Annales Societatis Geologorum Poloniae (2001), vol. 71: 139–188.

THE NANNOFOSSIL BIOSTRATIGRAPHY OF THE YOUNGEST DEPOSITS OF THE MAGURA NAPPE (EAST OF THE SKAWA RIVER, POLISH FLYSCH CARPATHIANS) AND THEIR PALAEOENVIROMENTAL CONDITIONS

Marta OSZCZYPKO-CLOWES

Institute of Geological Sciences, Jagiellonian University, Oleandry St. 2a, 30-063 Kraków, Poland

Oszczypko-Clowes, M., 2001. The nannofossil biostratigraphy of the youngest deposits of the Magura Nappe (East of the Skawa river, Polish Flysch Carpathians) and their palaeoenviromental conditions. *Annales Societatis Geologorum Poloniae*, 71: 139–188.

Abstract: The Magura Nappe is the largest and southernmost tectonic unit of the Western Outer Carpathians and differ in lithofacies development from the Middle and Marginal groups of units. The age studies of the youngest deposits of the Magura Nappe play an important role in understanding the tectogenesis of the Outer Carpathians. The aim of this work was to find the litho- and biostratigraphic correlation with the more external units. For this purpose the youngest deposits from selected sections of the Magura Nappe located east of the Skawa River, were chosen. For the lower limit of the youngest sediments, Middle/Upper Eocene variegated shales with *Reticulophragmium amplectens* Grzybowski were taken.

The analysis of nannoplankton assemblages enable to establish the age of these deposits which varies from Middle Eocene (NP15) up to Upper Oligocene (NP25) and Lower Miocene (NN2). The Eocene/Oligocene boundary lies within the NP21 nanno-zone and was found in the Krynica Zone within the Globigerina Marls (Leluchów section), in the Rača Zone within Poprad Sandstone Mbr of the Magura Fm. and in the Siary Zone within supra-Magura (Budzów) Beds (Budzów section), Wątkowa Sandstone (Ropica and Małastów sections) and within Zembrzyce (sub-Magura) Beds (Folusz section).

In the Rača and Krynica zones the youngest – Upper Oligocene deposits from the studied sections belong to the Malcov Fm., whereas in the Siary Zone they belong to the supra-Magura (Budzów) Beds. The age of the Malcov Fm. was determined as NP24 in Leluchów and as NP25 in the Nowy Sącz I borehole, whereas the Budzów Beds belong to zone NP24. The youngest deposits so far described from the Magura Nappe belong to the Zawada Fm. whose age was determined as NN2. In the Polish part of the Bystrica Zone deposits younger than NP18, have so far not been found.

The analysis of autochtonous nannoplankton assemblages from the Magura Basin enable to follow the palaeoecological changes in the Magura Basin, both in regional and global sense, from Late Eocene through Oligocene. The global changes are the drop of the water temperature accompanied by the progressing eutrophication of the Magura Basin.

Further events were also recorded in zone NP23. The assemblage of this zone was characterised by the presence of species which are believed to be indicative of brackish water and restricted to the Paratethys region.

Key words: the youngest deposits of the Magura Nappe, calcareous nannofossil, palaeoecology, Middle Eocene–Lower Miocene, West Carpathians.

Manuscript received 16 January 2001, accepted 2 October 2001

INTRODUCTION

The Magura Nappe is the largest and southernmost tectonic unit of the Western Outer Carpathians and differ in lithofacies development from the Middle and Marginal groups of units. The age studies of the youngest deposits of the Magura Nappe play an important role in understanding the tectogenesis of the Outer Carpathians. The aim of this work was to find the litho- and biostratigraphic correlation with the youngest deposits of the more external units known as the Moldavides (Fig. 1). This paper was prepared on the basis of the author's PhD thesis "Lithostratigraphy and nannofossils biostratigraphy of the youngest deposits from the middle part of the Magura Nappe (Polish Outer Carpathians)", which was written at the Institute of Geological Sciences, Jagiellonian University between 1996–1999 (see Oszczypko-Clowes, 2000).

PREVIOUS NANNOPLANKTON STUDIES OF THE PALAEOGENE DEPOSITS FROM THE MAGURA NAPPE

Calcareous nannoplankton studies in Poland were initiated by Radomski (1967, 1968, 1971), who introduced Polish readers to the principles of biology, ecology, systematic and the stratigraphy of *Coccolithophorales*. He also established the nannoplankton zonations of Palaeogene deposits in the Outer Carpathians with a special emphasis on the Babia Góra region in the Magura Nappe. Ten years later, Olszewska & Smagowicz (1977) proposed a new biostratigraphical scheme of the Late Cretaceous–Palaeogene deposits from the Dukla Unit, based on foraminiferal and calcareous nannoplankton investigations. The nannoplankton of the sub-Menilite Globigerina Marls (SMGM) in Znamirowice (Silesian Unit) were studied by Aubry (see Van Couvering *et al.*, 1981), who determined their Late Eocene (NP19–20, ? NP21) age. The nannoplankton research that was initiated by Radomski (1968) in the Magura Nappe was continued by Birkenmajer & Dudziak (1981). These authors established the nannofossil biostratigraphy of the Palaeogene deposits in the peri-Pieniny Klippen Belt zone (Fig. 2). The age of the Szczawnica Fm. was determined as Upper Paleocene–Lower Eocene (NP9–11). The deposits belonging to sub-Magura Beds and Łącko Marls were assigned as Lower Eocene (NP10–NP11), whereas the age of the Frydman Beds and Magura Sandstones were determined as Lower Eocene (NP11–NP12). The same ages were also suggested by Birkenmajer & Dudziak (1988b) for the beds located within the Pieniny Klippen Belt. These authors (Birkenmajer & Dudziak, 1988a), on the basis of nannofossil established the Lower Oligocene (NP21) age of the Malcov Beds in Samorody near Nowy Targ. The nannoplankton studies of Palaeogene deposits from Krynica were continued by Dudziak (see Oszczypko *et al.*, 1990). This author established the Upper Paleocene (NP9) age of the Szczawnica Fm., the Lower/Middle Eocene (NP10–14) age of the Zarzecze Fm., the Lower to Upper Eocene (NP10–11 to NP18) age of the Piwniczna Mbr of the Magura Fm., and the Upper Eocene (NP19–20) age of the Malcov Fm. In the early 1990's Olszewska & Smagowicz (see Cieszkowski, 1992), on the basis of their foraminiferal and nannoplankton studies, determined the age of the Waksmund and Bystre beds (peri-Klippen Belt zone of the Magura Nappe) as Upper Oligocene to Middle Miocene. In 1996 the author (Oszczypko, 1996) published her results based on more detailed nannoplankton research of the SMGM (Leluchów Marl Mbr of the Malcov Fm.). Finally the age of the marls was established as Upper Eocene–Lower Oligocene (NP19– 21, see Oszczypko-Clowes, 1998). More recently, Oszczypko-Clowes (1999) established age of the Smereczek Shale Mbr (Menilite Beds) to be Early Oligocene (NP22– NP23) and the Malcov lithofacies to be Upper Oligocene (NP24).

The nannofossil assemblages from selected sections of the Bystrica facies zone were studied by Dudziak (1991), who determined the ages of the following formations:

uppermost part of the Ropianka Beds – Upper Paleocene (NP9),

Łabowa Fm. – the Lower Eocene (NP11),

Beloveza Fm. – Lower to Middle Eocene (NP12–NP17),

Bystrica Fm. – Middle Eocene (NP14),

Żeleźnikowa Fm. – Middle Eocene (NP16–NP17),

Maszkowice Mbr of the Magura Fm. – Upper Eocene (NP18).

In the Rača facies zone, Aubry (see Van Couvering *et al.*, 1981) described the Middle Eocene calcareous nannoplankton from the upper part of the variegated shales (Łabowa Shale Fm.) in Polany near Grybów.

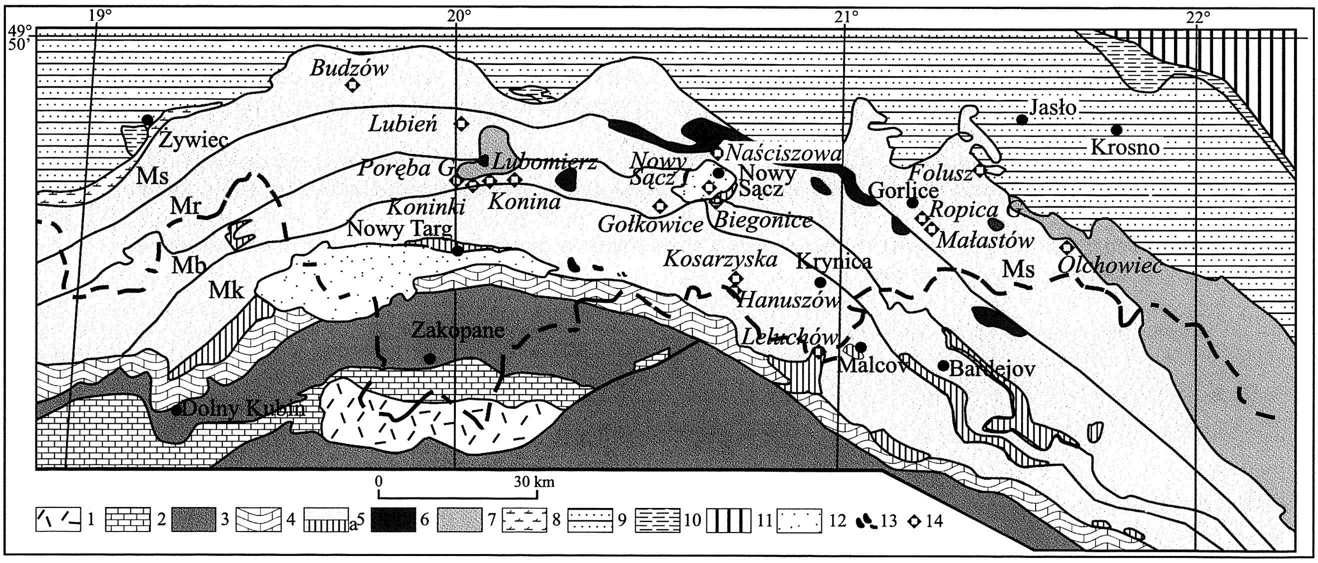


Fig. 1. Tectonic position of the Magura Nappe in Poland and Slovakia (after Żytko *et al.*, 1989 and Vozar & Kačer (1996), supplemented). *1* – crystalline core of the Tatra Mts, *2* – High Tatra and sub-Tatra units, *3* – Podhale flysch, *4* – Pieniny Klippen Belt, *5* – Magura Nappe, *5a* – Malcov Fm., *6* – Grybów unit, *7* – Dukla unit, *8* – Fore-Magura unit, *9* – Silesian unit, *10* – Sub-Silesian unit, *11* – Skole unit, *12* – Miocene deposits upon the Carpathians, *13* – andesite, *14* – investigated area; Ms – Siary, Mr – Rača, Mb – Bystrica and Mk – Krynica subunits

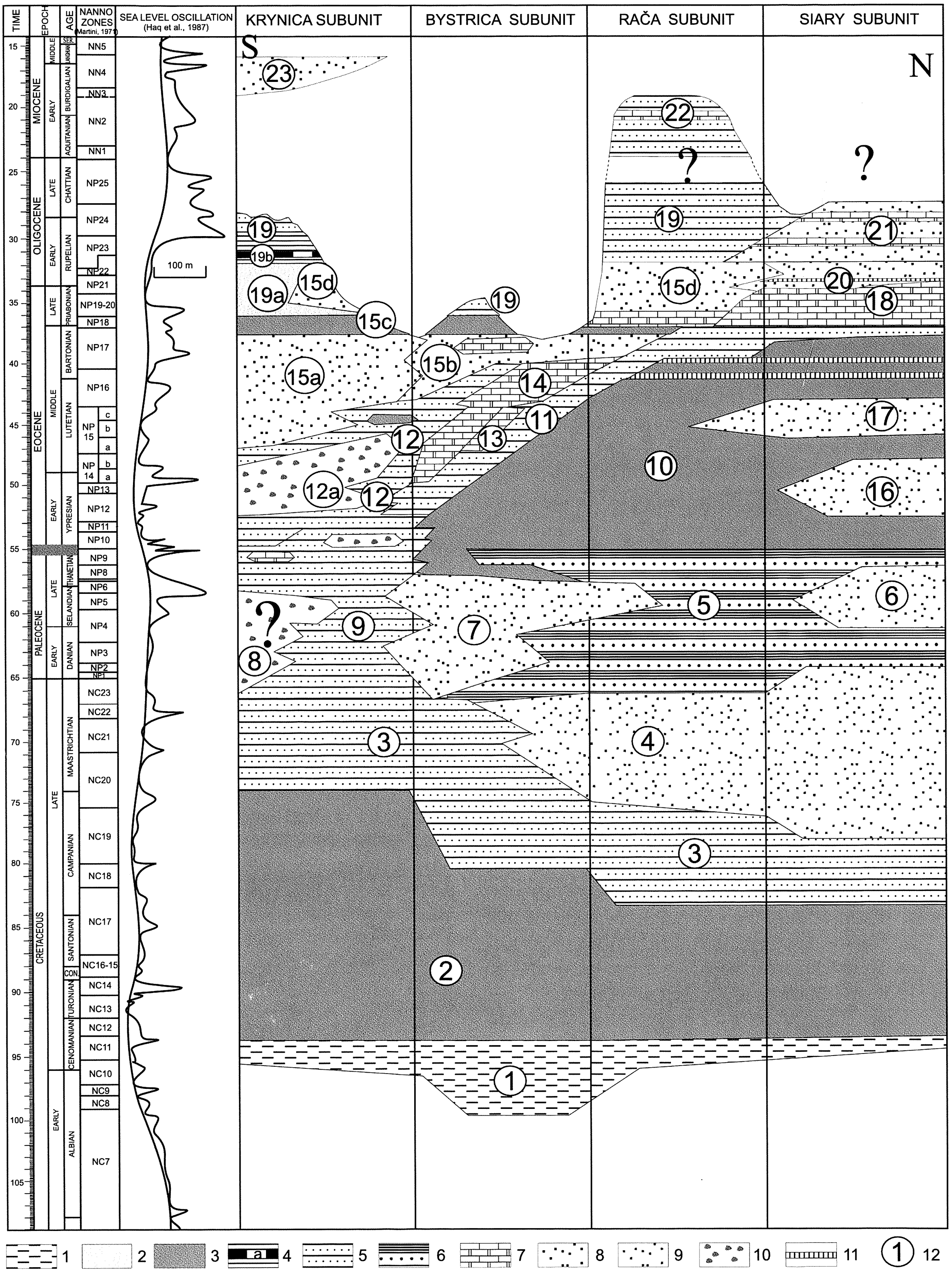


Fig. 2. Lithostratigraphy of the Magura Nappe in Poland (after Oszczypko & Oszczypko-Clowes, 2002). *1* – pelagic shales, *2* – pelagic marls, *3* – hemipelagic variegated shales, *4* – black shales, a – horstones, *5* – distal lime turbidites, *6* – distal turbidites, *7* – thick-bedded carbonate turbidites, *8* – chanel fan turbidites (muscovite), *9* – chanel fan turbidites (glauconite), *10* – conglomerates, *11* – tuffites, *12* – lithostratigraphic unit (see Birkenmajer & Oszczypko, 1989; Oszczypko, 1991): 1 – Hulina Fm., 2 – Malinowa Fm., 3 – Hałuszowa Fm. and Kanina Beds, 4 – Jaworzynka Beds, 5 – Ropianka Beds, 6 – Mutne and Łyska sandstones, 7 – Szczawina Sandstones, 8 – Jarmuta Fm., 9 – Szczawnica Fm., 10 – Łabowa Fm., 11 – Beloveza Fm., 12 – Zarzecze Fm., 12a – Krynica Sandstone Mbr, 13 – Bystrica Fm., 14 – Żeleźnikowa Fm., Magura Fm.: 15a – Piwniczna Mbr, 15b – Maszkowice Mbr., 15c – Mniszek Mbr, 15d – Poprad Mbr, 16 – Ciężkowice Sandstones, 17 – Pasierbiec Sandstones, 18 – Zembrzyce (sub-Magura) Beds, 19 – Malcov Fm., 19a – Leluchów Marls Mbr, 19b – Smereczek (Menilite) Mbr, 20 – Wątkowa Sandstone, 21 – Budzów (supra-Magura) Beds, 22 – Zawada Fm., 23 – Stare Bystre Beds

In the Siary facies zone, south of Myślenice, the calcareous nannoplankton of the supra-Magura Beds (Krzczonów and Tokarnia sections) were studied by Birkenmajer & Dudziak (1988c). In both cases the ages of these beds were determined as Lower Oligocene (NP21). Recently Kopciowski (1996) assigned the supra-Magura Beds from Małastów near Gorlice to the Lower Oligocene (NP21–22), whereas the olistrostome beds from Gładyszów were classified as Upper Oligocene – NP24 (Kopciowki & Garecka, 1996). In 1999 Oszczypko-Clowes published new biostratigraphical data from the Budzów, Ropica Górna and Małastów sections. The results of this study are included in this paper.

The nannofossil assemblages of Eocene–Oligocene deposits from the Krynica facies zone in Slovakia were also analysed. The Malcov Beds in the Mala Domasa section (SE of Bardejov) were assigned by Bystricka *et al.* (1970) to the Early Oligocene. The same beds in Orava were assigned by Potfaj (1983) to zones NP17–NP21 (Middle-Upper Eocene).

STUDIED SECTIONS AND SAMPLE PREPARATION

The field studies of the youngest deposits from the Magura Nappe were carried out between 1996–1999. For the lower limit of these sediments, the Middle/Upper Eocene variegated shales with *Reticulophragmium amplectens* Grzybowski were taken.

In the Siary and Rača facies zones these shales belong to the uppermost part of the Łabowa Fm., whereas in the Bystrica and Krynica zones they belong to the Mniszek Shale Mbr of the Magura Fm. Taking this supposition into account the following lithostratigraphic units were investigated: Hierogliphic Beds, Zembrzyce Beds, Wątkowa Sandstones, Budzów Beds, Poprad Sandstone Mbr of the Magura Fm., Malcov and Zawada fms. In addition, from the Krynica and Bystrica zones the other deposits were also studied, which could belong to the Poprad Mbr or Malcov Fm. All together, 15 sections and 3 exposures were studied from the given localities (Fig. 1):

Siary Zone: Budzów near Sucha, Ropica Górna, Małastów and Folusz near Gorlice and Olchowiec near Dukla;

Rača Zone: Naściszowa-Zabełcze and Biegonice close to Nowy Sącz, borehole Nowy Sącz I and Lubień near Myślenice;

Bystrica (Sącz) Zone: Gołkowice south of Stary Sącz, Poręba Górna, Koninki, Konina and Lubomierz near Mszana Dolna;

Krynica Zone: Leluchów near Muszyna, Kosarzyska and Hanuszów near Piwniczna.

Detailed studies with respect to the sections of the Bystrica Zone (except Gołkowice one) were already published by the author (see Oszczypko *et al.*, 1999b). For this reason, the data obtained from Poręba Górna, Koninki, Konina and Lubomierz were omitted. At the same time, in order to illustrate the whole range of species, the author decided to include the photographs of the species from the above mentioned sections.

The vast majority of the samples used for the nannofossil analyses were collected during the author's field work. However, some of them were obtained from N. Oszczypko (borehole Nowy Sącz I and exposure Biegonice A) as well as from E. Malata (Biegonice B). All 300 samples were prepared using the standard smear slide technique for light microscope (LM) observations. The investigation was carried out under LM at a magnification of 1000x using parallel and crossed nicols. Several of the specimens photographed in LM are illustrated in figures 36–42.

THE LITHOSTRATIGRAPHIC LOGS OF THE MIDDLE EOCENE–LOWER MIOCENE DEPOSITS

Siary Zone

Budzów section. This section is located on the northern slope of the Beskid Makowski Range along the Droździna stream (Figs 1, 3). In this section the Zembrzyce (sub-Magura) Beds occur at the top of the Pasierbiec Sandstones and are represented by a 100 m thick sequence of dark-greyish and black marly shales with intercalations of fine-grained, calcareous, thin to medium-bedded muscovite sandstones (Figs 3–5, see also Książkiewicz, 1966, 1974; Oszczypko-Clowes, 1999). Higher up in the section (Fig. 6), there is a complex (325 m thick) of the Wątkowa Sandstones (see Koszarski & Koszarski, 1985). These are blue-greenish, poorly calcareous, fine to medium-grained, sometimes conglomeratic thick-bedded glauconitic sandstones (up to 2.0 m). Subordinately, the sandstones are intercalated with layers of dark marls and turbiditic marly mudstones.

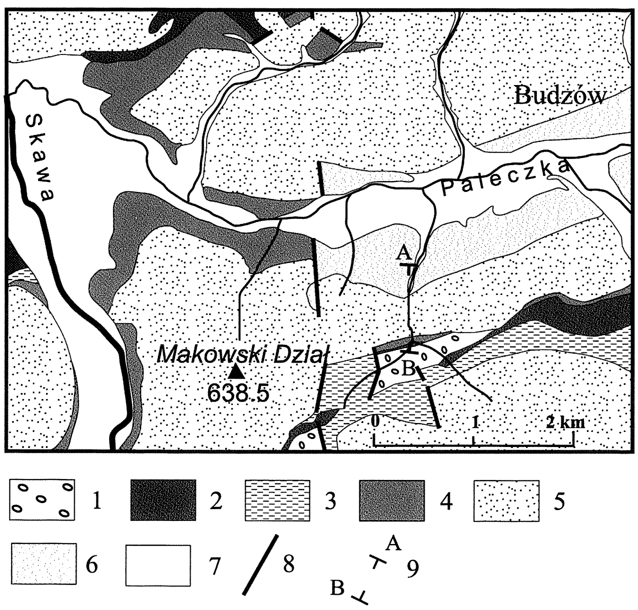


Fig. 3. Geological map of the Budzów area (after Książkiewicz, 1974, supplemented). *1* – Ciężkowice Sandstones, *2* – Łabowa Fm., *3* – Hierogliphic Beds, *4* – Zembrzyce Beds, *5* – Wątkowa Sandstones, *6* – Budzów Beds, *7* – Quaternary, *8* – faults, *9* – geological cross-section (see – Fig. 4)

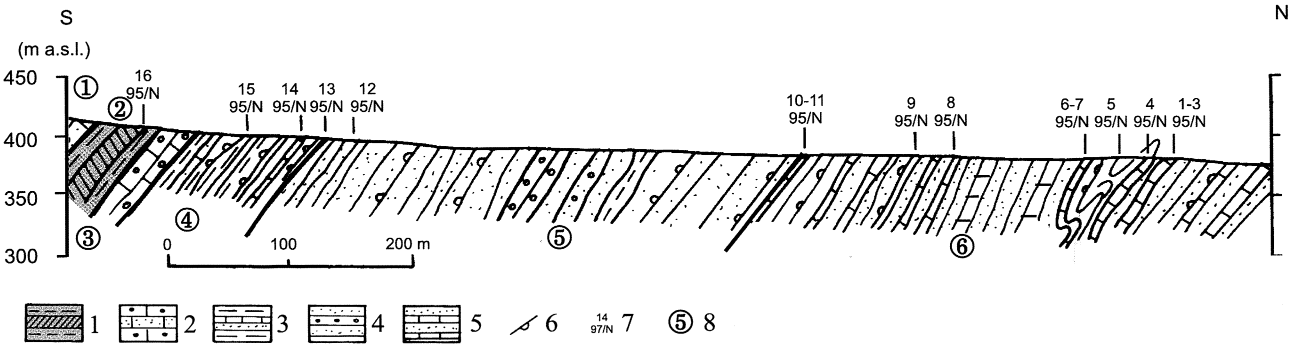


Fig. 4. Geological cross-section (A–B) along Droździnka stream in Budzów (loc. see – Fig. 3). *1* – variegated shales, *2* – glauconitic, thick-bedded sandstones and conglomerates, *3* – thin-bedded sandstones and shales, *4* – thick-bedded sandstones and conglomerates, *5* – turbiditic marls, *6* – sole marks, *7* – samples localities, *8* – lithostratigraphic units: 1 – Ciężkowice Sandstones, 2 – Łabowa Fm., 3 – Pasierbiec Sandstones, 4 – Zembrzyce Beds, 5 – Wątkowa Sandstones, 6 – Budzów Beds

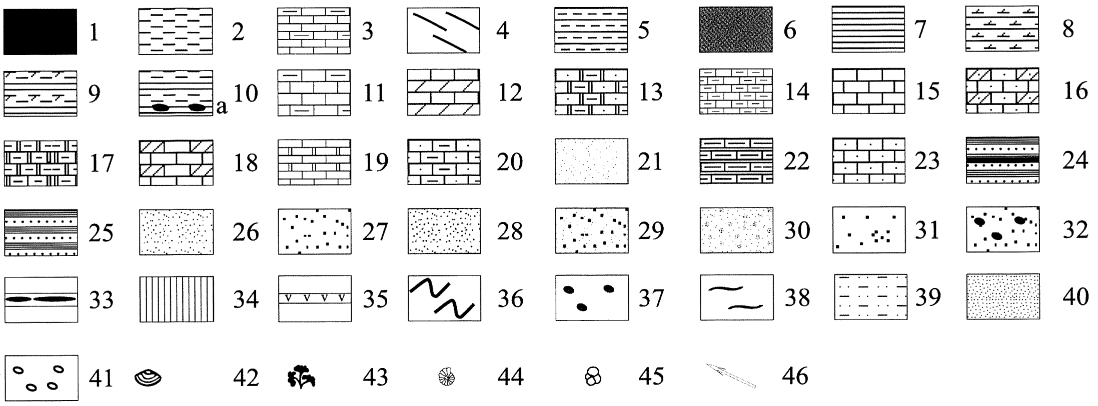
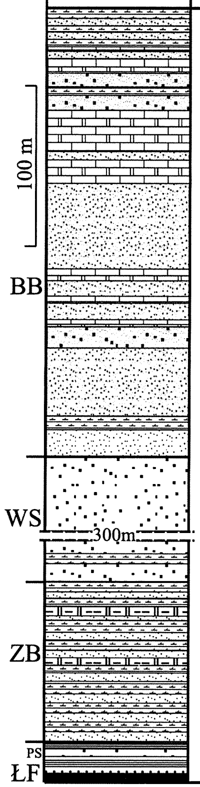


Fig. 5. Explanations to figures 6, 9, 11, 14, 17, 19, 22, 25–27, 43, 44. *1* – variegated shales, *2* – green calcareous shales, *3* – grey calcareous shales, *4* – dark-grey shales, *5* – greenish-grey calcareous shales, *6* – dark-russet marly shales, *7* – dark bituminous shales (Menilite Shales), *8* – greenish-grey marly mudstones and claystones, *9* – olive-grey, non-calcareous claystones and mudstones, *10* – greenish-yellow marly mudstones, a – sideritic concretions, *11* – red marls, *12* – greyish-green marls, *13* – olive marls, *14* – beige marls, *15* – creamy marls, *16* – creamy-greenish marls, *17* – grey, soft marls, *18* – russet marls, *19* – dark-grey, siliceous, turbiditic marls, *20* – Łącko-type bluish-grey marls, *21* – Łącko-type grey marls, *22* – laminated marls, *23* – sandy marls, *24* – thin-bedded turbidites with intercalation of red shales, *25* – thin- and medium-bedded sandstones with intercalations of non-calcareous shales, *26* – feldspar-glauconitic, fine and medium-grained sandstones, *27* – feldspar-glauconitic, coarse and very coarse-grained sandstones, *28* – glauconitic, fine and medium-grained sandstones, *29* – glauconitic, coarse and very coarse-grained sandstones, *30* – muscovite, fine and medium-grained sandstones, *31* – muscovite, coarse and very coarse-grained sandstones, *32* – conglomerates, *33* – spherosiderites, *34* – bentonitic shales, *35* – tuffites: "Gąsiory" & "Polany", *36* – convolution, *37* – clasts, *38* – "slurry" structures, Middle Miocene: *39* – claystones and mudstones, *40* – sands, *41* – gravels; *42* – macrofauna detritus, *43* – flora flakes, *44* – *Reticulophragmium amplectens*, *45* – SGM type microfauna, *46* – palaeotransport direction

The uppermost part of the Budzów section belongs to the Budzów (supra-Magura) Beds (Książkiewicz, 1966). The complex consists of green-greyish, greyish and brown, marly shales and marls with sporadic intercalations of glauconitic sandstones, 0.3 to 1 m thick. These marls are sometimes silicified and accompanied by a few centimetres of thick hornstone layers (Książkiewicz, 1966). In this section the thickness of the Budzów Beds is 300 m, whereas the total thickness of the deposits is up to 600 m (Książkiewicz, 1966).

Ropica Górna section. This section is located along the Sękówka stream, which in turn forms the right tributary of the Ropa river in the Beskid Niski Mountains (Figs 1, 7). The studied section starts at the top of the Pasierbiec Sandstone and displays a 5 meter thick sequence of Zembrzyce (sub-Magura) Beds, represented by thin-bedded turbidites with intercalations of marly shales (Fig. 8, see also Sikora, 1970; Widz, 1985; Kopciowski, 1996). In the upper part of the sequence a 10–20 cm thick layer of brown, Menilite-like shales was found (see Ślączka & Kaminski, 1998).

Higher up in the section Wątkowa Sandstones (Koszarski & Koszarski, 1985; Widz, 1985; Kopciowski, 1996; Oszczypko-Clowes, 1999) were exposed. Their basal part, which is 30 m thick, belongs to light, non-calcareous, glauconitic, medium to coarse-grained thick-bedded sandstones (0.6–1.5 m) and conglomerates (Fig. 9). These sandstones are rich in muddy clasts (up to 15 cm in diameter) and are also intercalated by thin layers of grey, marly claystones. These sandstones are followed by a 20 m thick packet of massive, grey marls with intercalations of thin to thick-



SAMPLE NUMBER	Braarudosphaera bigelowii	Chiasmolithus bidens	Chiasmolithus expansus	Chiasmolithus grandis	Chiasmolithus medius	Chiasmolithus oamaruensis	Chiasmolithus solitus	Clathrolitus spinosus	Coccolithus eopelagicus	Coccolithus pelagicus	Corannulus germanicus	Coronocyclus nitescens	Cyclicargolithus floridanus	Cyclicargolithus luminis	Dictyococcites bisectus	Discoaster barbadiensis	Discoaster deflandrei	Discoaster distinctus	Discoaster saipanensis	Discoaster strictus	Discoaster tanii	Discoaster tanii nodifer	Ericsonia fenestrata	Ericsonia formosa	Ericsonia subdisticha	Helicosphaera bramlettei	Helicosphaera compacta	Helicosphaera euphratis	Helicosphaera seminulumi	Isthmolithus recurvus	Lanternithus minutus	Neococcolithes dubius	Neococcolithees minutus	Orthozygus aureus	Pontosphaera multipora	Reticulofenestra callida	Reticulofenestra dictyoda	Reticulofenestra hillae	Reticulofenestra laevis	Reticulofenestra reticulata	Reticulofenestra umbilica	Sphenolithus moriformis	Sphenolithus radians	Sphenolithus spiniger	Transversopontis pulcher	Transversopontis pulcheroides	Zygrhablithus bijugatus
1/95/N									X	X			X		X									R						X	X										X	X	X				X
2/95/N									X	X			X		X									R						X	X					X		X		X	X	X					
3/95/N	X								X	X	X		X		X	R					X			R						X	X					X		X	X	X	X	X	X				X
4/95/N									X	X			X	X	X									R						X	X					X	X	X		X	X	X					
5/95/N									X	X					X																										X	X					
6/95/N						X			X	X			X	X	X											X		X	R	X	X				X	X		X	X	X	X	X				X	X
7/95/N	X			R		X			X	X		X	X		X								X	X	X					X	X				X	X				X	X	X					
8/95/N		R	R		R	X	R	X	X	X	X	X	X		X		X		X	R	X		X	X	X	X	X			X	X	X			X	X	X	X		X	X	X		X	X	X	X
9/95/N									X	X	X		X		X	X			X		X			X		X	X			X	X				X	X	X	X		X	X	X				X	
10/95/N	X								X	X	X		X		X	X			X					X			X			X	X					X	X			X	X	X			X		X
11/95/N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
12/95/N				R		X	R	R	X	X	X		X		X				X		X			X			X			X	X	X				X	X			X	X	X	X				X
13/95/N			R			X		R	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
14/95/N				X				R	X	X	X	X	X		X	X	X	R	X		X	X	X	X			X	X			X	X	X			X	X	X		X	X	X	X	X			X
15/95/N								R	X	X	X		X	X	X		X		X		X			X				X			X					X	X	X		X	X	X		X		X	X
16/95/N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Fig. 6. Distribution of the calcareous nannofossils in the Budzów section. X – determined species, R – reworked species, ŁF – Łabowa Fm., PS – Pasierbiec Sandstones, ZB – Zembrzyce Beds, WS – Wątkowa Sandstones, BB – Budzów Beds. For the other explanations see Fig. 5

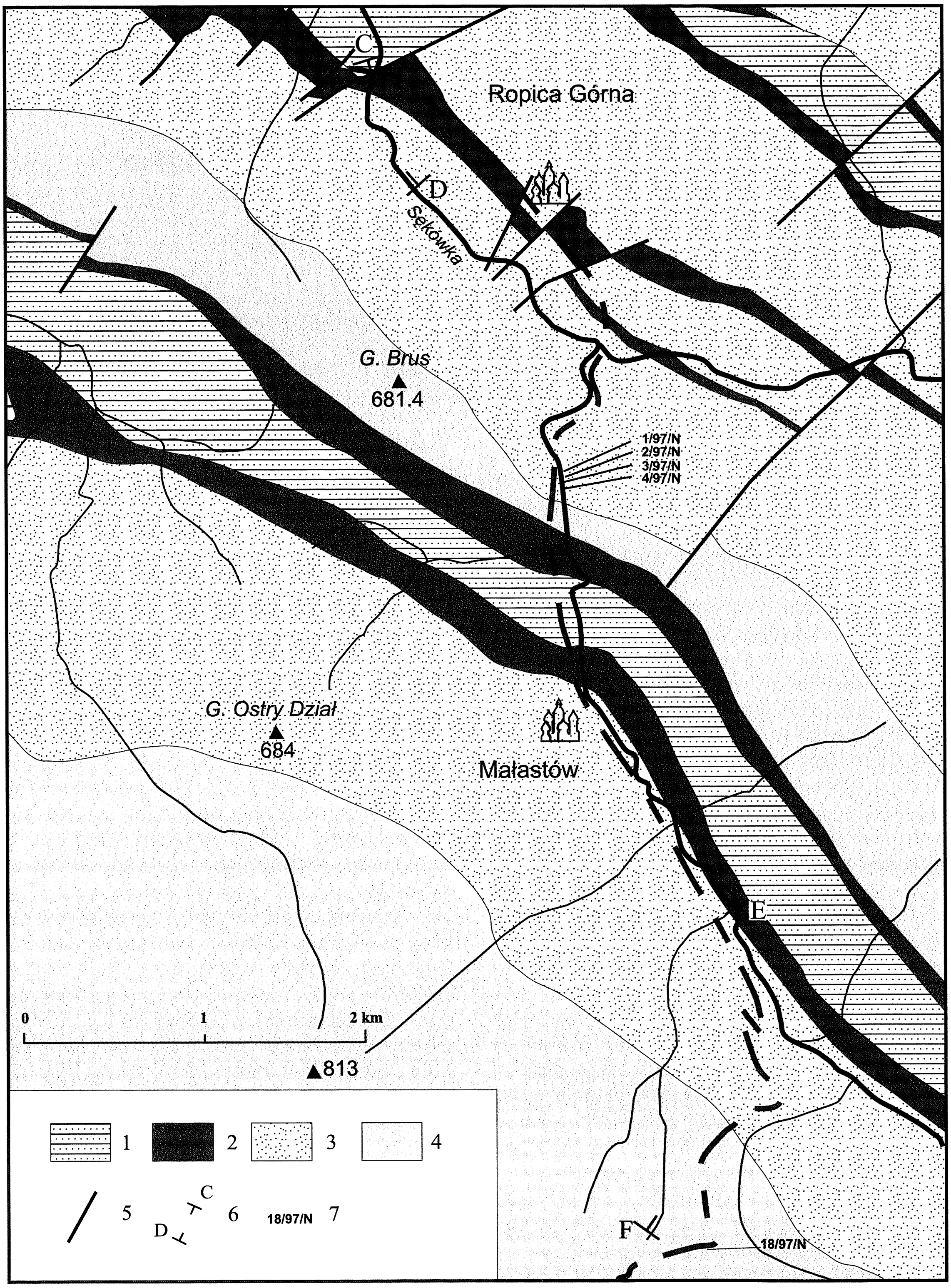


Fig. 7. Geological map of the Ropica Górna and Małastów area (after Sikora, 1968; Koszarski & Tokarski, 1968; Widz, 1985, supplemented). *1* – Inoceramian Beds, *2* – Łabowa Fm. and Zembrzyce Beds, *3* – Wątkowa Sandstones, *4* – Budzów Beds, *5* – faults, *6* – geological cross-section (see – Figs 8, 10), *7* – samples localities

bedded glauconitic sandstones. This interval passes upwards into a 40–45 m thick sequence of granule conglomerates and medium to coarse-grained, glauconitic, thick-bedded sandstones with T_{abc} Bouma intervals. This sequence is followed by a 1 m thick layer of grey marls and a 30 m thick sandstone interval. The sandstones are covered by a few metres thick packet of grey marls, marly shales, dark-brown, non-calcareous shales, with intercalations of

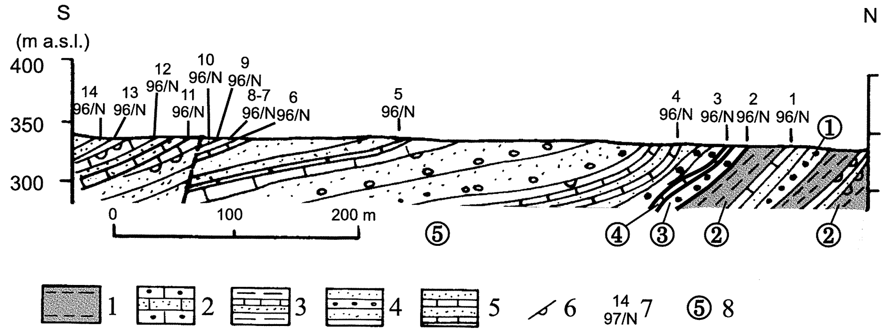


Fig. 8. Geological cross-section (C–D) along Sękówka stream in Ropica Górna (loc. see – Fig. 7). *1* – variegated shales, *2* – glauconitic, thick-bedded sandstones and conglomerates, *3* – thin-bedded sandstones and shales, *4* – thick-bedded sandstones and conglomerates, *5* – turbiditic marls, *6* – sole marks, *7* – samples localities, *8* – lithostratigraphic units: 1 – Ciężkowice Sandstones, 2 – Łabowa Fm., 3 – Pasierbiec Sandstones, 4 – Zembrzyce Beds, 5 – Wątkowa Sandstones

fine, calcareous, thin-bedded sandstones. These marls pass upwards into a few, very thick-bedded, amalgamated pebbly sandstones.

The first sandstone layer (up to 1.5 m thick) filled the erosional channel up to 40 cm deep. The basal surface of the conglomerate reveals huge flute-casts, indicating palaeotransport towards SW (210°), whereas the upper part of beds display trough cross-lamination. This part of the bed contains fragments of molluscs and *Nummulites* (see Ślączka & Kaminski, 1998). This thickening upward sequence is terminated by a 3 m thick layer of very coarse to fine-grained sandstone. This part of the section is cut by a NE–SW trending normal fault (Fig. 5). In the hanging wall occurs a 35–40 m thick packet of massive, greyish marls with sporadic intercalations of very thick-bedded (1–2.5 m) pebbly sandstones.

Małastów section. This section is located along Małastówka stream on the northern slope of the Magura Małastowska Mt (Fig. 7). The section consists of Wątkowa Sandstones and Budzów Beds. The Wątkowa Sst., up to 1000 m thick, can be divided into three sequences. The thickness of the individual sequences varies from 100 to 500 m (Figs 10, 11). The basal sequence, about 400 m thick, is composed of thick-bedded sandstones with subordinate intercalations of green-greyish soft marls, black-brown marls, and yellowish mudstones. The middle part of the sequence reveals two packets of marls, which are 3 to 8 m thick and contain intercalations of brown Menilite type shales.

The middle sequence, up to 500 m thick, is dominated by very thick-bedded (2–2.5 m) coarse to granule-grained sandstones and fine conglomerates. These sandstones display a large convolution and plastically deformed "slurried" divisions at the top of the beds. The sandstones alternate with marly shales, which are up to 1.5 m thick. The sequence terminates with a 10 m thick packet of marls. In this sequence the flute-casts reveal palaeotransport towards the SW (230°).

The uppermost sequence of Wątkowa Sst. (up to 100 thick) is composed of thick-bedded sandstones (0.8–1m) and is accompanied by soft marly layers, 1.5–10 m thick. These sandstones pass into the Budzów Beds, which are at least 470 m thick (Fig. 11). The lower part of the Budzów Beds (200 m thick) is composed of light, slightly calcareous and poorly sorted glauconitic sandstones, 0.3–1.8 m thick. These sandstones resemble "Harklowa" type sandstones (see Oszczypko, 1973; Oszczypko *et al.*, 1999b), and are accompanied by grey marls (0.3–3 m thick). Higher up in the section, there are thin to medium-bedded glauconitic sandstones with intercalations of brown-greenish silicified marls, up 2–3 m thick.

Folusz section. The Folusz section is located along the Kłopotnica stream on the northern slope of the Magura Wątkowska Range in the Beskid Niski Mts (Figs 1, 12). The studied section is composed of the Łabowa Fm., the Zembrzyce Beds and the basal part of the Wątkowa Sst.

The Zembrzyce Beds, 60 m thick, crops out at the top of the variegated shales of the Łabowa Fm. (Figs 13, 14). The lower portion of these beds is represented by green-greyish non-calcareous shales with rare intercalations of grey-bluish very fine-grained and very thin-bedded sandstones. Higher up in the section, dark-grey and dark-brown, marly claystones with a jarosite coating are visible (see Koszarski & Koszarski, 1985). These are overlain by a 0.4 m thick bed of poorly cemented, medium to coarse-grained sandstone. The sandstones are rich in small clasts of brown shales and coalified flakes. The sandstones are overlain by a 1.5 m thick layer of green-greyish shales, which Sikora (1970) correlated with SMGM. The basal part of the Wątkowa Sst. (about 30 m thick) is composed of thick-bedded (up to 1.3 m) coarse-grained glauconitic sandstones with T_{abc} Bouma intervals and fine conglomerates with intercalations of brown marly shales. These beds pass upwards to a series of amalgamated, very coarse-grained sandstones and fine conglomerates, up to 6 m thick, which display features of a sandy grain flow. The studied section terminates with light, very coarse, quartzitic sandstones with a ripple-cross convolution, often convoluted. These sandstones are intercalated with thin layers of marly claystones and with a very thin layer of laminated, non-calcareous claystone (tuffite ?). This part of the Wątkowa Sst. revealed palaeotransport toward the SW (200°–240°).

Olchowiec section. The studied section is located along the lower flow of the Olchowiec stream on the southern slope of the Suchań-Jasieniów Range in the Beskid Niski

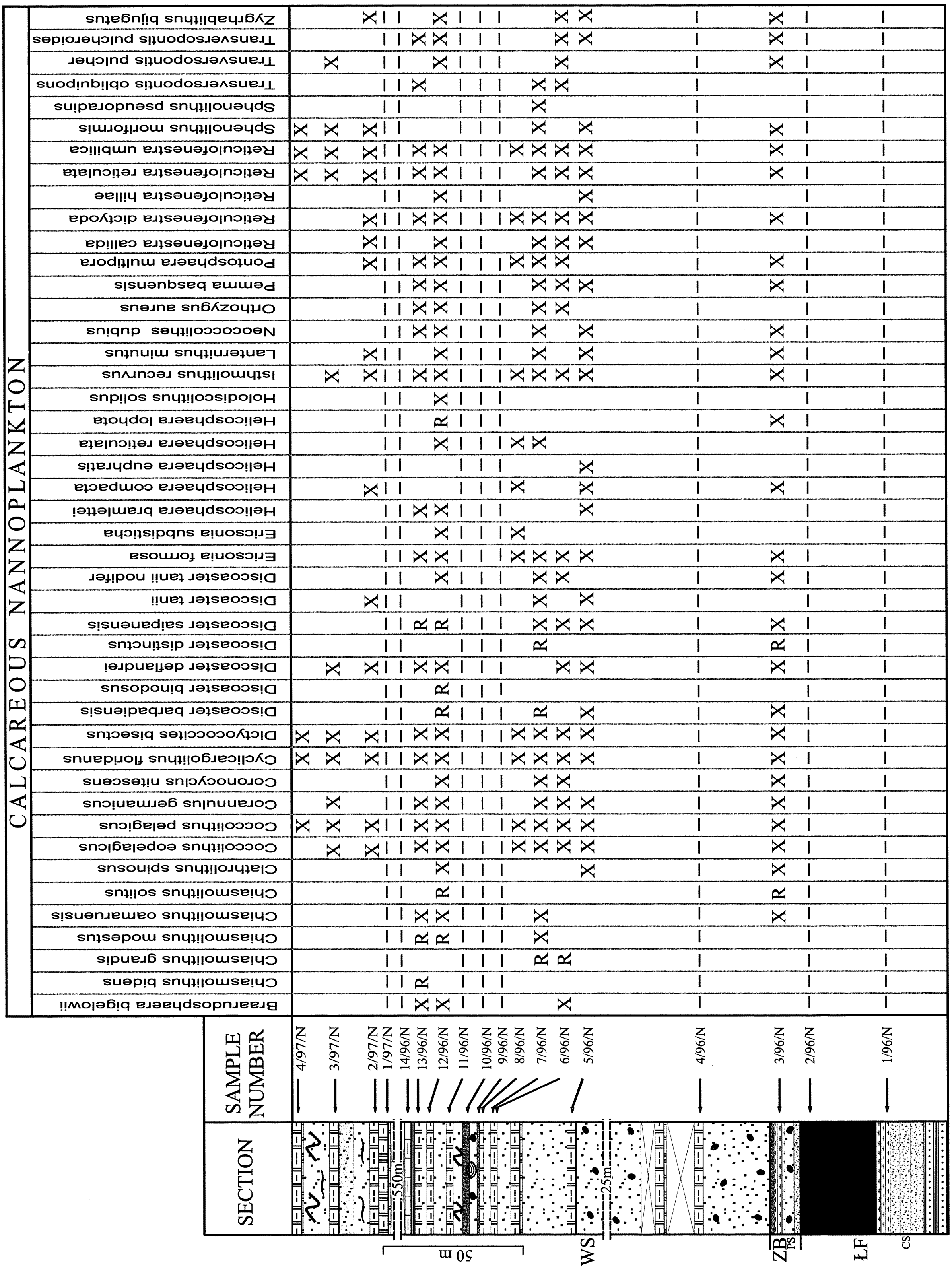


Fig. 9. Distribution of the calcareous nannofossils in the Ropica Górna section. X – determined species, R – reworked species. CS – Ciężkowice Sandstones, ŁF – Łabowa Fm., PS – Pasierbiec Sandstones, ZB – Zembrzyce Beds, WS – Wątkowa Sandstones. For the other explanations see Fig. 5

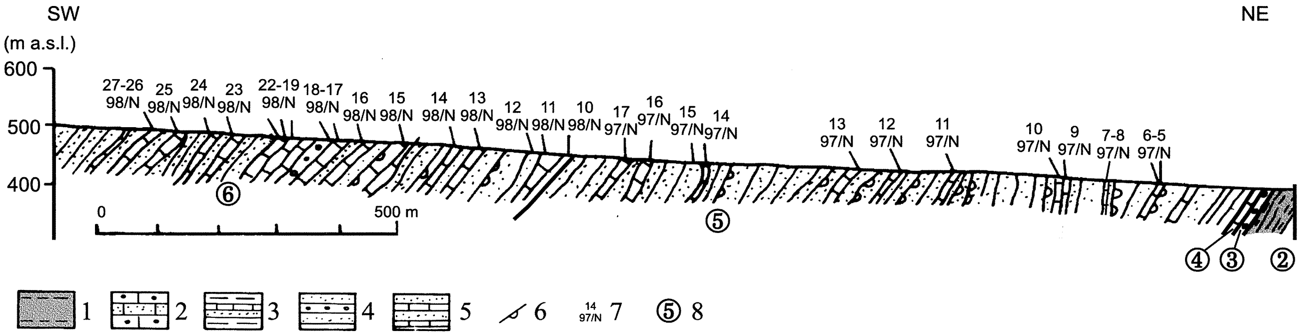


Fig. 10. Geological cross-section (E – F) along Małastówka stream in Małastów (loc. see – Fig. 7). *1* – variegated shales, *2* – glauconitic, thick-bedded sandstones and conglomerates, *3* – thin-bedded sandstones and shales, *4* – thick-bedded sandstones and conglomerates, *5* – turbiditic marls, *6* – sole marks, *7* – samples localities, *8* – lithostratigraphic units: 2 – Łabowa Fm., 3 – Pasierbiec Sandstones, 4 – Zembrzyce Beds, 5 – Wątkowa Sandstones, 6 – Budzów Beds

Mts (Figs 1, 15). In this section only, the Budzów Beds were subjected both to litho- and biostratigraphical studies (Figs 16, 17). These beds, up to 300 m thick, occur at the top of the Wątkowa Sst. (see Miziołek, 1990), and are represented by thick (up to 12 m) packets of brown-olive, dark-greenish or dark-greyish claystones and marly mudstones, which are often silicified. The characteristic feature of the Budzów Beds is their rhythmic repetition of thick-bedded glauconitic sandstones (0.4–0.6 m). In the Olchowiec section very thick-bedded sandstones are rather rare. These green-greyish sandstone (up to 3 m bed thick) reveal a parallel lamination at the base and a large-scale cross-stratification or convolution at the top. At about 150 and 200 m above the base of the Budzów Beds, sideritic marls (up to 60 cm thick) were observed (Fig. 17).

Rača Zone

Naściszowa-Zabełcze section. The Naściszowa-Zabełcze combined section (Figs 1, 18) is representative for the northern surrounding of the Nowy Sącz Basin. In the middle course of the Naściszowski stream, Hieroglyphic and Zembrzyce beds were studied. The Poprad Sandstone Mbr of the Magura Fm. was studied from the Zabełcze section. In the Naściszowski stream Hieroglyphic Beds 210 m thick, occur above the variegated shales of the Łabowa Sh. Fm. (see Oszczypko, 1973; Oszczypko & Wójcik, 1992). The uppermost part of the Hieroglyphic Beds is composed of very thin (1–5 cm) and thin-bedded sandstones with relatively thick intercalations of green-greyish, non-calcareous claystones and rare very thin (1–2 cm) intercalations of dark-grey marly claystones (Fig. 19). Higher up in the section Zembrzyce Beds (up to 110 m thick) are exposed (Oszczypko, 1973). These are made up of 1.5–2.0 m thick packets of thin-bedded turbidites with intercalations of dark-grey massive, marly mudstones with a parallel lamination. The Poprad Sandstone Mbr of the Magura Fm. begins with a 0.8 m thick layer of the light-grey, medium-grained, muscovite reach sandstone. These sandstones display palaeotransport towards the SW (240°).

Zabełcze exposures (see Oszczypko, 1973) are located in the road-cut and in the abandoned quarry in the Lubinka stream outlet (Fig. 18). The thick-bedded (1–3 m), medium to coarse-grained sandstones with a muddy-marly cement are exposed in the road-cut. These sandstones are intercalated with layers (few dozen cm thick) of green-greyish, non-calcareous claystones. The flute marks revealed palaeotransport towards the 70° (WSW).

Nowy Sącz I borehole. This borehole was drilled in the S periphery of Nowy Sącz (Fig. 18, see also Oszczypko, 1973; Oszczypko & Wójcik, 1992). In the borehole at a depth up to 540 m occur clayey-sandy deposits with numerous thin seams of lignite of the Upper Badenian Biegonice Fm. (Oszczypko, 1973; Oszczypko *et al.*, 1992). Below this depth, folded deposits of the Magura Nappe were reached (Figs 20–22). These deposits belong to the Malcov and Magura fms of the Rača Zone (Oszczypko, 1973; Blaicher & Oszczypko, 1975). The depth interval 540–602 m, is represented by dark-greyish, mainly non-calcareous claystones with sporadic intercalations (1–25 cm) of mudstones and very fine muscovite sandstones. Further down (602.0–606.5 m), fragments of light-yellowish marls, which could be the equivalent of SMGM, were reached (Oszczypko, 1973). Beneath the marls, down to a depth of 618.7 m, dark-greyish calcareous claystones and mudstones containing a few intercalations of thick-bedded muscovite sandstones were pierced. At 618.7–620.8 m there is a layer of brown-chocolate claystone and dark-greyish claystones. Deeper still, to a terminal depth 704 m, occur poorly-cemented thick-bedded, muscovite sandstones (Fig. 22). The Upper Eocene–Lower Oligocene age of the Malcov Fm. (depth 540.0–618.7 m) was determined on the basis of poorly preserved foraminifera assemblages, whereas the thick-bedded sandstones from interval 618.7–704.0 m were regarded as the Upper Eocene Magura Fm. of the Rača Zone (Oszczypko, 1973). For the purpose of nannofossil studies, the samples were collected only from the upper part of the Malcov Fm.

Lubień quarry. This small quarry is located south of Myślenice (Fig. 1), on the left bank of the Krzeczowski stream, the left tributary of the Raba river. The quarry displays a sequence of thick-bedded muscovite sandstones of the Poprad Mbr of the Magura Fm. (see Borysławski, 1982). These sandstones are intercalated with thin green-greyish

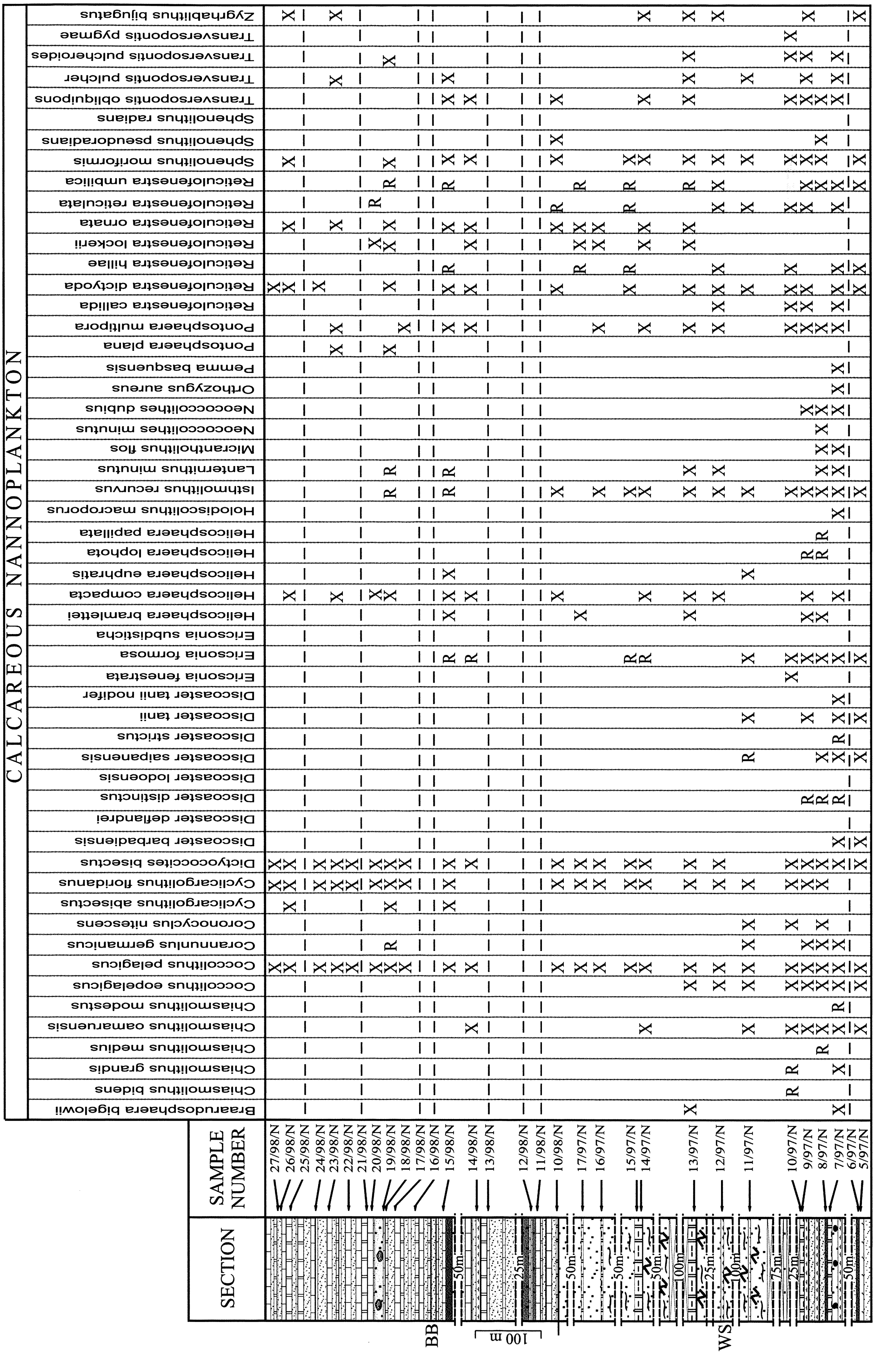


Fig. 11. Distribution of the calcareous nannofossils in the Małastów section. X – determined species, R – reworked species, WS – Wątkowa Sandstones, BB – Budzów Beds. For the other explanations see Fig. 5

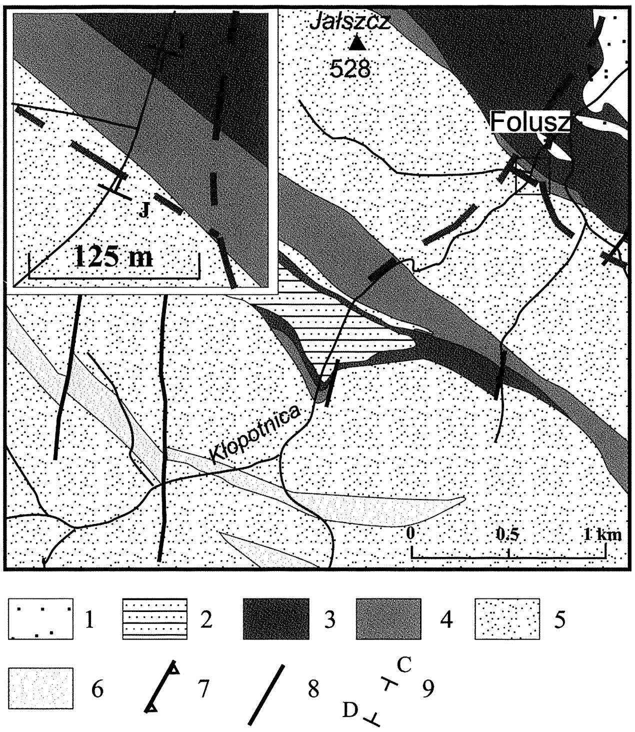


Fig. 12. Geological map of the Folusz area (after Koszarski & Tokarski, 1968, supplemented). Silesian Unit: *1* – Krosno Beds; Magura Nappe: *2* – Inoceramian Beds, *3* – Łabowa Fm., *4* – Zembrzyce Beds, *5* – Wątkowa Sandstones, *6* –Budzów Beds, *7* – Magura overthrust, *8* – faults, *9* – geological cross-section

marly claystones. The samples were collected from marly intervals.

Biegonice section. This section is located on the right bank of the Poprad river, close to the outlet of the Żeleźnikowski stream (Figs 18, 23). The section was first described by Oszczypko (1973), who established the Oligocene deposits of the Malcov Fm. at the front of the Bystrica Zone thrust (see also Blaicher & Oszczypko, 1975). Later, Oszczypko *et al.* (1990) also included thick-bedded "Łącko-type" marls to the Malcov Fm. Recently Oszczypko *et al.* (1999c) suggested that the Malcov Beds in the Biegonice section could belong to the Lower Miocene Zawada Fm. For the purpose of nannofossil studies, the samples were collected from the former Malcov Fm. (sequence A) as well as from "Łącko-type" marls (sequence B) (Fig. 24). Sequence A cropps out in the escarpment of the landslide (Figs 23, 25, see also Oszczypko, 1973). This sequence begins with at least a 1 m thick bed of green-yellowish calcareous mudstones with a Mn coating and is followed by a 0.3 m layer of light-creamy marls and olive-green marly claystones at the top. Further up there is a 0.6 m thick layer of creamy and olive soft marls with intercalations of soft, very fine-grained sandstones (1–3 cm thick). The next layer (1 m thick) consists of green-yellowish calcareous claystones and mudstones with a horizon of sideritic concretion at the base (see Oszczypko, 1973). The last two layers, which are 0.25 and 0.5 m thick, are built up of grey, marly claystones and cream-greenish marls with intercalations of grey claystones. These claystones are cut by the subvertical fault. In the hanging wall of the fault occur massive "Łącko-type" marls common to sequences A and B.

Sequence B (Figs 23, 26) begins with an at least 1.3 m thick bed of hard, bluish marl of the "Łącko-type" and is followed by a 1 m thick layer of marly claystone and soft marls. These grey and brown deposits are intercalated with 7 cm of blue-greyish, fine-grained, calcareous, cross-laminated sandstone, and are followed by three layers (5–15 cm thick) of bentonitic claystones. Higher in the section occur light-coloured, thick-bedded (1.2 m) glauconitic-muscovite sandstones, followed by 7.6 m thick packet of hard, dark-grey "Łącko-type" turbidite marls.

In the Biegonice section both sequences (A and B) belong to the Zawada Fm. The Zawada Fm. is at least 80 m thick and it is tectonically limited both from the Rača Zone, as well as from the Bystrica Zone (Fig. 24).

Bystrica Zone

Gołkowice section. This section is situated on the left bank of the Dunajec river, 500 m south of the Gołkowice bridge (Oszczypko & Wójcik, 1992). In this section (Figs 18, 27) the Maszkowice Mbr is overlain by the Mniszek Sh.

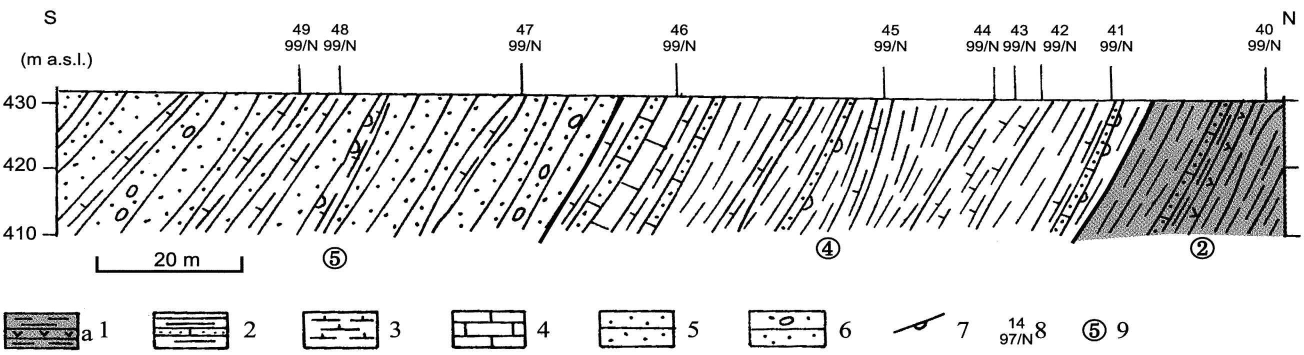
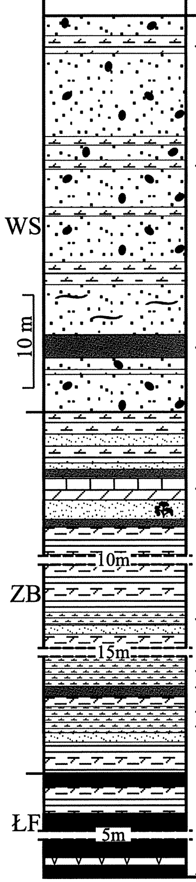


Fig. 13. Geological cross-section (G–H) along Kłopotnica stream in Folusz (loc. see – Fig. 12). *1* – variegated shales, *a* – tuffites, *2* – non-calcareous shales and thin-bedded sandstones, *3* – calcareous claystones, *4* – soft marls, *5* – glauconitic, thick-bedded sandstones, *6* – sandstones and conglomerates, *7* – sole marks, *8* – samples localities, *9* – lithostratigraphic units: 2 – Łabowa Fm., 4 – Zembrzyce Beds, 5 – Wątkowa Sandstones



CALCAREOUS NANNOPLANKTON

SAMPLE NUMBER	Blackites spinosus	Braarudosphaera bigelowii	Chiasmolithus grandis	Chiasmolithus modestus	Chiasmolithus oamaruensis	Chiasmolithus solitus	Coccolithus eopelagicus	Coccolithus pelagicus	Corannulus germanicus	Cyclicargolithus floridanus
49/99/N							X	X	X	X
48/99/N							X	X		X
47/99/N	R	X					X	X	X	X
46/99/N							X	X	X	X
45/99/N		X			X		X	X	X	X
44/99/N	R		R	R	X	R	X	X	X	X
43/99/N					X		X	X	X	X
42/99/N					X		X	X		X
41/99/N				R	X	R	X	X		X
40/99/N	–	–	–	–	–	–	–	–	–	–

SAMPLE NUMBER	Cyclicargolithus luminis	Dictyococcites bisectus	Discoaster barbadiensis	Discoaster deflandrei	Discoaster distinctus	Discoaster lodoensis	Discoaster saipanensis	Discoaster strictus	Discoaster tanii	Discoaster tanii nodifer
49/99/N		X			R					
48/99/N	X	X		X		X				
47/99/N		X		X			R			
46/99/N		X			R	X		R	X	
45/99/N	X	X								
44/99/N		X			R				X	
43/99/N		X	X	X	R		X	R	X	
42/99/N		X	X							
41/99/N		X	X	X	R		X			X
40/99/N	–	–	–	–	–	–	–	–	–	–

SAMPLE NUMBER	Ericsonia fenestrata	Ericsonia formosa	Ericsonia subdisticha	Helicosphaera bramlettei	Helicosphaera compacta	Helicosphaera euphratis	Helicosphaera lophota	Helicosphaera papillata	Helicosphaera seminulum	Holodiscolithus macroporus
49/99/N				X					R	
48/99/N					X					
47/99/N		X		X	X			X	R	X
46/99/N		X	X	X		X				
45/99/N		X		X	X					
44/99/N		X			X					
43/99/N		X								X
42/99/N	X	X					X			
41/99/N		X				X	X		R	
40/99/N	–	–	–	–	–	–	–	–	–	–

SAMPLE NUMBER	Holodiscolithus solidus	Isthmolithus recurvus	Lanternithus minutus	Micrantholithus flos	Neococcolithes dubius	Pemma basquensis	Pontosphaera plana	Pontosphaera multipora	Reticulofenestra callida	Reticulofenestra dictyoda
49/99/N		X								X
48/99/N		X			X					X
47/99/N	X	X	X							X
46/99/N		X	X							X
45/99/N		X	X		X			X	X	X
44/99/N		X	X	X	X	X	X	X	X	X
43/99/N		X	X						X	X
42/99/N		X								
41/99/N	X	X			X			X	X	X
40/99/N	–	–	–	–	–	–	–	–	–	–

SAMPLE NUMBER	Reticulofenestra hillae	Reticulofenestra reticulata	Reticulofenestra umbilica	Sphenolithus moriformis	Sphenolithus pseudoradians	Sphenolithus radians	Transversopontis obliquipons	Transversopontis pulcher	Transversopontis pulcheroides	Zygrhablithus bijugatus
49/99/N	X	X	X	X						
48/99/N	X		X	X					X	X
47/99/N	X		X	X	X		X	X	X	X
46/99/N	X		X	X			X		X	X
45/99/N	X	X		X		X			X	X
44/99/N	X	X	X	X				X	X	X
43/99/N	X	X	X	X		X			X	X
42/99/N	X		X	X						
41/99/N	X	X	X	X				X		X
40/99/N	–	–	–	–	–	–	–	–	–	–

Fig. 14. Distribution of the calcareous nannofossils in the Folusz section. X – determined species, R – reworked species, ŁF – Łabowa Fm., ZB – Zembrzyce Beds, WS – Wątkowa Sandstones. For the other explanations see Fig. 5

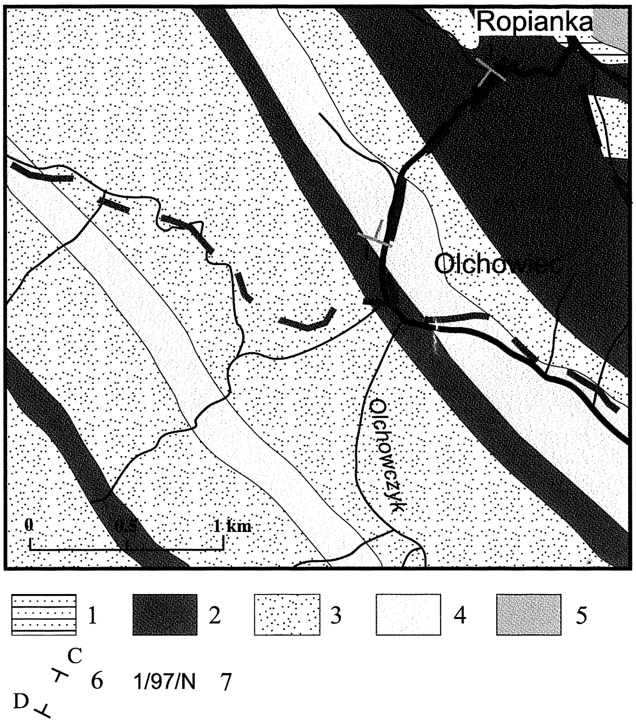


Fig. 15. Geological map of the Ropianka and Olchowiec area (after Ślączka, 1967 and Ślączka & Miziołek, 1995, supplemented). *1* – Inoceramian Beds, *2* – Łabowa Fm. and Zembrzyce Beds, *3* – Wątkowa Sandstones, *4* – Budzów Beds, *5* – strongly tectonised unit, *6* – geological cross-section (see – Fig. 16)

Mbr of the Magura Fm. (Oszczypko, 1979, 1991). The lowermost portion of the Mniszek Sh. Mbr is represented by cherry, non-calcareous shales, and is overlain by a 10 m sequence of olive-green marly claystones with sporadic intercalations of thin-bedded fine-grained sandstones. Higher up in the section, red shales occur more frequently. The total thickness of the variegated shales is 40 m. In the Gołkowice section the foraminiferal assemblages with *Reticulophragmium amplectens* and *Ammodiscus latus* are known (Oszczypko, 1973, 1979). The upper portion of this section is represented by green-greyish claystones up to 100 m thick, with a 20 m thick packet of thick-bedded sandstones. The sandstones are light-greyish and rich in clasts of brown and olive marly shales. In the Gołkowice section the total thickness of the Mniszek Sh. Mbr reaches at least 150 m (Fig. 27).

Krynica Zone

Hanuszów section. This section is located on the left slope of the Poprad river, 3 km south of Piwniczna (Figs 1, 28, see also Golonka & Rączkowski, 1983). In this section, the samples were collected from the Mniszek Sh. Mbr and Poprad Mbr of the Magura Fm. The section starts at top of the Piwniczna Sandstone Mbr (Fig. 29, see also Ostrowicka, 1966, 1979; Chrząstowski & Ostrowicka, 1978; Golonka & Rączkowski, 1983). At the top of the thick-bedded sandstones, there is a first layer of red shales belonging to Mniszek Sh. Mbr. Higher up in the section, crops out 35–40 m packet of blue-greenish claystones with thin (5–10 cm) layers of red claystones and sporadic intercalations of fine, thin-bedded sandstones. These deposits are overlain by thick-bedded, often, coarse-grained sandstones with numerous shaley clasts. Subordinately, medium-bedded sandstones (T_b) and 1–2 m thick packets of thin-bedded flysch with red intercalations, were observed. The flute marks display palaeotransport toward the NW (310°–340°). The total thickness of the Mniszek Sh. Mbr in the Hanuszów section is 100–110 m. Above the uppermost layers of red shales, the sandstones belonging to the Poprad Mbr, are exposed. The thickness of these thick-bedded sandstones is at least 50 m (Figs 29, 30).

Kosarzyska section. In the Kosarzyska area, two sections were investigated in the upper course of the Czercz stream and also along the Rogacz stream (Figs 28, 30). In the Czercz stream, samples were collected from the Kowaniec Beds (Alexandrowicz *et al.*, 1984). According to Golonka & Rączkowski (1983) these beds should be regarded as the equivalent of variegated shales with *Reticulophragmium amplectens* – Mniszek Sh. Mbr (see Birkenmajer & Oszczypko, 1989). In the Kosarzyska section, Kowaniec Beds are represented by thick-bedded sandstones and fine conglomerates with intercalations of thin- to medium-bedded sandstones and olive marly claystones. The thickness of the sandstone-claystone interval is up to 10 m. In the

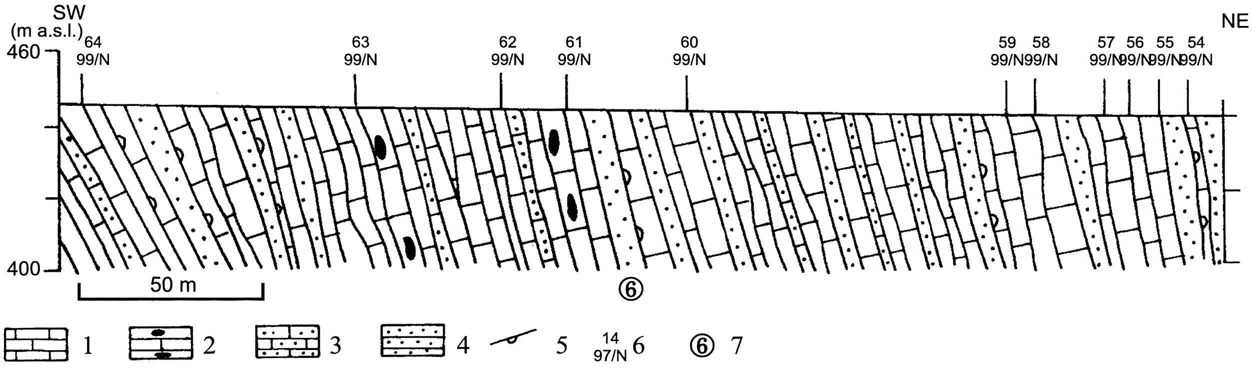
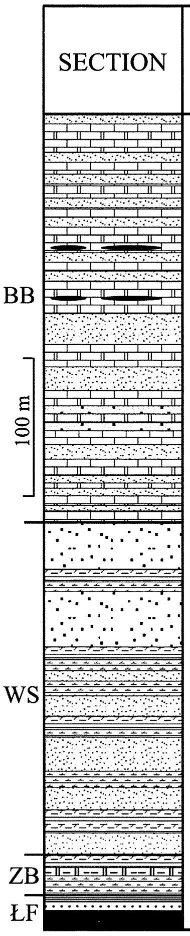


Fig. 16. Geological cross-section (I–J) along Ropianka stream in Olchowiec (loc. see – Fig. 15). *1* – marls, *2* – spherosiderites, *3* – fine-grained, thin and thick-bedded sandstones, *4* – coarse-grained, thick-bedded sandstones, *5* – sole marks, *6* – samples localities, *7* – Budzów Beds



CALCAREOUS NANNOPLANKTON

SAMPLE NUMBER	Braarudosphaera bigelowii	Chiasmolithus sp.	Chiasmolithus grandis	Chiasmolithus oamaruensis	Coccolithus eopelagicus	Coccolithus pelagicus	Coronocyclus nitescens	Cyclicargolithus abisectus	Cyclicargolithus floridanus	Dictyococcites bisectus	Discoaster deflandrei	Discoaster distinctus	Discoaster strictus	Ericsonia fenestrata	Ericsonia formosa	Helicosphaera bramlettei	Helicosphaera compacta	Helicosphaera euphratis	Helicosphaera lophota	Helicosphaera seminulum	Isthmolithus recurvus	Lanternithus minutus	Neococcolithes dubius	Pontosphaera plana	Pontosphaera multipora	Reticulofenestra dictyoda	Reticulofenestra hillae	Reticulofenestra ornata	Reticulofenestra reticulata	Reticulofenestra umbilica	Sphenolithus moriformis	Transversopontis fibula	Transversopontis obliquipons	Transversopontis pulcher	Transversopontis pulcheroides	Zygrhabilithus bijugatus
64/99/N	X	R			X	X		X	X	X	X	R	R			X	X		R	R	R	R		X	X	X	R	X	X	R	X			X	X	X
63/99/N	X				X	X	X	X	X	X			R			X	X	X	R	R	R	R		X		X	R	X			X			X		X
62/99/N						X			X	X					R						X				X	X	R	X	X					X	X	X
61/99/N						X			X	X					R	X	X				X	X					R	X		R	X		X		X	X
60/99/N						X			X	X					R	X	X				X				X		R	X		R		X	X	X	X	X
59/99/N		R			X	X			X	X							X				X			X	X	X	X			X			X	X		
58/99/N		X			X	X			X	X		R			R		X	X			X					X	X	X	X	X	X		X			
57/99/N						X			X	X			R								X	X				X	X				X				X	X
56/99/N						X			X	X	X						X				X					X	X			X					X	
55/99/N					X				X	X											X		X		X		X			X			X			
54/99/N		X	R	X	X	X	X		X	X	X		R	X	X	X	X				X	X			X	X	X		X	X	X		X	X	X	X

Fig. 17. Distribution of the calcareous nannofossils in the Olchowiec section. Lithostratygraphy of the Łabowa Fm., Zembrzyce Beds and Wątkowa Sandstones after Miziołek (1990). X – determined species, R – reworked species, ŁF – Łabowa Fm., ZB – Zembrzyce Beds, WS – Wątkowa Sandstones, BB – Budzów Beds. For the other explanations see Fig. 5

upper flow of the Czercz stream, above the Kowaniec Beds, thick-bedded sandstones, without any shale intercalations, were observed. According to the geological map (Golonka & Rączkowski, 1983) these sandstones, which display palaeotransport towards the WNW (290°), can be regarded as the Poprad Mbr of the Magura Fm.

In the Rogacz stream, above of the Kowaniec Beds, occurs a 1000 m thick sequence of the Magura Sandstone with variegated shales (Niemcowa shale, see Alexandrowicz *et al.*, 1984) at the top (Golonka & Rączkowski, 1983).

Leluchów section. The studied sections (A and B) are situated on the left bank of the Poprad river, close to the Polish–Slovak border (Figs 1, 31). Section A is located along a path, close to the orthodox church (Fig. 32), whereas section B is along a small right tributary of the Smereczek stream. The results of the litho- and biostratigraphy investigation of the Leluchów sections were partially published by the author (Oszczypko, 1996; Oszczypko-Clowes, 1998, 1999) with the exception of the uppermost part of the section A belonging to the Malcov Fm. *ss*.

The lowest part of the Leluchów sections (A and B) consist of thick-bedded sandstones and conglomerates (Figs 31–34). The muscovite sandstones, 0.4–2.5 m thick, are grey-bluish in colour and coarse to fine-grained, with intercalations of fine conglomerates. These sandstones belong to the Piwniczna Sandstone Mbr of the Magura Fm. In both sections (A and B), the actual contact between the Piwniczna Sandstone Mbr and the overlying marly shales of SMGM is not exposed (1–2 m break in exposure). The marly shales are soft and green with numerous calcite veins with thickness varying from 0.5 m (Fig. 33) to 2.5 m (Fig. 34). These are overlain by a 4 m thick marly unit of Lelu-

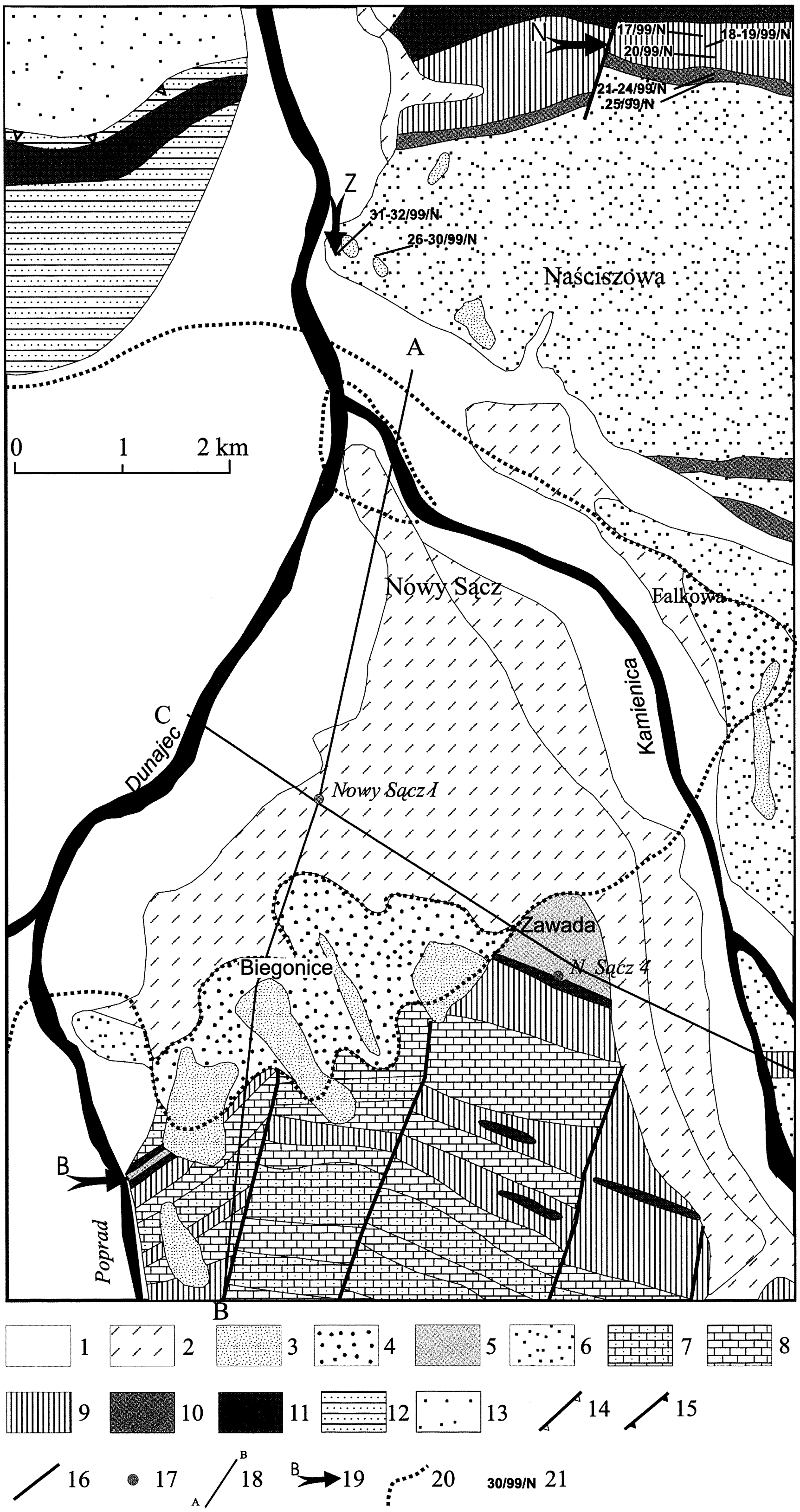


Fig. 18. Geological map of the Nowy Sącz area (after Oszczypko & Wójcik, 1992; Oszczypko *et al.*, 1999b supplemented). Quaternary: *1* – gravels, sands and clays of terraces of a height of 2-6 m, *2* – gravels, sands and clays of terraces of a height of 6-30 m, *3* – gravels, sands and clays of terraces of a height of 55-80 m.; Middle Miocene; *4* – Miocene fresh water molasses; Magura Nappe: *5* – Zawada Fm., Magura Fm.; *6* – Poprad Mbr, *7* – Maszkowice Mb., *8* – Żeleźnikowa Fm., *9* – Beloveza Fm., *10* – Zembrzyce Beds, *11* – Łabowa Fm., *12* – Inoceramian Beds, *13* – Grybów Unit, *14* – Magura overthrust, *15* – Bystrica overthrust, *16* – faults, *17* – boreholes, *18* – cross-section (see – Figs 20, 21), *19* – B, N, Z – location of the Biegonice, Naściszowa and Zabełcze exposures, *20* – extent of the fresh water Miocene, *21* – samples localities

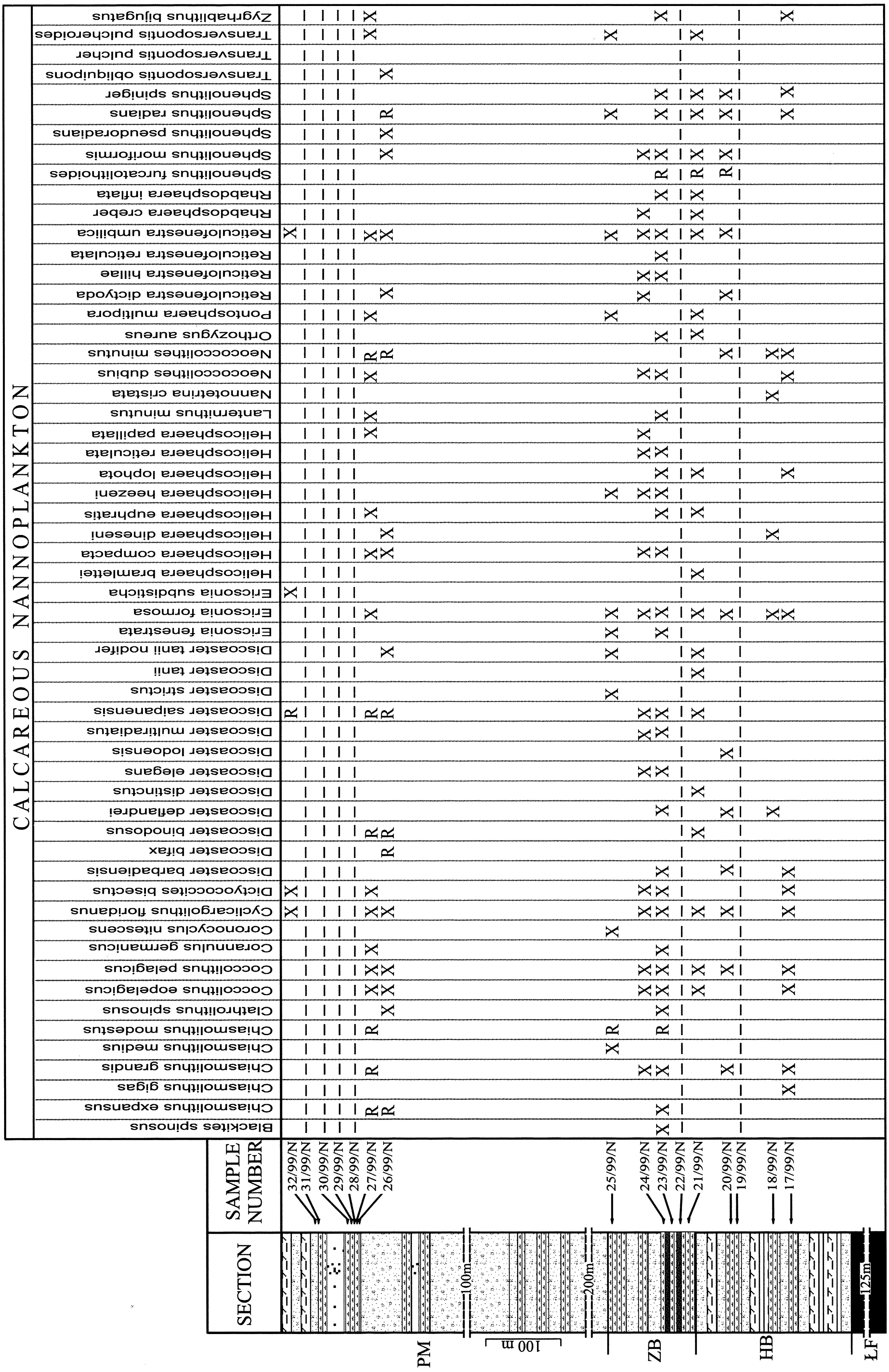


Fig. 19. Distribution of the calcareous nannofossils in the Naściszowa-Zabełcze section. X – determined species, R – reworked species. ŁF – Łabowa Fm., HB – Hieroglyphic Beds, ZB – Zembrzyce Beds, PM – Poprad Mbr For the other explanations see Fig. 5

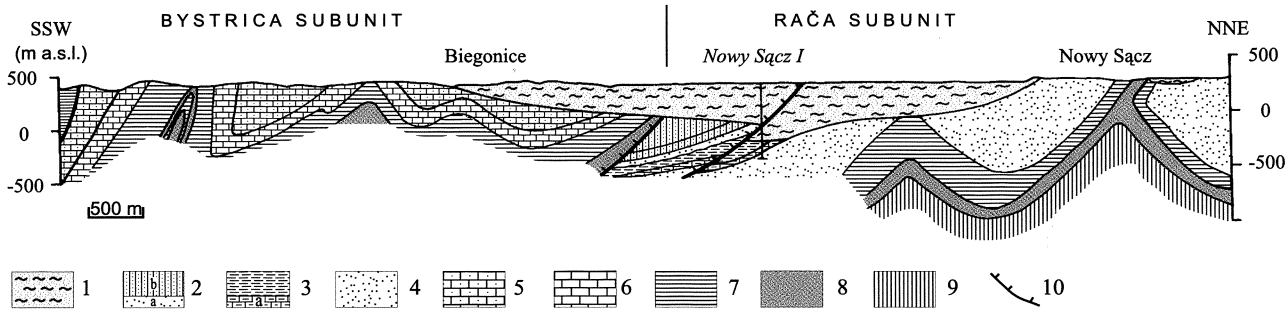


Fig. 20. Geological cross-section A–B (loc. see – Fig. 18) (after Oszczypko, 1973; Oszczypko *et al.*, 1999b). *1* – Paludal deposits (Middle Miocene), Magura Nappe: *2* – Zawada Fm., *a* – glauconitic sandstone, *b* – thick-bedded marls, *3* – Malcov Fm., *a* – Leluchów Marl Mbr, Magura Fm.: *4* – Poprad Mb, *5* – Maszkowice Mbr, *6* – Żeleźnikowa Fm., *7* – Beloveza Fm., *8* – Łabowa Fm., *9* – Inoceramian Beds, *10* – thrust

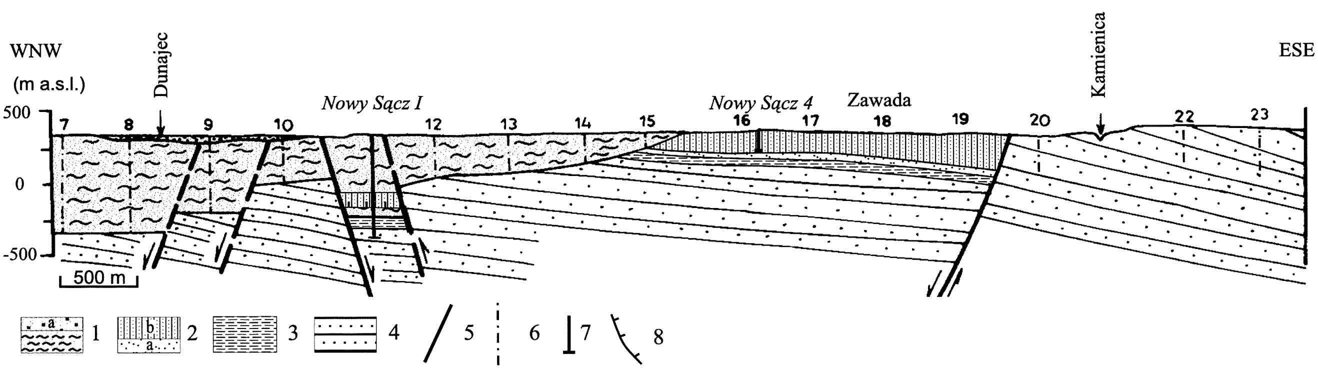


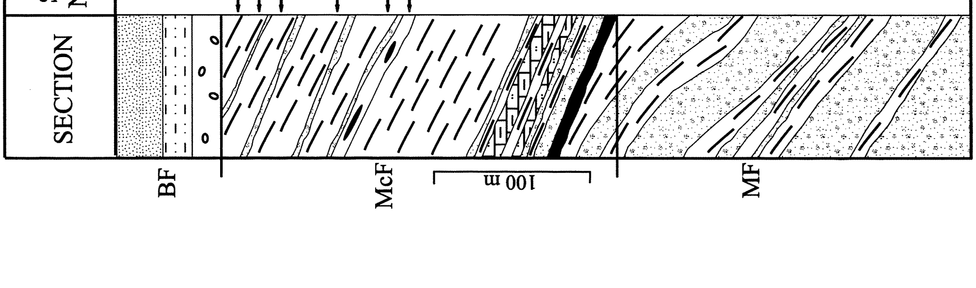
Fig. 21. Geological cross-section C–D (loc. see – Fig. 18) (after Oszczypko & Wójcik, 1992; Oszczypko *et al.*, 1999b). *1* – Paludal deposits, *1a* – offshore deposits, Magura Nappe: *2* – Zawada Fm., *a* – glauconitic sandstones, *b* – glauconitic sandstones and marls, *3* – Malcov Fm., *4* – Magura Fm., Poprad Mbr, *5* – faults, *6* – geoelectric sounding, *7* – boreholes, *8* – thrust

chów Marls Mbr. The marls are red, greyish-green, greenish and olive in colour. The red marls are bioturbated and contain burrows of *Planolites*, *Chondrites* and *Thalassinoides* (see Leszczyński, 1997). The Leluchów Marls Mbr is covered by, at least, 19 m of the Smereczek Shale Mbr, represented by dark Menilite-like shales (see Blaicher & Sikora, 1967). The lowermost portion of this member reveals a marly development with a few tuffite intercalations ("Gąsiory" ? level), and a thin (2–5 cm) intercalation of hornstones at the top. The upper portion of the Menilite Shales belongs to black non-calcareous, bituminous shales with a few layers of coarse-grained, thick-bedded sandstone. At the top of the Smereczek Mbr occurs a 25 m packet of coarse-grained, muscovite-rich, thick-bedded sandstones (1–1.5 m) with intercalations of green marly claystones and medium-bedded sandstones. In the uppermost part of the Leluchów section occur thin-bedded turbidites of the Malcov Fm. These flat-laying, south dipping strata consist of dark-grey marly shales with intercalations of thin bedded (10–12 cm), cross-laminated calcareous sandstones.

MIDDLE EOCENE–LOWER MIOCENE CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY

The most common Palaeogene nannofossil zonations are the standard zonation of Martini (1971), and the zonation of Bukry (1973), Okada & Bukry (1980).

The first occurrence (FO) of *Isthmolithus recurvus* Deflandre has traditionally been used as the base of the Upper Eocene. However, this taxon is not a reliable marker in the lower latitudes. The FO of *Sphenolithus pseudoradians* Bramlette & Wilcoxon has also been used as a zonal marker for the Upper Eocene. The FO of these species seems to be controversial as this taxon has also been reported in the Middle Eocene (see Perch-Nielsen, 1985, 1986). The Upper Eocene is therefore no longer considered as two separate zones NP19 and NP20, but as a combined zone NP19–20 (Aubry, 1983), which is an equivalent to subzone CP15b (Okada & Bukry, 1980). For a long time the last occurrence (LO) of *Discoaster barbadiensis* Tan or *Discoaster saipanensis* Bramlette & Riedel was used as a nannofossil event, marking the Eocene–Oligocene boundary which coincides with the base of NP21 (Martini & Ritzkowski, 1968). This can be correlated with the lower limit of P18 zone (planktonic foraminifers) (Blow, 1969; Martini, 1970).



CALCAREOUS NANNOPLANKTON	70w/99/N	69w/99/N	68w/99/N	67w/99/N	66w/99/N	65w/99/N
Braarudosphaera bigelowii				X		
Chiasmolithus altus						X
Chiasmolithus expansus			R			
Chiasmolithus gigas			R			
Chiasmolithus grandis			R		R	R
Chiasmolithus solitus						R
Coccolithus eopelagicus			X			
Coccolithus pelagicus			X	X	X	X
Cyclicargolithus abisectus			X	X	X	X
Cyclicargolithus floridanus	X	X	X	X	X	X
Dictyococcites bisectus	X	X	X	X	X	X
Ericsonia fenestrata			X			
Ericsonia formosa			R	R		
Helicosphaera compacta			X		X	X
Helicosphaera bramlettei			X			X
Helicosphaera euphratis			X			
Helicosphaera heezeni			R			
Helicosphaera lophota			R			
Helicosphaera papillata				R		
Helicosphaera recta						X
Helicosphaera seminulum			R	R		
Isthmolithus recurvus						R
Lanternithus minutus			R			
Neococcolithes dubius		R	R		R	R
Pontosphaera latelliptica						X
Pontosphaera multipora					X	X
Pontosphaera plana						X
Pontosphaera rothi						X
Reticulofenestra dictyoda	X		X		X	X
Reticulofenestra hillae			R			R
Reticulofenestra lockerii			X	X	X	X
Reticulofenestra ornata			X	X	X	X
Reticulofenestra umbilica		R	R	R	R	R
Sphenolithus capricornutus			X			
Sphenolithus conicus	X	X	X			
Sphenolithus furcatolithoides			R			
Sphenolithus moriformis			X			
Sphenolithus pseudoradians			R			
Transversopontis latus						X
Transversopontis obliquipons						X
Transversopontis pulcher	X				X	X
Transversopontis pulcheroides			X		X	
Transversopontis pygmae						X
Zygrhablithus bijugatus	X		X			X

Fig. 22. Distribution of the calcareous nannofossils in the borehole Nowy Sącz I. X – determined species, R – reworked species. MF – Magura Fm., McF – Malcov Fm., BF – Biegonice Fm. For the other explanations see Fig. 5

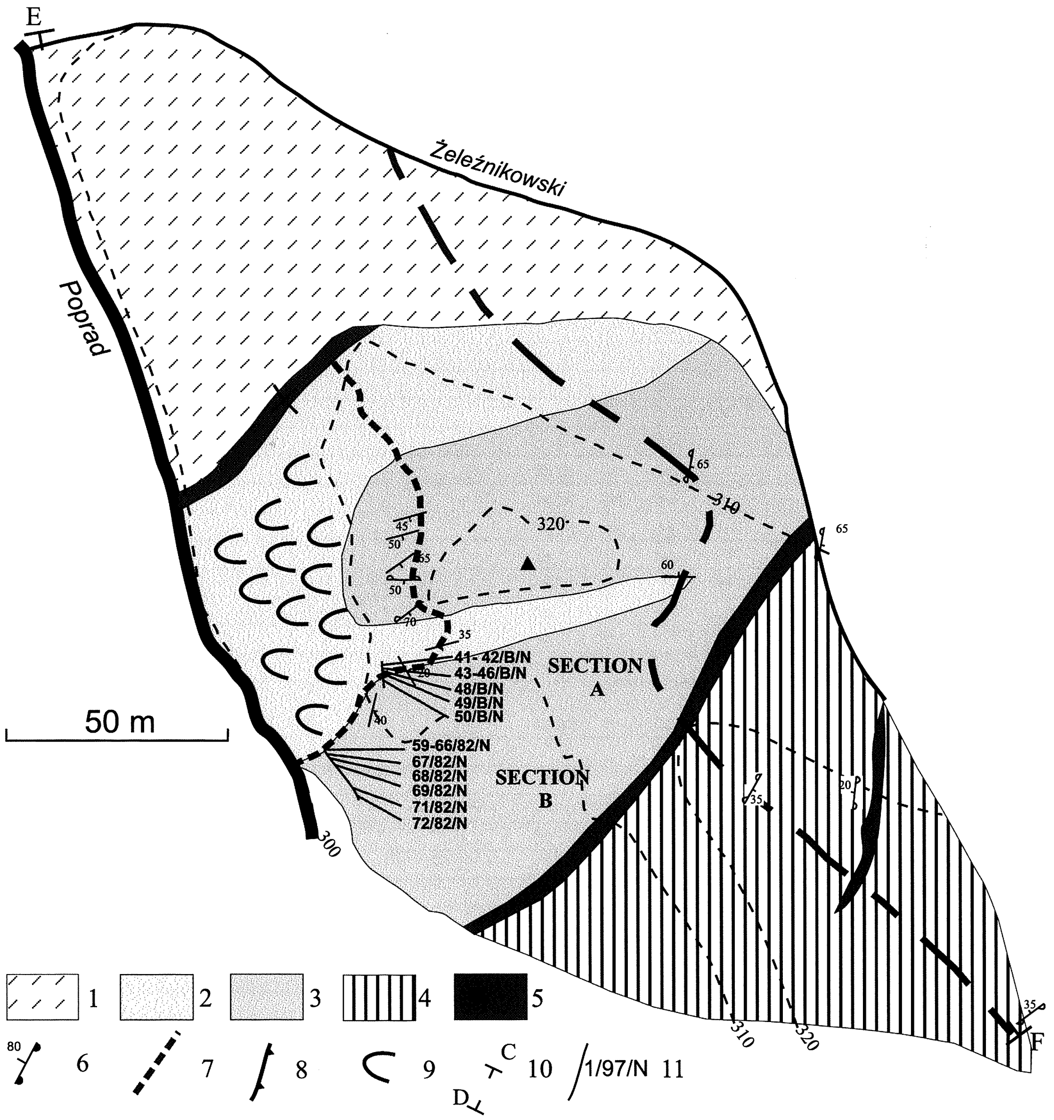


Fig. 23. Sketch-map of the Zawada Fm. in Biegonice (after Oszczypko, 1973, changed). Quaternary: *1* – gravels, sands and clays of terraces of a height of 2 m; Raca Zone: Zawada Fm.: *2* – soft marls and marly claystones, *3* – marls and thick-bedded sandstones; Bystrica Zone: *4* – Beloveza Fm., *5* – Łabowa Fm., *6* – attitude of beds and position of sole mark, *7* – steep escarpment, *8* – Bystrica overthrust, *9* – landslide colluvia, *10* – geological cross-section (see – below), *11* – samples localities

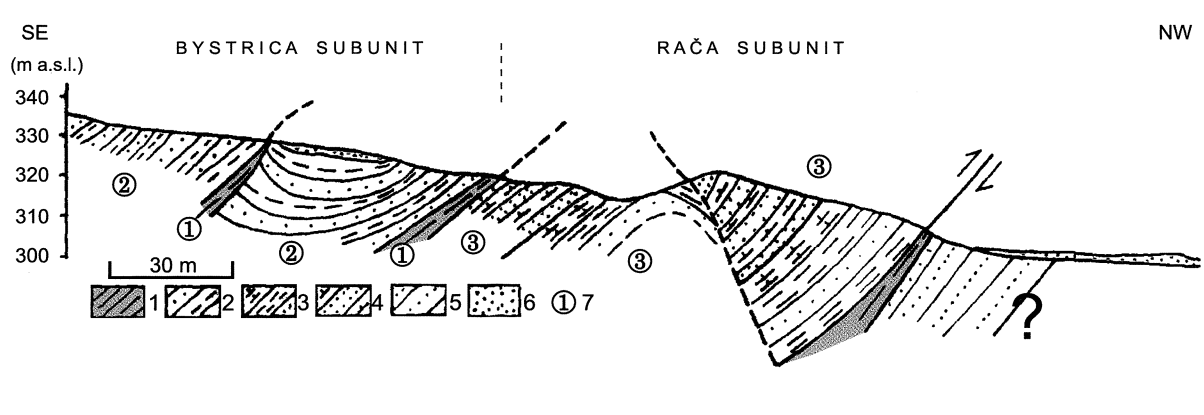


Fig. 24. Geological cross-section through the Bystrica overthrust in Biegonice (loc. see – Fig. 23) (after Oszczypko, 1973, modified). *1* – variegated shales, *2* – thin-bedded turbidites, *3* – thick-bedded sandstones and marls, *4* – soft marls, *5* – thick-bedded sandstones, *6* – gravels and sands, *7* – lithostratigraphic units: 1 – Łabowa Fm., 2 – Beloveza Fm., 3 – Zawada Fm.

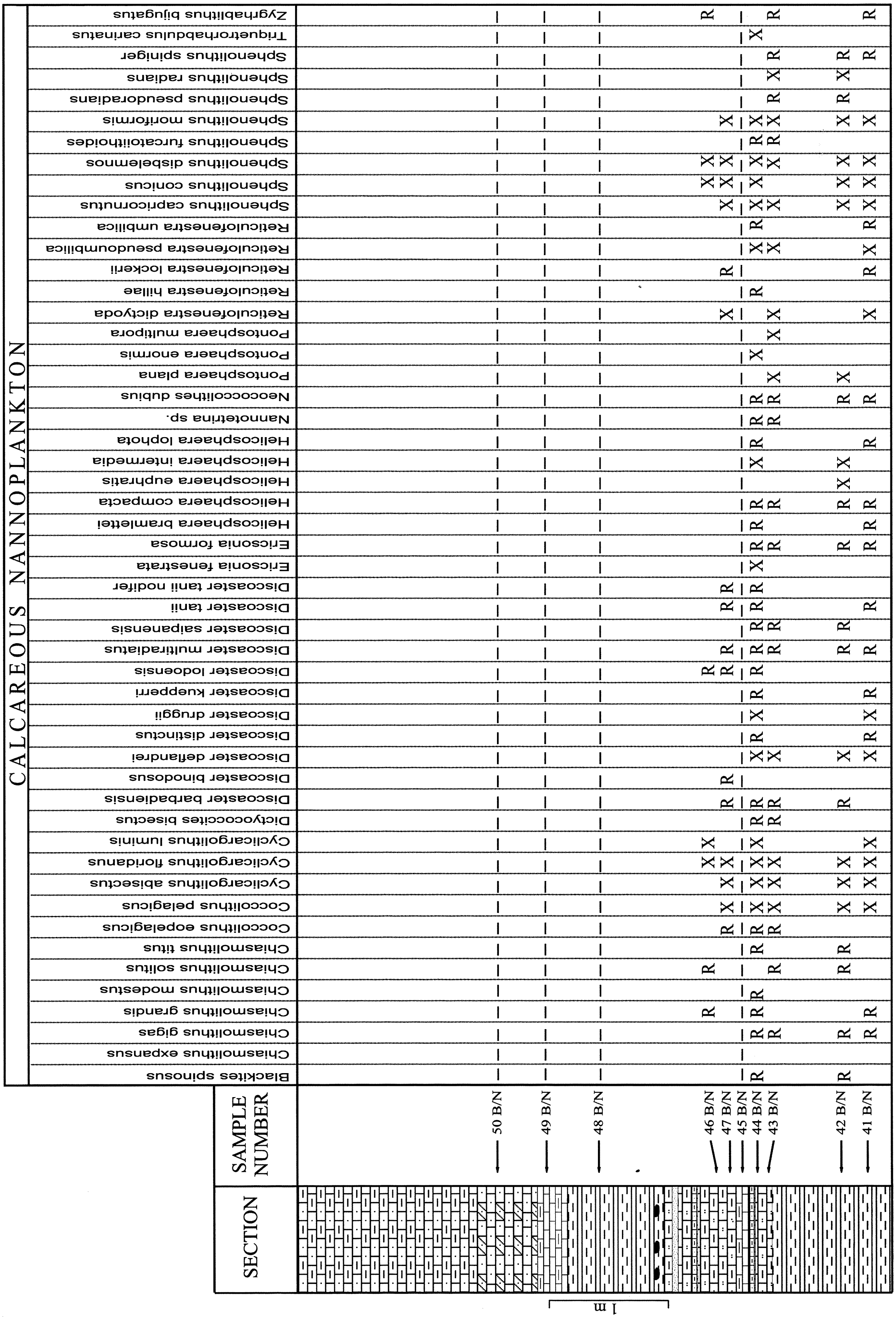
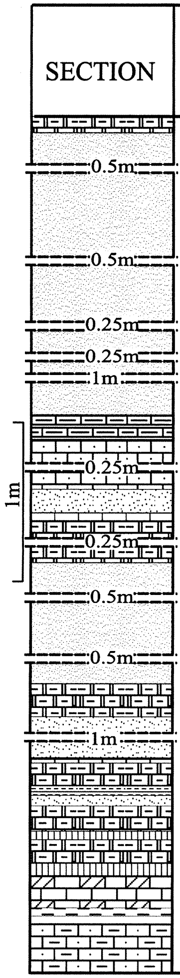


Fig. 25. Distribution of the calcareous nannofossils of the Zawada Fm. in the Biegonice A section. X – determined species, R – reworked species. For the other explanations see Fig. 5

SECTION



CALCAREOUS NANNOPLANKTON

SAMPLE NUMBER	Chiasmolithus danicus	Chiasmolithus expansus	Chiasmolithus gigas	Chiasmolithus grandis	Chiasmolithus solitus	Coccolithus eopelagicus	Coccolithus pelagicus	Coronocyclus nitescens	Cyclicargolithus abisectus	Cyclicargolithus floridanus	Cyclicargolithus luminis	Dictyococcites bisectus	Discoaster barbadiensis	Discoaster bifax	Discoaster binodosus	Discoaster deflandrei	Discoaster distinctus	Discoaster druggii	Discoaster lodoensis	Discoaster multiradiatus	Discoaster saipanensis	Discoaster strictus	Discoaster tanii	Discoaster tanii nodifer	Discoaster wemmelensis	Ericsonia formosa
72/82/N						R	X		X	X		R					R	X								
71/82/N									X						X		R	X			R			R	R	R
70/82/N		R	R	R		R	X		X	X			R			X	R				R		R		R	R
69/82/N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
68/82/N		R			R		X			X	X		R			X	R				R		R	R	R	R
67/82/N		R		R			X		X	X			R			X	R	X			R		R			R
66/82/N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
65/82/N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
64/82/N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
63/82/N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
62/82/N	R	R					X	X	X	X	X		R				R			R			R	R		R
61/82/N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
60/82/N		R	R		R	R	X	X					R			X	R		R		R	R	R	R		R
59/82/N				R			X	X	X	X	X		R	R			R	X	R	R	R	R				R

SAMPLE NUMBER	Helicosphaera bramlettei	Helicosphaera compacta	Helicosphaera euphratis	Helicosphaera lophota	Helicosphaera seminulum	Nannotetrina sp.	Neococcolithes dubius	Pontosphaera sp.	Pontosphaera plana	Pontosphaera multipora	Reticulofenestra dictyoda	Reticulofenestra hillae	Reticulofenestra lockerii	Reticulofenestra pseudoumbilica	Reticulofenestra umbilca	Sphenolithus disbelemnos	Sphenolithus capricornutus	Sphenolithus conicus	Sphenolithus editus	Sphenolithus furcatolithoides	Sphenolithus moriformis	Sphenolithus pseudoradians	Sphenolithus radians	Transversopontis pulcheroides	Triquetrorhabdulus carinatus	Zygrhablithus bijugatus
72/82/N		R					R		X	X	X			X		X			R		X	R			X	R
71/82/N	R						R			X		R								R	X					
70/82/N							R	X	X		X				R	X				R	X	R		X		R
69/82/N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
68/82/N	R					R	R	X		X	X				R	X					X		R			R
67/82/N		R				R	R			X				X	R	X		X			X					R
66/82/N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
65/82/N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
64/82/N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
63/82/N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
62/82/N									X		X				R	X		X			X		R	X		R
61/82/N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
60/82/N							R	X			X				R	X					X					R
59/82/N				R	R	R	R		X		X	R			R	X	X	X	R	R	X		R		X	R

Fig. 26. Distribution of the calcareous nannofossils of the Zawada Fm. in the Biegonice B section. X – determined species, R – reworked species. For the other explanations see Fig. 5

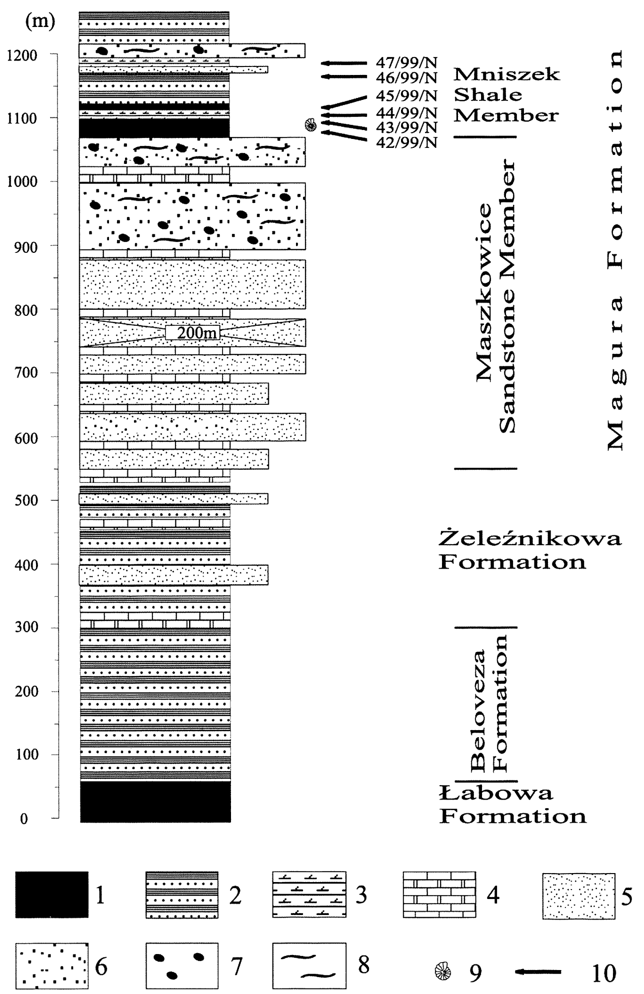


Fig. 27. Lithostratigraphical log of the Magura unit sediments in Gołkowice. *1* – variegated shales, *2* – thin- and medium-bedded sandstones with intercalations of marly shales, *3* – greenish-grey marly mudstones and claystones, *4* – dark-grey, siliceous, turbiditic marls, *5* – muscovite, fine and medium-grained sandstones, *6* – muscovite, coarse and very coarse-grained sandstones, *7* – mudstone clasts, *8* – "slurry" structures, *9* – *Reticulophragmium amplectens*, *10* – sample localities

However, subsequent studies have shown that the extinction of *D. saipanensis* and *D. barbadiensis* was diachronous and occurred earlier in the higher latitudes than in the lower ones (Cavelier, 1979). The extinction level of these discoasters is also older than the P17/P18 planktonic foraminiferal zonal boundary (Aubry, 1992). According to the Palaeogene Subcommission on Stratigraphy (Nocchi *et al.*, 1988a), the Eocene/Oligocene boundary is characterised by the LO of hantkeninids, whereas the LO of *D. barbadiensis* and *D. saipanensis* took place 0.5 mln years prior to the Eocene/Oligocene boundary (see Berggren *et al.*, 1995). Thus the Eocene/Oligocene boundary lies within the nannoplankton zones NP21 and subzone CP16a. However, Backman (1986) has shown that the pattern of *D. barbadiensis* extinction is more characteristic and distinctive than that of *D. saipanensis* (DSDP Holes 522 and 522A). Furthermore, rare specimens of both taxa continue to occur within the earliest Oligocene. According to Janin (1992) such an occurrence, usually interpreted as reworked, can be associated with the fact that very rare *D. barbadiensis* and/or *D. saipanensis* managed to survive the Eocene/Oligocene boundary.

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 the higher latitudes. This is why, in those areas, the secondary zonal markers such as *Cyclicargolithus abisectus* (Müller), *Helicosphaera recta* Haq, *Sphenolithus conicus* Bukry and *Ponthosphaera enormis* Locker should be used. The FO of *Cyclicargolithus abisectus* and *Helicosphaera recta* are usually found close to the FO of *Sphenolithus ciperoensis* (zonal marker for the lower boundary of NP24 zone) and thus can be used to approximate the NP23 and NP24 boundary (Martini & Müller, 1986). In the Paratethys region there is a lack of index species for the NP23 zone, making it only possible to establish the equivalent of this zone, which is characterised by the occurrence of *Transversopontis latus*, *Transversopontis fibula* Gheta and abundant *Reticulofenestra ornata* Müller. Such an association is believed to be endemic and restricted to the Paratethys region only (Nagymarosy & Voronina, 1992). The other useful biostratigraphic event characteristic for the Paratethys, is the abundant occurrence (acme) of *Reticulofenestra lockerii* Müller on the boundary of zones NP23/NP24 (Baldi-Beke, 1977; Baldi *et al.*, 1984). In order to separate NP24 zone from NP25, especially for areas with limited connection to the open ocean (e.g., Paratethys), the FO of *Pontosphaera enormis* has proven to be a useful event (Martini, 1981). If there is a lack of *Pontosphaera enormis* the FO of *Sphenolithus conicus* can approximate the boundary between NP24 and NP25 (Baldi-Beke, 1981). Melinte (1995; Melinte in Rusu *et al.*, 1996) divided NP25 zone in two subzones, defining them as follows: NP25a interval from the LO *Sphenolithus distentus* and/or FO *Pontosphaera enormis* to the FO *Helicosphaera paleocarteri* and/or FO *Triquetrorhabdulus carinatus* Martini and NP25b interval from the FO *Helicosphaera paleocarteri* and/or FO *Triquetrorhabdulus carinatus* to the LO *Dictyococcites bisectus* and/or FO *Helicosphaera scissura* (see Melinte in Rusu *et al.*, 1996).

The top of NP 25 was considered as an Oligocene/Miocene boundary, though according to Berggren *et al.* (1995), this boundary lies within NN1 zone (1 mln years above the lower limit of NN1). The Oligocene/Miocene boundary is characterised by the extinction of *Sphenolithus ciperoensis*, *Dictyococcites bisectus* (Hay, Mohler & Wade), *Zygrhablithus bijugatus* (Deflandre) and *Helicosphaera recta* Haq, though the order of extinction can vary for different regions. Furthermore some of these species can also appear in the Early Miocene (Okada & Bukry, 1980; Martini, 1986). Generally, it is possible to assume that the LO of *Sphenolithus ciperoensis* (lower latitudes) and the of LO *Dictyococcites bisectus* (higher latitudes) mark the Oligocene/Miocene boundary (Perch-Nielsen, 1985; Berggren *et al.*, 1995; Fornaciarii *et al.*, 1996).

The Miocene nannoplankton zonation is mainly based on the last LO or first occurrence FO of *Discoasters* and thus is easily accomplished in low latitudes where *Discoasters* are common in open ocean assemblages. However, these

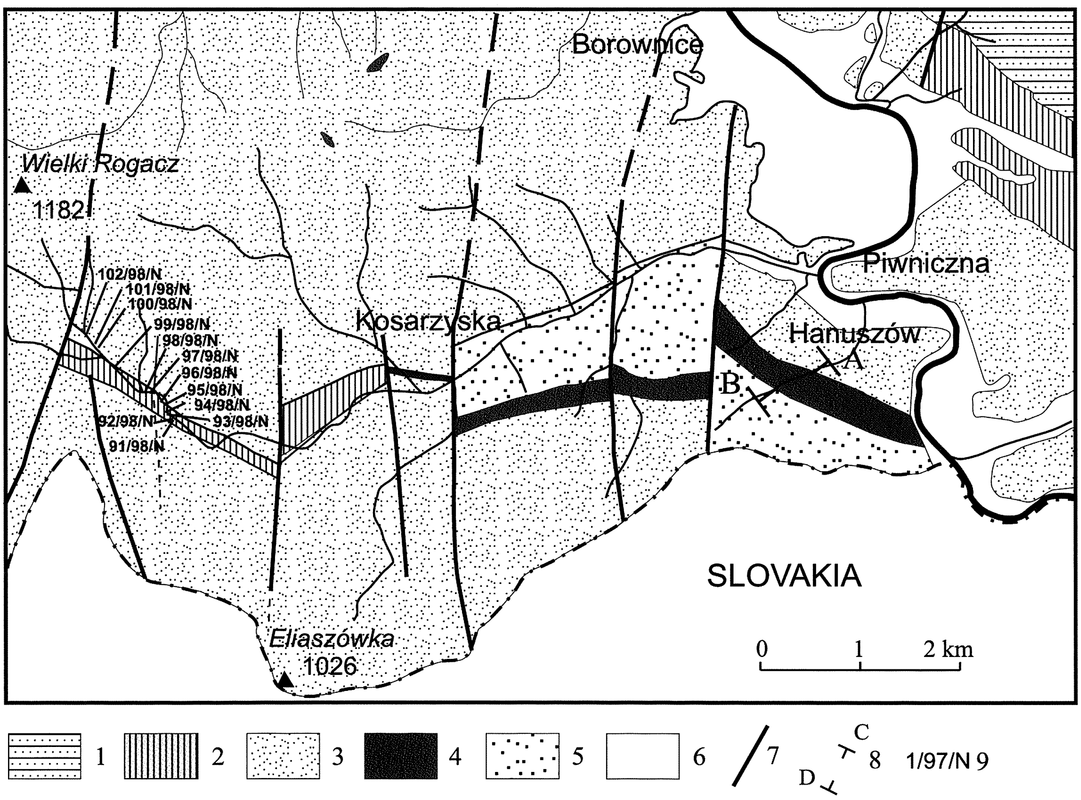


Fig. 28. Geological map of the Piwniczna area (after Golonka & Rączkowski, 1983, supplemented). *1* – Szczawnica Fm., *2* – Zarzecze Fm., Magura Fm.: *3* – Piwniczna Sandstone Mbr, *4* – Mniszek Shale Mbr; *5* – Poprad Sandstone Mbr, *6* – Quaternary, *7* – faults, *8* – geological cross-section (see – below), *9* – samples localities

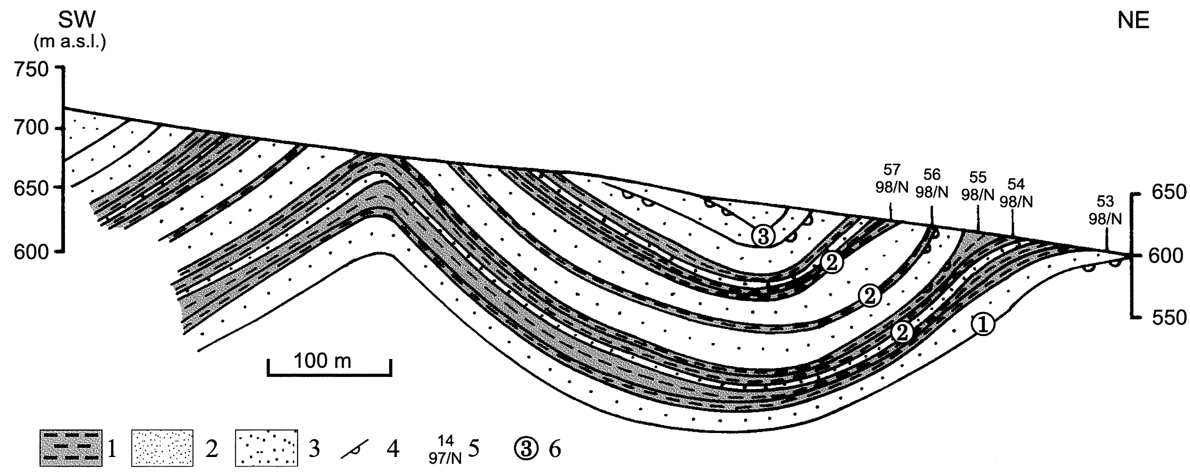


Fig. 29. Geological cross-section (A-B) through Magura Fm. in Hanuszów (loc. see – Fig. 28). *1* – variegated shales, *2* – thin-bedded sandstones, *3* – thick-bedded sandstones, *4* – sole marks, *5* – samples localities, *6* – lithostratigraphic units: Magura Fm.: 1 – Piwniczna Sandstone Mbr, 2 – Mniszek Shale Mbr; 3 – Poprad Sandstone Mbr

typically warm water and open oceanic species are rare or absent in the higher latitudes and also in assemblages from marginal seas. All other marker species belong to genera that are more common or even restricted to low latitudes. Therefore the zonation is most reliable and correlatable over a wider distance in low latitudes only. This explains why the Miocene zonation of Martini & Worsley (1970) as well as that of Okada & Bukry (1980) is reliable only in the lower latitudes. Owing to the Miocene, palaeoecological and palaeobiogeographical differentiation, which affected the nannofossil distribution, it was necessary to construct several regional schemes which modified previous zonations (Roth *et al.*, 1971; Müller, 1978; Raffi & Rio, 1979; Theodordis, 1984; Varol, 1989; Raffi *et al.*, 1995; Fornaciari & Rio,

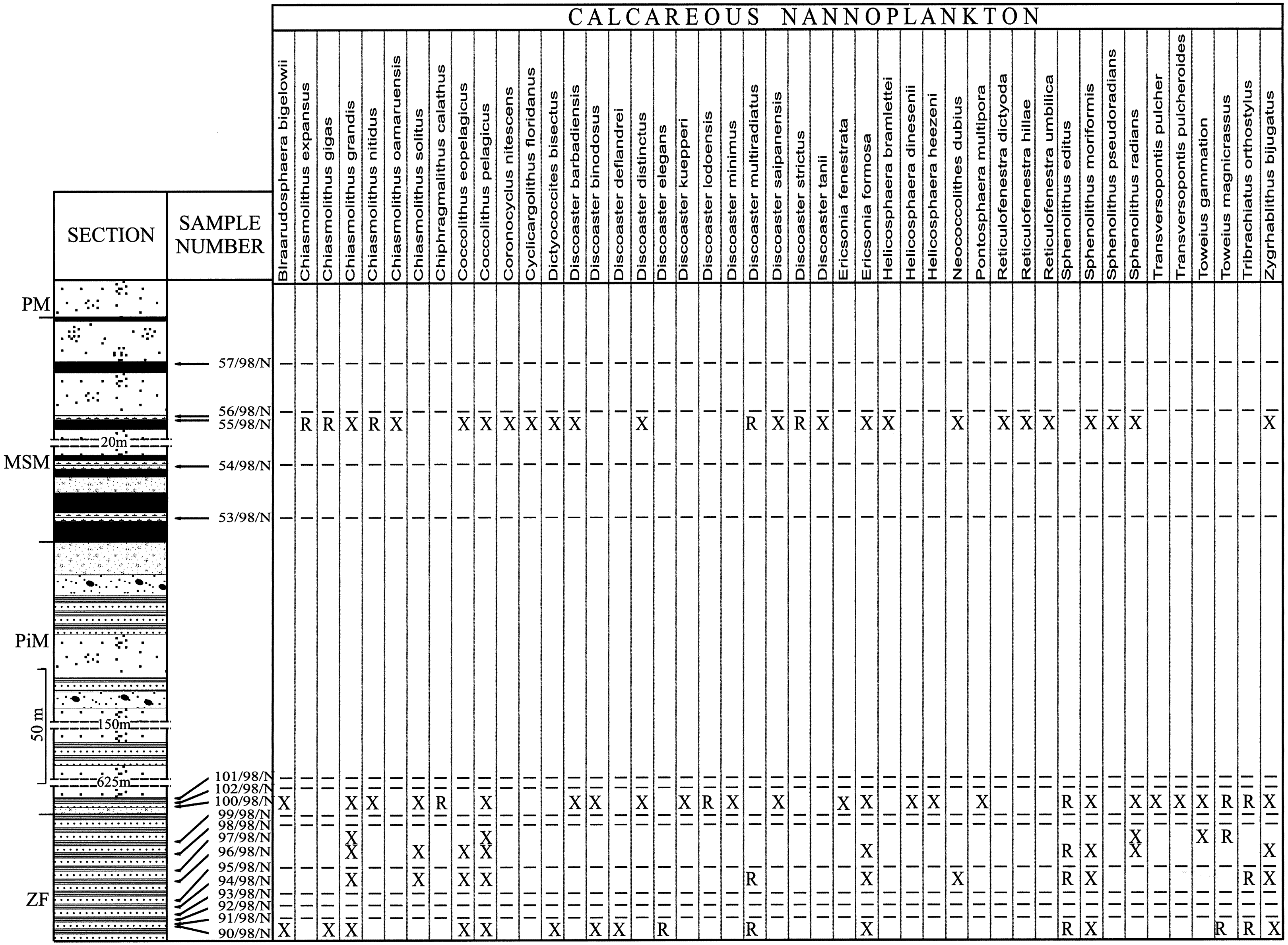


Fig. 30. Distribution of the calcareous nannofossils in the Hanuszów and Kosarzyska sections. X – determined species, R – reworked species. ZF – Zarzecze Fm., PiM– Piwniczna Sandstone Mb., MSM – Mniszek Shale Mb.; PM – Poprad Sandstone Mb. For the other explanations see Fig. 5

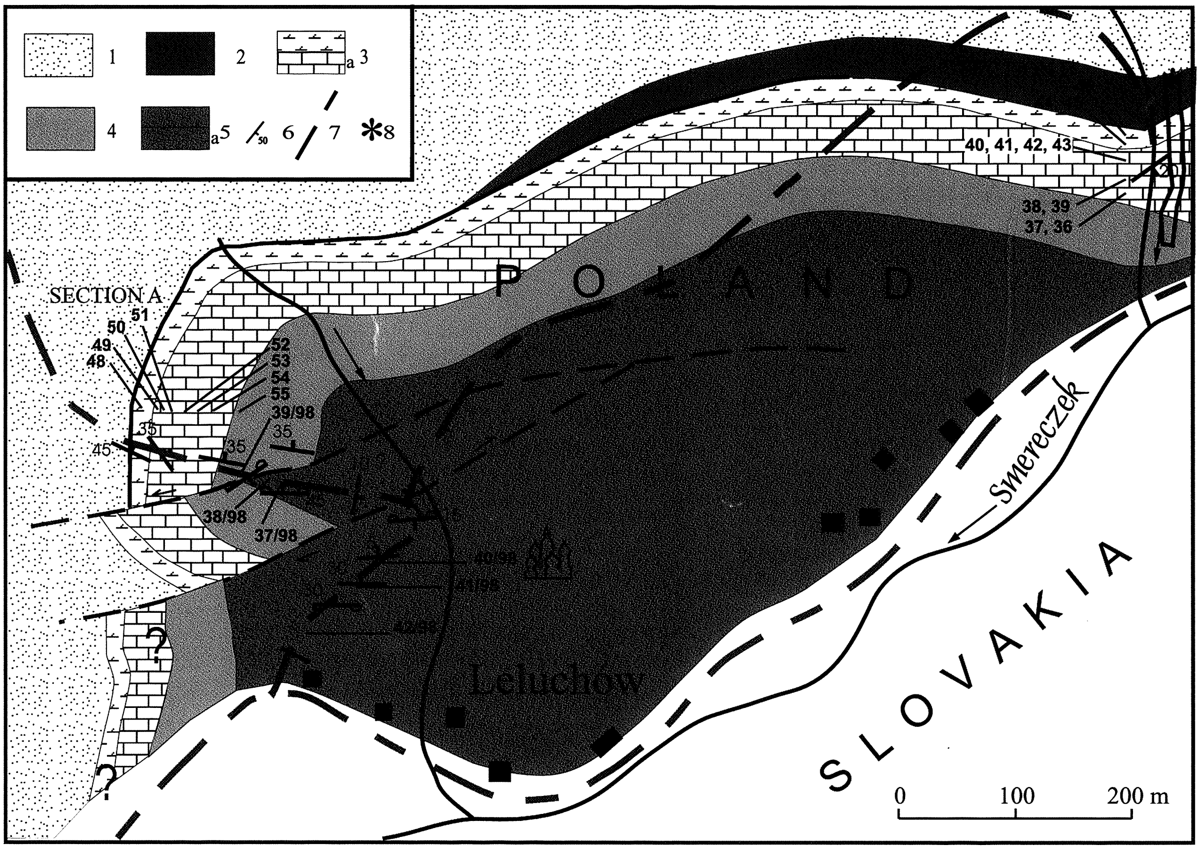


Fig. 31. Geological map of the Leluchów area (after Oszczypko, 1996, supplemented). Magura Fm.: *1* – Piwniczna Sandstone Mbr, *2* – Mniszek Shale Mbr; Malcov Fm.: *3* – Leluchów Marl Mbr, *a* – green shales, *4* – Smereczek Shale Mbr, *5* – Malcov Fm. *ss*, *a* – thick-beddded sandstones, *6* – attitude of beds and position of sole mark, *7* – faults, *8* – probable locality of artificial excavation described by Blaicher & Sikora (1967)

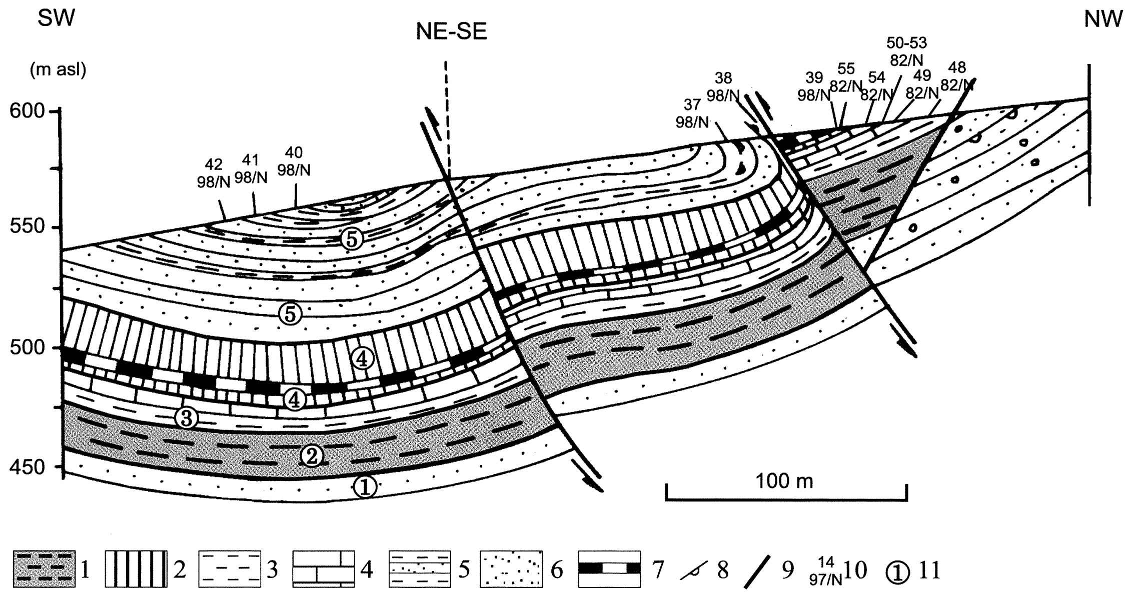


Fig. 32. Geological cross-section through Malcov Fm. in Leluchów (loc. see – Fig. 31). *1* – variegated shales, *2* – dark bituminous shales (Menilite Shales), *3* – green calcareous shales, *4* – Globigerina Marls, *5* – calcareous shales and thin-bedded sandstones, *6* – thick-bedded sandstones, *7* – hornstones, *8* – sole marks, *9* – faults, *10* – samples localities, *11* – lithostratigraphic units: Magura Fm.: 1 – Piwniczna Sandstone Mbr, 2 – Mniszek Shale Mbr; Malcov Fm.: 3 – Leluchów Marl Mbr, 4 – Smereczek Shale Mbr, 5 – Malcov Fm. *ss*

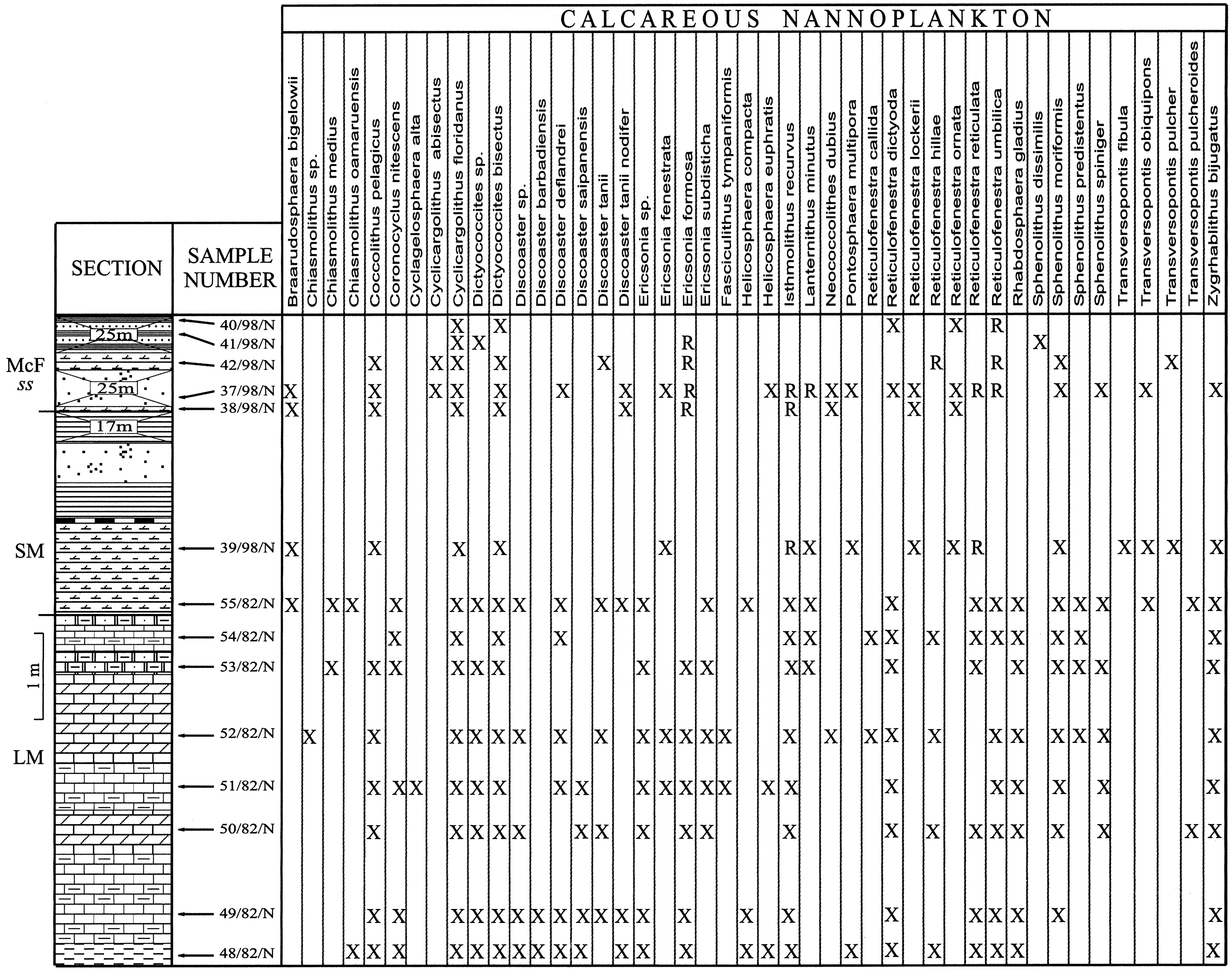
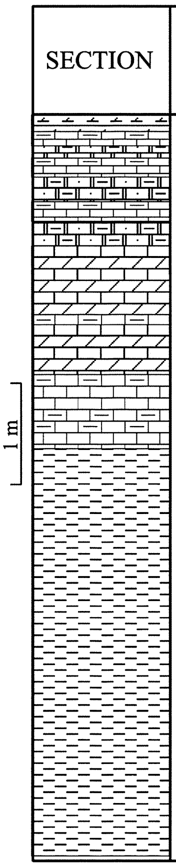


Fig. 33. Distribution of the calcareous nannofossils in the Leluchów A section. X – determined species, R – reworked species, LM – Leluchów Marl Mbr, SM – Smereczek Shale Mbr, McF – Malcov Fm. For the other explanations see Fig. 5



SAMPLE NUMBER	Braarudosphaera bigelowii	Chiasmolithus sp.	Chiasmolithus medius	Chiasmolithus oamaruensis	Coccolithus pelagicus	Coronocyclus nitescens	Cyclicargolithus floridanus	Dictyococcites bisectus	Discoaster sp.	Discoaster barbadiensis	Discoaster deflandrei	Discoaster saipanensis	Discoaster tanii	Discoaster tanii nodifer	Ericsonia sp.	Ericsonia cava	Ericsonia formosa	Ericsonia subdisticha	Fasciculithus tympaniformis	Helicosphaera compacta	Helicosphaera euphratis	Isthmolithus recurvus	Lanternithus minutus	Reticulofenestra callida	Reticulofenestra dictyoda	Reticulofenestra hillae	Reticulofenestra reticulata	Reticulofenestra umbilica	Rhabdosphaera gladius	Sphenolithus moriformis	Sphenolithus predistentus	Sphenolithus spiniger	Transversopontis obliquipons	Transversopontis pulcheroides	Transversopontis pulcheroides	Zygrhabilithus bijugatus
CALCAREOUS NANNOPLANKTON																																				
36/82/N	X	X	R	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
37/82/N		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
38/82/N		X			X	X	X	X	X						X		X	X	R			X	X	X	X			X		X	X	X				X
39/82/N					X		X	X	X		X				X		X	X				X	X	X	X					X	X	X	X			X
41/82/N					X	X	X	X	X		X		X		X		X	X	R		X	X		X	X		X	X		X		X				X
40/82/N					X		X	X	X		X		X	X	X		X	X				X		X	X	X	X	X		X		X				X
42/82/N					X		X	X							X		X					X	X	X	X	X	X		X	X		X				X
43/82/N					X		X	X	X		X	X	X		X		X					X		X	X	X	X	X	X	X		X			X	X
44/82/N					X		X	X	X	X	X	X	X		X		X			X	X	X		X	X	X	X	X	X	X		X				X
45/82/N					X		X	X	X	X	X	X	X		X		X			X		X		X	X	X	X	X	X	X		X				X
46/82/N					X		X	X	X	X	X	X	X		X		X				X	X		X	X	X	X	X	X	X						X

Fig. 34. Distribution of the calcareous nannofossils in the Leluchów B section. X – determined species, R – reworked species. For the other explanations see Fig. 5

1996; Fornaciari *et al.*, 1996; de Kaenel & Villa, 1996; Varol, 1998).

For the purpose of this work the standard zonation of Martini (1971) and Martini & Worsley (1970) was used. In the case where index species have not been observed, it was necessary to use the secondary index species of the following authors: Bukry (1973, 1975), Okada & Bukry (1980), Müller (1970), Baldi-Beke (1971), Perch-Nielsen, (1971, 1985), Raffi & Rio (1979), Martini & Müller (1986), Theodoris (1984), Aubry (1983, 1986), Fornaciari & Rio (1996), Fornaciari *et al.* (1996), Bown (1998). The detailed biozonal assignments are given below.

Nannotetrina fulgens Zone (NP15)

Definition: the base of the zone is defined by the FO of *Nannotetrina fulgens*, and the top by the LO of *Rhabdolithus gladius*.

Author: Hay in Hay *et al.* (1967), emend. Martini (1970), Bukry (1973).

Age: Middle Eocene.

Remarks: This zone (Fig. 35) was identified in Zarzecze Fm. from Kosarzyska (Figs 28, 30; samples: 90/98/N, 94/98/N, 96/98/N, 97/98/N).

The zone assignment is based on the occurrence of *Chiasmolithus gigas* (Bramlette & Sullivan) and the lack of *Cyclicargolithus floridanus* (Roth & Hay). The interval between the FO and the LO of *Chiasmolithus gigas* defines Bukry's subzone CP13b (Bukry, 1973). Subzone CP13b is the equivalent of middle part Martini's NP15 zone (Martini, 1970). At the same time, according to Aubry (1986) the FO of *Cyclicargolithus floridanus* takes place in the upper part of NP16.

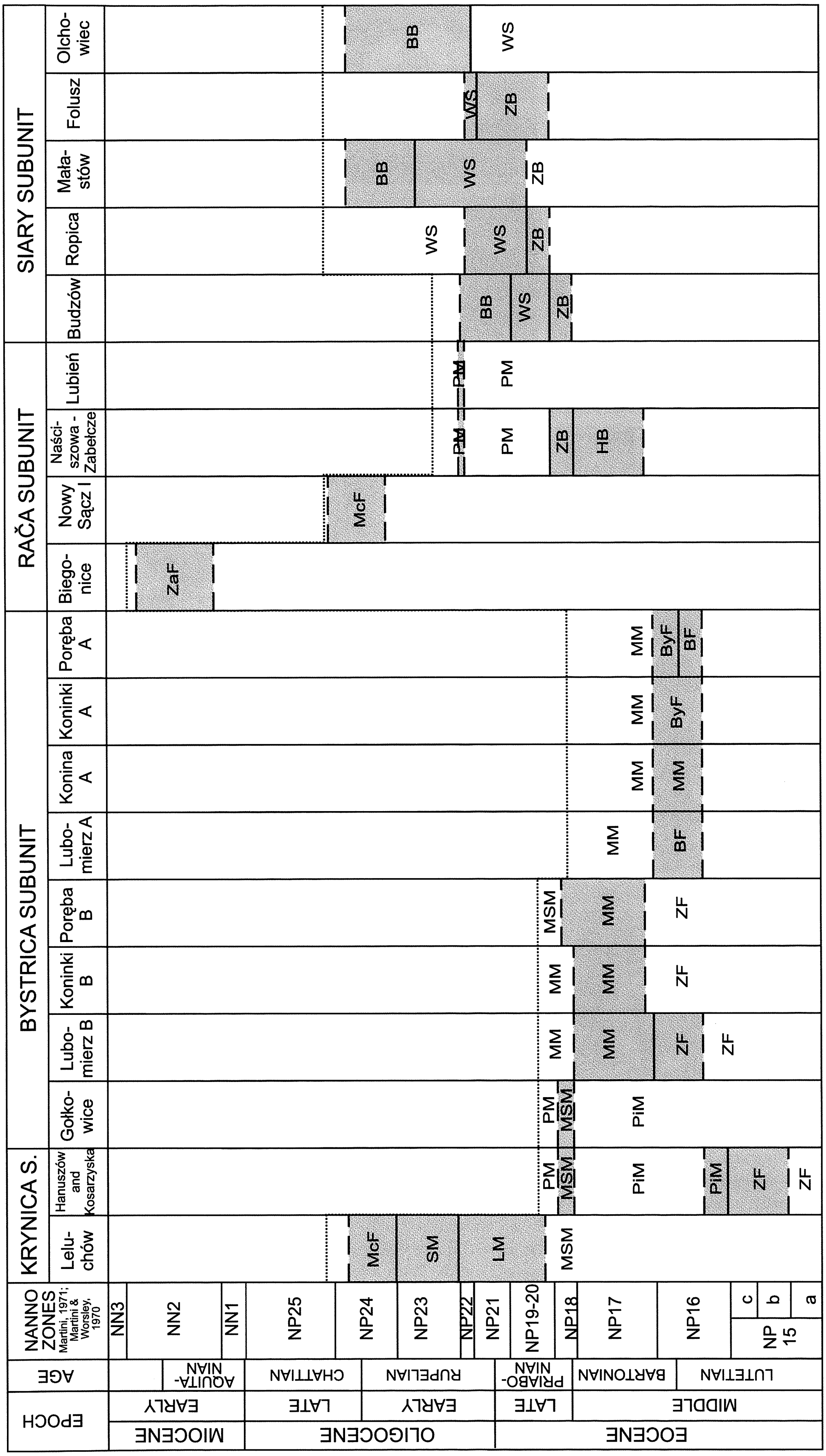


Fig. 35. The age of the studied sediments from the Magura Nappe. ZF – Zarzecze Fm., BF – Beloveza Fm., ByF – Bystrica Fm., HB – Hieroglyphic Beds, ZB – Zembrzyce Beds; Magura Fm.: PiM – Piwniczna Sandstone Mbr, MM – Maszkowice Sandstone Mbr, MSM – Mniszek Shale Mbr, PM – Poprad Sandstone Mbr; McF – Malcov Fm.: LM – Leluchów Marl Mbr, SM – Smereczek Shale Mbr, WS – Wątkowa Sandstone, BB – Budzów Beds, ZaF – Zawada Fm

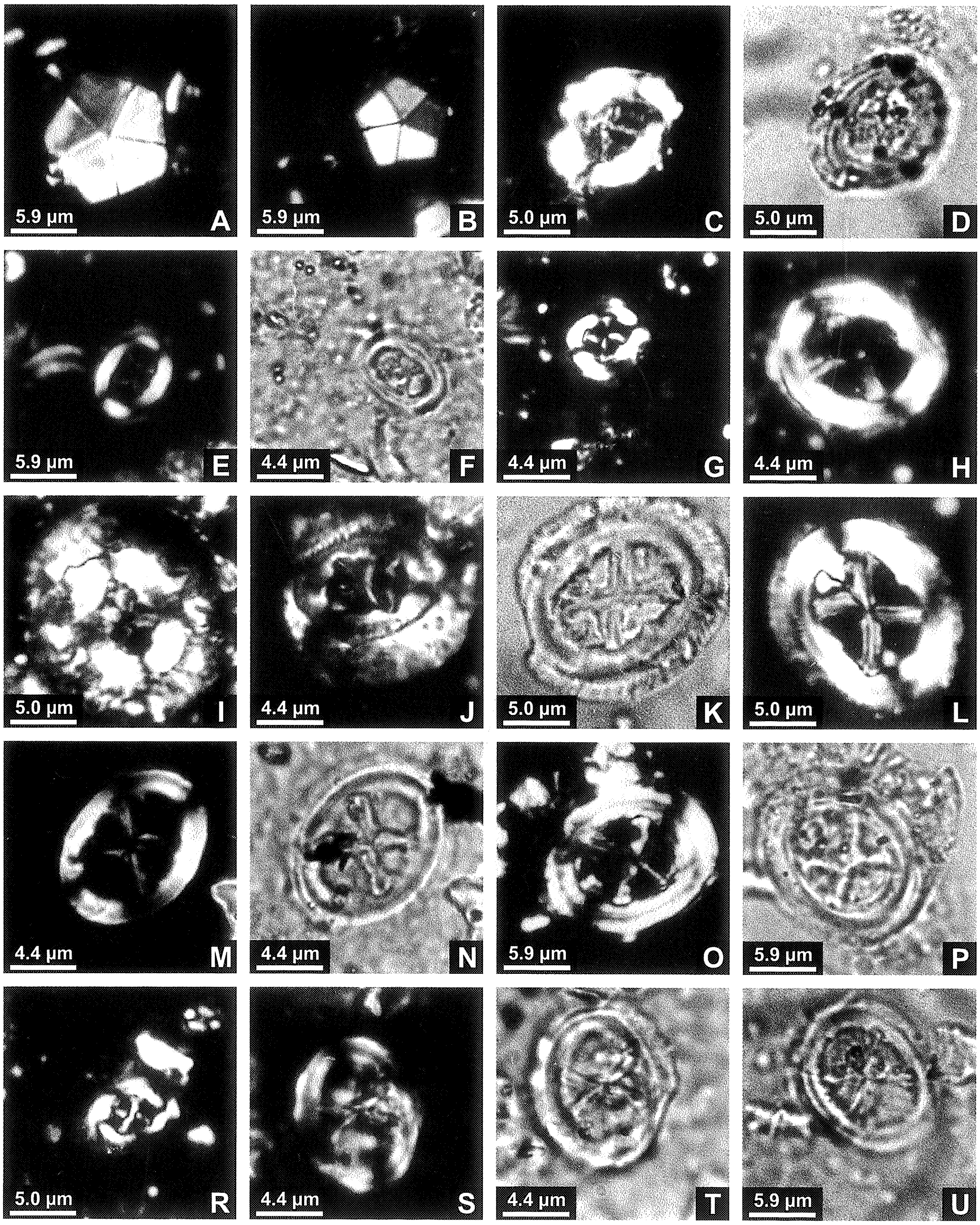


Fig. 36. LM microphotogaphs of calacareous nannofossil. **A** – *Braarudosphaera bigelowii* (Gran & Braarud), Ropica 13/96/N; **B** – *Braarudosphaera bigelowii* (Gran & Braarud), Ropica 13/96/N; **C** – *Chiasmolithus* cf. *C. altus* Bukry & Percival, Nowy Sącz 65w/99/N; **D** – *Chiasmolithus* cf. *C. altus* Bukry & Percival, Nowy Sącz 65w/99/N; **E** – *Chiasmolithus bidens* (Bramlette & Sullivan), Budzów 8/95/N; **F** – *Chiasmolithus bidens* (Bramlette & Sullivan), Budzów 8/95/N; **G** – *Chiasmolithus danicus* (Brotzen), Biegonice 68/82/N; **H** – *Chiasmolithus expansus* (Bramlette & Sullivan), Biegonice 60/82/N; **I** – *Chiasmolithus gigas* (Bramlette & Sullivan), Hanuszów 55/98/N; **J** – *Chiasmolithus gigas* (Bramlette & Sullivan), Biegonice 70/82/N; **K** – *Chiasmolithus grandis* (Bramlette & Riedel), Naściszowa 27/99/N; **L** – *Chiasmolithus grandis* (Bramlette & Riedel), Naściszowa 27/99/N; **M** – *Chiasmolithus medius* Perch-Nielsen, Budzów 8/96/N; **N** – *Chiasmolithus medius* Perch-Nielsen, Budzów 8/96/N; **O** – *Chiasmolithus modestus* Perch-Nielsen, Małastów 7/97/N; **P** – *Chiasmolithus modestus* Perch-Nielsen, Małastów 7/97/N; **R** – *Chiasmolithus* cf. *C. nitidus*, Hanuszów 55/98/N; **S** – *Chiasmolithus oamaruensis* (Deflandre), Budzów 13/95/N; **T** – *Chiasmolithus oamaruensis* (Deflandre), Budzów 13/95/N; **U** – *Chiasmolithus oamaruensis* (Deflandre), Folusz 41/99/N

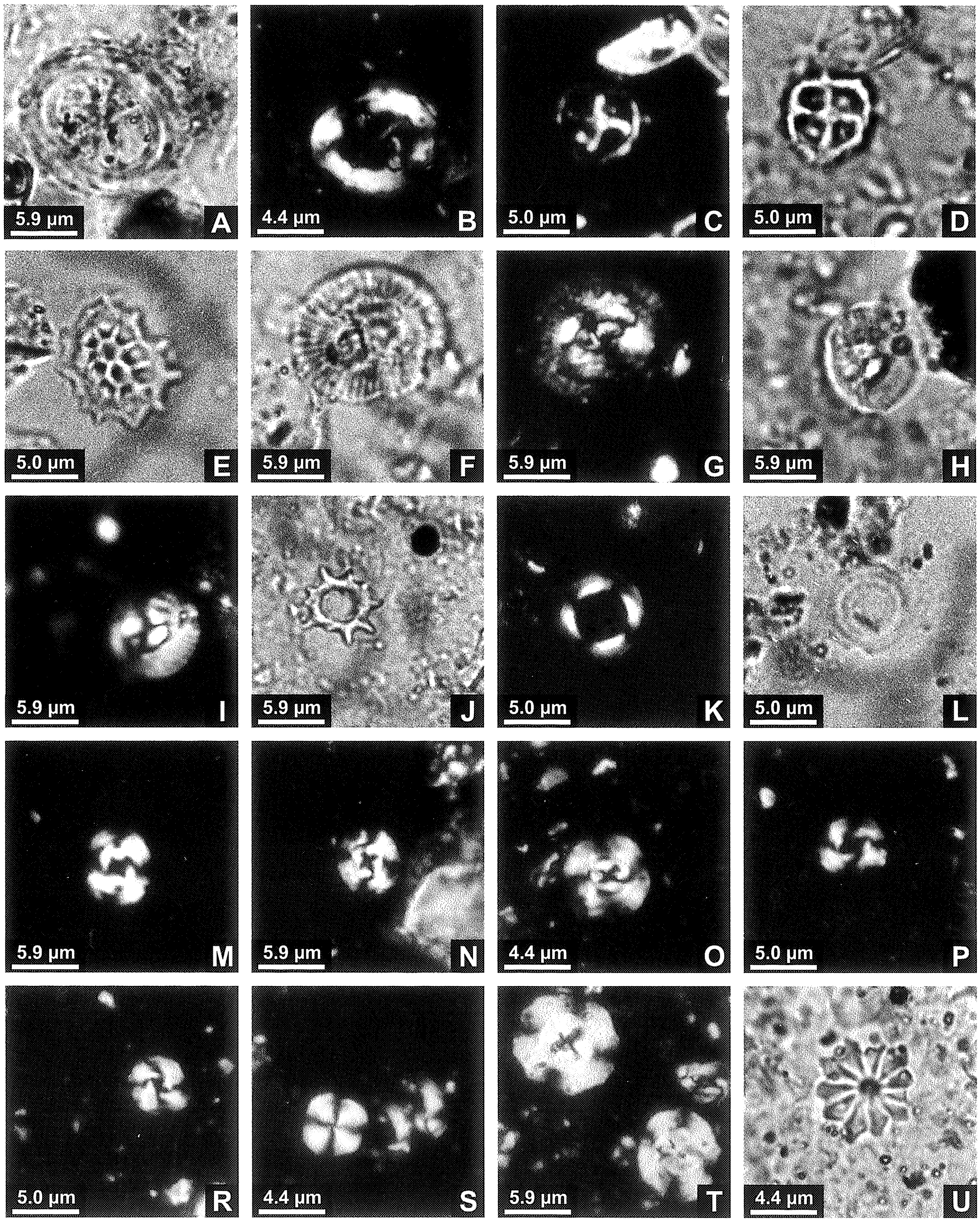


Fig. 37. LM microphotogaphs of calacareous nannofossil. **A** – *Chiasmolithus oamaruensis* (Deflandre), Ropica 12/96/N; **B** – *Chiasmolithus solitus* (Bramlette & Sullivan), Biegonice 60/82/N; **C** – *Chiphragmalithus calathus* Bramlette & Sullivan, Kosarzyska 100/98/N; **D** – *Chiphragmalithus calathus* Bramlette & Sullivan, Kosarzyska 100/98/N; **E** – *Clathrolithus spinosus* Martini, Naściszowa 23/99/N; **F** – *Coccolithus eopelagicus* (Bramlette et Riedel), Folusz 44/99/N; **G** – *Coccolithus eopelagicus* (Bramlette et Riedel), Folusz 44/99/N; **H** – *Coccolithus pelagicus* (Wallich), Folusz 44/99/N; **I** – *Coccolithus pelagicus* (Wallich), Folusz 44/99/N; **J** – *Corannulus germanicus* Stradner, Folusz 44/99/N; **K** – *Coronocyclus nitescens* (Kamptner), Naściszowa 25/99/N; **L** – *Coronocyclus nitescens* (Kamptner), Naściszowa 25/99/N; **M** – *Cyclicargolithus* cf. *C. abisectus* (Müller), Małastów 15/98/N; **N** – *Cyclicargolithus* cf. *C. abisectus* (Müller), Olchowiec 63/99/N; **O** – *Cyclicargolithus abisectus* (Müller), Biegonice 60/82/N; **P** – *Cyclicargolithus floridanus* (Roth & Hay), Biegonice 67/82/N; **R** – *Cyclicargolithus floridanus* (Roth & Hay), Biegonice 67/82/N; **S** – *Cyclicargolithus luminis* (Sullivan), Biegonice 68/82/N; **T** – *Dictyococcites bisectus* (Hay, Mohler & Wade), Leluchów 39/98/N; **U** – *Discoaster barbadiensis* Tan, Biegonice 60/82/N

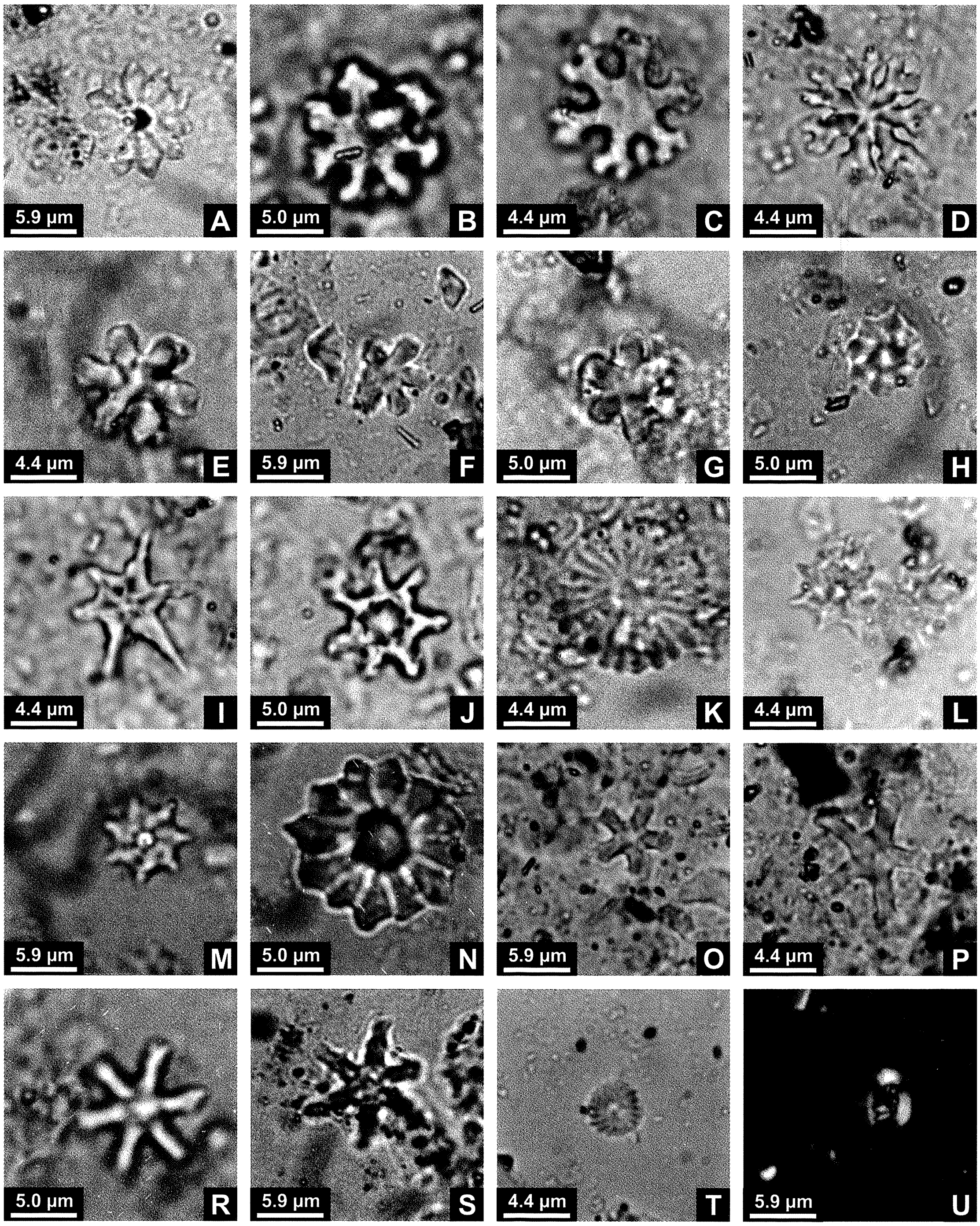


Fig. 38. LM microphotogaphs of calacareous nannofossil. **A** – *Discoaster barbadiensis* Tan, Małastów 7/97/N; **B** – *Discoaster binodosus* Martini, Kosarzyska 100/98/N; **C** – *Discoaster deflandrei* Bramlette & Riede, Budzów 8/95/N; **D** – *Discoaster* cf. *D. distinctus* Martini, Biegonice 60/82/N; **E** – *Discoaster* cf. *D. druggii* Bramlette & Wilcoxon, Biegonice 59/82/N; **F** – *Discoaster* cf. *D. druggii* Bramlette & Wilcoxon, Biegonice 67/82/N; **G** – *Discoaster* cf. *D. druggii* Bramlette & Wilcoxon, Biegonice 41/B/N; **H** – *Discoaster kuepperi* Stradner, Biegonice 41/B/N; **I** – *Discoaster lodoensis* Bramlette & Riedel, Biegonice 60/82/N; **J** – *Discoaster minimus* Sullivan, Kosarzyska 100/98/N; **K** – *Discoaster multiradiatus* Bramlette & Riedel, Biegonice 44/B/N; **L** – *Discoaster saipanensis* Bramlette & Riedel, Budzów 10/95/N; **M** – *Discoaster saipanensis* Bramlette & Riedel, Folusz 43/99/N; **N** – *Discoaster salisburgensis* Stradner, Lubomierz 8/98/N; **O** – *Discoaster tanii* Bramlette & Riedel, Biegonice 60/82/N; **P** – *Discoaster tanii* Bramlette & Riedel, Budzów 8/95/N; **R** – *Discoaster tanii nodifer* (Bramlette & Riedel), Naściszowa 21/99/N; **S** – *Discoaster tanii nodifer* (Bramlette & Riedel), Małastów 8/97/N; **T** – *Discoaster wemmelensis* Achuthan & Stradne, Biegonice 68/82/N; **U** – *Ericsonia fenestrata* (Deflandre & Fert), Małastów 10/97/N

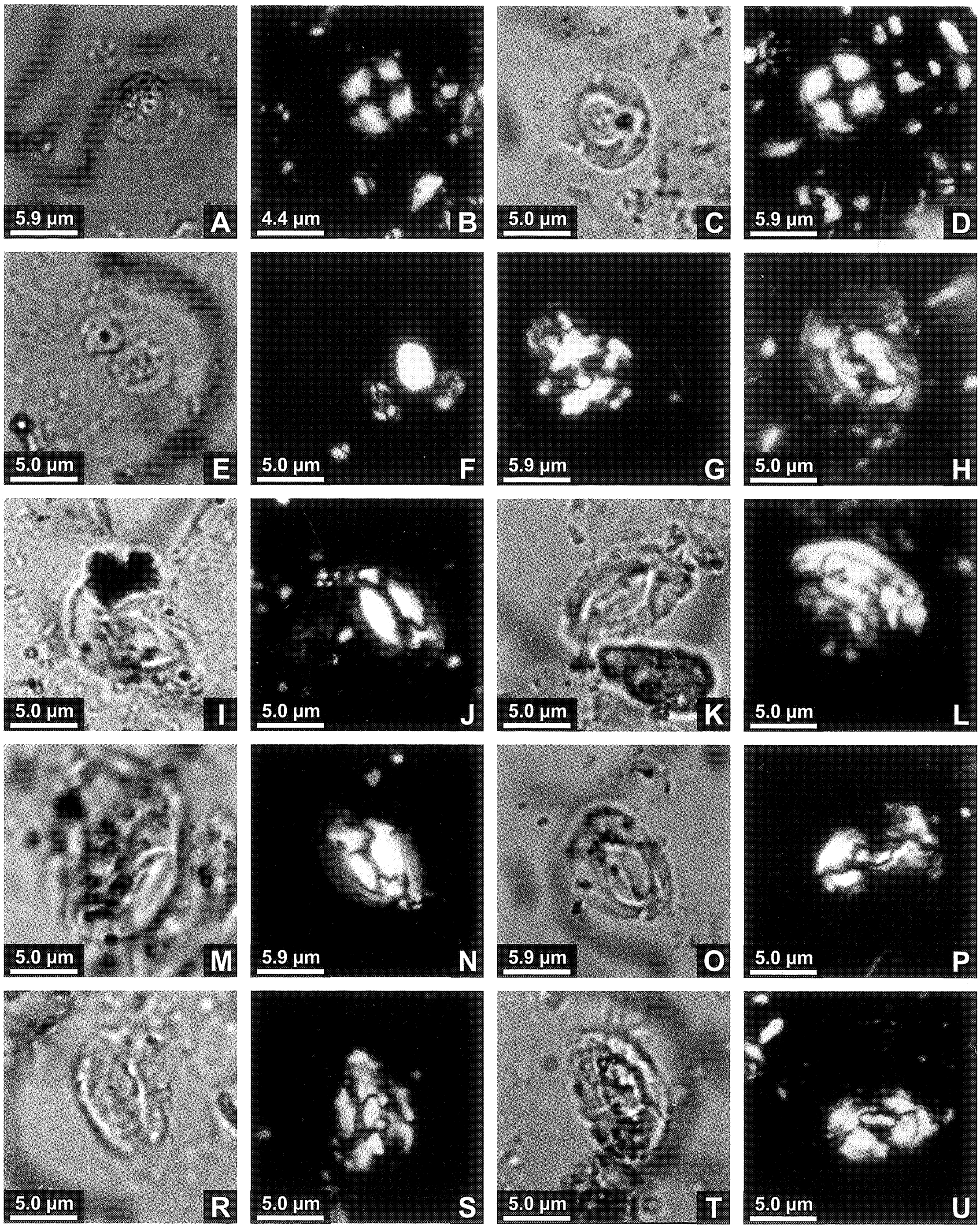


Fig. 39. LM microphotogaphs of calacareous nannofossil. **A** – *Ericsonia fenestrata* (Deflandre & Fert), Małastów 10/97/N; **B** – *Ericsonia formosa* (Kamptner), Biegonice 70/82/N; **C** – *Ericsonia formosa* (Kamptner), Hanuszów 55/98/N; **D** – *Ericsonia formosa* (Kamptner), Ropica 12/96/N; **E** – *Ericsonia subdisticha* (Roth & Hay), Poręba 77/98/N; **F** – *Ericsonia subdisticha* (Roth & Hay), Poręba 77/98/N; **G** – *Helicosphaera bramlettei* Müller, Ropica 13/96/N; **H** – *Helicosphaera bramlettei* Müller, Nowy Sącz 68w/99/N; **I** – *Helicosphaera bramlettei* Müller, Nowy Sącz 68w/99/N; **J** – *Helicosphaera compacta* Bramlette & Wilcoxon, Naściszowa 27/99/N; **K** – *Helicosphaera compacta* Bramlette & Wilcoxon, Naściszowa 27/99/N; **L** – *Helicosphaera compacta* Bramlette & Wilcoxon, Koninki 109/98/N; **M** – *Helicosphaera compacta* Bramlette & Wilcoxon, Koninki 109/98/N; **N** – *Helicosphaera compacta* Bramlette & Wilcoxon, Małastów 15/98/N; **O** – *Helicosphaera compacta* Bramlette & Wilcoxon, Małastów 15/98/N; **P** – *Helicosphaera euphratis* Haq, Naściszowa 23/99/N; **R** – *Helicosphaera euphratis* Haq, Naściszowa 23/99/N; **S** – *Helicosphaera* cf. *H. Heezenii* Bukry, Poręba 66/97/N; **T** – *Helicosphaera* cf. *H. heezenii* Bukry, Poręba 66/97/N; **U** – *Helicosphaera lophota* Bramlette & Sullivan, Ropica 12/96/N

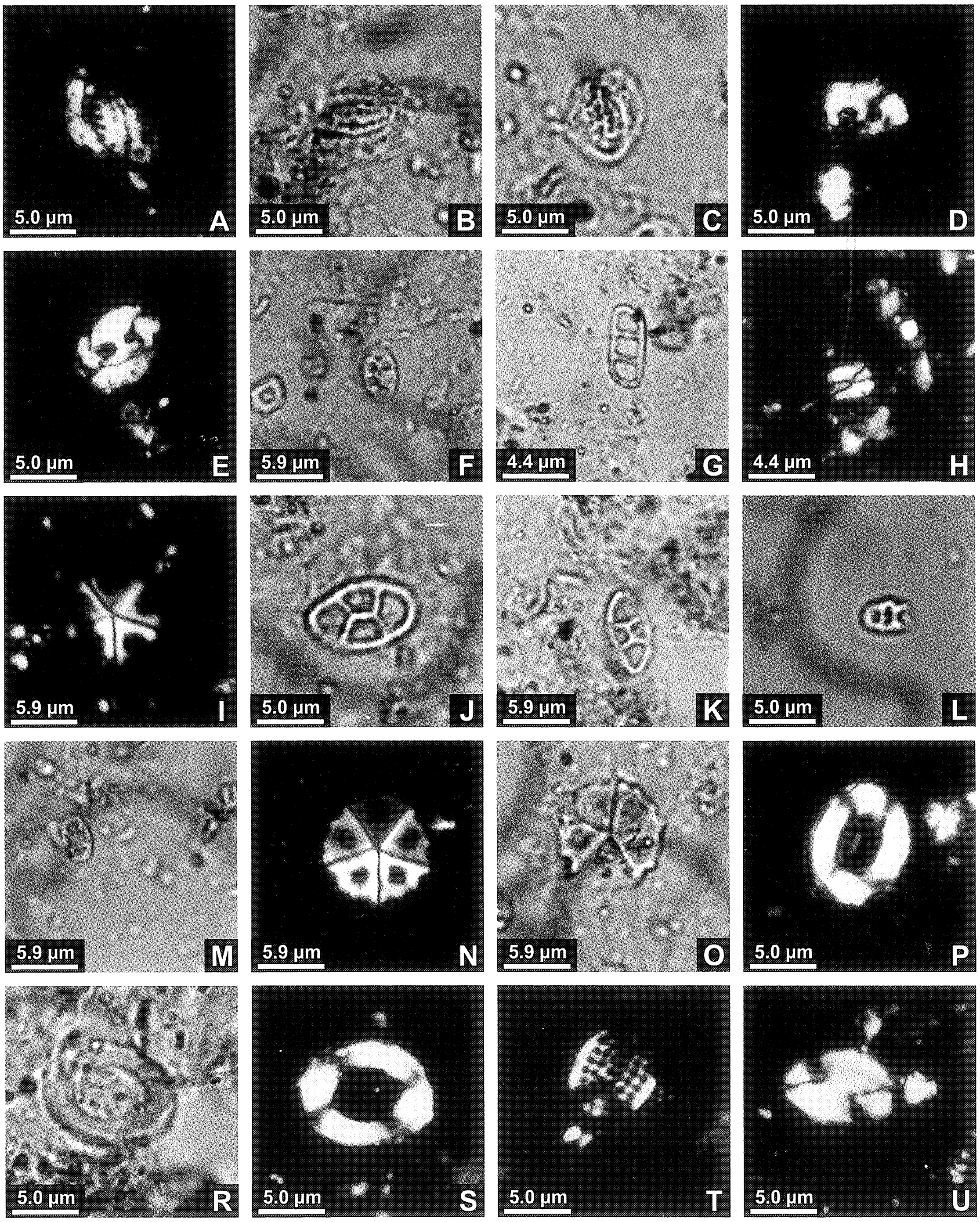


Fig. 40. LM microphotogaphs of calacareous nannofossil. **A** – *Helicosphaera papillata* Bukry & Bramlette, Nowy Sącz 67w/99/N; **B** – *Helicosphaera papillata* Bukry & Bramlette, Nowy Sącz 67w/99/N; **C** – *Helicosphaera papillata* Bukry & Bramlette, Małastów 8/97/N; **D** – *Helicosphaera recta* Haq, Nowy Sącz 65w/99/N; **E** – *Helicosphaera recta* Haq, Nowy Sącz 65w/99/N; **F** – *Holodiscolithus solidus* (Deflandre in Deflandre & Fert), Ropica 12/96/N; **G** – *Isthmohlithus recurvus* Deflandre, Budzów 9/95/N; **H** – *Lanternithus minutus* Stradner, Budzów 14/95/N; **I** – *Micrantholithus flos* Deflandre, Małastów 7/97/N; **J** – *Neococcolithes dubius* (Deflandre), Naściszowa 24/99/N; **K** – *Neococcolithes minutus* (Perch-Nielsen), Ropica 13/96/N; **L** – *Orthozygus aureus* (Stradner), Naściszowa 23/99/N; **M** – *Orthozygus aureus* (Stradner), Ropica 12/96/N; **N** – *Pemma basquensis* (Martini), Małastów 7/97/N; **O** – *Pemma basquensis* (Martini), Małastów 7/97/N; **P** – *Pontosphaera latelliptica* Baldi-Beke & Baldi, Nowy Sącz 65w/99/N; **R** – *Pontosphaera latelliptica* Baldi-Beke & Baldi, Nowy Sącz 65w/99/N; **S** – *Pontosphaera latelliptica* Baldi-Beke & Baldi, Nowy Sącz 65w/99/N; **T** – *Pontosphaera multipora* (Kamptner), Naściszowa 25/99/N; **U** – *Pontosphaera plana* (Bramlette & Sullivan), Lubomierz 6/98/N

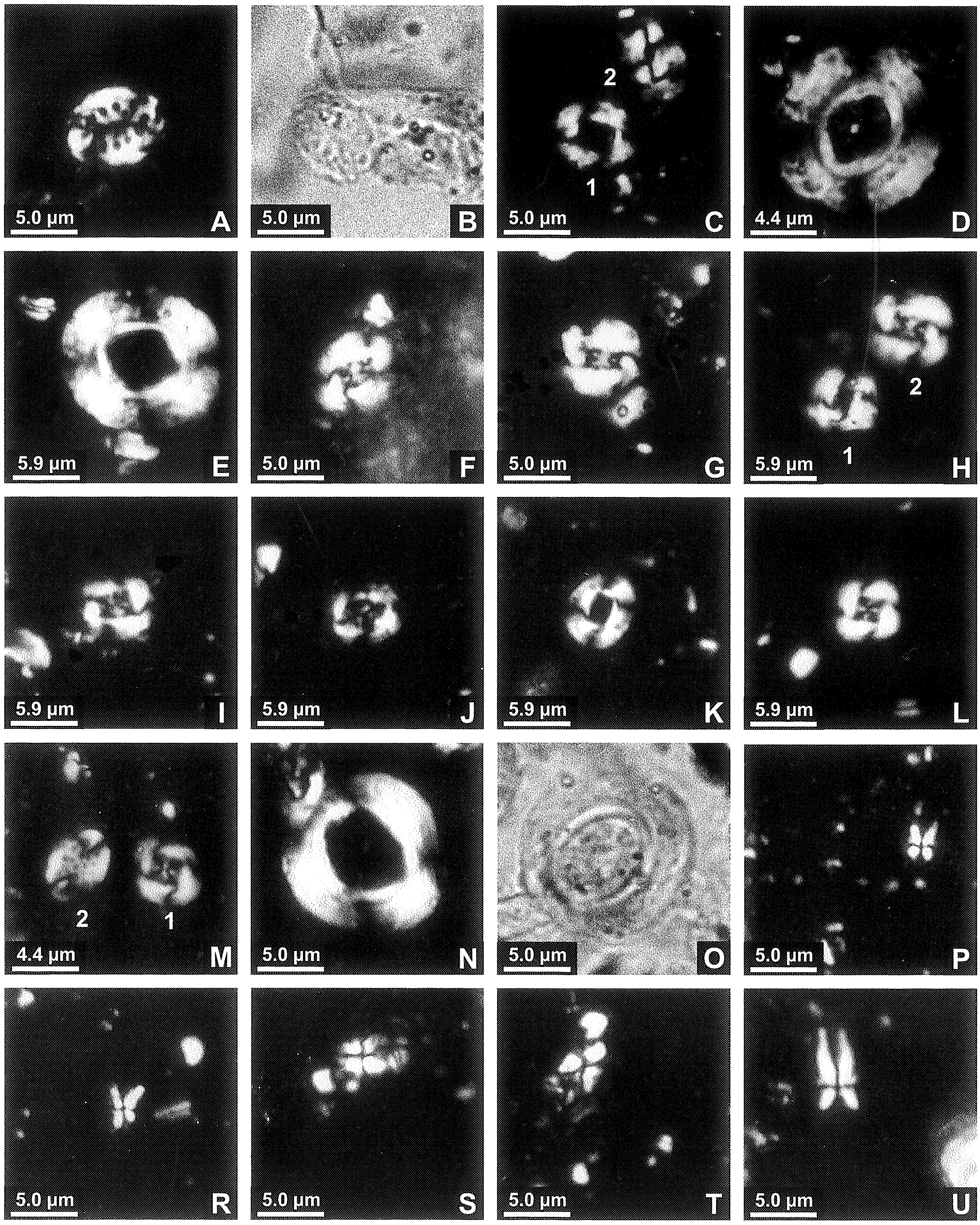


Fig. 41. LM microphotogaphs of calacareous nannofossil. **A** – *Pontosphaera rothi* Haq, Nowy Sącz 65w/99/N; **B** – *Pontosphaera rothii* Haq, Nowy Sącz 65w/99/N; **C: 1** – *Reticulofenestra dictyoda* (Deflandre *in* Deflandre & Fert), **2** – *Coccolithus pelagicus* (Wallich), Lubomierz 6/98/N; **D** – *Reticulofenestra hillae* Bukry & Percival, Budzów 13/95/N; **E** – *Reticulofenestra hillae* Bukry & Percival, Folusz 45/99/N; **F** – *Reticulofenestra lockerii* Müller, Nowy Sącz 65w/99/N; **G** – *Reticulofenestra lockerii* Müller, Nowy Sącz 68w/99/N; **H: 1** – *Reticulofenestra ornata* Müller, Małastów 15/98/N; **2** – *Reticulofenestra lockerii* Müller, **I** – *Reticulofenestra ornata* Müller, Olchowiec 60/98/N; **J** – *Reticulofenestra ornata* Müller, Olchowiec 60/98/N; **K** – *Reticulofenestra pseudoumbilica* (Gartner), Biegonice 67/82/N; **L** – *Reticulofenestra reticulata* (Gartner & Smith), Małastów 7/97/N; **M: 1** – *Reticulofenestra reticulata* (Gartner & Smith), **2** – *Pontosphaera multipora* (Kamptner), Budzów 9/95/N; **N** – *Reticulofenestra umbilica* (Levin), Naściszowa 25/99/N; **O** – *Reticulofenestra umbilica* (Levin), Naściszowa 25/99/N; **P** – *Sphenolithus* cf. *S. capricornutus* Bukry & Percival, Biegonice 41/B/N; **R** – *Sphenolithus* cf. *S. capricornutus* Bukry & Percival, Nowy Sącz 68w/99/N; **S** – *Sphenolithus* cf. *S. conicus* Bukry, Biegonice 41/B/N; **T** – *Sphenolithus* cf. *S. conicus* Bukry, Biegonice 41/B/N; **U** – *Sphenolithus furcatolithoides* Locker, Naściszowa 23/99/N

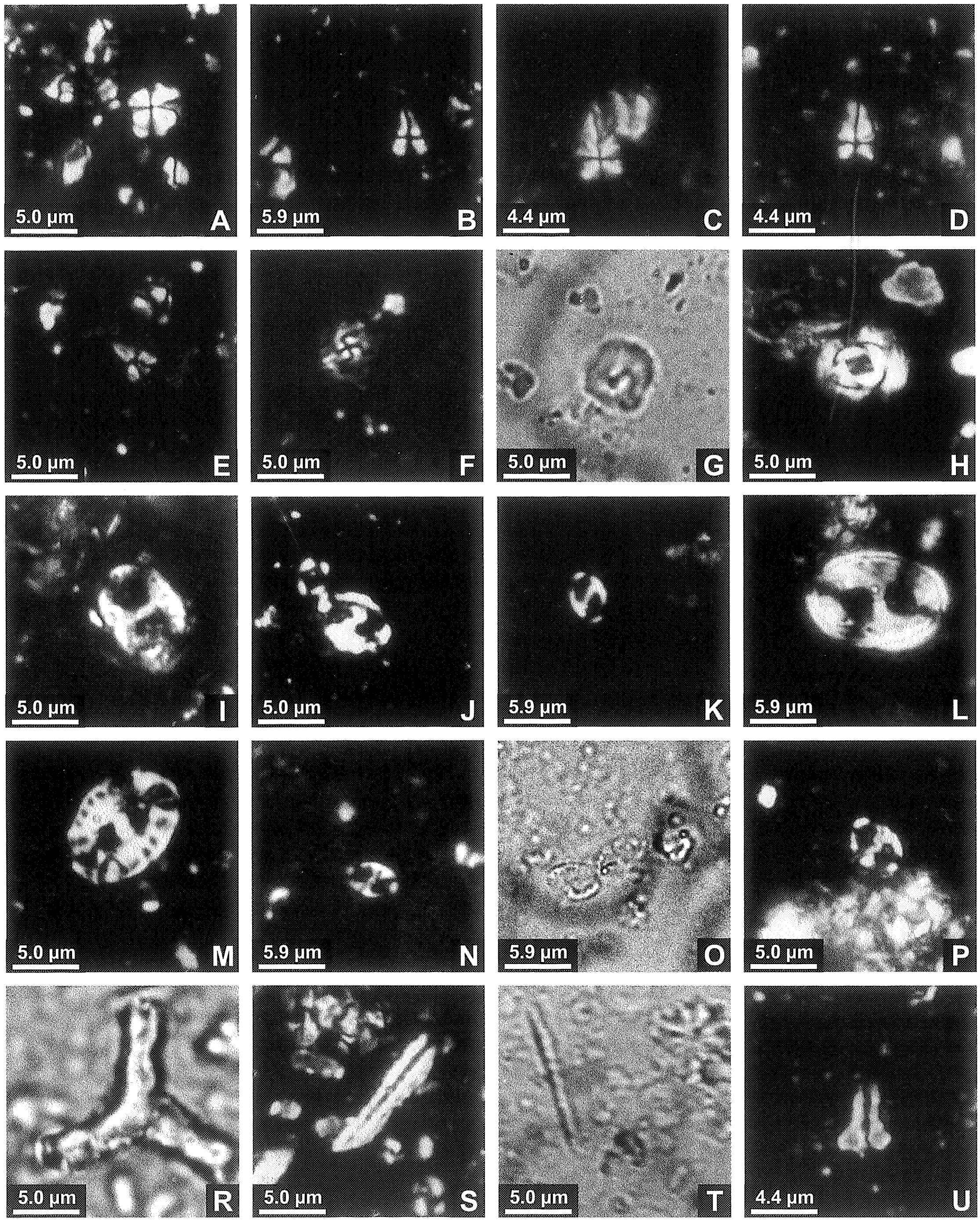


Fig. 42. LM microphotogaphs of calacareous nannofossil. **A** – *Sphenolithus moriformis* (Bronnimann & Stradner), Konina 8/98/N; **B** – *Sphenolithus orphanknollensis* Perch-Nielsen, Lubomierz 6/98/N; **C** – *Sphenolithus pseudoradians* Bramlette & Wilcoxon, Biegonice 72/82/N; **D** – *Sphenolithus radians* Deflandre, Biegonice 62/82/N; **E** – *Sphenolithus spiniger* Bukry, Lubomierz 6/98/N; **F** – *Toweius? gammation* (Bramlette & Sullivan), Lubomierz 1/98/N; **G** – *Toweius? gammation* (Bramlette & Sullivan), Lubomierz 1/98/N; **H** – *Toweius? magnicrassus* (Bukry), Kosarzyska 97/98/N; **I** – *Transversopontis fibula* Gheta, Leluchów 39/98/N; **J** – *Transversopontis* cf. *T. latus* Müller, Nowy Sącz 65w/99/N; **K** – *Transversopontis obliquipons* (Deflandre), Małastów 15/98/N; **L** – *Transversopontis pulcher* (Deflandre), Małastów 15/98/N; **M** – *Transversopontis pulcheroides* (Sullivan), Lubomierz 6/98/N; **N** – *Transversopontis pygmaea* (Locker), Małastów 10/97/N; **O** – *Transversopontis pygmaea* (Locker), Małastów 10/97/N; **P** – *Transversopontis pygmaea* (Locker), Nowy Sącz 65w/99/N; **R** *Tribrachiatus orthostylus* Shamrai, Kosarzyska 100/98/N; **S** – *Triquetrorhabdulus carinatus* Martini, Biegonice 44/B/N; **T** – *Triquetrorhabdulus carinatus* Martini, Biegonice 44/B/N; **U** – *Zygrhablithus bijugatus* (Deflandre), Budzów 15/95/N

Discoaster tani nodifer Zone (NP16)

Definition: the base of the zone is defined by the LO of *Rhabdolithus gladius*, and the top by the LO of *Chiasmolithus solitus*.
Author: Hay *et al.* (1967), emend. Martini (1970).
Age: Middle Eocene.
Remarks: This zone (Fig. 35) was identified in Piwniczna Sandstone Mbr from Kosarzyska (Kowaniec Beds, Golonka & Rączkowski, 1983) (Figs 28, 30; sample: 100/98/N).

The zone assignment is based on the presence of *Cyclicargolithus floridanus*, *Helicosphaera compacta* Bramlette & Wilcoxon. At the same time, *Discoaster tanii* Bramlette & Riedel is not present. According to Aubry (1986) the FO of *Cyclicargolithus floridanus* takes place in zone NP16. Usually, the FO of *Helicosphaera compacta* is found in the upper part of NP17 (Martini & Müller, 1986; Perch-Nielsen, 1985), although Aubry (1983) placed the FO of this species as low as in the upper part of NP16 (see Theodoridis, 1984; Varol, 1998). The assemblage of sample 100/98/N (Piwniczna Sandstone Mbr) does not reveal the presence *Chiasmolithus gigas*, *Cyclicargolithus floridanus* and *Helicosphaera compacta*. Taking into account the stratigraphical position of the Piwniczna Sandstone Mbr (Zarzecze Fm. is overlain by Piwniczna Sandstone Mbr) as well as the lack of *Chiasmolithus gigas*, it is possible to assume that the lowest part of this sandstone can be placed in the upper part of NP15 or the lower part of zone NP16. The species of *Cyclicargolithus floridanus* and *Helicosphaera compacta* are not present as their FO takes place in the upper part of NP16.

Discoaster saipanensis Zone (NP17)

Definition: the base of the zone is defined by the LO of *Chiasmolithus solitus* and the top by the FO of *Chiasmolithus oamaruensis*.
Author: Martini (1970).
Age: Middle Eocene.
Remarks: This zone (Fig. 35) was identified in Hierogliphic Beds from Naściszowa-Zabełcze (Figs 18, 19; samples: 17/99/N-20/99/N)

The zone assignment is based on the FO of *Discoaster tanii*, which is characteristic for the middle part of NP17 (see Bukry, 1973). At the same time both *Chiasmolithus solitus* (Bramlette & Sullivan) as well as *Chiasmolithus oamaruensis* (Deflandre) do not occur. The FO of the latter is an important biostratigraphical event marking the lower boundary of NP18. Additionally, these samples contain flat specimens of *Neococcolithes minutus* (Perch-Nielsen) which are characteristic for the zone NP17 (Aubry, 1986).

Chiasmolithus oamaruensis Zone (NP18)

Definition: the base of the zone is defined by the first occurrence of *Chiasmolithus oamaruensis* and the top by the first occurrence of *Isthmolithus recurvus*.
Author: Martini (1970).
Age: Late Eocene.
Remarks: This zone (Fig. 35) was identified in the following lithostratigraphical units: Zembrzyce Beds from Budzów (Figs 3, 6; samples: 15/95/N-13/95/N) and Naściszowa-Zabełcze (Figs 18, 19; samples: 21/99, 23/99/N-25/99/N), Mniszek Shale Mbr from Gołkowice (Figs 18, 27; sample: 44/99/N) and Hanuszów (Figs 29, 30; sample: 55/98/N).

The zone assignment is based on the first occurrence of *Chiasmolithus oamaruensis*, the presence of *Discoaster barbadiensis*, *Discoaster saipanensis* and the lack of *Isthmolithus recurvus* Deflandre. However, in the case of those samples collected from the Budzów (only part of them) and Naściszowa-Zabełcze sections, *Chiasmolithus oamaruensis* was not observed. These samples also contain at least two of the following species: *Orthozygus aureus* (Stradner) and/or *Corannulus germanicus* Stradner and/or *Helicosphaera euphratis* Haq. The first occurrence of these species takes place in the zone NP18 (Baldi-Beke, 1971; Perch-Nielsen, 1971, 1985).

Isthmolithus recurvus and *Sphenolithus pseudoradians* combined interval Zone (NP19–20)

Definition: the base of the zone is defined by the FO of *Isthmolithus recurvus* and the top by the LO of *Discoaster saipanensis* and/or *Discoaster barbadiensis*.
Author: Aubry (1983).
Age: Late Eocene.
Remarks: This zone (Fig. 35) was identified in the following lithostratigraphical units: the Zembrzyce Beds from Ropica (Figs 7, 9; sample: 3/96/N) and Folusz (Figs 12, 14; samples: 41/99/N-43/99/N), Wątkowa Sandstone from Budzów (Figs 3, 6; sample: 12/95/N), Ropica (Figs 7, 9; sample: 5/96/N) and Małastów (Figs 7, 11; samples: 5/97/N, 7/97/N), the Budzów Beds from Budzów (Figs 3, 6; samples: 10/95/N, 9/95/N), the Leluchów Marl Mbr (Figs 31, 33, 34; samples: 48/82/N, 49/82/N from section A and 46/82/N-44/82/N from section B).

The zone assignment is based on a co-occurrence of *Isthmolithus recurvus*, *Discoaster barbadiensis*, *Discoaster saipanensis* and *Reticulofenestra reticulata* (Gartner & Smith). Such an association is believed to be indicative of the combined interval zone NP19–20. Additionally, the presence of *Ericsonia formosa* (Kamptner), whose last occurrence indicates the upper limit of the zone NP21, was also observed.

Ericsonia subdisticha Zone (NP21)

Definition: the base of the zone is defined by the LO of *Discoaster saipanensis* and/or *Discoaster barbadiensis* and the top by the LO of *Ericsonia formosa*.
Author: Roth & Hay in Hay *et al.* (1967), emend. Martini (1970).
Age: Early Oligocene (Late Eocene/Early Oligocene cfr. Cavelier, 1979).
Remarks: This zone (Fig. 35)was identified in the following lithostratigraphical units: the Zembrzyce Beds from Folusz (Figs 12, 14; samples: 44/99/N-46/99/N), Wątkowa Sandstone from Ropica (Fig. 7, 9; samples: 6/96/N-8/96/N, 12/96/N, 13/96/N), Małastów (Figs 7, 11; samples: 8/97/N-11/97/N) and Folusz (Figs 12, 14; sample: 47/99/N), the Budzów Beds from Budzów (Figs 3, 6; samples: 8/95/N,

7/95/N) and Olchowiec (Figs 15, 17; sample 54/99/N), Leluchów Marl Mbr (Figs 31, 33, 34; samples: 50/82/N-53/82/N from section A and 43/82/N-37/82/N from section B).

The zone assignment is based on a continuous range of *Ericsonia formosa*, following the disappearance of *Discoaster saipanensis* and *Discoaster barbadiensis*. However in a few sections, very rare specimens of *Discoaster saipanensis* were observed within zone NP21. According to Janin (1992), very rare specimens of *Discoaster saipanensis* managed to survive the Eocene/Oligocene boundary. Furthermore, the assemblages of this zone are characterised by the more frequent occurrence of *Isthmolithus recurvus* than in that of NP19–20. According to many authors (Monechi, 1986; Perch-Nielsen *et al.*, in Pomerol & Premoli-Silva, 1986; Backman, 1987; Nocchi *et al.*, 1988b; Krhovský *et al.*, 1992) such an abundance increase of *Isthmolithus recurvus* is a characteristic biostratitraphic event at or just below the Eocene/Oligocene boundary. Problematic is also the biostratigraphic range of *Reticulofenestra reticulata*, which normally takes place prior to the LO of *Discoaster barbadiensis/Discoaster saipanensis* (Aubry, 1992), although in the Małastów, Leluchów and Budzów sections, these specimens passed to zone NP21. A similar pattern of *Reticulofenestra reticulata* have also been described by Müller (1978) and Varol (1998).

Helicosphaera reticulata Zone (NP22)

Definition: the base of the zone is defined by the LO of *Ericsonia formosa* and the top by the LO of *Reticulofenestra umbilica*.
Author: Bramlette & Wilcoxon (1967), emend. Martini (1970).
Age: Early Oligocene.
Remarks: This zone (Fig. 35) was identified in the following lithostratigraphical units: Wątkowa Sandstone from Ropica Górna (Figs 7, 9; samples: 2/97/N-4/97/N), Małastów (Figs 7, 11; sample: 12/97/N) and Folusz (Figs 12, 14; samples: 48/99/N, 49/99/N), the Budzów Beds from Budzów (Figs 3, 6; samples: 6/95/N-1/95/N) and Olchowiec (Figs 15, 17; samples: 55/99/N-59/99/N), Poprad Sandstone Mbr from Naściszowa-Zabełcze (Figs, 18, 19; samples: 26/99/N, 27/99/N, 32/99/N) and Lubień (sample: 74/99/N), Leluchów Marl Mbr (Figs 31, 33, 34; samples: 54/82/N from section A and 36/82/N from section B), Smereczek Shale Mbr (Figs 31, 33; sample: 55/82/N from section A).

The zone assignment is based on a continuous range of *Reticulofenestra umbilica* (Levin) following the disappearance of *Ericsonia formosa*. At the same time the species of *Reticulofenestra ornata* and *Transversopontis fibula* were not found.

Sphenolithus predistentus Zone (NP23)

Definition: the base of the zone is defined by the LO of *Reticulofenestra umbilica* and the top by the FO of *Sphenolithus ciperoensis*.
Author: Bramlette & Wilcoxon (1967), emend. Martini (1970).
Age: Middle Oligocene.
Remarks: This zone (Fig. 35) was identified in the following lithostratigraphical units: Wątkowa Sandstone from Małastów (Figs 7, 11; samples: 13/97/N-17/97/N), the Budzów Beds from Małastów (Figs 7, 11; samples: 10/98/N, 14/98/N) and Olchowiec (Figs 15, 17; samples: 60/99/N-62/99/N), the Smereczek Shale Mbr (Figs 31, 33; samples: 39/98/N, 38/98/N from section A).

The zone assignment is due to the co-occurrence of abundant *Reticulofenestra ornata*, *Transversopontis fibula* and *Reticulofenestra lockerii*, following the disappearance of *Reticulofenestra umbilica*. Such an association of species is characteristic for the equivalent of zone NP23 in the Paratethys region. It is also important to discuss the biostratigraphical range of *Isthmolithus recurvus* and *Lanternithus minutus* Stradner. Traditionally, the LO of these species takes place prior to the LO of *Reticulofenestra umbilica*. However, in the Małastów and Olchowiec sections both species are still present within zone NP23. A Similar pattern has also been observed by Edwards (1971) and Varol (1998).

Sphenolithus distentus Zone (NP24)

Definition: the base of the zone is defined by the FO of *Sphenolithus ciperoensis* and the top by the LO of *Sphenolithus distentus*.
Author: Bramlette & Wilcoxon (1967).
Age: Late Oligocene.
Remarks: This zone (Fig. 35) was identified in the following lithostratigraphical units: the Budzów Beds from Małastów (Figs 7, 11; samples: 15/98/N, 18/98/N-20/98/N, 22/98/N-24/98/N, 26/98/N, 27/98/N) and Olchowiec (Figs 15, 17; samples: 63/99/N, 64/99/N), the Malcov Fm. from borehole Nowy Sącz I (Fig. 22; samples: 65w/99/N-67w/99/N), the Malcov Fm. *ss.* from Leluchów (Figs 31, 33; samples: 37/98/N, 42/98/N-40/98/N from section A).

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

Sphenolithus ciperoensis Zone (NP25)

Definition: the base of the zone is defined by the LO of *Sphenolithus distentus* and the top by the LO of *Helicosphaera recta* and/or *Sphenolithus ciperoensis*.
Author: Bramlette & Wilcoxon (1967), emend. Martini (1976).
Age: Late Oligocene.
Remarks: This zone (Fig. 35) was identified in the Malcov Fm. from borehole Nowy Sącz I (Fig. 22; samples: 68w/99/N-70w/99/N).

The zone assignment is based on the first occurrence of *Sphenolithus capricornutus* Bukry & Percival and *Sphenolithus conicus* followed by a continuous range of *Cyclicargolithus abisectus*, *Zygrablithus bijugathus*, *Dictyococcites bisectus*. The latter is an index species for the upper limit of NP25 (Berggren *et al.*, 1995; Fornaciari *et al.*, 1996). The FO of *Sphenolithus conicus* has been traditionally used as the base of NN1 zone. However, Bizon & Müller (1979), Biolzi *et al.* (1981) and Melinte (1995) have observed the FO of these species as low as in the upper part of zone NP25.

Discoaster druggii Zone (NN2)

Definition: the base of the zone is defined by the FO of *Discoaster druggii*, and the top by the LO of *Triquetrorhabdulus carinatus*.
Author: Martini & Worsley (1970).
Age: Early Miocene.
Remarks: This zone (Fig. 35) was identified in the Zawada Fm. from Biegonice (Figs 23, 25, 26; samples: 41/B/N-44/B/N, 46/B/N, 47/B/N, 59/82/N, 60/82/N, 62/82/N, 67/82/N, 68/82/N, 70/82/N-72/82/N).

The zone assignment of the described section is based on a co-occurrence of the following species: *Sphenolithus conicus*, *Sphenolithus disbelemnos* Bramlette & Wilcoxon, *Discoaster druggii* Bramlette & Wilcoxon, *Reticulofenestra pseudoumbilica* (Gartner) and *Triquetrorhabdulus carinatus*. According to the standard zonation of Martini (1970) and Martini and Worsley (1970), the first occurrence of *Reticulofenestra pseudoumbilica* takes place in NN5. However, in the Intra- and Extra-Carpathian areas of Romania the FO of *Reticulofenestra pseudoumbilica* coincides with the FO *Discoaster druggii* (Marunteanu 1992), which corresponds to the lower limit of NN2. According to Young (in Bowm, 1998), the FO of *Sphenolithus disbelemnos* is a reliable biostratigraphical event characteristic for the lower limit of NN2 zone.

LITHO- AND BIOSTRATIGRAPHIC CORRELATION

Within the Magura Nappe it is possible to distinguish 3 turbiditic cycles (Oszczypko, 1992a, 1998). Each of them starts with variegated shales and terminates with thin-bedded turbidites. In the Late Cretaceous–Paleocene cycle, the boundaries between the lithostratigraphical units are more or less isochronous (Oszczypko, 1991, 1992a, b), whereas in the Eocene cycle the boundaries are diachronous. This is connected with the progressive growth of the Magura accretionary prism (Oszczypko, 1992a, 1999). The lowest lithostratigraphical unit of the Eocene cycle is formed by the Łabowa Fm. (Bystrica, Rača and Siary zones) and by the Zarzecze Fm. (Krynica Zone). The Zarzecze Fm. is represented by grey-greenish, thin to medium-bedded turbidites. Their thickness varies from a few dozen metres in the Peri-Pieniny Klippen Belt zone (Birkenmajer & Oszczypko, 1989) to 400–600 m in the Krynica area (Oszczypko *et al.*, 1999a). In the Kosarzyska section (Fig. 43), the uppermost portion of this formation belongs to the NP15 zone. The Zarzecze Fm. which contains thin intercalations of variegated shales was also observed in the southernmost part of the Bystrica Zone at the southern margin of the Mszana Dolna tectonic window (Oszczypko *et al.*, 1999c). In this area the determined nannofossil assemblages indicate zone NP16 (Oszczypko-Clowes in Oszczypko *et al.*, 1999c). In the Bystrica Zone (except for thrust sheet Tobołów-Turbaczyk), the equivalent of Zarzecze Fm. is formed by the Beloveza Fm. (Oszczypko, 1991), and represented by thin- and very thin-bedded, dark-greyish, calcareous turbidites with infrequent intercalations of variegated shales. The thickness of the formations varies from 250 to 500 m (Oszczypko, 1991). In Poręba Górna (section A) the upper part of this formation contains nannofossil assemblages belonging to NP16 (Oszczypko-Clowes in Oszczypko *et al.*, 1999c). Dudziak (1991) determined zone NP17 in the upper part of Beloveza Fm. from the Zbludza section. In the Rača Zone, the Hierogliphic Beds lying on top of the Łabowa Fm., are the equivalent of the Beloveza Fm. (Fig. 43). The nannofossil assemblages from the Naściszowa-Zabełcze section indicate NP17 for the Hierogliphic Beds. In the Ropica Górna and Małastów sections of the Siary Zone the Hierogliphic lithofacies was found as intercalations only in the Łabowa Fm. Thus, just above the variegated shales of the Łabowa Fm., there are Zembrzyce Beds (Fig. 44).

In the Krynica Zone the Zarzecze Fm. is overlain by the Piwniczna Sandstone Mbr of the Magura Fm. (Birkenmajer & Oszczypko, 1989; Oszczypko *et al.*, 1999a), and represented by thick-bedded sandstones and conglomerates up to 1 000 m thick. The sandstones contain rare intercalations of non-calcareous shales. In the Kosarzyska section (Fig. 43), calcareous nannofossil assemblages found in the lower part of the Piwniczna Sandstone Mbr belong to the lowest part of NP16. In the Bystrica Zone, the Beloveza Fm. is overlain by the Żeleźnikowa Fm. This formation consists of thin to medium-bedded turbidites of Beloveza lithofacies (up to 400 m thick) with frequent intercalations of Łącko marls (Oszczypko, 1986, 1991). According to Dudziak, these deposits belong to zone NP16. In the Naściszowa-Zabełcze section of the Rača Zone, the Żeleźnikowa Fm. is substituted by Late Eocene in age (NP18) Zembrzyce Beds. This unit, up to 110 m thick (Figs 19, 43), is dominated by dark-greyish marly claystones with intercalations of thin to thick-bedded sandstones. In the Siary Zone, the Zembrzyce Beds occur above the Łabowa Fm. These beds were studied in 5 localities (Fig. 44). In the Western part of the studied area (Budzów section) the Zembrzyce Beds are more calcareous than in the Eastern part (Folusz section). The thicknes of the beds varies from 100 m in Budzów, 60 m in the Folusz section, up to only a few metres in the Ropica Górna section. According to Kopciowski (1996), the thickness of the Zembrzyce Beds between Ropa and Banica, increases from 1 to 25 m. In the uppermost part of these beds, in the Ropica Górna and Folusz sections, occur thin intercalations of brown Menilite type shales (see Sikora, 1970; Koszarski & Koszarski, 1985; Ślączka & Kaminski, 1998). The age of these beds is diachronic: NP18 in Budzów, NP19–20 in Ropica Górna and NP21 in the Folusz section.

In the Krynica and Bystrica zones the Piwniczna and Maszkowice mbrs of the Magura Fm. are overlain by variegated shales of the Mniszek Mbr. Its thickness reached 100 m in the Hanuszów and Gołkowice sections. This member developed in the form of blue-greenish and red non-calcareous shales with sporadic intercalations of thin to thick-bedded sandstones. In the Leluchów section, a 10 cm layer of tuffite, was observed. This particular horizon was correlated by prof. T. Wieser (pers. comm.) with the Polany

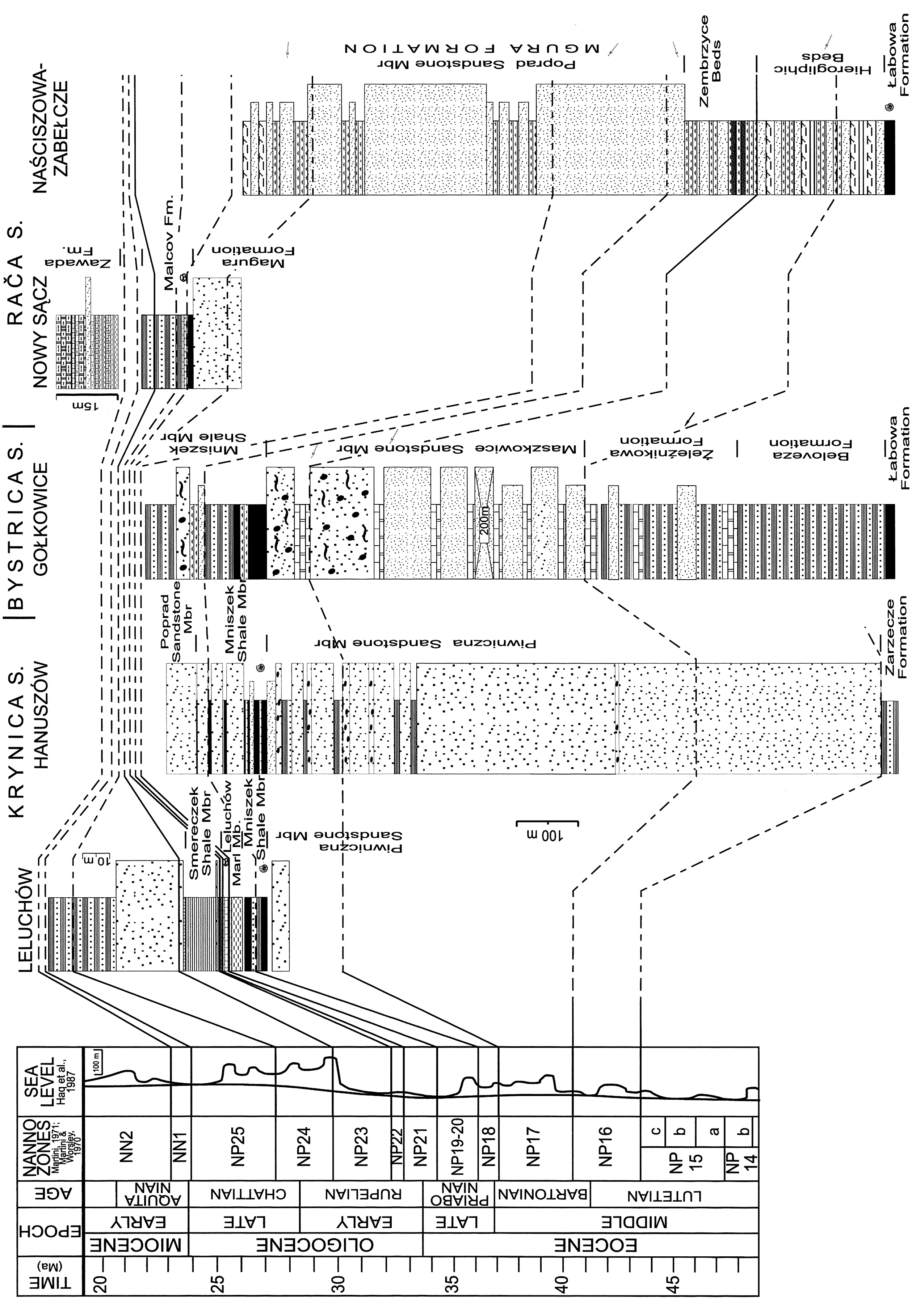


Fig. 43. Litho- and biostratigraphic correlation of the sections from Krynica, Bystrica and Rača subunits. For the other explanations see Fig. 5

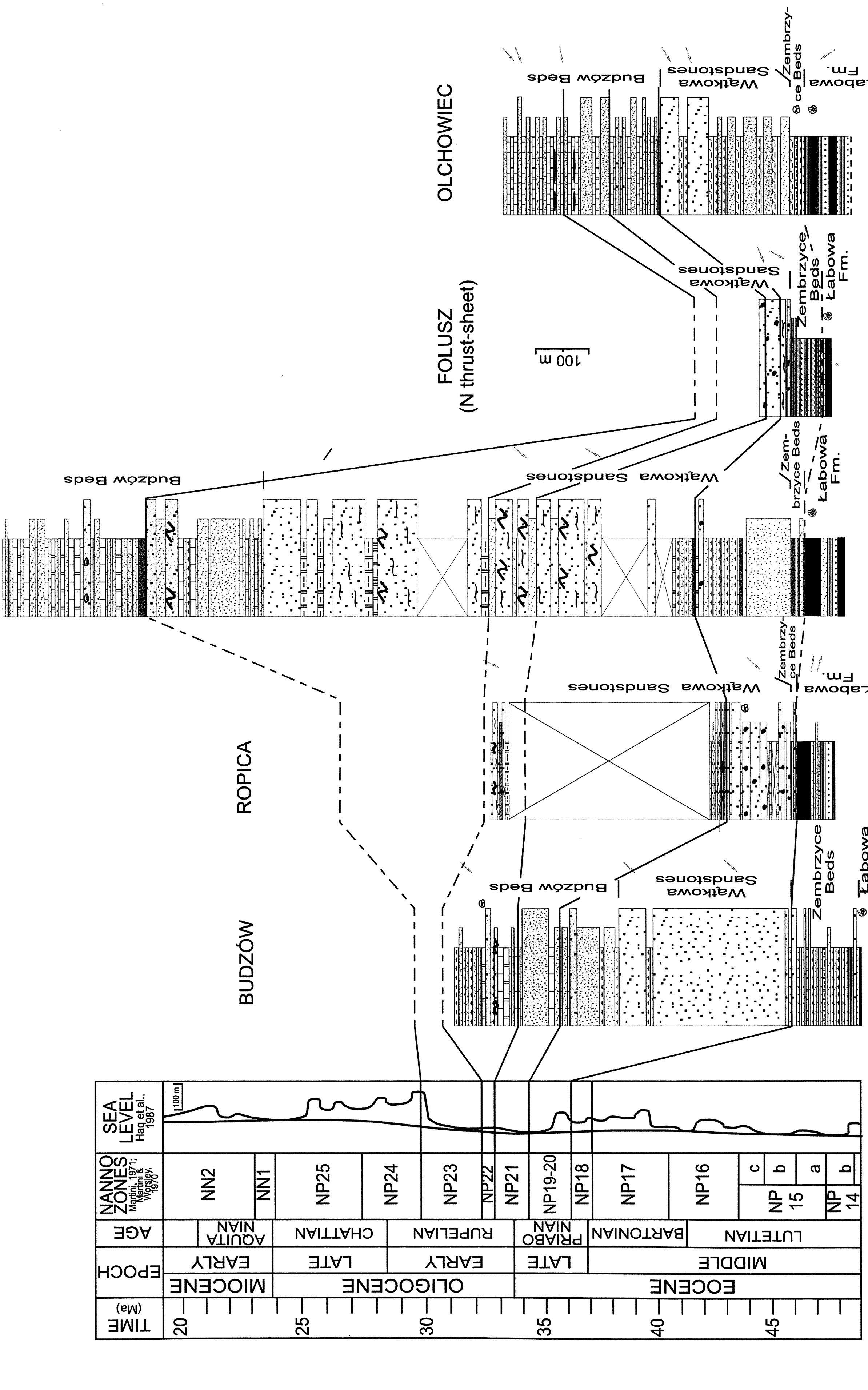


Fig. 44. Litho- and biostratigraphical correlation of the sections from Siary subunit. For the other explanations see Fig. 5

(P) tuffite horizon (see Van Couvering *et al.*, 1981) (Figs 33, 43). In the Mniszek Sh. Mbr, zone NP18 was determined. In the Krynica Zone, with the exception of Leluchów, above the Mniszek Mbr occurs the Poprad Sandstone Mbr of the Magura Fm. In the Naściszowa-Zabełcze section (Rača Zone) this member is situated above the Zembrzyce Beds. The Poprad Sandstone Mbr developed as thick-bedded, muscovite sandstones with sporadic intercalations of shales. In the studied sections of the Krynica and Bystrica zones the thickness of the Mniszek Mbr is up to 200 m (Fig. 43), whereas the age is not younger than NP18. In the Rača Zone, the thickness of the Poprad Mbr is up to 1000 m, and the youngest calcareous nannoplankton in the Naściszowa-Zabełcze and Lubień sections belongs to zone NP22. The clastic material contained in the Poprad sandstones was supplied from the SE (100–140°) in the Krynica and Bystrica zones and from the NE (60°) in the Rača Zone.

In the Siary Zone, Wątkowa Sandstones is exposed above the Zembrzyce Beds (Fig. 44). Their thickness oscillated from ca 325 m in the Budzów section (600 m according to Książkiewicz, 1966) to 1000 m in the Małastów section. According to Koszarski (1977) in the Folusz area (Magura Wątkowska Range) the thickness of these beds varies from 500 m in the NW part of the area to 900 m in SE. In the Budzów section the Wątkowa Sandstones are dominated by grey-greenish, fine to coarse-grained, sometimes conglomeratic, thick-bedded sandstones (0.4–2.0 m), whereas in the Ropica, Małastów and Folusz sections these beds are represented by coarse-grained/conglomeratic, very thick-bedded sandstones (2–2.5 m thick). These sandstones display a parallel lamination with big convolute structures at the top of the beds and sometimes with "slurry". In all of the studied sections the flute casts display palaeocurrent from the NE. In Budzów, zone NP19–20 was determined, in the Ropica section NP19–20, NP21 and NP22, whereas in the Małastów sections zone NP23 was additionally found. In the Folusz section the basal part of beds was assigned to zones NP21 and NP22. All these nannoplankton determinations reveales diachronism in the basal limit of the Wątkowa Sandstones.

In the Leluchów section of the Krynica Zone the Mniszek Sh. Mbr is overlain by the Malcov Fm. The lower portion of the formation is composed of (ca 4 m) green marly shales (Blaicher & Sikora, 1967). Higher up in the section occurs a 3.5–4 m packet of variegated SMGM (Leluchów Marl Mbr) passing upwards into Menilite-like shales (Smereczek Sh. Mbr). These are dark-greyish marly shales, followed by black-brown, silicified, horizontally laminated shales with a 1 cm layer of hornstones and a few thin layers of tuffite at the base ("Gąsiory" – tuffite horizon, see Blaicher & Sikora, 1967). Additionally, two thin intercalations of detritical *Bryozoa-Lithothamnium* limestones were found. The thickness of the Smereczek Sh. Mbr reached at least 19 m (see Blaicher & Sikora, 1967). The base of the Malcov lithofacies is composed of ca 25 m packet of thick-bedded, coarse-grained, muscovite sandstones with sporadic, thin intercalations of grey-greenish, marly shales and thin-bedded sandstones. The thick-bedded sandstones are overlain by grey marly shales with intercalations of thin-bedded, calcareous, muscovite sandstones.

In 1973 Oszczypko described from the Nowy Sącz I borehole a thin packet of variegated shales and marls, which pass upwards into the shaley flysch lithofacies of the Krosno-Menilite. These strata, at least 100 m thick, were assigned to the Malcov Fm. (Oszczypko, 1973, see also Oszczypko *et al.*, 1999c). The age of the Malcov Fm. is as follows: the Leluchów Marl Mbr belongs to zones NP19–20, 21 and 22 (Oszczypko-Clowes, 1998, 1999), the Smereczek Shale Mbr to zone NP23, whereas the Malcov lithofacies in the Leluchów section and the Nowy Sącz I borehole belong to zones NP24 and NP25, respectively.

In the Siary Zone (Budzów, Małastów and Olchowiec sections) the Budzów Beds are an equivalent of the Malcov Fm. Their thickness varies from at least 290 m in Olchowiec, up to 300 m in Budzów and 470 m in the Malastów sections (500 m in Małastów according to Kopciowski, 1996). The Budzów Beds are represented by marly claystones, silicified marls and spherosiderites with intercalations of medium to thick-bedded glauconitic sandstones. From West to East the amount of sandstones increased. As the result the following calcareous nannoplankton zones in the Budzów Beds were determined: zones NP19–20, NP21, NP22 in the Budzów section, zones NP23 and NP24 in the Małastów section and NP21, NP22, NP23 and NP24 in the Olchowiec section.

In the studied area the youngest deposits of the Magura Nappe belong to the Zawada Fm. documented on the southern periphery of the Nowy Sącz Basin. This formation was found in the Nowy Sącz 4 borehole (Fig. 18) as well as in the Zawada (Oszczypko *et al.*, 1999b) and Biegonice sections (Oszczypko-Clowes, 2000). These deposits, up to 200 thick, are represented by marly claystones, marls, pelosiderites and glauconitic sandstones. This formation occurs at the boundary between the Rača and Bystrica zones. Its relation to the Malcov Fm., however, has not been recognised yet. In both sections the youngest calcareous nannofossil assemblages belong to the zone NN2. This age was confirmed by the foraminiferal study of Malata who determined zone N5 in the Zawada section (see Oszczypko *et al.*, 1999c).

PALAEOECOLOGY

Late Eocene–Oligocene global climate changes

The Palaeogene may be seen in a general sense as a transition period between the globally warm (non-glaciated) Late Cretaceous and cooler (glaciated) Neogene and Pleistocene. Eocene and Oligocene were periods of major change in ocean circulation and the global climate. This caused a significant turnover in marine (Haq *et al.*, 1977; Savin, 1977; Keigwin, 1980; Keller, 1983; Keigwin & Corliss, 1986; Oberhänsli & Hsü, 1986; Shackleton, 1986; Boersma *et al.*, 1987; Rea *et al.*, 1990), as well as in terrestrial biotas (Chaney, 1940; Leopold & MacGinitie, 1972; Kemp, 1978; Wolfe, 1980, 1985; Wolfe & Poore, 1982; Retallack, 1986).

Changes in the ocean surface temperature during the Palaeogene are characterised by a steepening of the surface temperature gradient (Shackleton & Boersma, 1981; Keigwin & Corliss, 1986; Boersma *et al.*, 1987). This was primarily a result of the cooling of high latitude surface waters. The actual decrease in high latitude surface water temperature was estimated as much as ~7°–10°C during the Palaeogene (Shackleton & Kennett, 1975; Savin, 1977; Boersma *et al.*, 1987). The bottom water temperature also fell from ~12°–13°C in the Early Eocene, to ~8°–9°C in the Late Eocene, and ~3°–4°C in the earliest Oligocene.

The climate modelling sensitive studies of Sloan & Barron (1992) suggests that Palaeogene climatic changes occur due to the increasing elevation of continents (Andes, Himalayas) as well as due to changes in surface water temperature. A decrease in water temperature was also observed in areas where elevation was minor or even non existent (Europe, East Asia, North-East America, North Australia). The results of Sloan & Barron modelling (1992) reveal that:

1 – the rising mountains produced cooler temperatures in areas of orogenic uplift as well as surface water temperature changes even in the regions free from tectonic activity,

2 – changes in the sea-surface temperature, associated with the steepening of latitudinal surface water gradients, had a great influence on the continental climate. High latitude continental temperatures were decreasing distinguishably during the winter time whereas increased only moderately during the summer. As Sloan & Barron (1992) observed, the decrease of summer temperatures in high latitudes, and the latitudinal increase of the surface water gradient, mirror the condition of establishing and maintaining ice at high latitudes.

The initiation, as well as the continuous growth of ice on Antarctica could have been the result of gradual global cooling coupled with the uplift of continental areas even situated away from Antarctica. This was also due to steepening surface water temperature gradients caused by the progressive isolation of Antarctica from warmer low latitude surface waters (Prothero & Berggren, 1992). Before the Oligocene, Drake passage between South America and Antarctica was opened (see Golonka *et al.*, 1994), changing the ocean circulation from meridional to circum-Antarctic. This caused an increase in humidity and an increase of rainfalls, which was accompanied by the continuous decrease in temperature. Such a condition allowed ice accumulation.

Palaeoecological response of the calcareous nannoplankton

Species diversity. For the Budzów, Ropica, Małastów, Folusz, Naściszowa, and Leluchów sections the transition between the Upper Eocene and Lower Oligocene was documented. The analysis of autochthonous calcareous nannofossil carried out for the above mentioned sections is showing a distinct decrease in the species diversity. According to Andreyeva-Grigorovich & Savitskaya (in print) the maximum amount of species (140) was observed for the Middle Eocene, and decreased in the Late Eocene. It was confirmed in the studied sections, where in the Upper Eocene (NP19–20) the total amount of species is no more than 30. From such a diversified assemblage, in the zone NP19–20, *Discoaster barbadiensis* and *Discoaster saipanensis* became extinct. This event was followed by the extinction of *Ericsonia formosa* and *Pemma basquensis* in NP21, and by *Ericsonia subdisticha* (Roth & Hay), *Reticulofenestra umbilica*, *Reticulofenestra hillae* Bukry & Percival, *Reticulofenestra reticulata*, *Helicosphaera reticulata* Bramlette & Wilcoxon in the zone NP22. Finally, in the zone NP23 species of *Isthmolithus recurvus*, *Lanternithus minutus*, *Discoaster tanii*, *Discoaster tanii nodifer* Bramlette & Riedel and *Chiasmolithus oamaruensis* disappeared. At the same time in the zone NP18 appears *Orthozygus aureus*, *Chiasmolithus oamaruensis*, *Helicosphaera euphratis*, and in NP19–20 *Transversopontis obliquipons* (Deflandre). Between the zones NP21–22 no new species appeared. The evolutionary, first appearance took place as high as the lower limit of NP23. The new species are as follows *Reticulofenestra ornata*, *Reticulofenestra lockerii* and *Transversopontis fibula,* and their first occurrence is associated with the progressive isolation of the Paratethys. Reassuming, in the Late Eocene two species disappeared and four new species appeared, whereas in the Early Oligocene ten species became extinct and only three had their first occurrence. One could conclude, therefore, that the Early Oligocene is characterised by badly diversified nannofossil assemblages and by the lowest rate of species in the whole Palaeogene. Haq (1971, 1973) and Bukry (1978) provided evidence of a strong relationship between calcareous nannofossil diversity and the temperature of the ocean water throughout the Palaeogene. According to these authors the low diversity is associated with a lower temperature and vice versa. Therefore, the decline in diversity, that the calcareous nannoplankton underwent from Middle Eocene to Early Oligocene, is a clear indication of global climatic changes.

Temperature. Calcareous nannofossil biogeographic studies were first carried out by Haq & Lohman (1976), who showed that the distribution of nannofossil assemblages, like that of modern Coccolithophoridae (McIntyre & Bé, 1967; Okada & Honjo, 1973), is a function of latitude, hence of climate.

The calcareous nannofossil analysis carried out for the Budzów, Ropica, Małastów, Folusz, Naściszowa and Leluchów sections (Figs 1, 35) enables this work establish that, the Late Eocene assemblages were dominated by *Dictyococcites bisectus*, *Cyclicargolithus floridanus*, *Reticulofenestra umbilica*, *Coccolithus pelagicus*, *Ericsonia formosa* and *Reticulofenestra callida*. All of these species except for the *Ericsonia formosa* and *Reticulofenestra callida* are typical temperate water indicators (Wei & Wise, 1990). The only warm water species are *Ericsonia formosa*, *Discoaster barbadiensis*, *Discoaster saipanensis* which became extinct by the end of NP21 (*Ericsonia formosa*) and NP19–20. At almost the same time, new cold water taxa had their first occurrence in NP18 (*Chiasmolithus oamaruensis*) and in NP19–20 (*Isthmolithus recurvus*). It is also characteristic that large *Chiasmoliths* such as *Chiasmolithus gigas* and *Chiasmolithus grandis* (Bramlette & Riedel) are rare or practically absent at higher latitudes. This is probably an indication that cold waters eliminate large coccoliths, creating a favourable environmental condition for small and simple-shaped coccoliths (Bukry, 1971).

The abundance pattern of *Isthmolithus recurvus* is quite characteristic – occurring sporadically in NP19–20 and reaches a maximum in zone NP21. For the majority of studied sections species of *Chiasmolithus oamaruensis* rarely occurred. The exception is the Folusz (Figs 1, 35) section where this species occurred very frequently. Another cold water indicator – *Reticulofenestra callida* is characteristic and abundant for zones NP19–20 and NP21. In other ways the assemblages are characterised by the presence of both temperate (*Dictyococcites bisectus*, *Cyclicargolithus floridanus*, *Coccolithus pelagicus*, *Coccolithus eopelagicus*) and typically cold water taxa such as *Isthmolithus recurvus*, *Reticulofenestra callida*, *Reticulofenestra lockerii*, *Reticulofenestra ornata* (Wei & Wise, 1990). The latter two species had their first occurrence in NP23 zone, which also probably indicates a drop in the temperature of water masses. It is also important to mention that the assemblages of Budzów, Ropica, Małastów, Folusz, Naściszowa and Leluchów sections are scarce in species of *Helicosphaera*, *Sphenolithus* and *Discoaster* (Figs 1, 35). The species of *Helicosphaera* are known to prefer shallow and warm water masses (Bukry *et al.*, 1971; Haq & Lipps, 1971). The most abundant and diversified assemblages of *Sphenolithus* are characteristic of lower latitudes. At the middle latitudes the abundance and diversity drop by 50% whereas at higher latitudes the sphenolits are virtually absent (except *Sphenolithus moriformis*). Both the latitudinal abundance and the diversity pattern of sphenoliths indicate a preference for warm waters.

Therefore, Eo-Oligocene assemblages from the Magura Basin were dominated by mid-latitudinal species. All warm water taxa became extinct by the end of NP21. At the same time, from zone NP21 onwards there is a distinct increase in cold water taxa. As it was proven above, the changes in nannoplankton assemblages reflect a decrease in water temperature.

Salinity. The distribution of *Reticulofenestra ornata*, *Transversopontis fibula* and *Transversopontis latus* is limited both in space and in time (Nagymarosy & Voronina, 1992). According to Nagymarosy & Voronina (1992) these species are characteristic for the brackish-water environments and limited to the Paratethys. The above mentioned association is strictly characteristic for zone NP23. In the studied section of the Magura Basin endemic species were found in the Małastów, Olchowiec and Leluchów sections. So far *Transversopntis latus* was sporadically found. Rare *Transversopntis fibula* are observed in the Olchowiec and Leluchów sections. The low-diversity assemblages in the Olchowiec and Leluchów sections are characterised by an abundance of *Reticulofenestra ornata*. At this point it is important to state that the above mentioned assemblages do not form monospecific association (highly dominated by *Reticulofenestra ornata*) like that known from the East Paratethys (Nagymarosy & Voronina, 1992). It is also worth noticing that *Reticulofenestra ornata* is less frequent in assemblages from the Małastów section. This may be explained by the more significant dispersion of calcareous nannoplankton in turbidite deposits. With respect to those assemblages described from the Małastów, Olchowiec and Leluchów sections (Figs 1, 35) it is possible to prove that in the higher part of NP23 there was a distinct drop in salinity which led to the development of brackish-water environment. This event is associated with the complete isolation of the Paratethys (Baldi, 1980; Rusu, 1988; Rögl, 1999) and can be traced in both in the Central (Chert Mbr and Dynów Marl of Menilite Fm. in Zdanice-Pouzdrany unit, see Krhovský, 1981a, b; Krhovský *et al.*, 1992) and East Paratethys (Polbinian horizon, see Nagymarosy & Voronina, 1992).

Near the NP23/24 boundary, open-marine, calcareous nannofossil assemblages have developed again. Zone NP24 of the Małastów, Olchowiec and Leluchów sections, as well as the Nowy Sącz I borehole, is characterised by the presence of rich and highly diversified assemblages dominated by *Dictyococcites bisectus*, *Coccolithus eopelagicus*, *Coccolithus pelagicus*, *Cyclicargolithus abisectus*, *Cyclicargolithus floridanus*, *Helicosphaera compacta*, *Helicosphaera euphratis*, *Helicosphaera recta*, *Pontosphaera multipora*, *Sphenolithus moriformis* and *Zygrhablithus bijugatus*. At the same time typical low-salinity species (*Transversopontis pulcher*, *Transversopontis pulcheroides*, *Transversopontis obliquipons*, *Reticulofenestra ornata*) are very rare or even absent. Such assemblages indicate that, at the turn of NP23/24, normal salinity conditions in the Magura basin were restored. At that time the connection between the Paratethys and the North Sea as well as with the Mediterranean region was reestablished (see Baldi, 1980; Rusu, 1988; Rögl, 1999).

Trophic resources. Most of the Cenozoic calcareous nannofossil species are currently regarded as temperature-significant (eg. Bukry, 1973; Wei & Wise, 1990). However, it could be argued that the frequency of at least a few species during the Early Eocene may be related more to the oligotrophic condition than to the warm water environment. This may suggest that the extinction in the Late Eocene could have been determined by the loss of oligotrophic habitat rather than by cooling alone. Similarly, several Early Oligocene extinctions may be the consequence of further eutrophication in addition to the increased cooling effect (Aubry, 1992).

As disscused earlier, Eo-Oligocene calcareous nannofossil assemblages from the Magura Basin, reflect a characteristic drop in the species diversity. The minimum was reached in upper part of Early Oligocene. These changes reflect both a drop in surface water temperature as well as an increase in nutrient concentration. The relationship between high diversity and oligotrophy is reflected by the fact that the nannofossil assemblages in marginal seas, enriched in nutrients, are characterised by a much lower diversity in comparison to open oceans (Okada & Honjo, 1975). With regards to the Palaeogene evolution of calcareous nannofossil, it is difficult to separate the role of both factors because:

1. Intensified circulation and the mixing of water masses (Boersma *et al.*, 1987), caused a gradual cooling and increasing eutrophication,

2. Temperature and nutrient content possibly stimulated the growth of species and distribution within Coccolithophoridae.

The Early Oligocene assemblages from the Magura Basin were dominated by *Cyclicargolithus floridanus* and *Dictyococcites bisectus*. Species which are also common, but to a lesser extent include *Pontosphaera multipora*, *Transversopontis pulcher*, *Transversopontis pulcheroides*, *Transversopontis obliquipons* and *Zygrhablithus bijugatus*. According to Aubry (1992) and Krhovský *et al.* (1992), these are species which indicate the eutrophic condition. Oppositely, *Discoaster tanii*, *Discoaster tanii nodifer*, *Ericsonia formosa* and *Reticulofenestra umbilica* are species which require a low nutrient concentration. The first two are very rare whereas *Ericsonia formosa* and *Reticulofenestra umbilica* became extinct in the Early Oligocene. Thus, it is possible to assume that Early Oligocene assemblages are enriched in species, which prefer high nutrient supply.

CONCLUSIONS

1. On the basis of the research carried out for the selected sections, it was possible to establish the litho- and biostratigraphy of the youngest deposits of the middle part of the Magura Nappe in Poland.

2. The nannofossil analysis allowed the Late Oligocene age of the youngest deposits of the Magura Nappe, to be determined. These are Siary Zone – NP24 (Budzów Beds), Rača Zone – NP25 in (Malcov Fm.) and NP24 in the Krynica Zone (Malcov Fm.). In the northern part of Krynica as well as in the Bystrica zones, the youngest, so far, deposits belong to Upper Eocene (NP18 and NP19?), which might be due to the post-Badenian erosion.

3. The Lower Miocene (NN2) Zawada Fm. has been discovered in the Nowy Sącz area on the boundary between Rača and Bystrica zones. This formation probably overlapped the older, Upper Oligocene deposits.

4. At the turn of the Eocene a distinct differentiation of sedimentary conditions took place in the Magura Basin. In the southern, relatively shallow and slowly subsided part of the basin (Krynica Zone), pelagic Globigerina Marls were deposited, whereas in the northern, more deepwater part of the basin (Rača and Bystrica zones) high subsidence was compensated by high turbidite deposition. During the Late Oligocene (NP24) in both parts of the basin the rate of sedimentation became more or less the same.

5. Since the Late Eocene a distinct change in the nannoplankton assemblages was documented. This was manifested by a decrease in nannofossil diversity, the increase of medium and cold-water taxa followed by a decrease in warm-water taxa. These changes reflect both the drop of the water temperature as well as the progressing eutrophication of the Magura Basin.

6. In the Magura Basin, as in the other parts of the Central and Eastern Paratethys, zone NP23 is characterised by the presence of brackish water nannofossil, which indicated the maximum isolation of that bioprovince from the oceanic circulation.

7. At the end of Oligocene, after the deposition of the Malcov Fm. and Budzów Beds, the Magura Basin was probably folded, partly uplifted and finally overthurst on to the For-Magura and Silesian units. This was probably followed by the Early Burdygalian transgression, which partially flooded the Magura Nappe. The deposition of the Lower Miocene (NN2) turbidite Zawada Fm. was connected with this sedimentary event.

Acknowledgements

The author is greatly indebted to prof. A. Ślączka (Jagiellonian Univ.) and prof. A. Andreyeva-Grigorovich (Commenius Univ., Bratislava), for their fruitful discussion and help offered during her PhD studies. Many thanks are due to Ass. Prof. B. Olszewska (Pol. Geol. Inst.) and Ass. Prof. M. Cieszkowski (Jagiellonian Univ.) for their suggestions concerning the PhD manuscript. Special thanks are offered to my father for his help during the field work and for discussion on the manuscript. The author is also grateful to Dr E. Gaździcka, Dr. M. Krobicki and the Anonymous Reviewer for their critical remarks on the manuscript. My appreciation should also be extended to Dr. M. Doktor for his help in the preparation of the microphotograph plates. My husband David is gratefully acknowledged for helpful in correcting the English text. The research was financially supported by KBN grant no. 6PO4D05115.

REFERENCES

Alexandrowicz, S., Cieszkowski, M., Golonka, J., Kutyba, J., Oszczypko, N. & Paul, Z., 1984. The stratigraphy of the Krynica Zone of the Magura Nappe in the Polish Flysch Carpathians (In Polish, English summary). *Biuletyn Instytutu Geologicznego*, 340: 23–39.

Andreyeva-Grigorovich, A., S. & Savitskaya, N., in press. Fossil Coccolitophorides as indication of the climatic changes in Eocene Paleobasins of the South region of CIS. (In Russian, English summary). *Algal Journal.*

Aubry, M. P., 1983. Biostratigraphie du Palaeogene epicontinental de l'Europe du Nord- Ouest. Etude fondee sur les nannofosiles calcaires. *Documents des Laboratoires de Geologie*, Lyon. 89, 317 p.

Aubry, M. P., 1986. Palaeogene calcareous nannoplankton biostratigraphy of northwestern Europe. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 55: 267–334.

Aubry, M. P., 1992. Late Palaeogene calcareous nannoplankton evolution: A tale of climatic deterioration. In: Prothero, D. R. & Berggren W. A. (eds), *Eocene–Oligocene climatic and biotic evolution.* Princeton Univ. Press, Princeton, pp. 272–309.

Backman, J., 1986. Late Paleocene to middle Eocene calcareous nannofossil biochronology from the Shatsky Rise, Walvis Ridge and Italy. In: Shackleton, N. J. (ed.), Boundaries and events in the Palaeogene. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 57: 43–59.

Backman, J., 1987. Quantitative calcareous nannofossil biochronology of Middle eocene through Early Oligocene sediment from DSDP Sites 522 and 523. In: Stradner, H. & Perch-Nielsen, K. (eds), *International Nannoplankton Association Vienna Meeting 1985 Proceedings. Geologisches Bundesanstalt Wien, Abhandlungen*, 39: 21–32. Wien.

Baldi T., 1980. The early history of Paratethys. *Földtani Közlöny*, 110: 456–472.

Baldi T., Horvath M., Nagymarosy A. & Varga P., 1984. The Eocene–Oligocene boundary in Hungary. The Kiscelain stage. *Acta Geologica Hungarica*, 27: 1-2, 41–65.

Baldi-Beke M., 1971. The Eocene nannoplankton of the Bakony Mountains, Hungary. Annales Instituti Geologici Publici Hungarici. *A Magyar Allami Földtani Intezet Evkonyve*, 54: 13–39.

Baldi-Beke M., 1977. Stratigraphical and facial subdivision of the Buda-type Oligocene based on nannoplankton. *Földtani Közlöny*, 107: 59–89.

Baldi-Beke, M., 1981. The nannoplankton of the Transdanubian

Palaeogene Formations. *Geologica Hungarica, Series Paleontologica*, 43: 1–307.

Bartek, L. R, Sloan, L., Anderson, J. B. & Ross, M. I., 1992. Evidence from the Antarctic continental margin of Late Palaeogene ice sheets: A manifestation of plate reorganization and synchronous changes in atmospheric circulation over the emerging southern ocean. In: Prothero, D. R. & Berggren, W. A. (eds), *Eocene–Oligocene climatic and biotic evolution. Princeton University Press*, Princeton, pp. 131–159.

Berggren, W. A., Kent, D. V., Swisher, C., C., & Aubry, M. P., 1995. A revised Cenozoic geochronology and chronostratigraphy. In: Berggren, W., Kent, D., Aubry, M. & Hardenbol, J. (eds). *Geochronology, Time Scales and Global Stratigraphic Correlation. Society of Economic Paleontologist and Mineralogists, Special Publication*, 54, 129–212.

Biolzi, M., Müller, C. & Palmieri, G., 1981. Calcareous nannoplankton. In: Gelati, R. & Steininger, F. (eds), *In search of the Palaeogene – Neogene boundary stratotype, part II. Revista Italiana Di Paleontologia i Stratigrafia*, 89 (4): 460–471.

Birkenmajer, K. & Dudziak, J., 1981. Age of the Magura Flysch, Palaeogene, along the northern boundary of the Pieniny Klippen Belt, Carpathians, Poland, based on nannoplankton. (In Polish, English Summary). *Studia Geologica Polonica*, 70: 7–36.

Birkenmajer, K. & Dudziak, J., 1988a. Nannoplankton dating of the terminal flysch deposits (Oligocene)in the Magura Basin, Outer Carpathians. *Bulletin of the Polish Academy of Sciences, Earth Sciences*, 36 (1): 1–13.

Birkenmajer, K. & Dudziak, J., 1988b. Age of Palaeogene flysch in the Pieniny Klippen Belt Carpathians, Poland, based on calcareous nannoplankton. *Bulletin of the Polish Academy of Sciences, Earth Sciences*, 36 (1): 15–24.

Birkenmajer, K. & Dudziak, J., 1988c. Nannoplankton dating of the terminal flysch deposits (Oligocene) in the Magura basin, Outer Carpathians. *Bulletin of the Polish Academy of Sciences, Earth Sciences*, 36 (1): 1–13.

Birkenmajer, K. & Oszczypko, N., 1989. Cretaceous and Palaeogene lithostratigraphic units of the Magura Nappe, Krynica Subunit, Carpathians. *Annales Societatis Geologorum Poloniae*, 59: 145–181.

Bizon, G. & Müller C., 1979. Remarks on the Oligocene/Miocene boundary based on the results obtained from the Pacific and the Indian Ocean. *Annales Gëologiques des pays Hellëniques. Laboratoire de Geologie de l'Universitetë Athënes*, 1: 101–111.

Blaicher, J. & Oszczypko, N., 1975. The Malcov Beds in the Nowy Sącz Depression (Polish Middle Carpathians). In: *Proceedings of the Xth Congress of Carpatho-Balkan Geological Association, 1973. Stratigraphy and Paleontology*, Geologicky ustav D. Štura, Bratislava, pp. 2–30.

Blaicher, J. & Sikora, W., 1967. Stratygrafia jednostki rychwałdzkiej w Leluchowie. (In Polish only). *Kwartalnik Geologiczny*, 11: 453–454.

Blow, W. H., 1969. Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. In Bronniman, P. R. & Renz, H. H. (eds). *Proceedings of the First International Conference on Planktonic microfossils.* Geneva 1976, Leiden, E. J. Brill, 1: 199–421.

Boersma, A., Premoli-Silva, I. & Shackleton, N. J., 1987. Atlantic Eocene planktonic foraminiferal paleohydrographic indicators and stable isotope paleoceanography. *Paleoceanography*, 2: 287–331.

Borysławski, A., 1982. *Budowa geologiczna płaszczowiny magurskiej na południe od Tokarni.* (In Polish only). Unpublished PhD. Thesis. Polish Geological Institute, Warsaw, 160 pp.

Bown, P., 1998. Calcareous nannofossil biostratigraphy. Kluwer Academic Publishers, Dorderecht, 315 pp.

Bramlette, M. N. & Wilcoxon, J., 1967. Middle Tertiary calcareous nannoplankton of the Cipero Section, Trinidad. *W. I. Tulanne Studies Geology*, 24: 44–60.

Bukry, D., 1971. Discoaster evolutionary trends. *Micropaleontology*, 17: 43–52.

Bukry, D., 1973. Low-latitude coccolith biostratigraphic zonation. *Initial Reports of the Deep Sea Drilling Project*, 15: 127–149.

Bukry, D., 1975. Coccolith and silicoflagellate stratigraphy of northwestern Pacific Ocean, Deep Sea Drilling Project Leg 32. *Initial Reports of the Deep Sea Drilling Project*, 3: 677–701.

Bukry, D., 1978. Biostratigraphy of Cenozoic marine sediment by calcareous nannofossils. *Micropaleontology*, 9: 93–131.

Bukry, D., Douglas, R., King, S. & Krasheninnikov, V., 1971. Planktonic mikrofossil biostratigraphy of the northwestern Pacific Ocean. In: Heezen, B. *et al.* (eds), *Initial Reports of the Deep Sea Drilling Project*, 6: 1253–1300.

Bystricka, H., Leško, B. & Samuel, O., 1970. Stratigrafia paleogennych serie severne od Malé Domase. (In Slovak only). *Geologickie Prace, Spravy*, 51: 149–163.

Cavelier, C., 1979. La limite Éocene–Oligocene en Europe occidentale. *Sciences Géologiques Mémoire*, 54: 280 pp.

Chaney, R. W., 1940. Tertiary forests and continental history. *Geological Society of America Bulletin*, 51: 469–488.

Chrząstowski, J. & Ostrowicka, H., 1978. Budowa geologiczna i surowce mineralne regionu muszyńskiego (In Polish only). *Zeszyty Naukowe Uniwersytetu Jagiellońskigo*, D VI, Pr. Hist., 60: 12–44.

Cieszkowski, M., 1992. Marine Miocene deposits near Nowy Targ, Magura Nappe, Flysch Carpathians (South Poland). *Geologica Carpathica*, 46: 339–346.

Cieszkowski, M. & Olszewska, B., 1986. Malcov Beds in Magura nappe near Nowy Targ, Outer Carpathians, Poland. *Annales Societatis Geologorum Poloniae*, 56: 53–71.

Dudziak, J., 1991. Age of Palaeogene deposits in the Bystrica subunit (Magura Nappe, Polish Carpathians) based on the calcareous nannoplankton. *Bulletin of the Polish Academy of Sciences, Earth Sciences*, 39 (4): 331–341.

Edwards, A. R., 1971. A calcareous nannoplankton of the New Zeland Palaeogene. In: Farinacci, A. (ed.). *Proceedings of the Second Plantktonic Conference Roma, 1970.* Edizioni Tecnoscienza, Rome, 1: 381–419.

Fornaciari, E. & Rio, D., 1996. Latest Oligocene to Early Middle Miocene quantitative calcareous nannofossil biostratigraphy in the Mediterranean region. *Micropaleontology*, 42: 1–37.

Fornaciari, E., di Stefano, A., Rio, D. & Negri, A., 1996. Middle Miocene quantitative calcareous nannofossil biostratigraphy in the Mediterranean region. *Micropaleontology*, 42: 38–64.

Gedl, P., 1999. Palinologiczny zapis granicy eocen–oligocen w polskich Karpatach fliszowych – wyniki wstępne (In Polish only). *Przegląd Geologiczny*, 47: 394–398.

Golonka, J. & Rączkowski, W., 1983. Szczegółowa Mapa Geologiczna Polski 1: 50 000, arkusz Piwniczna (In Polish only). Wydawnictwa Geologiczne, Warszawa.

Golonka, J., Ross, M. & Scotese, C., 1994. Phanerozoic paleogeography and paleoclimatic modeling maps. *Canadian Society of Petroleum Geologist Memoir*, 17: 1–47.

Haq, B. U., 1971. Palaeogene calcareous nannoflora. Part IV: Palaeogene nannoplankton biostratigraphy and evolutionary rates in Cenozoic calcareous nannoplankton. *Stockholm Contribution in Geology*, 24: 129–158.

Haq, B. U., 1973. Transgressions, climatic change and diversity of calcareous nannoplankton. *Marine Geology*, 15: M25–M30.

Haq, B. U. & Lipps, J. H., 1971. Calcareous nannoplankton and silicoflagellate, Site 69 to 75. In: Tracey, J., Sutton, G. *et al.* (eds), *Initial Reports of the Deep Sea Drilling Project*, 8: 143–146.

Haq, B. U. & Lohmann, G. P., 1976. Early Cenozoic calcareous nannoplankton biogeography of the Atlantic Ocean. *Marine Micropaleontology*, 1: 119–194.

Haq, B. U., Hardenbol, J. & Vail, P. R., 1987. Chronology of fluctuating sea levels since the Triassic. *Sciences*, 235: 1156–1167.

Haq, B.U., Premoli-Silva, I & Lohmann, G. P., 1977. Calcareous plankton paleobiogeographic evidence for major climatic fluctuations in the early Cenozoic Atlantic Ocean. *Journal of Geophysical Research*, 82: 3861–3875.

Hay, W., Mohler, H., Roth, P., Schmidt, R. & Boudreaux, J., 1967. Calcareous nannoplankton zonation of the Cenozoic of the Gulf Coast and Caribbean-Antillean area and transoceanic correlation. *Transaction of Gulf Coast Association of Geological Society*, 17: 428–480.

Janin, M. C., 1992. The discoaster Ray Number Evolution: Stratigraphical Application. In: Decima, F. P., Monechi, S. & Rio, D., (eds), *Proceedings of the International Nannoplankton Association Conference, Firenze, 1989. Memorie di Scienze Geologiche XLIII*: 171–194. Padova.

Kaenel, E. de & Villa, G., 1996. Oligocene–Miocene calcareous nannofossil biostratigraphy and palaeoecology from the Iberia Abyssal Plain. *Proceedings of the ODP, Scientific Results*, 149: 79–145.

Keigwin Jr., L. D., 1980. Palaeoceanographic change in the Pacific at the Eocene–Oligocene boundary. *Nature*, 260: 513–515.

Keigwin, L. D. & Corliss, B. H., 1986. Stable isotopes in late middle Eocene to Oligocene foraminifera. *Geological Society of America Bulletin*, 97: 335–345.

Keller, G., 1983. Paleoclimatic analyses of middle Eocene through Oligocene planktic foraminiferal faunas. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 43: 73–94.

Kemp, E. M., 1978. Tertiary climatic evolution and vegetation history in the southeast Indian Ocean region. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 24: 169–208.

Kopciowski, R., 1996. Geology of the Siary Zone between Ropa and Banica (Magura Nappe). (In Polish, English summary). *Biuletyn Państwowego Instytutu Geolgicznego*, 374: 21–39.

Kopciowski, R. & Garecka, M., 1996. Najmłodsze utwory strefy Siar – jednostki magurskiej. (In Polish only). *Przegląd Geologiczny*, 40: 486–489.

Koszarski, L., 1977. Rozwój najmłodszych osadów wschodniej części płaszczowiny magurskiej. (In Polish only). *Sprawozdania z Posiedzeń Komisji Naukowych PAN Oddział w Krakowie* XX/1 (I-VI 1976): 174–175.

Koszarski, L. & Koszarski, A., 1985. Marginale zone of the Magura Nappe and its relation to lower units. In: Koszarski, L. (ed.), *Geology of the Middle Carpathians and Carpathian Foredeep. Guide to Excurs. 3, Carpatho- Balkan Geological Association, 13 Congress (Cracow, Poland 1985)*: 1–254. Kraków.

Koszarski, L. & Tokarski, A., 1968. Szczegółowa Mapa Geologiczna Polski (bez utworów czwartorzędowych). Arkusz M34-91B Osiek – wydanie tymczasowe. (In Polish only). Instytut Geologiczny.

Krhovský, J., 1981a. Stratigrafie a paleontologie menilitoveho souvrstvi zdanicke jednotky a diatomiu pouzdranske jednotky (In Czech only). *Zemny Plyn a Nafta*, 26 (1): 45–62.

Krhovský, J., 1981b. Microbiostratigraphic correlations in the Outer Flysch Units of the southern Moravia and influence of the eustasy on their palaeogeographical development. *Zemny Plyn Nafta*, 26 (4): 665–688 and 955–975.

Krhovský, J., Adamowá, J., Hladíkowá, J. & Maslowská, H., 1992. Paleoenviromental changes across the Eocene/Oligocene boundary in the Ždanice and Pouzdrany Units (Western Carpathians, Chechoslovakia) : The long- term trend and orbitally forced changes in calcarous nannofossil assemblages. In: Hamrsmid, B. & Young, J. (eds), Nannoplankton research. *Proceedings of Fourth INA Conference, Prague, 1991*, Knihovnička zemniho plynu a nafty, Hodonin, 2: 105–187.

Książkiewicz, M., 1966. Geologia regionu babiogórskiego. (In Polish only). *Przewodnik 39 Zjazdu Polskiego Towarzystwa Geologicznego*, Instytut Geologiczny, Warszawa. 5–59.

Książkiewicz, M., 1974. Szczegółowa Mapa Geologiczna Polski 1: 50 000, arkusz Sucha Beskidzka.(In Polish only). Instytut Geologiczny, Warszawa.

Leopold, E. B. & MacGinitie, H. D., 1972. Development and affinities of Tertiary floras in the Rocky Mountains. In Graham, A. (ed.), *Floristics and paleofloristics of Asia and Eastern North America.* Amsterdam, Elsevier, pp.147–200.

Leszczyński, S., 1997. Origin of the Sub- Menilite Globigerina Marl (Eocene–Oligocene transition) in the Polish Outer Carpathians. *Annales Societatis Geologorum Poloniae*, 67: 367–427.

Martini, E., 1970. Standard Palaeogene calcareous nannoplankton zonation. *Nature*, 226: 560–561.

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

Martini, E., 1981. Nannoplankton in der Ober-Kreide, im Alttertiar und im tieferen Jungtertiar von Suddeutschland und dem angrenzenden Osterreich. *Geologica Bavarica*, 82: 345–356.

Martini, E., 1986. Palaeogene calcareous nannoplankton from the southwest Pacific Ocean, Deep Sea Drilling Project, Leg 90. *Initial Reports of the Deep Sea Drilling Project*, 90: 747–761.

Martini, E. & Müller, C., 1986. Current Tertiary and Quaternary calcareous nannoplankton stratigraphy and correlations. *Newsletter on Stratigraphy*, 16 (2): 99–112.

Martini, E. & Ritzkowski, S., 1968. Was ist das "Unter- Oligocän"? Eine analyse der Beyrisch'schen und V. Koenen'schenfassung der Stufe mit Hilfe des fossilen Nannoplanktons. *Akademie der Wissenschaften Göttingen, Nachrichten, II. Mathematische - Physische Kl.*, 1968, 13: 231–250.

Martini, E. & Worsley, T., 1970. Standard Neogene calcareous nannoplankton zonation. *Nature*, 225: 289–290.

Marunteanu, M., 1992. Distribiution of the the Miocene calcareous nannofossils in the Intra- and Extra- Carpathian areas of Rumania. In: Hamrsmid, B. & Young, J. (eds), *Nannoplankton research – Proceedings of Fourth INA Conference, Prague, 1991.* Knihovnička zemniho plynu a nafti, Hodonin, 2: 247–262.

McIntyre, A., & Bé, A. H., 1967. Modern Coccolithophoridae of the Atlantic Ocean. *Deep Sea Research*, 14: 561–597.

Melinte, M., 1995. Changes in nannofossil assemblages during the Oligocene – Lower Miocene interval in the Eastern Carpathians and Transylvania. Abstracts 10th RCMNS, Bucharest 1995, *Romanian Journal of Stratigraphy*, 76, suppl., 7: 171–172.

Miziołek, M., 1990. *Budowa geologiczna i stratygrafia osadów w Kotlinie Ropianki (Beskid Niski na S od Dukli).* (In Polish only). Unpublished Msc. Thesis. Jagiellonian Uniwersity, Kraków, 128 pp.

Monechi, S., 1986. Calcareous nannofossils events around the Eocene–Oligocene boundary in the Umbrian Apennines (Italy).

Palaeogeography, Palaeoclimatology, Palaeoecology, 57: 61–69.
Müller, C., 1970. Nannoplanktonen-Zonen der Unteren Meeresmolasse Bayerns. *Geologica Bavarica*, 63: 107–118.
Müller, C., 1978. Remarks on biostratigraphic useful nannofossils in the Palaeogene of the northern hemisphere. *Newsletter on Stratigraphy*, 7: 45–52.
Nagymarosy, A. & Voronina, A., 1992. Calcareous nannoplankton from the Lower Maykopian beds (early Oligocene, Union of Independent States). In Hamrsmid, B. & Young, J.(eds), Nannoplankton research. *Proceedings of Fourth INA Conference, Prague, 1991*, Knihovnička zemniho plynu a nafti, Hodonin, 2: 187–221.
Nocchi, M., Monechi, S., Coccioni, R., Madile, M., Monaco, P., Orlando, M., Parisi, G. & Premoli-Silva, I., 1988a. The extinction of Hantkeninidae as a marker for recognising the Eocene–Oligocene boundary. A proposal. In Coccioni, R. *et al.* (eds), *International Subcommission of Palaeogene strata, E/O Meetieng, Ancona October 1987, Special Publication*, 1: 249–252.
Nocchi, M., Parisi, G., Monaco, P., Monechi, S. & Madile, M. 1988b. Eocene and Early Oligocene micropaleontology and paleoenvironments in SE Umbria, Italy. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 67: 181–244.
Oberhänsli, H. & Hsü, K. G., 1986. Paleocene–Eocene paleoceanography. In Hsü, K. G., (ed.), Mesozoic and Cenozoic Oceans. *American Geophysical Union Geodynamics Series*, 15: 85- 100.
Okada, H. & Bukry, D., 1980. Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation. *Marine Micropaleontology*, 5 (3): 321–325.
Okada, H. & Honjo, S., 1973. The distribution of oceanic coccolithophorids in the Pacific. *Deep-Sea Research*, 20: 355–374.
Okada, H. & Honjo, S., 1975. The distribution of Coccolithophores in marginal sea along the western Pacific Ocean and in the Red Sea. *Marine Biology*, 31: 271–285.
Olszewska, B. & Smagowicz, M., 1977. Porównanie podziałów biostratygraficznych górnej kredy i paleogenu jednostki dukielskiej na podstawie otwornic planktonicznych i nannoplanktonu wapiennego. (In Polish only). *Przegląd Geologiczny*, 25: 359–364.
Ostrowicka, H., 1966. Profil litologiczny gruboławicowych piaskowców w Piwnicznej.(In Polish only). *Sprawozdania z Posiedzeń Komisji Naukowych PAN, Oddział w Krakowie*, 10 (2): 608–610.
Ostrowicka, H., 1979. Lithostratigraphy of the Magura nappe in the vicinity of Piwniczna (Polish Flysch Carpathians). (In Polish, English summary). *Rocznik Polskigo Towarzystwa Geologicznego*, 49: 67–84.
Oszczypko, M., 1996. Calcareous nannoplankton of the Globigerina Marls (Leluchów Marls Member), Magura Nappe, West Carpathians. *Annales Societatis Geologorum Poloniae*, 66: 1–15.
Oszczypko, N., 1973. The geology of the Nowy Sącz Basin. (In Polish, English summary) *Biuletyn Instytutu Geologicznego*, 273: 101–190.
Oszczypko, N., 1979. Geology of the northern slopes of the Beskid Sądecki Mts between Dunajec and Poprad rivers (Magura Nappe, Carpathians, Poland). *Rocznik Polskigo Towarzystwa Geologicznego*, 49 (3-4): 293–325.
Oszczypko, N., 1991. Stratigraphy of the Palaeogene deposits of the Bystrica Sub-unit (Magura Nappe, Polish Outer Carpathians). *Bulletin of the Polish Academy of Sciences Earth Sciences*, 39 (4): 415–431.
Oszczypko, N., 1992a. Late Cretaceous through Palaeogene evolution of Magura Basin. *Geologica Carpathica*, 43: 333–338.
Oszczypko, N., 1992b. Evolution of the Magura Basin in Late Cretaceous and Palaeogene. (In Polish, English summary). *Przegląd Geologiczny*, 7: 397–404.
Oszczypko, N., 1998. The Western Carpathians Foredeep-development of the foreland basin in front of the accretionary wedge and its burial history (Poland). *Geologica Carpathica*, 49: 415–431.
Oszczypko, N., 1999. From remnant oceanic basin to collision-related foreland basin – a tentative history of the Outer Western Carpathians. *Geologica Carpathica*, 50, special issue: 161–163.
Oszczypko, N. & Oszczypko-Clowes, M., 2002. The new findings of Lower Miocene deposits in the Nowy Sącz area (Magura Nappe, Polish Outer Carpathians). *Geological Quarterly*, 46(1).
Oszczypko, N. & Wójcik, A., 1992. *Szczegółowa Mapa Geologiczna Polski, arkusz Nowy Sącz*. (In Polish only). Polska Agencja Ekologiczna S. A., Warszawa.
Oszczypko, N., Dudziak, J. & Malata, E., 1990. Stratigraphy of the Cretaceous through Palaeogene deposits of the Magura Nappe in the Beskid Sądecki Range, Polish Outer Carpathians. *Studia Geologica Polonica*, 97: 109–181.
Oszczypko, N., Malata, E., Oszczypko-Clowes, M. & Duńczyk, L., 1999a. Geology of the Krynica area (Magura Nappe, Polish Outer Carpathians). (In Polish, English summary). *Przegląd Geologiczny*, 47: 549–559.
Oszczypko, N., Andreyeva-Grigorovich, A. S., Malata, E. & Oszczypko-Clowes, M., 1999b. The Lower Miocene deposits of the Rača Subunit near Nowy Sącz (Magura Nappe, Polish Outer Carpathians). *Geologica Carpathica*, 50: 1–15.
Oszczypko, N., Malata, E. & Oszczypko-Clowes, M., 1999c. Revised position and age othe the Eocene deposits on the northern slope of the Gorce Range (Bystrica Subunit, Magura Nappe, Polish Western Carpathians). *Slovak Geological Magazine*, 5: 235–254.
Oszczypko-Clowes, M., 1998. Late Eocene–Early Oligocene calcareous nannoplankton and stable isotopes ($\delta^{13}C$, $\delta^{18}O$) of the Globigerina Marls in the Magura Nappe (West Carpathians). *Slovak Geological Magazine*, 4: 95–107.
Oszczypko-Clowes, M.,1999. The Late Eocene to Early Miocene nannoplankton stratigraphy of the Magura Nappe (Western Carpathians, Poland). *Geologica Carpathica*, 50, special issue: 59–62.
Oszczypko-Clowes, M., 2000. *Lithostratigraphy and nannofossils biostratigraphy of the youngest deposits from the middle part of the Magura Nappe (Polish Outer Carpathians)*. PhD Thesis. Jagiellonian Uniwersity, Kraków, 180 pp.
Perch-Nielsen K., 1971. Elektronmikroskopische Untersuchungen an Coccolihten und vervandten Formen aus dem Eozan von Danemark. *Det. Kongelige DanskeVidenskabernes selskab Biologia Skrifter*, 18 (3): 1–76.
Perch-Nielsen, K., 1985. Cenozoic calcareous nannofossils,. In: Bolli, H., Saunders, J. S. and Perch-Nielsen, K. (eds), *Plankton Stratigraphy*. Cambridge University Press 11: 427–554.
Perch-Nielsen, K., 1986. Calcareous nannofossil events at the Eocene–Oligocene boundary. In: Pomerol, Ch. & Premoli-Silva, I. (eds), *Terminal Eocene events*. Elsevier, Amsterdam, pp. 275–287.
Pomerol, Ch. & Premoli-Silva, I., 1986. The Eocene–Oligocene transition: Events and boundary. In: Pomerol, Ch. & Premoli-Silva, I. (eds), *Terminal Eocene Events*. Elsevier, Amsterdam, pp. 1–40.
Potfaj, M., 1983. Magura sandstone and Malcov beds in Orava Re-

gion (West Carpathians). (In Slovak, English summary). *Geologickie Prace, Spravy*, 79: 117–140.

Prothero, D. R. Berggren, W. A., 1992. Eocene–Oligocene climatic and biotic evolution. Princeton University Press, Princeton, pp. 309.

Radomski, A., 1967. Some stratigraphic units based on nannoplankton in the Polish Outer Carpathians. *Biuletyn Instytutu Geologicznego*, 211: 385–393.

Radomski, A., 1968. Calcareous nannoplakton zones in Palaeogene of the Western Polish Carpathians. (In Polish, English summary). *Rocznik Polskiego Towarzystwa Geologicznego*, 38: 545–605.

Radomski, A., 1971. Nannoplankton wapienny i jego znaczenie stratygraficzne. (In Polish only). *Postępy Nauk Geologicznych*, 3: 87–114.

Raffi, I. & Rio, D., 1979. Calcareous nannofossil biostratigraphy of DSDP Site 132 – Leg 13 (Tyrrhenian Sea – western Mediterranean). *Rivista Italiana di Paleontologia e Stratigrafia*, 85: 127–172.

Raffi, I., Rio, D., d'Atri A., Fornaciari E. & Rochetti S., 1995. Quantitative distribution patterns and biomagnetostratigraphy of Middle and Late Miocene calcareous nannofossil from western equatorial Indian and Pacific Oceans (Lesg 115, 130 and 138). *Proceedings of ODP, Scientific Results*, 138: 479–502.

Rea, D. K., Zachos, J. C., Owen, R. M. & Gingerich, P. D., 1990. Global change at the Paleocene–Eocene boundary: Climatic and evolutionary consequences of tectonic events. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 79: 117–128.

Retallack, G. J., 1986. Fossil soils as ground for interpreting for long-term controls on ancient rivers. *Journal of Sedimentary Petrology*, 56:1–18.

Roth, P. H., Baumann, P. & Bertolino, V., 1971. Late Eocene–Oligocene calcareous nannoplankton from central and northern Italy. In: Farinacci, A. (ed), *Proceedings of the II Planktonic Conference Roma 1970.* Edizioni Tecnoscienza, Rome, 2: 1069–1097.

Rögl, F., 1999. Mediterranean and Paratethys. Facts and hypotheses of an Oligocene to Miocene paleogeography (short overwiev). *Geologica Carpathica*, 50: 339–345.

Rusu, A., 1988. Oligocene events in Transylvania (Romania) and the first separation of Paratethys. *Dari de seama Institutului de Geologie si Geofizica*, 72-73 (1985; 1986), 5: 207–223.

Rusu, A., Popescu, G. & Melinte, M., 1996. Oligocene–Miocene transition and main geological events in Romania, 28 August - 2 September 1996. A. Excursion guide. Romanian Journal Paleont., 76 suppl., 1: 3–47.

Savin, S. M., 1977. The history of the Earth's surface temperature during the past 100 million years. *Annual Review of Earth and Planetary Sciences*, 5: 319–355.

Shackleton, N. J., 1986. Palaeogene stable isotope events. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 57: 91–102.

Shackleton, N. J. & Kennet, J. P., 1975. Paleotemperature history of the Cenozoic and the initiation of Antarcic glaciation: oxygene and carbon isotope analyses in D.S.D.P. sites 272, 279 and 281. *Initial Reports of the Deep Sea Drilling Project*, 29: 743–755.

Shackleton, N. J. & Boersma, A., 1981. The climate of the Eocene ocean. *Journal Geological Society of London*, 138: 153–157.

Sikora, W., 1968. Szczegółowa Mapa Geologiczna Polski (bez utworów czwartorzędowych). Arkusz M34-91A Gorlice – wydanie tymczasowe. (In Polish only). Instytut Geologiczny, Warszawa.

Sikora, W., 1970. Geology of the Magura Nappe between Szymbark Ruski and Nawojowa. (In Polish, English summary). *Biuletyn Instytutu Geologicznego*, 235: 5–121.

Sloan, L. & Barron, E. J., 1992. Palaeogene climatic evolution: A climate model investigation of the influence of continental elevation and sea-surface temperature upon continental climate. In: Prothero, D. R. & Berggren, W. A. (eds), *Eocene–Oligocene climatic and biotic evolution.* Princeton University Press, Princeton, pp. 202–217.

Ślączka, A., 1967. Szczegółowa Mapa Geologiczna Polski (bez utworów czwartorzędowych). Arkusz M34-92C Tylawa – wydanie tymczasowe. (In Polish only). Instytut Geologiczny, Warszawa.

Ślączka, A. & Miziołek, M., 1995. Geological setting of Ropianka Beds in Ropianka (Polish Carpathians). (In Polish, English summary) *Annales Societatis Geologorum Poloniae*, 65: 29–41.

Ślączka, A. & Kaminski, M., 1998. A guidebook to Excursions in the Polish Flysch Carpathians. *Grzybowski Foundation Special Publication.* 165 pp.

Theodoridis, S. A., 1984. Calcarous nannofossils of the Miocene and revision of the helicoliths and discoasters. *Utrecht Micropaleontological Bulletins*, 32. Utrecht. 271 pp.

Van Couvering, J. A., Aubry, M. P., Berggren, W. A., Bujak, J. P., Naeser, C. W. & Wieser, T., 1981. The Terminal Eocene Event and the Polish connection. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 36: 321–362.

Varol, O., 1989. Eocene calcareous nannofossils from Sile (northwest Turkey). *Revista Espanola de Micropaleontologia*, 2: 273–320.

Varol, O., 1998. Palaeogene. In: Bown, P. (ed.), *Calcareous nannofossil Biostratigraphy.* Kluwer Academic Publishers, Dordrecht: 200–224.

Vozar, J. & Kačer, S. (eds), 1996. Geological map of Slovak Republic. Geological Survey of Slovak Republic, Bratislava.

Wei, W. & Wise Jr., S. W., 1990. Biogeographic gradients of Middle Eocene–Oligocene calcareous nannoplankton in the South Atlantic Ocean. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 79: 29–61.

Widz, D., 1985. Budowa geologiczna rejonu Siary - Sękówka - Ropica Górna. Unpublished Msc. Thesis. Jagiellonian University, Kraków, 84pp.

Wolfe, J. A. 1980. Tertiary climates and floristic relationships at high latitudes in the Northern Hemisphere. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 30: 313–323.

Wolfe, J. A., 1985. Distributions of major vegetational types during the Tertiary. In: Sundquist, E. T., and Broecker, W. S. (eds), The carbon cycle and atmospheric CO_2. Natural variations Archaean to present. *American Geophysical Union Geophysical Monograph*, 32: 357–376.

Wolfe, J. A. & Poore, R. Z., 1982. Tertiary marine and nonmarine climatic trends. In: Berger, W. Crow, U, J. C. (eds.), *Climate in Earth history. National Research Council Studies in Geophysics.* Washington. D.C., National Academy Press, pp. 154–158.

Young, J. 1998. Miocene. In: Bown, P. (ed.), *Calcareous nannofossil Biostratigraphy.* Kluwer Academic Publishers, Dordrecht: 2225–265.

Żytko, K., Gucik, S., Ryłko, W., Oszczypko, N., Zając, R., Garlicka, I., Nemčok, J., Elias, M., Mencik, E., Dvorak, J., Stranik, Z., Rakuš, M. & Matejovska, O., 1989. Geological map of the Western Outer Carpathians and their Foreland without Quaternary formation. In: Poprawa, D. & Nemčok, J. (eds), *Geological Atlas of the Western Outer Carpathians.* Państwowy Instytut Geologiczny, Warszawa.

Streszczenie

BIOSTRATYGRAFIA I WARUNKI PALEOŚRODOWISKOWE NAJMŁODSZYCH OSADÓW PŁASZCZOWINY MAGURSKIEJ NA WSCHÓD OD SKAWY W OPARCIU O NANOPLANKTON WAPIENNY (POLSKIE KARPATY FLISZOWE)

Marta Oszczypko-Clowes

W polskiej części płaszczowiny magurskiej najmłodsze osady zachowały się na północy, w strefie Siar oraz na południu, w strefie krynickiej (Fig. 1, 2). Na północy najmłodsze osady należą do warstw z Budzowa, na południu do formacji malcowskiej. W strefie Siar obszary występowania warstw budzowskich mają charakter zwarty (Fig. 3–17). Po stronie słowackiej izolowane wystąpienia formacji malcowskiej znane są z wąskich stref synklinalnych na granicy stref krynickiej i bystrzyckiej oraz bystrzyckiej i raczańskiej. Najbardziej zachodnie występowanie formacji malcowskiej w strefie raczańskiej znane jest z okolic Nowego Sącza (Fig. 18–26). W strefie krynickiej formacja malcowska ograniczona jest do izolowanych brachysynklin, które są usytuowane w strefie przypienińskiej, na wschód od Popradu oraz z okolic Nowego Targu (Cieszkowski & Olszewska, 1986) (Fig. 27–34). Zarówno w części północnej, jak i południowej najmłodsze osady należą do późnego oligocenu. Pozwala to sądzić, iż pomimo istotnych różnic w wykształceniu facjalnym osadów deponowanych w północnej (warstwy budzowskie) i południowej części basenu (formacja malcowska), czas zakończenia depozycji w obu częściach basenu był w przybliżeniu ten sam. Być może sedymentacja formacji malcowskiej (NP25) zakończyła się nieco później od depozycji warstw budzowskich (NP24). Sedymentcja formacji z Zawady (NN2) prawdopodobnie związana była z innym, najmłodszym epizodem rozwoju basenu magurskiego. Obecność formacji malcowskiej oraz formacji z Zawady w Kotlinie Sądeckiej, pod przykryciem utworów późnego badenu–sarmatu może sugerować, że obecne rozprzestrzenienie formacji malcowskiej związane jest z posarmackim wypiętrzeniem i ścięciem erozyjnym płaszczowiny magurskiej. Sądząc z wieku odsłaniających się na powierzchni utworów, najsilniej wypiętrzona i zerodowana została środkowa część płaszczowiny magurskiej (między Dunajcem i Skawą), a najsłabiej część wschodniosłowacka. Nie można jednak wykluczyć, że brak śladów utworów późnoeoceńsko–oligoceńskich w północnej części strefy krynickiej oraz w strefie bystrzyckiej może wynikać z wcześniejszych uwarunkowań.

Badania nanoplanktonu wapiennego pozwoliły udokumentować wiek opisywanych utworów, który mieści się w przedziale od eocenu środkowego (NP15) po późny oligocen (NP25) oraz wczesny miocen (NN2) (Fig. 35). Z uwagi na częstotliwość występowania i sposób zachowania nanoplanktonu wapiennego (Fig. 36–42) najlepiej udokumentowane zostały profile w strefie Siar oraz formacja malcowska w Leluchowie (strefa krynicka). Największym ubóstwem nanoplanktonu odznaczały się piaskowcowe ogniwa formacji magurskiej. Dodatkowym czynnikiem utrudniającym badania tej formacji był spory udział form redeponowanych. Największa redepozycja, przy równoczesnym obfitym występowaniu form autochtonicznych, stwierdzona została w formacji z Zawady (por. Oszczypko *et al.*, 1999b), co świadczy o intensywnej erozji utworów eoceńskich na obrzeżeniu wczesnomioceńskiego zbiornika.

Granica eocen/oligocen przebiega w obrębie poziomu NP21 tj. w obrębie margli globigerinowych w strefie krynickiej (Leluchów), w obrębie ogniwa popradzkiego formacji magurskiej w strefie raczańskiej oraz piaskowców z Wątkowej, warstw budzowskich oraz warstw zembrzyckich (Fig. 43, 44). W północnej części strefy krynickiej oraz w całej strefie bystrzyckiej poziom ścięcia erozyjnego usytuowany jest poniżej tej granicy.

Analiza autochtonicznych zespołów nanoplanktonu wapiennego płaszczowiny magurskiej wykazuje jednoznaczne zmniejszanie się zróżnicowania gatunkowego. W porównaniu ze środkowym eocenem ilość gatunków, począwszy od późnego eocenu gwałtownie się zmniejsza. Najniższym stopniem zróżnicowania gatunkowego charakteryzują się osady wczesnego oligocenu. Równocześnie zespoły umiarkowanych szerokości geograficznych zostały wzbogacone w gatunki zimnolubne. W jakim stopniu zmiany te odzwierciedlają spadek temperatury wód oceanicznych, a w jakim stopniu postępującą eutrofizację basenu nie jest możliwe do jednoznacznego rozstrzygnięcia. Niewątpliwie te same gatunki nanoplanktonu wskazują, że w oligocenie w zbiorniku magurskim następowała eutrofizacja stowarzyszona z oziębianiem się wód powierzchniowych. W oligoceńskim basenie magurskim najlepiej udokumentowane zostało zjawisko wysłodzenia. Pierwsze oznaki zmian w zasoleniu zaznaczają się już we wczesnym rupelu (NP22), jednakże maksymalne wysłodzenie miało miejsce dopiero w środkowym rupelu (NP23). Wydarzenie to można wiązać z maksymalną izolacją Paratetydy (Baldi, 1980; Rusu, 1988; Rögl, 1999). W Leluchowie wysłodzenie zaznacza się w obrębie łupków ze Smereczka (łupki menilitowe). Według Gedla (1999) w przeciwieństwie do niżej leżących margli globigerinowych, w łupkach menilitowych zespoły palinofacji prawie całkowicie składają się z elementów lądowych.

Odkrycie dolnomioceńskich, sfałdowanych osadów w płaszczowinie magurskiej wymaga modyfikacji dotychczasowych interpretacji paleogeograficznych. Istotne znaczenie ma wyjaśnienie czy sedymentacja formacji z Zawady (NN2) odbywała się w ciągłości z osadami oligoceńskimi formacji malcowskiej i warstw budzowskich czy też poprzedzona została fałdowaniami i erozją (Oszczypko *et al.*, 1999b). Wyjaśnienia wymaga również problem połączenia zatoki mioceńskiej w Kotlinie Sądeckiej z Orawą, basenami wiedeńskim i wschodniosłowackim.