation of the Dukla Nappe (Cieszkowski *et al*., 1985) and the Grybów Nappe (Świdziński, 1963), known also as the Klęczany-Pisarzowa Unit (Kozikowski, 1953, 1956). These tectonic units are composed predominantly of Late Eocene-Oligocene deposits. There is a common understanding (see Bieda *et al*., 1963; Geroch *et al*., 1967; Korab and Durkovič, 1978), that the FMGN display transitional litho-facies, which linked the Silesian and Magura basins.

The position and age of the youngest deposits, beneath the Magura Nappe sole thrust, determine both the minimal amplitude of the Magura Nappe overthrust as well as the time in which the overthrusting of this unit began.

The aim of this study was to recognize the lithostratigraphy and age of youngest deposits of the Grybów Nappe in the Ropa tectonic window, which displays the most complete stratigraphic record of all the tectonic windows of the Magura Nappe. Additionally, it is necessary to revise the age determination, especially given that recent biostratigraphic data published by Gedl (2005) suggests the presence of the Eocene–Oligocene transition in Chełmski brook section of the Ropa tectonic window. The facies and age determination of the youngest deposits from the Grybów succession records the termination of the Fore-Magura basins.

PREVIOUS STUDY

Preliminary lithostratigraphic studies of the Grybów Nappe were carried out in the last century (Kozikowski, 1953, 1956; Sikora, 1960, 1970; Świdziński, 1963). These studies have been recently modified by Oszczypko-Clowes and Oszczypko (2004) and Oszczypko-Clowes and Ślączka (2006).

The age of the youngest Grybów Nappe deposits is generally regarded as Oligocene. Foraminifera studies were carried out by Kozikowski (1956), Blaicher (in Sikora, 1960, 1970) and Olszewska (1981). Nannofossil studies were initiated by Smagowicz (see Burtan *et al*., 1992; Cieszkowski, 1992) in the Klęczany tectonic window. Smagowicz (see Burtan *et al*., 1992; Cieszkowski, 1992) recognized latest Eocene–Early

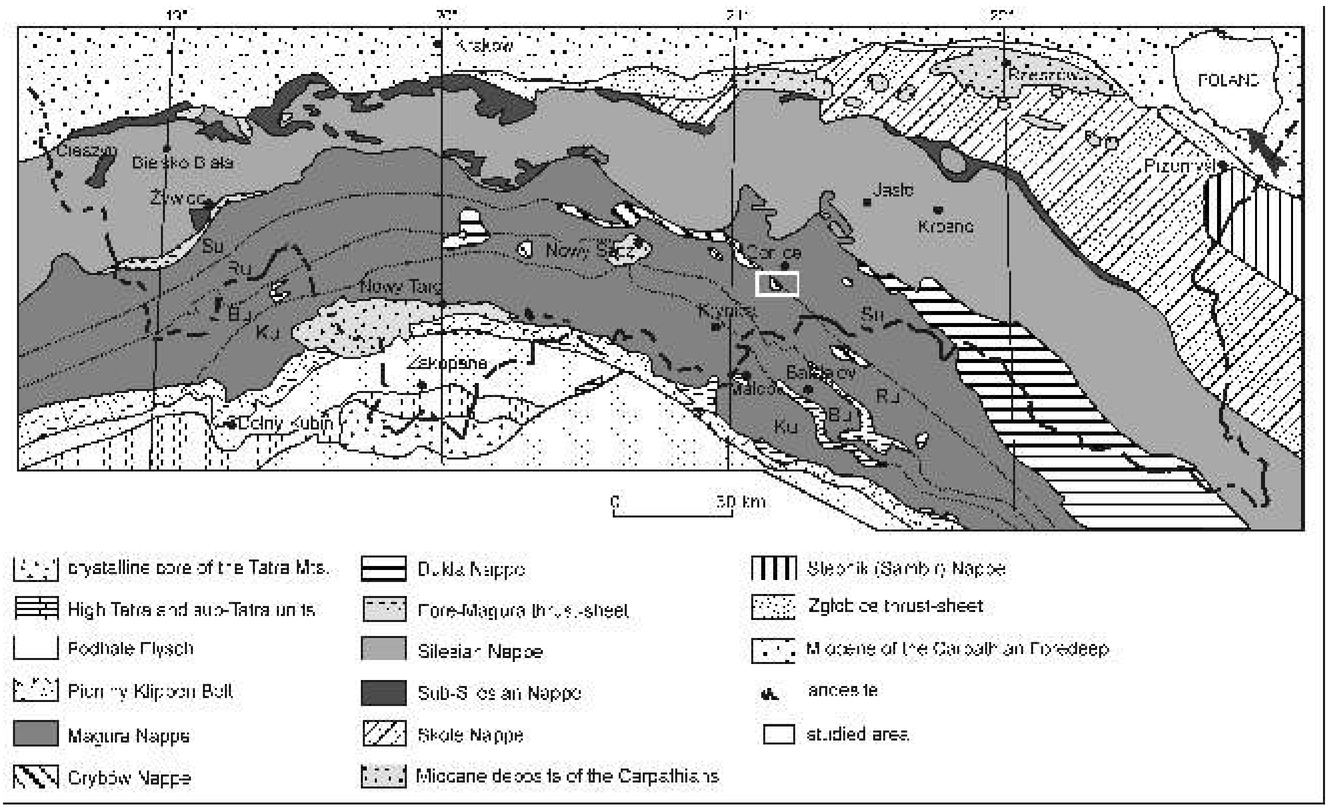

Fig. 1. Tectonic map of the Northern Carpathians (compiled by Oszczypko-Clowes, 2001)

Su — Siary, Ru — Rača, Bu — Bystrica, Ku— Krynica subunits

Oligocene nannofossil associations from the Sub-Grybów Beds (Burtan *et al*., 1992; Cieszkowski, 1992). More recently, detailed calcareous nannoplankton studies of the Grybów Nappe of Mszana Dolna and also of the Szczawa tectonic windows (Oszczypko-Clowes and Oszczypko, 2004) as well as the Grybów tectonic window (Oszczypko-Clowes and Ślączka, 2006) have been carried out. In the Mszana Dolna tectonic window the youngest deposits were assigned to NP24 (Krosno Beds, Dukla Nappe) and NP23–NP25 (Cergowa Beds, Grybów Nappe). Similar ages were also established in the Grybów Unit of the Szczawa tectonic window. Zones NP22–NP24 were determined in the Grybów Beds, whereas the Cergowa Beds belong to zone NP24 (Oszczypko-Clowes and Oszczypko, 2004). In the Grybów tectonic window the following zones were determined: NP24 (Grybów Marl Formation) and NP24–NP25 (Cergowa Beds, see Oszczypko-Clowes and Ślączka, 2006). Recently, a biostratigraphy based on dinoflagellates from the Ropa tectonic window was proposed by Gedl (2005).

STUDIED SECTIONS AND SAMPLE PREPARATION

All samples used for the nannofossil analyses were collected during fieldwork between 2001 and 2006. The fieldwork involved geological mapping using a scale of 1:10 000 along the stream, a short sedimentological description of the beds and also sampling for calcareous nannoplankton investigations. Both pelagic marls and calcareous claystones were sampled as well as turbiditic, calcareous mudstones. In the case of the latter the highest Bouma interval (Te) was sampled. The samples were collected from two sections: the Górnikowski and Chełmski brooks (Fig. 2). Altogether 64 samples were collected, among which 10 were barren. All samples were prepared using the standard smear slide technique for light microscope (LM) observations. The investigation was carried out under LM *Nikon — Eclipse E 600 POL*, at a magnification of 1000× using parallel and crossed nicols.

LITHOSTRATIGRAPHY

The Ropa tectonic window is located *ca*. 12–15 km south-west from Gorlice. The tectonic window is 3 km wide and up to 12 km long. The sections are located on the northern slope of the Beskid Niski Range along the Górnikowski and Chełmski brooks (Fig. 2). Both streams are left bank tributaries of the Ropa River.

Both sections were first described by Kozikowski (1956), Sikora (1960, 1970), Ślączka (1973) and Koszarski and Koszarski (1985). Sikora (1960, 1970) distinguished four thrust-sheets composed of the following lithostratigraphic units: Hieroglyphic Beds with green shales, Sub-Menilite Globigerina Marls, Sub-Grybów Beds with a "*Bryozoa* and *Lithothamnium*" horizon, Grybów Beds with hornstones at

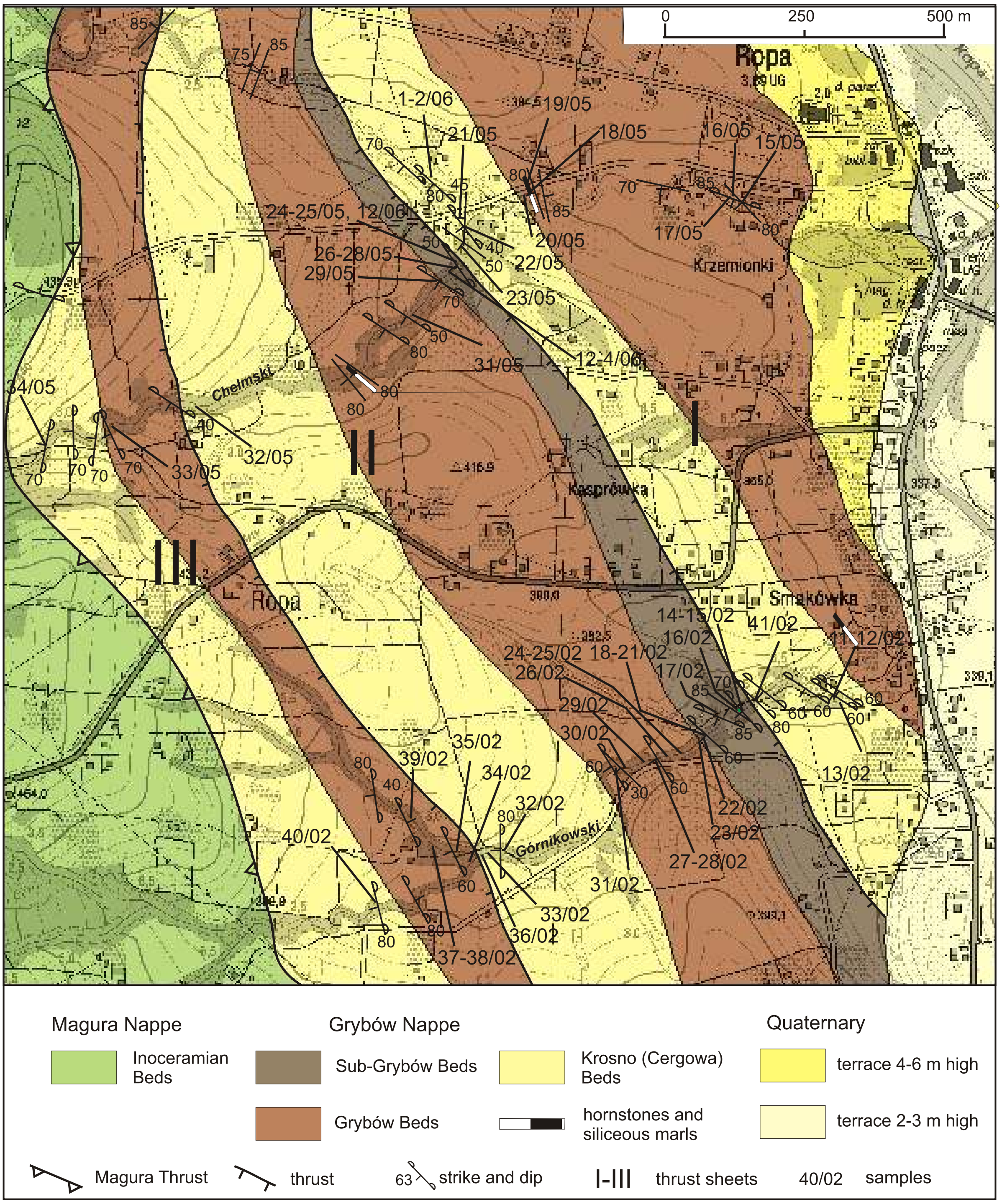

Fig. 2. Geological map of the Ropa tectonic window (modified after Sikora, 1960)

the top, and Krosno Beds at a level of the Jasło limestones. Sikora (1960, 1970) found the Hieroglyphic Beds and Globigerina Marls in the Ropa River bedrock and in the Chełmski brook. With the exception of the Hieroglyphic Beds and Globigerina Marls, I have recognized all of these lithostratigraphic divisions. These differences can be related to the very poor state of present-day exposures in comparison to those observed during the second half of the last century. It should be underlined that, according to Kozikowski (1956) and Kozikowski and Jednorowska (1957), the oldest strata of the Ropa tectonic window are represented by the Sub-Grybów Beds. More recently Gedl (2005) (Chełmski brook) documented a transition from the Hieroglyphic to the Sub-Grybów Beds. He described both the lithology and the dinocysts from this section with special emphasis on the Globigerina Marls. The lithostratigraphic succession begins with the Sub-Grybów Beds and is represented by a minimum 75 m thick shaley–marly–sandstone sequence, exposed in the

Górnikowski and Chełmski brooks at the top of thrust-sheet II (Figs. 3, 4, see also Sikora, 1970). These sections display an upwardly coarsening and thickening sequence. The lower part of the sequence is dominated by brown marly mudstones with frequent intercalations of green and black non-calcareous, bioturbated hemipelagites, up to 2 m thick (Figs. 3–5). The upper part of the sequence is characterized by increasing amounts of dark grey and brown marly mudstones with intercalations of thin- to thick-bedded calcareous and siliciclastic turbidites with Tbc and Tabc Bouma intervals, in which the flute casts record palaeotransport from the south-east and the south (Figs. 4, 6). The grey, green-greyish, dark-greyish and black marly shales are intercalated with calcareous, muscovite-rich sandstones. These are blue-greenish, poorly calcareous, fine to medium grained, sometimes coarse-grained thick-bedded sandstones (up to 1.2 m). The sandstones are composed of quartz, feldspars and dispersed glauconite grains. Other types of sandstones typical of the Sub-Grybów Marls are thin- and medium-bedded, micaceous and laminated. In the uppermost part of the Górnikowski brook sections appears a 30 cm thick coarse-grained calcareous sandstones with calcareous flakes (*Bryozoa* and *Lithothamnium* Sandstone, see Sikora, 1970).

Higher in the section occurs the Grybów Marl Formation (Figs. 3, 6, 7). These beds were first distinguished as the Grybów shales (Uhlig, 1888) and then named by Kozikowski (1956) as the Grybów Beds. A few years later Sikora (1960) re-named them again to Grybów Shales. More recently Oszczypko-Clowes and Ślączka (2006) provided a detailed description of the Grybów section and distinguished a new formal lithostraphigraphic unit named the Grybów Marl Formation.

In the Ropa tectonic window this formation is represented by a 200–300 m thick succession and is composed of black, hard, platy-splitting marls with sporadic intercalations of thin- and medium-bedded dark grey soft marls and thin- to thick-bedded dark sandstones (Figs. 3, 7). The thickness of these fine-grained sandstones varies from 0.3 to 1 m. These turbidites display Tab and Tbc Bouma intervals. Within the upper part of the formation, thick lenses of ferreginous dolomites (siderites) occur. The highest part of the Grybów Marl Formation is represented by marls, which are locally silicified and accompanied by layers a few centimetres thick of hornstone.

The uppermost part of the succession belongs to the Krosno Beds (Figs. 3, 7) (Kozikowski, 1956; Sikora, 1960, 1970). However, according to Ślączka (1971) these represent the Cergowa Beds', a shaley lithofacies known from the Dukla Nappe (Ślączka, 1971; Korab and Durkovič, 1978). From the formal lithostratigraphy point of view it is better to correlate these beds with the Krosno shale lithofacies than with the Cergowa Beds, which are dominated by thick-bedded sandstones (see Ślączka, 1971). These flat-laying, south-dipping strata consist of Krosno-like, dark grey marly shales with intercalations of thin bedded (2–12 cm), cross-laminated calcareous sandstone. In the upper reach of the Górnikowski brook, inside the lower part of the Krosno Beds, Sikora (1960, 1970) described a few very thin beds of the Jasło Limestone. In my view, these laminated limestones, which are 5 cm thick, occur at the boundary between the Grybów Marl Formation and the Krosno Beds. The Krosno Beds shaw fining- and thinning-upwards sequences. Towards the top of the sections profiles the number and thickness of sandstone layers decrease and the successions are dominated by marly pelites.

The same development of the Krosno Beds is known from all the other tectonic windows of the Magura Nappe (Oszczypko-Clowes and Oszczypko, 2004; Oszczypko-Clowes and Ślączka, 2006). According to Oszczypko and Ślączka (1979) the appearance of the Krosno shaley lithofacies is typical of the Late Oligocene–Early Miocene diachronous closure of the flysch basins (see also Svabenicka *et al*., 2007).

CHARACTERISTICS OF THE NANNOFOSSIL ASSEMBLAGES

RESULTS

The majority of the samples examined yielded poor and badly preserved nannofossil assemblages. Some specimens could not be identified because of strong etching and mechanical damage. Their abundance in the samples is usually low. The following samples were devoid of nannofossils: 41/02/N, 24/02/N, 25/02/N, 33/02/N, 40/02/N, 23/05/N, 12/05/N, 24/05/N, 25/05/N and 34/05/N. The distribution pattern of nannofossils is illustrated in Table 1 and 2. Several of the specimens photographed in LM are illustrated in Figure 8.

SUB-GRYBÓW BEDS

The abundance pattern is different for certain samples. It varies from more than 20 specimens (per observation field) in samples 14/02/N, 26/05/N, 27/05/N down to less than 5 specimens (per observation field) in samples 15/02/N–17/02/N, 1/07N–3/07N. A semi-quantitative study of the autochthonous nannoplankton assemblage indicates the domination of placoliths over other morphological types (eg. asteroliths, sphenoliths and helicospheres).

The assemblage is dominated by *Cyclicargolithus floridanus* and *Dictyococcites bisectus.* Also the species *Coccolithus pelagicus*, *Cyclicargolithus abisectus*, *Ericsonia fenestrata*, *Reticulofenestra lockerii* and *Sphenolithus moriformis* are abundant, but to a lesser extent. Additionally, sample 14/02/N is abundant in *Helicosphaera compacta*, *Helicosphaera papilata* and *Helicosphaera reticulata.* The youngest species determining the age is *Cyclicargolithus abisectus*

GRYBÓW BEDS

The nannofossils are poorly preserved and the assemblages reveal generally low diversity as well as a low number of specimens. The only samples containing a relatively rich assemblage (9, 10 specimens per observation field) are 18/02/N, 20/02/N–23/02/N, 26/02/N, 15/05/N, 18/05/N, 30/05/N, 31/05/N. These assemblages are characterized by the presence of *Coccolithus eopelagicus*, *Coccolithus pelagicus*, *Cyclicargolithus floridanus*, *Dictyococcites bisectus*, *Discoaster tanii*, *Discoaster tanii nodifer*, *Isthmohlithus recurvus*, *Lanternithus minutus*, *Neococcolithes dubius*, *Reticulofenestra*

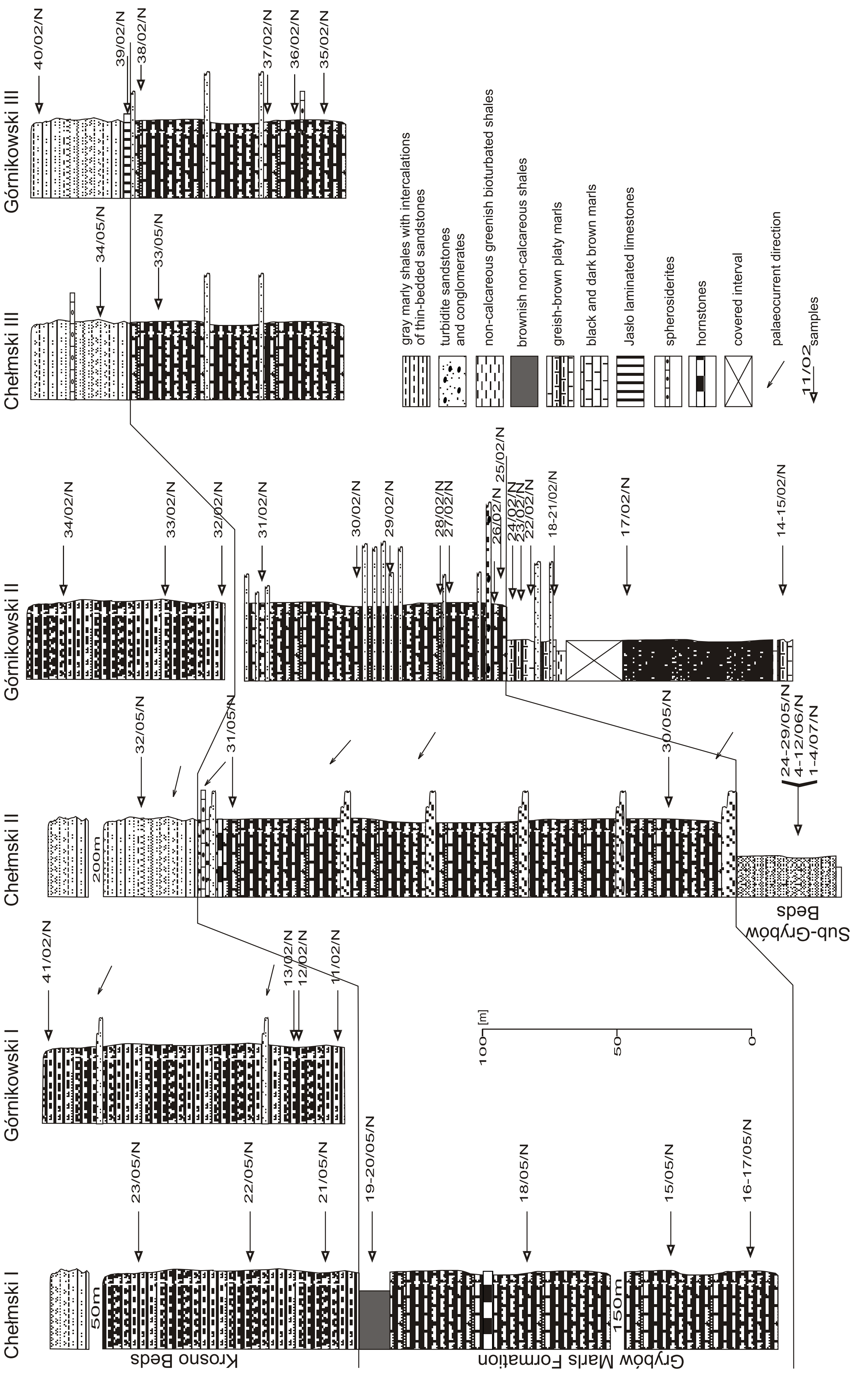

Fig. 3. Lithostratigraphic logs of the Grybów Nappe in the Ropa tectonic window

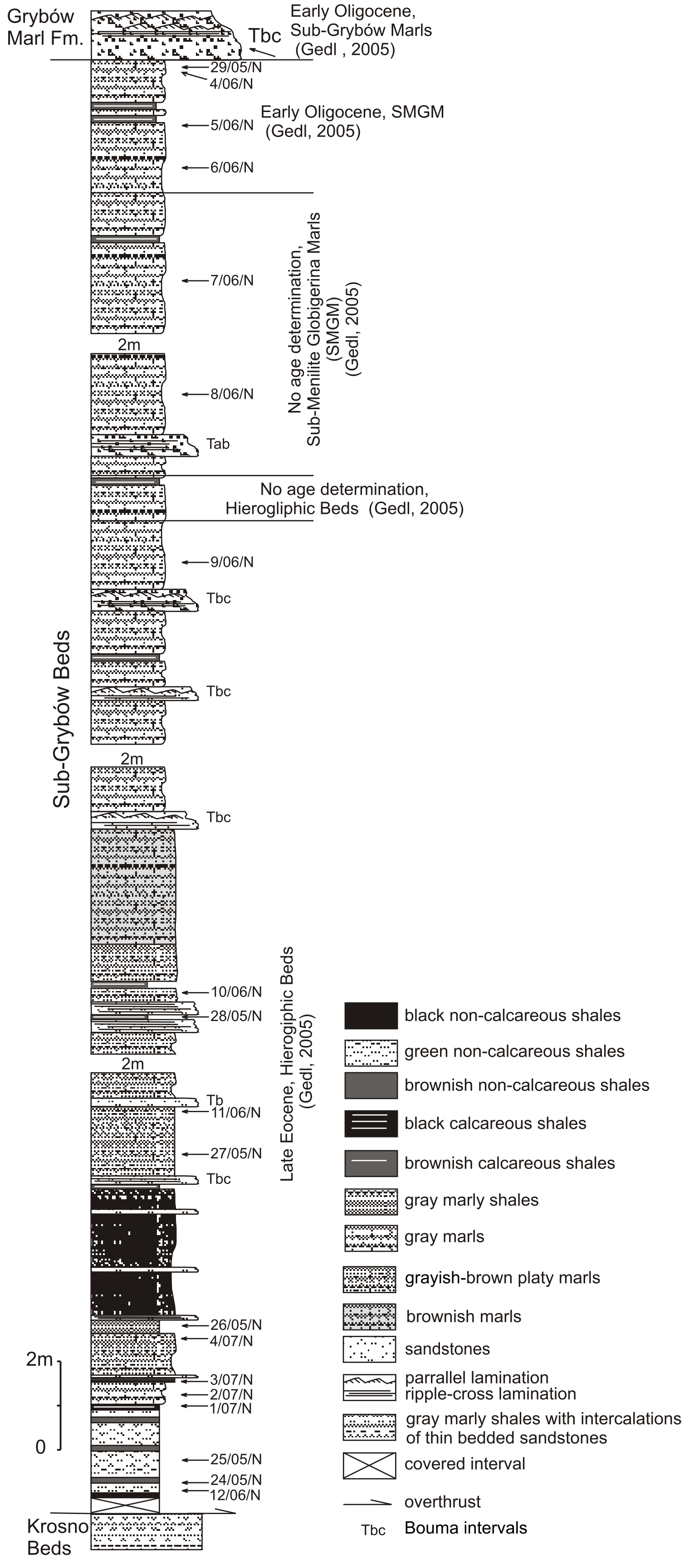

Fig. 4. Detailed lithostratigraphic log of the Sub-Grybów Beds in the Ropa tectonic window

dictyoda, *Reticulofenestra umbilica*, *Sphenolithus moriformis*, *Sphenolithus radians*. The most abundant are *C. abisectus*, *C. floridanus*, *D. bisectus* and *C. pelagicus*. The youngest species determining the age are *C. abisectus* and *S. dissimilis.*

KROSNO BEDS

These samples contain a rich assemblage with more than 20 specimens per observation field. The nannofossil association is characterized by the presence of *Cyclicargolithus abisectus*, which is accompanied by *Cyclicargolithus floridanus*, *Dictyococcites bisectus*, *Reticulofenestra lockerii*, *Reticulofenestra dictyoda* and *Reticulofenestra ornata*. Additionally some of the samples contained *Helicosphaera euphratis*, *Helicosphaera compacta*, *Helicosphaera recta*, *Pontosphaera multipora*, *Pontosphaera plana* and *Sphenolithus moriformis*. The nannofossil association is characterized by the co-occurrence of *Coccolithus eopelagicus*, *C. pelagicus*, *Cyclicargolithus abisectus*, *C. floridanus*, *Dictyococcites bisectus*, *Sphenolithus moriformis* and *Zygrhablithus bijugatus* (Deflandre). The most important species found in both sections are *C. abisectus*, *Helicosphaera recta* and *Reticulofenestra lockerii*. Additionally samples 16/02/N, 18/02/N contained *S. conicus* Bukry.

BIOSTRATIGRAPHIC INTERPRETATION

For the purpose of this work the standard zonation of Martini (1971) and Martini and Worsley (1970) was used. The Oligocene nannoplankton zonation is mainly based on the last (LO) or first occurrence (FO) of sphenoliths. These typically warm water species are rare or absent in higher latitudes. In the case where index species have not been observed, it was necessary to use the secondary index species of the following authors: Baldi-Beke (1977, 1981), Perch- Nielsen, (1985), Martini and Müller (1986), Melinte (1995), Fornaciari *et al*. (1996) and Young (1998). The detailed biozonal assignments are as follows:

Sphenolithus distentus Zone (NP24)

D e f i n i t i o n. — The base of the zone is defined by the first occurrence of *Sphenolithus ciperoensis* and the top by the last occurrence of *Sphenolithus distentus.*

A u t h o r. — Bramlette and Wilcoxon (1967), emend Martini (1970).

A g e. — Late Oligocene.

Fig. 5. Exposures of the Sub-Grybów Beds in Chełmski brook

A — transition from non-calcareous black green and brownish shales to the gray marls; **B** — green and black non-calcareous, bioturbated hemipelagites; **C** — dark gray platy laminated marls with intercalations of very thin-bedded sandstones; the arrow (1 m in length) shows the stratigrapic succession

R e m a r k s. — This zone was identified in the following lithostratigraphical units (Figs. 3, 4): Sub-Grybów Beds, Grybów Marl Formation and Krosno Beds.

The zonal assignment is based on the FO of *Cyclicargolithus abisectus*. In addition, *Sphenolithus dissimilis* and *Helicosphaera recta* were also observed. The FO of these species is characteristic for zone NP24 (see Perch-Nielsen, 1985).

Sphenolithus ciperoensis Zone (NP25)

D e f i n i t i o n. — The base of this zone is defined by the last occurrence of *Sphenolithus distentus* and the top by the last occurrence of *Helicosphaera recta* and/or *Sphenolithus ciperoensis*.

A u t h o r. — Bramlette and Wilcoxon (1967), emend Martini (1970).

A g e. — Late Oligocene.

R e m a r k s. — This zone was identified in the following lithostratigraphical units (Figs. 3, 4) — Krosno Beds.

The assignment of zone NP25 is based on the first occurrence of *Sphenolithus conicus* and followed by a continuous range of *Cyclicargolithus abisectus*, *Dictyococcites bisectus* and *Zygrhablithus bijugatus*. The FO of *Sphenolithus conicus* has been traditionally used as the base of zone NN1. However, Bizon and Müller (1979), Biolzi *et al.* (1983) and Melinte (1995) have observed the FO of these species as low as in the upper part of zone NP25. The top of NP25 was considered for a long time as an Oligocene–Miocene boundary, though according to Berggren *et al*. (1995), this boundary lies within the NN1 zone. The Oligocene–Miocene boundary is characterized by the extinction of *Sphenolithus ciperoensis* (lower latitudes) and *Dictyococcites bisectus* (higher latitudes) (Perch-Nielsen, 1985; Berggren *et al*., 1995; Fornaciari *et al*., 1996; Young (1998).

Fig. 6. Exposures of Sub-Grybów Beds in Chełmski brook

A — gray marls and brownish calcareous shales; **B** — gray marls and brownish calcareous shales and thick-bedded sandstone; **C** — transition from the Sub-Grybów Beds to the Grybów Beds, according to Gedl (2005) transition from the Sub-Menillite Globigerina Marls to the Sub-Grybów Beds, gray marls and brownish calcareous shales and thick-bedded sandstone (110 cm) with Tabc Bouma intervals

PALAEOECOLOGY

The analysis of autochthonous Oligocene nannofossils, carried out for the Ropa sections, exhibits the lowest rate of species turnover in the whole Paleogene (see Bown *et al*., 2004). It is important to note that the Late Oligocene assemblages from Ropa are scarce in species of the *Sphenolithus* and *Discoaster* groups (Wei and Wise, 1990). The *Discoaster* group (Wei and Wise, 1990) includes any species of *Discoaster*, and these are generally considered as warm water indicators (Bukry, 1973). There is an easily visible trend of decreasing discoaster abundance towards higher latitudes. The most abundant and diverse assemblages of *Sphenolithus* are characteristic of lower latitudes. At mid latitudes the abundance and diversity drop by 50% whereas at lower latitudes they are virtually absent (except for *Sphenolithus moriformis*). Both the latitudinal abundance and the diversity pattern of sphenoliths indicate a preference for warm waters. Late Oligocene assemblages from Ropa are dominated by *Dictyococcites bisectus*, *Cyclicargolithus abisectus*, *Cyclicargolithus floridanus* and *Coccolithus pelagicus*. All of these species are typical temperate-water indicators. At the same time the amounts of typically cold-water taxa such as *Reticulofenestra lockerii* and *Reticulofenestra ornata* (see Wei and Wise, 1990; Aubry, 1992; Krhovský *et al*., 1992; Oszczypko-Clowes, 2001) are relatively low.

The abundance pattern and the species diversity of nannoplankton assemblages reflect temperate to coldish temperatures in the surface water of the Grybów Basin. These waters were also rather rich in nutrient content. The most abundant species are *Dictyococcites bisectus*, *Cyclicargolithus abisectus* and *Cyclicargolithus floridanus* which are indicative for a eutrophic environment.

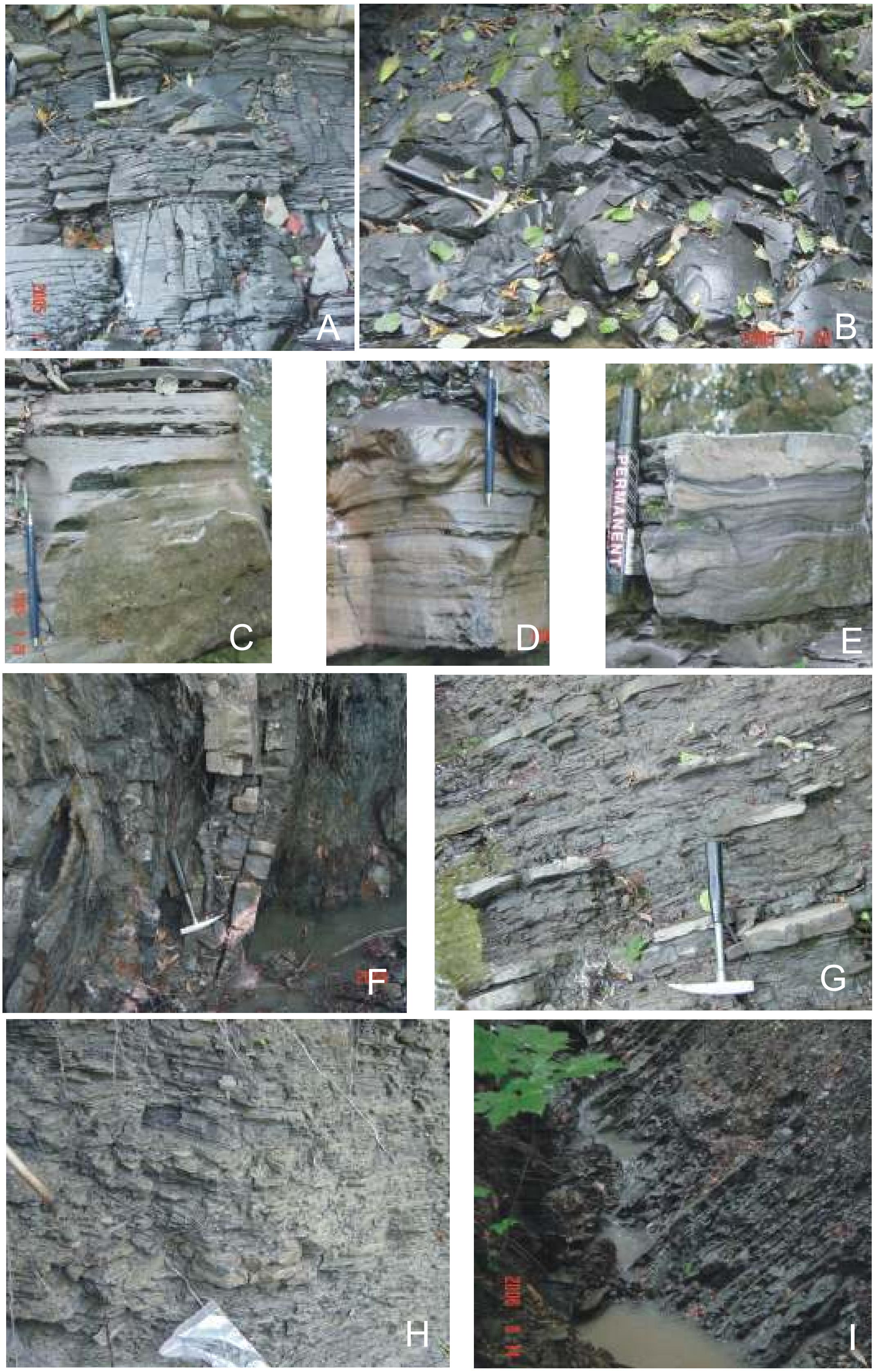

Fig. 7. Exposures of the Grybów Marls Formation and the Krosno Beds in Chełmski brook

A — gray marls of the Grybów Marls Formation (thrust-sheet I); **B** — massive gray brownish marls, Grybów Marls Formation (thrust-sheet II); **C** — medium-bedded sandstone with parallel lamination and small shalley clasts at the bottom of the Grybów Marls Formation (thrust-sheet II); **D** — medium-bedded, coarse to medium-grained sandstone with parallel and convolute lamination, Grybów Marls Formation (thrust-sheet II); **E** — medium-bedded, medium-grained sandstone with convolutions, Grybów Marls Formation (thrust-sheet II); **F** — black non-calcarous shales with hornstones, the uppermost part of the Grybów Marls Formation (thrust-sheet II); **G**–**I** — gray calcareous shales with very thin-bedded, fine-grained sandstones, Krosno Beds (G, H — thrust-sheet I; I — thrust-sheet II)

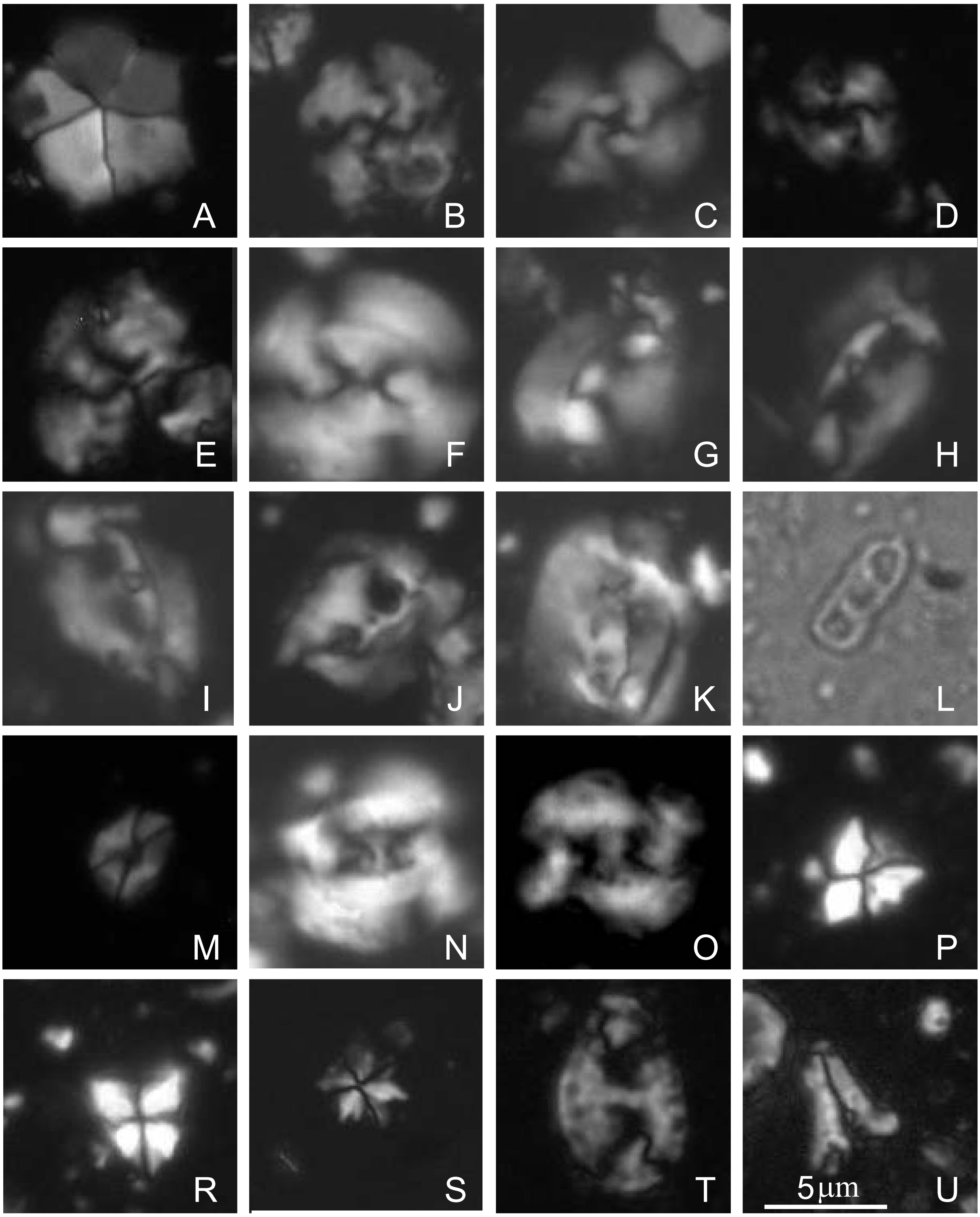

Fig. 8. LM microphotographs of calcareous nannofossils from the Oligocene deposits of the Ropa tectonic widow

A — *Braarudosphaera bigelowii*, sample 12/02/N, Górnikowski brook (thrust-sheet I); **B** — *Cyclicargolithus abisectus*, sample 26/05/N, Chełmski brook (thrust-sheet II); **C** — *Cyclicargolithus abisectus*, sample 14/02/N, Górnikowski brook, (thrust-sheet II); **D** — *Cyclicargolithus floridanus*, sample 13/02/N, Górnikowski brook (thrust-sheet I); **E** — *Dictyococcites bisectus*, sample 11/02/N, Górnikowski brook (thrust-sheet I); **F** — *Dictyococcites bisectus*, sample 2/06/N, Chełmski brook (thrust-sheet I); **G** — *Helicosphaera compacta*, sample 27/05/N, Chełmski brook (thrust-sheet II); **H** — *Helicosphaera perch-nielsenia*, sample 27/05/N, Chełmski brook (thrust-sheet II); **I** — *Helicosphaera perch-nielsenia*, sample 39/02/N, Górnikowski brook (thrust-sheet III); **J** — *Helicosphaera recta*, sample 28/05/N, Chełmski brook (thrust-sheet II); **K** — *Helicosphaera reticulata*, sample 39/02/N, Górnikowski brook (thrust-sheet III); **L** — *Isthmohlithus recurvus*, sample 11/02/N, Górnikowski brook (thrust-sheet I); **M** — *Lanternithus minutus*, sample 28/05/N, Chełmski brook (thrust-sheet II); **N** — *Reticulofenestra lockerii*, sample 14/02/N, Górnikowski brook (thrust-sheet II); **O** — *Reticulofenestra lockerii*, sample 26/05/N, Chełmski brook (thrust-sheet II); **P** — *Sphenolithus conicus*, sample 11/02/N, Górnikowski brook (thrust-sheet I); **R** — *Sphenolithus conicus*, sample 11/02/N, Górnikowski brook (thrust-sheet I); **S** — *Sphenolithus dissimilis*, sample 27/05/N, Chełmski brook (thrust-sheet II); **T** — *Transversopontis pulcher*, sample 11/02/N, Górnikowski brook (thrust-sheet I); **U** — *Zygrhablithus bijugatus*, sample 39/02/N, Górnikowski brook (thrust-sheet III);

Table 1

Calcareous nannofossil distribution in the Ropa tectonic window — Górnikowski brook section

Górnikowski brook	Oligocene																									
	Thrust-sheet I			Thrust-sheet II																		Thrust-sheet III				
Lithostratigraphical units	Cergowa Beds (CB)			Sub-Grybów Beds (SGB)										Grybów Marl Formation (GMF)						CB		GMF			CB	
Nannoplankton zones Martini (1971)	NP 25	NP 25	NP 25	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24
Sample number	11/	12/	13/	14/	15/	16/	17/	18/	19/	20/	21/	22/	23/	26/	27/	28/	29/	30/	31/	32/	34/	35/	36/	37/	38/	39/
	02/N																									
Braarudosphaera bigelowii		X		X	X																		X			X
Chiasmolithus grandis					R																		R			R
Coccolithus eopelagicus					X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X					
Coccolithus pelagicus	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Coronocyclus nitescens	X		X																			X	X	X	X	X
Cyclicargolithus abisectus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cyclicargolithus floridanus	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cyclicargolithus luminis	X		X																			X	X	X	X	X
Dictyococcites bisectus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Discoaster barbadiensis	R	R	R			R		R			R						R					X	X	X	X	X
Discoaster deflandrei	X		X			X	X	X				X			X	X	X	X	X				X			
Discoaster tanii	X	X	X																							
Discoaster tanii nodifer	X	X	X																							
Ericsonia fenestrata	X			X																	X					
Ericsonia formosa			R	R		R					R						R							X		X
Helicosphaera bramlettei		X	X																							
Helicosphaera euphratis	X	X	X														X	X	X			X				
Helicosphaera compacta	X	X	X	X														X			X			X		
Helicosphaera papilata				X																		X	X	X		X

Tab. 1 cont.

Górnikowski brook	Oligocene																									
	Thrust-sheet I			Thrust-sheet II																		Thrust-sheet III				
Lithostratigraphical units	Cergowa Beds (CB)			Sub-Grybów Beds (SGB)										Grybów Marl Formation (GMF)						CB		GMF			CB	
Nannoplankton Zones Martini (1971)	NP 25	NP 25	NP 25	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24	NP 24
Sample number	11/	12/	13/	14/	15/	16/	17/	18/	19/	20/	21/	22/	23/	26/	27/	28/	29/	30/	31/	32/	34/	35/	36/	37/	38/	39/
	02/N																									
Helicosphaera perch-nielsenia				X																						X
Helicosphaera recta				X		X																	X			X
Helicosphaera reticulata				X																						X
Isthmohlithus recurvus	X		X	X	X	X	X	X		X	X	X	X	X	R											
Lanternithus minutus	X	X	X	X	X	X	X	X		X	X	X	X	X	R				R				R	R	R	
Neococcolithes dubius	X			X																			R	R		
Pontosphaera multipora	X	X	X		X									X												
Pontosphaera plana	X	X	X																							
Reticulofenestra dictyoda	X	X	X	X		X		X		X	X	X	X	X					X							
Reticulofenestra lockerii		X	X	X	X			X		X	X	X	X	X	X	X			X	X				X	X	
Reticulofenestra minuta		X	X			X														X				X	X	X
Reticulofenestra ornata	X	X	X	X	X		X	X		X	X	X	X	X		X	X		X	X				X		X
Reticulofenestra reticulata	R	R					R																X	X	X	
Reticulofenestra umbilica	R	R	R	R			X							R												
Sphenolithus conicus	X	X	X																							
Sphenolithus dissimilis	X	X	X	X			X																	X		X
Sphenolithus moriformis	X		X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X			X		
Sphenolithus pseudoradians																							X	X		X
Sphenolithus radians	R	R	R				X		R		R	R			R		R									
Transversopontis fibula	R	R	R																							
Transversopontis latus					X																					
Transversopontis obliquopons	X				X											X										
Transversopontis pulcher	X				X											X								X		X
Zygrhablithus bijugatus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

X — autochtonous species, R — reworked species

Table 2

Calcareous nannofossil distribution in the Ropa tectonic window — Chełmski brook section

Chełmski brook	Oligocene																													
	Thrust-sheet I										Thrust-sheet II																			TS III
Lithostratigraphical units	Grybów Marl Formation (GMF)						Cergowa Beds (CB)				Sub-Grybów Beds (SGB)																GMF		CB	GMF
Nannoplankton Zones	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
Martini (1971)	24	24	24	24	24	24	24	24	25	25	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Sample number	15/	16/	17/	18/	19/	20/	21/	22/	1/	2/	1/	2/	3/	4/	26/	27/	11/	28/	10/	9/	8/	7/	6/	5/	4/	29/	30/	31/	32/	33/
	05/N								06/N		07/N				05/N		06/N	05/N	06/N							05/N				
Braarudosphaera bigelowii	X			X																	X	X								
Chiasmolithus grandis	R												R									R							R	
Coccolithus eopelagicus											X	X	X	X		X	X			X										
Coccolithus pelagicus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
Coronocyclus nitescens							X																							
Cyclicargolithus abisectus	X	X	X	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Cyclicargolithus floridanus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Cyclicargolithus luminis	X					X																								
Dictyococcites bisectus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X	X	X	X
Discoaster barbadiensis													R									R				R				
Discoaster deflandrei									X	X												X								
Discoaster tanii							X																							
Discoaster tanii nodifer												X																		
Ericsonia fenestrata					X	X			X	X			X				X					X					X			
Ericsonia formosa							R					R			R			R			R	R								
Helicosphaera bramlettei											X	X	X	X		X						X					X	X	X	
Helicosphaera euphratis	X																													
Helicosphaera compacta	X		X	X			X				X	X	X	X		X	X	X				X	X		X	X				
Helicosphaera papilata																														
Helicosphaera perch-nielsenia									X							X														
Helicosphaera recta					X						X	X	X	X				X				X		X			X			X
Helicosphaera reticulata																														
Isthmohlithus recurvus	X			X		X	X												X			X								
Lanternithus minutus	X	X	X		X							X	X	X	X			X			X	X		X	X		X			
Neococcolithes dubius																		X												
Pontosphaera latelliptica				X	X		X				X	X	X																	
Pontosphaera multipora				X												X	X	X	X	X	X									
Pontosphaera plana											X	X	X	X	X	X	X					X		X	X	X	X	X	X	

Tab. 2 cont.

Chełmski brook	Oligocene																													
	Thrust-sheet I										Thrust-sheet II																			TS III
Lithostratigraphical units	Grybów Marl Formation (GMF)						Cergowa Beds (CB)				Sub-Grybów Beds (SGB)																GMF		CB	GMF
Nannoplankton zones	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
Martini (1971)	24	24	24	24	24	24	24	24	25	25	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Sample number	15/	16/	17/	18/	19/	20/	21/	22/	1/	2/	1/	2/	3/	4/	26/	27/	11/	28/	10/	9/	8/	7/	6/	5/	4/	29/	30/	31/	32/	33/
	05/N								06/N		07/N				05/N		06/N	05/N	06/N							05/N				
Reticulofenestra callida						X			X	X		X																		
Reticulofenestra dictyoda								X	X	X	X	X	X	X		X											X			
Reticulofenestra lockerii	X			X			X	X	X	X	X	X	X	X	X	X	X		X		X		X	X		X	X	X		X
Reticulofenestra minuta	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
Reticulofenestra ornata	X	X	X	X	X	X	X	X			X	X	X	X		X		X	X	X	X	X	X	X	X	X		X		
Reticulofenestra umbilica	R			R			R	R					R			R			R		R					R				
Sphenolithus calyculus																														
Sphenolithus conicus									X	X																				
Sphenolithus dissimilis	X	X	X								X	X	X	X		X		X	X	X	X		X			X				
Sphenolithus editus							R																							
Sphenolithus moriformis		X	X	X	X		X	X	X	X		X	X	X	X		X		X			X	X	X					X	
Sphenolithus pseudoradians																														
Sphenolithus radians							R																							
Transversopontis fibula											R	R	R	R		R														
Transversopontis latus				X																										
Transversopontis obliquopons											X	X	X	X						X	X	X	X				X	X	X	X
Transversopontis pulcheroides								X				X	X																	
Triquetrorhabdulus carinatus							X																							
Zygrhablithus bijugatus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

X — autochtonous species, R — reworked species

OCCURENCE OF THE HIEROGLYPHIC BEDS AND SUB-MENILITE GLOBIGERINA MARLS IN THE SECTIONS STUDIED — DISCUSSION

According to Sikora (1960, 1970), the bases of the thrust-sheets II in the Górnikowski and Chełmski brooks include thin intervals of thin-bedded glauconitic sandstones with intercalations of green and black non-calcareous shales (Hieroglyphic Beds) overlain by 6–8 m thick yellow-greenish soft marls — the Globigerina Marls (SMGM). The foraminiferal test of the Hieroglyphic Beds (sample 114 Gry) from Chełmski brook documented a Lower Eocene age for these beds (see Sikora, 1960). Unfortunately in both of the Sikora papers (1960, 1970) there is a lack of age documentation concerning the SMGM. The same opinion can also be found documented in a geology guide book (Ślączka, 1971). In 2005 Gedl published profiles and pictures from Chełmski brook (right tributary, Gedl, 2005), which are identical to figure 6C herein, though the lithostratigraphy and age interpretations that he provided are quite different. Gedl (2005) followed the lithostratigraphical interpretations of Sikora (1960, 1970) and Ślączka (1971). These interpretations regard the Hieroglyphic Beds as the oldest deposits (compare Figs. 2–4 of this paper), containing poorly preserved but a diversified dinocyst assemblages indicating a Late Eocene age. Taking into account the author's nannofossil determination the Hieroglyphic Beds are of Early/Late Oligocene (NP24) age. In Gedl's (2005) interpretations the Eocene–Oligocene transition is located at the boundary between the SMGM (Sub-Grybów Beds in this paper) and Sub-Grybów beds (Grybów Marl Formation in this paper). According to Gedl (2005) 11 metres of SMGM contain dinocyst assemblages, that do not allow for age determination. Only the uppermost part of the marly succession as well as the lowermost part of the Sub-Menillite Beds contains Early Oligocene dinocysts. Taking into account the dinocyst age determination, Gedl (2005) provides a relatively broad interpretation of the palaeogeographic as well as climatic changes at the Eocene–Oligocene boundary in the Outer Carpathian Flysch Basin, which seems inappropriate especially as the described deposits are of Late Oligocene age.

It is important to stress that the SMGM are typical pelagic marls without turbiditic intercalations. In the sections studied the so-called SMGM are represented by marls, marly mudstones and sandstones of turbiditic origin.

CONCLUSIONS

1. The sections studied of the Ropa tectonic window are composed of: the Sub-Grybów Beds, the Grybów Marls Formation and the Krosno Beds.
2. The Hieroglyphic Beds, the Sub-Menilite Globigerina Marls and their age equivalents have not been found.
3. The age of the Sub-Grybów Beds and the Grybów Marls Formation, based on nannofossil data, correspond to NP24.
4. The youngest deposits of the Ropa tectonic window belong to the Krosno Beds and represent zones NP24 and NP25. The same development of the Krosno Beds is known from all the other tectonic windows of the Magura Nappe and is typical of the closure stage of the flysch basins.
5. The abundance pattern and the species diversity of the nannoplankton assemblages reflect temperate to cool temperatures in the surface waters of the Grybów Basin.

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