Geological Quarterly, 2002, **46** (2): 117–133

Newly discovered Early Miocene deposits in the Nowy Sącz area (Magura Nappe, Polish Outer Carpathians)

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Oszczypko N. and Oszczypko-Clowes M. A. (2002) — Newly discovered Early Miocene deposits in the Nowy Sącz area (Magura Nappe, Polish Outer Carpathians). Geol. Quart., **46** (2): 117–133. Warszawa.

In the Nowy Sącz area Early Miocene marine deposits have been discovered in the southern part of the Rača Subunit, and at the front of the Bystrica Subunit of the Magura Nappe. These deposits belong to the Zawada Formation, which is represented by medium- to thick-bedded glauconitic sandstones with intercalations of thick-bedded marls and marly claystones. The formation is at least 550 m thick. Calcareous nannofossils show the age of the formation to be Early Burdigalian (NN1–2–3 biozones). Due to a lack of exposures the relationship between the deposits of the Malcov and the Zawada formations is not yet clear. However, comparing the youngest age of the Malcov Formation in the Nowy Sącz I borehole (NP 25) with the age of the Zawada Formation suggests sedimentary continuity transition between these formations.

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Key words: Outer Carpathians, Magura Nappe, Early Miocene, calcareous nannoplankton, palaeotectonic implications.

INTRODUCTION

The Magura Nappe, the largest and innermost tectonic unit of the Western Carpathians, is subdivided into four facies-tectonic subunits (Fig. 1). From south to the north these are: the Krynica, Bystrica, Rača and Siary subunits (Koszarski *et al*., 1974). These subunits comprise stratigraphic successions which young progressively towards the north, registering stages in the development of the Magura accretionary wedge. According to traditional opinion the outer Carpathian flysch basin was progressively folded from south to north, towards the North European Platform. Constraining this concept involves understanding the role of the youngest deposits of the Magura Nappe in the evolution and palaeogeography of the Outer Carpathian fold and thrust belt. There is common agreement (see Książkiewicz ed., 1962; Bieda *et al*., 1963; Geroch *et al*., 1967; Korab and Durkovič, 1978), that the Fore-Magura Group of units contain transitional lithofacies which linked the Silesian and Magura basins. This opinion is consistent with the view of Książkiewicz (1957) that, during the Late Cretaceous to Eocene, the Silesian Cordillera separated the western part of the Magura Basin from the Silesian Basin. This concept was recently questioned by Nemčok *et al*. (2000), who regards the Magura Basin as a western prolongation of the Silesian Basin. According to Nemčok the present-day position of the Magura Nappe is a result of the Mid-Miocene eastwards escape of the Alcapa terrain together with the Pieniny Klippen Belt (PKB) and the Magura Nappe in relation to the Fore-Magura/Silesian Group of units. In the Western Carpathians, the Magura Nappe is best exposed and recognised in Poland. During the last forty years a relationship between the Late Cretaceous-Eocene stratigraphic record of the Magura Nappe and the more external units (so-called “Moldavides” *sensu* Sandulescu, 1988) was established in this region. The discovery of Late Oligocene/Early Miocene deposits in the Magura Nappe makes possible the correlation of the youngest deposits from the Magura Nappe with those from the Dukla/Silesian units. This correlation may result in a clearer understanding of the terminal stages of the development of the Outer Carpathians. This work documents new findings of Early Miocene deposits in the Magura Nappe.

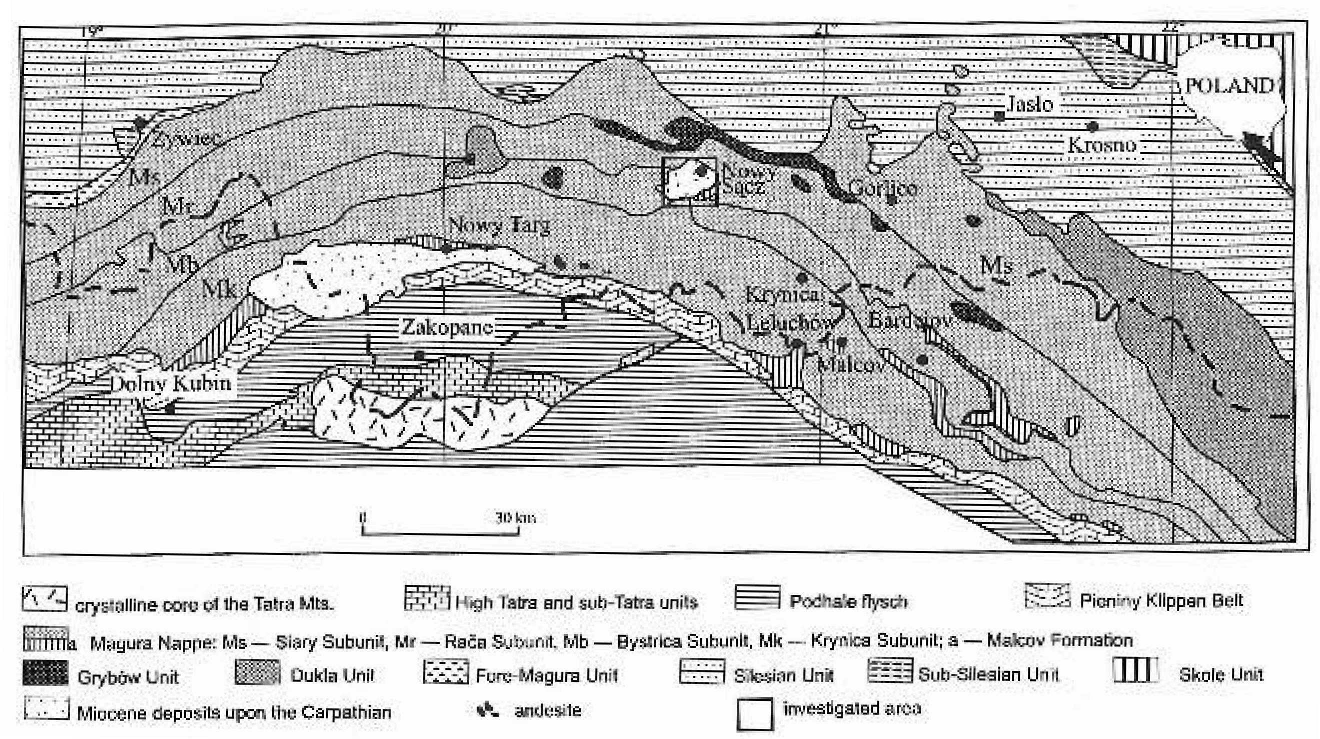


Fig. 1. Tectonic position of the Magura Nappe in Poland and Slovakia (after Żytko *et al*., 1989; supplemented)

PREVIOUS STUDIES

During the 130 years history of stratigraphical studies in the Magura Nappe, opinion concerning the age of the youngest deposits has changed considerably. Until the 1950's, the Late Eocene Magura Sandstones were regarded as the youngest deposits in the Magura Nappe. In 1959, Książkiewicz and Leško discovered, in the Eastern-Slovakian part of the Magura Nappe, deposits similar in facies development and stratigraphical position to the Oligocene Menilite and Krosno beds of the Outer Flysch Carpathians (see also Nemčok, 1961). These deposits are known as the Malcov Beds or Malcov Formation (see Świdziński, 1961*a*, *b*; Birkenmajer and Oszczypko, 1989). In the Polish part of the Magura Nappe, the Malcov Formation has been found in a few isolated localities. At first these beds were recognised in the Leluchów section (Figs. 1 and 2) on the Polish-Slovakian border (see Świdziński, 1961*b*; Blaicher and Sikora, 1967; Nemčok, 1985; Birkenmajer and Oszczypko, 1989; Chrząstowski *et al*., 1995; Oszczypko, 1996; Oszczypko-Clowes, 1998). Later on, the Malcov Formation was described from the Rača Subunit in the Nowy Sącz Basin (Figs. 1 and 3) (Oszczypko, 1973; Blaicher and Oszczypko, 1975) and from the Nowy Targ area (Cieszkowski and Olszewska, 1986) close to the PKB. In the early 1990's Olszewska and Smagowicz (in Cieszkowski, 1992), on the basis of foraminiferal and nannoplankton studies, determined the age of the Waksmund and Stare Bystre beds (Peri-Klippen Belt Zone of the Magura Nappe) as Late Oligocene to Mid-Miocene. According to Cieszkowski (1992), these deposits should be regarded as the uppermost part of the continuous Paleogene/Miocene succession of the Magura Nappe in the Krynica Subunit. Taking into account the lack of information concerning the age of the youngest Paleogene deposits in this area, as well as the lack of exposures showing continuous transition between the Eocene/Oligocene Magura Nappe and Early/Mid-Miocene Waksmund Formation, this opinion is difficult to sustain. Early Miocene deposits have also been documented in the Nowy Targ PIG 1 borehole (Paul and Poprawa, 1992).

The next important stage was the discovery of the Early Miocene Zawada Formation in the Nowy Sącz 4 borehole (Oszczypko *et al*., 1999) and in the Biegonice section (Oszczypko-Clowes, 2001) in the Nowy Sącz area.

The Nowy Sącz 4 borehole was situated in the Zawada hamlet on the SE periphery of the Nowy Sącz Basin (Fig. 3). The borehole penetrated deposits which were formerly described as the Malcov Formation of the Rača Subunit (Oszczypko, 1973). In the Nowy Sącz 4 borehole (Fig. 3) two different lithological and stratigraphical successions were recognised beneath 10 m of Quaternary loams. The upper succession (from 10.0–12.8 m depth) is represented by non-calcareous, bluish-grey shales with thin intercalations of red shales. The age of these deposits was determined as Late Mid-Eocene (see Oszczypko *et al*., 1999).

The lower succession penetrated at a depth of 12.8–25 m, comprises alternating beds of grey-bluish, dark brown and green calcareous mudstones and green to brown calcareous claystones. The deposits are intercalated by light grey, calcareous, glauconitic sandstones. These medium- to thick-bedded sand-

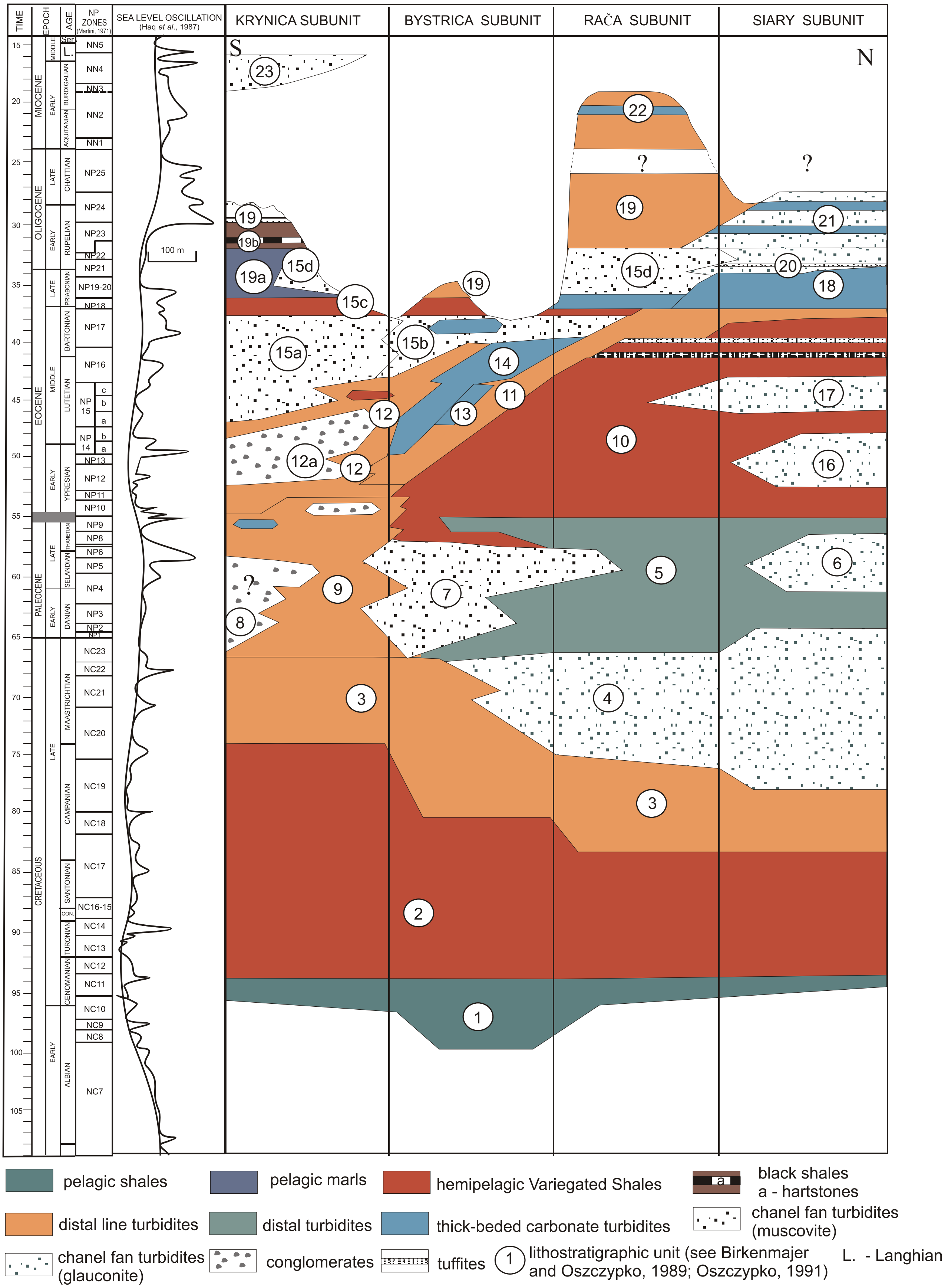


Fig. 2. Lithostratigraphy of the Magura Nappe in Poland (after Oszczypko *et al*., 1999; changed)

1 — Hulina Formation; 2 — Malinowa Formation; 3 — Hałuszowa Formation and Kanina Beds; 4 — Jaworzynka Beds; 5 — Ropianka Beds; 6 — Mutne and Łyska sandstones; 7 — Szczawina sandstones; 8 — Jarmuta Formation; 9 — Szczawnica Formation; 10 — Łabowa Formation; 11 — Beloveza Formation; 12 — Zarzecze Formation: 12a — Krynica Sandstone Member; 13 — Bystrica Formation; 14 — Żeleźnikowa Formation; Magura Formation: 15a — Piwniczna Member, 15b — Maszkowice Member, 15c — Mniszek Member, 15d — Poprad Member; 16 — Ciężkowice Sandstones; 17 — Pasierbiec Sandstones; 18 — Zembrzyce (sub-Magura) Beds; 19 — Malcov Formation: 19a — Leluchów Marls Member, 19b — Smereczek (Menilite) Member; 20 — Wątkowa Sandstone; 21 — Budzów (supra-Magura) Beds; 22 — Zawada Formation; 23 — Stare Bystre Beds

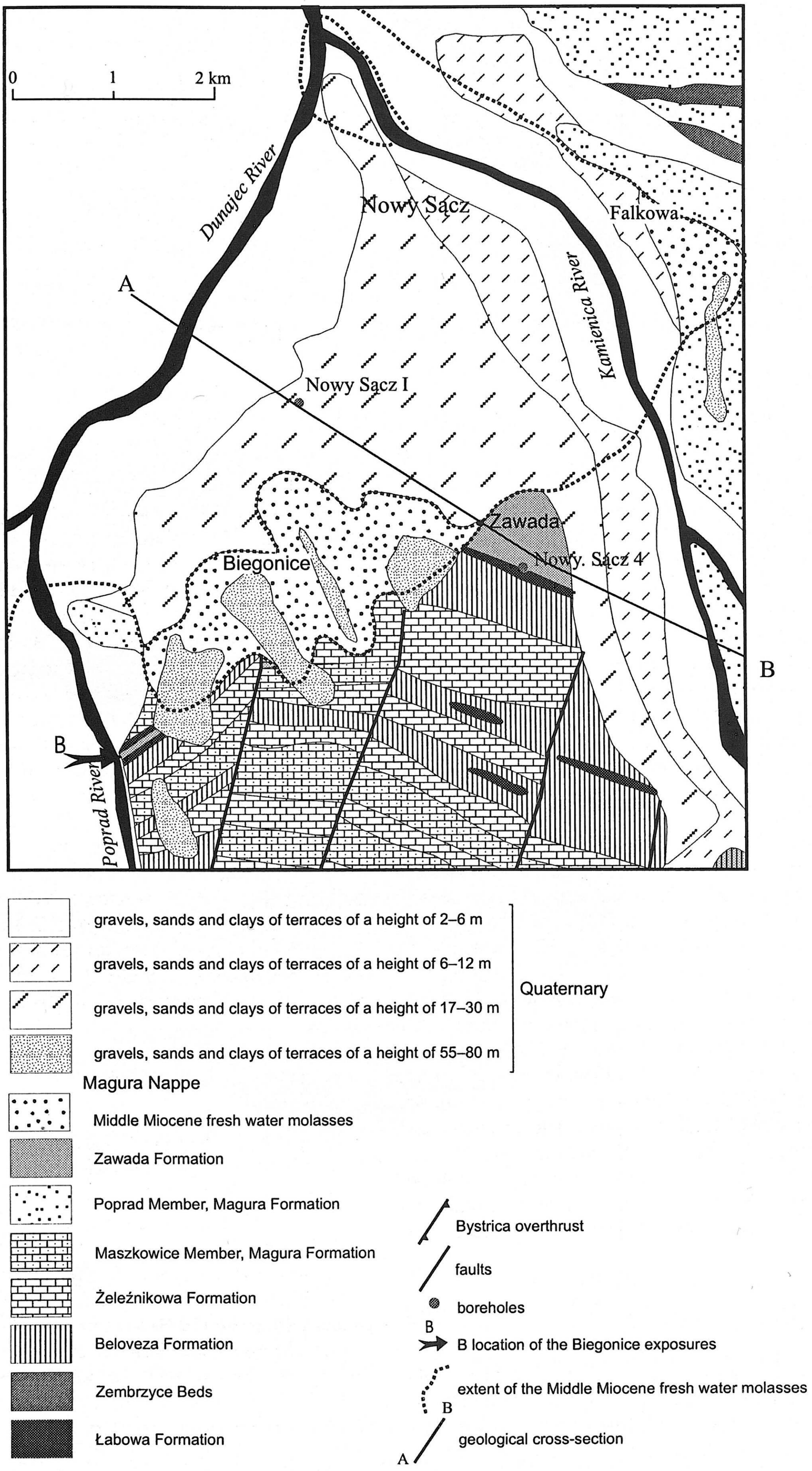


Fig. 3. Geological map of the Nowy Sącz area (after Oszczypko and Wójcik, 1992 and Oszczypko *et al.*, 1999)

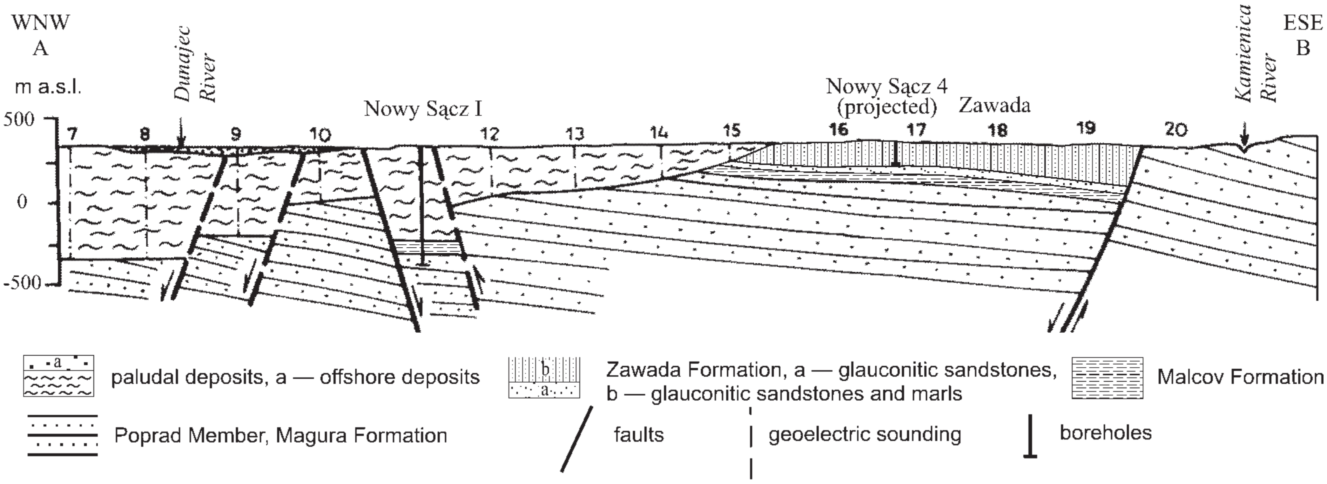


Fig. 4. Geological cross-section (after Oszczypko, 1973 and Oszczypko *et al.,* 1999) (for location see Fig. 3)

stones are fine- to medium-grained and contain green siliceous veinlets. At the depth interval of 12.8–14.35 m the angle of dip is 10–40° with bedding the right way up, whereas at the depth interval of 11.4–16.8 m the deposits are tectonically disturbed, and the angle of dip varies from 5 to 80°. At the depth interval of 23.5–23.8 m, the dip varies from 40° up to vertical and overturned attitudes at the base of the succession. Deposits found at 12.8–25 m depth interval were assigned to the Zawada Formation of the Rača Subunit (Oszczypko *et al*., 1999). On the basis of foraminiferal and calcareous nannoplakton studies, the age of the Zawada Formation was determined as Early Miocene (N5, NN2–3 zones), which is the same as that of the youngest strata in the Silesian and Skole units (see Koszarski *et al*., 1995; Ślęzak *et al*., 1995; Olszewska, 1997). The facies development of the Zawada Formation is similar to the glauconitic facies characteristic of the northern, marginal part of the Magura Basin (see also Oszczypko, 1973; Oszczypko *et al*., 1999).

The Biegonice section (Oszczypko, 1973) is located on the right bank of the Poprad River (Fig. 3). Oszczypko (1973) assigned this sequence to the Malcov Formation of the Rača Subunit. The age was determined by Blaicher (see Blaicher and Oszczypko, 1975) as Oligocene. The foraminifera from the Biegonice section were compared with those from the Middle Krosno Beds at Niebylec (Blaicher and Oszczypko, 1975). According to recent data, the age of the youngest foraminifera from the Biegonice sections are not older than Early Miocene (Oszczypko *et al*., 1999). Calcareous nannoplankton obtained from the Biegonice sections were recently studied by Oszczypko-Clowes (2001) who assigned these deposits to NN2.

GEOLOGICAL SETTING

After the discovery of the Early Miocene deposits in the Nowy Sącz 4 borehole and the small exposure in Biegonice, we concluded that the distribution of these deposits must be more extensive than anticipated. Our field studies were focused on the south-east margin of the Nowy Sącz Depression (Fig. 3), in the area between Biegonice, Zawada, and Poręba Mała hamlets, where the Malcov Formation had earlier been found (Oszczypko, 1973; Blaicher and Oszczypko, 1975). The discovery of these Early Miocene deposits prompted the reexamination of geoelectric soundings formerly made in this area (see Oszczypko, 1973). In the Zawada area these investigations documented a 250 m thick layer of low-resistivity strata which is underlain by a high resistivity horizon which corresponds with the top of the Poprad Member of the Magura Formation. In our opinion only a part of this low resistivity layer can be correlated with the Malcov Formation penetrated in the Nowy Sącz I borehole (Figs. 3 and 4).

During the 1999–2000, in the Łazy Biegonickie-Zawada-Poręba Mała area (*ca.* 12 sq. km), we revised the geological map of Oszczypko (1973) and Oszczypko and Wójcik (1992), and collected samples for calcareous nannoplankton (Fig. 5). We concluded that part of this strata, formerly included by Oszczypko (1973) within the Beloveza, Łącko and Hierogliphic beds, resembles the Zawada Formation from the Nowy Sącz 4 borehole (Oszczypko *et al*., 1999) as well as from the Biegonice section (Oszczypko-Clowes, 2001).

RESULTS

In the area studied, the Zawada Formation is exposed in the bedrock of three small stream and road cuts and a small quarry on the Dział Hill (Fig. 5). In the quarry, layer of light coarse-grained, glauconitic calcareous sandstone a few metres thick is visible. This succession begins with 15 cm of granule conglomerates with nummulites (see Oszczypko, 1973) passing upwards into laminated sandy limestones. Formerly, these limestones Oszczypko (1973) were assigned to the Łącko Beds. In the well exposed Łazy Biegonickie Stream section the deposits belonging to the Zawada Formation were examined along a 700 m long section (Figs. 5 and 6). The lower part of the formation, which is exposed in the upper thrust sheet, reveals an alternation of thick-bedded dark grey, soft marls, dark marly claystones and thick-bedded (60–70 cm) medium-grained, laminated, sandy limestones, similar to those from Dział Hill. The

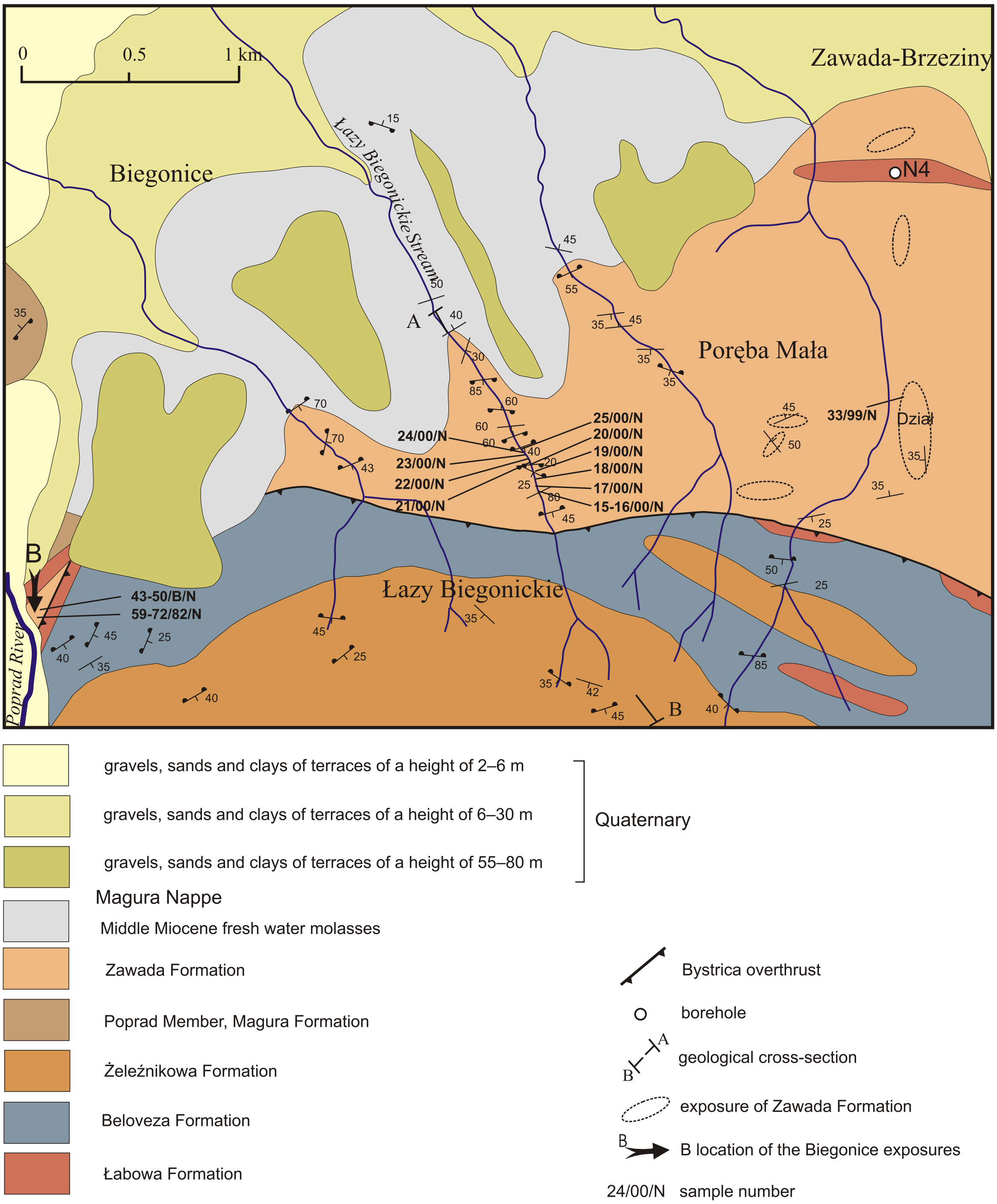


Fig. 5. Geological sketch-map of the Poręba Mała-Zawada area

middle part of the studied section (100 m thick) is composed of repeated, 2–3 m thick, sequences of light very coarse- to medium-grained, poorly cemented, thick-bedded (80–120 cm), glauconite sandstones, dark grey, soft marls and grey marly claystones. These sequences are interbedded with 1–3 m thick alternations of thin- to medium-bedded fine-grained calcareous sandstones and marly claystones. These laminated sandstones are locally capped by a 5–10 cm thick layer of mudstones rich in coalified debris. The lower and middle part of the Zawada Formation in the area of Łazy Biegonickie-Zawada were formerly referred by Oszczypko (1973) to the Łącko Beds (now Żeleźnikowa Formation) of the Bystrica Subunit. The upper part of the formation, located in the middle section of the Łazy Biegonickie Stream (Figs. 5–7), is very badly exposed. It is composed of dark and dark brown marly claystones with subordinate intercalations of fine-grained, thin- to medium-bedded glauconitic/micaceous sandstones, similar to those penetrated in the Nowy Sącz 4 borehole (Oszczypko *et al.*, 1999). These lithofacies, at least 300 m thick (Fig. 7), were formerly described by Oszczypko (1973) as the Beloveza Beds of the Bystrica Sub-

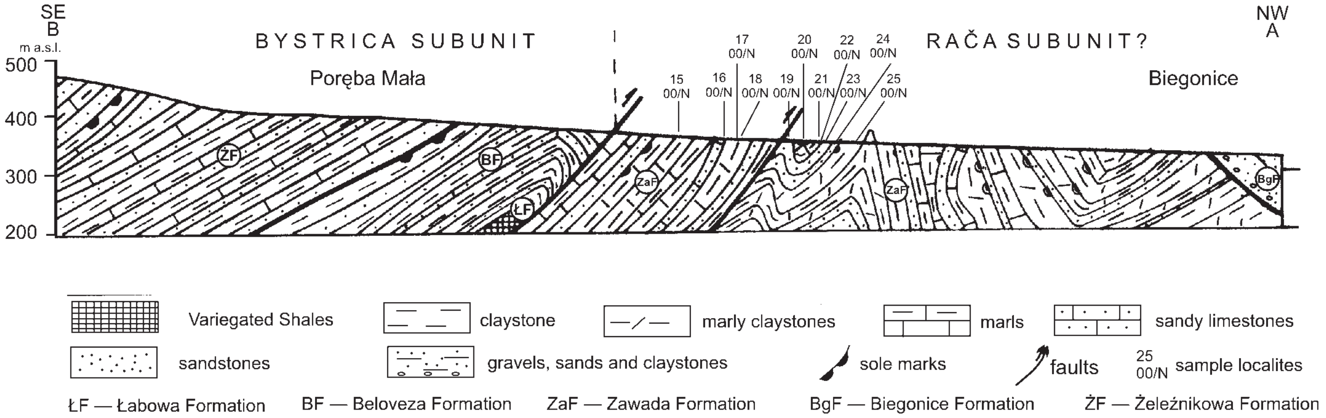


Fig. 6. Geological cross-section (for location see Fig. 5)

unit. The total thickness of the Zawada Formation in the area studied is at least 550 m (Fig. 7). The strata are folded into a W–E trending anticline with steep (60–80°) limbs. On the southern limb of the anticline a 300 m thick thrust-sheet has been documented. Towards the NE the Zawada Formation is discordantly covered by the Mid- Miocene Biegonice Formation (Late Badenian/Sarmatian; see Oszczypko *et al*., 1992). The southern limit of the Zawada Formation is related to the thrust plane of the Bystrica Subunit (Figs. 5 and 6). The Bystrica thrust sheet is built up of thin-bedded flysch of the Beloveza Formation (?Early/Mid- Eocene). Eastwards towards Nawojowa, the front part of the Bystrica thrust sheet contains intercalations of red shales. Towards the south, the Beloveza Formation passes upwards into the Żeleźnikowa Formation (Mid-Eocene, see Oszczypko, 1973, 1991; Oszczypko and Wójcik, 1992). At the southern boundary of Zawada hamlet there is a narrow belt of Variegated Shales (Oszczypko, 1973). In borehole Nowy Sącz 4 these Variegated Shales of Mid-Eocene age were penetrated at the top of the Early Miocene Zawada Formation, and interpreted as the thrust sole of the Bystrica Subunit (Oszczypko *et al*., 1999). Our study does not support this interpretation. According to new data, the front of the Bystrica Subunit is situated 2 km south of the Nowy Sącz 4 borehole (comp. Figs. 3 and 5). The red shales in the Zawada hamlet can be explained as olistostrome fragments inside the Zawada Formation as well as the erosional outlier of the Bystrica Subunit.

The Biegonice section is located 4 km west of Poręba Mała village, on the right bank of the Poprad River, close to the outlet of the Żeleźnikowski Stream (Figs. 3, 5 and 8; see also Oszczypko, 1973; Oszczypko-Clowes, 2001). In this section the Zawada Formation is exposed only in a small landslide scarp dating from the 1960's. The lower part of the sections can only be interpreted from landslide debris, which contain blue-grey, marly claystones with intercalations of thin- to medium-bedded calcareous sandstones containing intercalations of red shales (see Variegated Shales and Beloveza Beds on figures 7 and 8, in Oszczypko, 1973). The upper part of the section is about 15 m thick and ESE dipping (30–50°) crops out in the escarpment of the landslide (Fig. 9; see also Oszczypko, 1973). Sequence A begins with a bed of green-yellowish calcareous mudstones at least 1 m thick with a manganese coating and is followed by soft olive-green claystones and greyish marly claystones. Higher up occurs a very thin intercalation of muscovite mudstones followed by olive soft marls and green-yellowish calcareous claystones and mudstones with a horizon of sideritic concretions at the base (see Oszczypko, 1973). The uppermost portion of sequence A is covered by the massive “Łącko type” marls, which are common for sequences A and B (Fig. 9).

Sequence B begins with a bed of hard, bluish marls of the “Łącko type” at last 1.3 m thick and is followed by a 1 m thick layer of marly claystones and soft marls with intercalations of thin-bedded calcareous sandstones and bentonitic claystones. Higher in the section occur light-coloured, thick-bedded (1.2 m) glauconitic-micaceous sandstones, rich in foraminiferal debris. This sandstone is followed by a 7 m thick packet of “Łącko type” hard marls. The lower and upper boundaries of the Biegonice section are tectonic. Below the lower contact, there is probably the Magura Formation of the Rača Subunit, whereas the upper contact is part of the thrust plane bounding of the Bystrica Subunit (see Oszczypko, 1973; Oszczypko-Clowes, 2001).

CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY

All 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 1000 x using phase contrast and crossed nicols. Several of the specimens photographed in LM are illustrated in Plate I.

The samples examined from the Poręba Mała and Biegonice sections contain well preserved and diverse calcareous nannofossils, which can be grouped into two different assemblages.

Nannofossil assemblage of samples: 33/99/N, 15/00/N, 16/00/N, 17/00/N, 18/00/N from Poręba Mała (Figs. 5 and 7; Tab. 1).

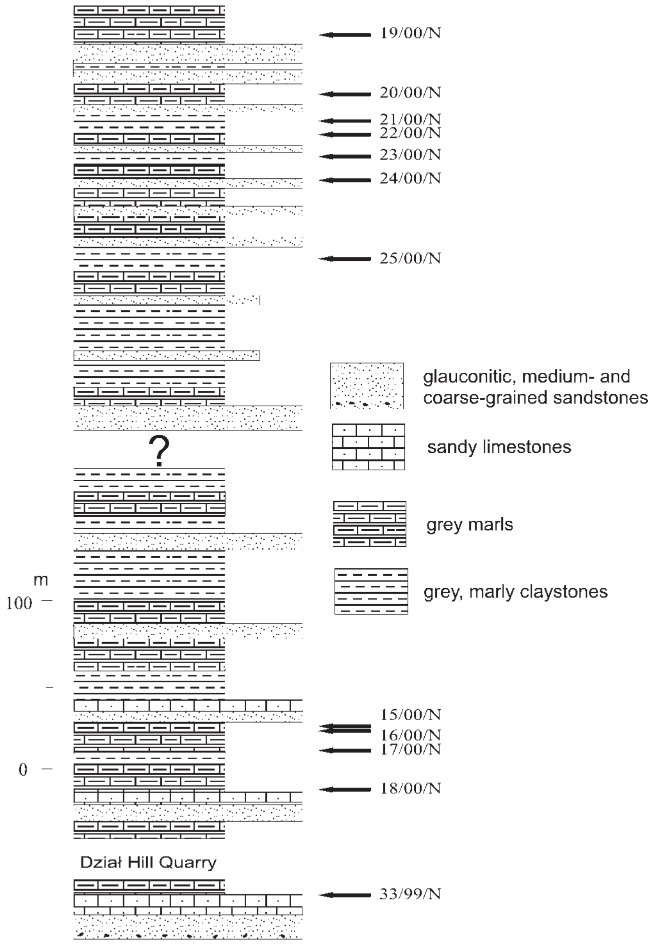


Fig. 7. Lithostratigraphical log of the Zawada Formation in the Poręba Mała area

The abundance pattern varies from more than 25 species (per observation field) in sample 17/00/N, to 10–20 species (per observation field) in samples 33/99/N,15/00/N and 16/00/N. The smallest amount of species (less than 5 per observation field) were observed in the sample 18/00/N. The autochthonous assemblage consists of: *Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus abisectus, C. floridanus, Discoaster deflandrei, Helicosphaera euphratis, Ponthosphaera plana, P. multipora, Reticulofenestra dictyoda, Sphenolithus conicus, S. dissimilis, S. moriformis, Transversopontis pulcher*, *T. pulcheroides, Triquetrorhabdulus carinatus* and *Zygrhablithus bijugatus*. Additionally, sample 17/00/N contains species of *Sphenolithus delphix*. The assemblage is dominated by *Coccolithus eopelagicus, Cyclicargolithus abisectus* and *C. floridanus*. Also the species *Sphenolithus conicus, S. dissimilis* and *S. moriformis* are abundant, but to a lesser extent.

Nannofossil assemblage of samples: 19/00/N, 20/00/N, 21/00/N, 22/00/N, 23/00/N, 24/00/N, 25/00/N from Poręba Mała and samples: 41/B/N, 42/B/N, 43/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, 71/82/N, 72/82/N from Biegonice (Figs. 5, 7 and 9; Tab. 1–3).

The abundance pattern is different for certain samples. It varies from more than 25 species (per observation field) in samples 43/B/N, 44/B/N, 67/82/N, 19/00/N and 23/00/N down to 10–20 species (per observation field) in samples 41/B/N, 42/B/N, 59/82/N, 60/82/N, 62/82/N, 64/82/N, 68/82/N, 70/82/N, 71/85/N, 72/82/N, 20/00/N, 21/00N, 24/00/N and 25/00/N. The lowest abundance pattern (less than 5 species per observation field) was observed in samples 46/B/N, 47/B/N, 48/B/N, and 22/00/N. The autochthonous assemblage consist of: *Coccolithus pelagicus, Coronocyclus nitescens, Cyclicargolithus abisectus, C. floridanus, C. luminis, Discoaster deflandrei, D. druggii, Helicosphaera euphratis, Ponthosphaera enormis, P. plana, P. multipora, Reticulofenestra dictyoda, R. pseudoumbilica, Sphenolithus disbelemnos, S. conicus, S. capricornutus, S. moriformis* and *Triquetrorhabdulus carinatus.* Quantitative studies of autochthonous nannoplankton assemblage indicates the domination of placoliths over other morphological types (eg. asteroliths, sphenoliths, helicospheres).

The assemblage is dominated by *Cyclicargolithus floridanus* and *Coccolithus pelagicus,* whereas *Cyclicargolithus abisectus, Reticulofenestra dictyoda, Sphenolithus conicus, S. moriformis* and *Triquetrorhabdulus carinatus* are less common. The youngest species, determining the age of the assemblage, are *Discoaster druggii, Reticulofenestra pseudoumbilica*, *Sphenolithus disbelemnos.* Additionally, sample 23/00/N contain species of *Helicosphaera ampliaperta* and *Umbilicosphaera rotula*.

Almost all samples investigated are highly dominated by reworked species, especially those of Mid-/Late Eocene age. The level of reworking is highest in samples 44/B/N and 67/82/N where reworked taxa represent more than 50% of all determined species, whereas in samples 59/82/N, 60/82/N, 68/82/N, 70/82/N, 41/B/N, 42/B/N, 16/00/N, 17/00/N and 21/00/N it decreases considerably, reaching a value not higher than approximately 20–30%. The remaining samples contain less than 20% of reworked species. The allochthonous assemblage consists mostly of Mid-/Late Eocene species such as: *Blackites spinosus*, *Chiasmolithus gigas*, *Ch. grandis, Ch. modestus, Ch. solitus, Ch. titus, Discoaster barbadiensis, D. distinctus, D. lodoensis, D. saipanensis, D. strictus, D. tanii, D. tanii nodifer, Ericsonia formosa, Helicosphaera bramlettei, H. compacta, H. lophota, Neococcolithes dubius, Reticulofenestra hillae, R. umbilica, Sphenolithus pseudoradians, S. spiniger* and *Zygrhablithus bijugatus*. This assemblage is dominated by coccoliths of the genera *Chiasmolithus, Discoaster* and *Sphenolithus.*

The top of NP25 was considered for a long time as being at the Oligocene/Miocene boundary, though according to Berggren *et al*. (1995), this boundary lies within the NN1 Zone. The Oligocene/Miocene boundary is characterised by the extinction of *Sphenolithus ciperoensis* (lower latitudes) and *Dictyococcites bisectus* (higher latitudes) (Perch-Nielsen, 1985; Berggren *et al*., 1995; Fornaciari *et al*., 1996; Young (in Bown, 1998).

The Miocene nannoplankton zonation of Martini and Worsley (1970) as well as that of Okada and Bukry (1980) is based mainly on the last (LO) or first occurrence (FO) of discoasters. These typically warm water and open oceanic

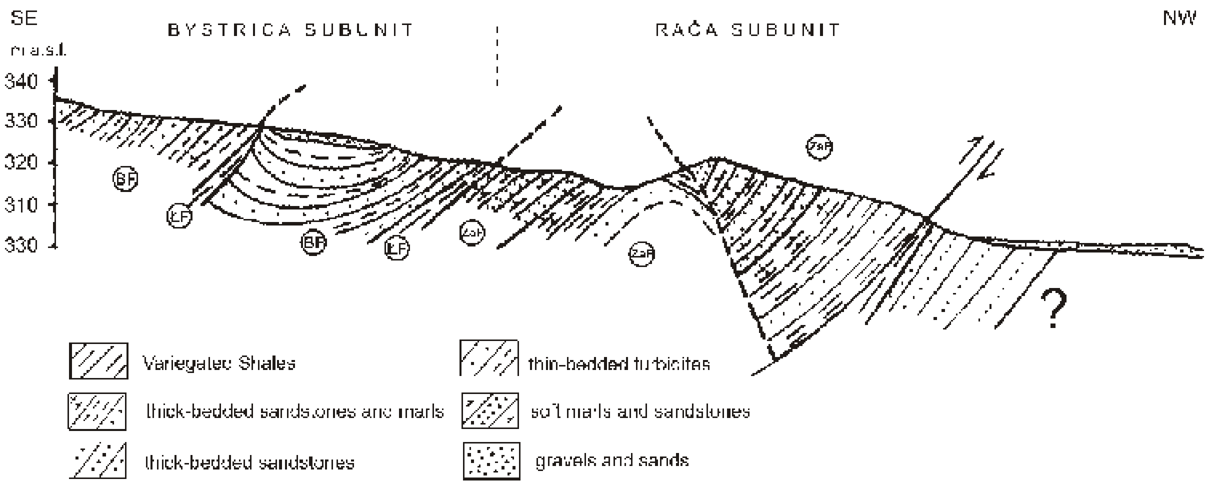


Fig. 8. Geological cross-section through the Bystrica overthrust in Biegonice (after Oszczypko, 1973; modified)

Explanations in the circle as in Fig. 6

species are rare or absent from higher latitudes and also from assemblages of marginal seas. Therefore this zonation is most reliable only at lower latitudes. For higher latitudes it is necessary to use the secondary index species of the following authors: Raffi and Rio (1979), Theodoridis (1984), Raffi *et al*. (1995), Fornaciari and Rio (1996), Fornaciari *et al*. (1996), de Kaenel and Villa (1996), Varol (1998) and Young (in Bown, 1998).

THE BIOZONAL ASSIGNMENTS

Triquetrorhabdulus carinatus Zone (NN1)

Definition: the base of the zone is defined by the last occurrence of *Helicosphaera recta* and/or *Sphenolithus ciperoensis*, and the top by the first occurrence of *Discoaster druggii.*

Author: Bramlette and Wilcoxon (1967), emend. Martini and Worsley (1970).

Age: Early Miocene and/or latest Oligocene.

Remarks. — This zone was identified in the Zawada Formation from the Poręba Mała section (samples: 15/00/N, 16/00/N, 17/00/N, 18/00/N).

The zonal assignment is based on the continuous range of *Sphenolithus conicus*, *S. dissimilis* and *Triquetrorhabdulus carinatus* following the disappearance of *Dictyococcites bisectus*. Traditionally the LO of *Helicosphaera recta* was used to define the base of NN1 (Martini and Worsley, 1970). It is now well known that these species appeared also in the Early Miocene. This is why it was recommended for many years to use the LO of *Sphenolithus ciperoensis* to define the base of NN1 as used in the Okada and Bukry (1980) zonation for the base of their CN1 Zone. However, this species is common in low latitudes and almost absent in higher ones. Therefore, Perch-Nielsen (1985), Berggren *et al*. (1995), Fornaciari *et al*. (1996) and Young (in Bown,1998) suggested redefining the base of NN1 as the LO of *Dictyococcites bisectus.*

The biostratigraphic range of *Sphenolithus delphix* is also problematic. This taxon was reported by Aubry (1985) from NP25 and NN1, though, according to Young (in Bown, 1998), this species is only characteristic for the upper part of NN1.

Discoaster druggii Zone (NN2)

Definition: the base of the zone is defined by the first occurrence of *Discoaster druggii*, and the top by the last occurrence of *Triquetrorhabdulus carinatus.*

Author: Martini and Worsley (1970).

Age: Early Miocene.

Remarks. — This zone was identified in the Zawada Formation from the Poręba Mała section (samples: 19/00/N, 20/00/N, 21/00/N, 22/00/N, 23/00/N, 24/00/N, 25/00/N) and from the Biegonice section (samples: 41/B/N, 42/B/N, 43/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, 71/82/N, 72/82/N).

The zone assignment is based on the co-occurrence of the following species: *Sphenolithus conicus*, *S. disbelemnos*, *Discoaster druggii*, *Reticulofenestra pseudoumbilica* and *Triquetrorhabdulus carinatus.* According to the standard zonation of Martini and Worsley (1970) and Martini (1971) the first occurrence of *Reticulofenestra pseudoumbilica* takes place in NN5. However, this taxon was reported by Marunteanu (1991) from the lower limit of NN2. According to Young (in Bown, 1998), the FO of *Sphenolithus disbelemnos* and/or *Umbilicosphaera rotula* is a reliable biostratigraphical event characteristic for the lower limit of the NN2 Zone.

In the case of the Nowy Sącz 4 borehole, the assemblage did not contain *Triquetrorhabdulus carinatus.* The LO of this species is characteristic for the upper boundary of NN2. The absence of this species might be due to the poor preservation of this assemblage. However, this could also imply that the whole assemblage belongs to NN3.

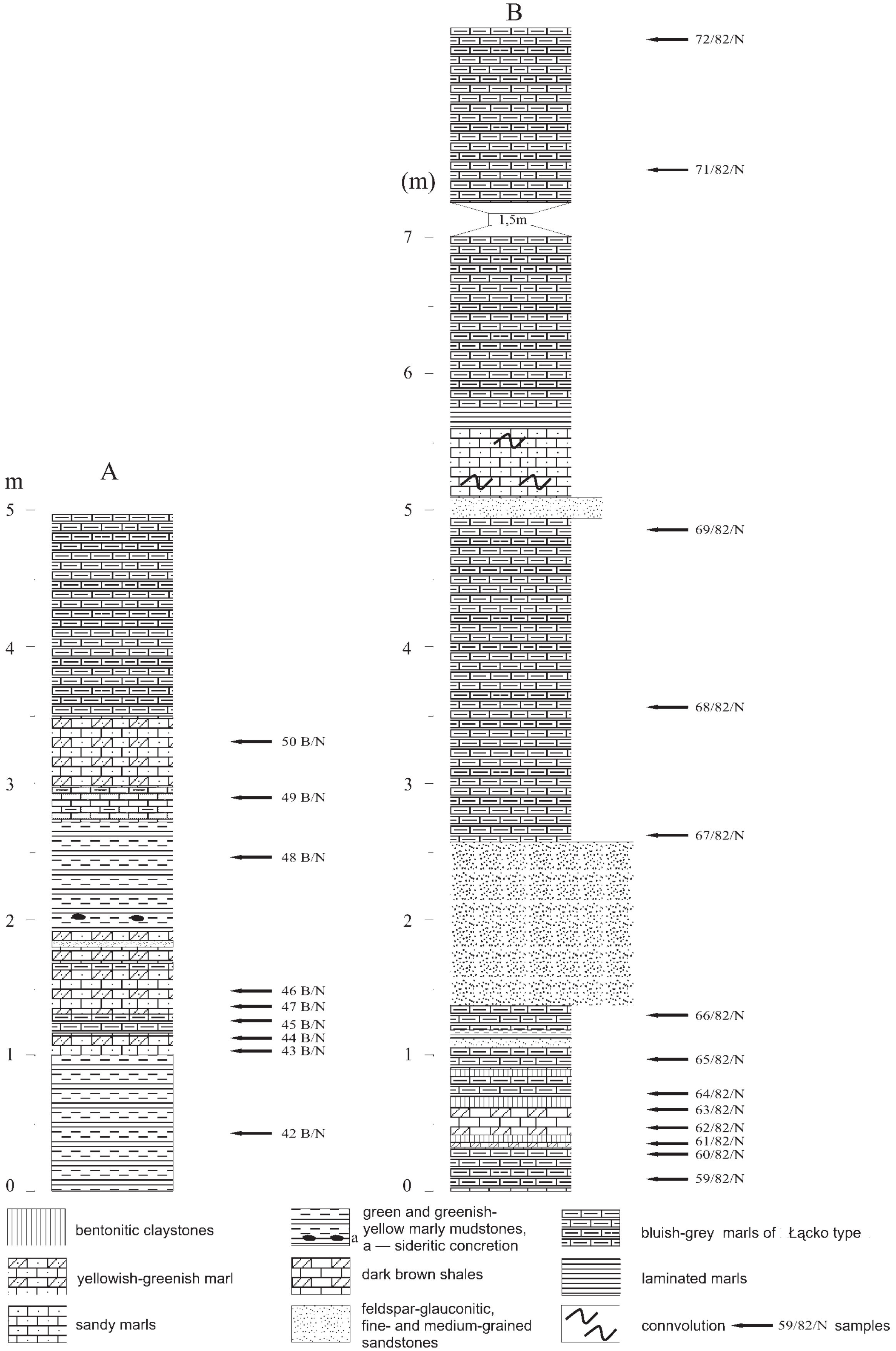


Fig. 9. Lithostratigraphical log of the Zawada Formation in Biegonice A and B sections (after Oszczypko-Clowes, 2001; simplified)

Table 1

Distribution of calcareous nannofossils in the Poręba Mała section (X — autochthonous species, R — reworked species)

Species	33 99/N	15 00/N	16 00/N	17 00/N	18 00/N	19 00/N	20 00/N	21 00/N	22 00/N	23 00/N	24 00/N	25 00/N
Chiasmolithus altus			R		R							
Chiasmolithus expansus				R								
Chiasmolithus gigas				R				R				
Chiasmolithus grandis			R	R				R				
Chiasmolithus solitus						R		R				
Coccolithus eopelagicus	X	X	X	X	X	R	R	R		R	R	R
Coccolithus pelagicus	X	X	X	X		X	X	X		X	X	X
Coronocyclus nitescens						X				X		
Cyclicargolithus abisectus	X	X	X	X	X	X	X	X		X		X
Cyclicargolithus floridanus	X	X	X	X	X	X	X	X		X	X	X
Cyclicargolithus leptoporus								X				
Cyclicargolithus luminis										X		
Discoaster adamanteus						R					R	
Discoaster barbadiensis			R	R								
Discoaster deflandrei	X		X	X		X		X				X
Discoaster distinctus				R								
Discoaster druggii						X	X	X		X	X	
Discoaster multiradiatus				R								
Discoaster tanii				R	R							
Discoaster tanii nodifer			R									
Ericsonia fenestrata	X											X
Ericsonia formosa			R	R				R				
Helicosphaera amliaperta										X		
Helicosphaera bramlettei				R								
Helicosphaera compacta			R	R		R	R	R		R		
Helicosphaera euphratis	X	X		X		X	X	X		R	R	
Helicosphaera intermedia	X			X								
Helicosphaera lophota								R				
Neococcolithes dubius			R	R		R						
Pontosphaera latelliptica		R										
Pontosphaera multipora	X			X		X	X	X		X		
Pontosphaera plana				X				X				
Pontosphaera rothi				X								X
Reticulofenestra daviessii	X						X			X		
Reticulofenestra dictyoda	X	X	X	X			X	X		X	X	X
Reticulofenestra minuta		X		X			X				X	X
Reticulofenestra umbilica												
Rhabdosphaera sp				R								R
Sphenolithus calyculus						X					X	
Sphenolithus capricornutus										X		
Sphenolithus conicus	X		X	X	X	X	X	X		X	X	
Sphenolithus delphix				X						X		
Sphenolithus disbelemnos							X	X			X	
Sphenolithus dissimillis			X	X		X	X			X	X	
Sphenolithus moriformis	X	X	X	X	X	X		X				X
Sphenolithus radians				R		R						
Transversopontis fibula				R		R				R		
Transversopontis pulcher			X	X						X		X
Transversopontis pulcheroides	X	X	X	X		X	X	X		X		
Triquetrorhabdulus carinatus			X	X			X					
Triquetrorhabdulus milowii								X				
Umbilicosphaera rotula										X		
Zygrhablithus bijugatus	X	X	X	X	X	R	R			R	R	

Table 2

Distribution of calcareous nannofossils in the Biegonice A section (X — autochthonous species, R — reworked species)

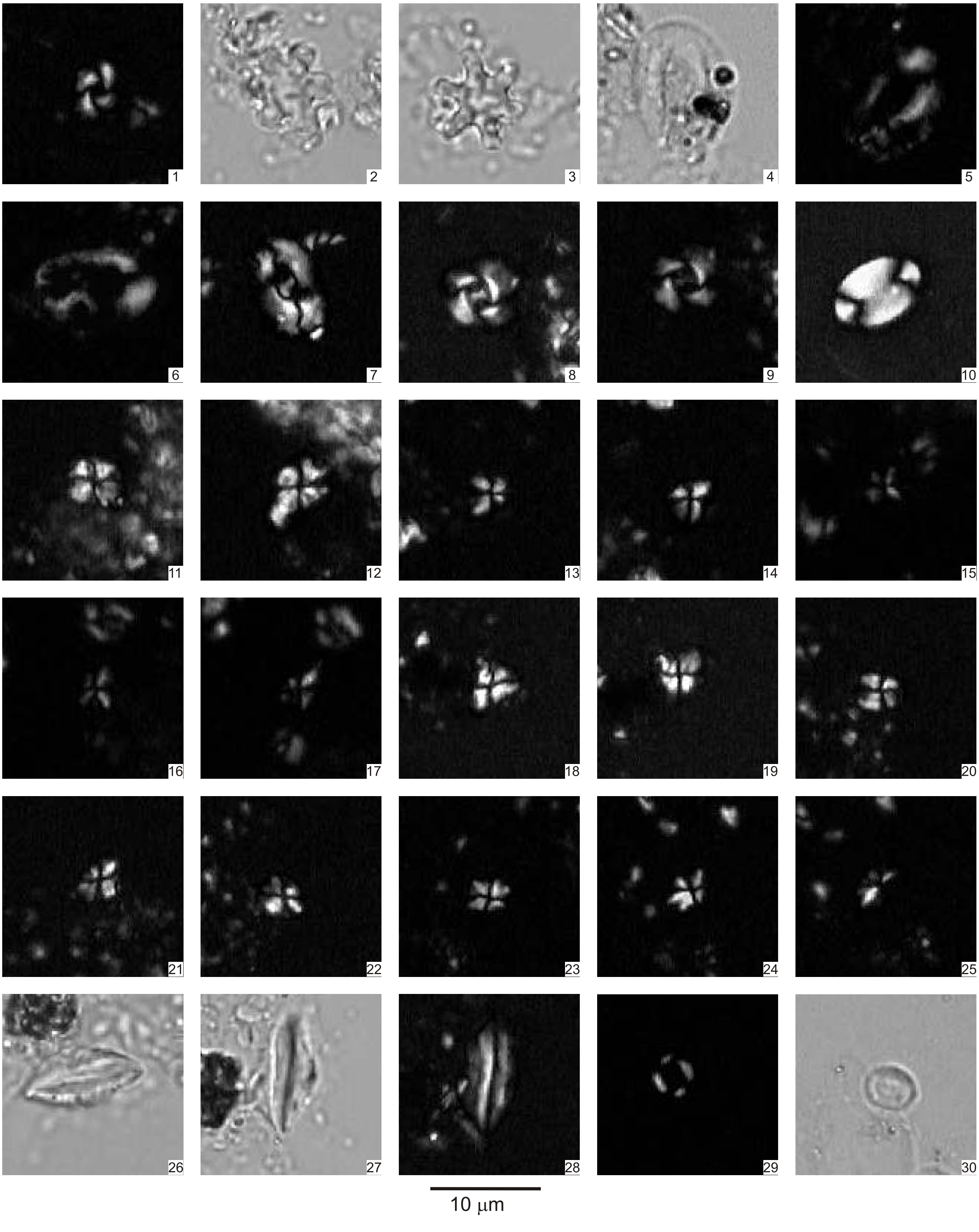
Species	41 B/N	42 B/N	43 B/N	44 B/N	45 B/N	47 B/N	46 B/N	48 B/N	49 B/N	50 B/N
Blackites spinosus		R		R	-			-	-	-
Chiasmolithus expansus					-			-	-	-
Chiasmolithus gigas	R	R	R	R	-			-	-	-
Chiasmolithus grandis	R			R	-		R	-	-	-
Chiasmolithus modestus				R	-			-	-	-
Chiasmolithus solitus		R	R		-		R	-	-	-
Chiasmolithus titus		R		R	-			-	-	-
Coccolithus eopelagicus			R	R	-		R	-	-	-
Coccolithus pelagicus	X	X	X	X	-	X		-	-	-
Cyclicargolithus abisectus	X	X	X	X	-	X		-	-	-
Cyclicargolithus floridanus	X	X	X	X	-	X	X	-	-	-
Cyclicargolithus luminis	X			X	-		X	-	-	-
Dictyococcites bisectus			R	R	-			-	-	-
Discoaster barbadiensis		R	R	R	-	R		-	-	-
Discoaster binodosus					-		R	-	-	-
Discoaster deflandrei	X	X	X	X	-			-	-	-
Discoaster distinctus	R			R	-			-	-	-
Discoaster druggii	X			X	-			-	-	-
Discoaster kuepperi	R			R	-			-	-	-
Discoaster lodoensis				R	-	R	R	-	-	-
Discoaster multiradiatus	R	R	R	R	-	R	R	-	-	-
Discoaster saipanensis		R	R	R	-			-	-	-
Discoaster tanii	R			R	-	R		-	-	-
Discoaster tanii nodifer				R	-	R		-	-	-
Ericsonia fenestrata				X	-			-	-	-
Ericsonia formosa	R	R	R	R	-			-	-	-
Helicosphaera bramlettei	R			R	-			-	-	-
Helicosphaera compacta	R	R	R	R	-			-	-	-
Helicosphaera euphratis		X			-			-	-	-
Helicosphaera intermedia		X		X	-			-	-	-
Helicosphaera lophota	R			R	-			-	-	-
Nannotetrina sp.			R	R	-			-	-	-
Neococcolithes dubius	R	R	R	R	-			-	-	-
Pontosphaera enormis				X	-			-	-	-
Pontosphaera multipora			X		-			-	-	-
Pontosphaera plana		X	X		-			-	-	-
Reticulofenestra dictyoda	X		X		-	X		-	-	-
Reticulofenestra hillae				R	-			-	-	-
Reticulofenestra lockerii	R				-	R		-	-	-
Reticulofenestra pseudoumbilica	X		X	X	-			-	-	-
Reticulofenestra umbilica	R			R	-			-	-	-
Sphenolithus capricornutus	X	X	X	X	-	X		-	-	-
Sphenolithus conicus	X	X		X	-	X	X	-	-	-
Sphenolithus disbelemnos	X	X	X	X	-	X	X	-	-	-
Sphenolithus furcatolithoides			R	R	-			-	-	-
Sphenolithus moriformis	X	X	X	X	-	X		-	-	-
Sphenolithus pseudoradians		R	R		-			-	-	-
Sphenolithus radians		R	R		-			-	-	-
Sphenolithus spiniger	R	R	R		-			-	-	-
Triquetrorhabdulus carinatus				X	-			-	-	-
Zygrhablithus bijugatus	R		R		-		R	-	-	-

Table 3

Distribution of calcareous nannofossils in the Biegonice B section (X — autochthonous species, R — reworked species)

Species	59 82/N	60 82/N	61 82/N	62 82/N	63 82/N	64 82/N	65 82/N	66 82/N	67 82/N	68 82/N	69 82/N	70 82/N	71 82/N	72 82/N
Chiasmolithus danicus			-	R	-	-	-	-			-			
Chiasmolithus expansus		R	-	R	-	-	-	-	R	R	-	R		
Chiasmolithus gigas		R	-		-	-	-	-			-	R		
Chiasmolithus grandis	R		-		-	-	-	-	R		-	R		
Chiasmolithus solitus		R	-		-	-	-	-		R	-			
Coccolithus eopelagicus		R	-		-	-	-	-			-	R		R
Coccolithus pelagicus	X	X	-	X	-	-	-	-	X	X	-	X		X
Coronocyclus nitescens	X	X	-	X	-	-	-	-			-			
Cyclicargolithus abisectus	X		-	X	-	-	-	-	X		-	X	X	X
Cyclicargolithus floridanus	X		-	X	-	-	-	-	X	X	-	X		X
Cyclicargolithus luminis	X		-	X	-	-	-	-		X	-			
Dictyococcites bisectus			-		-	-	-	-			-			R
Discoaster barbadiensis	R	R	-	R	-	-	-	-	R	R	-	R		
Discoaster bifax	R		-		-	-	-	-			-			
Discoaster binodosus			-		-	-	-	-			-		R	
Discoaster deflandrei		X	-		-	-	-	-	X	X	-	X		
Discoaster distinctus	R	R	-	R	-	-	-	-	R	R	-	R	R	R
Discoaster druggii	X		-		-	-	-	-	X		-		X	X
Discoaster lodoensis	R	R	-		-	-	-	-			-			
Discoaster multiradiatus	R	R	-	R	-	-	-	-			-			
Discoaster saipanensis	R	R	-		-	-	-	-	R	R	-	R	R	
Discoaster strictus	R	R	-		-	-	-	-			-			
Discoaster tanii		R	-	R	-	-	-	-	R	R	-	R		
Discoaster tanii nodifer		R	-	R	-	-	-	-		R	-		R	
Discoaster wemmelensis			-		-	-	-	-		R	-	R	R	
Ericsonia formosa	R	R	-	R	-	-	-	-	R	R	-	R	R	
Helicosphaera bramlettei			-		-	-	-	-		R	-		R	
Helicosphaera compacta			-		-	-	-	-	R		-			R
Helicosphaera euphratis			-		-	-	-	-			-			
Helicosphaera lophota	R		-		-	-	-	-			-			
Helicosphaera seminulum	R		-		-	-	-	-			-			
Nannotetrina sp.	R		-		-	-	-	-	R	R	-			
Neococcolithes dubius	R	R	-		-	-	-	-	R	R	-	R	R	R
Pontosphaera sp.		X	-		-	-	-	-		X	-	X		
Pontosphaera multipora			-		-	-	-	-	X	X	-		X	X
Pontosphaera plana	X		-	X	-	-	-	-			-	X		X
Reticulofenestra dictyoda	X	X	-	X	-	-	-	-		X	-	X		X
Reticulofenestra hillae	R		-		-	-	-	-			-		R	
Reticulofenestra lockerii			-		-	-	-	-			-			
Reticulofenestra pseudoumbilica			-		-	-	-	-	X		-			X
Reticulofenestra umbilica	R	R	-	R	-	-	-	-	R	R	-	R		
Sphenolithus capricornutus	X		-		-	-	-	-			-			
Sphenolithus conicus	X		-	X	-	-	-	-	X		-	X		
Sphenolithus disbelemnos	X	X	-	X	-	-	-	-	X	X	-			X
Sphenolithus editus	R		-		-	-	-	-			-			R
Sphenolithus furcatolithoides	R		-		-	-	-	-			-	R	R	
Sphenolithus moriformis	X	X	-	X	-	-	-	-	X	X	-	X	X	X
Sphenolithus pseudoradians			-		-	-	-	-			-	R		R
Sphenolithus radians	R		-	R	-	-	-	-		R	-			
Transversopontis pulcheroides			-	X	-	-	-	-			-	X		
Triquetrorhabdulus carinatus	X		-		-	-	-	-			-			X
Zygrhablithus bijugatus	R	R	-	R	-	-	-	-	R	R	-	R		R

PLATE I



LM microphotographs of selected species from Poręba Mała section. **1** — *Cyclicargolithus floridanus* (Roth et Hay), sample 21/00/N. **2** — *Discoaster deflandrei* Bramlette et Riedel, sample 25/00/N. **3** — *Discoaster* cf. *D. druggii* Bramlette et Wilcoxon, sample 21/00/N. **4–6** — *Helicosphaera ampliaperta* Bramlette et Wilcoxon, sample 23/00/N. **7** — *Helicosphaera euphratis* Haq, sample 21/00/N. **8, 9** — *Reticulofenestra daviesii* (Haq), sample 20/00/N. **10** — *Pontosphaera plana* (Bramlette et Sullivan), sample 17/00/N. **11, 12** — *Sphenolithus calyculus* Bukry, sample 24/00/N. **13, 14** — *Sphenolithus conicus* Bukry, sample 21/00/N. **15, 16** — *Sphenolithus delphix* Bukry, sample 23/00/N. **17–22** — *Sphenolithus disbelemnos* Fornaciari et Rio: **17, 18** — sample 21/00/N, **19–22** — sample 24/00/N. **23–25** — *Sphenolithus dissimilis* Bukry et Percival, sample 20/00/N. **26–28** — *Triquetrorhabdulus milowii* Bukry, sample 21/00/N. **29, 30** — *Umbilicosphaera rotula* (Kamptner), sample 23/00/N (**2, 3, 4, 26, 27, 30** — parallel nicols, all the other — crossed nicols)

LITHOSTRATIGRAPHIC CORRELATION

The deposits cropping out in the Poręba Mała-Zawada areas and in the Biegonice section as well as in the Nowy Sącz 4 borehole (Figs. 5, 7 and 9) reveal the same facies-lithological development, age and tectonic position. A common feature of these deposits is the presence of marly claystones and marls with intercalations of thick-bedded sandy limestones and glauconitic sandstones. Such a development of facies and lithology suggests their correlation with the Budzów Beds, the Wątkowa Sandstone and the Harklowa facies of the Magura Sandstones developed in the marginal part of the Magura Nappe near Gorlice (Szymakowska, 1966). The Zawada Formation differs from the Malcov Formation both in their facies-lithological development and in age. The relationship between these two formations is not clear due to a lack of exposures (Figs. 3–5 and 8). Geophysical data suggest that the Zawada Formation overlaps the Malcov Formation (see Figs. 3 and 4), but this superimposed position of the Zawada Formation over the Malcov Formation could have either a stratigraphic or tectonic character (overthrust?). The stratigraphic contact of both formations is suggested by the progressive younger age of the deposits: the Late Oligocene (NP25) age of the Malcov Formation in the Nowy Sącz I borehole (Oszczypko-Clowes, 2001) and the Early Miocene (NN1) age of the basal portion of the Zawada Formation in the quarry on Dział Hill as well as and in the Łazy Biegonickie Stream. This suggest continuous deposition in the Magura Basin, although a submarine erosional hiatus between these two formations cannot be excluded. Such an interpretation is in conflict with the different style of tectonic deformation of the Malcov and Zawada formations. In the Nowy Sącz I borehole the Malcov Formation lies relatively flat (5–42°; see Oszczypko, 1973), whereas the Zawada Formation is folded and steeply dipping. The same is observed in the Biegonice section, where the lower boundary of the Zawada Formation is tectonic (Oszczypko *et al.*, 1999; Oszczypko-Clowes, 2001). In all locations the Zawada Formation occurs beneath the Bystrica Subunit frontal thrust (Figs. 5 and 6). This suggests a post Early Burdigalian age of folding of the Zawada Formation and of the overthrust of the Bystrica Subunit.

PALAEOTECTONIC IMPLICATIONS

The Outer Carpathian Flysch Belt is traditionally subdivided into two group of nappes: the external one known as the middle group (Książkiewicz, 1977) as well as the Moldavides (Sandulescu, 1988) or the Krosno-Menilite (Tomek and Hall, 1993; Plašienka *et al.*, 1997) and the internal one known as the Magura Nappe (Książkiewicz, 1977; Sandulescu, 1988; Plašienka *et al.*, 1997). The Magura Nappe was regarded as a Late Eocene/Oligocene accretionary wedge (Sandulescu, 1988; Oszczypko, 1992, 1999), overthrust onto the Krosno-Menilite zone (Moldavides) — an Early/Mid-Miocene accretionary wedge (Birkenmajer, 1986; Sandulescu, 1988; Plašienka *et al.*, 1997; Oszczypko, 1998, 1999). The discovery of folded Early Miocene marine deposits in the Magura Nappe close to the Pieniny Klippen Belt (Paul and Poprawa, 1992; Cieszkowski, 1992) and recent findings of Early Miocene deposits in the Nowy Sącz area (Oszczypko *et al.*, 1999; Oszczypko and Oszczypko-Clowes, this issue), implies significant revision of the previous opinions on the terminal stages of the Magura Basin evolution (see Książkiewicz, 1977; Jiřiček and Seifert, 1990; Oszczypko, 1992; Kovač *et al.*, 1998 and bibliography therein). This revised model should take account of the broad extent of the Early Burdigalian marine deposits in the Western Carpathians and their relationship to palaeotectonic processes. The Burdigalian deposits are known from the Carpathian Foredeep (see Jurkova *et al.*, 1983; Garecka and Olszewska, 1998), from the terminal Krosno-Menilite flysch basin (see Andreyeva-Grigorovich and Gruzman, 1994; Krhovsky *et al.*, 1995; Koszarski *et al.*, 1995; Ślęzak *et al.*, 1995; Andreyeva-Grigorovich *et al.*, 1997; Garecka and Olszewska, 1998; Kovač *et al.*, 1998), in the Magura Nappe (Paul and Poprawa, 1992; Cieszkowski, 1992; Oszczypko *et al.*, 1999; Oszczypko and Oszczypko-Clowes, this issue) and the Central Western Carpathians (Halašova *et al.,* 1996; Kovač and Zlinska, 1998). The occurrence of folded marine Early Burdigalian deposits in the Magura Nappe can be explained alternatively: by Late Burdigalian folding and thrusting of the Magura Nappe together with the more external (Moldavides) units, or by Late Oligocene/Early Miocene progressive synsedimentary folding and thrusting. In the first case, the Early Burdigalian deposits of the Krosno-Menilite basin should be expected beneath the Magura overthrust. So far, such deposits have not been recognised in the tectonic windows of the Magura Nappe. The second explanation suggests that the Late Oligocene northwards thrusting of the frontal part of the Magura Nappe onto the terminal Krosno-Menilite flysch basin was accompanied by the formation of a syntectonic piggy-back type basin on the Magura Nappe. This explains a significant amount of the reworked foraminiferal fauna and nannoplankton, mostly from the Mid-Eocene pelagic facies, which can be observed in the Zawada Formation. This material may have been derived from the eroded and uplifted frontal part of the Magura Nappe and the Fore-Magura units. The deposition of the Zawada Formation could have been more or less simultaneous with the deposition of the Gorlice Beds, which contain blocks derived from the front of the Magura Nappe (Jankowski, 1997). The Burdigalian Magura basin was probably connected *via* the Orava sea-way with the Vienna Basin (see Oszczypko *et al.*, 1999). At the same time, another seaway connection between the Outer Carpathian Basin and Filakovo/Petervasara Basin *via* East Slovakian Basin existed (see Sztano, 1994; Halašova *et al.*, 1996; Kovač and Zlinska, 1998). During the Ottnangian, and after deposition of the Zawada Formation and terminal flysch deposits (see Krhovsky *et al.*, 1995; Andreyeva-Grigorovich *et al.*, 1997; Oszczypko, 1998), the Outer Carpathians were finally folded and uplifted.

CONCLUSIONS

1. In the Nowy Sącz area Early Miocene marine deposits have been newly discovered in the southern part of the Rača

Subunit, and at the front of Bystrica Subunit of the Magura Nappe.

2. These deposits belong to the Zawada Formation, which is represented by medium- to thick-bedded glauconitic sandstones with intercalations of thick-bedded marls and marly claystones.

3. The thickness of the Zawada Formation is at least 550 m.

4. On the basis of calcareous nannofossil studies the age of the formation was determined as Early Burdigalian (NN1–2–3 Biozones).

5. Due to lack of exposures the relationship between the deposits of the Malcov and the Zawada formations is not yet clear, but a continuous transition between these formations can not be excluded.

6. In the Magura Nappe there are perspectives for further discovery of Early Miocene deposits elsewhere.

Acknowledgements. The authors are indebted to Prof. Aida S. Andreyeva-Grigorovich (Lviv University, Ukraine, and Comenius University, Bratislava, Slovak Republik) for consultations. David Clowes is gratefully acknowledged for help in correcting the English text. The authors are gratefully indebted to Dr. E. Gaździcka and Dr. A. Wójcik for critical review of this paper. The present work was supported by Polish Scientific Research Found Project No. 6PO4D 04019 granted to N. Oszczypko.

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