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LATE CRETACEOUS FORAMINIFERIDS FROM SECTIONS IN THE ZABRATÓWKA AREA (SKOLE NAPPE, OUTER CARPATHIANS, POLAND)

Oliwia KOWALCZEWSKA & M. Adam GASIŃSKI

Jagiellonian University, Institute of Geological Sciences, Gronostajowa St. 3a, 30-387 Kraków, Poland; e-mails: oliwia.kowalczewska@doctoral.uj.edu.pl, adam.gasinski@uj.edu.pl

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Abstract: Well preserved Late Cretaceous–Palaeogene planktonic and benthic foraminiferal assemblages were studied in the Zabratówka section of the Ropianka Formation in the Skole Nappe. The *Racemiguembelina fructicosa* and *Abathomphalus mayaroensis* standard foraminiferal biozones were distinguished. The K-T boundary was recognized within the interval between samples ZB10B–ZB9A, mainly composed of marly mudstones, interlayered with thin-bedded sandstones, and is characterized by the disappearance of planktonic taxa and an abundance of agglutinated species. Foraminiferal assemblages, collected from the turbiditic flysch-type sediments, indicate a primary depositional environment on the outer shelf to the upper part of the continental slope, with shallowing during the Maastrichtian in the part of the Skole Basin studied. The foraminiferids correspond to the assemblages of a palaeobiogeographical “transition” zone, located between the Boreal and Tethyan domains.

Key words: Foraminiferids, palaeobathymetry, Late Cretaceous, Maastrichtian, Skole Nappe, Ropianka Formation, Outer Carpathians.

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INTRODUCTION

The first biostratigraphical observations on the Ropianka Formation in the Skole Nappe are known from the 19th century. However, the scientists of previous centuries focused their attention on macrofossils and agglutinated foraminifera. Hilber (in Uhlig, 1888) and Grzybowski (1903) dated these sediments on the basis of *Inoceramus* sp. Friedberg (1901, 1903, 1908) was able to identify *Inoceramus salisburgensis* Fugger and Kastner in an outcrop located in the village of Chmielnik and the agglutinated foraminiferids *Dendrophrya excelsa* Grzybowski, *Dendrophrya robusta* Grzybowski and *Dendrophrya robusta* Grzybowski var. *maxima* Friedberg in an outcrop at the village of Albigowa.

From recent biostratigraphical studies based on foraminiferids, presented by Gasiński and Uchman (2009, 2011) and additional studies based on diatoms (Gasiński *et al*., 2013), it became clear that the Late Cretaceous sediments of the Skole Nappe are rich in planktonic foraminiferal index taxa, rarely found in the Polish Outer Carpathians. The latest studies by Kędzierski *et al.* (2015) indicated a discrepancy between the nannoplankton and foraminiferal biozonations. Therefore, biostratigraphical studies were undertaken regarding a newly discovered section in the Cretaceous part of the Skole Nappe (Gasiński and Uchman, 2009, 2011). The studies focus on the youngest Cretaceous index taxa *Abathomphalus mayaroensis* (Bolli), *Racemiguembelina fructicosa* (Egger) and other Late Cretaceous planktonic species. Planktonic foraminiferids, unlike the benthic agglutinated taxa, which are the most common in the Polish Flysch Carpathians, provide better stratigraphic resolution and are more useful for the determination of the K-T boundary in the sediments.

One of the most important achievements was related to the documentation of the *Abathomphalus mayaroensis* and *Racemiguembelina fructicosa* zones, which are rarely recognized in the Polish Carpathians (Gasiński and Uchman, 2009, 2011; Kędzierski *et al*., 2015).

GEOLOGICAL SETTING

The study area is located in the Skole Nappe of the Polish Outer Carpathians (Figs 1, 2). Numerous sole markings formed by palaeocurrents (Książkiewicz, 1962) indicate that the material accumulating in the Skole Nappe was derived mainly from the NW margin of the basin, called the Northern Cordillera or the Marginal Cordillera (Książkiewicz, 1962; Bromowicz 1974; Salata and Uchman, 2013;

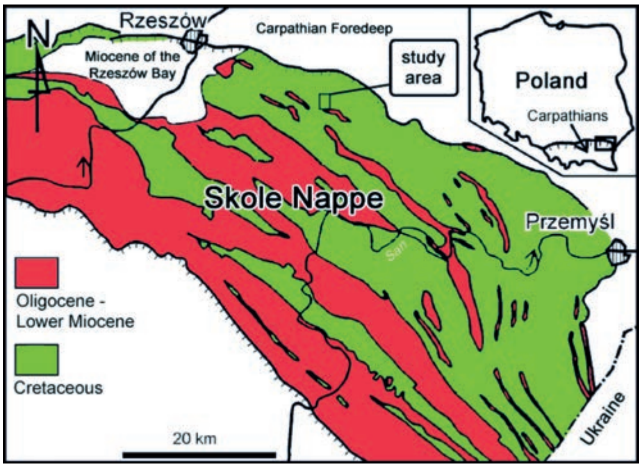

Fig. 1. Location of the study area in the Skole Nappe, modified after Gasiński and Uchman (2009) and references therein.

Łapcik, 2018). During the Miocene, the sediments were folded and thrust to the north.

The sediments of the Ropianka Formation (Inoceramian Beds; Kotlarczyk, 1978) are the main subject of the studies carried out. The history of geological research on the Ropianka Formation in the study area began at the end of the 19th century with the work of Tietze (1883), who described the so-called Ropianka beds near the village of Albigowa to the north and determined their age as "older Tertiary". Hilber (1885) studied the sediments in the vicinity of Rzeszów and Łańcut and considered the beds to be Neocomian in age. Also Grzybowski (1899) recognized the Ropianka-type deposits in the stream at Zabratówka. Friedberg (1900) noted the occurrence of these beds at Husów and Albigowa. The tectonics and further characteristics of these rocks were described by Wdowiarz (1936, 1949). They were formalized as the Ropianka Formation by Kotlarczyk (1978). He divided the formation into the oldest Cisowa Member

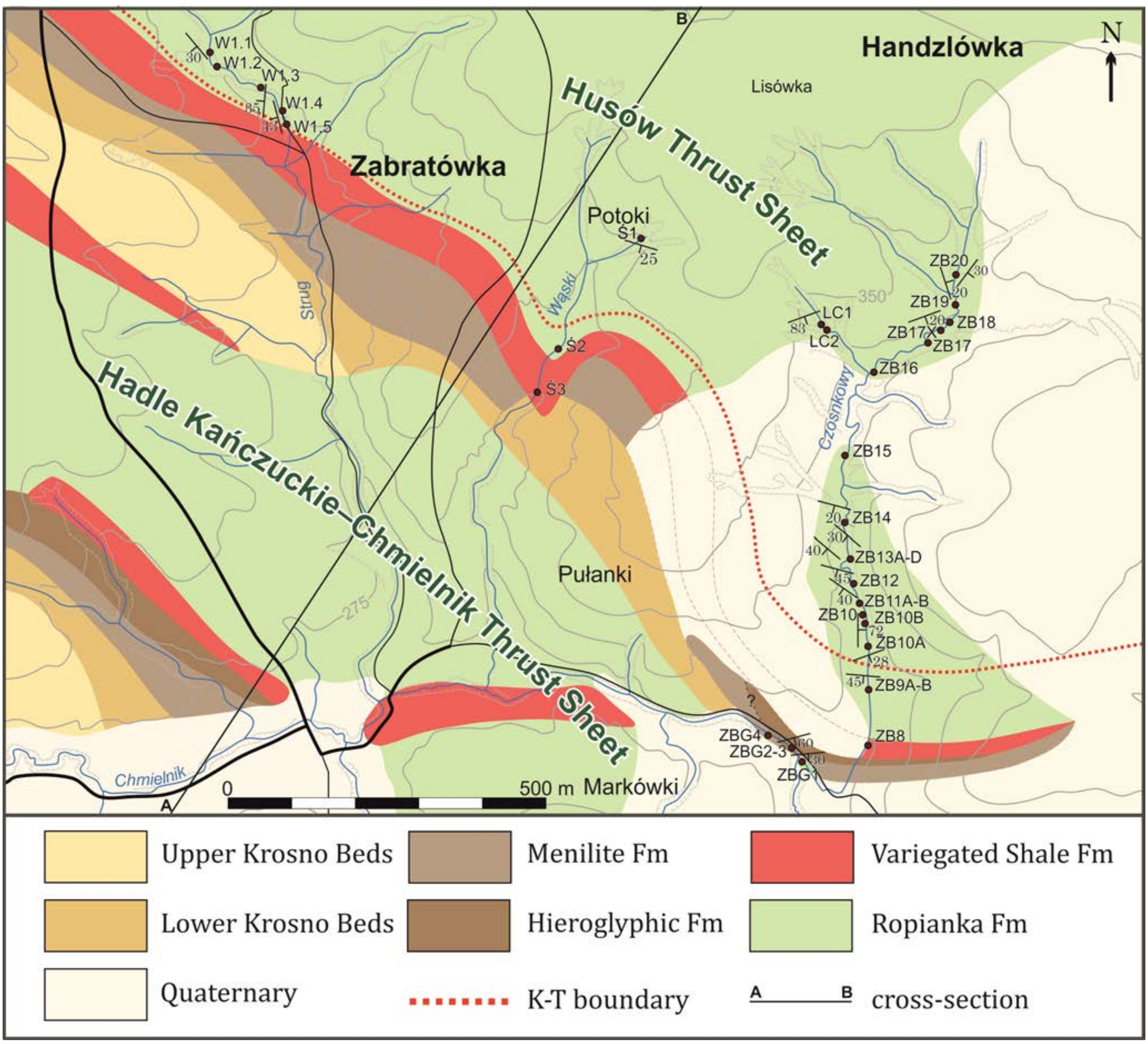

Fig. 2. Map of the study area after Wyczawska (1980), simplified. Lithostratigraphical division after Wdowiarz (1949), modified. Location of the samples indicated.

(Turonian–lower Campanian), the Wiar Member (lower Campanian–lower Maastrichtian), the Leszczyny Member (lower Maastrichtian–lower Paleocene) and the Wola Korzeniecka Member (Paleocene; Fig. 3).

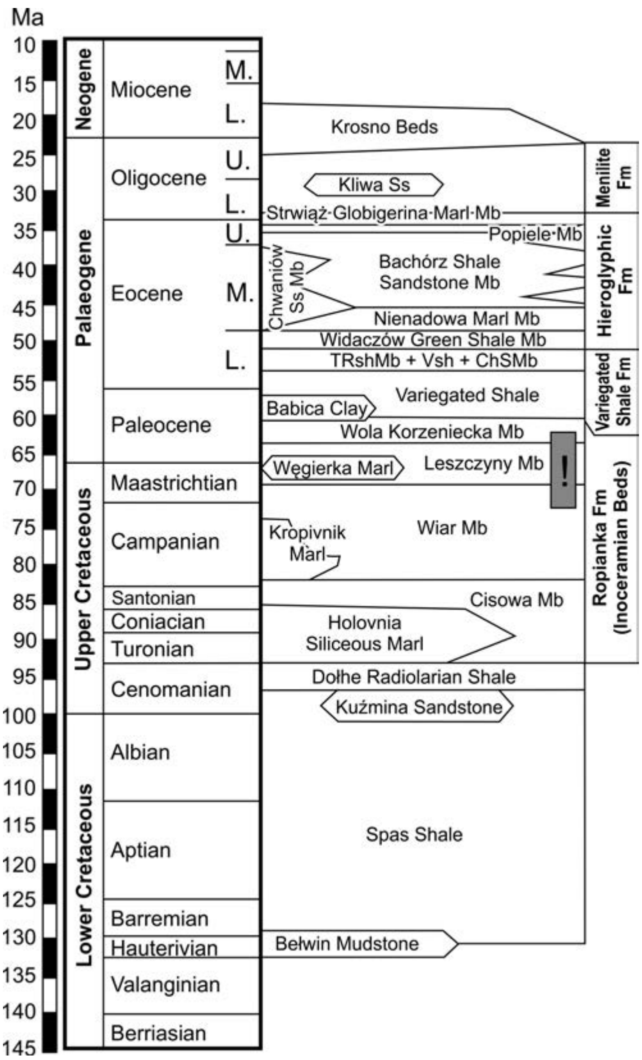

Fig. 3. Stratigraphy of the Skole Nappe, after Gasiński and Uchman (2009, 2011) and references therein, modified. Time scale after Cohen *et al*. (2013; updated). TRShMb – Trójca Red Shale Member, VSh – Variegated Shale, ChSMb – Chmielnik Striped Sandstone Member. Interval studied is marked by exclamation mark.

The complex sedimentology and petrography of the Ropianka Formation were described by Bromowicz (1974, 1986), who also estimated its total thickness as being 400 m. Malata (2001) proposed the subdivision of the Ropianka Formation (as the Rybotycze Formation) into the Fucoid Marl Member (Campanian–lower Maastrichtian) and the Leszczyny Sandstone Member (Maastrichtian), with the Makówka Slump Debris (upper Maastrichtian) occurring above or within it.

The sediments studied are composed of alternating fine- to medium-grained sandstones and marls or marly shales, usually grey or beige in colour. Occasionally, non-marly shales, conglomerates, mudstone clasts in the sandstones and intraclasts of coal are present. In the upper part of the Ropianka Formation, in the Czosnkowy Stream section (Fig. 4), the deposits of a submarine landslide were observed. In the upper part of the Czosnkowy section, the sediments are represented by sandstones and marls in similar proportions. Downward in the section, very fine, marly siltstones interlayered with thin beds of sandstones and marls become more frequent. In the lowermost part of the section, thin-bedded turbidites are present. These deposits have been correlated with the upper part of the Ropianka Formation, i.e., the Wola Korzeniecka Member, the Leszczyny Member and perhaps the upper part of the Wiar Member (Kotlarczyk, 1978).

LOCATION OF THE STUDY AREA

The sections studied are located along three streams at the village of Zabratówka, about 15 km southeast of Rzeszów (Fig. 2). Two of them are located in the village and the third with a few tributaries is located in the forest, between the villages of Zabratówka and Husów. Outcrops are small and isolated with mostly consequent strikes and similar dips indicating a monoclinal structure (Fig. 5) that is part of the larger, more complex structures, known as the Husów Thrust Sheet and Hadle Kańczuckie-Chmielnik Thrust Sheet (Wdowiarz, 1949), or according to Malata (2001), forming part of Zabratówka Syncline.

METHODS

Thirty-seven samples were collected in the field and analyzed. Each sample weighed not less than 400 g and was collected from the marls that most likely represent the last part of the turbiditic sequence. The parameters of the beds, such as strikes and dips, were measured along with the GPS coordinates of the outcrops. Micropalaeontological material was prepared in the laboratory using the conventional method of disintegration (heating and freezing in Glauber's salt), followed by sieving through a set of sieves. Within the relatively rich samples, 300 specimens of foraminiferids were picked and mounted on slides. Reflected light photographs as well as SEM-micrographs of the specimens were taken. The results of the analysis are presented in Figs 6–10, together with quantitative data. The samples and the foraminiferids collection are housed at the Department of Palaeozoology of the Institute of Geological Sciences, Jagiellonian University.

MICROPALAEONTOLOGICAL ANALYSIS AND BIOSTRATIGRAPHICAL EVALUATION

The most common species among agglutinated taxa (Figs 11, 13) include *Ammodiscus* sp., *Trochamminoides* sp. and *Karrerulina* sp. Less numerous, but common, are *Nothia* sp., *Kalamopsis grzybowskii* (Dylążanka), *Caudammina ovula* (Grzybowski) and *Spiroplectinella dentata* (Reuss). Less numerous are *Hormosina velascoensis* Cush-

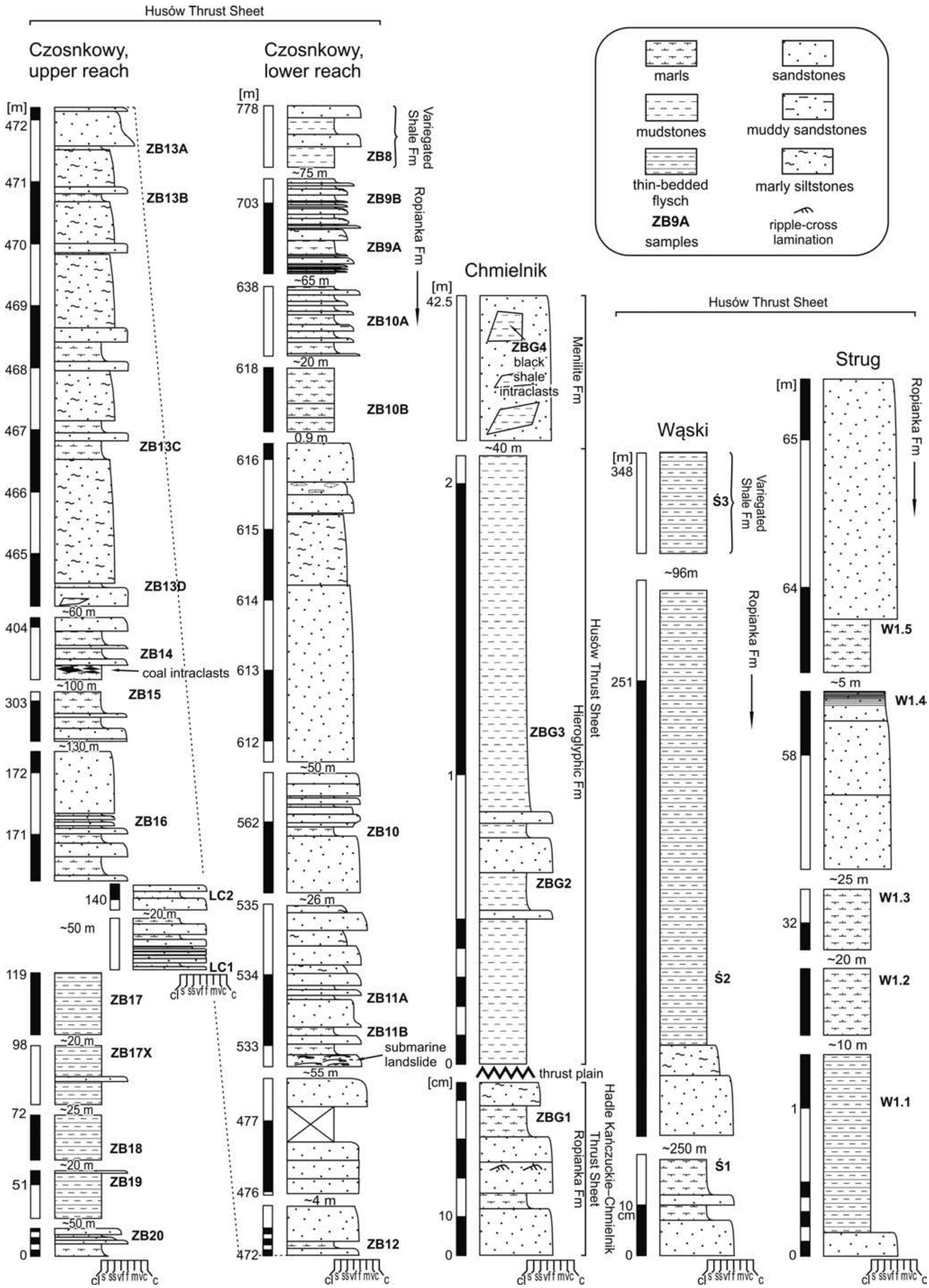

Fig. 4. Lithological columns with locations of the samples.

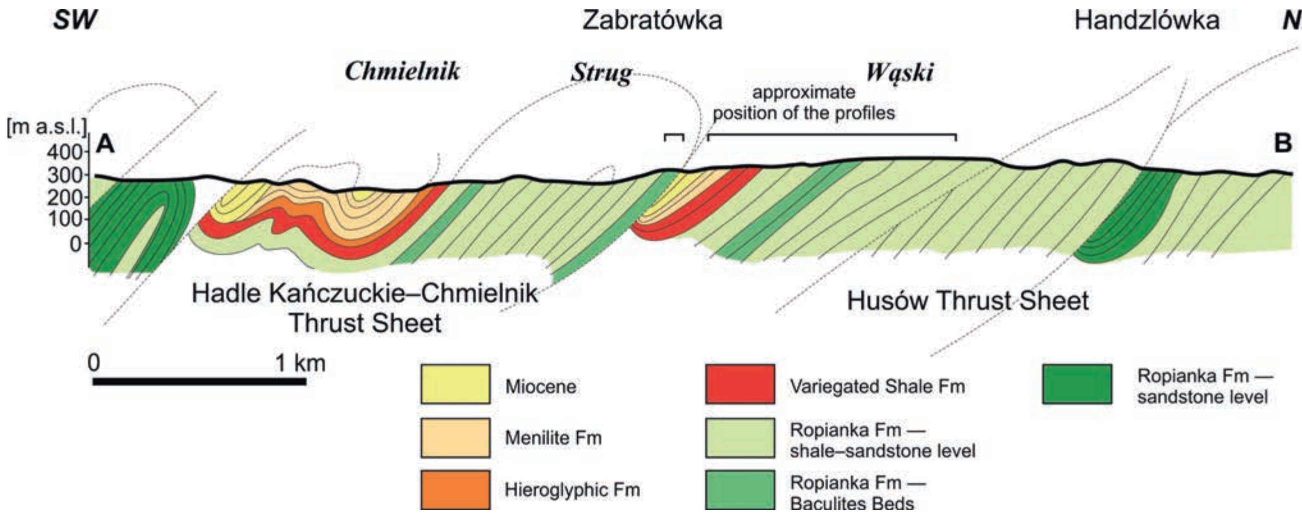

Fig. 5. Geological cross-section of the study area, see Figure 2 for location (modified after Wdowiarz, 1949).

man, *Saccammina* sp., *Glomospira* sp., *Rzehakina inclusa* (Grzybowski), *Rzehakina epigona* (Rzehak), *Rzehakina fissistomata* (Grzybowski), *Spiroplectammina* cf. *lanceolata* (Huss), *Arenobulimina preslii* (Reuss) and *Recurvoides* sp. *Caudammina gigantea* (Geroch), *Reophax* sp. and *Marssonella oxycona* (Reuss) (ZBG1) occur sporadically.

Most of benthic calcareous taxa (Figs 11–13) are represented by *Lenticulina* sp., *Cibicides* sp., *Anomalina* sp., *Nodosaria* sp. and *Pullenia* sp. *Gavelinella* sp., *Osangularia* sp., *Dentalina* sp., *Cibicidoides* sp., *Guttulina* sp. and *Oolina* sp. are rarer. *Nonion* sp., *Lingulogavelinella* sp. and *Marginulina* sp. are less numerous. *Quadrimorphina allomorphinoides* (Reuss) (W1.5), *Bolivinoides draco* (Marsson) (ZB10B; Figs 11, 13) as well as *Stensioeina* sp. (ZB11, Fig. 11) were found only in the samples mentioned here.

Non-keeled planktonic foraminifera (Figs 12, 13) are dominated by heteroheliciids, i.e., *Heterohelix striata* (Ehrenberg), *Heterohelix navarroensis* Loeblich and *Heterohelix globulosa* (Ehrenberg) and occur in every sample that contains planktonic foraminiferids. *Archaeoglobigerina* sp. and *Racemiguembelina fructicosa* (Egger) are also present. *Hedbergella* sp. and *Globigerinelloides* sp. are less numerous. Keeled taxa (Figs 12, 13) are less numerous and represented mainly by *Globotruncana* sp., *Globotruncanita* sp. and *Contusotruncana* sp. In samples ZB10B, ZB11A, W1.1, W1.2 and W1.5, *Abathomphalus* cf. *mayaroensis*. (Figs 12N–Q, 13R–T) was found.

Samples from the Czosnkowy Stream are diverse. Samples from the lower reach of the stream (ZB7–ZB9B) as well as samples ZB11B and ZB20 contain only agglutinated taxa. Sample ZB10A does not contain agglutinated forms. Additionally, in this sample, planktonic foraminiferids of *Heterohelix* sp. were noted. In samples ZB10B, ZB11A and ZB12, relatively abundant keeled taxa were observed. In samples ZB10A–ZB19, poor foraminiferal assemblages were noted and in sample ZB20 only few agglutinated specimens were found. In samples LC1 and LC2, collected from a small tributary of the Czosnkowy Stream, an agglutinated fauna is present, along with *Lenticulina* sp. In LC1, *Caudammina gigantea* (Geroch) is dominant. In the Chmielnik Stream, agglutinated foraminifera predominate. Only in sample ZBG1 planktonic species are present. In samples from the Wąski Stream, agglutinated taxa predominate. The exception is sample Ś1, containing only *Heterohelix* sp. and *Cibicides* sp. The best preserved, mixed assemblages were found in the samples from the Strug Stream. For sample W1.1, where planktonic taxa are predominant; agglutinated forms are absent.

The age of the sediments studied was determined on the basis of the foraminiferal assemblages. Ten planktonic index taxa were identified. The biostratigraphical ranges of the taxa studied, plotted with the standard planktonic foraminiferal biozones, are presented in Fig. 14.

Two planktonic foraminiferal biozones were distinguished in the section studied, i.e. the *Racemiguembelina fructicosa* and the *Abathomphalus mayaroensis* zones. Owing to the lack of K/T survivors (e.g., *Guembelitria cretacea* Cushman; Gasiński and Uchman, 2009, 2011) and because of redeposition in the upper part of the section, it is impossible to delineate the position of the Cretaceous–Palaeogene boundary. However, the difference between samples ZB10B and ZB9A (and younger ones) is clearly visible. Samples ZB9A to ZB8 contain agglutinated forms only and may represent the Palaeogene. They also indicate somewhat different environmental conditions. Following the lithostratigraphy of the Ropianka Formation, the Cretaceous–Palaeogene boundary is located within the Leszczyny Member.

REMARKS ON PALAEOECOLOGY

On the basis of micropalaeontological analysis, it is possible to identify the environmental conditions present in the Skole Basin during the time interval considered, although it is important to note that the sediments studied were redeposited.

In most of the samples collected, agglutinated forms are more frequent than calcareous, benthic or planktonic foraminifera. Most samples contain only agglutinated taxa. This may be related to the high input of terrigenous material

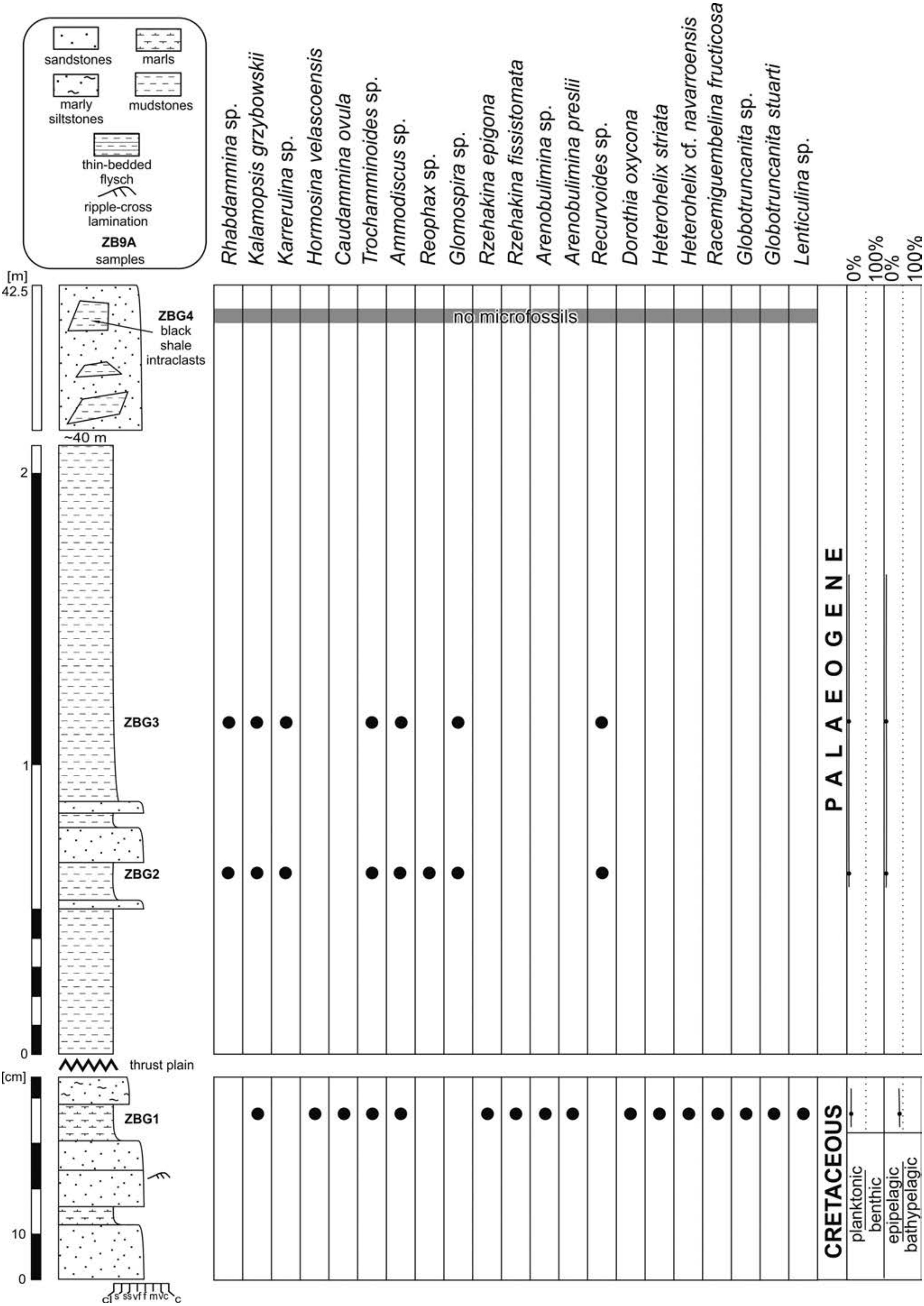

Fig. 6. Species occurrence, standard foraminiferal biozonation and quantitative analysis of foraminiferal assemblages of the samples studied from the Chmielnik Stream.

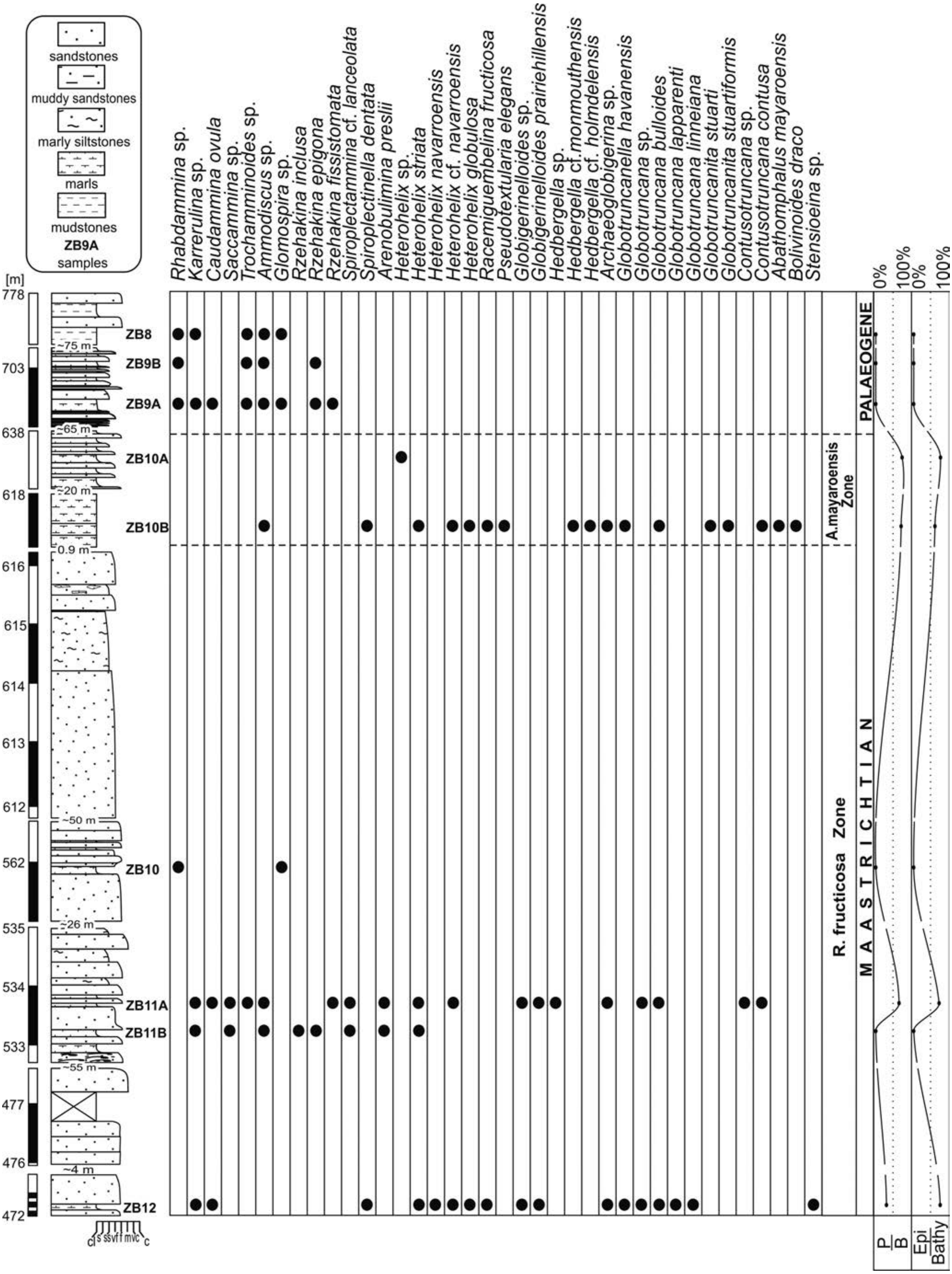

Fig. 7. Species occurrence, standard foraminiferal biozonation and quantitative analysis of foraminiferal assemblages of the samples studied from the lower reach of the Czosnkowy Stream.

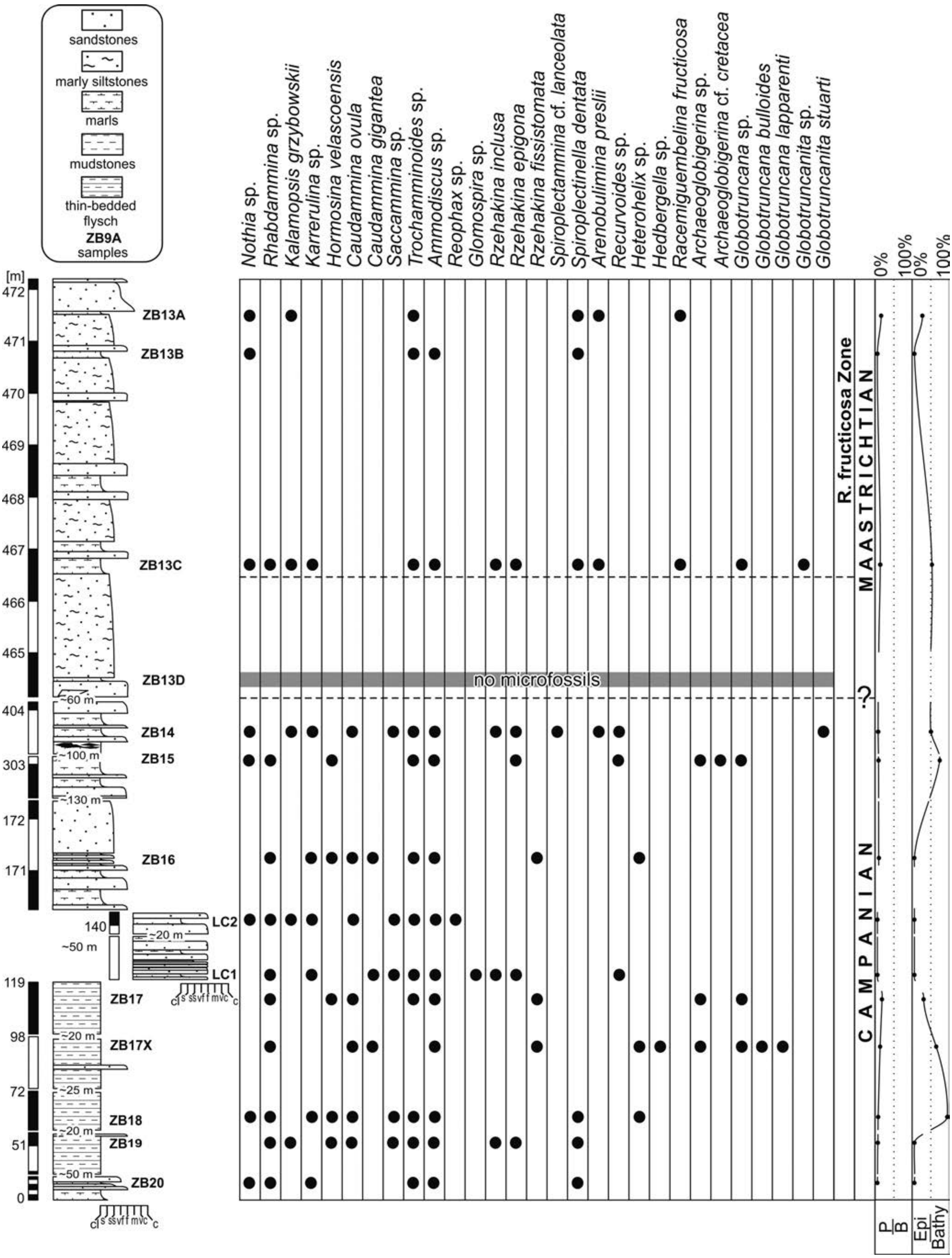

Fig. 8. Species occurrence, standard foraminiferal biozonation and quantitative analysis of foraminiferal assemblages of the samples studied from the upper reach of the Czosnkowy Stream.

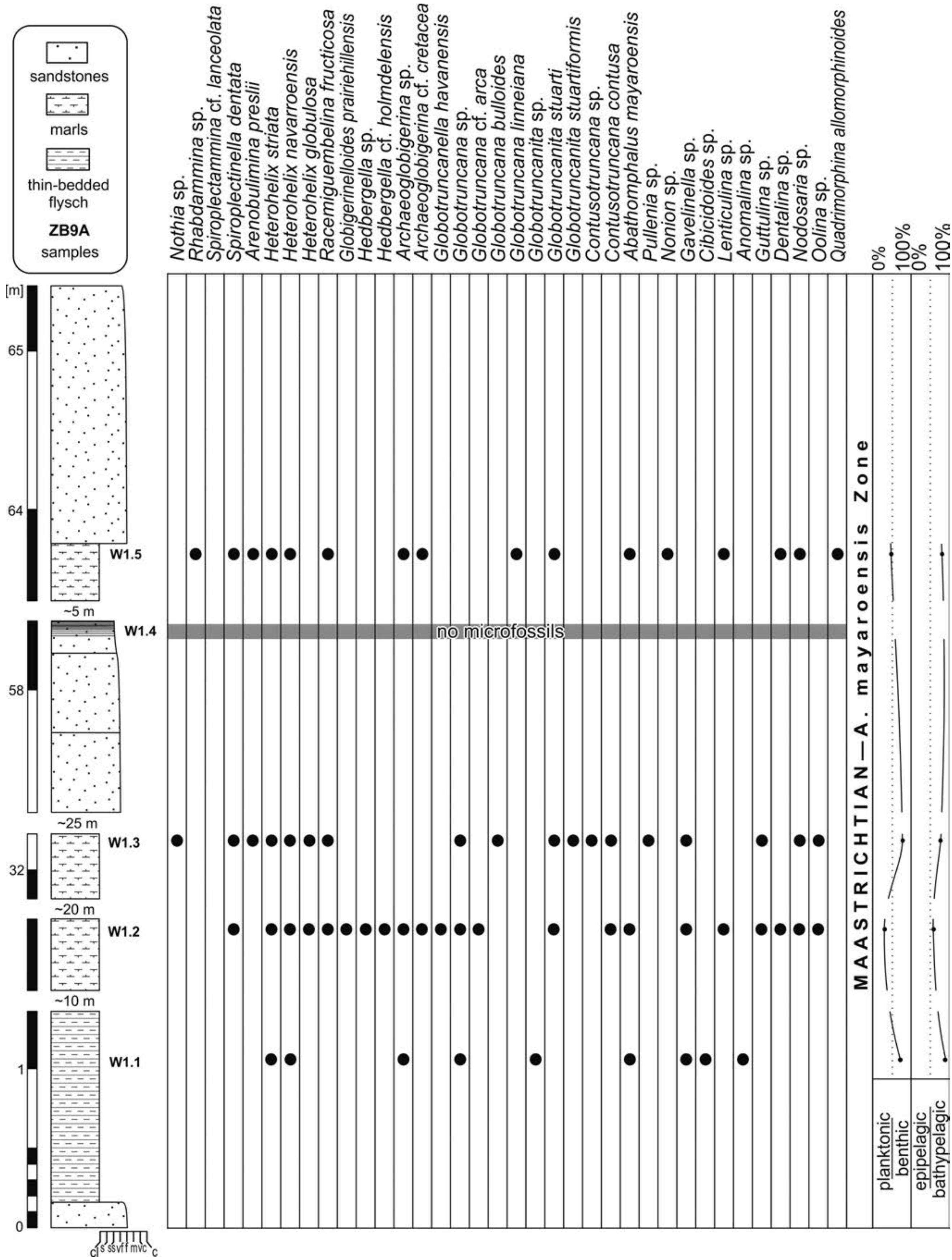

Fig. 9. Species occurrence, standard foraminiferal biozonation and quantitative analysis of foraminiferal assemblages of the samples studied from the Strug Stream.

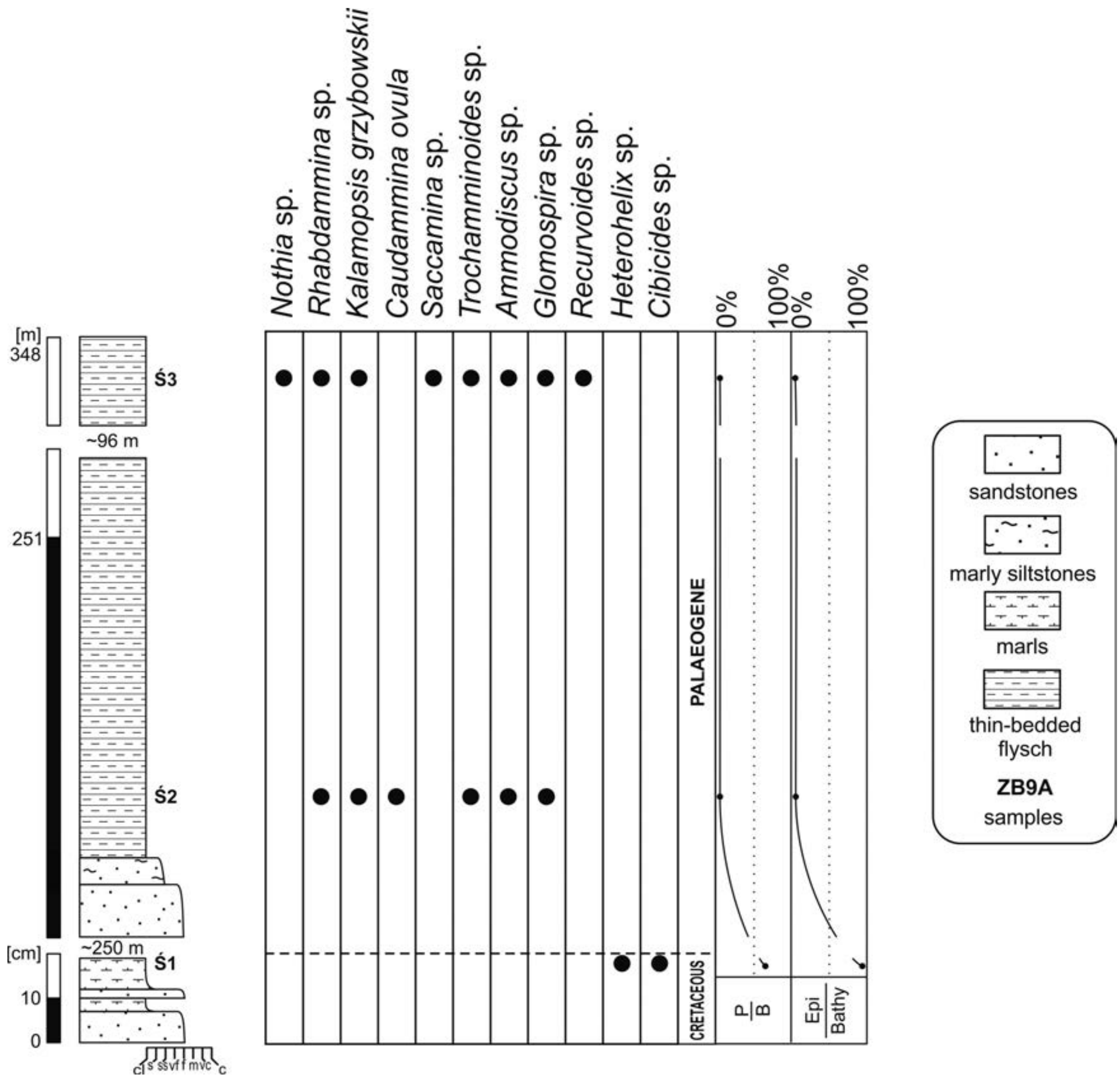

Fig. 10. Species occurrence, standard foraminiferal biozonation and quantitative analysis of foraminiferal assemblages of the samples studied from the Wąski Stream.

as well as to an environment preferred by agglutinated taxa, located at a depth close to the calcite compensation depth (CCD). Assemblages with few planktonic forms and with abundant agglutinated taxa may indicate depths close to the CCD, whereas the high abundance of planktonic foraminiferids may reflect depths above the foraminiferal lysocline. Keeled, bathypelagic forms, such as *Globotruncana* sp. or *Globotruncanita* sp., prefer depths corresponding to the deeper part of continental slope. Their reduced numbers in the assemblages and the dominance of epipelagic, non-keeled forms, indicate shallower parts of the basin, i.e., a shelf environment (Gasiński, 1997).

Comparing the ratio of epipelagic/bathypelagic foraminifera (Figs 6–10), fluctuations in sea level may be interpreted. In the section studied, one level dominated by planktonic forms is visible (Figs 9, 11; samples ZB11A––ZB10B, W1.1–W1.5). It is possible that during the time interval considered, the environmental and life conditions were more favourable for the biota analyzed. On the basis of the gradual changes in the foraminiferal assemblages analyzed, it can be assumed that during the Late Cretaceous a shallowing of the Skole Basin took place. A deterioration of the foraminiferal assemblages analyzed both in quantity and quality downward can be observed within the profile.

It must be taken into consideration that the sediments studied were redeposited as a turbiditic sequence, so any palaeobathymetric determinations based on the composition of foraminiferal assemblages are related to their primary, sedimentological environment. It also should be noted that the specimens are relatively well preserved and not broken or fragmented.

According to Marcinowski and Gasiński (2002) and Gasiński and Uchman (2011), the assemblages studied are characteristic for a transition zone that existed during the mid-Cretaceous and was located between the Boreal and Tethyan provinces. In addition to planktonic taxa, benthic taxa typical of a transitional biogeoprovince, rarely present in the Tethyan Domain, were found, i.e., *Bolivinoides draco* (Marsson) in sample ZB10B and *Stensioeina* sp. in sample ZB12 (Fig. 9). These species are dominant in Boreal assemblages. Therefore, their presence indicates the proximity of the Boreal Province (Gasiński, 1997).

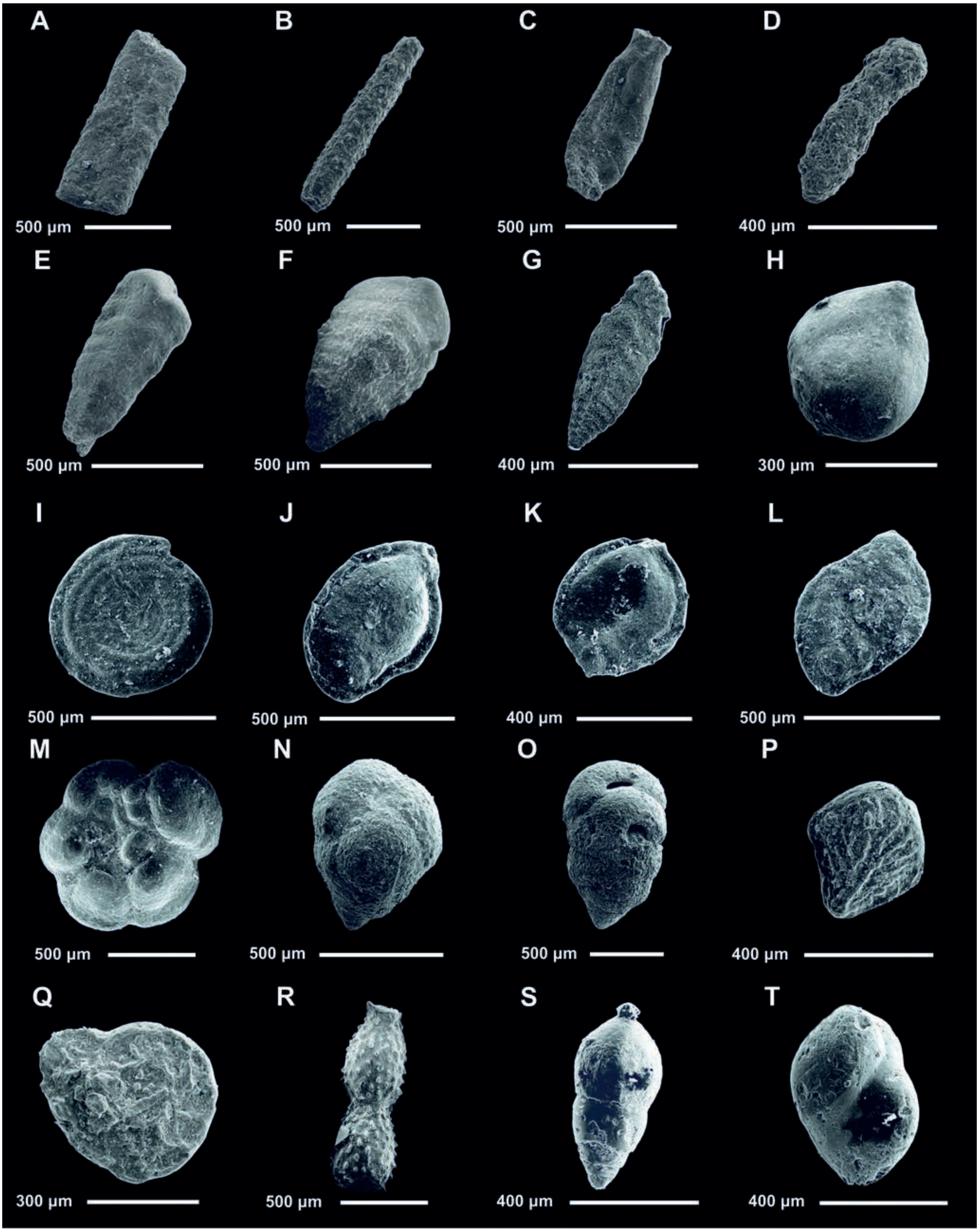

Fig. 11. SEM images of benthic foraminifera. **A.** *Nothia* sp., sample ZB13A. **B.** *Rhabdammina* sp., ZB17. **C.** *Kalamopsis grzybowskii* (Dylążanka), ZB13C. **D.** *Karrerulina* sp., ZB17X. **E, F.** *Spiroplectinella dentata* (Reuss), W1.2. **G.** *Spiroplectammina* cf. *lanceolata* (Huss), ZB15. **H.** *Caudammina ovula* (Grzybowski), ZB17X. **I.** *Ammodiscus* sp., ZB17. **J, K.** *Rzehakina epigona* (Rzehak), ZB15. **L.** *Rzehakina fissistomata* (Grzybowski), ZB13C. **M.** *Trochamminoides* sp., ZB17. **N.** *Arenobulimina preslii* (Reuss), ZB13C. **O.** *Bulimina* sp., ZBG1. **P.** *Bolivinoides draco* (Marsson), ZB10B. **Q.** *Stensioeina* sp., ZB12. **R.** *Nodosaria* sp., W1.2. **S.** *Oolina* sp., W1.2. **T.** *Guttulina* sp., W1.2.

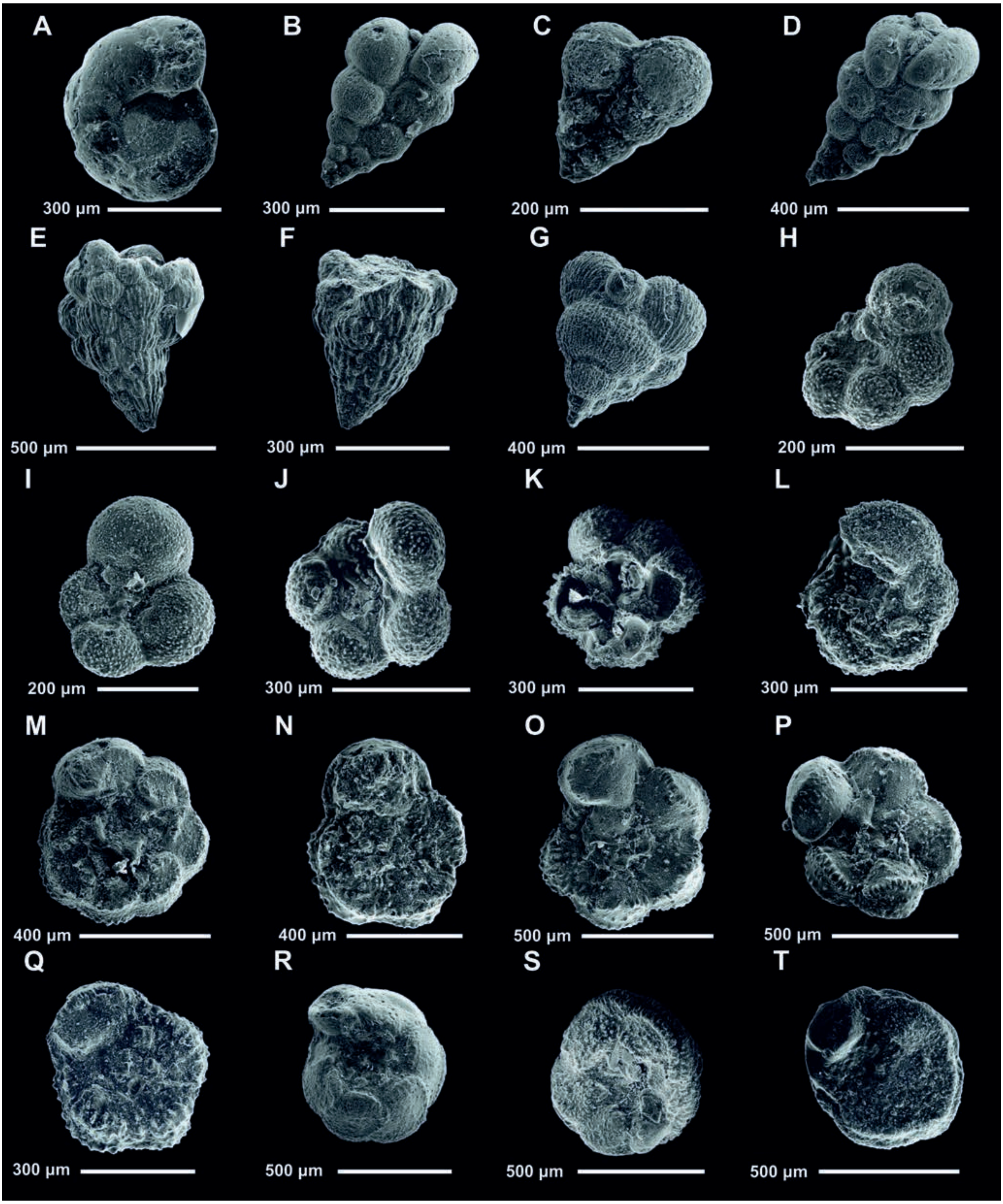

Fig. 12. SEM images of planktonic and benthic foraminifera. **A.** *Anomalinoides* sp., W1.5. **B, C.** *Heterohelix striata* (Ehrenberg); B – W1.2, C – ZB11A. **D.** *Heterohelix globulosa* (Ehrenberg), ZB10B. **E, F.** *Racemiguembelina fructicosa* (Egger); E – W1.2, F – W1.5. G. *Pseudotextularia elegans* (Rzehak), ZB10B. **H.** *Globigerinelloides prairiehillensis* Pessagno, W1.2. **I.** *Hedbergella* cf. *holmdelensis* Olsson, W1.2. **J, K.** *Archaeoglobigerina* cf. *cretacea* d'Orbigny; J – W1.2, K – ZB15. **L.** *Globotruncana lapparenti* Brotzen, ZB17X. **M.** *Globotruncana linneiana* d'Orbigny, W1.5. **N–Q.** *Abathomphalus mayaroensis* (Bolli); N – W1.1, O, P – W1.2, Q – ZB10B. **R.** *Globotruncanita stuarti* (de Lapparent), ZB12. **S, T.** *Contusotruncana contusa* (Cushman); S – W1.2, T – ZB11A.

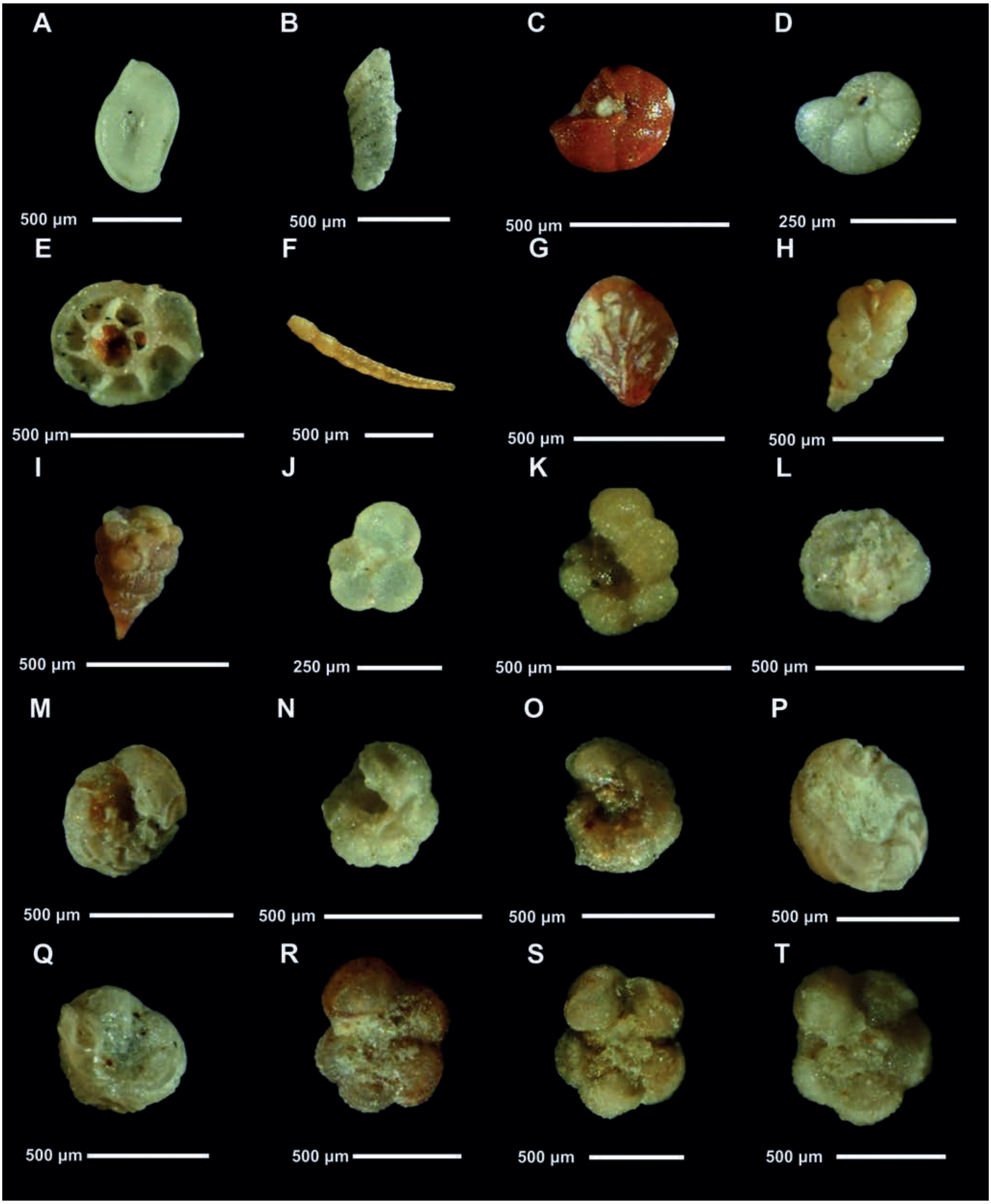

Fig. 13. Reflected-light photographs of planktonic and benthic foraminifera. **A.** *Rzehakina epigona* (Rzehak), ZBG1. **B.** *Marginulina* sp., ZB12. **C.** *Pullenia* sp., ZB10B. **D.** *Anomalina* sp., ZB11A. **E.** *Lenticulina* sp., cross-section, ZBG1. **F.** *Dentalina* sp., ZB10B. **G.** *Bolivinoides draco* (Marsson), ZB10B. **H.** *Heterohelix globulosa* (Ehrenberg), ZB10B. **I.** *Racemiguembelina fructicosa* (Egger), ZB10B. **J.** *Hedbergella* cf. *holmdelensis* Olsson, W1.2. **K.** *Archaeoglobigerina* cf. *cretacea* d'Orbigny, W1.2. **L.** *Globotruncanita stuartiformis* (Dalbiez), W1.5. **M.** *Globotruncana* sp., W1.2. **N.** *Globotruncana bulloides* Vogler, ZB17X. **O.** *Globotruncana lapparenti* Brotzen, ZB17X. **P, Q.** *Contusotruncana contusa* (Cushman), ZB11A. **R–T.** *Abathomphalus mayaroensis* (Bolli); R – ZB10B, S, T – W1.2.

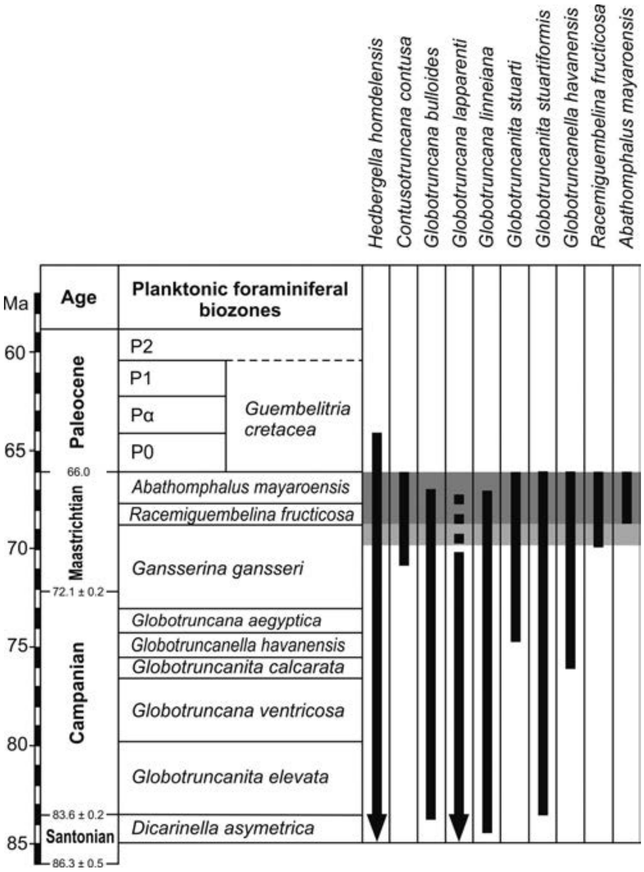

Fig. 14. Biostratigraphical ranges of the planktonic index taxa studied (modified after Gasiński and Uchman, 2009). Biozonation combined after Robaszynski *et al.* (1984), Caron (1985), Robaszynski and Caron (1995), Premoli-Silva and Rettori (2002) and Premoli-Silva and Verga (2004). Time scale after Cohen *et al.* (2013; updated). Biozones recognized in the samples studied are marked grey.

CONCLUSIONS

- The sediments studied belong to upper part of the Ropianka Formation and are of Maastrichtian–Paleocene age.
- Two planktonic foraminiferal biozones were distinguished, i.e., the *Racemiguembelina fructicosa* and *Abathomphalus mayaroensis* zones.
- The epipelagic/bathypelagic ratio estimated for the assemblages studied corresponds to the depth of the primary, sedimentological environment, located on an outer shelf/shallower part of a continental slope.
- The foraminiferal assemblages studied are typical for the transition zone between the Boreal and Tethyan domains.
- The K-T boundary is located approximately between samples ZB10B and ZB9A in the Czosnkowy Stream as well as above sample W1.5, collected from the Strug Stream section.

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