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The Cretaceous-Paleogene boundary in turbiditic deposits identified to the bed: a case study from the Skole Nappe (Outer Carpathians, southern Poland)

M. ADAM GASIŃSKI and ALFRED UCHMAN

Institute of Geological Sciences, Jagiellonian University, Oleandry Str. 2a, 30-063 Kraków, Poland;
adam.gasinski@uj.edu.pl; alfred.uchman@uj.edu.pl

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Abstract: The Cretaceous-Paleogene (K-T) boundary has been recognized in turbiditic sediments of the Ropianka Formation in the Skole Nappe (Bąkowiec section) on the basis of planktonic foraminiferids with an accuracy of 40 cm. Such precise determination of the K-T boundary for the first time in the Carpathians and in turbiditic flysch sediments in general was possible due to the successive occurrence of the Early Paleocene planktonic taxa of the P1 Zone above the latest Maastrichtian *Abathomphalus mayaroensis* Zone with the *Racemiguembelina fructicosa* Subzone. The trends in composition of the latest Maastrichtian foraminiferal assemblages are similar to the Gaj section from the adjacent thrust sheet, probably due to the influence of the same paleoenvironmental factors.

Key words: Paleocene, Maastrichtian, K-T boundary, Carpathians, paleoecology, biostratigraphy, turbidites, foraminiferids.

Introduction

The identification of the Cretaceous-Paleogene (K-T) boundary in turbiditic deposits is problematic, mostly because of the absence of index fossils, especially planktonic foraminifers, and because of redeposition processes disturbing the stratigraphic record. Only a few attempts can be found in the literature, where the boundary is determined within some portion of the section (Melinte 1999; Bubík et al. 2002; Chira et al. 2009). Gasiński & Uchman (2009) put the boundary within a 3 m thick interval of the Ropianka Formation (Upper Cretaceous–Paleocene) section in the Skole Nappe in the Polish Flysch Carpathians. The boundary was identified above the last occurrence of the planktonic Cretaceous foraminifers, including the index taxon *Abathomphalus mayaroensis*, and below the occurrence of benthic foraminifers typical of the Paleogene. As a result of new investigations in a better exposed section of the Ropianka Formation in the adjacent thrust sheet, not only the Cretaceous but also the Paleogene index planktonic foraminiferids have been found that enabled us to recognize the K-T boundary with the accuracy to two beds for the first time in these turbiditic deposits. Micropaleontological analysis of this section, and the K-T boundary in particular, are the main aim of this paper.

Geological setting

The Skole Nappe is the most external major nappe of the Polish Flysch Carpathians (Fig. 1A). It is composed of Lower Cretaceous–Miocene deep-sea, mostly flysch sediments that accumulated in the Skole Basin, a segment of the northern Neotethys, and were folded and thrust northward during the Miocene. The Upper Cretaceous–Paleocene sediments are distinguished as the Ropianka Formation, which was also named the Inoceramian Beds for a long time (Kotlarczyk 1978). They are overlain by the Eocene Variegated Shale Formation (Rajchel 1990). For the complex history of research on the Ropianka Formation in the Skole Nappe see Kotlarczyk (1978). SE of Rzeszów, Wdowiarz (1949) distinguished the lower, middle and upper levels in the Ropianka Formation (his Inoceramian Beds), which are altogether 500 m thick. Kotlarczyk (1978) subdivided the Ropianka Formation into the Cisowa Member (Turonian–Lower Campanian), Wiar Member (Lower Campanian–Lower Maastrichtian), Leszczyny Member (Lower Maastrichtian–Lower Paleocene) and Wola Korzeniecka Member (Paleocene). For further details see Gasiński & Uchman (2009) and references therein.

The lower part of the studied section (GPS coordinates: N49°59.040′; E022°14.910′; ±9 m) starts along an unnamed stream, a tributary of the Handzlowski Potok Stream (Sawa River in the lower part), the gorge of which is incised into the southern slope of the Patria Hill (426 m a.s.l.) along the border between the Husów and Handzlówka villages, and continues along the Handzlowski Potok Stream in the Bąkowiec forest on the territory of the Husów village (Fig. 1B). The outcrops are small and isolated (Figs. 1B, 2), but consequent strikes and dips of beds suggest a monoclinal structure forming a part of the Husów Thrust Sheet. The thrust sheet is disturbed by Variegated Shale occurring in a narrow stripe stretching along the Handzlowski Potok Stream (Wdowiarz 1949), which suggests an internal thrust.

Some tectonic reductions are possible here. Nevertheless, the outcrops have stratigraphic continuity.

The lower part of the section is composed of turbiditic medium, rarely thick or thin beds, which contain calcareous sandstones at the base and thick layers of grey and grey-bluish marls and marly siltstones to mudstones at the top (Fig. 2). In the middle part of the section, about 4 m thick debris flow deposits containing different marls, dark shale and sandstone clasts occur. Higher up, the contribution of thick sandstone and marly beds increases. Along the Handzlowski Potok Stream, where the upper part of the section is exposed, thin and medium beds prevail and marly layers are replaced by calcareous shales in the higher part of this interval. The K-T boundary was identified here in a natural scarp on the right side of the stream, in a 15 m thick interval, which is not tectonically disturbed (GPS coordinates: N49°58.706′; E022°14.879′; ±11 m). Isolated outcrops of red, non-calcareous shales, with intercalations of rare sandstones and green shales along the stream belong already to the Variegated Shale Formation. Down the stream, massive or indistinctly bedded calcareous mudstones occur. They probably belong to the Babica Clay (Paleocene), which is a unit within the Variegated Shale Formation, composed mostly of mud flow deposits (Kotlarczyk 1978; Rajchel 1990 and references therein).

The boundary interval (Fig. 3) includes two turbiditic-hemipelagic rhythms. The first rhythm is composed of a 15 cm-thick, fine-grained, grey sandstone with rusty colouration, which rests on a grey marlstone, displays a sharp base and a transition to greenish-grey marly mudstone at the top. The marly mudstone is 8.5 cm thick and displays rusty spots. The second rhythm contains very fine-grained, sharply based grey sandstone, 5.5–6 cm thick, which passes into a greenish-grey marlstone. The marlstone is 8–11 cm thick. It is overlain by a loaded, 3.5–7.5 cm thick, very fine-grained, laminated, grey sandstone passing into a greenish-grey mudstone.

Stratigraphically, the studied deposits are an equivalent of the Leszczyny Member and, in its lowest part, possibly of the uppermost part of the Wiar Member of the Ropianka Formation *sensu* Kotlarczyk (1978, 1988). The lithology of the Leszczyny Member is very variable and includes marl-rich olistostromes. It is not clear whether the Wiar Member or the Leszczyny Member can

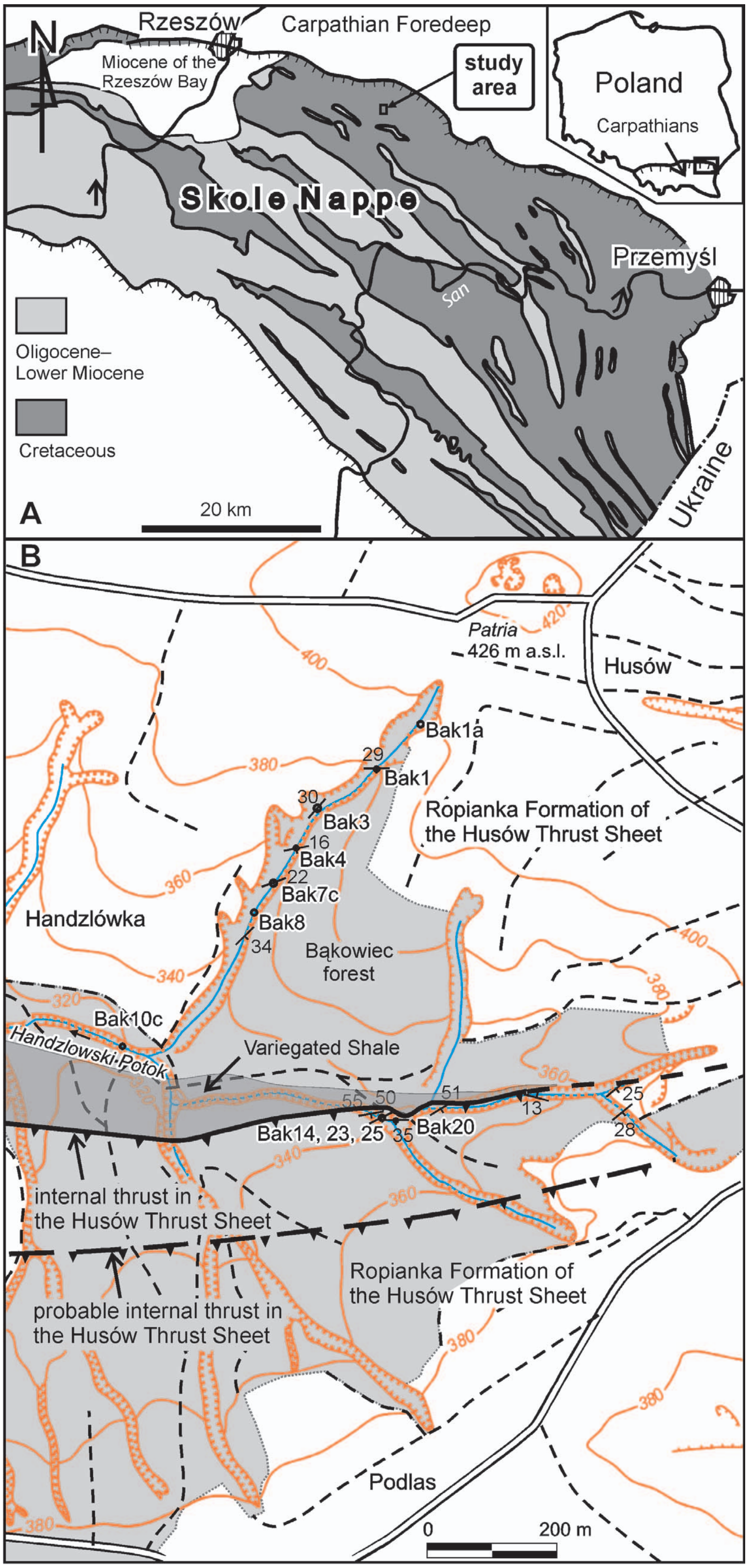

Fig. 1. Location map. **A** — Location of the study area in the Skole Nappe (simplified after Kotlarczyk 1988). **B** — Map of the study area. Tectonic unit designation and range of the Variegated Shale after Wdowiarz (1949), completed and modified. Location of samples (Bak 1, etc.) and orientation of beds indicated.

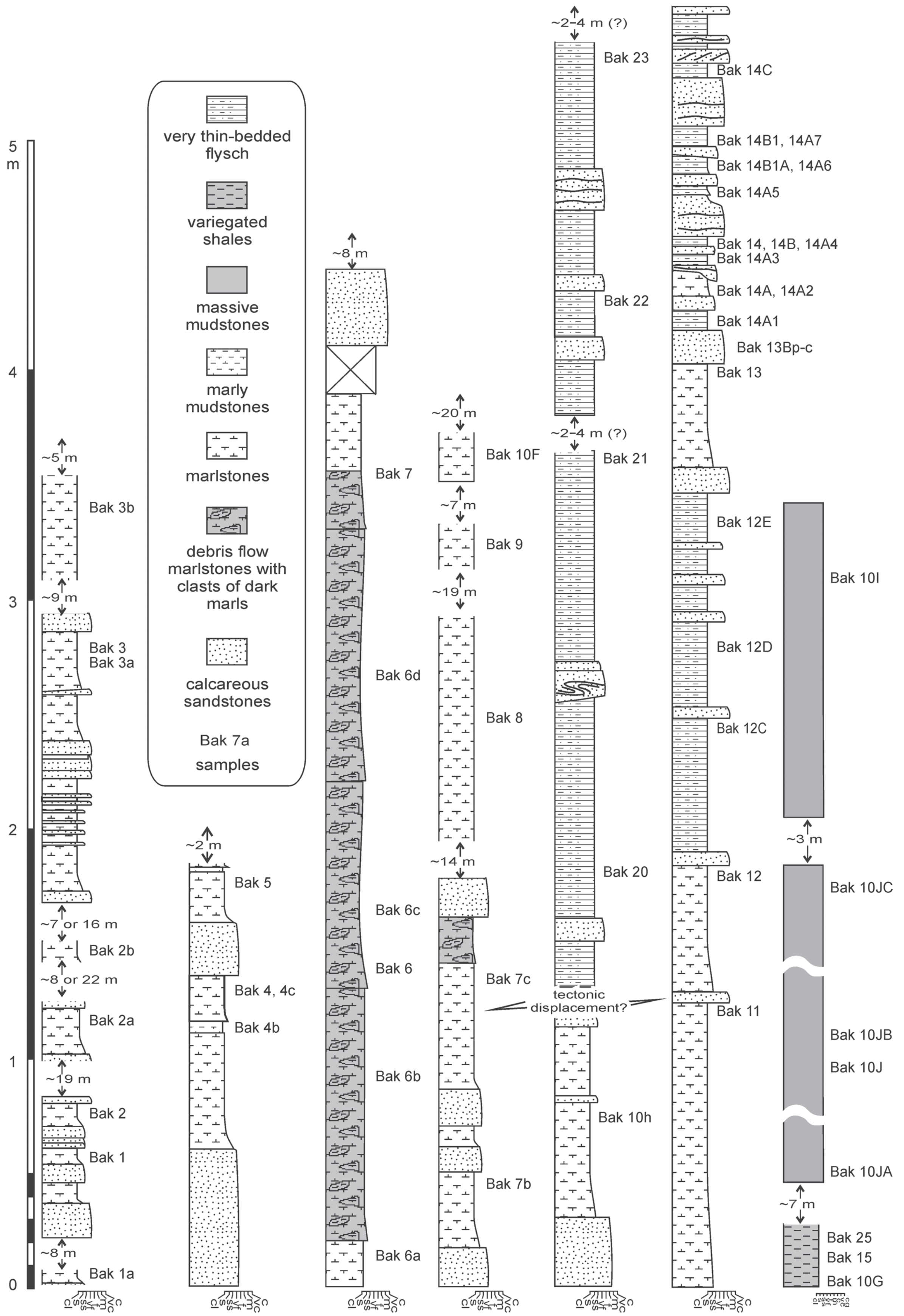

Fig. 2. Lithological columns with location of the samples.

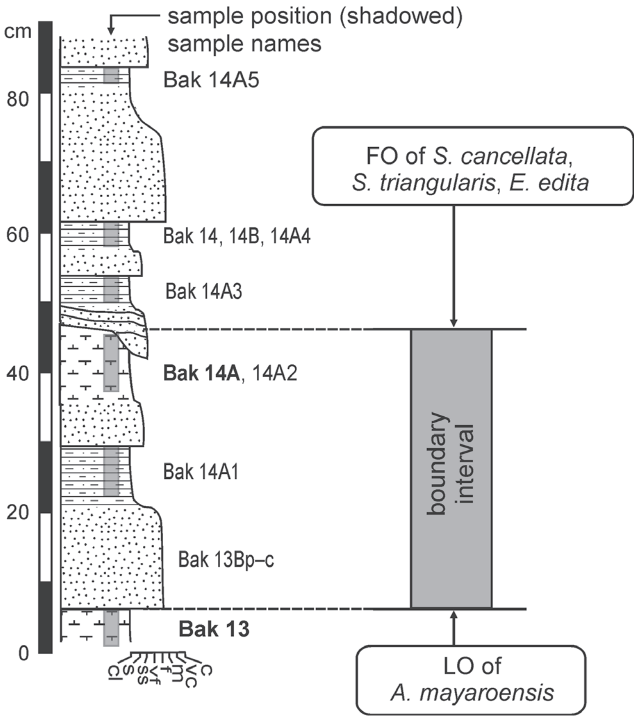

Fig. 3. Detail of the K-T boundary section, with indication of samples and the boundary interval. The key samples in bold.

be distinguished in the study area, however a general fining up section is one of the typical features of the Leszczyny Member (Kotlarczyk 1978) and these members are recognized west of the study area (J. Kotlarczyk, personal communication, 2008).

The K-T boundary in turbiditic sediments of the Carpathians

Globally, the Cretaceous-Paleocene (K-T) boundary is precisely located at the base of the so-called "boundary level", as defined mainly in pelagic and hemipelagic sequences (MacLeod & Keller 1996; Apellániz at al. 1997; Kaiho & Lamolda 1999; Arenillas et al. 2004; Keller 2004; Molina et al. 2006, and others). This boundary is situated between the *Abathomphalus mayaroensis* (latest Maastrichtian) and *Guembelitria cretacea* (earliest Paleocene) Biozones (Robaszynski & Caron 1995; Premoli-Silva et al. 2004, and others).

In turbiditic dominated sequences of the deep Alpine flysch basins, the K-T boundary is very difficult to identify due to the rare occurrence of index planktonic foraminiferids and strong redeposition causing the occurrence of mixed foraminiferal assemblages. Only in a few cases, the identification was narrowed to some relatively thin intervals. The boundary occurs within about a meter thick interval in the Magura Unit in Moravia, Czech Republic, based on dinocyst assemblages (Bubík et al. 2002). In the Romanian Carpathians, it was identified within tens of meters by means of the calcareous nannoplankton and foraminiferids (Melinte 1999; Chira et al. 2009).

The K-T boundary in the studied section

Recent studies of the Ropianka Formation of the Skole Unit in the Husów area (Gaj section), Polish Carpathians (Gasiński & Uchman 2009), based on 25 samples, allowed recognition of the latest Maastrichtian *Abathomphalus mayaroensis* standard Biozone and overlying Paleogene deposits. The K-T boundary has been narrowed to a 3 m thick interval, where the latest Cretaceous planktonic foraminiferids disappear and Paleogene benthic agglutinated foraminiferids (relatively long ranging species) appear. So far, it was the most precisely identified K-T boundary in the Polish Carpathians. More precise work in this section is limited due to its poor exposition.

In the better exposed Bąkowiec section, in the adjacent thrust sheet, 58 samples from the fine-grained parts of turbiditic-hemipelagic beds were analysed in our study. The majority of them contain relatively rich and well-preserved foraminiferal assemblages. They can also be seen in thin sections from the sandstone beds. Similarly to the Gaj section (Gasiński & Uchman 2009), the *Gansserina gansseri* and *Abathomphalus mayaroenesis* standard Biozones were recognized (Fig. 4). The intermediate *Racemiguembelina fructicosa* Zone is also distinguished, the meaning of which is discussed below.

Moreover, the appearance of the Paleocene foraminiferids *Subbotina cancellata* Blow (Fig. 5M), *Subbotina triangularis* (White) (Fig. 5N), *Eoglobigerina* cf. *edita* (Subbotina) (Fig. 5O) point to the earliest Paleocene zone (P1 Zone *sensu* Olsson et al. 1999) (Fig. 6). The latest Maastrichtian (*A. mayaroensis*) and the lowest Paleocene foraminifers occur within a 40 cm thick interval (Figs. 3, 7) limited to two depositional turbiditic-hemipelagic rhythms. Thus, this is the most precisely determined K-T boundary in turbiditic sediments.

From the base of the studied section, the *Gansserina gansseri* Zone (after Robaszynski & Caron 1995; Premoli-Silva et al. 2004) can be recognized. Planktonic foraminiferal assemblages contain the index species (Fig. 4). The first appearance (FO) of *Abathomphalus mayaroensis* (Bolli) is noted from the sample Bak 2a (Figs. 4, 8M,N) and it delineates the base of the *A. mayaroensis* Zone (Fig. 6). The FO of *Racemiguembelina fructicosa* Egger (Fig. 4R) in sample Bak 2a and its last occurrence (LO) in sample Bak 7 (Fig. 4) allowed us to recognize the *Racemigeumbelina fructicosa* Zone (Fig. 6), which is used by some authors (Gradstein et al. 2004) as the Partial Range Zone within the lower part of *A. mayaroensis* Zone. The LO of *A. mayaroensis* in sample Bak 13 below the FO of *Subbotina cancellata* Blow, *S. triangularis* (White) and *Eoglobigerina edita* (Subbotina) in sample Bak 14A (Fig. 7) has been interpreted as the latest Maastrichtian (*A. mayaroensis* Zone). The latter three taxa indicate the P1 Zone of the Early Paleocene (Olsson et al. 1999) (Fig. 6). It should be underlined that the K-T boundary is indentified within a sequence that is only 40 cm thick (Fig. 3). The rusty layer overlain by the dark boundary layer, known from pelagic and hemipelagic sections are not recognized here, but this can be explain by the turbiditic deposition.

The nearest located deep-sea K-T boundary outside the Carpathians was identified in "turbiditic and partly hemipe-

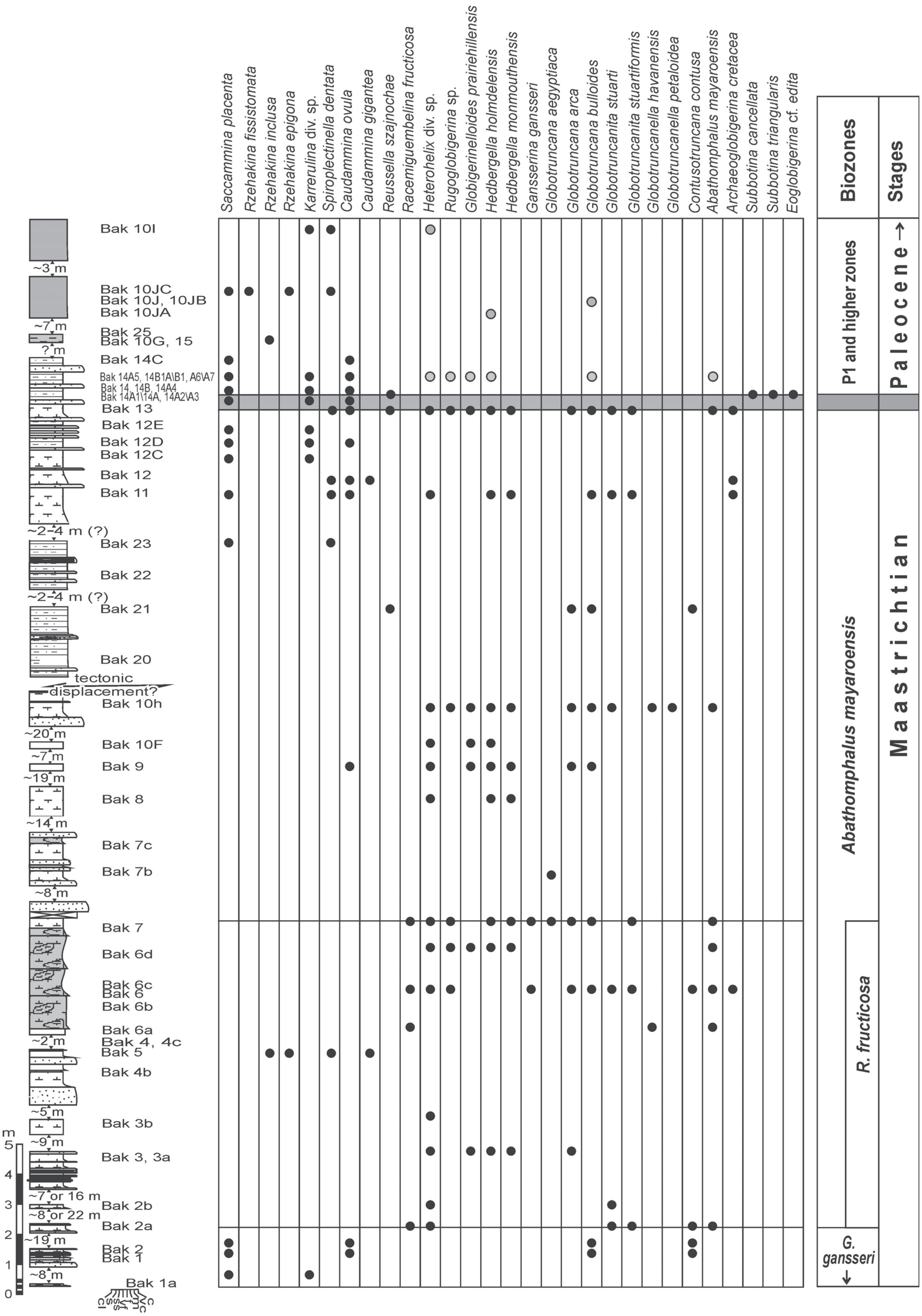

Fig. 4. Species occurrence in the studied samples with indication of standard biozones. Occurrences of redeposited taxa in grey circles.

Fig. 5. Benthic and planktonic foraminiferids of the Bąkowiec section. **A** — *Saccammina placenta* (Grzybowski), Bak 14B. **B** — *Hormosina velascoensis* (Cushman), Bak 10Jc. **C** — *Ammodiscus* sp., Bak 10JA. **D** — *Spiroplectammina* sp. (cross-section), Bak 5. **E** — *Spiroplectinella dentata* (Alth), Bak 11. **F–H** — *Rzehakina fissistomata* (Grzybowski), Bak 10Jc. **I** — *Rzehakina* cf. *inclusa* (Grzybowski), Bak 5. **J** — *Arenobulimina preslii* (Reuss), Bak 10H. **K** — *Anomalinoides nobilis* Brotzen, Bak 10H. **L** — *Quadrimorphina allomorphinoides* (Reuss), Bak 1. **M** — *Subbotina cancellata* Blow, Bak 14A. **N** — *Subbotina triangularis* (White), Bak 14A. **O** — *Eoglobigerina* cf. *edita* (Subbotina), Bak 14A. **P, U** — *Hedbergella holmdelensis* Olsson; P — Bak 3A, U — Bak 11. **R** — *Racemiguembelina fructicosa* Egger, Bak 6a. **S** — *Heterohelix striata* (Ehrenberg), Bak 6. **T** — *Hedbergella monmouthensis* (Olsson), Bak 3A.

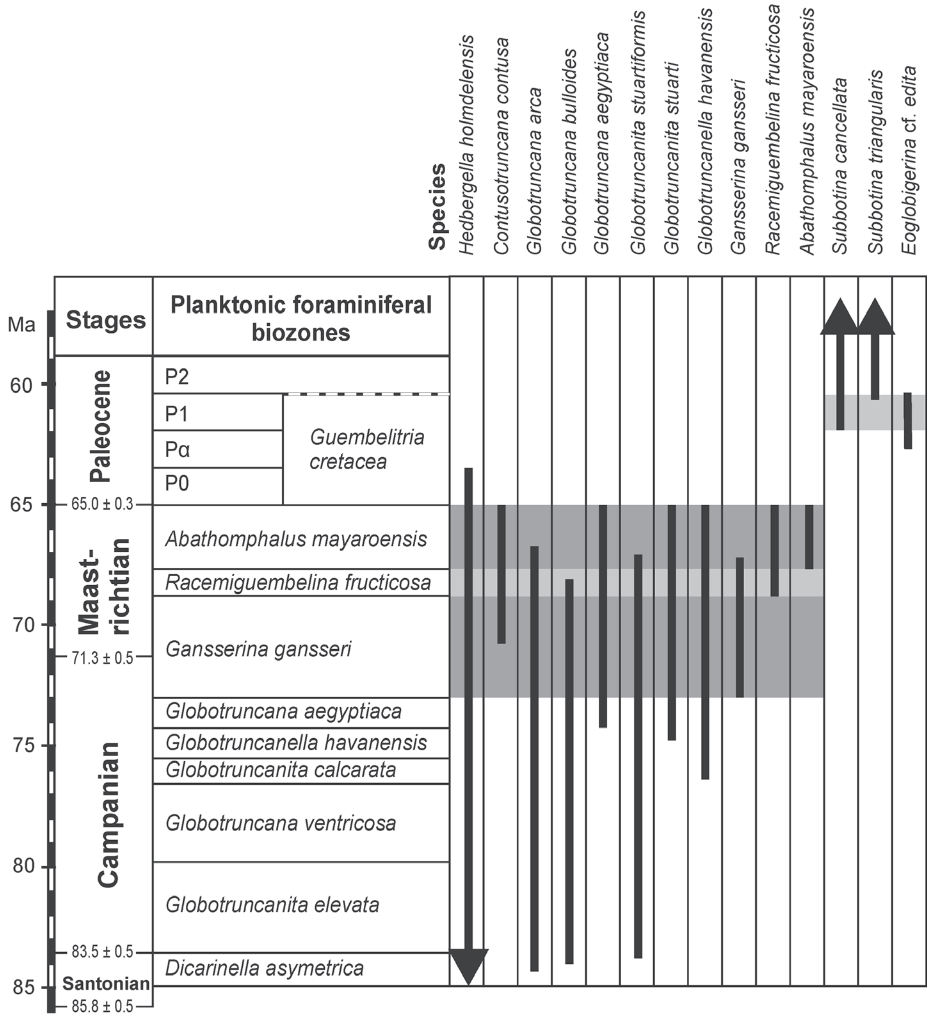

Fig. 6. Biostratigraphical ranges of the studied planktonic index taxa. Ranges of species and biozones plotted (combined) after Robaszynski et al. (1984), Caron (1985), Robaszynski & Caron (1995), Olsson et al. (1999) and Premoli-Silva & Verga (2004). The grey area indicates biozones recognized in the studied material.

lagic sediments" of the Gosau Group in the Eastern Alps (Austria; Rotwandgraben section; Lahodynsky 1988; Peryt et al. 1997); however, it is not clear whether the boundary is in the turbiditic or hemipelagic sediments. In an other section of the Gosau Group at Gams, the K-T boundary is recognized in hemipelagic sediments of a series composed of siliciclastic and mixed siliciclastic-carbonate strata deposited at the middle bathyal paleodepth (Egger et al. 2004, 2009).

Paleoecology

Qualitative analysis of the studied foraminiferal assemblages is presented in Fig. 9. Index and typical foraminiferids are shown in Figs. 5, 8. The planktonic/benthic ratio, relation of epipelagic to bathypelagic taxa among planktonic foraminiferal assemblages, numbers of agglutinated in relation to calcareous foraminiferids within the benthic assemblages and amount of suspension feeders (tubular forms) within the agglutinated foraminiferids assemblages were calculated.

Charts showing the mentioned coefficients clearly fluctuate (Fig. 9). Close to the K-T boundary foraminiferal assemblages of samples from Bak 11 to Bak 14A (14A1–14A7) display rapid quantitative changes considered as an ecological event. Before this event, planktonic taxa, which were abundant (Bak 11), suddenly decrease in numbers (Bak 12, 12C). Similarly, epipelagic forms, abundant among planktonic assemblages, form about 50 % in Bak 11 decrease to about 25 % in Bak 13. Increasing number of epipelagic (non-keeled taxa, r-strategists, opportunistic species) among planktonic assemblages confirms a shallower depositional environment (Gasiński 1997; Gasiński et al. 1999, 2001). However, any sedimentological signal of shallowing suggests redeposition of sediments from a shallower zone.

In contrast, agglutinated species, especially suspension feeders, formerly relatively scarce among benthic assemblages (Bak 13) sharply increase in number (Bak 14A). Agglutinated foraminiferids are more abundant in coarser sediments of clearly turbiditic origin. In turbiditic sediments, the suspension feeder morphological group dominates.

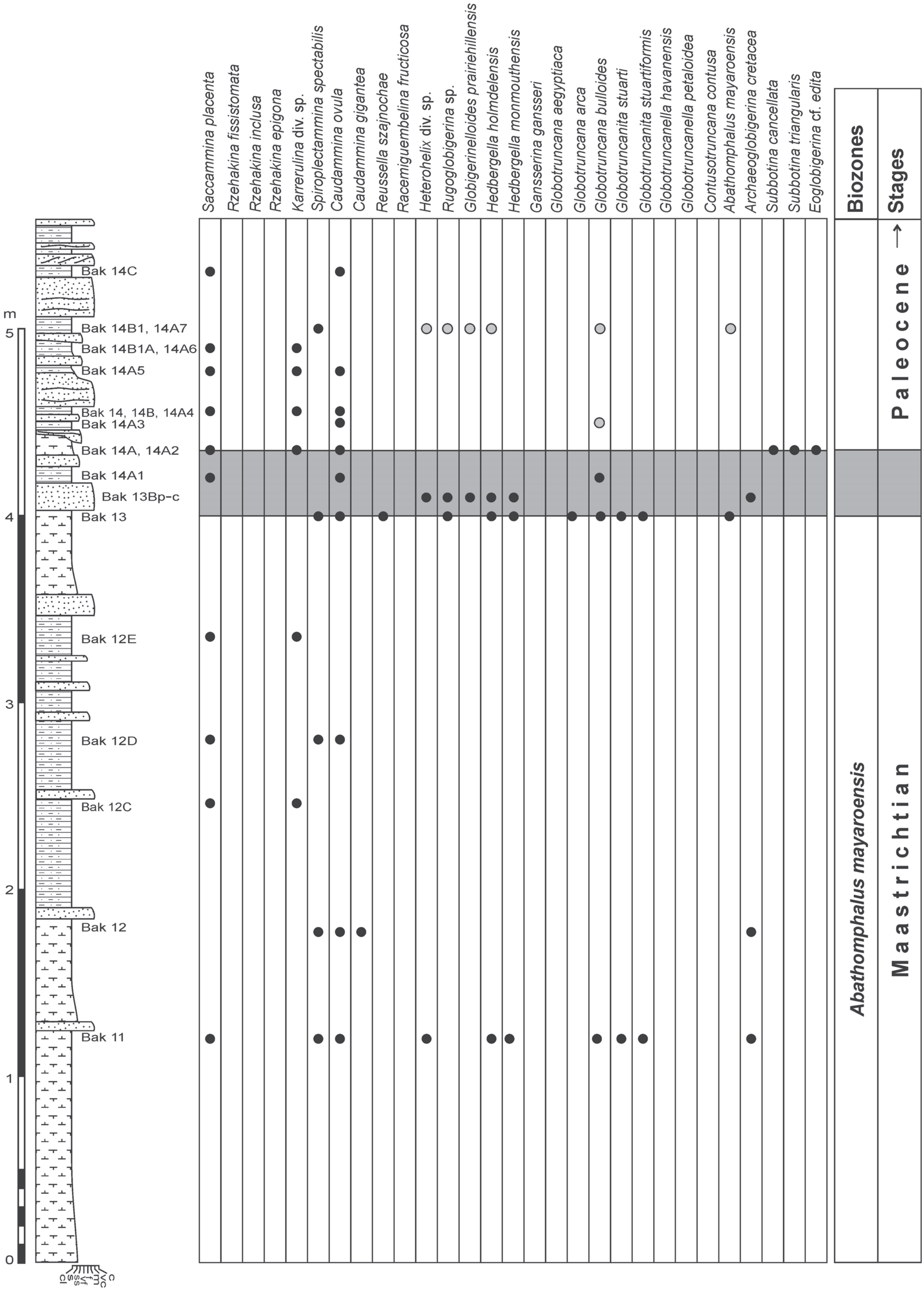

Fig. 7. Species occurrence in the studied samples in the upper part of the K-T boundary interval in the Bąkowiec section, with indication of standard biozones. The K-T boundary is located in the grey zone. Occurrences of redeposited taxa in grey circles.

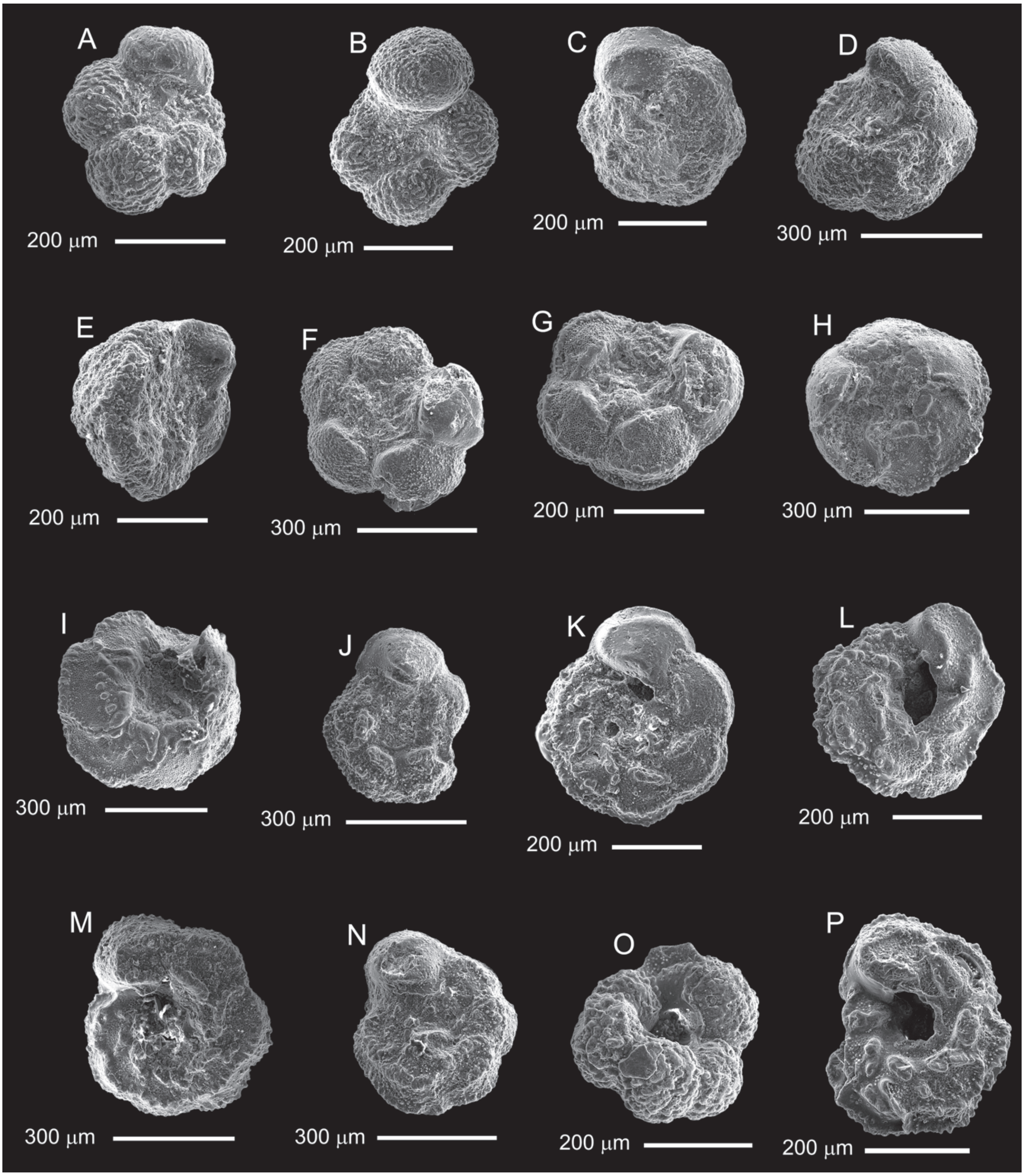

Fig. 8. Planktonic foraminiferids of the Bąkowiec section. **A, B** — *Rugoglobigerina rugosa* (Plummer); A — Bak 6, B — Bak 7. **C** — *Globotruncana* cf. *arca* Cushman, Bak 6. **K, L, P** — *Globotruncana bulloides* Vogler, Bak 11. **D, I** — *Globotruncanita stuartiformis* (Dalbiez); D — Bak 2A, I — Bak 7. **E** — *Contusotruncana contusa* (Cushman), Bak 2A. **F, G** — *Gansserina gansseri* (Bolli), Bak 6. **H** — *Globotruncanita stuarti* (de Lapparent), Bak 2A. **J** — *Globotruncana aegyptiaca* Nakkady, Bak 7. **M, N** — *Abathomphalus mayaroensis* (Bolli); M — Bak 6, N — Bak 7. **O** — *Archaeoglobigerina* sp., Bak 13.

The correlation of quantitative charts of composition of foraminiferal assemblages between the studied samples and those collected from the Gaj section (Gasiński & Uchman 2009) points to their close similarity, especially in the part dated as the latest Maastrichtian (Gaj section) and K-T boundary (studied section) (Fig. 9). It suggests that the similar factors influenced boundary section environment in this part of the Skole Basin.

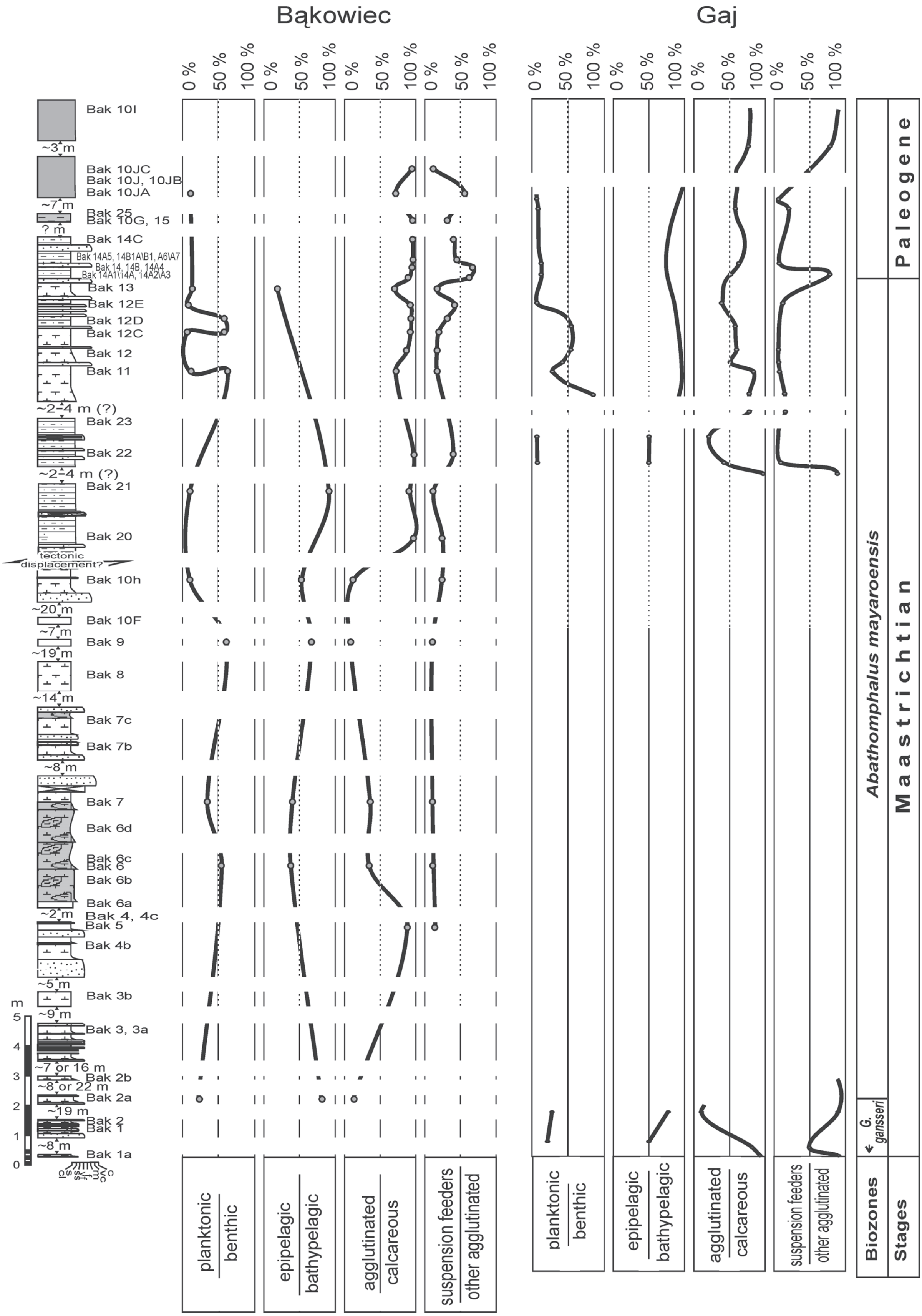

Fig. 9. Quantitative analysis of the studied foraminiferal assemblages in the Bąkowiec and Gaj sections. The Gaj section data from Gasiński & Uchman (2009).

Drastic changes of foraminiferal assemblages have also been observed in the K-T boundary sections in the pelagic/hemipelagic facies (MacLeod & Keller 1996; Apellániz et al. 1997; Kaiho & Lamolda 1999; Arenillas et al. 2004; Keller 2004, and others).

Conclusions

1. The K-T boundary was identified in the turbiditic sediments with the accuracy of 40 cm for the first time.

2. The *Gansserina gansseri*, *Abathomphalus mayaroensis* (Late Maastrichtian) and P1 (Early Paleocene) standard biozones were recognized in the studied section on the basis of planktonic foraminiferids.

3. The *Racemiguembelina fructicosa* Zone as the Partial Range Zone within the lower part of *A. mayaroensis* Zone has been determined for the first time in the Carpathians and the flysch sediments.

4. Drastic qualitative and quantitative fluctuations among the studied foraminiferal assemblages were recognized around the K-T boundary similar to those indicated in the Gaj section (next thrust sheet).

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References

Apellániz E., Baceta J.I., Bernaola-Bilbao G., Nunez-Betelu K., Orue-Etxebarría X., Payros A., Pujalte V., Robin E. & Rocchia R. 1997: Analysis of uppermost Cretaceous–lowermost Tertiary hemipelagic successions in the Basque Country (western Pyrenees): evidence for a sudden extinction of more than half planktic foraminifer species at the K/T boundary. *Bull. Soc. Géol. France* 168, 783–793.

Arenillas I., Arz J.A. & Molina E. 2004: A new high-resolution planktic foraminiferal zonation and subzonation for the lower Danian. *Lethaia* 37, 79–95.

Bubík M., Adamová M., Bąk M., Franců E., Franců J., Gedl P., Mikuláš R., Švábenická L. & Uchman A. 2002: Results of the investigations at the Cretaceous/Tertiary boundary in the Magura Flysch near Uzgruň. *Geol. Výz. na Moravě a ve Slezsku v roce 2001*, Brno,18–22 (in Czech).

Chira C.M., Balc R., Cetean C., Juravle D.T., Filipescu S., Igritan A., Florea F. & Popa M.V. 2009: Cretaceous/Paleogene boundary in north-eastern Romania. *Bericht. Geol. Bundestanst.* 78, 8.

Egger H., Rögl F. & Wagreich M. 2004: Biostratigraphy and facies of Paleogene deep-water deposits at Gams (Gosau Group, Austria). *Ann. Naturhist. Mus. Wien* 106A, 281–307.

Egger H., Koeberl C., Wagreich M. & Stradner H. 2009: The Cretaceous-Paleogene (K/Pg) boundary at Gams, Austria: Nannoplankton stratigraphy and geochemistry of a bathyal northwestern Tethyan setting. *Stratigraphy* 6, 333–347.

Gasiński M.A. 1997: Tethyan-Boreal connection: influence on the evolution of mid-Cretaceous planktonic foraminiferids. *Cretaceous Res.* 18, 505–514.

Gasiński M.A. & Uchman A. 2009: Latest Maastrichtian foraminiferal assemblages from the Husów region (Skole Nappe, Outer Carpathians, Poland). *Geol. Carpathica* 60, 4, 283–294.

Gasiński M.A., Jugowiec M. & Ślączka A. 1999: Late Cretaceous foraminiferids and calcareous nannoplankton from the Weglówka Marls (Subsilesian Unit, Outer Carpathians, Poland). *Geol. Carpathica* 50, 63–73.

Gasiński M.A., Leśniak T. & Piotrowski M. 2001: Latest Maastrichtian Foraminiferal Abathomphalus mayaroensis Zone in the Subsilesian Unit (Polish Outer Carpathians). *Bull. Polish Acad. Sci. Earth Sci.* 49, 89–97.

Gradstein F., Ogg J. & Smith A. 2004: A Geologic Time Scale. *Cambridge University Press*, Cambridge, 1–589.

Kaiho K. & Lamolda M.A. 1999: Catastrophic extinction of planktonic foraminifera at the Cretaceous-Tertiary boundary evidenced by stable isotopes and foraminiferal abundance at Caravaca, Spain. *Geology* 27, 355–358.

Keller G. 2004: Paleoecology of Late Maastrichtian-early Danian planktonic foraminifera in the eastern Tethys. *J. Foram. Res.* 34, 1, 49–73.

Kotlarczyk J. 1978: Stratigraphy of the Ropianka Formation or of Inoceramian Beds in the Skole Unit of the Flysch Carpathians. *Prace Geol., Polska Akademia Nauk, Oddział w Krakowie, Komisja Nauk Geologicznych* 108, 1–82 (in Polish with English summary).

Kotlarczyk J. 1988: Outline of the stratigraphy of the marginal tectonic units of the Carpathian orogen. In: Kotlarczyk J., Pękala K. & Gucik S. (Eds.): Przewodnik 59 Zjazdu Polskiego Towarzystwa Geologicznego, Karpaty Przemyskie, 16–18 września 1988. *Wydaw. AGH*, Kraków, 23–62 (in Polish only).

Lahodynsky R. 1988: Lithostratigraphy and sedimentology across the Cretaceous/Tertiary boundary in the Flyschgosau (Eastern Alps, Austria). *Riv. Esp. Paleont.* N° Extr., 73–82.

MacLeod N. & Keller G. 1996: The Cretaceous-Tertiary Mass extinction: Biotic and environmental events. *Norton Press*, New York, 1–595.

Melinte M.C. 1999: Cretaceous/Tertiary boundary in the East Carpathians (Romania), based on nannofloral evidence. *Acta Paleont. Romaniae* 2 (1999), 269–273.

Molina E., Alegret L., Arenillas I., Arz J.A., Gallala N., Hardenbol J., Salis K., von Steurbaut E., Vandenberghe N. & Zaghbib-Turki D. 2006: The global boundary stratotype section and point for the base of the Danian stage (Paleocene, Paleogene, "Tertiary" Cenozoic) at El Kef, Tunisia — Original definition and revision. *Episodes* 29, 263–273.

Olsson R.K., Hemleben C., Berggren W.A. & Huber B.T. 1999: Atlas of Paleocene planktonic foraminifera. *Smithsonian Contr. Paleobiol.* 85, 1–252.

Peryt D., Lahodynsky R. & Durakiewicz T. 1997: Deep-water agglutinated foraminiferal changes and stable isotope profiles across the Cretaceous-Paleogene boundary in the Rotwandgraben section, Eastern Alps (Austria). *Palaeogeogr. Palaeoclimatol. Palaeocol.* 132, 287–307.

Premoli-Silva I. & Verga D. 2004: Practical manual of Cretaceous Planktonic Foraminifera. International School on Planktonic Foraminifera. *3° Course: Cretaceous. Verga et Rettori eds. Universites of Perugia and Milano*, Tipografia Pontfelcino, Perugia, 1–283.

Rajchel J. 1990: Lithostratigraphy of the Upper Paleocene and Eocene deposits in the Skole Unit. *Zesz. Nauk. AGH, Geol.* 48, 1–112 (in Polish with English summary).

Robaszynski F. & Caron M. 1995: Foraminiferes planctoniques du Crétacé: commentaire de la zonation Europe-Méditerrané. *Bull. Soc. Géol. France* 6, 681–692.

Wdowiarz S. 1949: Structure géologique des Karpates Marginales au sud-est de Rzeszów. *Biul. Państw. Inst. Geol.* 11, 1–51.