

Biostratigraphy of the Early Miocene of the Southern Poland based on planktic foraminifera and calcareous nannoplankton

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The marine Miocene in the Southern Poland occurs within the flysch sequence of Outer Carpathians and in its foredeep. In Carpathians a continuous succession of nannoplankton zones from NP24 to NN4 had been found, while the earliest sediments of the foredeep may be assigned only to the NN3 nannoplankton and N6–N7 foraminiferal zones. Selected species of foraminifera and calcareous nannoplankton have been described and illustrated.

Key words: Lower Miocene, biostratigraphy, foraminifers, planktonic taxa, calcareous nannoplankton, Carpathians, Poland

Introduction

The marine Miocene sediments of the Southern Poland accumulated in two basins: in the residual flysch through and in the foreland depression (Oszczytko, 1997). The Miocene sediments of the flysch through constitute undisturbed continuation of the Cretaceous–Paleogene sequence, those of the foreland basin form several distinctive units. The Early Miocene sediments occur within the flysch sequences and in the innermost part of the foreland basin situated close to and underneath the Carpathian thrust (Fig. 1). For the long time their occurrence and stratigraphy were of lesser importance for geologists due to obscure sedimentological character of the strata and the lack of stratigraphically significant fossils. New geological data from wells performed by Polish Geological Institute and oil industry as well as application of new groups of fossils to stratigraphical research and, in some cases, radiometric datations resulted in more modern interpretation of geological structure and age of the discussed sediments (Ślaczka, 1977; Strzępka, 1981; Van Couvering et al., 1981; Buła & Jura, 1983; Nowak, 1984; Moryc, 1989; Koszarski et al., 1995; Ślęzak et al., 1995a, b; Garecka et al., 1996; Garecka & Olszewska, 1997). The present paper is a contribution to the knowledge of planktic foraminifera and calcareous nannoplankton of the Early Miocene sediments of Carpathians and the adjacent part of the foredeep and their stratigraphy.

Litho- and biostratigraphy of the Early Miocene sediments in Carpathians and their foredeep

The Carpathians. It is difficult to ascertain the beginning of the Miocene within the continuous sedimentary sequences of the Flysch Carpathians. This event can be only provisionally located with help of combined litho-, biostratigraphic and radiometric data. The primary importance for the location of the base of the Miocene in the Outer Carpathians has the horizon of laminated Jasło Limestone. In Poland it occurs within Lower Krosno Beds but is regarded as a large scale sedimentary event traceable in the whole Carpathian geosyncline (Haczewski, 1981, 1989). The calcareous nannoplankton assemblages of the laminated Jasło Limestone indicate NP24 zone (Koszarski et al., 1995; Jugowiec, 1996). The earliest Miocene NN1 zone was always

spotted above laminated Jasło Limestone at the distance depending of local sedimentation rate (Koszarski et al., 1995). Other markers useful for Carpathian Miocene stratigraphy are radiometrically dated tuff horizons occurring within Krosno Beds (Sikora et al., 1959). These are: the Radziszów Tuff (20.5 m.y.) in the boundary between the Middle and Upper Krosno Beds, the Bandrów Tuff (18.4 m.y.) situated about 150 m above the base of the Upper Krosno Beds, and the two Krzywe tuffs (19.8/15.6 m.y. respectively) identified about 500 m above the base of the Upper Krosno Beds within layers of the diatomite shales (Sikora et al., 1959; Wieser, 1985). The radiometric data thus indicate the Miocene age for majority of the Menilite–Krosno series (in the southern part of the Silesian unit the top of the series has olistostromal character and was separated as „the Gorlice Beds” by Jankowski, 1997). It should be stressed, however, that these are single determinations not supported by additional research.

The foraminifera of the discussed part of the Menilite–Krosno series were grouped initially into two, and later three assemblages (Olszewska, 1982, 1984, 1997). Their specific composition reflect local biotope changes; the world Early Miocene markers such as *Turborotalia kugleri* (Bolli), *Globoquadrina dehiscens* (Chapmann, Parr et Collins), or *Globorotalia foshi* Cushman occur sporadically and seem to have abnormally small size.

The earliest, Aquitanian assemblage occurs between the laminated Jasło Limestones up to a shaly intercalation of Niebylec Shales situated at the base of the Middle Krosno Beds (Fig. 2). Its transitional character is reflected in a specific composition of the assemblage. To characteristic species belong: *Globigerina praebulloides* Blow, *Tenuitella munda* (Jenkins), *Tenuitellinata ciperoensis* (Bolli), *T. postcretacea* (Myatlyuk), *Chiloguembelina gracillima* (Andreae), and, in the upper part of its range, single representatives of *Tenuitella inaequiconica* (Subbotina), *Cassigerinella boudecensis* Pokorny and *Chiloguembelitra samwelli* (Jenkins).

The Burdigalian assemblages (lower and upper) occur within the remaining part of the flysch sequence. The lower Burdigalian assemblage have still more endemic character reflected by the occurrence of such species as: *Cassigerinella boudecensis* Pokorny, *Globorotalia tetracamerata* Subbotina, *Tenuitella inaequiconica* (Subbotina), *T. brevispira* (Subbotina), *T. denseconnexa* (Subbotina), *Paragloborotalia pseudokugleri* (Blow), *Tenuitellinata pseudoedita* (Subbotina), with single specimens of: *Globoquadrina dehiscens*

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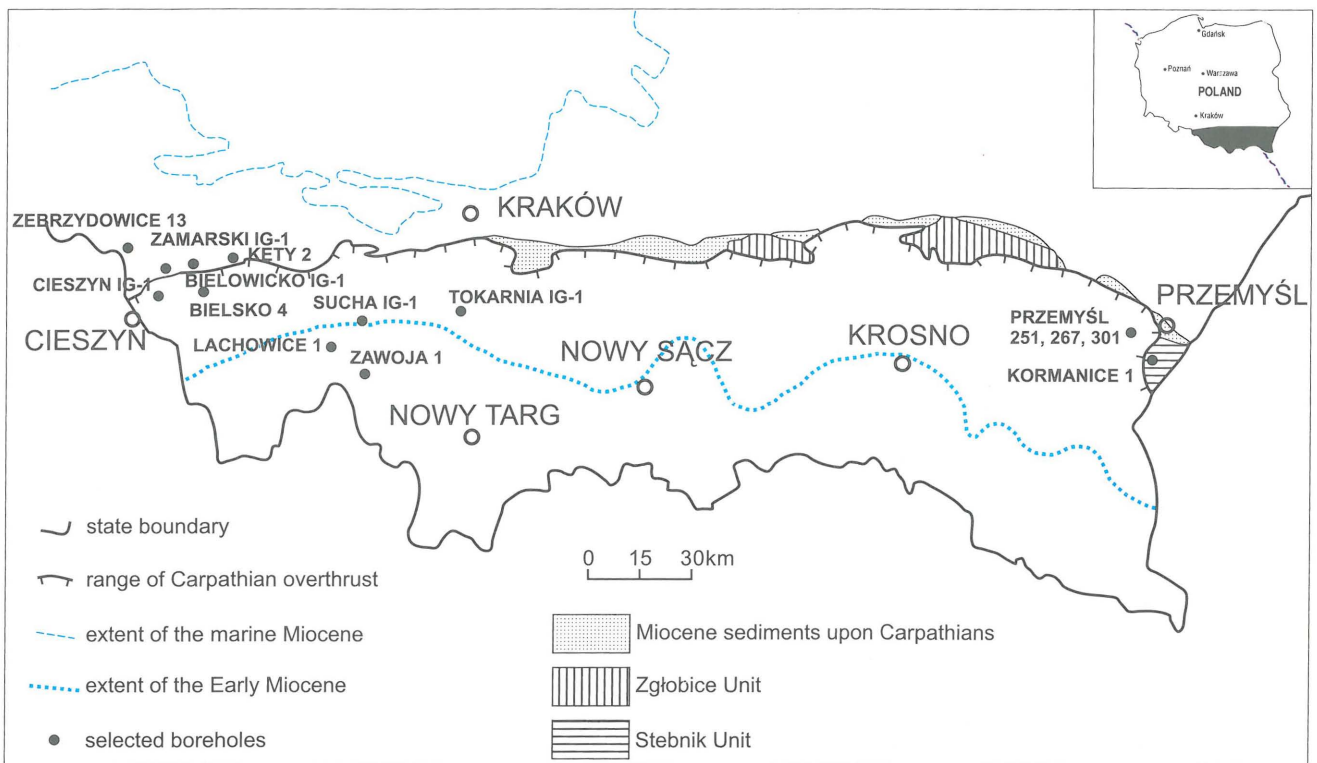


Fig. 1. Sketch-map of the Outer Carpathians and their foredeep (after Oszczypko, 1997, simplified)

Time (Ma)	Tethys stages	Paratethys stages Rógl, (1990)	BIOZONATION Berggren et al., (1995)		LITHOSTRATIGRAPHY			
			Foraminifera	Nannoplankton	CARPATHIANS		Foredeep	
					Silesian, Skole units	W part	E part	
15	LANGHIAN	BADENIAN	M6	NN5	Krzywe Tuff	Skawina Fm.	Balich Beds	
16			M5 (N8)	NN4		Bielsko Mb.	Stebnik Beds	
17	BURDIGALIAN	KARPATIAN	M4 (N7)		NN3	Bandrów Tuff	Zebrzydowice Fm.	Vorotyshe Beds
18		OTTNANGIAN	M3 (N6)	Sucha Fm.				
19	EGGENBURGIAN	EGGENBURGIAN	M2 (N5)	NN2	Radziszów Tuff	Zawoja Fm.		
20			M1 (N4)			NN1	Niebylec Shale	
21	AQUITANIAN	EGERIAN	M1 (N4)	NN1	Niebylec Shale			
22	CHATTIAN					P22	NP25	
23		KISCELIAN	KISCELIAN	P21	NP24	Jasło Limestones		
24								
25	RUPELIAN	KISCELIAN	P21	NP24	Jasło Limestones			
26								
27								
28								
29								

Fig. 2. Lithostratigraphy of the Early Miocene sediments of Carpathians and their foredeep

(Chapman, Parr et Collins), *Subbotina connecta* (Jenkins), *Globigerinoides primordius* Blow et Banner, *Globoconella ex gr zealandica* (Hornibrook). The upper Burdigalian assemblage is much more diversified and more similar to the rich Middle Miocene assemblages of the foredeep. More

frequently occur representatives of genera *Globigerinoides*: *G. primordius* Blow et Banner, *G. immaturus* Le Roy, *G. trilobus* (Reuss), *Globoquadrina* and *Dentoglobigerina*: *Globoquadrina dehiscens* (Chapmann, Parr et Collins), *Dentoglobigerina praedeheiscens* (Blow et Banner), *D. globularis* (Bermudez). Other characteristic planktic species are: *Catapsydrax stainforthi* Bolli, Loeblich et Tappan, *Globigerina bollii* Cita et Premoli Silva, *Globoturborotalita woodi* (Hornibrook), *Paragloborotalia siakensis* (Le Roy), *P. pseudocontinua* (Jenkins). Among benthic species the occurrence of *Valvulineria complanata* (d'Orbigny), *Coryphostoma digitalis* (d'Orbigny), *Cibicides mediocris* Finlay, *Pullenia bulloides* (d'Orbigny), *Melonis pompilioides* (Fichtel et Moll) and *Sphaeroidina bulloides* d'Orbigny, *Ammonia beccarii* (Linne), *Virgulopsis tuberculata* (Ehrenberg) is noteworthy (Olszewska & Szymakowska, 1984).

The essential changes in Carpathian stratigraphy resulted from application of calcareous nannoplankton for biostratigraphical research. They were summarised in several papers clearly indicating the Early Miocene age of the last stage of the flysch sedimentation (Kozarski et al., 1995; Ślęzak et al., 1995a, b; Jugowiec,

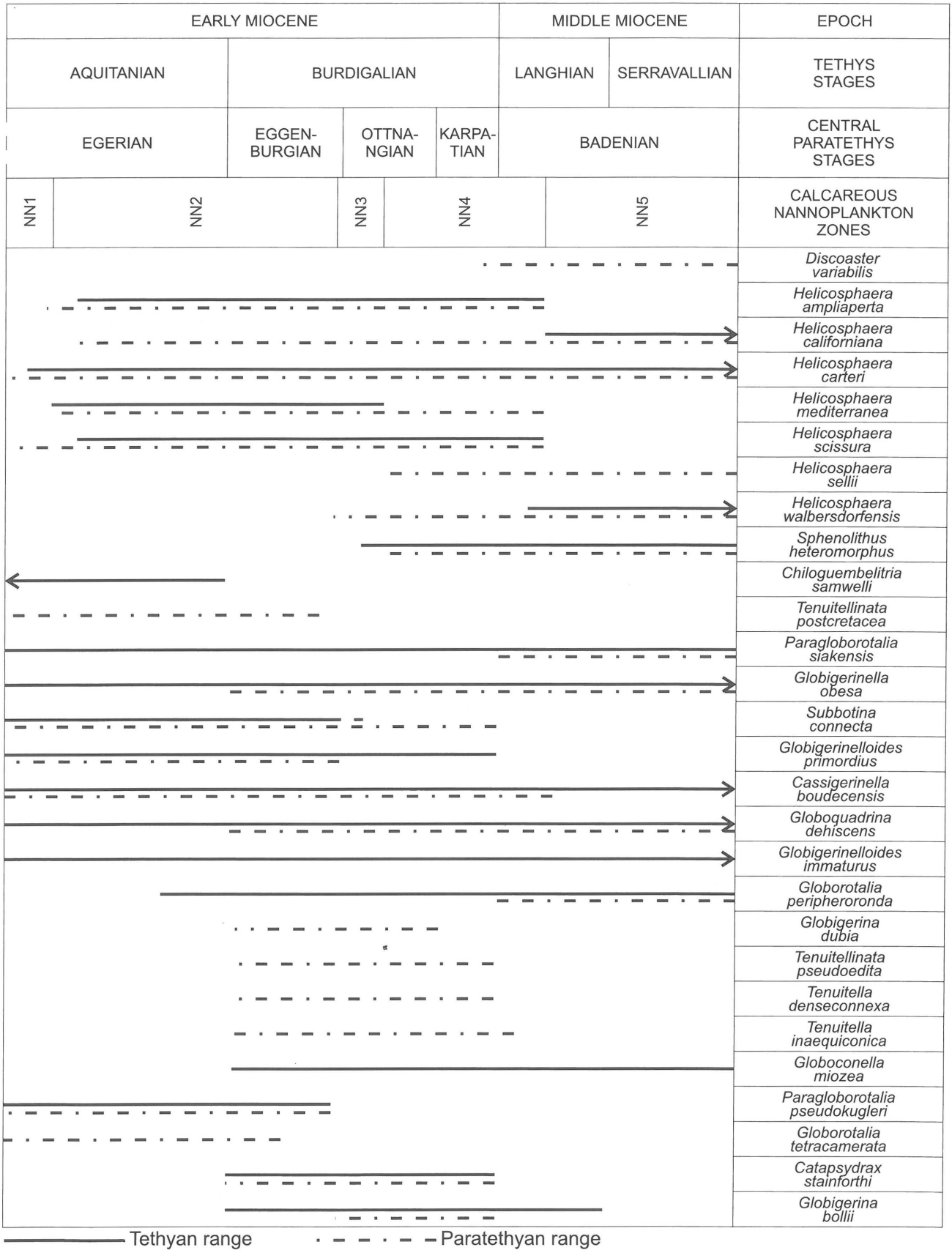


Fig. 3. Stratigraphic range of nannofossils and foraminifera from the Early Miocene sediments of Carpathians and their foredeep

1996). As it was previously mentioned the laminated Jasło Limestones contain calcareous nannoplankton indicating the NP24 (Late Rupelian–Early Chattian) zone. The assignment of Niebylec Shale (bottom of Middle Krosno Beds) to the NN2 zone is well documented by the presence of: *Helicosphaera ampliapertura* Bramlette et Wilcoxon, *H. carteri* (Wallich) and *Sphenolithus belemnos* Bramlette et Wilcoxon (Ślęzak et al., 1995a). The upper part of the Middle Krosno Beds and the lower part of the Upper Krosno Beds on the base of cooccurrence of *Sphenolithus belemnos* Bramlette et Wilcoxon and *Helicosphaera walbersdorfensis* Müller were assigned to NN3 coccolith zone (Koszarski et al., 1995; Ślęzak et al., 1995b). In the upper part of the Upper Krosno Beds in the Skole Unit the specimens of *Discoaster variabilis* Martini et Bramlette and *Sphenolithus heteromorphus* Deflandre were recorded, indicating NN4 and possibly even NN5 zone for the terminal sediments of the Flysch Carpathians (Ślęzak et al., 1995b).

The Carpathian Foredeep.

1. Western part. During recent attempts on formalization of the Early Miocene sediments in the western part of the Carpathian Foredeep (Garecka et al., 1996) the following subdivision were proposed (in stratigraphical order): the Zawoja Formation, the Zebrzydowice Formation, the Sucha Formation, the Dębowiec Formation (with Stachorówka, Bielsko and Komorowice members).

The Zawoja Formation is regarded as the oldest member of the early Miocene succession in the south-western part of the foredeep (Moryc, 1989; Oszczytko, 1997). Its assignment to the Miocene, however is based only on its position in the sequence, the biostratigraphical research revealed, so far, Cretaceous and Paleogene foraminifera (Oszczytko, 1997). The age older than Miocene cannot be excluded.

The green-grey clays of the Zebrzydowice Formation are known from the paleovalleys in the westernmost part of the foredeep (Buła & Jura, 1983). Its paleontological inventory includes among others, planktic foraminifera such as: *Catapsydrax stainforthi* Bolli, Loeblich et Tappan, *Globorotalia peripheroronda* Blow et Banner, *G. praescitula* Blow, *Globoconella miozea* (Finlay). Their occurrence suggest N6–N7 foraminiferal zones (Ottangian–Lower Karpatian) as the time span of the Zebrzydowice Formation. This conclusion is supported by findings in the lower part of the formation *Discoaster aulakos* Gartner known since NN3 coccolith zone.

The Sucha Formation was recognised in the same area as the Zawoja Formation (Ślęczka, 1977). It is characterised by frequent occurrence of olistostromes containing flysch and basement rocks. The rapid sedimentation in the type area may be responsible for rather poor paleontological data and contamination of foraminiferal and coccolith assemblages by redeposited species. Foraminiferal assemblages from the type locality contain: *Tenuitellinata pseudoedita* (Subbotina), *Tenuitella inaequiconica* (Subbotina), *T. denseconnexa* (Subbotina), *Globorotalia tetracamerata* Subbotina, *Subbotina scalena* (Rögl). The calcareous nannoplankton is represented by single specimens of: *Discoaster druugii* Bramlette et Wilcoxon and *Helicosphaera ampliapertura* Bramlette et Wilcoxon suggesting age younger than NN2 coccolith zone (Garecka et al., 1996). Lithological equivalents of the Sucha Formation in the western part of the foredeep (the Zamarski Mb. of Dębowiec Fm.), containing such foraminiferal and coccolith species as: *Globorotalia praescitula* Blow, *Globoconella miozea* (Finlay), *Sphenoli-*

thus heteromorphus Deflandre, *Discoaster variabilis* Martini et Bramlette justify attribution of the Zamarski Mb. to the upper part of the NN4 coccolith zone (base of Badenian) suggesting possible diachroneity of the upper boundary of the Sucha Formation.

The conglomerates and coarse grained sandstones of the Dębowiec Formation are transitional to more clayey Middle Miocene Skawina Formation. Fossils are found only in scarce intercalations of claystones and mudstones in the Bielsko and Komorowice members. Foraminifera in the sediments of the Bielsko Member are not stratigraphically significant, but the coccolith species such as: *Sphenolithus heteromorphus* Deflandre, *Discoaster variabilis* Martini et Bramlette, *Calcidiscus leptoporus* (Murray et Blackman) (upper part of the NN4 zone) indicate the earliest Middle Miocene age. In the overlying Komorowice Member (Dębowiec Beds of Tołwiński, 1950) foraminiferal assemblages from the more fine grained sediments already contain *Globoconella bykova* (Aisenstadt) a Middle Miocene marker from the Central Paratethys. The coccolith assemblages contain: *Sphenolithus heteromorphus* Deflandre and *Reticulofenestra pseudoumbilica* (Gartner) indicating at least the NN4 zone.

2. Eastern part. In the eastern part of the foredeep the Early Miocene sediments constitute a part of the Stebnik unit extending to the adjacent part of the Western Ukraine. In Poland these sediments, previously underlying the Carpathians, were folded and pushed northwards to the range front (Ney, 1968). The Stebnik Unit is composed of several informal subdivisions of which to the Early Miocene may be referred only two: the Vorotyshe Beds, and a part of Stebnik Beds (Garecka & Olszewska, 1997).

The Vorotyshe Beds, in Poland probably representing the upper part of this subdivision (Ney et al., 1974), are composed of grey claystones with dispersed gypsum and salt. Planktic foraminifera (in the contrary to the benthic ones) are poorly diversified and composed of long living species: *Cassigerinella boudecensis* Pokorny, *Globorotalia tetracamerata* Subbotina, *Tenuitella inaequiconica* (Subbotina), *T. denseconnexa* (Subbotina), *Tenuitellinata pseudoedita* (Subbotina), *Globoquadrina dehiscens* (Chapmann, Parr et Collins), *Globigerina cf. foliata* Bolli, *Dentoglobigerina altispira* (Cushman et Jarvis), *Globigerinoides trilobus* (Reuss). The coccolith assemblage is more significant and composed of: *Helicosphaera ampliapertura* Bramlette et Wilcoxon, *H. walbersdorfensis* Müller, *Reticulofenestra pseudoumbilica* (Gartner), *Sphenolithus heteromorphus* Deflandre. The specific composition of the assemblage suggests NN3–NN4 coccolith zones what allowed the attribution of the examined part of the Vorotyshe Beds to (? Upper) Ottangian–Karpatian (Garecka & Olszewska, 1997).

The Stebnik Beds are characterised by sediments of variegated colours, being probably (at least in part) deposited in lacustrine environment (Gurzhiy, 1969). Foraminiferal assemblages (especially their benthic components) already resemble more diversified Middle Miocene faunas. The planktic foraminifera also display moderate diversity, regardless of scarcity of specimens. To characteristic species belong: *Globoquadrina dehiscens* (Chapmann, Parr et Collins), *Globorotalia foshi* Cushman, *Paragloborotalia pseudocontiniosa* (Jenkins), *Tenuitellinata pseudoedita* (Subbotina), *Subbotina scalena* (Rögl), *Globigerina bolli* Cita et Premoli Silva, *Catapsydrax stainforthi* Bolli, Loeblich et Tappan, *Globigerinoides immaturus* Le Roy. The

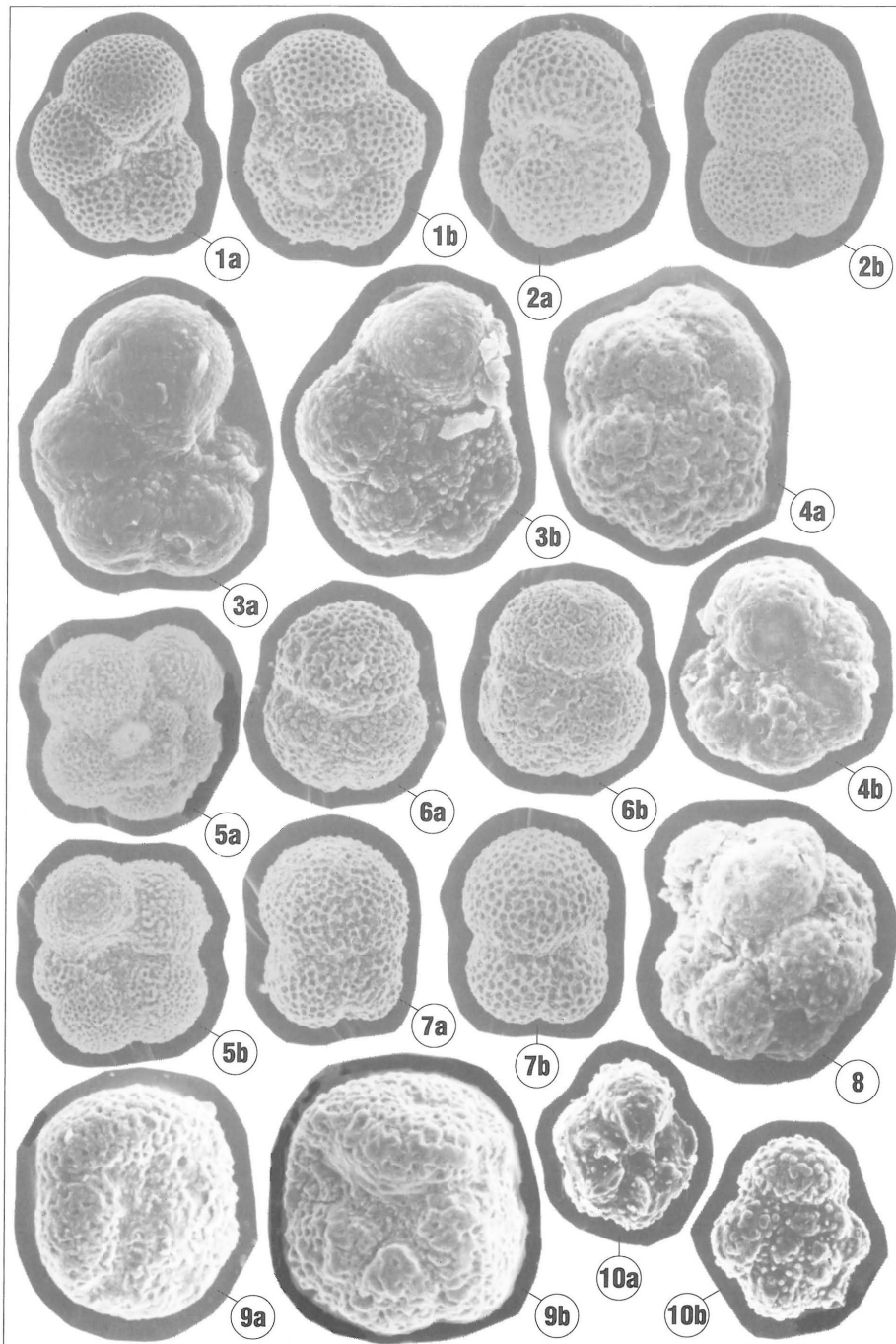


PLATE I. 1 — *Paragloborotalia siakensis* (Le Roy), x 132, a — umbilical side, b — spiral side, Kołaczyce, Outer Carpathians, Gorlice Beds; 2 — *Globigerinoides primordius* Blow et Banner, x 96, a — umbilical side, b — spiral side, Kołaczyce, Outer Carpathians, Gorlice Beds; 3 — *Tenuitella inaequiconica* (Subbotina), x 400, a — umbilical side, b — spiral side, Mszanka, Outer Carpathians, Gorlice Beds; 4 — *Paragloborotalia pseudokugleri* (Blow), x 300, a — spiral side, b — umbilical side, Mszanka, Outer Carpathians, Gorlice Beds; 5 — *Tenuitellinata postcretacea* (Myatlyuk), x 132, a — spiral side, b — umbilical side, Kołaczyce, Outer Carpathians, Upper Krosno Beds; 6 — *Subbotina connecta* (Jenkins), x 96, a — umbilical side, b — spiral side, Kołaczyce, Outer Carpathians, Gorlice Beds; 7 — *Globigerinoides immaturus* Le Roy, x 96, a — spiral side, b — umbilical side, Kołaczyce, Outer Carpathians, Gorlice Beds; 8 — *Cassigerinella boudecensis* Pokorný, x 268, side view, Radziszów, Outer Carpathians, Upper Krosno Beds; 9 — *Globoquadrina dehiscentis* (Chapman, Parr et Collins), x 100, a — spiral side, b — umbilical side, Kluczowa, Outer Carpathians, Gorlice Beds; 10 — *Tenuitella denseconnexa* (Subbotina), x 150, a — umbilical side, b — spiral side, Mszanka, Outer Carpathians, Gorlice Beds

calcareous nannoplankton assemblages from the Stebnik Beds contain numerous Paleogene and Cretaceous forms that accompany sparse but significant Miocene species: *Sphenolithus heteromorphus* Deflandre, *Helicosphaera walbersdorfensis* Müller, *Discoaster* cf. *variabilis* Martini et Bramlette, *Helicosphaera* cf. *californiana* Bukry. Their occurrence indicates the top of NN4 coccolith zone suggesting that Stebnik Beds in Poland, like in the Ukraine, cross the Early/Middle Miocene boundary.

Paleontological chart

A. Foraminifera.

Taxonomy after Odrzywolska-Bieńkowska & Olszewska (1996)

Chiloguembeltria samwelli (Jenkins)

Pl. II, Fig. 6

1978 *Guembeltria samwelli* D.G. Jenkins, p. 132–137, pl. 1, fig. 1–9.

Description. Test triserial, short, chambers globular, sutures straight. Periphery rounded, lobulate. Aperture high, semicircular opening at the base of the last chamber. Additional openings may be present on tops of preceding chambers. Surface smooth, finely perforate.

Occurrence. Carpathians: Middle–Upper Krosno Beds. Foredeep: Sucha Fm., Vorotyshche Beds.

Globoconella miozea (Finlay)

Pl. II, Fig. 3a

1939 *Globorotalia miozea* H.J. Finlay, p. 326, pl. 29, fig. 159–161.

Description. Test rounded in outline, discoidal in section periphery acute. Spiral side slightly convex with 2 whorls. In the last whorl 5–6 rectangular chambers. Sutures curved, weakly depressed. Umbilical side truncate. Chambers triangular, slightly inflated. Sutures radial, depressed. Umbilicus closed. Aperture low slit with lip. Surface coarsely perforated.

Occurrence. Foredeep: Zebrzydowice Fm.

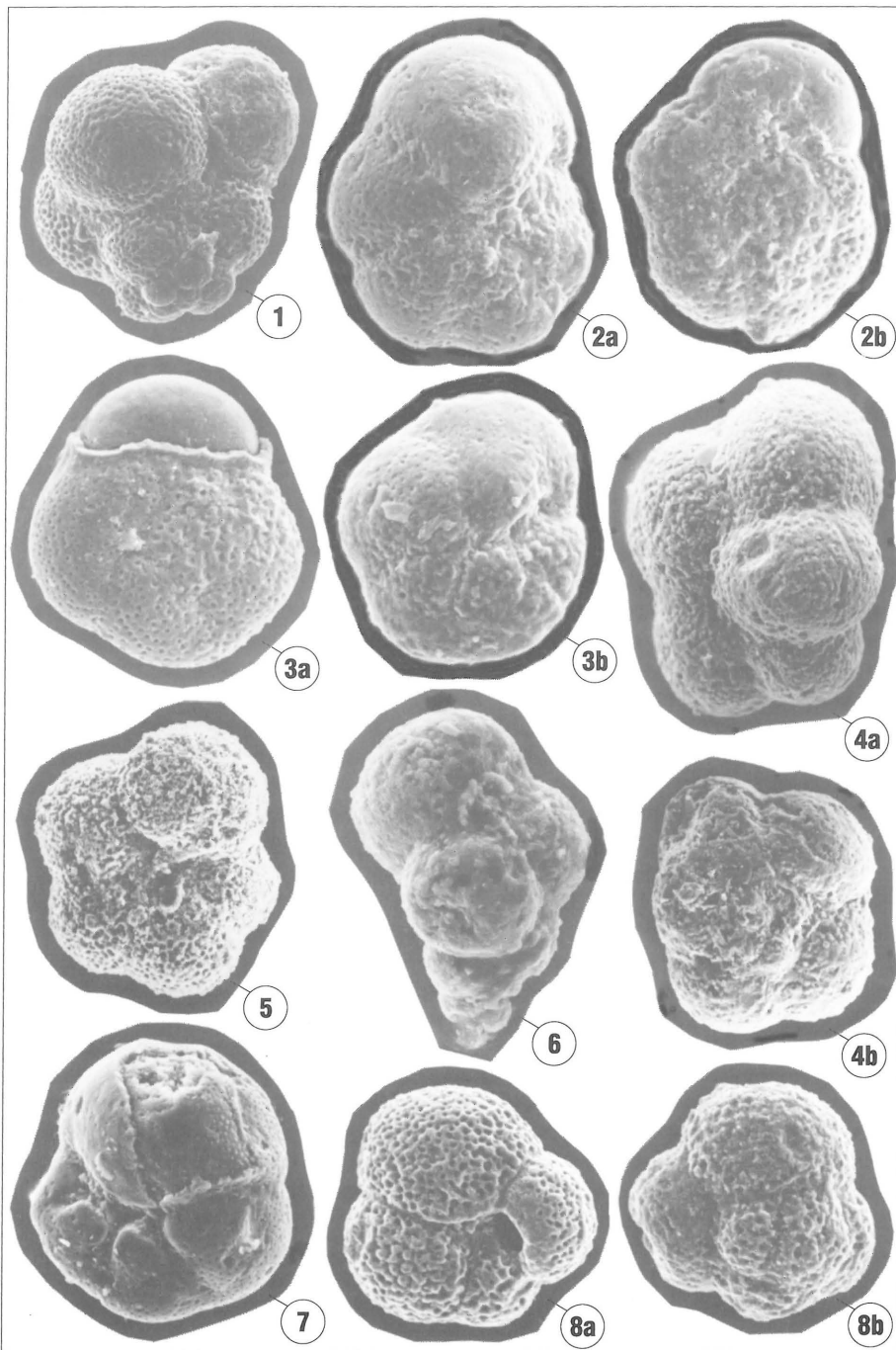


PLATE II. 1 — *Globigerina dubia* Egger, x 180, side view, Kołaczyce, Outer Carpathians, Gorlice Beds; 2 — *Globorotalia peripheroronda* Blow et Banner, x 150, a — umbilical side, b — spiral side, Jaworze IG 1, Foredeep, Zebrzydowice Fm.; 3 — *Globoconella miozea* (Finlay), x 240, a — spiral side, b — umbilical side, Zebrzydowice 13, Foredeep, Zebrzydowice Fm.; 4 — *Catapsydrax stainforthi* Bolli, Loeblich et Tappan, a — umbilical side, b — spiral side, Cieszyn IG 1, Foredeep, Zebrzydowice Fm.; 5 — *Tenuitellinata pseudoedita* (Subbotina), x 120, umbilical side, Fredropol, Stebnik unit, Vorotyshche Beds; 6 — *Chilogümbeltria samwelli* (Jenkins), x 300, side view, Huta Brzaska, Carpathians, Upper Krosno Beds; 7 — *Globorotalia tetracamerata* Subbotina, x 210, umbilical view, Komarnice 1, Stebnik unit, Vorotyshche Beds; 8 — *Globigerina bolii* Cita et Premoli Silva, x 250, a — umbilical side, b — spiral side, Pikulice, Stebnik unit, Balich Beds

Globorotalia peripheroronda Blow et Banner
Pl. II, Fig. 2a, b

1966 *Globorotalia peripheroronda* W.H. Blow, F. Banner, p. 294, pl. 1, fig. 1; tab. 2, fig. 1–3.

Description. Test oval in outline. Periphery subacute, lobulate. Spiral side almost flat with 2,5 whorls. In the last whorl 6 semilunate chambers moderately increasing in size. Sutures curved, depressed. Umbilical side conical. Chambers triangular, inflated. Sutures radial, depressed. Umbilicus very small, depressed. Aperture an extraumbilical arch with lip. Surface smooth.

Occurrence. Foredeep: Zebrzydowice Fm.

Globorotalia tetracamerata Subbotina
Pl. II, Fig. 7

1960 *Globorotalia tetracamerata*, N.N. Subbotina et al., p. 65–66, pl. 13, fig. 1.

Description. Test oval in outline. Periphery subacute, slightly lobulate. Spiral side slightly convex with 2 whorls. In the last whorl 4 semilunate chambers rapidly increasing in size. Sutures curved, almost flush. Umbilical side conical. Chambers triangular, inflated.

Sutures radial, depressed. Umbilicus closed. Aperture an extraumbilical arch with thin lip. Surface smooth.

Occurrence. Carpathians: Upper Krosno Beds, Gorlice Beds. Foredeep: Sucha Fm., Vorotyshche Beds.

Paragloborotalia pseudokugleri (Blow)
Pl. I, Fig. 4a

1969 *Globorotalia (Turborotalia) pseudokugleri* W.H. Blow, p. 391, pl. 10, fig. 4–6; tab. 39, fig. 5, 6.

Description. Test circular in outline, tightly coiled, periphery rounded to subacute, slightly lobulate. Spiral side slightly inflated with 2,5 whorls. In the last whorl 6–7 trapezoidal chambers slowly increasing in size. Sutures inclined, curved, depressed. Umbilical side convex. Chambers roughly triangular, inflated. Sutures radial, depressed. Umbilicus small, depressed. Aperture an extraumbilical low arch with lip. Surface coarsely pitted.

Occurrence. Carpathians: Upper Krosno Beds, Gorlice Beds. Foredeep: Vorotyshche Beds.

Paragloborotalia siakensis (Le Roy)
Pl. I, Fig. 1a, b

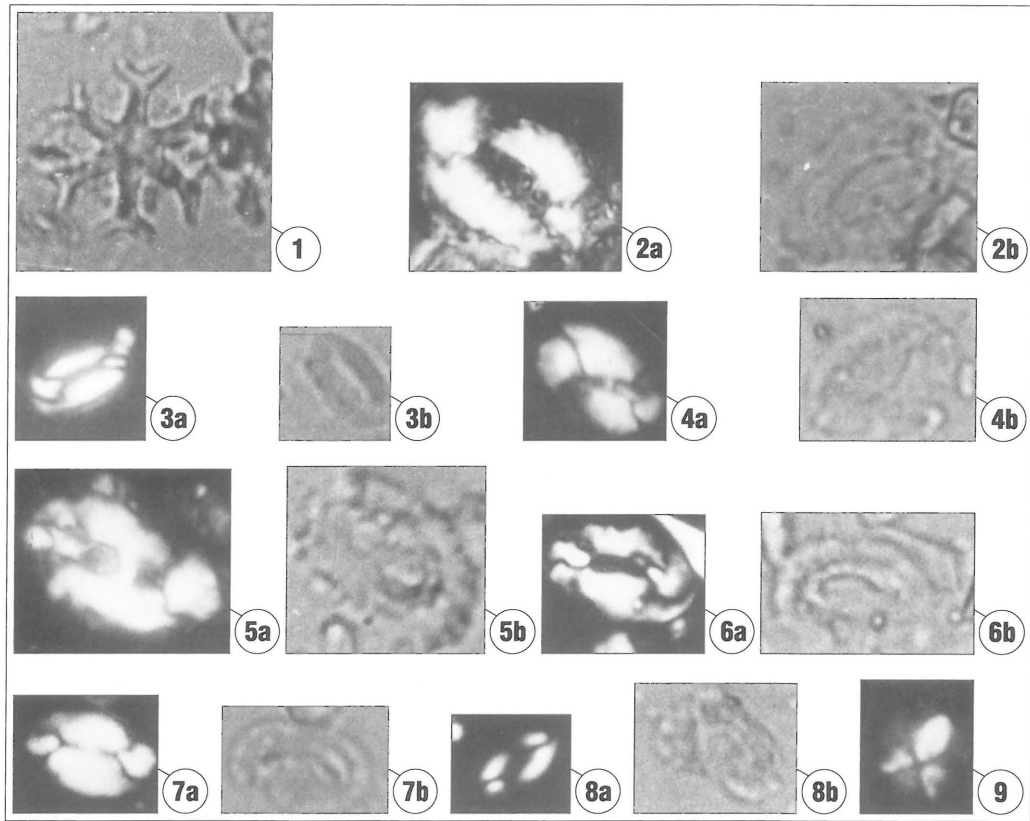


PLATE III. 1 — *Discoaster variabilis* Martini et Bramlette, x 2,400, NL, Upper Krosno Beds, Dębowiec Fm. (Zamarski Mb., Bielsko Mb.), Stebnik Beds; 2 — *Helicosphaera ampliaptera* Bramlette et Wilcoxon, x 2,400, a — CN, b — NL, Niebylec Shaly Member, Middle–Upper Krosno Beds, Gorlice Beds, Sucha Fm., Vorotyshche Beds, Stebnik Beds; 3 — *Helicosphaera californiana* Bukry, x 2,400, a — CN, b — NL, Niebylec Shaly Member, Middle–Upper Krosno Beds, Stebnik Beds; 4 — *Helicosphaera carteri* (Wallich) Kamptner, x 2,400, a — CN, b — NL, Niebylec Shaly Member, Middle–Upper Krosno Beds, Stebnik Beds; 5 — *Helicosphaera mediterranea* Müller, x 2,400, a — CN, b — NL, Niebylec Shaly Member, Middle–Upper Krosno Beds, Vorotyshche Beds, Stebnik Beds; 6 — *Helicosphaera scissura* Miller, x 2,400, a — CN, b — NL, Niebylec Shaly Member, Lower Krosno Beds, Middle–Upper Krosno Beds, Gorlice Beds, Zebrzydowice Fm., Vorotyshche Beds, Stebnik Beds; 7 — *Helicosphaera sellii* (Bukry et Bramlette), x 2,400, a — CN, b — NL, Vorotyshche Beds, Stebnik Beds; 8 — *Helicosphaera walbersdorfensis* Müller, x 2,400, a — CN, b — NL, Niebylec Shaly Member, Middle–Upper Krosno Beds, Vorotyshche Beds, Stebnik Beds; 9 — *Sphenolithus heteromorphus* Deflandre, x 2,400, CN, Upper Krosno Beds, Dębowiec Fm. (Bielsko Mb., Zamarski Mb.), Vorotyshche Beds, Stebnik Beds

1939 *Globigerina siakensis* L.W. Le Roy, p. 39–40, pl. 3, fig. 30, 31.

Description. Test oval in outline, periphery rounded, lobulate. Spiral side almost flat, with 3 whorls. In the last whorl 5–5.5 chambers, rectangular, rapidly increasing in size. Sutures straight, depressed. Umbilical side slightly convex. Chambers roughly circular, inflated. Sutures radial, depressed. Umbilicus small, shallow. Aperture an extraumbilical, low arch. Surface moderately pitted.

Occurrence. Carpathians: Upper Krosno Beds, Gorlice Beds. Foredeep: Bielsko Mb. (Dębowiec Fm.).

Tenuitella denseconnexa (Subbotina)

Pl. I, Fig. 10a, b

1960 *Globorotalia denseconnexa* Subbotina; [in:] N.N. Subbotina et al., p. 67–69, pl. 13, fig. 4–6.

Description. Test roughly oval to circular in outline, periphery rounded to subacute, lobulate. Spiral side almost flat with 2.5 whorls. In the last whorl 6–7 chambers, globular to rectangular, weakly inflated, slowly increasing in size. Sutures straight, depressed. Umbilical side convex. Chambers roughly triangular, inflated. Sutures radial, depressed. Umbilicus small. Aperture an extraumbilical, low arch. Surface frequently covered with delicate pustules.

Occurrence. Carpathians: Middle–Upper Krosno Beds, Gorlice Beds. Foredeep: Vorotyshche Beds.

Tenuitella inaequiconica (Subbotina)

Pl. I, Fig. 3a, b

1960 *Acarinina inaequiconica*, N.N. Subbotina, p. 202, pl. 7, fig. 13, 14.

Description. Test oval in outline, periphery rounded, lobulate. Spiral side almost flat with 2 whorls. In the last whorl 5 rectangular, slightly inflated chambers, rapidly increasing in size. Sutures straight depressed. Umbilical side convex. Chambers roughly triangular, inflated. Sutures radial, depressed. Umbilicus small. Aperture an extraumbilical, low arch with lip. Surface smooth, rarely pustulose.

Occurrence. Carpathians: Middle–Upper Krosno Beds, Gorlice Beds. Foredeep: Zebrzydowice Fm., Sucha Fm., Dębowiec Fm., (Bielsko Mb., Komorowice Mb.), Vorotyshche Beds, Stebnik Beds.

Tenuitellinata postcretacea (Myatlyuk)

Pl. I, Fig. 5a, b

1950 *Globigerina postcretacea*, E.V. Myatlyuk, p. 280 pl. 4, fig. 3.

Description. Test circular in outline periphery rounded. Spiral side convex, with 2.5 whorls. In the last whorl 5 globular chambers, slowly increasing in size. Sutures straight, depressed. Umbilical side convex with depressed umbilicus. Chambers globular. Sutures radial, depressed. Aperture a low umbilical arch. Surface perforate, cancellate.

Occurrence. Carpathians: Upper Krosno Beds, Gorlice Beds. Foredeep: Zebrzydowice Fm., Stebnik Beds.

Tenuitellinata pseudoedita (Subbotina)

Pl. II, Fig. 5

1960 *Globigerina pseudoedita*, N.N. Subbotina et al., p. 55–56, pl. 10, fig. 1, 3.

Description. Test circular in outline, rather tightly coiled, periphery rounded. Spiral side flat with 2,5 whorls. In the last whorl 5 semiglobular chambers slowly increasing in size. Sutures straight, depressed. Umbilical side convex. Chambers roughly triangular, slightly inflated. Sutures radial, depressed. Umbilicus closed. Aperture an extraumbilical very low arch. Surface microperforate, smooth.

Occurrence. Carpathians: Gorlice Beds. Foredeep: Sucha Fm., Dębowiec Fm. (Komorowice Mb.), Vorotyshche Beds, Stebnik Beds.

Catapsydrax stainforthi Bolli, Loeblich et Tappan

Pl. II, Fig. 4a, b

1957 *Catapsydrax stainforthi*, H.M. Bolli et al., p. 38, pl. 7, fig. 11.

Description. Test roughly circular in outline, periphery rounded, slightly lobulate. Spiral side convex with 2,5 whorls. In the last whorl 4 chambers, globular almost equal in size. Sutures straight, depressed. Umbilical side convex. Chambers, rectangular, inflated. Sutures radial, depressed. Umbilicus and the primary aperture covered by bulla extending to the spiral side. Secondary openings at margins of bulla. Surface pitted.

Occurrence. Foredeep: Zebrzydowice Fm., Stebnik Beds.

Globoquadrina dehiscens (Chapmann, Parr et Collins)

Pl. I, Fig. 9a, b

1934 *Globigerina dehiscens* Chapman et al., p. 569, pl. 11, fig. 36.

Description. Test subquadrate in outline, periphery more or less truncate. Spiral side flat with 2 whorls. In the last whorl 4 rectangular chambers, rapidly increasing in size. Sutures inclined, depressed. Umbilical side truncate. Chambers roughly triangular, inflated. Sutures radial, depressed. Umbilicus deep. Aperture a low, umbilical arch, with a toothlike flap. Surface coarsely pitted.

Occurrence. Carpathians: Middle–Upper Krosno Beds. Foredeep: Dębowiec Fm. (Bielsko Mb.), Vorotyshche Beds, Stebnik Beds.

Subbotina connecta (Jenkins)

Pl. I, Fig. 6a, b

1964 *Globigerina woodi* Jenkins subsp. *connecta* Jenkins, D.G. Jenkins, p. 72, text–fig. 1.

Description. Test oval in outline, tightly coiled, periphery broadly rounded. Spiral side almost flat, with 2,5 whorls. In the last whorl 3 trapezoidal chambers, the last one occupies a half of the test. Sutures straight, slightly depressed. Umbilical side convex. Early chambers roughly triangular, the last one semicircular. Sutures radial, slightly depressed. Umbilicus closed. Aperture an extraumbilical slit at the base of the last chamber. Surface covered with calcite crust, cancellate.

Occurrence. Carpathians: Upper Krosno Beds, Gorlice Beds.

Cassigerinella boudecensis Pokorný

Pl. I, Fig. 8

1955 *Cassigerinella boudecensis* n.sp., M. Pokorný, p. 138, text–fig. 1 a, b.

Description. Test oval in outline, periphery rounded, lobulate. Tiny globular chambers in early stage enroll planispirally later biserially. Sutures depressed. Aperture an asymmetrical, extraumbilical arch. Surface smooth, but may be covered by delicate pustules.

Occurrence. Carpathians: upper part of the Lower to Upper Krosno Beds, Gorlice Beds. Foredeep: Zebrzydowice Fm., Sucha Fm., Vorotyshche Beds, Stebnik Beds.

Globigerina bolli Cita et Premoli Silva

Pl. II, Fig. 8a, b

1960 *Globigerina bolli*, M.B. Cita, I. Premoli Silva, p. 119–120, pl. 13, fig. 1.

Description. Test oval in outline closely coiled, periphery

rounded. Spiral side weakly convex with 2 whorls. In the last whorl 4 globular chambers, moderately increasing in size. The last chamber smaller than preceding one. Sutures straight, depressed. Umbilical side convex. Chambers triangular to rectangular, inflated. Sutures deeply incised. Umbilicus opened, deep. Aperture an umbilical arch, sometimes covered by additional chamber. Surface hispid or covered by a calcite crust.

Occurrence. Carpathians: Upper Krosno Beds. Foredeep: Stebnik Beds.

Globigerina dubia Egger

Pl. II, Fig. 1

1857 *Globigerina dubia* n.sp. J.G. Egger, p. 281, pl. 9, fig. 7–9.

Description. Test conical, circular in outline, periphery lobate. Spiral side high, with 3 whorls. In the last whorl 5 globular chambers rapidly increasing in size, the last one often inclined toward the umbilicus. Sutures straight, depressed. Umbilical side weakly convex. Chambers globular. Sutures depressed. Umbilicus deep. Aperture an umbilical, moderately high arch. Surface pitted.

Occurrence. Carpathians: Gorlice Beds. Foredeep: Zebrzydowice Fm.

Globigerinoides immaturus Le Roy

Pl. I, Fig. 7a, b

1939 *Globigerinoides sacculifer* (Brady) var *immaturus*, L. Le Roy, p. 263, pl. 3, fig. 19–21.

Description. Test oval in outline, closely coiled, periphery rounded, lobulate. Spiral side convex with 2 whorls. In the last whorl 3,5 roughly globular chambers, rapidly increasing in size. The last chamber occupies half of the test. Sutures straight, depressed. Umbilical side convex, chambers similar to the spiral side. Umbilicus closed. Primary aperture low, extraumbilical, arch. One secondary opening on spiral side at the intersection of spiral and chamber sutures. Surface cancellate or coarsely perforate.

Occurrence. Carpathians: Gorlice Beds. Foredeep: Zebrzydowice Fm.

Globigerinoides primordius Blow et Banner

Pl. I, Fig. 2a, b

1962 *Globigerinoides primordius*, W.H. Blow, F. Banner, p. 115, pl. 9, fig. D–F.

Description. Test oval in outline, somewhat loosely coiled periphery rounded, lobulate. Spiral side slightly convex with 2,5–3 whorls. In the last whorl 4 globular chambers rapidly increasing in size. Sutures straight, depressed. Umbilical side inflated. Chambers globular. Sutures radial incised. Umbilicus small, depressed. Primary aperture a low umbilical arch. One secondary sutural opening on the spiral side at the intersection of spiral and chamber suture. Surface cancellate or coarsely perforate.

Occurrence. Carpathians: Middle–Upper Krosno Beds, Gorlice Beds.

B. Calcareous nannoplankton.

Discoaster variabilis Martini et Bramlette

Pl. III, Fig. 1

1963 *Discoaster variabilis* Martini E. and Bramlette M.N., p. 854, pl. 104, fig. 4–9.

Description. Asterolith with 5 or 6 rays (rarely 3 or 4). A central area has in its centre a stellate knob, the tips of which extend to the margin between the arms (convex side). On the concave side small ridges extend out from the more prominent knob along the median line of the arms. The arms terminate with a bifurcation forming an angle of about 90°. Between the bifurcation a thin web is found (occasionally). The interarm area is V-shaped. The arms are slightly tapering.

Occurrence. Carpathians: Upper Krosno Beds. Foredeep: Dębowiec Fm. (Zamarski Mb., Bielsko Mb.), Stebnik Beds.

Helicosphaera ampliaperita Bramlette et Wilcoxon

Pl. III, Fig. 2a, b

1967 *Helicosphaera ampliaperita* Bramlette M.N. and Wilcoxon J.A., p. 105, pl. 6, fig. 1–4.

Description. A large form. The outline of this helicolith varies from elliptical to roughly triangular. There is no bridge in the

relatively wide, long-elliptical central opening. The wing is overlapping (of variable size). The bright central area is surrounded by the optical rim in cross-polarized light. In a light microscope this form may be confused with other species, in which the central bar is broken out.

Occurrence. Carpathians: Niebylec Shales, Middle–Upper Krosno Beds, Gorlice Beds. Foredeep: Sucha Fm., Vorotyshche Beds, Stebnik Beds.

Helicosphaera californiana Bukry
Pl. III, Fig. 3a, b

1981 *Helicosphaera californiana* Bukry D., USNM 307315, pl. 4, fig. 9–11.

Description. Small, very elongate helicolith with a long narrow slit along the long axis of the central area. In a cross-polarized light the rim is faint and narrow. The wing is overlapping. It is distinguished from similar *Helicosphaera scissura* and *Helicosphaera carteri* by its much smaller size, and a narrower format in a cross-polarized light.

Occurrence. Carpathians: Niebylec Shale, Middle–Upper Krosno Beds. Foredeep: Stebnik Beds.

Helicosphaera carteri (Wallich) Kamptner
Pl. III, Fig. 4a, b

1954 *Helicosphaera carteri* (Wallich G.C.) Kamptner E., p. 21, 73, fig. 17–19.

Description. The helicolith varies in size. Symmetrically to asymmetrically elliptical. In the central area there are two openings visible on the proximal side and two equivalent pierced depressions on the distal side. The bridge and central openings are slightly inclined in normal direction or may be aligned with the longer axis of the helicolith. The overlapping wing varies in size. In a cross polarized light helicolith is entirely bright.

Occurrence. Carpathians: Niebylec Shale, Middle–Upper Krosno Beds. Foredeep: Stebnik Beds.

Helicosphaera mediterranea Müller
Pl. III, Fig. 5a, b

1981 *Helicosphaera mediterranea* Müller C., p. 428, pl. 1, fig. 13–14.

Description. The large helicolith with a symmetrically elliptical outline. In the central area there are two large openings separated by a bridge which is nearly perpendicular to the long axis of the helicolith. The bridge is optically continuous with a proximal part of the central area. The wing is overlapping. In a cross-polarized light helicolith is entirely bright.

Occurrence. Carpathians: Niebylec Shale, Middle–Upper Krosno Beds. Foredeep: Vorotyshche Beds, Stebnik Beds.

Helicosphaera scissura Miller
Pl. III, Fig. 6a, b

1981 *Helicosphaera scissura* Miller P., p. 433, pl. 3, fig. 10a–11c.

Description. A long, elliptical, medium-sized helicolith with small to moderate rounded terminal flange, extending beyond periphery of the distal shield. In the central area there is a narrow, elongate opening or slit along long axis of the helicolith. There is no bridge. The bright central area is surrounded by the optical rim in cross-polarized light. This helicolith has often been identified with, or referred to, *Helicosphaera ampliaperta* because of its similar morphology and stratigraphic range.

Occurrence. Carpathians: Lower Krosno Beds, Niebylec Shale, Middle–Upper Krosno Beds, Gorlice Beds. Foredeep: Zebrzydowice Fm., Vorotyshche Beds, Stebnik Beds.

Helicosphaera sellii (Bukry et Bramlette)
Pl. III, Fig. 7a, b

1969 *Helicosphaera sellii* Bukry D. and Bramlette M.N., p. 134, pl. 2, fig. 3–7.

Description. The helicolith is small to medium sized and symmetrically elliptical in outline. On the proximal side an oblique bridge separates two oblique slits. On the distal side the two large openings are separated by a bridge which run, more or less parallel to the minor axis of the helicolith or is distinctly oblique. The bridge is in optical continuity with the surrounding structure. The wing is

short and overlapping. The bright central area is surrounded by the optical rim in cross-polarized light.

Occurrence. Foredeep: Vorotyshche Beds, Stebnik Beds.

Helicosphaera walbersdorfensis Müller
Pl. III, Fig. 8a, b

1974 *Helicosphaera walbersdorfensis* Müller C., p. 392, pl. 2, fig. 15, pl. 4, fig. 35–37, 45–46.

Description. A very small form. The outline varies from roughly triangular to symmetrically elliptical. The narrow central area is divided into two small openings (slits) by a narrow, oblique bridge. These slits are not easily distinguishable in the light microscope. The bridge appears weakly birefringent. The wing is usually large and overlapping. The bright central area is surrounded by the optical rim in cross-polarized light.

Occurrence. Carpathians: Niebylec Shale, Middle–Upper Krosno Beds. Foredeep: Vorotyshche Beds, Stebnik Beds.

Sphenolithus heteromorphus Deflandre
Pl. III, Fig. 9

1953 *Sphenolithus heteromorphus* Deflandre G., p. 1785–1786, fig. 1–2.

Description. Conical or pyramidal with blunt edges. The apical spine is not visible between crossed nicols at 0° but becomes very bright at 45°. It has a more compact proximal shield or column, where the column and lateral elements are about equal in height. The apical spine varies in length (usually short).

Occurrence. Carpathians: Upper Krosno Beds. Foredeep: Dębowiec Fm. (Bielsko Mb.), Zamarski Mb., Vorotyshche Beds, Stebnik Beds.

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