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FORAMINIFERAL STRATIGRAPHY OF PALAEOGENE DEEP-WATER RED FACIES IN THE GORCE MOUNTAINS (MAGURA NAPPE, POLISH OUTER CARPATHIANS)

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Abstract: The deposition of red and variegated mudstones and claystones characterized the ancient Tethys Ocean during Cretaceous and Palaeogene times, including in its north-western part, the Alpine–Carpathian deep-water basins. Palaeogene variegated sediments, containing red mudstone and claystone layers, crop out in the Gorce Mountains (Rosocha creek, near Lubomierz) in the Magura Nappe (Bystrica Subunit) of the Polish Outer Carpathians. These sediments occur as layers 1–10 cm thick and as packages of layers 2–3 m thick that are associated with very thin-bedded turbidites. The entire succession is tectonically disturbed and parts of it belong to the Ropianka, Łabowa Shale and Beloveža Formations. The sediments studied contain 27 genera and 59 species that belong to deep-water agglutinated foraminiferal (DWAF) assemblages. Tubular taxa, which are frequent in various Mesozoic–Cenozoic flysch sediments are relatively rare in the section studied. The assemblages are moderately diverse (3–20 taxa per sample). Excluding tubular forms, the most common taxa belong to *Trochamminoides – Paratrochamminoides* spp., *Saccammina placenta*, glomospirids, *Recurvoides – Recurvoidella* spp. and karrerulinids. The oldest part of the red sediments, referable to the Ropianka Formation, represents the upper part of the *Rzehakina fissistomata* Zone (probably the Upper Palaeocene). The youngest red sediments, forming thin intercalations in the Beloveža Formation, represent the acme of *Reticulophragmium amplectens* (middle Lutetian). Owing to tectonic disturbances, most of the Lower Eocene part of the variegated facies of the Łabowa Shale Formation is not preserved in the section studied. The upper part of it, a package 2 m thick, represents the lower part of the *Reticulophragmium amplectens* Zone. The small thickness (10–15 m) of the Łabowa Shale Formation in the section studied is similar to other sections in the southern part of the Bystrica Subunit. It is probably of a sedimentary nature, reflecting a decreasing number of mud-rich, gravitational flows in the southern part of the Magura Basin during the Early Eocene. Nevertheless, the strong tectonic disturbances that took place in this area during the Oligocene–Miocene folding and overthrusting influenced the reduction in thickness of these sediments.

Key words: Agglutinated Foraminifera, red claystones and mudstones, Palaeocene, Eocene, Magura Nappe, Polish Outer Carpathians, Gorce Mountains.

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INTRODUCTION

The deposition of red and varicoloured (both red and green) mudstones and claystones was characteristic for the ancient Tethys Ocean during Cretaceous and Palaeogene times (e.g. Hu *et al.*, 2012). This was the case in the north-western part, which included the Carpathian deep-water basins (cf., Bąk, 2002; Hu *et al.*, 2005). In the Outer Carpathians, sedimentation of these claystones and mudstones continued up to the end of the Eocene (Książkiewicz, 1962; Jurkiewicz, 1967). It ended with the deposition of white calcareous pelagic sediments of the *Globigerina* Marl (Leszczyński, 1997). The red claystones and mudstones in the Cretaceous–Palaeogene deposits of the Carpathians (e.g., Ślączka, 1963; Koszarski, 1966; Traczyk, 1978) resemble those from the Atlantic and Pacific Oceans (Biscaye, 1965; Gleason *et al.*, 2002). Nevertheless, the rate of sedimentation of these deposits was strictly controlled by gravitational flows, which were generated on the slopes of the surrounding and intrabasinal ridges (cf., Leszczyński and Uchman,

Table 1

Lithostratigraphy of Campanian–Middle Eocene sediments of the Bystrica Subunit (Magura Nappe, Outer Carpathians) in the Gorce Mountains and the Beskid Wyspowy Mountains (summarized after Oszczypko *et al.*, 2005)

Stage	Lithostratigraphic unit	Thickness	Accumulation rate (m/Myr) (calculated from Oszczypko and Oszczypko-Clowes, 2006)
Early–Middle Eocene	Beloveža Formation	50–120 m	25–60
Early Eocene	Łabowa Shale Formation	200150 (? 200) m	3–20 (? 30)
Maastrichtian-Palaeocene	Ropianka Formation	80–100 m	15–20
Campanian-Maastrichtian	Szczawina Sandstone Formation	20–350 m	5–65

1991; Oszczypko and Oszczypko-Clowes, 2006). Consequently, their thickness and restricted lateral extension differ from one basin to another, and even within the same basin (summary in Oszczypko *et al.*, 2006).

Recognition of the stratigraphic position of the variegated facies in the Carpathians is difficult, owing to the Oligocene–Miocene thrusting and folding, which were especially strong within mudstone-siltstone siliciclastic sediments. Moreover, these sediments are devoid of calcareous nanno- and microfossils, which are the most important stratigraphic indicators. In such cases, the only stratigraphic data come from siliceous microfossils, including radiolarian and agglutinated foraminiferal assemblages (e.g., Bąk M., 1995; Sanfilippo and Nigrini, 1998; Bąk and Barwicz-Piskorz, 2005, 2006; Barwicz-Piskorz and Rajchel, 2012).

In the Outer Carpathians, the red-coloured facies, mainly claystones and mudstones, were characteristic of the Turonian–Campanian (Late Cretaceous) and the Early–Middle Eocene times in all tectonic and facies units (summary in Oszczypko, 2006; Olszewska and Malata, 2006). This paper presents the results of stratigraphic studies of the Palaeogene red facies, belonging to the Bystrica Subunit of the Magura Nappe, Polish Outer Carpathians, outcropping in the Gorce Mountains. These sediments were accumulated in the Magura Basin below the CCD, as documented by composition of assemblages of benthic Foraminifera, which are devoid of calcareous forms (e.g., Olszewska and Malata, 2006). The surrounding ridges were affected by tectonic activity, which generated gravitational flows that spread across the basin floor. Consequently, sedimentation of the red claystones and mudstones was sporadic and related to the formation of packages of siliciclastic (partly calcareous) thin-bedded turbidites.

GEOLOGICAL SETTING

The Palaeogene (mainly Lower–Middle Eocene) variegated claystones including red layers, occur in all tectonic-facies units in the Magura Nappe (summary in Oszczypko, 2006). The section studied is in the Bystrica Subunit, the sediments of which form the northern foot of the Gorce Mountains, one of the highest regions in the Polish part of the Beskidy Range (Fig. 1). In this area, the ridges are built of thick-bedded sandstones, belonging to the Magura Formation (Fig. 1D), while the valleys are developed along the faults and within the thin- and middle-bedded turbidites of the Ropianka, Łabowa Shale and the Beloveža Formations. Red Palaeogene sediments occur in several lithostratigraphic units, but their thickness is greatest in the Łabowa Shale Formation. The detailed lithostratigraphy of this area (Tab. 1) was presented by Oszczypko *et al.* (2005).

Geological section and lithostratigraphy

The section studied lies along the Rosocha Creek, a left tributary of the Mszanka River, in the vicinity of the Lubomierz village, about 50 km south of Kraków (Fig. 1B, C). The Rosocha valley is on the northern slopes of Mt. Kudłoń (1274 m a.s.l.). In the middle part of this valley (Fig. 1D), sediments belonging to the Ropianka, the Łabowa Shale and the Beloveža Formations are exposed on both banks of the stream for a distance of about 150 m (Fig. 2). Four packages with red claystones and mudstones occur within all of these formations, including:

– red, poorly calcareous claystones and mudstones, as a thin (3–10 cm) intercalations in the turbiditic succession (*ca* 30 m thick) of the Ropianka Formation (package 1; Fig. 2). These turbidites contain thin-bedded (up to 4 cm) mudstones and very fine-grained sandstones, parallel- and cross-laminated, some of them with trace fossils. The sandstones pass upwards into grey-blue calcareous shales. A single, yellow layer of bentonite, 2 cm thick, also was found there;

– red, non-calcareous claystones and mudstones, 3 m thick, representing a part of the Łabowa Shale Formation (package 2; Fig. 2). These red sediments are in tectonic contact with a succession of thick-bedded (0.7–1.0 m) sandstones, 3 m thick;

– red, non-calcareous claystones and mudstones (1–3 cm thick), as intercalations in a turbidite succession, 4 m thick, which belongs to the Beloveža Formation (package 3; Fig. 2). The turbidites contain very thin-bedded mudstones (1–4 cm thick), intercalated with the varicoloured claystones and mudstones, which predominate in this succession. The neighbouring strongly folded packages of turbidites, devoid of any intercalations of red shale, also belong to the Belo- veža Formation;

– red, poorly calcareous claystones and mudstones, in sedimentary contact with thick-bedded sandstones (at least 1.5 m thick), similar to those, which are in tectonic contact with package 2 (the Łabowa Shale Formation), and to those in the middle part of the section (package 4; Fig. 2). The red

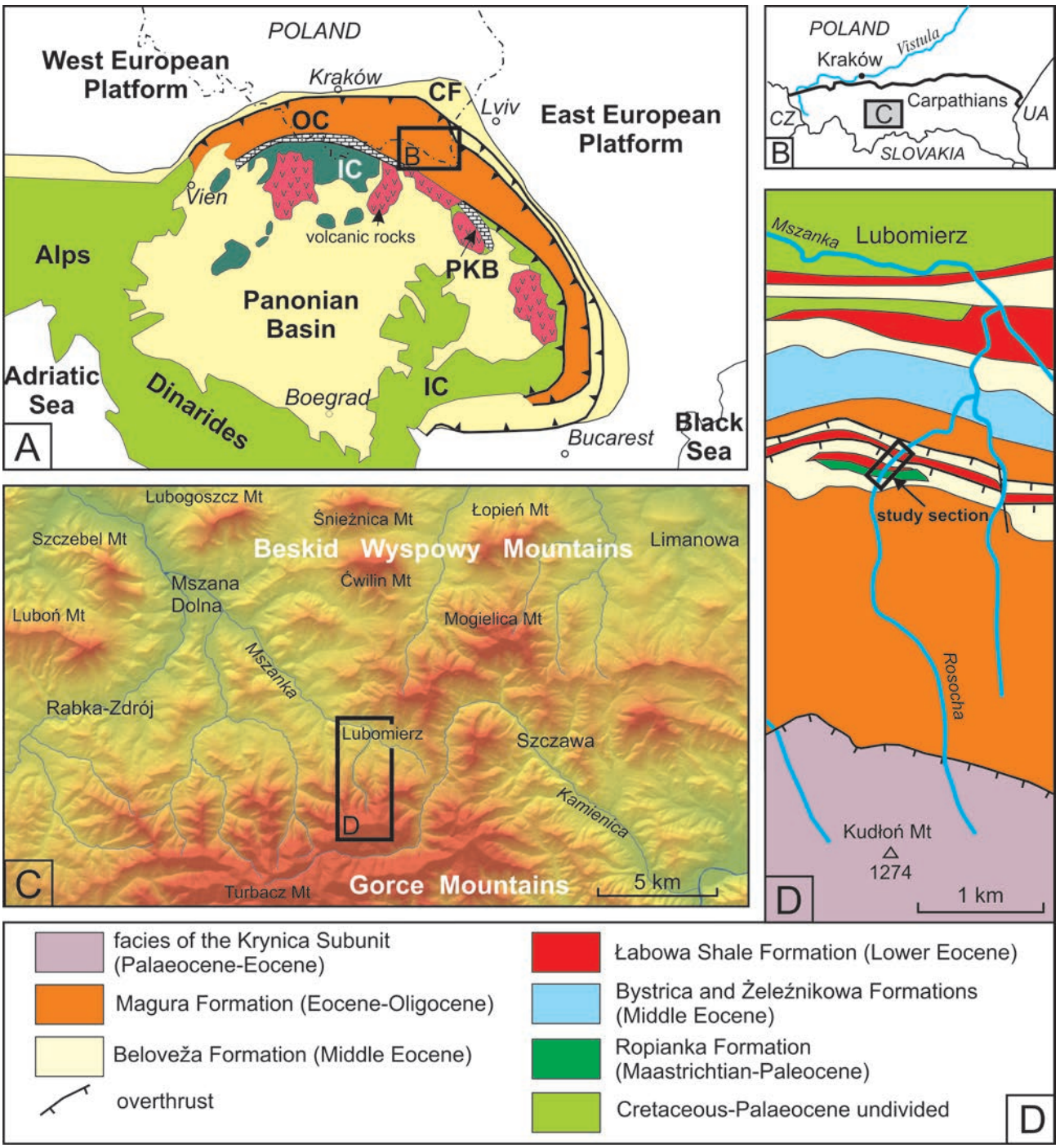

Fig. 1. Location of study area. **A.** Outer Carpathians (OC) against the background of a simplified geological map of the Alpine orogens and their foreland; IC – Inner Carpathians, CF – Carpathian Foredeep, PKB – Pieniny Klippen Belt. **B, C.** Location of study area in Polish part of Carpathians (B) with contour map (C) of the surroundings of Lubomierz village (Gorce and Beskid Wyspowy Mountains; Bryndal, 2011). **D.** Geologic map of study area (after Oszczypko *et al.*, 2005; supplemented) with location of section, studied at Rosocha Creek (black rectangle)

sediments and sandstones form here a small anticline, which is in tectonic contact with the folded turbidites of the Beloveža Formation. Most probably these red sediments belong to the Łabowa Shale Formation, corresponding to package 2, which occurs in the same stratigraphic position.

The sediments of the Łabowa Shale Formation and surrounding units lie within the Konina–Lubomierz Thrust Sheet that forms the southern part of the Bystrica Subunit in the Magura Nappe. This thrust sheet is in tectonic contact with the Krynica Subunit at a distance of 2.2 km to the south of the section studied. The Krynica Subunit is composed of a thick succession of Upper Cretaceous–Oligocene turbidites in this area (Birkenmajer and Oszczypko, 1989).

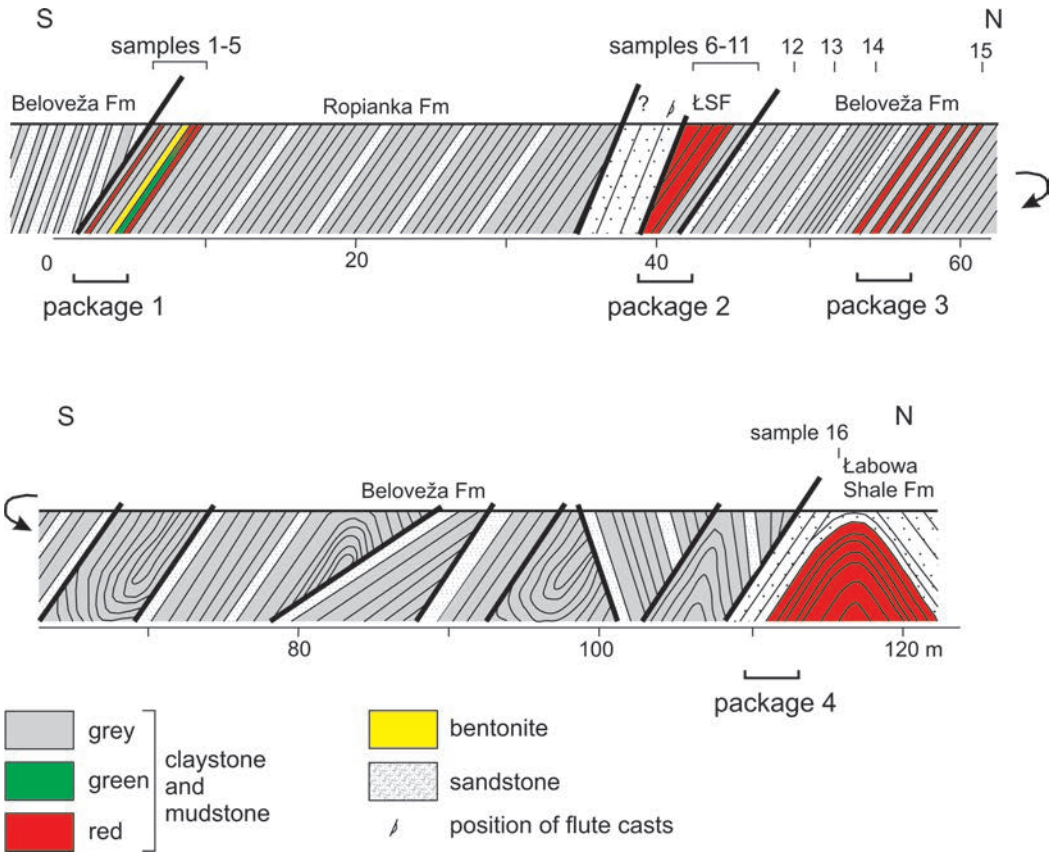

Fig. 2. Geological cross-section along Rosocha valley (Lubomierz area, Bystrica Subunit, Magura Nappe), with location of red and variegated claystones and mudstones from various lithostratigraphic units; ŁSF – Łabowa Shale Formation; numbers over the section are related to sample locations

MATERIAL AND METHODS

Four sections, containing red claystones and mudstones, were sampled during the present study (Figs 2, 3). The red sediments vary in the details of their lithology, with regard to the calcium carbonate content (see Fig. 3), which was identified by its reaction with dilute hydrochloric acid. The red claystones of the Łabowa Shale and in the Beloveža formations are calcium carbonate free.

The micropalaeontological studies were based on agglutinated foraminifers. Radiolarians have not been found there. A standard procedure for the preparation of micropalaeontological slides was employed. It included the extraction of microfossils from 16 samples, weighing 20–300 g, which were dried and disintegrated by repeated heating in a sodium carbonate solution, dried, and then sieved, using a 63 μm mesh. The samples and the residues were weighed before and after the extraction procedure to measure the number of specimens in 1 gram of the sediment. All foraminiferal specimens were picked and placed on microfaunal slides.

RESULTS

The foraminiferal assemblages in red claystones, presented in Table 2, represent only the deep-water agglutinated forms. Tubular taxa, which are frequent in the hemipelagic sediments of various flysch basins (e.g., Kuhnt and Kaminski, 1989; Kaminski *et al.*, 1996; Bąk, 2004), as distinct from turbidite deposits, are relatively rare in the sections studied. They are dominated by forms, belonging to *Rhabdammina*, *Psammosiphonella*, *Nothia* and *Bathysiphon*. Their numbers increase in the claystones of the fine-grained turbidites of the Beloveža Formation. The relative abundance of deep-water agglutinated foraminifera (DWAF) per gram of sediment, varies from sample to sample, from 4 to 43 specimens, depending on the type of sediment. Most probably, some samples with a very low diversity value index belong to a mixed layer of the T*e* part of the Bouma sequence from the mudstone part of the turbidite and the true hemipelagic layer, which are macroscopically difficult to differentiate.

27 genera and 59 species of DWAF were identified in samples from the red sediments and the surrounding shales. The assemblages are moderately diverse (between 3 and 20 taxa per sample). Excluding tubular forms, similar assemblages characterize the red packages of all of the formation (Fig. 4). The most common taxa belong to *Trochamminoides* (Fig. 5P) – *Paratrochamminoides* spp., *Saccammina placenta*, glomospirids, *Recurvoides* (Fig. 5M, N) – *Recurvoidella* spp. and karrerulinids (Fig. 5H–L). Some species are characteristic for particular red shale packages. This relates to the more common occurrences of glomospirids in the Łabowa Shale Formation and of *Karrerulina conversa* in the Ropianka Formation.

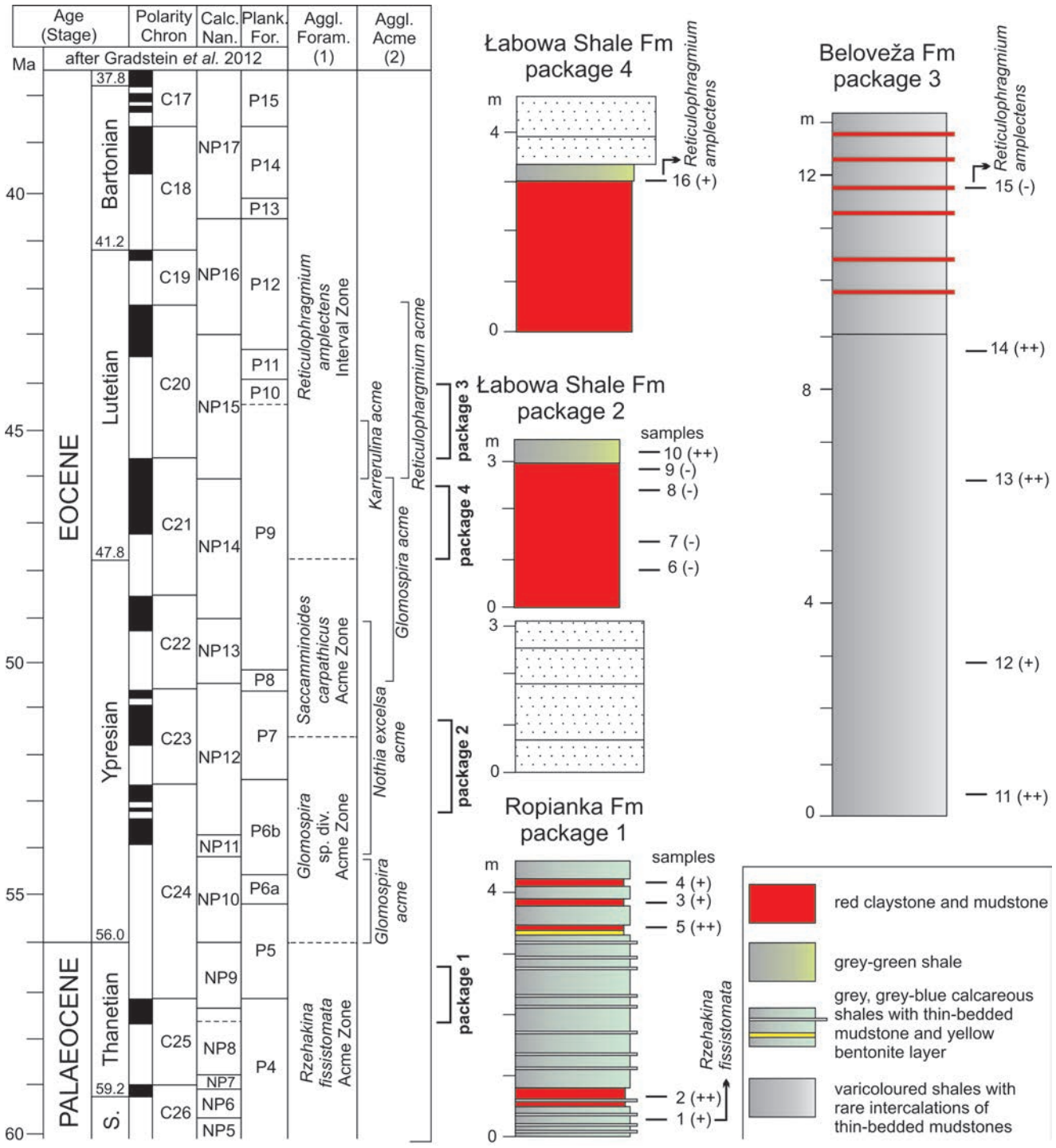

Fig. 3. Palaeocene and Eocene stratigraphic subdivisions, geomagnetic polarity scale, zonation of calcareous nannofossils (Calc. Nan.), planktonic foraminifera (Plank. For.) (Vandenberghe *et al.*, 2012) and agglutinated foraminifera (2 – Olszewska, 1997), deep-water agglutinated foraminifera acmes in Western Tethys and North Atlantic (1 –Kaminski and Gradstein, 2005) with lithologic logs of Rosocha section (Bystrica facies, Magura Nappe, Outer Carpathians), plotted against biostratigraphic markers and calcium carbonate content (in brackets); (-) – carbonate-free, (+) – traces of $CaCO_3$, (++) low $CaCO_3$ content

The frequency of agglutinated foraminiferal assemblages differs also between the red and the varicoloured claystones of the Beloveža Formation. The red sediments are enriched in specimens of *Saccammina placenta* and *Recurvoides – Recurvoidella*, and are depleted in ammodiscids and in *Karrerulina conversa*.

Certain taxa occur only in the red facies of the Ropianka Formation (*Remesella varians* (Glaessner); Fig. 5C, D; Table 2), while others are characteristic only of the Ropianka and Łabowa Shale Formations, e.g. rzehakinids (Fig. 5A, B; Table 2), and others were found only in the Łabowa Shale and the Beloveža Formations (Fig. 5E–G; Table 2), e.g. *Reticulophragmium amplectens* (Grzybowski).

Table 2

Distribution of Palaeogene agglutinated foraminifera at Rosocha Creek (Bystrica facies, Magura Nappe, Outer Carpathians); four fragments of tubular species were calculated as one individual

	Package 1					Package 2					Package 3					P4
	Ros-1	Ros-2	Ros-5	Ros-3	Ros-4	Ros-6	Ros-7	Ros-8	Ros-9	Ros-10	Ros-11	Ros-12	Ros-13	Ros-14	Ros-15	Ros-16
Ammobaculites aglutinans										1						
Ammodiscus cretaceus	1						2				2			5	8	
A. peruvianus					2									4	4	
A. tenuissimus								1								
Annectina grzybowskii		3									2			2		3
Aschemocella grandis				2							2					
Bathysiphon microraphidus	2		1	1		3			3							
Bathysiphon sp.		2				2						2	1			
Caudammina ovulum	3	1	2					1	4	1	3	2		6	3	
Cribrostommoides trinitatensis	2	1														
C. subglobulosus								1	1							
Dorothia sp.														1	1	
Glomospira gordialis		1				1	2				2				4	3
G. irregularis	2		1	1			1	2			3					
G. serpens				1			3								1	
Haplophragmoides horridus		2	1	1					2							
H. retroseptus											1	3			4	
H. eggeri	1							1								
H. suborbicularis									2							
H. stomatus								1								
Haplophragmoides sp.						1										1
Karrerulina conversa	13												1	25		
K. horrida						2		1			11					
Lituotuba lituiformis											2					
Nothia excelsa		1								1	1	3				
N. robusta				4	2	2		2		1	2			2		1
Paratrochamminoides heteromorphus				9										1		
P. cf. *mitratus*	1													2		
Paratrochamminoides sp.										1						
Psammosiphonella cylindrica					1				3		3					
Repmanina charoides						1				1				3	3	2
Rhabdammina linearis	5	1	1	1		1			2					1		1
Rhabdammina sp.						1				1				3	1	1
Recurvoidella lamella	4	3	2						2	1	1					
Recurvoides contortus				3	6		1									1
R. nucleosus	1							1								
R. retroseptus	1						1	1	2	1						
Recurvoides sp.						2		1								
Remesella varians	1													1		
Reophax duplex		2						3				2				
Reophax sp.						1		1						1		
Reticulophragmium amplectens															7	4
R. intermedium		2														
Rzehakina epigona	2								1							
R. fissistomata	1															
R. minima	1								1							

Table 2 continued

	Package 1					Package 2					Package 3					P4
	Ros-1	Ros-2	Ros-5	Ros-3	Ros-4	Ros-6	Ros-7	Ros-8	Ros-9	Ros-10	Ros-11	Ros-12	Ros-13	Ros-14	Ros-15	Ros-16
Saccammina grzybowskii	4			1												
S. placenta	1	2	3	4	3		8	8		2	6	5	6	4	2	
Spiroplectammina navarroana											3					
Subreophax pseudoscalaria							1									
Subreophax sp.	3									1	3					
Trochammina spp.				2		2	1		1	2	2					
Trochamminoides dubius		1		2			3									
T. coronatus											3			12		
T. grzybowskii	1	1							2		2	4		4		1
T. variolaris		3		2												
T. proteus					1	1		2		6	6	1		3	7	2
T. subcoronatus				1			9	1						16		
Trochamminoides sp.	2				2	2										

Stratigraphy

The deep-water agglutinated foraminifers (DWAF), studied in four red claystone and mudstone packages, represent assemblages of different ages. The lowermost package 1 (in the Ropianka Fm.) contains species, typical for the Palaeocene (?Upper Palaeocene), including forms, which belong to the rzehakinids (Table 2; Fig. 3), with *R. fissistomata* (Grzybowski) and *Remesella varians* (Glaessner).

Rzehakina fissistomata was used as the index species in several zonations of the bathyal–abyssal sediments of the Outer Carpathians, which were based on agglutinated taxa (Geroch and Nowak, 1984; Bubík, 1995; Olszewska, 1997; Bubík *et al.*, 1999; Bąk, 2004; Bąk and Wolska, 2005). This zone corresponds to different parts of the Palaeocene or to the entire Palaeocene in these zonations. The FAD of *R. fissistomata* is correlated with the Early Maastrichtian in bathyal environments of the South Atlantic (e.g., Koutsoukos, 2000). It appeared later in abyssal sediments of the Carpathians, close to the Maastrichtian–Palaeocene boundary (Bubík *et al.*, 1999). The LAD of this species is not clearly defined. It is marked below the base of the DWAF assemblages with the *Glomospira* spp. acme that is correlated with the Palaeocene–Eocene boundary (cf. Bąk, 2004).

Remesella varians was described from the uppermost Cretaceous–Palaeocene in the NW Caucasus by Glaessner (1937). After that, this species was reported from numerous regions of the Western Tethys, North Atlantic and the Caribbean region (summary in Kaminski and Gradstein, 2005), corresponding to the Maastrichtian–Palaeocene.

Two red claystone and mudstone packages, i.e. package 3 and package 4, contain the DWAF assemblages with a younger stratigraphic marker, i.e. *Reticulophragmium amplectens* (Grzybowski) (Table 2; Fig. 3). Its first occurrence (FO) is correlated with the Lower Eocene (middle Ypresian) in the Outer Carpathians, on the basis of correlation with the nannoplankton zonal scheme by Olszewska and Smagowicz (1977; Zone NP12). In other bathyal and abyssal sediments, its FO was described above the Lower Eocene *Glomospira* spp. acme. The LO of this species is known from the vicinity of the Eocene–Oligocene boundary (summary in Kaminski and Gradstein, 2005).

The thickest, non-calcareous red shale package 2 does not contain stratigraphic markers that represent any DWAF species (Tab. 2). Their faunas resemble the assemblages, described from various tectonic-facies units of the Outer Carpathians from the Lower–Middle Eocene, belonging to the Łabowa Shale and Beloveža Formations (e.g., Geroch, 1960; Geroch *et al.*, 1967; Jurkiewicz, 1967; Jednorowska, 1968; Morgiel and Szymakowska, 1978; Morgiel and Olszewska, 1981; Oszczypko *et al.*, 1990, 1999, 2005; Bubík, 1995; Bąk *et al.*, 1997; Waśkowska-Oliwa, 2001; Kender *et al.*, 2005; Golonka and Waśkowska, 2012). These are characterized by an enhanced content of tubular forms, associated with large numbers of specimens of glomospirids, saccamminids and the *Trochamminoides – Paratrochamminoides* group.

DISCUSSION

Biostratigraphic context

On the basis of the occurrence of *Rzehakina fissistomata*, a foraminifer characteristic for the Palaeocene, the sedimentation of the red sediments started in the study area in the Late Palaeocene. However, it is not possible to elaborate the detailed stratigraphy, using only the DWAF assemblages.

The most characteristic feature of the younger red claystones and mudstones in the Magura Nappe (also in other Outer Carpathian nappes), namely the Early Eocene agglutinated foraminifer assemblage with abundant *Glomospira* spp. (e.g., Morgiel and Olszewska, 1981; Olszewska, 1997), distinguished as the *Glomospira* Acme Zone, is not preserved in the sections studied. Another younger stratigraphic horizon, i.e. the *Saccamminoides carpathicus* Zone, distinguished in many local zonal schemes, on the basis of the DWAF assemblages, is also absent in the sections stud-

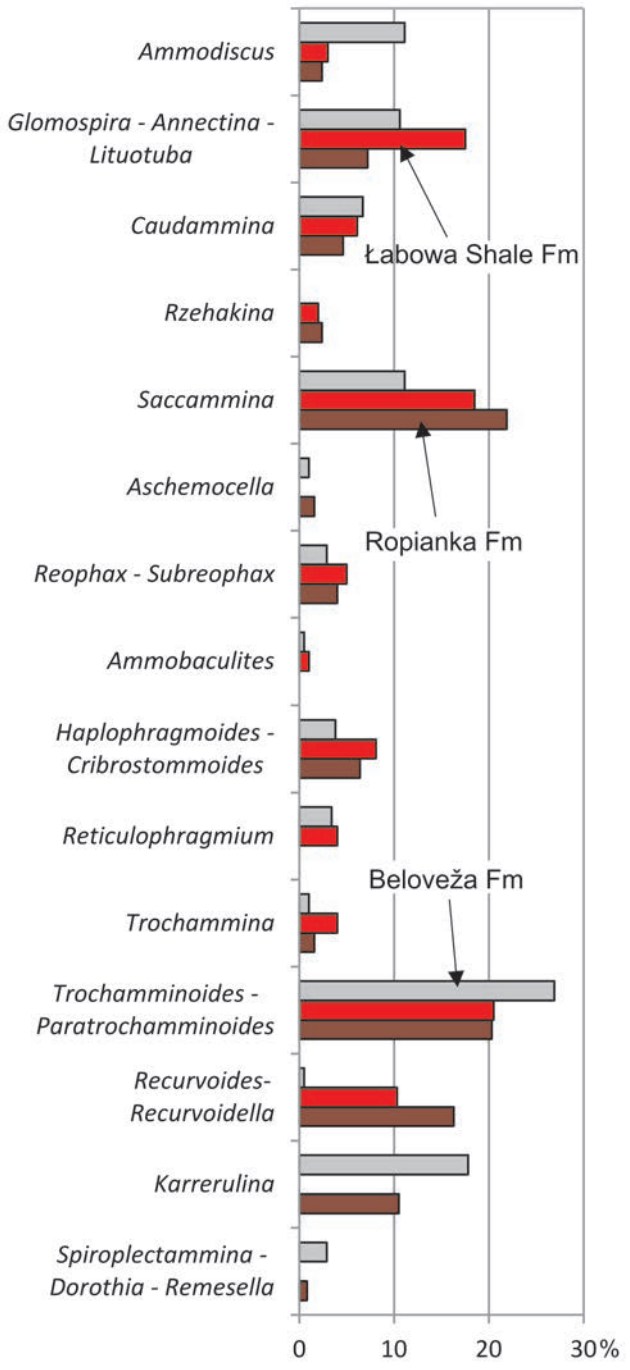

Fig. 4. Percentage content of foraminiferal genera in red facies of Łabowa Shale Formation and Ropianka Formation against varicoloured shales of Beloveža Formation

ied. This indicates a wide stratigraphic gap within the succession of variegated facies in the study section, due to tectonic disturbances (Fig. 3). Such an interpretation is related to the tectonic position of the study area, i.e. within the narrow Konina – Lubomierz Thrust Sheet. This is mainly composed of thin- and medium-bedded turbidites that were folded and thrusted beneath a thick succession of thick-bedded sandy turbidites of the Krynica Subunit during Oligocene–Miocene time.

The youngest red claystones, which crop out in the study section, represent the *Reticulophragmium amplectens* Zone. According to Olszewska (1997), the base of this zone is correlated with the base of the Middle Eocene (Lutetian). Taking into account the correlation of the planktonic foraminiferal and calcareous nannoplankton zonations with the benthic (agglutinated) foraminiferal occurrences, presented by Kaminski and Gradstein (2005), the *R. amplectens* acme was correlated with the nannoplankton NP15 to early NP16 Zones. In the modern correlation of the calcareous nannoplankton zonation with magneto- and chronostratigraphy, this acme corresponds to the middle Lutetian (about 46–42 Ma; Vandenberghe *et al.*, 2012).

The above data are in good agreement with earlier biostratigraphic studies within the Magura Nappe, in the Gorce and Beskid Wyspowy ranges (Oszczypko, 1991; Oszczypko *et al.* 1999, 2005), slightly extending the ranges of the red facies in the Gorce Mountains area.

Lithostratigraphic context

The Palaeogene variegated facies of the Bystrica Subunit (Magura Nappe) that occur in the Gorce and Beskid Wyspowy Mountains have been included to the Łabowa Shale Formation (Oszczypko, 1991; Oszczypko *et al.*, 1999, 2005). They contain a few thick packages of non-calcareous shales and claystones, several metres thick, interrupted vertically by argillaceous turbidites with thin intercalations of green and red shales. In the studied section, the Łabowa Shale Formation is represented only by two thin packages (2–3 m thick) of the red claystones and mudstones. One of them (a part of the *R. amplectens* Zone), most probably represents the uppermost part of the Łabowa Shale Formation. The position of the second one is uncertain, owing to a lack of stratigraphic markers. The characteristic feature of the Łabowa Shale Formation in this area is the occurrence of a package of thick-bedded sandstones, 2–3 m thick, with beds exceeding 70 cm. It is not clear, if they represent the same lithostratigraphic horizon (tectonically divided) or two separate horizons. A similar facies also was described from the Poręba Wielka section in the Gorce Mountains (Oszczypko *et al.*, 2005), where two thick beds of sandstone occur near the base of this formation.

The total thickness of the Łabowa Shale Formation in the section studied is difficult to estimate, owing to strong tectonic disturbances in this area. On the basis of features of the sediments and a comparison with neighbouring sections, the Łabowa Shale Formation is probably 10–15 m thick. This value is similar to those, noted from other sections in the southern part of the Bystrica Subunit in the Gorce Mountains (Fig. 6), where it ranges from 20 to 30 m (Oszczypko, 1991; Oszczypko *et al.*, 2005), locally exceeding 50 m. In the middle and the northern parts of this subunit, the Łabowa Shale Formation total thickness increases gradually up to 150 m (Młyńczyska and Półrzeczki sections; Malata *et al.*, 1996; Oszczypko *et al.*, 2005). The sedimentary origin of the thickness differences of the Łabowa Shale Formation is taken into account, because of the numerous argillaceous turbidites in the middle part of this formation, as described in the Półrzeczki and Młyńczyska sections.

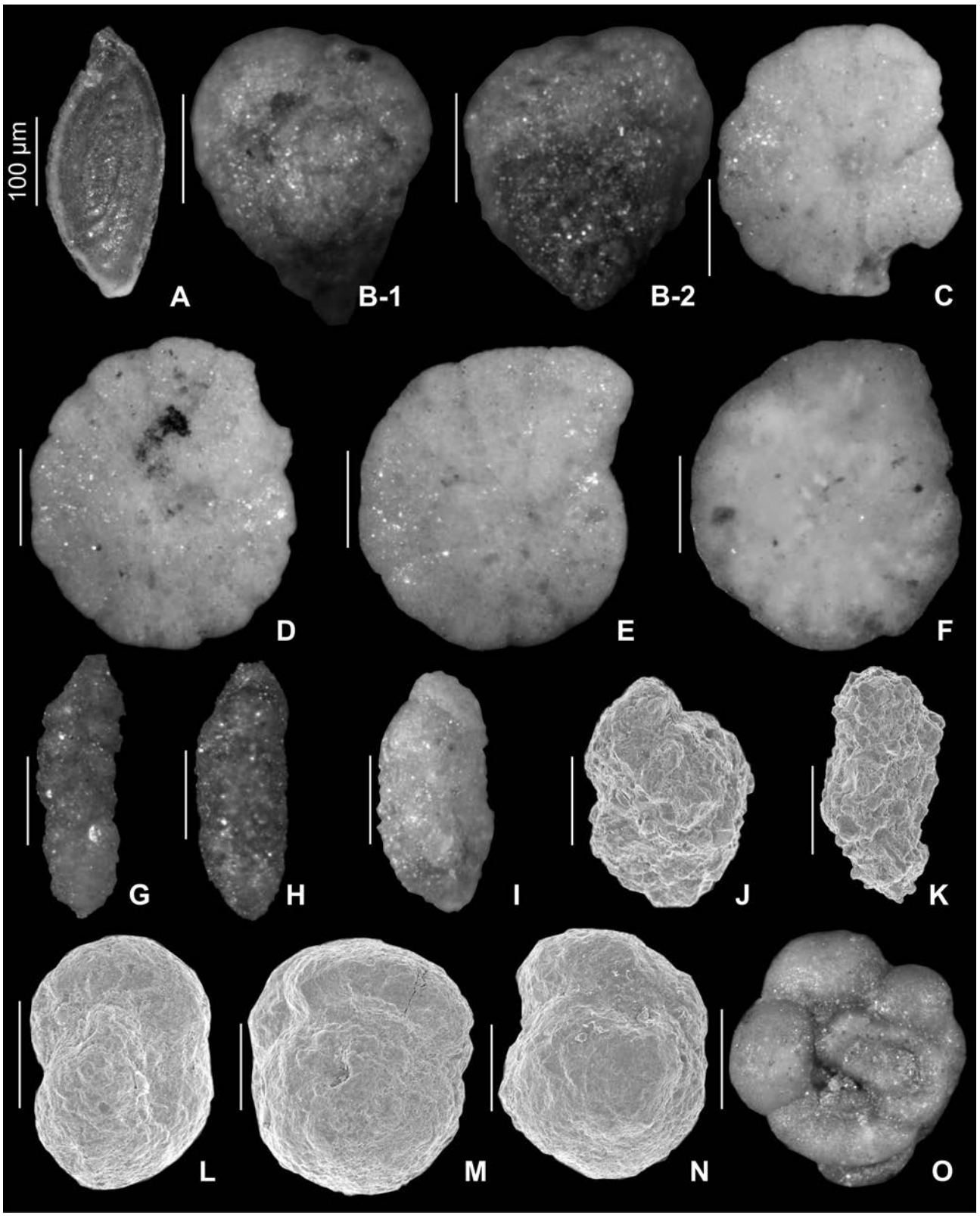

Fig. 5. Selected deep-water agglutinated foraminifers with stratigraphic index species (A–F) from Palaeocene–Middle Eocene sediments at Rosocha section (Bystrica Subunit, Magura Nappe, Outer Carpathians): **A.** *Rzehakina minima* Cushman & Renz, sample Ros-1. **B.** *Remesella varians* (Glaessner), sample Ros-1. **C–F.** *Reticulophragmium amplectens* (Grzybowski), C – sample Ros-16, D–E – sample Ros-15. **G.** *Karrerulina conversa* (Grzybowski), sample Ros-14. **H–K.** *Karrerulina horrida* (Mjatliuk), H – sample Ros-11, I–K – sample Ros-11. **L.** *Haplophragmoides eggeri* Cushman, sample Ros-1. **M.** *Recurvoides retroseptus* (Grzybowski), sample Ros-1. **N.** *Recurvoides nucleosus* (Grzybowski), sample Ros-8. **O.** *Trochamminoides subcoronatus* (Grzybowski), sample Ros-14

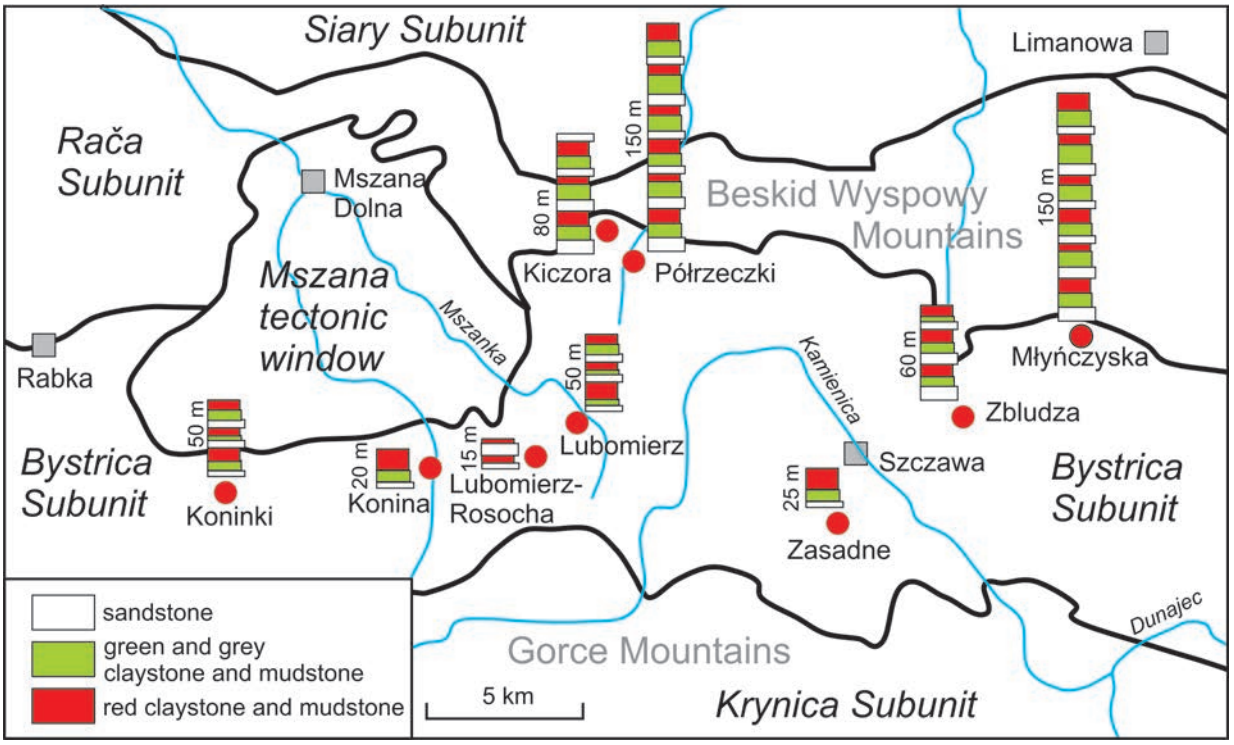

Fig. 6. Total thickness of Łabowa Shale Formation in various sections of Bystrica facies (Magura Nappe, Outer Carpathians), Gorce Mountains and Beskid Wyspowy Mountains (based on Oszczypko, 1991; Malata *et al.*, 1996; Oszczypko *et al.*, 2005; this study)

The low accumulation rate during Palaeocene–Early Eocene times in this part of the Magura Basin (3–20 m/Myr; Tab. 1), compared to data from the neighbouring Rača Subunit (15–110 m/ Myr; Oszczypko and Oszczypko-Clowes, 2006), may confirm this interpretation.

CONCLUSIONS

1. Palaeogene red claystones and mudstones occur in the Ropianka, Łabowa Shale and Beloveža Formations of the Gorce Mountains (Rosocha section), in the Bystrica Subunit of the Magura Nappe, Outer Carpathians.

2. Deep-water agglutinated foraminiferal (DWAF) assemblages, occurring in these strata, contain forms that belong to 59 species. Tubular forms are rare in the red sediments. The most common taxa belong to *Trochamminoides – Paratrochamminoides* spp., *Saccammina placenta*, glomospirids, *Recurvoides – Recurvoidella* spp. and karrerulinids. The relative abundance of DWAF varies from 4 to 43 specimens per sample in one gram of sediment, depending on the type of sediment.

3. The stratigraphically oldest part of the red sediments, occurring as intercalations a few centimetres thick in the Ropianka Formation, represents the upper part of the *Rzehakina fissistomata* Zone, corresponding most probably to the Upper Palaeocene.

4. The stratigraphically youngest red claystones and mudstones in the section studied, occurring as intercalations a few centimetres thick in the Beloveža Formation, represent the acme of *Reticulophragmium amplectens* (according to Kaminski and Gradstein, 2005). Using the chronostratigraphy of Vandenberghe *et al.* (2012), a correlation of this acme with the calcareous nannoplankton of the NP15 to early NP16 Zones (Kaminski and Gradstein, 2005) shows that it corresponds to the middle Lutetian (about 46–42 Ma).

5. The Early Eocene red sediments of the Łabowa Shale Formation are strongly tectonized in the study area. Their lower and middle parts, corresponding to the *Glomospira* spp. Acme Zone and to the *Saccamminoides carpathicus* Zone, are not preserved there. The upper part of the Łabowa Shale Formation, represented by continuous red shales 2 m thick, belongs to the lower part of the *Reticulophragmium amplectens* Zone.

6. The small thickness of the Łabowa Shale Formation (10–15 m) in the section studied is similar to values, noted from other sections in the Konina – Lubomierz Thrust Sheet (Bystrica Subunit). Comparisons of the total thickness of the Łabowa Shale Formation of the Bystrica Subunit (Gorce Mountains) with that of the corresponding sediments of the Rača Subunit (Beskid Wyspowy Mountains) reveal that an increase in thickness of up to 150 m is probably sedimentary in nature. It may be the result of an increased number of mud-rich gravitational flows in the northern part of the Magura Basin during the Early Eocene.

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