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THE LOWER MIOCENE DEPOSITS OF THE RAČA SUBUNIT NEAR NOWY SĄCZ (MAGURA NAPPE, POLISH OUTER CARPATHIANS)

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Abstract: In the area of Nowy Sącz the Lower Miocene, marine deposits (of the N 5, NN 2–3 biozones) have been discovered in the southern part of the Rača Subunit of the Magura Nappe. These deposits belong to the Zawada Fm., which probably overlaps the Malcov Fm. (Upper Eocene–Oligocene) with an erosional hiatus. These folded deposits are represented by medium- to thick-bedded glauconitic sandstones with intercalations of thick-bedded marls. Facies-lithological development of the Zawada Fm. displays features characteristic for the northern part of the Magura Basin (Siary facies zone). During the Early Burdigalian the partly folded Magura Nappe was flooded from the residual flysch basin located in the north. At that time the seaway connection between this basin and the Vienna Basin via the Orava area was probable established.

Key words: Lower Miocene, Outer Carpathians, Magura Nappe, Rača Subunit, lithostratigraphy, calcareous nannoplankton, foraminifers, paleogeography.

Introduction

The Magura Nappe, the largest and innermost tectonic unit of the Western Capathians, is subdivided into four facies-tectonic subunits (Fig. 1). From south to north these are: the Krynica, Bystrica, Rača and Siary subunits (Koszarski et al. 1974). Up to the end of fifties the Upper Eocene Magura Sandstones were regarded as the youngest deposits of the Magura Nappe. In 1959, Książkiewicz & Leško discovered in the Eastern-Slovak part of the Magura Nappe deposits with a facies development and stratigraphic position similar to the Oligocene Menilite and Krosno Beds of the Outer Flysch Carpathians. Those deposits were described by Świdziński (1961a,b) as the Malcov Beds.

In Eastern Slovakia (Fig. 1) these deposits filled three narrow, NW–SE trending synclines (see Nemčok 1961, 1985). The middle syncline (Malcov–Richvald–Raslavice) covers a tectonic contact? between the Bystrica and Krynica subunits,

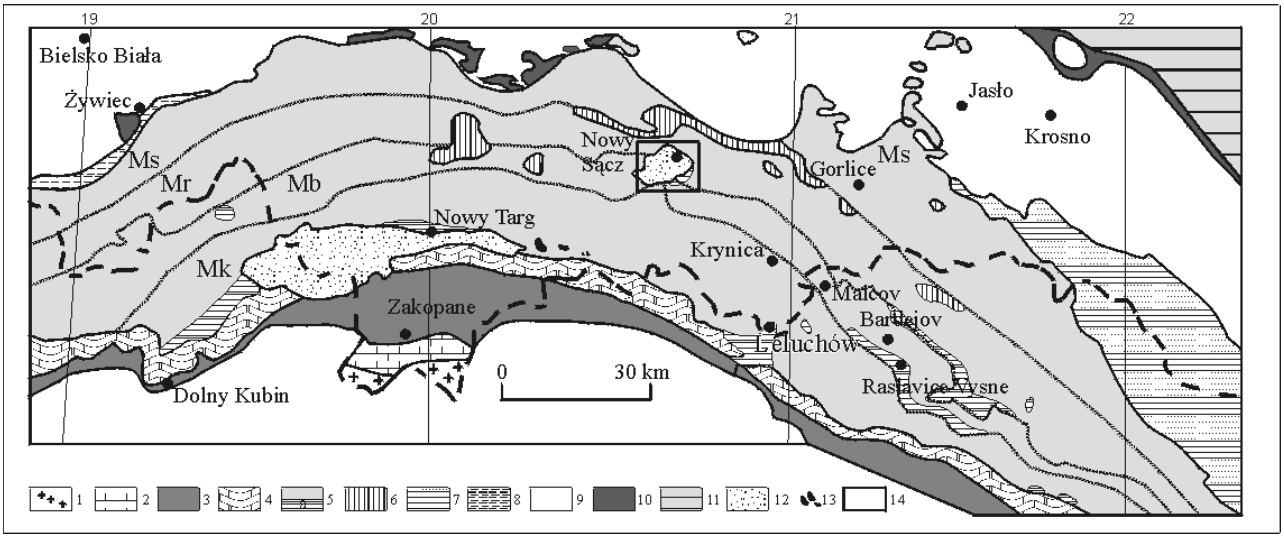


Fig. 1. Tectonic position of the Magura Nappe in Poland and Slovakia (after Żytko et al. 1989, supplemented): 1— crystalline core of the Tatra Mts., 2 — High Tatra and sub-Tatra Units, 3 — Podhale flysch, 4 — Pieniny Klippen Belt, 5 — Magura Nappe, 5a — Malcov Fm., 6 — Grybów Unit, 7 — Dukla Unit, 8 — 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 Subunit, Mr — Rača Subunit, Mb — Bystrica Subunit, Mk — Krynica Subunit.

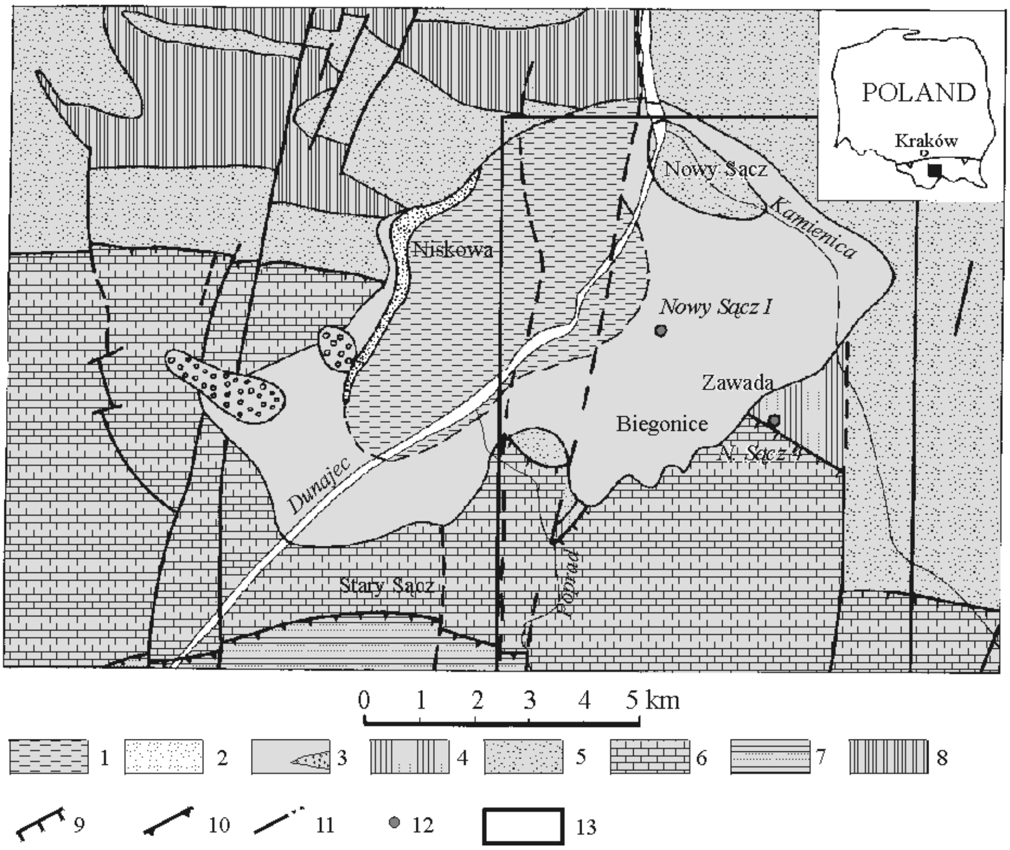


Fig. 2. Geological map of the Nowy Sącz Depression (based on Oszczypko et al. 1992, supplemented). **Middle Miocene:** 1 — marine offshore deposits, 2 — littoral deposits, 3 — paludal deposits, 3a — alluvial fan deposits; **Magura Nappe:** 4 — Senonian-Paleocene deposits, 5 — Eocene deposits of the Rača Subunit, 6 — Eocene deposits of the Bystrica Subunit, 7 — Eocene deposits of the Krynica Subunit, 8 — Zawada Fm. (Lower Miocene), 9 — thrust of Bystrica Subunit, 10 — thrust of the Krynica Subunit, 11 — faults, 12 — boreholes, 13 — area of Fig. 3.

whereas the northern one, known as the Brezovka Syncline (Dlhá Lúka-Brezovka-Okrúhle) masks the tectonic contact between the Rača and Bystrica subunits. In the Polish part of the Magura Nappe the Malcov Beds are known from a few separated localities. At first, these beds were found in the Leluchów section (Fig. 1) on the Polish-Slovak border. This section is located along the contact between the Pieniny Klippen Belt and Magura Nappe (see Świdziński 1961b; Blaicher & Sikora 1967; Nemčok 1985; Birkenmajer & Oszczypko 1989; Oszczypko et al. 1990; Oszczypko 1996; Oszczypko-Clowes 1998a). Later on, the Malcov Beds were described in the Rača Subunit in the area of the Nowy Sącz Basin (Figs. 1, 2), in the central, depressed part of the Magura Nappe (Oszczypko 1973; Blaicher & Oszczypko 1975; Oszczypko & Wójcik 1992) and then in the Nowy Targ area (Cieszkowski & Olszewska 1986) close to the PKB (Fig. 1). The Malcov Beds were also described from Orava by Potfaj (1983). Later on these beds were established as the Malcov Formation (see Birkenmajer & Oszczypko 1989) with two local members: the Leluchów Marl Member (Globigerina Marls) and Smereczek Shale Member (Menilite Beds). The Malcov Fm. was regarded as the youngest (Late Eocene-Oligocene) deposits of the Rača, Bystrica and Krynica subunits of the SE part of the Magura Nappe (see Birkenmajer & Oszczypko 1989; Oszczypko 1991). In the northern, marginal part of the Magura Nappe (Siary Subunit) the Wątkowa Sandstone and Budzów Beds (Supra-Magura Beds) are equivalents to the Malcov Fm. (see Książkiewicz 1966; Koszarski et al. 1974; Oszczypko 1991). According to recent calcareous nannoplankton investigations, the age of the Leluchów Marl Mb. (Globigerina Marls) has been determined as the uppermost Eocene-Early Oligocene (NP 19/20, 21 and 22, see M. Oszczypko 1996; Oszczypko-Clowes 1998a). The upper part of the Malcov Fm., developed in turbiditic facies is not older than Early Oligocene (NP 22, see Oszczypko-Clowes 1998b). In the western part of the Magura Nappe in Poland (Budzów section, Fig. 1) the age of the Wątkowa Sandstone was determined as NP 19/20, whereas Budzów (Supra-Magura) Beds were assigned to the NP 19/20, NP 21 and NP 22 zones (see Oszczypko-Clowes 1998b).

The Malcov Formation in the area of Nowy Sącz — revision

Nowy Sącz I borehole. A series of the Middle Miocene fresh-water sediments of the Biegonice Fm. was pierced to a depth of 540 m (Fig. 4, see also Oszczypko 1973; Oszczypko et al. 1992). Below the depth of 540 m, black-grey, clayey shales with a few very thin-bedded intercalations of calcareous and muscovitic sandstones were penetrated. These turbidites revealed T_{bc} Bouma's intervals, whereas medium-bedded sandstones showed T_{bc} + mconv. Within this complex, resembling the Krosno Beds, a few cm thick layer of light yellow siderite was found. At the bottom of the shaly-sandstone complex (from a depth of 602.0 m to 606.5 m), light-yellow marls occurred. The next underlying beds were developed as black, grey, clayey shales and siltstones with some layers of thick bedded, coarse- to fine-grained, strongly calcareous light-grey sandstones. The succeeding complex (from 616.6 m to 620.8 m) was developed as brown-reddish, clayey shales and green marly shales. Deposits occurring between 540 m and 620.8 m were defined as the Malcov Fm. (see Oszczypko 1973; see also Blaicher & Oszczypko 1975; Birkenmajer & Oszczypko 1989; and Oszczypko et al. 1990). The basal portion of this sequence could belong to the Leluchów Marl Mb. Below the Malcov Fm. to a depth of 704 m, thick-bedded, muscovite sandstones of the Magura Formation were recognized (Fig. 4). In the pierced section the angles of dip were very differentiated. To a depth of 620.8 m the inclination was relatively gentle (5°–42°), below 620.8 m it was steep (50°–70°).

The core samples from the Malcov Fm. of the Nowy Sącz I borehole furnished relatively poor foraminiferal fauna (see Oszczypko 1973). Only samples from a depth of 543–551 m contained richer Late Eocene-Oligocene microfauna with the assemblage of small globigerinas: *Globigerina officinalis* Subbotina, *Globigerina leroy* (Banner et Blow) and *Turborotalia bannerblowi* (Blaicher). Similar foraminiferal fauna is known from the upper part of the Globigerina Marls and from the Menilite Beds. Within reddish-brown-green clayey, shales (616.6–618.7 m) scanty Middle–Late Eocene benthic foraminifers were found.

Biegonice section. The Biegonice section, at least 100 m thick, is located on the steep bank of the Poprad river (Figs. 2, 3). In the lower part of the section, grey-greenish, muscovitic siltstones and grey-bluish, marly claystones occur with some thin layers of grey, muscovitic, calcareous sandstones. Some clayey-sideritic concretions (10 cm in diameter) have been observed within the siltstones. The upper part of the section begins with soft, olive-grey marls and shales with sporadic intercalations of very thin-bedded (T_c) calcareous sandstones. These marls pass upwards into thick-bedded (1.2 m) medium- to fine-grained, light, moderately calcareous glauconite sandstone with T_{abc} Bouma's intervals. The uppermost portion of the section is represented by the dark-grey, thick-bedded (0.5–4.0 m), hard marls of the Łącko type, with a few intercalations of thin- to medium-bedded bluish, calcareous sandstones. The lower and upper boundaries of these, ESE dipping (30–50°) deposits are tectonic. The upper tectonic boundary belongs to the thrust of the Bystrica Subunit (see Oszczypko 1973; Oszczypko & Wójcik 1992). Assemblages of foraminifers occurring in samples from the Biegonice section consist mainly of planktonic and less abundant benthonic species of various stratigraphic ranges (see Blaicher & Oszczypko 1975; Oszczypko et al. 1990). The Early-, Middle- and Late-Eocene as well as Oligocene forms were noticed. The youngest Oligocene species *Rotalia stellata* Reuss, *Globorotalia denseconnexa* Subbotina, *Bagatella latiaperta* Subbotina, *Globanomalina evoluta* Subbotina, *Globigerina angulisuturalis* Bolli were compared with the foraminiferal fauna from the Middle Krosno Beds at Niebylec (Blaicher & Oszczypko 1975). According to the recent data about the stratigraphic ranges of *Tenuitella denseconnexa* (Subbotina) and *Globigerinella evoluta* Subbotina (Odrzywolska-Bieńkowa & Olszewska 1996; Garecka & Olszewska 1998) the age of the assemblage is not older than Early Miocene. It is in agreement with the latest age determination of the horizon of the Niebylec Shales that has been assigned to the Early Miocene (NN 2 Zone see Ślęzak et al. 1995).

Zawada section. Similarly developed deposits crop out in the small exposures at Zawada (2.5 km toward SE from the borehole Nowy Sącz I, Fig. 3, see also Oszczypko 1973; Blaicher & Oszczypko 1975). As in the Biegonice section, these exposures are located at the front of the Bystrica Subunit thrust (Figs. 2, 3), where light-grey laminated marls and single layers of thick-bedded sandstones are found. The sandstones are fine-grained, glauconitic, with siliceous-illitic cement with characteristic siliceous veinlets. These sandstones are identical with the Wątkowa Sandstone and the so-called Harklowa type of the Magura Sandstones developed in the marginal part of the Magura Nappe near Gorlice (Świdziński 1953; Szymakowska 1966). At Zawada, the glauconitic sandstones and marls are overlain by greenish-yellow, clayey shales as well as by a complex of light-grey and yellow-grey marls a few meters thick. Within these marls, a 5 cm thick layer of yellow-grey siderite has been found. In thin-sections from the marls sometimes fairly abundant small globigerinas have been observed.

The blue-grey, marly shales furnished abundant benthonic and planktonic foraminiferal fauna. On the basis of the planktonic species *Globorotalia denseconnexa* Subbotina, *Turborotalia inaequiconica* Subbotina, *Globigerina apertura* Cushman, *Globigerina praebulloides* Banner et Blow, *Globanomalina evoluta* Subbotina, the age was regarded as Oligocene (see Oszczypko 1973; Blaicher & Oszczypko 1975). At present, it should be regarded as Early Miocene, as in the Biegonice section, due to the modified stratigraphic ranges of the above mentioned species (Garecka & Olszewska 1998).

Nowy Sącz 4 borehole. In 1984, south of the above described exposures, the shallow borehole Nowy Sącz 4 (Figs. 2, 3, 5, 6) was drilled and sampled in the course of geological mapping (see Oszczypko & Wójcik 1992). This 25 m deep borehole pierced the following deposits:

0–10.0 m: loams and clays (Pleistocene).

10.0–12.8 m: non-calcareous, bluish-grey shales with thin intercalation of red shales — Łabowa Shale Formation (Middle Eocene) of the Bystrica Subunit.

12.8–14.35 m: grey-bluish, parallel-laminated, calcareous (++HCl) mudstones with underlying fine- to medium-grained, calcareous (+ HCl), medium-bedded (T_{bc} turbidite) glauconitic sandstones with green siliceous veinlets (angle of dip 10–40°, normal position of bedding).

14.35–14.4 m: grey, calcareous mudstones.

14.4–16.8 m: bluish-grey, medium to fine-grained, thick-bedded muscovite-glauconitic sandstones with intercalations of greenish and grey calcareous mudstones (angle of dip 5° in the upper part up to 80° in the base of complex).

16.8–18.3 m: greenish-grey, weathered? claystones.

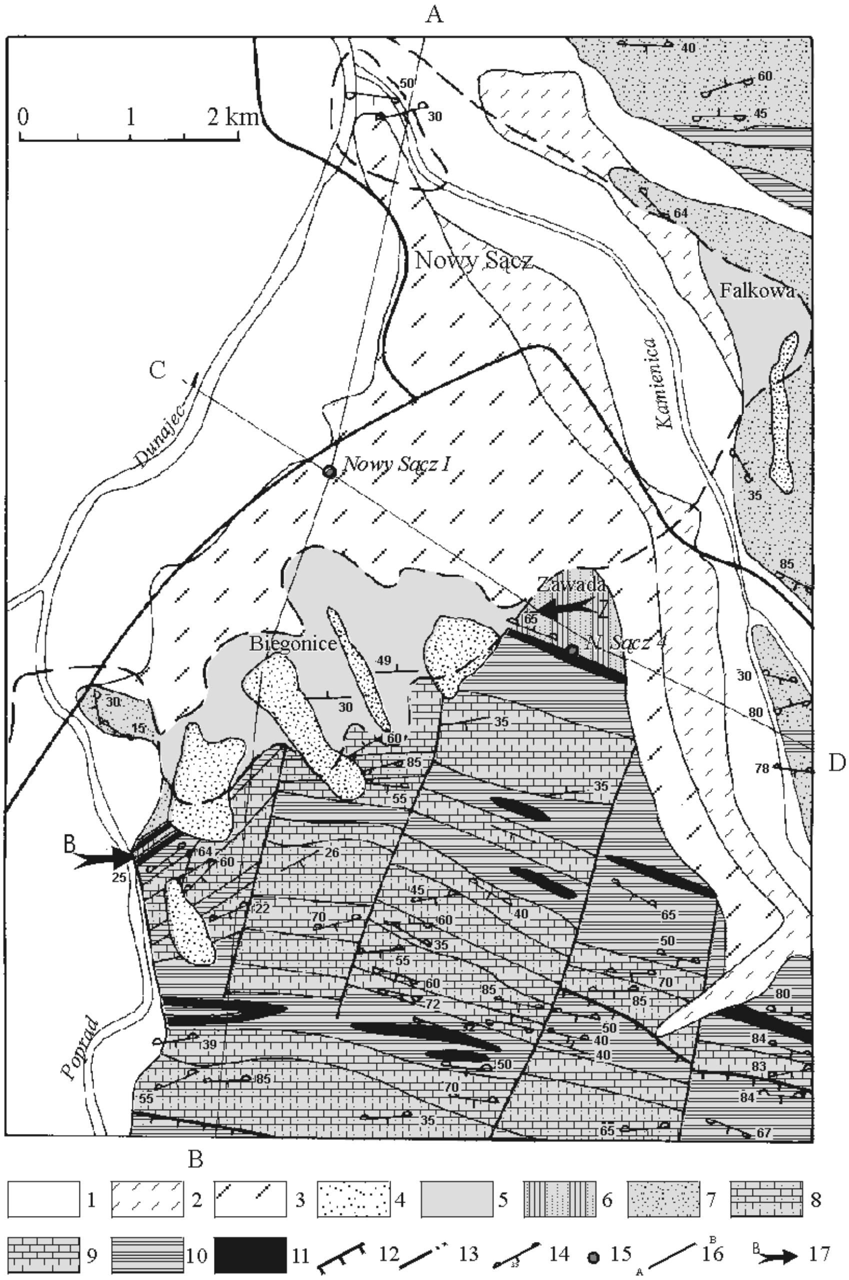


Fig. 3. Geological map of the Nowy Sącz area (based on Oszczypko & Wójcik 1992, supplemented). **Quaternary:** 1 — gravels, sands and clays of terraces of a height of 2–6 m, 2 — gravels, sands and clays of terraces of a height of 6–12 m, 3 — gravels, sands and clays of terraces of a height of 17–30 m, 4 — gravels, sands and clays of terraces of a height of 55–80 m; **Middle Miocene:** 5 — paludal deposits, Magura Nappe, 6 — Zawada Fm. (Lower Miocene), Magura Fm., 7 — Poprad Mb. (Upper Eocene), 8 — Maszkowice Mb. (Middle Eocene), 9 — Żeleźnikowa Fm. (Middle Eocene), 10 — Beloveža Fm. (Lower-Middle Eocene), 11 — Łabowa Fm. (Lower Eocene), 12 — inverse faults, 13 — faults, 14 — attitude of beds and position of sole mark, 15 —boreholes, 16 — cross-section, 17 — B, Z-location of the Biegonice and Zawada exposures.

18.3–19.8 m: dark brown and green calcareous (++HCl) mudstones.

19.8–20.65 m: light grey, fine-grained, convoluted, calcareous (+++HCl) sandstone with intercalation of grey, calcareous (+++HCl) shales.

20.65–23.10 m: dark brown, calcareous mudstones and olive-green shales with 3 cm intercalation of very fine-grained sandstone.

23.1–25.0 m: fine- to medium-grained, calcareous sandstone (+HCl) with siliceous veinlets and brown-greenish, calcareous shales and grey mudstone with parallel, sandy lamination. Angle of dip from 40° (23.5–23.8 m) up to vertical and overturned position (23.95–24.6 m).

Deposits occurring from a depth of 12.8 to 25 m belong to the Rača Subunit and are regarded as a new formation: the Zawada Formation (Early Miocene).

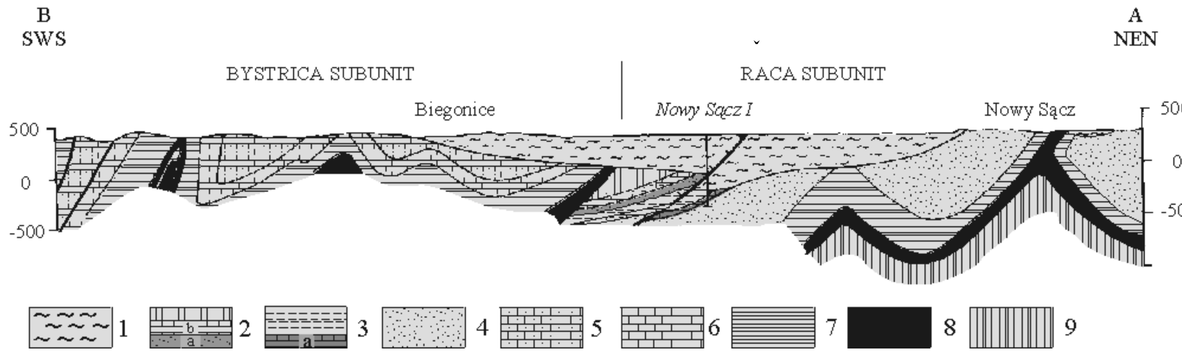


Fig. 4. Geological cross-section A–B (based on Oszczypko & Wójcik 1992, supplemented). 1 — Paludal deposits (Middle Miocene), Magura Nappe, 2 — Zawada Fm. (Lower Miocene), a — glauconitic sandstone, b — thick-bedded marls, 3 — Malcov Fm. (Upper Eocene–Oligocene), a — Leluchów Marl Mb., Magura Fm., 4 — Poprad Mb. (Upper Eocene), 5 — Maszkowice Mb. (Middle Eocene), 6 — Żeleźnikowa Fm. (Middle Eocene), 7 — Beloveža Fm. (Lower–Middle Eocene), 8 — Łabowa Fm. (Lower Eocene), 9 — Inoceramian Beds (Senonian–Paleocene).

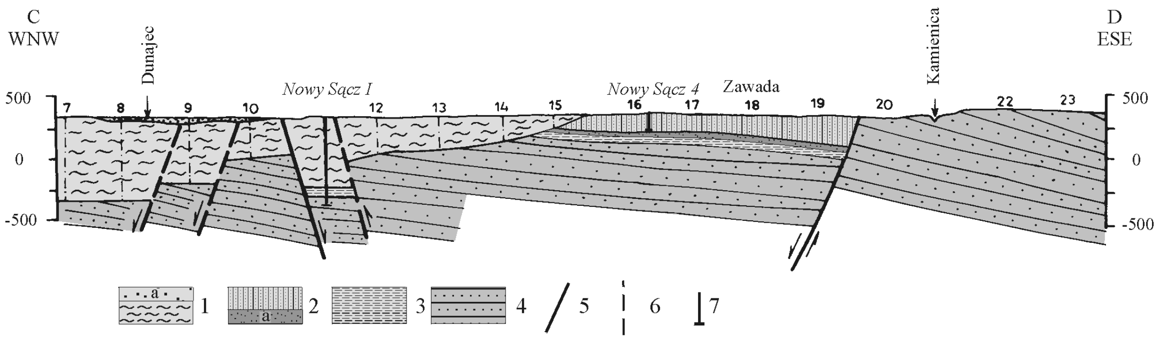


Fig. 5. Geological cross-section C–D (based on Oszczypko 1973, supplemented). 1 — Paludal deposits (Middle Miocene), 1a — offshore deposits, Magura Nappe, 2 — Zawada Fm. (Lower Miocene), 2a — glauconitic sandstones, 3 — Malcov Fm. (Upper Eocene–Oligocene), 4 — Magura Fm.—Poprad Mb. (Upper Eocene), 5 — faults, 6 — geoelectric sounding, 7 — boreholes.

Biostratigraphy

Studied material and methods. Core samples from borehole Nowy Sącz 4 were collected between 10 and 25 m of the penetrated section for biostratigraphic purposes. Small foraminifers have been examined in 14 samples and nannoplankton in 9.

To isolate the foraminifers, samples were frozen and heated in a solution of sodium sulphate several times, then washed over 63 μm mesh sieve and air-dried. After drying, individual foraminifers were hand-picked. Some of the planktonic species, important for the age determination are illustrated by SEM microphotographs (Plate I).

For the nannoplankton examination all samples were prepared with the standard smear slide technique for light microscope (LM) observations. The investigations were carried out under LM at magnification of 1024× and 1600× using phase contrast and crossed nicols. Several specimens photographed under LM are illustrated in Plate II.

Small foraminifers. The abundance, sizes and preservation of the foraminifers vary from sample to sample. Planktonic, benthonic calcareous and agglutinated foraminifers occur in the studied material. Corrosion and destruction of tests have been noticed among calcareous specimens.

Only two samples from the first 3 m contain autochthonous assemblages homogenous in respect of the age of the foraminifers, whereas in the remaining ones the taxons forming each assemblage are of different age. In those cases older, reworked specimens are in the majority. The youngest planktonic taxons, the most important for age determination are very difficult to find because they are very small in size and much less frequent than the reworked species.

In the samples 28/85/N and 30/85/N (Fig. 6), the flysch type agglutinated assemblages have been found. *Ammodiscus latus* Grzybowski and *Reticulophragmium amplectens* (Grzybowski) are the most significant species in those assemblages determining the age as the upper part of the Middle Eocene (Geroch & Nowak 1984; Olszewska 1997).

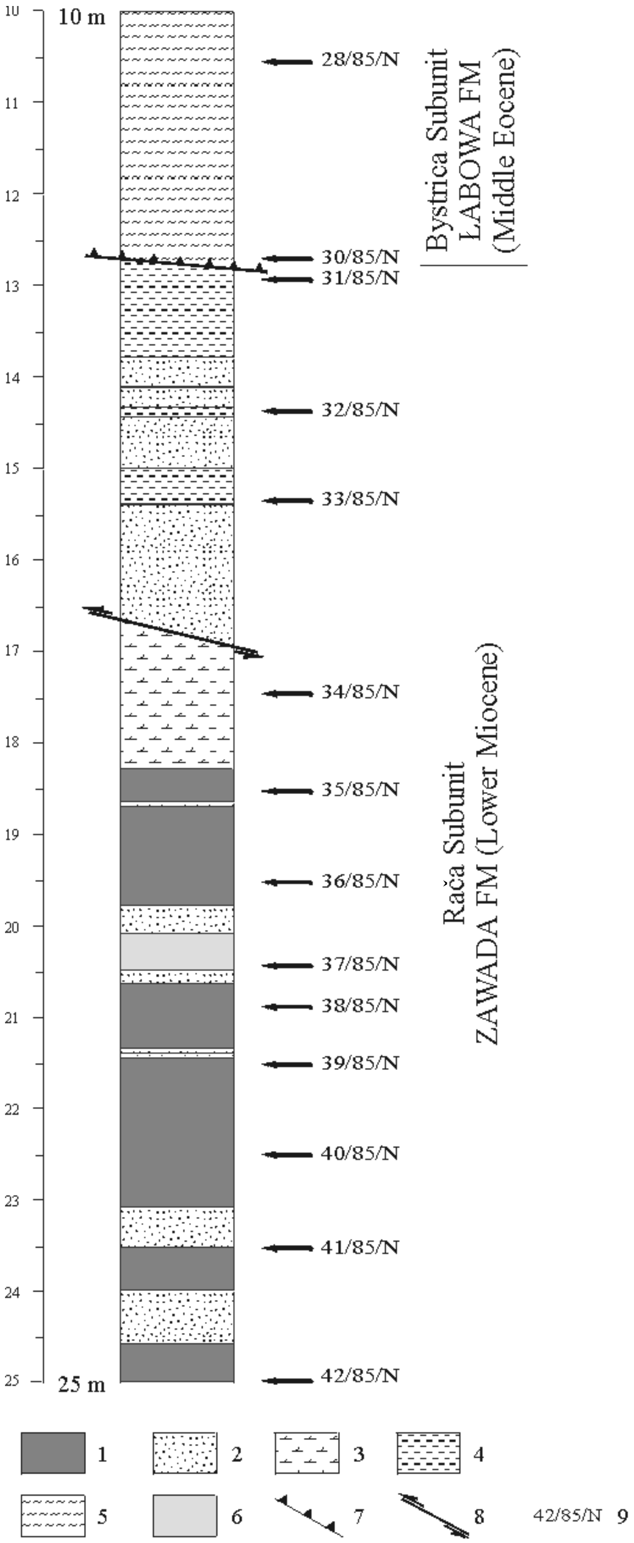
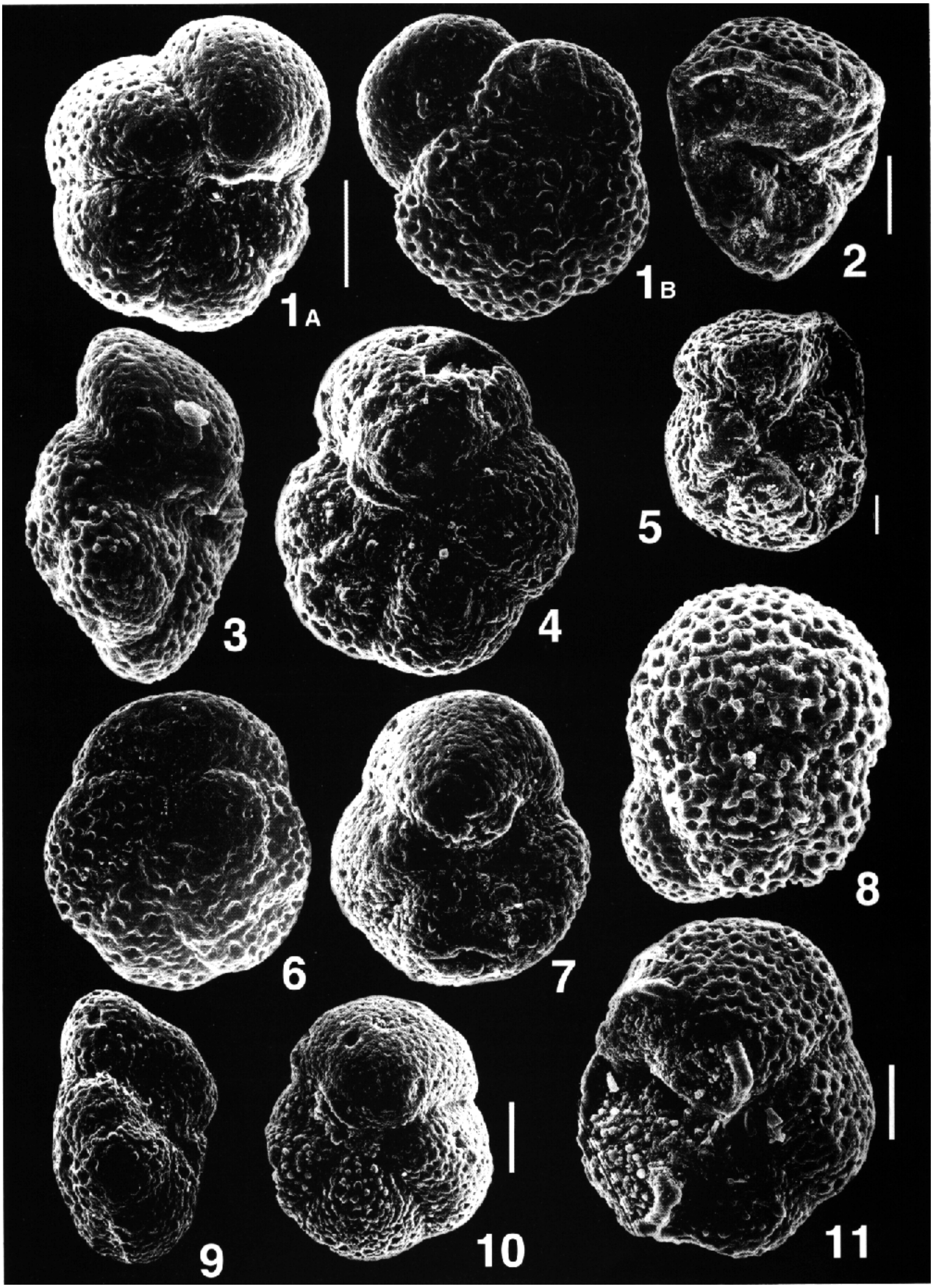


Fig. 6. Geological log of the Nowy Sącz-4 borehole. 1 — grey-bluish calcareous mudstones, 2 — thin to thick-bedded glauconitic sandstones, 3 — greenish-grey claystones, 4 — greenish and grey calcareous mudstones, 5 — variegated shales, 6 — grey calcareous shales, 7 — overthrust, 8 — inverse fault, 9 — samples.

The sample 31/85/N contains impoverished assemblage with very small and poorly preserved planktonic forms, impossible for precise determination.

In the sample 32/85/N at the depth of 14.4 m, the Early Miocene species *Globorotalia praescitula* Blow and single specimen of *Globigerinoides primordius* Blow et Banner have been noticed for the first time in the section (Fig. 7). Planktonic foraminifers are the main component of the assemblage with dominance of the Middle Eocene species *Turborotalia frontosa* (Subbotina), *Acarinina* ex.gr. *bulbrooki* (Bolli), *Globanomalina micra* (Cole), *Globigerina eocaena* Gümbel and *Subbotina linaperta* (Finlay). The next three samples consist mainly of agglutinated foraminifers with *Haplophragmoides walteri* Grzybowski, *Paratrochamminoides* div.sp. and in one case with single specimens of *Reticulophragmium amplectens* (Grzybowski). These taxons are common elements in the Eocene assemblages. Among calcareous forms the benthonic species *Cribroelphidium subgranosum* (Egger) (s. 34/85/N) and planktonic *Globorotalia* cf. *praescitula* and *Globorotalia* cf. *zealandica* Hornibrook have been recognized indicating Early Miocene age. The sample 36/85/N at the depth of 19.5 m (Fig. 7) has appeared to be the most important among the others. The foraminiferal fauna is relatively rich though generally of the very small sizes. This is an entirely calcareous assemblage with planktonic forms making more than 95 %. It has been noticed that some tests of the foraminifers are empty and very fragile. The Middle Eocene species are dominant (see Fig. 7). *Globanomalina micra, Turborotalia frontosa* and *Acarinina* ex.gr. *bulbrooki* are the most numerous. Younger species, that is Late Eocene–Early Oligocene such as *Tenuitella liverovskae* (Bykova), *Globoquadrina tripartita* (Koch), *Globigerina ampliapertura* Bolli are also present though they are much rarer. The youngest Early Miocene species so far recognized, are represented by *Globorotalia praescitula* (relatively common), *Globorotalia kingmai* Scott, Bishop et Burt, *Paragloborotalia* cf. *mayeri* (Cushman et Ellisor), *Tenuitellinata pseudoedita* (Subbotina), *Globigerinoides trilobus* (Reuss) and *Chiloguembelitria samwelli* (Jenkins). The benthonic foraminifers are represented by the genera C*aucasina, Bolivina, Trifarina, Bulimina* and *Cibicides.* Other Early Miocene species *Globoquadrina dehiscens* (Chapman, Parr et Collins) and *Globoturborotalita* cf. *woodi* (Jenkins) have been found in the samples 39/85/N at the depth of 21.5 m (Fig. 7). In the last sample at the depth of 25 m, *Globoquad-*

Plate I: SEM microphotographs of selected planktonic foraminifers from the Zawada Fm. **Figs. 1, 3–4** — *Globorotalia kingmai* Scott, Bishop et Burt, ×500; **Fig. 1A** — umbilical side; **Fig. 1B** — spiral side, sample 42/85/N; **Fig. 3** — side view; **Fig. 4** — umbilical side, sample 36/85/N; **Figs. 2, 5** — *Globoquadrina dehiscens* (Chapman, Parr et Collins), sample 42/85/N; **Fig. 2** — side view, ×350; **Fig. 5** — umbilical side, ×200; **Figs. 6–7, 9–11** — *Globorotalia praescitula* Blow; **Fig. 6** — spiral side, ×500, sample 42/85/N; **Fig. 7** — umbilical side, ×500, sample 36/85/N; **Fig. 9** — side view, ×500; **Fig. 10** — umbilical side, ×350; **Fig. 11** — umbilical side, ×390, sample 36/85/N; **Fig. 8** — *Globigerinoides trilobus* (Reuss), ×500, sample 36/85/N. Scale bar = 50 μm. For specimens 3, 4, 6, 7, 8, 9 the same scale bar as in Fig.1.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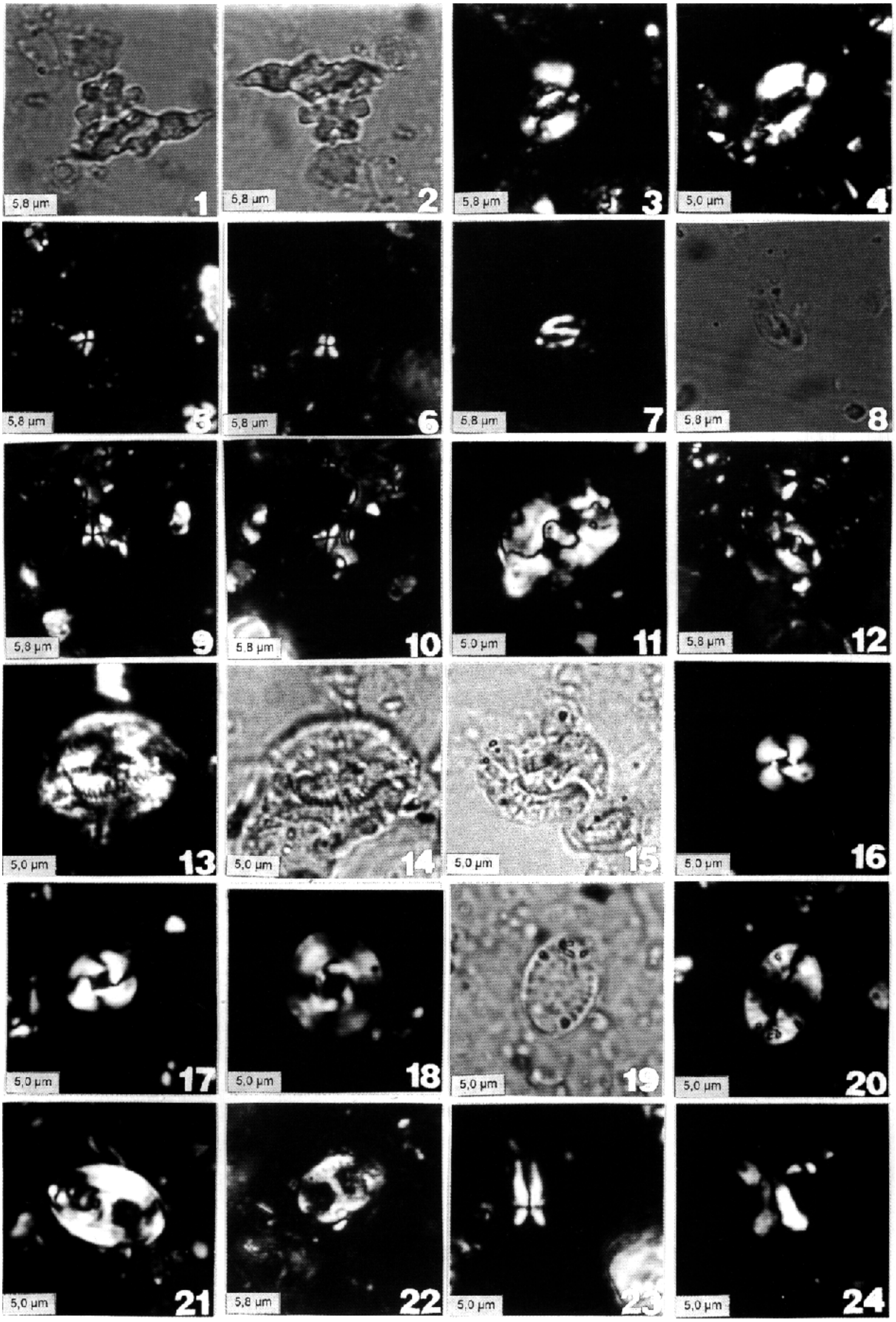
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rina dehiscens is the most numerous among other Early Miocene species. Besides them and the Eocene planktonic species the piritized Oligocene forms such as *Tenuitellinata ciperoensis* (Bolli) has been also found.

The age determinations based on the youngest foraminiferal species, so far recognized, indicate that deposits occurring in the Nowy Sącz 4 borehole down from 12.8 m are of the Early Miocene age, but not older than N 5 Zone, that is the middle part of the Early Miocene (Berggren et al. 1995). *Globorotalia praescitula* seems to be the most significant element of the foraminiferal fauna. This species is known from many localities and from different environments throughout the world (Keller 1981; Jenkins 1977; Bizon & Glaçon 1978; Scott et al.1990). According to Bolli & Saunders (1985) its range is from N 5 to N 9 planktonic zones. This taxon has also been reported by Olszewska in the Ottnangian–Karpatian deposits in the Polish part of the Carpathian Foredeep (Odrzywolska-Bieńkowa & Olszewska 1996). *Globoquadrina dehiscens* also has its FO at the beginning of the N 5 Zone. *Chiloguembelitria samwelli* and *Globigerinoides primordius* are known to have their LO within the Early Miocene (Bolli & Saunders 1985; Odrzywolska-Bieńkowa & Olszewska 1996). *Globorotalia kingmai* was described for the first time from the Altonian stage of New Zealand, which is regarded as the uppermost Early Miocene (Scott et al. 1990).

Taxonomic note

Globorotalia kingmai Scott, Bishop et Burt
Pl. I: Figs. 1, 3–4.

1990 *Globorotalia kingmai* G.H. Scott et al., p. 21–23, fig. 16.

Description: Test circular in outline, lobulate, with almost symmetrical outer margin. In axial orientation discoidal with rounded or slightly compressed periphery. In the final whorl 5 chambers, triangular on the umbilical side and crescent on spiral side. The last chamber symmetrically arched on the spiral side and distinctly convex on the umbilical side. Inner whorls poorly visible. Sutures radial on the umbilical side and curved on the other side. Aperture a low extraumbilical arch with distinct lip.

Remarks: Our specimens are much smaller in size (about 160–180 μm) than the holotype. Found in sample 36/85/N and 42/85/N.

Calcareous nannoplankton. The examined samples yield well preserved and diverse calcareous nannoplankton assemblages (Fig. 8), highly dominated by the reworked species, especially those of Middle/Late Eocene such as *Chiasmolithus gigas* (Bramlette et Sullivan), *Chiasmolithus grandis* (Bramlette et Riedel), *Chiasmolithus oamaruensis* (Deflandre), *Discoaster barbadiensis* Tan, *Discoaster bifax* Bukry, *Sphenolithus radians* Deflandre. The level of reworking is the highest in sample 36/85/N and reworked taxons represent more than 60 % of all determined species, whereas in samples 37/85/N, 38/85/N and 39/85/N it is decreasing considerably, reaching values not higher than approximately 20–30 %.

The autochthonous assemblage is dominated by *Cyclicargolithus floridanus* (Roth et Hay), *Cyclicargolithus abisectus* (Müller), *Coccolithus pelagicus* (Wallich) and *Sphenolithus conicus* Bukry whereas *Sphenolithus belemnos* Bramlette et Wilcoxon, *Helicosphaera gertae* Bukry, *Helicosphaera intermedia* Martini, *Helicosphaera scisura* Miller, *Discoaster druggii* Bramlette et Wilcoxon are less common.

The Miocene nannoplankton zonation is mainly based on the last (LO) or first occurrence (FO) of *Discoaster* and thus is easily accomplished in low latitudes, where discoasters are common in open ocean assemblages. However, these typically warm water and open oceanic species are rare or absent in the higher latitudes and in assemblages from marginal seas. All the other marker species belong to genera that are more common or even restricted to low latitudes and thus the zonation is most reliable and correlable over wide distance in low latitudes only.

The zone assignment of the described section is based on a continuous range of *Sphenolithus conicus* and *Sphenolithus belemnos* followed by the FO of *Discoaster druggii*. The FO of *Discoaster druggii* is the biostratigraphic event marking the lower boundary of the NN 2 Zone. The upper boundary of the NN 2 Zone is usually marked by the LO of *Triquetrorhabdulus carinatus* Martini, which was not found in the assemblages from the Nowy Sącz 4 section. The absence of this species may be due to poor preservation of the whole assemblage. However, at the same time, we cannot exclude the possibility of the presence of the NN 3 Zone.

It is also necessary to discuss the biostratigraphic ranges of *Reticulofenestra pseudoumbilica*, *Sphenolithus belemnos* and *Helicosphaera vedderi* Bukry. According to the standard zonation of Martini (1970) and Martini & Worsley (1970) the first occurrence of *Reticulofenestra pseudoumbilica* (Gartner) takes place in NN 5. However, in the Intra- and Extra-Carpathian areas of Romania the FO of *Reticulofenestra pseudoumbilica* co-

Plate II: LM microphotographs of selected calcareous nannoplankton from the Zawada Fm. **Fig. 1.** *Discoaster druggii* Bramlette et Wilcoxon sample 36/85/N; **Fig. 2.** *Discoaster druggii* Bramlette et Wilcoxon sample 36/85/N; **Fig. 3.** *Helicosphaera scisura* Miller sample 40/85/N; **Fig. 4.** *Helicosphaera scisura* Miller sample 40/85/N; **Fig. 5.** *Sphenolithus conicus* Bukry sample 40/85/N; **Fig. 6.** *Sphenolithus conicus* Bukry sample 40/85/N; **Fig. 7.** *Helicosphaera vedderi* Bukry sample 40/85/N; **Fig. 8.** *Helicosphaera vedderi* Bukry sample 40/85/N; **Fig. 9.** *Sphenolithus conicus* Bukry sample 36/85/N; **Fig. 10.** *Sphenolithus conicus* Bukry sample 36/85/N; **Fig. 11.** *Helicosphaera euphratis* sample 40/85/N; **Fig. 12.** *Helicosphaera intermedia* Martini sample 40/85/N; **Fig. 13.** *Helicosphaera gertae* Bukry sample 40/85/N; **Fig. 14.** *Helicosphaera gertae* Bukry sample 40/85/N; **Fig. 15.** *Helicosphaera gertae* Bukry sample 40/85/N; **Fig. 16.** *Cyclicargolithus floridanus* (Roth et Hay) sample 37/85/N; **Fig. 17.** *Cyclicargolithus floridanus* (Roth et Hay) sample 37/85/N; **Fig. 18.** *Cyclicargolithus abisectus* (Müller), sample 36/85/N, **Fig. 19.** *Ponthosphaera multipora* (Kamptner) sample 39/85/N, **Fig. 20.** *Ponthosphaera multipora* (Kamptner) sample 39/85/N; **Fig. 21.** *Transversopontis pulcher* (Deflandre) sample 36/85/N; **Fig. 22.** *Transversopontis fibula* Gheta sample 40/85/N; **Fig. 23.** *Sphenolithus furcatolithoides* Locker sample 40/85/N; **Fig. 24.** *Zygrhablithus bijugatus* (Deflandre) sample 36/85/N.

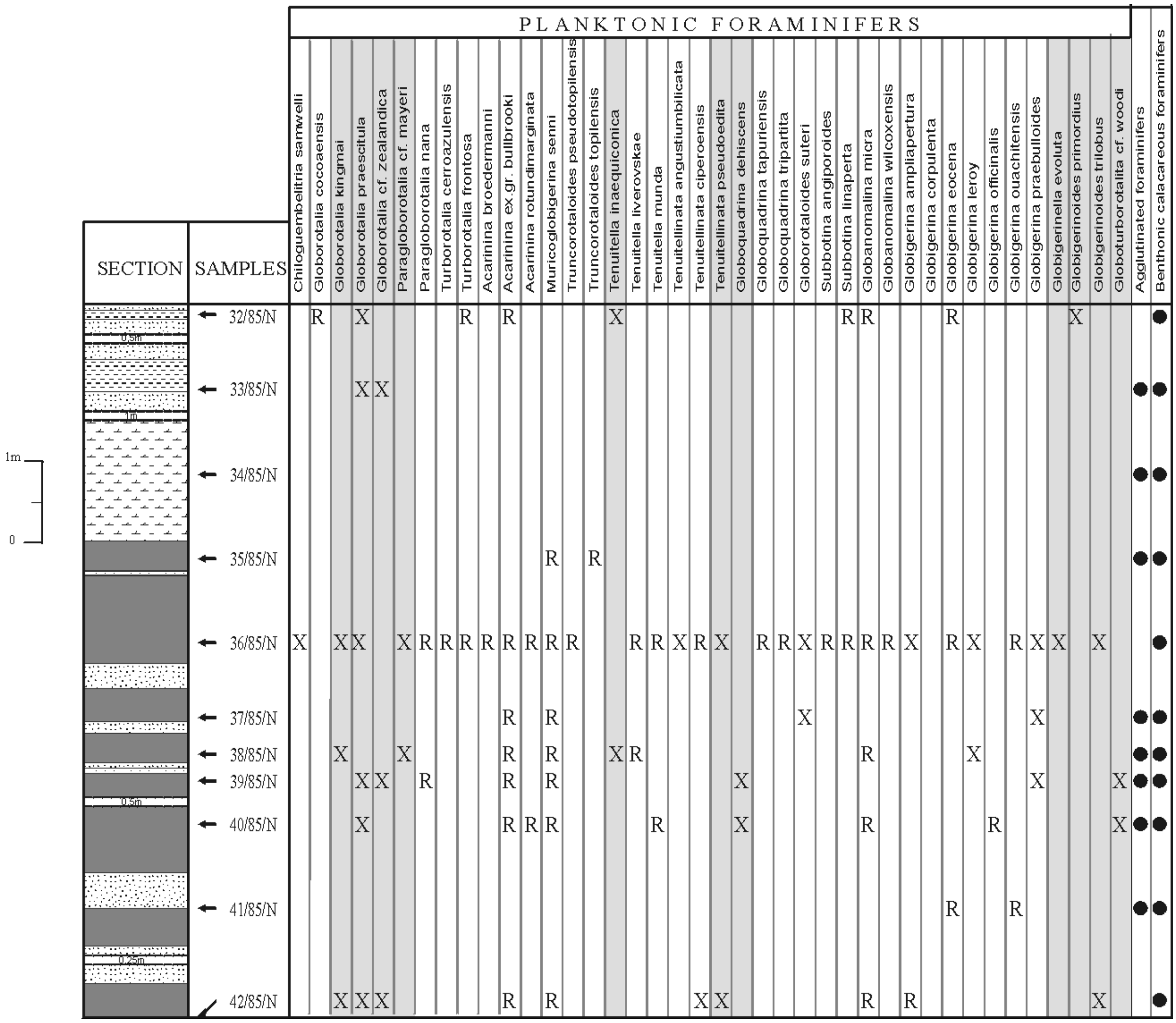


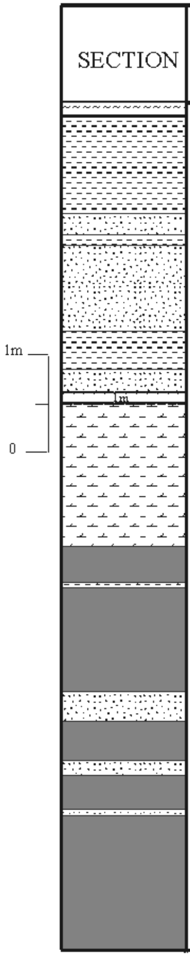
Fig. 7. Distribution of selected foraminifers of the Zawada Fm. in the Nowy Sącz-4 borehole. X — autochthonous species, R — reworked species. Grey stripe — biostratigraphically important species. For other explanations see Fig. 6.

incides with the FO *Discoaster druggii* (Marunteanu 1991), which corresponds with the lower limit of NN 2 Zone. The biostratigraphic range of *Helicosphaera vedderi* is also problematic. This taxon was reported by Bukry (1973, 1975) from his zones CN 3 and CN 4, though, according to Theodoridis (1984), *Helicosphaera vedderi* ranges from as low as his Eu-discoaster druggii Subzone. The Eu-discoaster Subzone of the "Integrated Miocene Zonation" corresponds to the lower part of NN 2 Zone. Finally, the FO of *Sphenolithus belemnos,* used by Bukry to define the base of his Sphenolithus belemnos Zone, is usually found slightly below the LO of *Triquetrorhabdulus carinatus.* which is in contradiction to Martini & Worsley (1970), who placed the FO of this species as low as NN 1 Zone. In conclusion, it can be said that the calcareous nannoplankton from the Zawada section belongs to zone NN 2, but the presence of the lower part of NN 3 Zone cannot be excluded.

Lithostratigraphic correlation

In our previous papers (Oszczypko 1973; Blaicher & Oszczypko 1975; Birkenmajer & Oszczypko 1989; Oszczypko et al. 1990 and Oszczypko & Wójcik 1992) the youngest deposits penetrated in the Nowy Sącz I borehole and deposits from the Biegonice and Zawada sections were assigned to the Malcov Formation. In the light of new geological and biostratigraphic data obtained from borehole Nowy Sącz 4 and from re-examinations of the samples from Biegonice (Malata in Oszczypko et al. 1990), the authors decided to revise their previous view. Our new suggestions are as follows:

1) The deposits cropping out in the Biegonice and Zawada sections as well as in the Nowy Sącz 4 borehole (Figs. 2, 3, 5, 6) reveal the same facies-lithological development, age and tectonic position. A common feature of these deposits is



CALCAREOUS NANNOPLANKTON

SAMPLES	Braarudosphaera bigelowii	Chiasmolithus expansus	Chiasmolithus gigas	Chiasmolithus grandis	Chiasmolithus oamaruensis	Chiasmolithus solitus	Coccolithus eopelagicus	Coccolithus pelagicus	Coronocyclus nitescens	Cyclicargolithus abisectus	Cyclicargolithus floridanus	Dictyococcites bisectus.	Dictyococcites callidus	Dictyococcites hesslandii	Discoaster adamanteus	Discoaster barbadiensis	Discoaster bifax	Discoaster binodosus	Discoaster deflandrei	Discoaster distinctus	Discoaster druggii	Discoaster germanicus	Discoaster saipanensis	Discoaster strictus	Discoaster tani nodifer	Discoaster wemmelensis	Ericsonia fenestrata	Ericsonia formosa	Helicosphaera euphratis	Helicosphaera gertae	Helicosphaera intermedia	Helicosphaera lophota	Helicosphaera scisura	Helicosphaera seminullum	Helicosphaera vedderi	Holodiscolithus solidus	Neococcolithes dubius	Pontosphaera sp.	Pontosphaera plana	Pontosphaera multipora	Reticulofenestra dictyoda	Reticulofenestra hillae	Reticulofenestra minuta	Reticulofenestra pseudumbilica	Sphenolithus belemnos	Sphenolithus capricornutus	Sphenolithus conicus	Sphenolithus dissimilis	Sphenolithus furcatolitoides	Sphenolithus moriformis	Sphenolithus pseudoradians	Sphenolithus radians	Tranversopontis fibula	Tranversopontis obliquipons	Tranversopontis pulcher	Tranversopontis pulcheroides	Zygrhabitlthus bijugatus
31/85/N		R		R		R		X			X	R	R	R		R											R					R		R				X		X	R									X		R				X	R
32/85/N			R	R	R	R		X		X	X	R		R	X	R	R	R				R				R	R	R		X				R				X		X	R				X		X	R		X		R				X	R
33/85/N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
34/85/N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
36/85/N		R	R	R		R	X	X	X	X	X	R		R		R	R	R		R		R			R	X	X		X	X	X					X	R	X		X	R	X		X	X	X	X	R	R	X	R	R		X	X	X	R
37/85/N	X	R	R	R	R	R	X	X	X	X	X	R		R		R	R	R	X				R		R	X	R	R		X	X						R	X		X	R		X	X	X	X	X			X				X	X	X	R
38/85/N	X	R			R	R	X		X	X	X			R		R	R	R	X	R				R		X	R	X			X						R	X		X	R		X	X	X	X	X			X	R				X	X	R
39/85/N	X	R			R	R	X		X	X	X			R		R	R	R		R	X			R		R	R	R		X	X						R	X		X	X		X	X	X	X	X			X				X	X	X	R
40/85/N	X								X	X	X					R			X		X							R	X	X	X		X		X		R			X	R		X		X		X		R				R	X	X	X	R

Fig. 8. Distribution of calcareous nannofosils in the Nowy Sącz-4 borehole. X — determined species, R — reworked species. Grey stripe — biostratigraphically important species. For other explanations see Fig. 6.

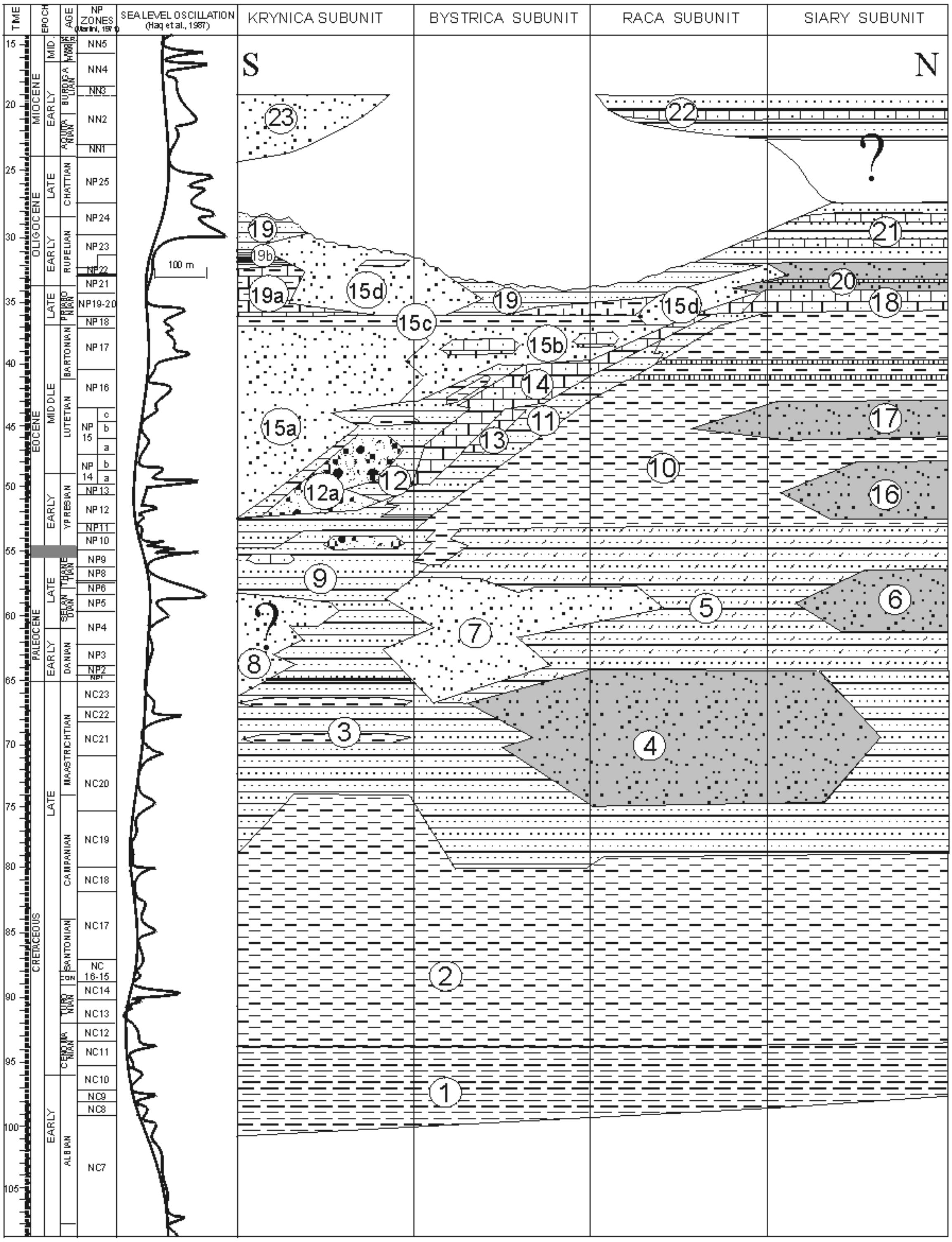


Fig. 9. Lithostratigraphy of the Magura Nappe in Poland (after Oszczypko 1992, supplemented). 1 — pelagic shales, 2 — pelagic marls, 3 — hemipelagic variegated shales, 4 — distal limy turbidites, 5 — distal turbidites, 6 — thick-bedded carbonate turbidites, 7 — channel fan turbidites (muscovite), 8 — channel fan turbidites (glauconite), 9 — black shales and hornstones, 10 — tuffites, 11 — 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*— Beloveža Fm., *12* — Zarzecze Fm., *12a* — Krynica Sandstone Mb., *13* — Bystrica Fm., *14* — Żeleźnikowa Fm., Magura Fm., *15a* — Piwniczna Mb., *15b* — Maszkowice Mb., *15c* — Mniszek Mb., *15d* — Poprad Mb., *16* — Ciężkowice Sandstone, *17* — Pasierbiec Sandstone, *18* — Zembrzyce (Sub-Magura) Beds, *19* — Malcov Fm., *19a* — Leluchów Marls Mb., *19b* — Smereczek (Menilite) Mb., *20* — Wątkowa Sandstone, *21* — Budzów (Supra-Magura) Beds, *22* — Zawada Fm., *23* — Stare Bystre Beds.

the presence of the thick-bedded glauconitic sandstones and medium- to thick-bedded marls suggesting their facies connection with the glauconitic development, typical for the northern part of the Magura Basin. On the other hand, the Malcov Fm. and older formations of the Rača Subunit are rather related to the muscovite (southern) development (see Oszczypko 1973).

2) We propose to establish the Zawada Formation as a new lithostratigraphic unit.

3) The Zawada Fm. differs from the Malcov Fm. both in facies-lithological development and in age.

4) The relationship between these two formations is not clear due to the lack of exposures (Figs. 2, 3, 4, 5). In the Biegonice section the lower boundary of the Zawada Fm. is probably of tectonic origin (Fig. 3), whereas in the more eastern area the Zawada Fm. probably overlaps the Malcov Fm. (see Figs. 4, 5). This superimposed position of the Zawada Fm. over the Malcov Fm. could have either a primary (sedimentological) or a secondary (tectonic) character.

5) In all locations the Zawada Fm. occurs above the Late Eocene–Oligocene deposits of the Rača Subunit and beneath the Bystrica Subunit frontal thrust (Figs. 2, 3, 4, 5).

Structural and paleogeographical implications

The Outer Carpathian Flysch Belt could be subdivided into two groups (Książkiewicz 1977; Săndulescu 1988; Plašienka et al. 1997): the Krosno-Menilite (Moldavian) nappes in the north and the Magura Nappe in the south. The Magura Nappe is traditionally regarded as an Oligocene accretionary wedge (Săndulescu 1988; Oszczypko 1992; Oszczypko 1997), overthrust onto the Krosno-Menilite zone (Moldavides sensu Săndulescu 1988) — an Early/Middle Miocene accretionary wedge.

Our latest investigations in the Nowy Sącz area have given the possibility for better definition of the Magura Nappe development in Poland. This nappe was completely uprooted from its substratum along the ductile Upper Cretaceous variegated shales. At the southern margin of the Mszana Dolna tectonic window the Cenomanian-Albian spotty shales are locally preserved (Fig. 9). From the Campanian to the Late Eocene the Magura Basin was dominated by the deep-water turbiditic deposition. At the turn of Eocene the bottom of the Magura Basin was partly inversed. It was probably the result of both the submarine folding of the Krynica, Bystrica and Rača subunits and a global fall of the sea level (Fig. 9, see also Haq et al. 1987). This event was followed by an Early Oligocene subsidence and intensive deposition in the northern part of the basin (Siary zone).

The occurrence of the folded Lower Miocene marine deposits, discovered by the present authors in the Nowy Sącz area, requires some modification to the previous opinions (Książkiewicz 1977; Săndulescu 1988; Oszczypko 1992; Jiříček & Seifert 1990; Kováč et al. 1989). For later consideration it is very important to recognize the relationship between the Lower Miocene Zawada Fm. and the Upper Eocene–Lower Oligocene Malcov Fm. If we exclude tectonic contact between these two formations there are two possible explanations: sedimentological transition or erosional boundary. Taking into account the lack of information about the Upper Oligocene and the lowermost Miocene (NN 1 Zone) deposits in the Nowy Sącz area, the erosional hiatus between these two formations (Fig. 9) is more probable than the continuous deposition in the Magura Basin suggested by Cieszkowski (1992). Having accepted our thesis, it is possible to suggest the following paleogeographical scenario (Fig. 10): after the Middle Oligocene folding, the Magura Nappe was formed and thrust towards the north onto the terminal Krosno-Menilite flysch basin (see Andreyeva-Grigorovich & Gruzman 1994; Oszczypko 1997, 1998; Kováč et al. 1998). During the Burdigalian high stand of the sea level (see Haq et al. 1987), part of the Magura Nappe was flooded by marine transgression and the Zawada Fm. was deposited in the Rača Zone (Fig. 10). This flooding probably affected only depressed parts of the already formed Magura Nappe. The Early Miocene planktonic foraminifers from the Zawada Fm. do not indicate the depth of the sea because these species are known both from neritic deposits (Scott 1972; Scott et al. 1990) and from bathial depths (Keller 1981). At that time the seaway connection with the Vienna Basin via Orava (see Cieszkowski 1992) was probably established (Fig. 10). At the same time another seaway connection between the residual flysch basin and the Fiľakovo/Petervására Basin via the East Slovak Basin existed (see Sztano 1994; Halasová et al. 1996; Kováč & Zlinská 1998). The Zawada Fm. is characterized by a significant amount of reworked foraminiferal fauna and nannoplankton mostly from the Middle Eocene pelagic facies. This fact suggests erosion of the uplifted part of the northern zone of the Magura Basin (?Fore-Magura). The deposition of the Zawada Fm. could be more or less simultaneous with deposition of the Gorlice Beds, which contain blocks derived from the front of the Magura Nappe (Jankowski 1997). In the more external part of the basin, the Upper Krosno and Polyanitsa Beds were deposited (see Ślęzak et al. 1995; Koszarski et al. 1995; Andreyeva-Grigorovich et al. 1997). During the Ottnangian and after deposition of the

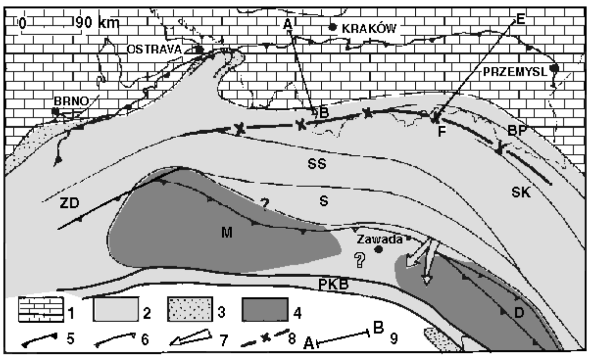


Fig. 10. Palinspastic sketch-map of the Carpathian Foreland Basin during the Early Burdigalian (Eggenburgian) (after Oszczypko 1997, supplemented); 1 — North European land, 2 — nerithic and bathyal deposition, 3 — shallow marine deposition, 4 — Carpathian land, 5 — recent Carpathian front, 6 — active thrust, 7 — possible seaways, 8 — zero line of Wise's vectors, 9 — cross-section; *Abbreviations:* PKB — Pieniny Klippen Belt; M — Magura Nappe; D — Dukla Unit; S — Silesian Unit; ZD — Ždánice Unit; SS — Subsilesian Unit; SK — Skole Unit; BP — Boryslav — Pokuty Unit.

Krepice Fm. (Moravia, Krhovský et al. 1995) Vorotyshche Fm. (Ukraine, Andreyeva-Grigorovich et al. 1997) and Salt Fm. (Romania, Micu 1982) the Outer Carpathians were finally folded and uplifted.

Conclusions

1) The youngest, marine, folded deposits of the Magura Nappe belong to the Early Miocene (N 5, NN 2–3 zones) and are of the same age as the youngest strata of the Silesian and Skole units (Upper Krosno Fm.).

2) These turbidite deposits are developed in glauconitic facies which is characteristic of the northern, marginal, part of the Magura Basin.

3) In the Nowy Sącz area (Rača Subunit) the Lower Miocene strata of the Zawada Fm. probably overlapped, with erosional hiatus, the older Eocene-Oligocene Magura accretionary wedge.

4) The Early Miocene Magura Basin was relatively deep and reached the upper/?middle bathyal depths.

5) This basin was connected with the Lower Miocene residual flysch basin which occupied the sedimentary area of the Silesian-Subsilesian and Skole units.

6) In the middle part of the Magura Nappe a seaway connection was established between the residual flysch basin and the Vienna Basin via the Orava area during the Early Miocene period.

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