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FORAMINIFERAL BIOSTRATIGRAPHY OF THE POLISH OUTER CARPATHIANS: A RECORD OF BASIN GEOHISTORY

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Abstract: A new biostratigraphical scheme based on foraminifera is established for the Polish flysch Carpathians. Within the total sedimentary sequence of the flysch Carpathians (covering the time span from the latest Jurassic to early Miocene) 23 foraminiferal zones have been designated. Latest Jurassic–early late Eocene zones (18) are based on the most characteristic agglutinated taxa; late Eocene–early Miocene zones (5) are based on plankton species. The characteristic assemblages reflect not only the environmental diversity of the Carpathian basins but also changes that took place during its initiation, development and closure. The succession of assemblages also bear traces of events of the geohistory of the NW Tethys at that time. The majority of foraminiferal species characterising the designated zones has been described and illustrated in an Atlas of a guide and characteristic fossils – Cretaceous (Malinowska, 1984) and in the Tertiary volume submitted to print.

Abstrakt: Dla utworów fliszowych polskich Karpat zewnętrznych zaproponowano schemat biostratygraficzny oparty na otwornicach. Wyróżniono 23 poziomy obejmujące całą sekwencję sedymentacyjną fliszu. 18 poziomów (najwyższa jura–niższy górny eocen) opartych jest na charakterystycznych dla Karpat gatunkach aglutynujących, 5 poziomów (wyższy górny eocen–dolny miocen) przy braku gatunków aglutynujących, opartych jest na gatunkach planktonicznych. Zespoły otwornic charakteryzujące poszczególne poziomy biostratygraficzne odzwierciedlają zróżnicowanie środowiskowe związane z powstaniem, rozwojem i zanikiem geosynkliny fliszowej Karpat. Zespoły te odzwierciedlają również globalne zmiany paleośrodowiskowe, które w interwale czasowym: górna jura – dolny miocen miały miejsce na obszarze NW Tetydy. Większość gatunków wykorzystanych dla charakterystyki poziomów biostratygraficznych jest opisanych i zilustrowanych w dwóch tomach „Atlasu skamieniałości przewodnich i charakterystycznych: Kreda" (Malinowska, 1984) i „Trzeciorzęd" (Olszewska *et al.*, 1996).

Key words: Upper Jurassic, Cretaceous, Paleogene, Neogene, foraminifera, biostratigraphy, Outer Carpathians.

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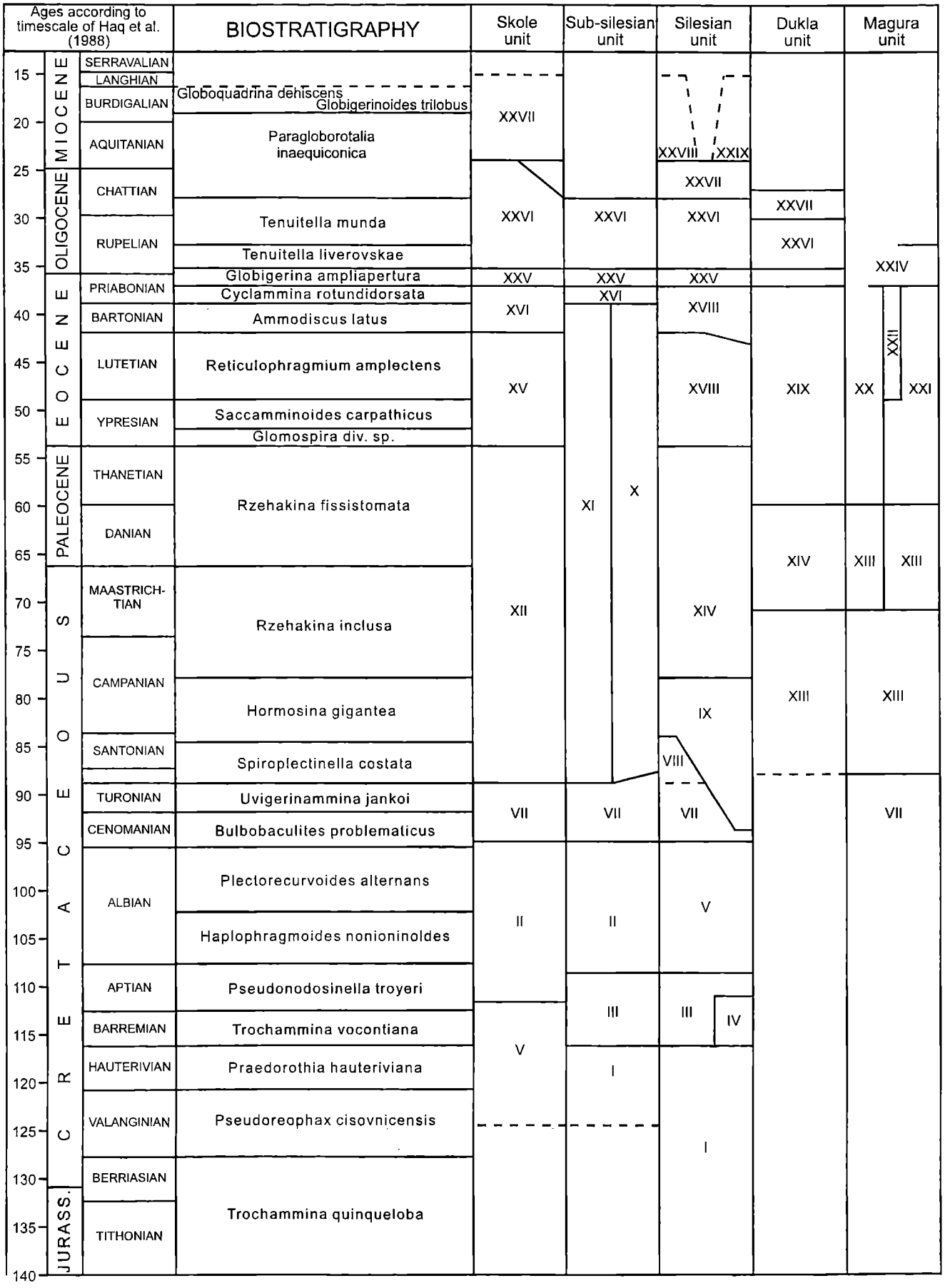
INTRODUCTION

The flysch basin of the Polish Outer Carpathians constitute a part of the Alpine geosynclinal system. Their origin and development were closely related to geohistory of that domain, reflecting at the same time, major geological events of the NW Tethys. Palaeogeographical reconstructions of the flysch basins suggest existence of the several throughs subdivided by (? submarine) elevations. The elevations are regarded as main sources of the abundant clastic debris, the dominant component of the flysch sediments (Unrug, 1979). The slopes of individual basins were sites of accumulation of hemipelagic (calcareous or noncalcareous) sediments, that occasionally spread over basin floor (Eljaš, 1979). It is assumed that the geohistory of the flysch basins had three stages: 1 – Kimmeridgian–Albian, 2 – Cenomanian–Eocene, 3 – Oligocene–Miocene (Koszarski, 1963). During the first stage in the, topographically weakly diversified and poorly oxygenated basins, characteristic dark coloured shales and marls accumulated (formations I–V; Fig. 1). The Austrian phase of the Early-Alpine tectonic movements opened the second stage in the development of the flysch basin, which underwent subdivision into distinct throughs and elevations, with dominating flysch-type sedimentation, well oxygenated, nutrient rich water and free connections with the open ocean (Hesse, 1975; Leszczyński & Uchman, 1991) (Fig. 1, formations VI–XXV). The Pyrenean phase of the Alpine orogenesis initiated (like in the Alps) the gradual reduction of the Carpathian flysch basin. Its final closure, presumably took place at the end of the early Miocene (formations XXVI–XXIX; Fig. 1).

The normal marine environment of the flysch basin


Ages according to timescale of Haq et al. (1988)
BIOSTRATIGRAPHY
Skole unit
Sub-silesian unit
Silesian unit
Dukla unit
Magura unit
CENOZOIC
MESOZOIC
CRETACEOUS
JURASS.
MIOCENE
OLIGOCENE
EOCENE
PALEOCENE
SERRAVALIAN
LANGHIAN
BURDIGALIAN
AQUITANIAN
CHATTIAN
RUPELIAN
PRIABONIAN
BARTONIAN
LUTETIAN
YPRESIAN
THANETIAN
DANIAN
MAASTRICHTIAN
CAMPANIAN
SANTONIAN
TURONIAN
CENOMANIAN
ALBIAN
APTIAN
BARREMIAN
HAUTERIVIAN
VALANGINIAN
BERRIASIAN
TITHONIAN
Globoquadrina dehiscens
Globigerinoides trilobus
Paragloborotalia inaequiconica
Tenuitella munda
Tenuitella liverovskae
Globigerina ampliapertura
Cyclammina rotundidorsata
Ammodiscus latus
Reticulophragmium amplectens
Saccamminoides carpathicus
Glomospira div. sp.
Rzehakina fissistomata
Rzehakina inclusa
Hormosina gigantea
Spiroplectinella costata
Uvigerinammina jankoi
Bulbobaculites problematicus
Plectorecurvoides alternans
Haplophragmoides nonioninoldes
Pseudonodosinella troyeri
Trochammina vocontiana
Praedorothia hauteriviana
Pseudoreophax cisovnicensis
Trochammina quinqueloba
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stimulated the development of many plants and animals: dinoflagellates, diatoms, coccolithophores, calcareous algae, tintinnids and calpionellids, radiolarians, foraminifers, ostracods as well as anthozoa, brachiopoda, mollusca or echinodermata. However, conditions of preservation in the flysch basins favoured forms with broad geographical distribution, great abundance and considerable resistance to dissolution. These conditions are fulfilled by only two groups: foraminifera and calcareous nannoplankton. Among foraminifera only taxa with agglutinated tests were preserved well enough to provide a continuous stratigraphic record. However, their applicability to stratigraphy, despite the works of J. Grzybowski and his followers (see Kaminski *et al.*, 1993), was not generally accepted. Nevertheless, Carpathian micropaleontologists, based on the one hundred-year tradition of investigations of flysch foraminifera, after the effort of introducing the study of the applied micropaleontology, (i.e. using the benthic foraminifera to correlate the strata), were determined to make the next step, i.e. to elaborate the zonal scheme for the flysch sediments. Early informal zonations based on foraminifera were presented on the occasion of the VI-th Congress of the Carpatho-Balkan Geological Association (Bieda *et al.*, 1963), and during the X-th European Micropalaeontological Colloqium in Poland (Geroch *et al.*, 1967). Improved versions of foraminiferal zonations appeared much later (Morgiel & Olszewska, 1981; Geroch & Nowak, 1984).

The intensified studies on the calcareous (mainly planktic) foraminifera and calcareous nannoplankton, carried out during the last ten years, improved the calibration of zones based on agglutinated species, and at the same time, enabled the introduction of complementary zones in part of Carpathian sequences devoid of characteristic agglutinated taxa (Fig. 2). Such a combined zonal scheme, for a practical current work is presented in this paper (Fig. 3). The proposed zonation is based primarily on species of agglutinated foraminifera with addition when possible accompanying benthic and planktic calcareous species.

The lithostratigraphical framework of the flysch Carpathians used in this paper is based on recent work of Wójcik *et al.* (1995). The chronostratigraphy is that of Haq *et al.* (1988).

BIOSTRATIGRAPHY

Trochammina quinqueloba Zone (Acme zone)

Age: Upper Tithonian–Berriasian.
Author: Olszewska (1983a).
Definition: The zone corresponds to the abundant occurrence of the index species in foraminiferal assemblages.
Remarks: The foraminiferal assemblage of the zone is characterised by an abundance of *Trochammina quinqueloba* Geroch accompanied by: *Glomospira variabilis* Kubler and Zwingli, *Glomospira miliolidaeformis* Balakhmatova, *Reophax helveticus* Haeusler, *Thalmannammina neocomiensis* Geroch, *Pseudoreophax cisovnicensis* Geroch (small and rare), *Melathrokerion spiralis* Gorbachik. The *T. quinqueloba* Zone does not encompass oldest sediments of the Carpathian geosyncline so called "Lower Cieszyn Shales". The dark unstratified marlstones of this lithological unit are of non-turbidite character. They yielded numerous calcified radiolarians and foraminifera similar to coeval epicontinental assemblages such as: *Palaeogaudryina varsoviensis* (Bielecka & Pożaryski), *Vaginulinopsis embaensis* (Furssenko & Poljenova), *Tristix temirica* Dain, *Planularia poljenovae* Kuznetsova, *Lenticulina dogieli* Furssenko. The age of the Lower Cieszyn Shales (upper Kimmeridgian = lower Tithonian in Haq *et al.*, 1988) is based on calcareous dinoflagellate cysts. The zones: *Stomiosphaera moluccana*, *Colomisphaera pulla* and *Parastomiosphaera malmica* were designated there (Nowak, 1968).

Pseudoreophax cisovnicensis Zone (Acme zone)

Age: Valanginian.
Authors: Morgiel and Olszewska (1981).
Definition: This zone corresponds to the numerous occurrence of the index species in foraminiferal assemblages.
Remarks: Within the zone the following species make their appearance: *Praedorothia hauteriviana* (Moullade), *Falsogaudryinella tealbyensis* (Bartenstein), *Trochammina vocontiana* Moullade, *Verneuilinoides neocomiensis* Mjatliuk. Other characteristic species are: *Rhizammina indivisa* Brady, *Hyperammina gaultina* Ten Dam, *Glomospirella gaultina* Berthelin, *Conorboides hofkeri* (Bartenstein et Brand), *Lenticulina meridiana* (Bartenstein, Bettenstaedt et Kovatcheva).

Praedorothia hauteriviana Zone (Acme zone)

Age: Hauterivian.
Authors: Geroch and Nowak (1984). Emended herein.
Definition: The zone corresponds to frequent occurrence of the index species in foraminiferal assemblages.

Fig. 1. Litostratigraphy of the Polish flysch Carpathians after Wójcik *et al.* (1995). I – Cieszyn Shales and Marls Formation, II – Spas Shales Formation, III – Verovice Shales Formation, IV – Grodziszcze Sandstones and Shales Formation, V – Lgota Sandstones and Shales Formation, VI – Makowa Radiolarian Shales Formation, VII – Cebula Variegated Shales Formation, VIII – Lanckorona Variegated Shales and Marls Formation, IX – Godula Variegated Shales and Sandstones Formation, X – Węglówka Marls and Shales Formation, XI – Frydek Marls, Shales and Sandstones Formation, XII – Rybotycze Inoceramian Sandstones and Shales Formation, XIII – Mogielica (Ropa) Inoceramian Sandstones and Shales Formation, XIV – Istebna Sandstones, Conglomerates and Shales Formation, XV – Żohatyn Variegated Shales Formation, XVI – Bachórz Hieroglyphic Shales and Sandstones Formation, XVII – Ciężkowice Sandstones Formation, XVIII – Łączki Jagiellońskie Hieroglyphic Shales and Sandstones Formation, XIX – Solinka Hieroglyphic Sandstones and Shales Formation, XX – Bednarka Variegated Shales Formation, XXI – Zarzecze Shales and Sandstones Formation, XXII – Grzehynia Hieroglyphic Sandstones and Shales Formation, XXIII – Magura Sandstones Formation, XXIV – Malcov Sandstones and Shales Formation, XXV – Znamirowice Globigerina Marls Formation, XXVI – Rudawka Rymanowska Menilitic Shales Formation, XXVII – Krosno Sandstones and Shales Formation, XXVIII – Strzyżów Sandstones and Shales Formation, XXIX – Gorlice Shales with Olistoliths Formation

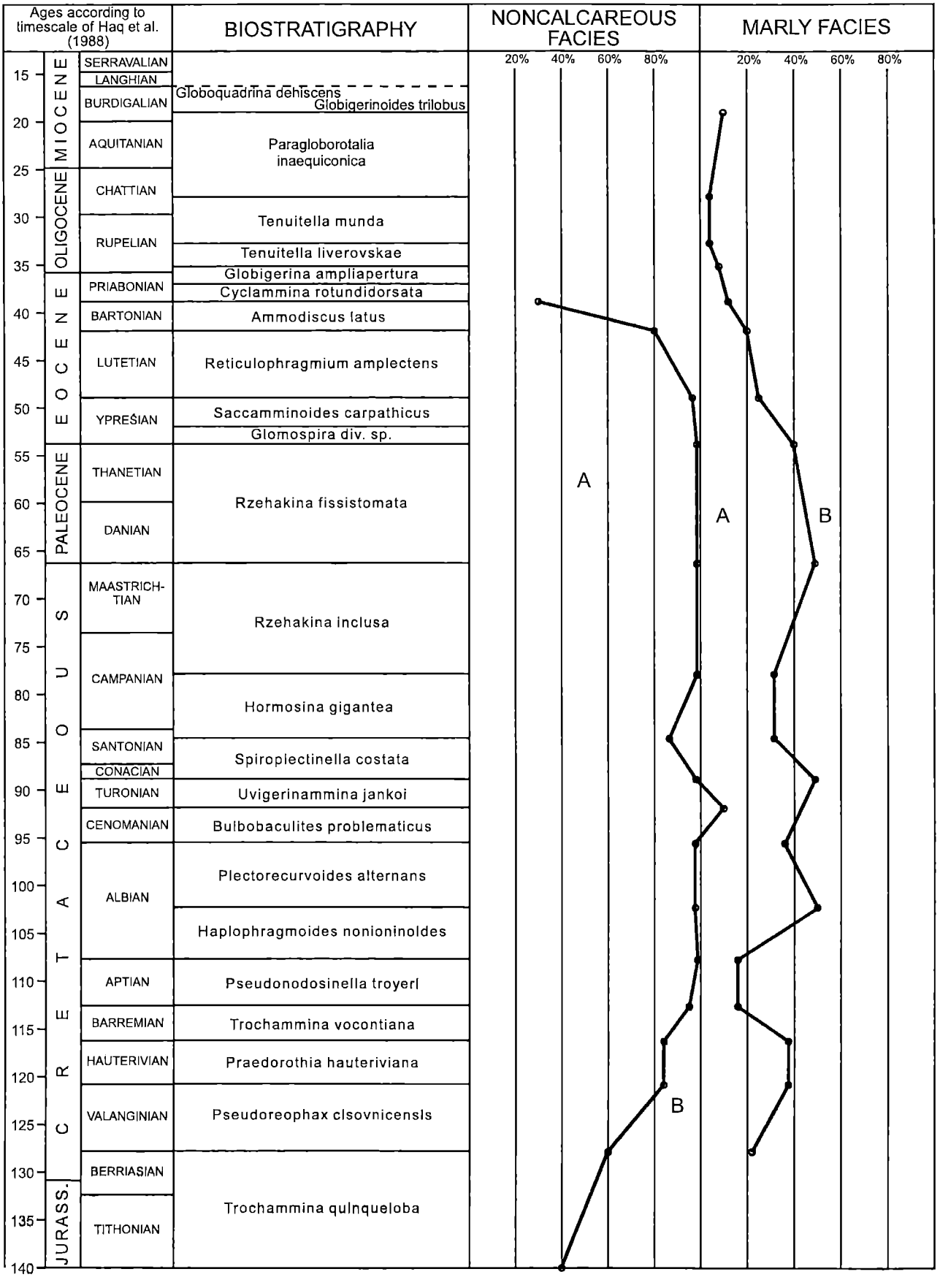


Fig. 2. Distribution of agglutinated and calcareous foraminifera in the vertical profile of the flysch sediments of the Outer Carpathians. A. Agglutinated species. B. Calcareous species

Remarks: Typical assemblage of the zone contains: *Praedorothia hauteriviana* (Moullade), *Falsogaudryinella tealbyensis* (Bartenstein), *Verneuilinoides neocomiensis* Mjatliuk, *Ammobaculoides carpathicus* Geroch, *Thalmannammina neocomiensis* Geroch, *Epistomina caracolla* (Roemer). Within the zone *Globuligerina hoterivica* (Subbotina) appears for the first time.

Trochammina vocontiana Zone (Acme zone)

Age: Barremian.
Authors: Morgiel and Olszewska (1981).
Definition: The zone corresponds to numerous occurrence of the index species in foraminiferal assemblages.
Remarks: Within the zone the following species appear: *Pseudobolivina variabilis* (Vašiček), *Haplophragmoides nonioninoides* (Reuss), *Gaudryinella sherlocki* Bettenstaedt, and in the upper part: *Gavelinella barremiana* Bettenstaedt, *Hedbergella planispira* (Tappan), *Hedbergella infracretacea* (Glaessner). Other characteristic species are: *Dorothia kummi* (Zedler), *Dorothia subtrochus* (Bartenstein), *Verneuilina schizea* Cushman et Alexander, *Caudamnina crassa* (Geroch), *Lagena neocomiana* Bartenstein and Brand, *Lenticulina collignoni* Espitalie et Sigal, *Lenticulina ouachensis* (Sigal), *Orbitolina conoidea* Gras.

Pseudonodosinella troyeri Zone (Acme zone)

Age: Aptian.
Authors: Geroch and Nowak (1984). Emended herein.
Definition: The zone corresponds to the frequent occurrence of the index species in foraminiferal assemblages.
Remarks: Characteristic for the zone are: *Verneuilinoides subfiliformis* Bartenstein, *Gaudryina oblonga* Zaspelova, *Gaudryina filiformis* Berthelin, *Gaudryinella scherlocki* Bettenstaedt, *Caudammina crassa* Geroch, *Thalmannammina neocomiensis* Geroch, *Pseudonodosinella troyeri* (Tappan), *Trochammina abrupta* Geroch, *Trochammina regina* Tairov, *Plectorecurvoides irregularis* Geroch, *Valvulineria loetterlei* (Tappan), *Hedbergella planispira* (Tappan), *Hedbergella infracretacea* (Glaessner), *Hedbergella delrioensis* (Carsey). Within the zone, the LO of *Verneuilinoides neocomiensis* Mjatliuk is observed.

Haplophragmoides nonioninoides Zone (Acme zone)

Age: Early Albian.
Authors: Geroch and Nowak (1984).
Definition: The zone corresponds to the frequent occurrence of the index taxon in foraminiferal assemblages.
Remarks: Characteristic species of zone are: *Haplophragmoides nonioninoides* (Reuss) – frequent, *Hippocrepina depressa* (Vašiček), *Hyperammina gaultina* Ten Dam, *Glomospirella gaultina* Berthelin, *Caudammina crassa* (Geroch), *Pseudonodosinella troyeri* (Tappan), *Haplophragmoides kirki* Wickenden, *Thalmannammina neocomiensis* Geroch, *Gaudryina filiformis* Berthelin, *Recurvoides contortus* Earland, *Gaudryina oblonga* Zaspelova, *Trochammina vocontiana* Moullade.

Plectorecurvoides alternans Zone (Interval zone)

Age: Middle–Late Albian (without uppermost part).
Authors: Geroch and Nowak (1984). Emended herein.
Definition: Interval between the FO of *Plectorecurvoides alternans* Noth and the FO of *Bulbobaculites problematicus* (Neagu).
Remarks: In sediments referred to the zone for the first time lighter, greenish, colours of sediments appear, signaling of the new sedimentary conditions related to global changes, a result of the rearrangement of continental plates (Berggren & Hollister, 1977). Better life conditions and the intensified diversification of biotas are reflected in the fossil record. In addition to the abundant and diverse agglutinated foraminifera, samples yield increased numbers of calcareous species (planktic and benthic), calcareous nannoplankton, radiolarians and occasionally, also calcareous dinoflagellate cysts. Noncalcareous sediments usually contain: *Plectorecurvoides alternans* Noth, *Hippocrepina depressa* Vašiček, *Caudammina crassa* (Geroch), *Haplophragmoides kirki* Wickenden, *Recurvoides imperfectus* Hanzlíková, *Gaudryina filiformis* Berthelin. In the upper part of the zone *Haplophragmoides falcatosuturalis* Neagu and *Kalamopsis grzybowskii* (Dylążanka) appear. Many Neocomian species end their occurrence within the zone. Among others: *Pseudobolivina variabilis* (Vašiček), *Haplophragmoides nonioninoides* (Reuss) and *Gaudryina oblonga* Zaspelova. Assemblages from marly sediments, in addition to arenaceous species also contain: *Orithostella formosa* (Brotzen), *Gavelinella intermedia* (Berthelin), *Valvulineria loetterllei* (Tappan), *Hedbergella planispira* (Tappan), *Hedbergella delrioensis* (Carsey), *Heterohelix moremani* (Cushman), and in the upper part of the zone: *Planomalina buxtorfi* Gandolfi and *Rotalipora appenninica* (Renz).

Bulbobaculites problematicus Zone (Partial range zone)

Age: uppermost Albian–Cenomanian.
Authors: Morgiel and Olszewska, (1981) as *Ammobaculites problematicus* Zone.
Definition: The zone corresponds to the partial range of the index species in sediments of the flysch Carpathians.
Remarks: Noncalcareous sediments assigned to the zone contain: *Bulbobaculites problematicus* (Neagu) – frequent, *Plectorecurvoides alternans* Noth, *Recurvoides imperfectus* Hanzlíková, *Haplophragmoides kirki* Wickenden, *Haplophragmoides bulloides* Beissel, *Hormosina ovulum* (Grzybowski), *Textularia foeda* (Reuss). Assemblages from the upper part of the zone contain first specimens of *Uvigerinammina jankoi* Majzon (?*Uvigerinammina praejankoi Neagu)*. Within the zone the LO of the following species are observed: *Hippocreppina depressa* Vašiček, *Glomospirella gaultina* (Berthelin), *Thalmannammina neocomiensis* Geroch, *Trochammina vocontiana* Moullade and *Haplophragmoides falcatosuturalis* Neagu. Assemblages from the marly sediments include: *Pseudoclavulina gaultina* (Morozova), *Spiroplectinella roemeri* (Lalicker), *Spiroplectinella gandolfi* (Carbonnier), *Gyroidinoides mauretanicus* (Carbonnier), *Gavelinella schloenbachi* (Reuss), *Cibicides polyrraphes* (Reuss). In the lower part of the zone species *Planomalina buxtorfi* (Gandolfi) and *Rotalipora apenninica* (Renz) occur; in the upper part: *Rotalipora reicheli* (Mornod), *Rotalipora cushmani* (Morrow), *Praeglobotruncana stephani* (Gandolfi), *Praeglobotruncana gibba* Klaus and *Guembelitria cenomana* (Keller) are observed. The occurrence of radiolarites and radiolaria bearing green clays is also characteristic for the zone.

Uvigerinammina jankoi Zone (Acme zone)

Age: Turonian.
Authors: Morgiel and Olszewska (1981).
Definition: The zone corresponds to the abundant occurrence of the index species in foraminiferal assemblages.
Remarks: For noncalcareous sediments of the zone the following species are characteristic: *Uvigerinammina jankoi* Majzon, *Uvigerinammina praejankoi* Neagu, *Thalmannammina subturbinata* (Grzybowski), *Rhabdammina cylindrica* Glaessner, *Gerochammina lenis* (Grzybowski), *Recurvoides godulensis* Hanzlíková, *Haplophragmoides herbichi* Neagu, *Spiroplectinella praelonga* (Reuss), *Dorothia oxycona* (Reuss), *Trochamminoides subcoronatus* (Grzybowski), *Trochamminopsis challengeri* (Brönnimann et Whittaker), *Trochammina subvesicularis* Hanzlíková, *Gaudryina bentonensis* (Carman), *Hormosina* sp., (transitional between

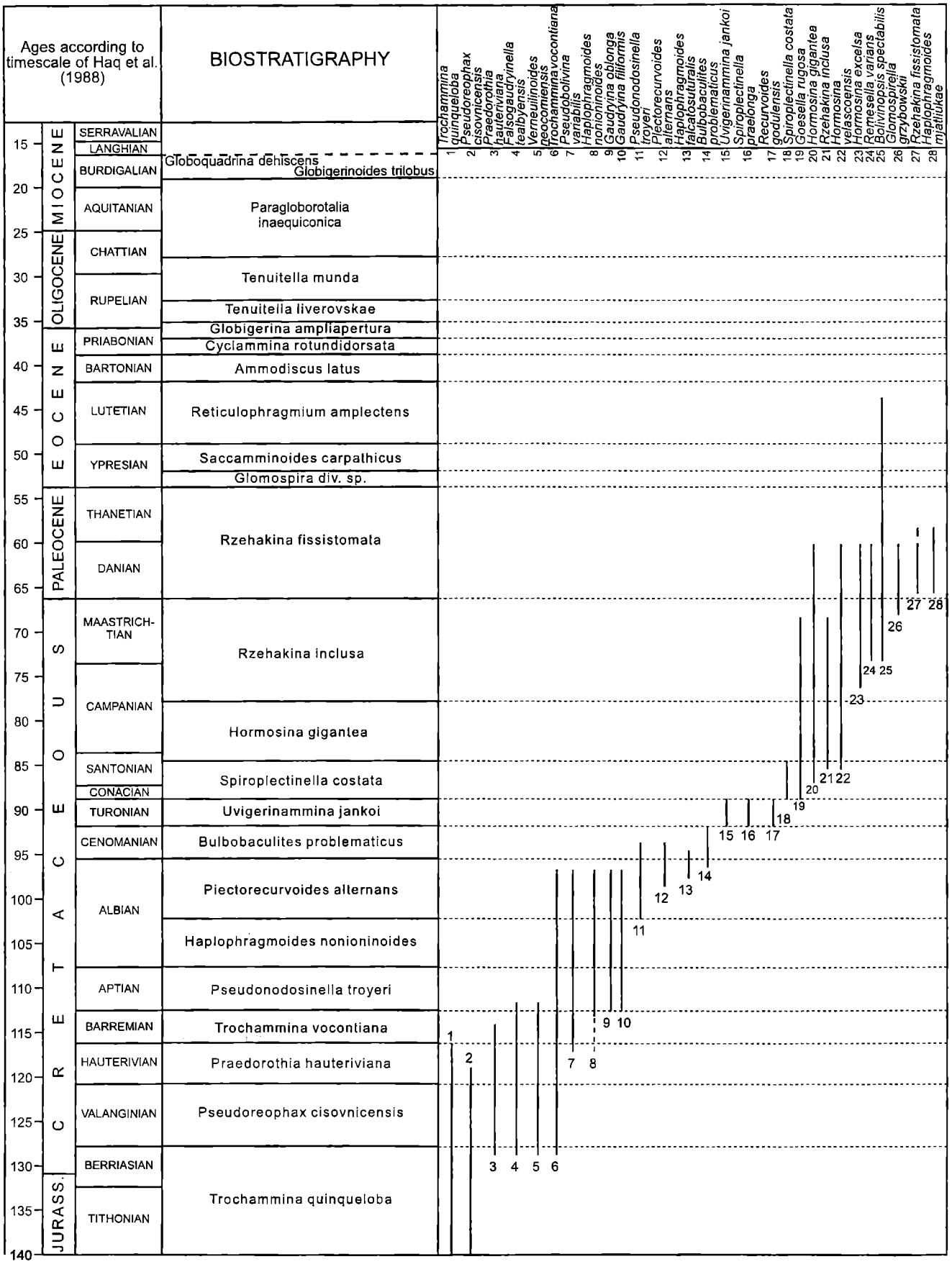
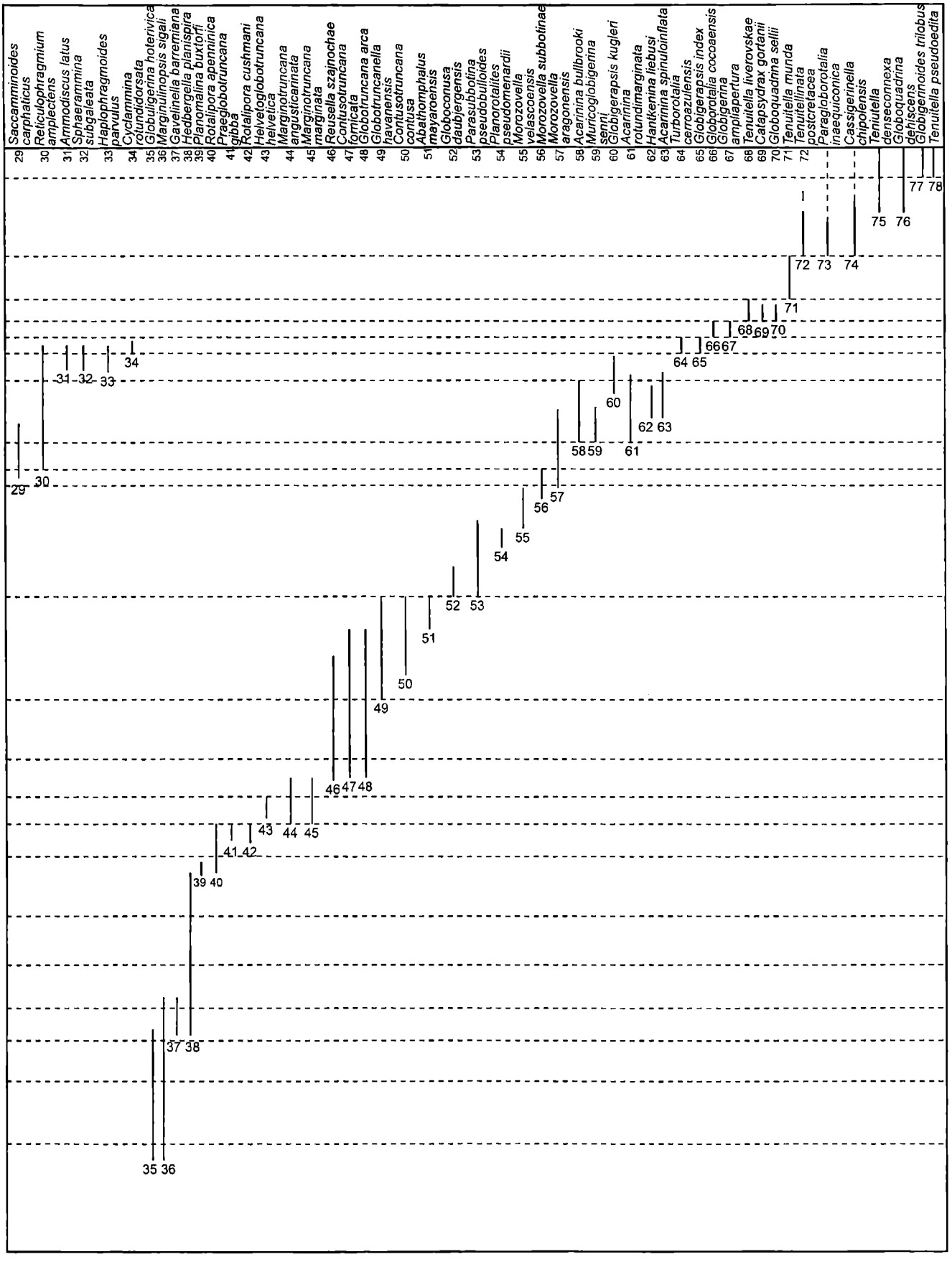


Fig. 3. Distribution of characteristic foraminifera


29 Saccamminoides carphaticus
30 Reticulophragmium amplectens
31 Ammodiscus latus
32 Sphaerammina subgaleata
33 Haplophragmoides parvulus
34 Cyclammina rotundidorsata
35 Globuligerina hoterivica
36 Marginulinopsis sigali
37 Gavelinella barremiana
38 Hedbergella planispira
39 Planomalina buxtorfi
40 Rotalipora apenninica
41 Praeglobotruncana gibba
42 Rotalipora cushmani
43 Helvetoglobotruncana helvetica
44 Marginotruncana angusticarinata
45 Marginotruncana marginata
46 Reussella szajnochae
47 Contusotruncana fornicata
48 Globotruncana arca
49 Globotruncanella havanensis
50 Contusotruncana contusa
51 Abathomphalus mayaroensis
52 Globoconusa daubjergensis
53 Parasubbotina pseudobulloides
54 Planorotalites pseudomenardii
55 Morozovella velascoensis
56 Morozovella subbotinae
57 Morozovella aragonensis
58 Acarinina bullbrooki
59 Muricoglobigerina senni
60 Globigerapsis kugleri
61 Acarinina rotundimarginata
62 Hantkenina liebusi
63 Acarinina spinuloinflata
64 Turborotalia cerroazulensis
65 Globigerapsis index
66 Globorotalia cocoaensis
67 Globigerina ampliapertura
68 Tenuitella liverovskae
69 Catapsydrax gortanii
70 Globoquadrina sellii
71 Tenuitella munda
72 Tenuitellinata postcretacea
73 Paragloborotalia inaequiconica
74 Cassigerinella chipolensis
75 Tenuitella denseconnexa
76 Globoquadrina dehiscens
77 Globigerinoides trilobus
78 Tenuitella pseudoedita

Caudammina crassa (Geroch) and *Hormosina gigantea* (Geroch). Marly sediments of the zone contain usually assemblages composed of: *Pseudoclavulina gaultina* (Morozova), *Dorothia crassa* (Marsson), *Ataxophragmium depressum* (Perner), *Gyroidinoides nitidus* (Reuss), *Eponides karsteni* (Reuss), *Lingulogavelinella globosa* (Brotzen), *Stensioeina praexculpta* (Keller), *Praeglobotruncana stephani* (Gandolfi), *Dicarinella imbricata* (Mornod), *Helvetoglobotruncana helvetica* (Bolli), *Marginotruncana marginata* (Reuss), *Marginotruncana tricarinata* (Quereau), *Globotruncana angusticarinata* (Gandolfi), *Globotruncana lapparenti* (Brotzen), and *Whiteinella archaeocretacea* Pessagno. Noteworthy is the presence of the calcareous dinoflagellate cysts: *Pithonella ovalis (Kaufmann), Pithonella sphaerica* (Kaufmann) and *Stomiosphaerina biedai* Nowak (Nowak, 1974).

Spiroplectinella costata Zone (Interval zone)

Age: Coniacian–early Santonian.
Authors: Morgiel and Olszewska (1981).
Definition: Interval between the FO of *Spiroplectinella costata* (Huss) and the FO of *Rzehakina inclusa* (Grzybowski).
Remarks: Foraminiferal assemblages of the zone contain abundant arenaceous and calcareous taxa. To the former belong: *Spiroplectinella costata* (Huss), *Spiroplectinella dentata* (Alth), *Spiroplectammina navarroana* Cushman, *Pseudonodosinella parvula* (Huss), *Pseudoclavulina amorpha* (Cushman), *Dorothia crassa* (Marsson), *Hormosina ovulum* (Grzybowski), *Karrerulina horrida* (Mjatliuk), *Gerochammina lenis* (Grzybowski), *Nothia excelsa* (Grzybowski), *Rzehakina epigona* (Rzehak). In the upper part of the zone appear: *Hormosina gigantea* Geroch, *Spiroplectinella subhaeringensis* (Grzybowski), *Pseudoclavulina subhaeringensis* (Grzybowski), *Goesella rugosa* Hanzlíková, *Gaudryina carinata* Franke. Assemblages of calcareous taxa include: *Stensioeina exsculpta* (Reuss), *Globorotalites multiseptus* Brotzen, *Eponides concinnus* Brotzen, *Eponides whitei* Brotzen, *Anomalina kelleri* Mjatliuk, *Lobatula ribbingi* (Brotzen), *Lobatula excavata* (Brotzen), *Gavelinella sandidgei* (Brotzen), *Marginotruncana coronata* (Bolli), *Marginotruncana pseudolinneiana* Pessagno, *Marginotruncana ventricosa* (White), *Archaeoglobigerina blowi* Pessagno.

In the upper part of the zone *Contusotruncana fornicata* (Plummer) appear.

Hormosina gigantea Zone (Acme zone)

Age: late Santonian–early Campanian.
Authors: Morgiel and Olszewska (1981).
Definition: The zone corresponds to the abundant occurrence of the index species in foraminiferal assemblages.
Remarks: Characteristic for the zone is a gradual decrease of arenaceous taxa toward the top. The following species are common in the assemblages: *Hormosina gigantea* Geroch, *Hormosina velascoensis* Cushman, *Saccammina placenta* (Grzybowski), *Nothia excelsa* (Grzybowski), *Kalamopsis grzybowskii* (Dylążanka), *Hormosina ovulum* (Grzybowski), *Thalmannammina subturbinata* (Grzybowski), *Rzehakina epigona* (Rzehak), *Spiroplectinella dentata* (Alth), *Dorothia crassa* (Marsson). Calcareous assemblages are typically composed of: *Aragonia ouezzanensis* (Rey), *Reussella szajnochae* (Grzybowski), *Pleurostomella wadowicensis* (Grzybowski), *Eponides subcandidulus* (Grzybowski), *Osangularia cordieriana* (d'Orbigny), *Stensioeina pommerana* Brotzen, *Bolivinoides delicatula* Cushman, *Biglobigerinella multispina* (Lalicker), *Striataella striata* (Ehrenberg), *Heterohelix globulosa* (Ehrenberg), *Pseudoguembelina costulata* (Cushman), *Globotruncana arca* (Cushman), *Globotruncana linneiana* (d'Orbigny), *Contusotruncana fornicata* (Plummer), *Rugoglobigerina rugosa* (Plummer), in the upper part of the zone *Pseudotextularia elegans* (Rzehak) also appears.

Rzehakina inclusa Zone (Interval zone)

Age: late Campanian–Maastrichtian.
Authors: Morgiel and Olszewska (1981).
Definition: Interval between the FO of *Rzehakina inclusa* (Rzehak) and the FO of *Rzehakina fissistomata* (Grzybowski).
Remarks: Generally two types of foraminiferal assemblages are characteristic for the zone (Olszewska, 1984b). They are connected with two lithofacies representing different paleoenvironments: outer shelf – upper bathyal (grey marls of the Frydek type), middle – lower bathyal (red marls of the Węglówka type). In the assemblages of the Węglówka type, the content of agglutinated species is relatively high. The following species are present: *Rzehakina inclusa* (Grzybowski). *Rzehakina epigona* (Rzehak), *Hormosina velascoensis* Cushman, *Hormosina excelsa* (Dylążanka), *Hormosina ovulum* (Grzybowski), *Dorothia crassa* (Marsson), and in the upper part of the zone: *Remesella varians* (Glaessner), *Bolivinopsis spectabilis* (Grzybowski), *Glomospira diffundens* Cushman et Renz. The accompanying calcareous species include: *Charltonina florealis* (White), *Stensioeina beccariiformis* (White), *Pullenia coryelli* White, *Cibicidoides bembix* (Marsson), *Pseudoguembelina excolata* (Cushman), *Pseudotextularia elegans* (Rzehak), *Globotruncanella havanensis* (Voorwijk), *Globotruncanita stuartiformis* (Dalbiez), *Contusotruncana contusa* (Cushman), and in the upper part of the zone: *Planoglobulina acervulinoides* (Egger), *Abathomphalus mayaroensis* (Bolli).

Assemblages of the grey marls are composed predominantly of calcareous foraminifera, both small and large. The typical assemblage contains: *Brizalina incrassata* (Reuss), *Bolivinoides draco* (Marsson), *Bolivinoides decoratus* (Jones), *Chilostomella ovoidea* Reuss, *Nonionella robusta* Plummer, *Florilus troostae* (Visser), *Allomorphina cretacea* Reuss, *Quadrimorphina allomorphinoides* (Reuss), *Praebulimina carseyae* (Plummer), *Pseudouvigerina cristata* (Marsson), *Reussella cimbrica* (Brotzen), *Pullenia cretacea* Cushman and *Daviesina minuscula* (Hofker). The large Cretaceous species: *Cymbalopora radiata* Hagenow, *Orbitoides media* (d'Archiac), *Siderolites calcitrapoides* Lamarck are also present. Ostracods and fragments of echinodermata and mollusca are characteristic for the facies.

Planktic foraminifera of the Frydek-type assemblages are composed of numerous: *Striataella striata* (Ehrenberg), *Heterohelix globulosa* (Ehrenberg), *Heterohelix pulchra* (Brotzen), *Biglobigerinella multispina* (Lalicker), *Globigerinelloides escheri* (Kaufman) and *Pseudotextularia elegans* (Rzehak), *Planoglobulina acervulinoides* (Egger), *Rugoglobigerina rugosa* (Plummer), *Kuglerina rotundata* (Brönnimann), *Globotruncana arca* (Cushman), *Globotruncanita stuarti* (Lapparent), *Contusotruncana contusa* (Cushman). In the early assemblages of this facies occurs *Globotruncanella havanensis* (Voorwijk), in the late assemblages – *Abathomphalus mayaroensis* (Bolli) (Morgiel & Liszkowa, 1981).

Rzehakina fissistomata Zone (Acme zone)

Age: Paleocene.
Author: Olszewska (present work).
Definition: The zone corresponds to the frequent occurrence of the index species in foraminiferal assemblages.
Remarks: The characteristic features of the Palaeocene sedimentation in the flysch basins of Carpathians were the gradual decrease of sedimentation rate and a gradual unification of fa cies.These processes may have had a favourable influence on the marine biotas in the flysch basins. Over 100 species of agglutinated foraminifera are known from the Palaeocene noncalcareous clays, and close to 100 species of calcareous foraminifera occur in the

coeval marls (Jednorowska, 1975). A typical agglutinated assemblage contains: *Hormosina velascoensis* Cushman, *Hormosina trinidadensis* Cushman et Renz, *Hormosina ovulum* Grzybowski, *Rzehakina fissistomata* (Grzybowski), *Bolivinopsis spectabilis* (Grzybowski), *Sphaerammina gerochi* Hanzlíková, *Glomospira diffundens* Cushman et Renz, *Glomospirella grzybowskii* (Jurkiewicz), *Haplophragmoides mjatliukae* Maslakova. Locally, in the lower Palaeocene assemblages, the last occurrences of the species: *Remesella varians* (Glaessner), *Dorothia crassa* (Marsson), *Spiroplectinella dentata* (Alth) and *Hormosina gigantea* Geroch have been observed. The transitional character of the Palaeocene assemblages is also evident among calcareous benthic foraminifera. Species such as: *Charltonina florealis* (White), *Stensioeina beccariiformis* (White), *Anomalina rubiginosa* Cushman, *Neoflabellina semireticulata* (Cushman et Jarvis), *Tappanina selmensis* (Cushman), *Aragonia velascoensis* (Cushman) still occur in the lower Palaeocene assemblages. Other characteristic calcareous benthic species are: *Nuttallides truempyi* (Nuttall), *Bulimina midwayensis* Plummer, *Pullenia coryelli* White, *Nodosarella kugleri* Cushman et Renz, *Pleurostomella clavata* (Cushman), *Osangularia velascoensis* (Cushman) (in Węglówka-type marls). In the Frydek-type marls *Paralabamina toulmini* (Brotzen), *Pseudouvigerina wilcoxensis* Cushman et Ponton, *Loxostomoides applinae* (Plummer), *Pulsiphonina prima* (Plummer), *Cibicides alleni* (Plummer), *Ceratobulimina perplexa* Plummer, *Karreria fallax* Rzehak, *Coleites reticulosus* (Plummer), *Anomalina umbilicata* Brotzen, occur. Planktic foraminifera, absent in the noncalcareous sediments, form several local zones (Jednorowska, 1975) comparable to standard zonations of Bolli (1966) and Toumarkine et Luterbacher (1985). The most common forms are: *Subbotina triloculinoides* (Plummer), *Parasubbotina pseudobulloides* (Plummer), *Igorina angulata* (White), *Chiloguembelina crinita* (Glaessner), *Planorotalites pseudomenardii* (Bolli), *Acarinina nitida* (Martin), *Morozovella aequa* (Cushman et Renz), *Morozovella velascoensis* (Cushman), *Subbotina velascoensis* (Cushman), *Muricoglobigerina angulosa* (Brönnimann).

Glomospira sp. div. Zone (Acme zone)

Age: early early Eocene.
Authors: Morgiel and Olszewska (1981).
Definition: The zone corresponds to the interval of common occurrence in the studied sequences of an almost monotypic assemblage of *Glomospira* sp. roughly between the last occurrence of *Haplophragmoides mjatliukae* Maslakova and the first occurrence of *Saccamminoides carpathicus* Geroch.
Remarks: Noncalcareous sediments assigned to the zone contain assemblages consisting of numerous specimens of *Glomospira charoides* (Jones et Parker) and *Glomospira gordialis* (Jones et Parker) with rare: *Rhabdammina cylindrica* Glaessner, *Thalmannammina subturbinata* (Grzybowski), *Trochamminoides subcoronatus* (Grzybowski), *Gerochammina lenis* (Grzybowski). Locally assemblages with numerous *Recurvoides* sp. div. and *Trochamminoides* sp. div. occur (Morgiel & Szymakowska, 1978).

Coeval marly sediments contain also: *Haplophragmoides walteri* (Grzybowski), *Gerochammina lenis* (Grzybowski), *Ammolagena clavata* (Jones et Parker), *Nuttallides truempyi* (Nuttall), *Aragonia aragonensis* (Nuttall), *Cibicidoides praemundulus* Berggren et Miller, *Eponides umbonatus* (Reuss). Planktic foraminifera belong to P6b–P7 standard zones (Berggren *et al.*, 1995). Most typical are: *Morozovella marginodentata* (Subbotina), *Morozovella subbotinae* (Morozova), *Morozovella acutispira* (Bolli et Cita) *Truncorotaloides collactea* (Finlay), *Globorotalia lensiformis* Subbotina, *Acarinina nitida* (Martin), *Acarinina primitiva* (Finlay), and, in the upper part: *Morozovella formosa* (Bolli), *Morozovella gracilis* (Bolli).

Saccamminoides carpathicus Zone (Acme zone)

Age: late early Eocene.
Authors: Morgiel and Olszewska (1981).
Definition: The zone corresponds to the interval of numerous occurrence of the index species in foraminiferal assemblages.
Remarks: The upper lower Eocene sediments of the flysch basin reflect the conditions of calm sedimentation (Atlas, 1962). Noncalcareous sediments (predominantly red clays) contain: *Saccamminoides carpathicus* Geroch, *Rhabdammina cylindrica* Glaessner, *Glomospira irregularis* (Grzybowski), *Haplophragmoides walteri* (Grzybowski), *Bolivinopsis spectabilis* (Grzybowski), *Gerochammina conversa* (Grzybowski), *Trochamminoides subcoronatus* (Grzybowski), *Trochamminoides folius* (Grzybowski), *Paratrochamminoides deformis* (Grzybowski), *Recurvoides turbinatus* (Brady). Within the zone the FO of *Reticulophragmium amplectens* (Grzybowski) occurs. In the marly sediments assigned to the zone, in addition to the mentioned agglutinated forms the species: *Nodosarella subnodosa* Guppy, *Osangularia plerophalia* (Gümbel), *Nuttalides truempyi* (Nuttall), *Aragonia aragonensis* (Nuttall), *Falsoplanulina ammophila* (Gümbel), *Cibicidoides havanensis* (Cushman et Bermudez), *Korobkovella grosserugosa* (Gümbel), *Morozovella aragonensis* (Nuttall), *Acarinina pentacamerata* (Subbotina), *Subbotina linaperta* (Finlay), *Globigerina eocaena* (Gümbel), *Globanomalina wilcoxensis* (Cushman et Ponton), *Chiloguembelina wilcoxensis* (Cushman et Ponton) are observed. In the upper part of the zone *Acarinina densa* (Cushman) and *Morozovella caucasica* (Glaessner) have been found indicating correlation to standard planktonic foraminiferal zones P8–P9 (Berggren *et al.*, 1995).

Reticulophragmium amplectens Zone (Interval zone)

Age: early middle Eocene (Lutetian).
Authors: Morgiel and Olszewska (1981).
Definition: Interval between the LO of *Saccamminoides carpathicus* Geroch and the FO of *Ammodiscus latus* (Grzybowski) and *Haplophragmoides parvulus* Blaicher.
Remarks: The early middle Eocene sedimentary conditions in the flysch basins favoured the accumulation of marly sediments (Atlas, 1962). Assemblages of foraminifera usually contain both agglutinated and calcareous species. A typical assemblage contains: *Reticulophragmium amplectens* (Grzybowski), *Haplophragmoides walteri* (Grzybowski), *Haplophragmoides suborbicularis* (Grzybowski), *Recurvoides nucleolus* (Grzybowski), *Recurvoides contortus* Earland, *Trochamminoides subcoronatus* (Grzybowski), *Trochamminoides variolarius* (Grzybowski), *Trochamminoides grzybowskii* Kaminski et Geroch, *Ammobaculites deflexus* (Grzybowski), *Bolivinopsis spectabilis* (Grzybowski), *Karrerulina coniformis* (Grzybowski), *Gerochammina conversa* (Grzybowski), *Nuttallides truempyi* (Nuttall), *Eponides umbonatus (Reuss), Cibicidoides grimsdalei* (Nuttall), *Cibicidoides eocaenus* (Gümbel), *Cibicidoides havanensis* (Cushman et Bermudez), *Falsoplanulina ammophila* (Gümbel), *Ellipsodimorphina subcompacta* (Liebus), *Nodosarella subnodosa* Guppy, *Pleurostomella eocaena* (Gümbel), *Acarinina bullbrooki* (Bolli), *Acarinina rotundimarginata* Subbotina, *Globigerina eocaena* (Gümbel), *Subbotina linaperta* (Finlay), *Turborotalia boweri* (Bolli), *Testacarinata aculeata* (Jenkins), *Truncorotaloides collactea* (Finlay), *Muricoglobigerina senni* (Beckmann). Rich in planktonic foraminifera marly sediments of Dukla and Subsilesian units include representatives of the genus *Hantkenina*: *Hantkenina liebusi* Shokhina and *Hantkenina mexicana* Cushman suggesting correlation to zones P10–P12 (Berggren *et al.*, 1995).

Ammodiscus latus Zone (Interval zone)

Age: late middle Eocene (Bartonian).
Authors: Morgiel and Olszewska (1981).
Definition: Interval between the FO of *Ammodiscus latus* (Grzybowski) and the FO of *Cyclammina rotundidorsata* (Hantken).
Remarks: By the end of the middle Eocene in the flysch basins hemipelagic sedimentation still prevails. The noncalcareous clays contain assemblages of the arenaceous species: *Ammodiscus latus* (Grzybowski), *Labrospira scitula* (Brady), *Reophax pilulifer* (Brady), *Reophax elongatus* (Grzybowski), *Rhabdammina cylindrica* Glaessner, *Recurvoides nucleolus* (Grzybowski), *Recurvoides contortus* Earland, *Lituotuba lituiformis* (Brady), *Gerochammina conversa* (Grzybowski). Locally, *Sphaerammina subgaleata* (Vašíček) and *Haplophragmoides parvulus* Blaicher also occur.

Marly sediments, in addition to numerous agglutinated forms contain: *Nuttallides truempyi* (Nuttall), *Eponides umbonatus* (Reuss), *Lobatula rzehaki* (Grzybowski), *Linaresia semicribrata* (Beckmann), *Cibicidoides grimsdalei* (Nuttall), *Laterostomella cubensis* (Palmer), *Aragonella dumblei* (Weinzierl et Applin), *Globigerapsis kugleri* Bolli, Loeblich & Tappan, *Globigerapsis micra* (Shutskaya), *Globorotaloides suteri* Bolli, *Globanomalina micra* (Cole), *Acarinina spinuloinflata* (Bolli), *Globigerina eocaena* (Gümbel), *Subbotina minima* (Jenkins) suggesting correlation with standard zones P13–P14 (Berggren *et al.*, 1995).

Cyclammina rotundidorsata Zone (Interval zone)

Age: early late Eocene.
Authors: Morgiel and Olszewska (1981).
Definition: Interval between the FO of *Cyclammina rotundidorsata* (Hantken) and the FO of *Globigerina ampliapertura* Bolli.
Remarks: Deep water, hemipelagic sedimentation continued in the Carpathians basins into the late Eocene. Underwater slump deposits (Popiele Beds) accumulated locally. Characteristic feature of both types of sediments is the increase in $CaCO_3$ content towards the top of the sequences (Atlas, 1962).

A typical foraminiferal assemblage contains: *Cyclammina rotundidorsata* (Hantken), *Reophax pilulifer* (Brady), *Recurvoides nucleolus* (Grzybowski), *Arenobulimina dorbignyi* (Reuss), *Bulimina truncana* (Gümbel), *Heterolepa perlucida* (Nuttall), *Alabamina dissonata* (Cushman et Renz), *Uvigerina jacksonensis* (Cushman), *Pleurostomella acuta* (Hantken), *Daucina multicostata* Galloway et Morrey, *Cibicides vortex* Doreen, *Lobatula rzehaki* (Grzybowski), *Nodosarella tuberosa* (Gümbel), *Turborotalia pomeroli* (Toumarkine et Bolli), *Turborotalia cerroazulensis* (Cole), *Globigerapsis index* (Finlay), *Subbotina linaperta* (Finlay), *Subbotina eocaena* (Gümbel), *Globorotaloides suteri* Bolli, *Subbotina angiporoides* (Hornibrook), *Parasubbotina danvillensis* (Howe et Wallace). Shallow-water assemblages of the Popiele Beds contain: *Spiroplectinella dalmatina* (de Witt Puyt), *Almaena taurica* Samoilova, *Queraltina epistominoides* (Marie), *Uvigerina multistriata* (Hantken), *Nonion laeve* (d'Orbigny), *Pararotalia lithothamnica* (Uhlig), *Latibolivina reticulata* (Hantken), *Rosalina uhligi* (Grzybowski), *Valvulineria alpina* Hillebrandt. Other coeval, shallow water assemblages indicating a carbonate platform environment are known from autochtonous limestones in the Tatra Mts (Inner Carpathians), and also from olistoliths found in flysch sediments. Characteristic for those assemblages are the larger foraminifera: *Nummulites incrassatus* de la Harpe, *Discocyclina varians* (Kaufmann), *Orbitoclypeus nummuliticus* (Gümbel), *Asterocyclina stella* (Gümbel), *Sphaerogypsina globulus* (Reuss), *Gyroidinella magna* Le Calvez, *Eorupertia cristata* (Gümbel), *Korobkovella grosserugosa* (Gümbel), fragments of calcareous algae (*Lithothamnium*) and Bryozoa.

Globigerina ampliapertura Zone (Interval zone)

Age: late late Eocene.
Author: Olszewska (present work).
Definition: Interval between the FO of *Globigerina ampliapertura* Bolli and the FO of *Tenuitella liverovskae* (Bykova).
Remarks: Characteristic for the zone is the gradual disappearance of agglutinated species, as well as all oceanic calcareous taxa, among them the index upper Eocene planktic species: *Turborotalia cerroazulensis* (Cole), *Globigerapsis index* (Finlay), *Globorotalia cocoaensis* Cushman, *Globorotalia cunialensis* Toumarkine et Bolli (Olszewska, 1983b, 1984a).

A typical assemblage of the zone contains: *Reophax pilulifer* Brady, *Recurvoides nucleolus* (Grzybowski), *Arenobulimina dorbignyi* (Reuss), *Daucina multicostata* Galloway et Morrey, *Heterolepa perlucida* (Nuttall), *Cibicidoides praemundulus* Berggren et Miller, *Cibicidoides grimsdalei* (Nuttall), *Gyroidinoides girardanus (Reuss)*, *Eponides umbonatus* (Reuss), *Ellipsodimorphina robusta* (Cushman), *Pleurostomella incrassata* (Hantken), *Bulimina bermudezi* Hagn, *Nuttallides truempyi* (Nuttall), *Falsoplanulina ammophila* (Gümbel), *Globigerina ampliapertura* Bolli, *Globigerina officinalis* Subbotina, *Globigerina ouachitaensis* Howe et Wallace, *Globorotaloides suteri* Bolli, *Subbotina transdanubica* (Samuel), *Subbotina angiporoides* (Hornibrook), *Subbotina krosnensis* (Blaicher), *Catapsydrax unicavus* Bolli, Loeblich & Tappan, *Catapsydrax perus* (Todd), *Globigerinita cryptomphala* (Glaessner), *Globigerinita corpulenta* (Subbotina). At the top of the zone appear: *Catapsydrax gortanii* Borsetti and *Tenuitella liverovskae* (Bykova). The composition of assemblage suggests correlation with zone P17 (Berggren *et al.*, 1995).

Tenuitella liverovskae Zone (Acme zone)

Age: Early Rupelian.
Author: Olszewska (present work).
Definition: The zone corresponds to the numerous occurrence of the index species in foraminiferal assemblages.
Remarks: Worldwide and regional environmental modifications at the Eocene/Oligocene boundary (Corliss *et al.*, 1981; Olszewska, 1984a) caused dramatic changes in foraminiferal assemblages.The Early Oligocene assemblages of the Outer Carpathians are composed predominantly of small, calcareous benthic and planktic species probably indicating a restricted, rather shallow environment. A typical assemblage contains: *Globocassidulina globosa* (Hantken), *Bolivina crenulata* Cushman, *Brizalina fastigia* (Cushman), *Angulogerina tenuistriata* (Reuss), *Cibicides amphisylensis* (Andreae), *Cibicides lopjanicus* Mjatliuk, *Fursenkoina schreibersiana* (Czjžek), *Reussella oberburgensis* (Freyer), *Svratkina perlata* (Andreae), *Alabamina wolterstorfi* (Franke), *Valvulineria tumeyensis* Cushman et Simonson, *Chilostomella tenuis* Bornemann, *Anomalinoides affinis* (Hantken), *Chiloguembelina gracillima* (Andreae), *Globigerina officinalis* Subbotina, *Globigerina praebulloides* Blow, *Subbotina vialovi* Mjatliuk, *Subbotina droogeri* Mjatliuk, *Parasubbotina karpatica* (Mjatliuk), *Tenuitella liverovskae* (Bykova), *Tenuitellinata angustiumbilicata* (Bolli), *Paragloborotalia nana* (Bolli). Rare specimens of *Globigerina ampliapertura* Bolli, *Globoquadrina selii* Borsetti, *Globoquadrina tripartita* Koch, *Globoquadrina tapuriensis* (Blow et Banner) and *Catapsydrax gortanii* Borsetti also occur within the zone.

Tenuitella munda Zone (Acme zone)

Age: late Rupelian–early Chattian.
Author: Olszewska (this paper).
Definition: The zone corresponds to frequent occurrence of the index species in foraminiferal assemblages. The upper limit of the

zone roughly coincides with the top of the laminated Jasło limestones (NP 24/25 in Ślęzak *et al.*, 1995).

Remarks: Benthic assemblages of the zone are strongly facies dependent. Forms common in all facies are: *Caucasina schiskinskyae* (Samoilova), *Cibicides lopjanicus* Mjatliuk, *Bolivina crenulata* Cushman, *Brizalina melettica* (Andreae), *Epistominella stellata* Dabagyan, *Uvigerinella majcopica* Kraeva, *Allomorphina trigona* (Reuss), *Virgulinella chalkophila* (Hagn), *Fursenkoina dibollensis* (Cushman and Applin), *Chilostomella cylindrica* (Reuss). The rather uniform planktic assemblage includes: *Tenuitella munda* (Jenkins), *Paragloborotalia nana* (Bolli), *Tenuitellinata ciperoensis* (Bolli), *Tenuitellinata postcretacea* (Mjatliuk), *Tenuitellinata angustiumbilicata* (Bolli), *Globigerina praebulloides* Blow, *Globigerina officinalis* Subbotina. At the top of the zone: *Paragloborotalia inaequiconica* (Subbotina) and *Cassigerinella chipolensis* (Cushman et Ponton) appear.

Paragloborotalia inaequiconica Zone (Acme zone)

Age: late Chattian–early Burdigalian.

Author: Olszewska (present work).

Definition: The zone corresponds to the abundant occurrence of the index species in foraminiferal assemblages. In the upper part of the zone occurs the layer called the Radziszów tuff, with an isotopic age of 20,5 Ma (Wieser, 1979).

Remarks: Characteristic for the zone is the gradual appearance of species more typical for the lower Miocene sediments of the Outer Carpathians and its foredeep. In the lower part of the zone occur: *Cibicides borislavensis* Aisenstadt, *Caucasina schiskinskyae* (Samoilova), *Caucasina tenebricosa* Pishvanova, *Cassidulina margareta* Karrer, *Pullenia bulloides* (Reuss), *Nonion commune* (d'Orbigny), *Brizalina subdilatata* (Pishvanova), *Ammonia beccarii* (Linne), numerous specimens of *Paragloborotalia inaequiconica* (Subbotina) and *Cassigerinella chipolensis* (Cushman et Ponton). Moreover there occur: *Tenuitella brevispira* (Subbotina), *Globigerina praebulloides* Blow, *Tenuitellinata postcretacea* (Mjatliuk). In the upper part of the zone the FO of: *Chiloguembelitria samwelli* (Jenkins), *Globoquadrina dehiscens* (Chapman, Parr & Collins), *Globigerinoides primordius* Blow et Banner, *Paragloborotalia pseudocontinuosa* (Blow), *Paragloborotalia semivera* (Hornibrook), *Globoturborotalita woodi* (Jenkins), *Subbotina connecta* (Jenkins), *Globigerinella evoluta* (Subbotina), *Tenuitella denseconnexa* (Subbotina), *Tenuitellinata pseudoedita* (Subbotina) and *Globorotalia tetracamerata* Subbotina are observed.

Globoquadrina dehiscens – Globigerinoides trilobus Zone (Assemblage zone)

Age: late Burdigalian.

Author: Olszewska (present work).

Definition: The zone is characterised by the presence of both index species in foraminiferal assemblages. It embraces Carpathian sediments from the Radziszów tuff up to the top of the flysch sequence.

Remarks: The assemblages are usually composed of: *Spiroplectinella carinata* (d'Orbigny), *Textularia deperdita* d'Orbigny, *Valvulineria complanata* (d'Orbigny), *Cibicides ungerianus* (d'Orbigny), *Cibicides borislavensis* Aisenstadt, *Marginulina hirsuta* d'Orbginy, *Sphaeroidina bulloides* (d'Orbigny), *Melonis pompilioides* (Fichtel and Moll), *Ammonia beccarii* (Linne), *Cassigerinella chipolensis* (Cushman et Ponton), *Chiloguembelitria samwelli* (Jenkins), *Globigerinoides trilobus* (Reuss), *Globigerinoides immaturus* (Le Roy), *Paragloborotalia inaequiconica* (Subbotina), *Paragloborotalia siakensis* (Le Roy), *Globoturborotalita woodi* (Jenkins), *Subbotina connecta* (Jenkins), *Globoquadrina globularis* Bermudez, *Globoquadrina baroemoenensis* (Le Roy), *Globoquadrina dehiscens* (Chapman, Parr & Collins), *Tenuitella brevispira* (Subbotina), *Tenuitella denseconnexa* (Subbotina), *Tenuitellinata pseudoedita* (Subbotina), *Globoconella incognita* (Walters).

The above described assemblage is, up to now, the youngest known from the Outer Carpathian flysch. Among the benthic taxa are many that are common in the Middle Miocene of the region. On the other hand planktic associations lack regional early Middle Miocene markers such as: *Globigerinoides bisphericus* Todd and *Praeorbulina sicana* (Di Stefani). The occurrence of calcareous nannoplankton assemblages from the top of Carpathian sequences with the species *Discoaster variabilis* Martini et Bramlette (FO top of zone NN4) suggests continuation of sedimentation until the end of the early Miocene or even in the beginning of the Middle Miocene (Ślęzak *et al.*, 1995).

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REFERENCES

Atlas Geologiczny Polski, 1962. Zagadnienia stratygraficzno-facjalne. Z.13. Kreda i starszy trzeciorzęd w polskich Karpatach zewnętrznych. Wyd. Geol., Warszawa.

Berggren, W. A., Kent, D. V., Swischer, C. C., & Aubry, M.-P., 1995. A revised Cenozoic geochronology and chronostratigraphy. In: Scholle, P. (ed.), *Geochronology, Time Scales and Global Stratigraphic Correlation.* SEPM Spec. Public., 54: 129–203.

Berggren, W. A. & Hollister, C. D., 1977. Plate tectonic and paleocirculation – commotion in the ocean. *Tectonophysics*, 38: 11–48.

Bieda, F., Geroch, S., Koszarski, L., Książkiewicz, M. & Żytko, K., 1963. Stratigraphie des Karpates externes polonaises. Recherches géologiques dans les Karpates. *Inst. Geol. Biul.*, 181: 1–153.

Bolli, H., 1966. Zonation of Cretaceous to Pliocene marine sediments based on planktonic foraminifers. *Bol. Inf. Assoc. Venez. Geol. Min. Petrol.*, 9: 3–32.

Corliss, B. H., Aubry, M-P., Berggren, W. A., Fenner, J. M., Keigwin, Jr. L. D. & Keller, G., 1984. The Eocene/Oligocene boundary event in the deep sea. *Science*, 226: 806–810.

Eljaš, M., 1979. Facies and paleogeography of the Silesian unit in the western part of the Czechoslovak flysch Carpathians. *Véstik Ústr. Úst. Geol.*, 54: 327–339.

Geroch, S., Jednorowska, A., Książkiewicz, M. & Liszkowa, J., 1967. Stratigraphy based upon microfauna in the Western Polish Carpathians. *Inst. Geol. Biul.*, 211: 185–25.

Geroch, S. & Nowak, W., 1984. Proposal of zonation for the Late Tithonian – Late Eocene based upon arenaceous foraminifera from the Outer Carpathians, Poland. In: Oertli H. J. (ed.), *Benthos '83; 2nd Int. Symp. Benthic Foraminifera (Pau, April 1983)* – Elf Aquitaine, Esso REP: and Total CFP, Pau and Bordeaux, 1984, pp. 225–239.

Haq, B. U., Hardenbol, J. & Vail, P. R., 1988. Mesozoic and Cenozoic chronostratigraphy and eustatic cycles. In: Wilgus, C. K., Hastings, B. S., *et al.* (eds.), *Sea-level changes an integrated approach.* SEPM Spec. Public., 42: 71–108.

Hesse, R., 1975. Turbiditic and non-turbiditic mudstone of Cretaceous Flysch section of the East Alps and other turbinate

basins. *Sedimentology*, 22: 387–416.

Jednorowska, A., 1975. Small Foraminifera assemblages in the Paleocene of the Polish Western Carpathians. *Studia Geol. Polon.*, 47: 3–103 (In Polish with English summary).

Kaminski, M. A., Geroch, S. & Kaminski, D. G., 1993. *The origin of applied micropaleontology: the school of Józef Grzybowski*. Grzybowski Foundation Spec. Public., 1, 323 pp.

Koszarski, L., 1963. Types fondamentaux des depots et principales etapes de leur developpement dans le geosynclinal du flysch des Karpates. *Assoc. Geol. Karp.-Balk. V-th Congr., 1963*, III, pp. 253–25.

Leszczyński, S. & Uchman, A., 1991. To the origin of variegated shales from flysch of the Polish Carpathians. *Geol. Carpathica*, 42: 279–289.

Malata, E., 1985. Charakterystyka mikrofaunistyczna utworów górnej kredy i paleogenu łuski przedmagurskiej Karpat fliszowych. Archiwum Państwowego Instytutu Geologicznego, Kraków, 80 pp. (unpublished).

Malinowska, L. (ed.), 1984. Geology of Poland, V,III, Atlas of Guide and Characteristic Fossils, Part 2c, Mesozoic, Cretaceous, 478 pp.

Morgiel, J. & Olszewska, B., 1981. Biostratigraphy of the Polish External Crapathians based on agglutinated foraminifera. *Micropaleontology*, 27: 1–30.

Morgiel, J. & Szymakowska F., 1978. Stratygrafia paleocenu i eocenu jednostki skolskiej. *Biul. Inst. Geol.*, 310: 40–60.

Nowak, W., 1968. Stomiosphaerids of the Cieszyn Beds (Kimmeridgian–Hauterivian) in the Polish Cieszyn Silesia and their stratigraphic value. *Rocz. Pol. Tow. Geol.*, 38: 275–312 (In Polish with English summary).

Nowak, W., 1974. *Stomiosphaerina* nov. gen. (Incertae sedis) of the Upper Cretaceous in the Polish Flysch Carpathians. *Rocz. Pol. Tow. Geol.*, 44: 51–62.

Olszewska, B., 1980. Stratygrafia osadów kredy górnej i paleogenu w centralnej części jednostki dukielskiej na podstawie otwornic. *Biul. Inst. Geol.*, 326: 59–97.

Olszewska, B., 1983. Zespół z *Trochammina quinqueloba* Geroch – ? najstarszy zespół otwornic aglutynujących polskich Karpat zewnętrznych. *Kwart. Geol.*, 27: 444–445.

Olszewska, B., 1984a. Otwornice bentoniczne podmenilitowych margli globigerinowych polskich Karpat zewnętrznych. *Prace Inst. Geol.*, 110: 1–31.

Olszewska, B., 1984b. Interpretacja paleoekologiczna otwornic kredy i paleogenu polskich Karpat zewnętrznych. *Biul. Inst. Geol.*, 346: 7–45.

Olszewska, B., Odrzywolska-Bieńkowa, E., Giel, M. D., Pożaryska, K. & Szczechura, J., 1996. Rząd Foraminiferida. In: Malinowska, L., Piwocki, M. (eds.), *Atlas skamieniałości przewodnich i charakterystycznych; t. III, cz. 3a, Paleogen*, Polska Agencja Ekologiczna, pp. 45–216.

Ślęzak, J. M., Koszarski, A. & Koszarski, L., 1995. Calcareous nannoplankton stratigraphy of the terminal flysch deposits from the Skole Nappe (Oligocene–Miocene, Polish Carpathians, Krosno Beds). In: J. A. Flores, J. A., & Sierro F. J., (eds.), *Proceedings 5th International Nannofossils Association Conference in Salamanca*, pp. 267–277.

Toumarkine, M. & Luterbacher, H., 1985. Paleocene and Eocene planktic foraminifera. In: Bolli H. M., *et al* (eds.), *Plankton Stratigraphy*. Cambridge University Press, Cambridge, pp. 87–154.

Unrug, R., 1979. Palinspastic reconstruction of the Carpathian arc before the Neogene tectogenesis. *Rocz. Pol. Tow. Geol.*, 49: 3–18.

Wieser, T., 1979. Korelacja horyzontów tufowych warstw krośnieńskich na podstawie cech mineralogicznych i wieku bezwzględnego. *Kwart. Geol.*, 23: 930.

Wójcik, A., Jankowski, L., Kopciowski, R., Malata, T., Marciniec, P. & Nescieruk P., 1995. Opracowanie formalnych jednostek litostratygraficznych Karpat zewnętrznych i zapadliska dla celów Szczegółowej Mapy Geologicznej Polski. Archiwum Państwowego Instytutu Geologicznego, Kraków, 121 pp. (unpublished).

Streszczenie

BIOSTRATYGRAFIA OTWORNICOWA POLSKICH KARPAT ZEWNĘTRZNYCH: ZAPIS HISTORII GEOLOGICZNEJ BASENU

Barbara Olszewska

Uważa się, że geosynklina Karpat zewnętrznych składała się z kilku basenów sedymentacyjnych oddzielonych podmorskimi wyniesieniami i lądami (wyspami) (Unrug, 1979). Obszary lądowe dostarczały do basenów materiału klastycznego, z którego powstały utwory fliszowe. Utwory te zawierają, w przewadze, redeponowany materiał wyższej części stoku i zewnętrznych partii szelfu przemieszczony wgłąb basenów przez prądy zawiesinowe lub spływy kohezyjne. W przerwach między wystąpieniami kolejnych spływów grawitacyjnych utwory autochtoniczne (ilaste lub wapniste) pokrywały również dna basenów. W specyficznym środowisku sedymentacji fliszowej szansę na zachowanie się w osadzie miały głównie organizmy o dużej liczebności i szerokim rozprzestrzenieniu. W geosynklinie Karpat fliszowych należały do nich przede wszystkim otwornice i wapienny nannoplankton. W kredzie i we wczesnym paleogenie środowisko fliszowe geosynkliny karpackiej sprzyjało głównie otwornicom o skorupkach krzemionkowych. Dlatego też one pierwsze znalazły zastosowanie w badaniach stratygraficznych, służąc do opracowania lokalnych biostratygrafii (Bieda *et al.*, 1963; Geroch *et al.*, 1967; Morgiel & Olszewska, 1981; Geroch & Nowak, 1984). Zmiany w środowisku sedymentacji na przełomie eocenu i oligocenu spowodowały prawie całkowity zanik otwornic o skorupkach krzemionkowych (Olszewska, 1984a) zmuszając do poszukiwania gatunków przydatnych dla biostratygrafii wśród otwornic o skorupkach wapiennych (głównie planktonicznych).

Przedstawiona poniżej propozycja schematu biostratygraficznego stanowi sukcesję poziomów opartą na obydwu grupach otwornic. Od stropu jury do niższej części górnego eocenu poziomy oparte są na gatunkach krzemionkowych, od wyższej części górnego eocenu aż do końca dolnego miocenu na gatunkach wapiennych planktonicznych.

1 – Poziom *Trochammina quinqueloba* (tyton górny–berias) z *T. quinqueloba*, *Glomospira variabilis*, *Melathrokerion spiralis*.

2 – Poziom *Pseudoreophax cisovnicensis* (walanżyn) z: *P. cisovnicensis*, *Hyperammina gaultina*, *Glomospirella gaultina*, *Conorboides hofkeri*, *Lenticulina meridiana*.

3 – Poziom *Praedorothia hauteriviana* (hoteryw) z: *P. hauteriviana*, *Falsogaudryinella tealbyensis*, *Verneuilinoides neocomiensis*, *Ammobaculoides carpathicus*, *Plectorecurvoides irregularis*.

4 – Poziom *Trochammina vocontiana* (barem) z: *T. vocontiana*, *Dorothia kummi*, *Caudammina crassa*, *Gavelinella barremiana*, *Marginulinopsis sigali*, *Globuligerina hoterivica*.

5 – Poziom *Pseudonodosinella troyeri* (apt) z: *Verneuilinoides subfiliformis*, *Gaudryinella scherlocki*, *Gaudryina oblonga*, *Pseudonodosinella troyeri*, *Trochammina abrupta*, *Hedbergella infracretacea*.

6 – Poziom *Haplophragmoides nonioninoides* (alb dolny) z:

H. nonioninoides, *Hippocrepina depressa*, *Haplophragmoides kirki*, *Gaudryina filiformis*.

7 – Poziom *Plectorecurvoides alternans* (alb środkowy–alb górny) z: *P. alternans*, *Recurvoides imperfectus*, *Haplophragmoides gigas minor*, *Thalmannammina neocomiensis*, *Gavelinella djaffarovi*.

8 – Poziom *Bulbobaculites problematicus* (alb najwyższy–cenoman) z: *B. problematicus*, *Plectorecurvoides alternans*, *Haplophragmoides bulloides*, *Pseudoclavulina gaultina*, *Hormosina ovulum*, *Textularia foeda*, *Planomalina buxtorfi*, *Rotalipora appeninnica*, *R. cushmani*.

9 – Poziom *Uvigerinammina jankoi* (turon) z: *U. jankoi*, *U. praejankoi*, *Gerochammina lenis*, *Recurvoides godulensis*, *Dorothia oxycona*, *Spiroplectinella praelonga*, *Helvetoglobotruncana helvetica*, *Globotruncana lapparenti*.

10 – Poziom *Spiroplectinella costata* (koniak–santon dolny) z: *S. costata*, *Goesella rugosa*, *Spiroplectammina navarroana*, *Rzehakina epigona*, *Pseudoclavulina subhaeringensis*, *Dorothia crassa*, *Stensioeina praexsculpta*, *Marginotruncana marginata*.

11 – Poziom *Hormosina gigantea* (santon górny–kampan dolny) z: *H. gigantea*, *H. velascoensis*, *Nothia excelsa*, *Kalamopsis grzybowskii*, *Spiroplectinella dentata*, *Reussella szajnochae*, *Globotruncana arca*, *Contusotruncana fornicata*.

12 – Poziom *Rzehakina inclusa* (kampan górny–mastrycht) z: *R. inclusa*, *Hormosina excelsa*, *Remesella varians*, *Bolivinopsis spectabilis*, *Stensioeina beccariiformis*, *Globotruncanella havanensis*, *Contusotruncana contusa*, *Abathomphalus mayaroensis*.

13 – Poziom *Rzehakina fissistomata* (paleocen) z: *R. fissistomata*, *Haplophragmoides mjatliukae*, *Glomospirella grzybowskii*, *Sphaerammina gerochi*, *Nuttallides truempyi*, *Loxostomoides applinae*, *Subbotina triloculinoides*, *Planorotalites pseudomenardii*, *Morozovella velascoensis*.

14 – Poziom *Glomospira* sp. div. (eocen dolny niższy) z: *G. charoides*, *G. gordialis*, *G. irregularis*, *Morozovella subbotinae*, *M. marginodentata*.

15 – Poziom *Saccamminoides carpathicus* (eocen dolny wyższy) z: *S. carpathicus*, *Haplophragmoides walteri*, *Recurvoides turbinatus*, *Gerochammina conversa*, *Cibicidoides havanensis*, *Aragonia aragonensis*, *Morozovella aragonensis*.

16 – Poziom *Reticulophragmium amplectens* (eocen środkowy niższy) z: *R. amplectens*, *Haplophragmoides suborbicularis*, *Trochamminoides subcoronatus*, *Karrerulina coniformis*, *Recurvoides contortus*, *Cibicidoides grimsdalei*, *Anomalinoides capitatus*, *Acarinina bullbrooki*, *Subbotina eocaena*.

17 – Poziom *Ammodiscus latus* (eocen środkowy wyższy) z: *A. latus*, *Sphaerammina subgaleata*, *Labrospira scitula*, *Haplophragmoides parvulus*, *Linaresia semicribrata*, *Globigerapsis kugleri*, *Globanomalina micra*, *Laterostomella cubensis*.

18 – Poziom *Cyclammina rotundidorsata* (eocen górny niższy) z: *C. rotundidorsata*, *Reophax pilulifer*, *Recurvoides nucleolus*, *Arenobulimina dorbignyi*, *Heterolepa perlucida*, *Pleurostomella acuta*, *Turborotalia cerroazulensis*, *Globigerapsis index*.

19 – Poziom *Globigerina ampliapertura* (eocen górny wyższy) z: *G. ampliapertura*, *Subbotina linaperta*, *Globigerina officinalis*, *Subbotina krosnensis*, *Catapsydrax unicavus*, *Globigerinita cryptomphala*, *Heterolepa perlucida*, *Gyroidinoides girardana*, *Ellipsodimorphina robusta*, *Bulimina bermudezi*.

20 – Poziom *Tenuitella liverovskae* (oligocen dolny niższy) z: *T. liverovskae*, *Globigerina praebulloides*, *G. officinalis*, *Subbotina vialovi*, *S. droogeri*, *Parasubbotina karpatica*, *Chiloguembelina gracillima*.

21 – Poziom *Tenuitella munda* (oligocen dolny wyższy–oligocen górny niższy) z: *T. munda*, *Tenuitellinata ciperoensis*, *T. postcretacea*, *Paragloborotalia nana*, *Caucasina schiskinskyae*.

22 – Poziom *Paragloborotalia inaequiconica* (oligocen górny wyższy–dolny burdygał) z: *P. inaequiconica*, *Cassigerinella chipolensis*, *Tenuitella brevispira*, a w górnej części z: *Chiloguembelitria samwelli*, *Paragloborotalia semivera*, *Tenuitellinata pseudoedita*, *Globoturborotalita woodi*, *Globigerinoides primordius*, *Caucasina tenebricosa*, *Ammonia beccarii*.

23 – Poziom *Globoquadrina dehiscens – Globigerinoides trilobus* (burdygał górny) z: *G. dehiscens*, *G. baroemoenensis*, *G. trilobus*, *Paragloborotalia siakensis*, *Tenuitellinata pseudoedita*.

Zespół powyższy jest najmłodszym zespołem otwornicowym napotkanym w utworach fliszowych Karpat polskich. Nie stwierdzono jak dotąd gatunków otwornic wskazujących jednoznacznie na kontynuowanie sedymentacji fliszu w miocenie środkowym, mimo że występujące w końcowej części sukcesji fliszowej gatunki wapiennego nannoplanktonu (Ślęzak *et al.*, 1995) zdają się wskazywać na taką możliwość.