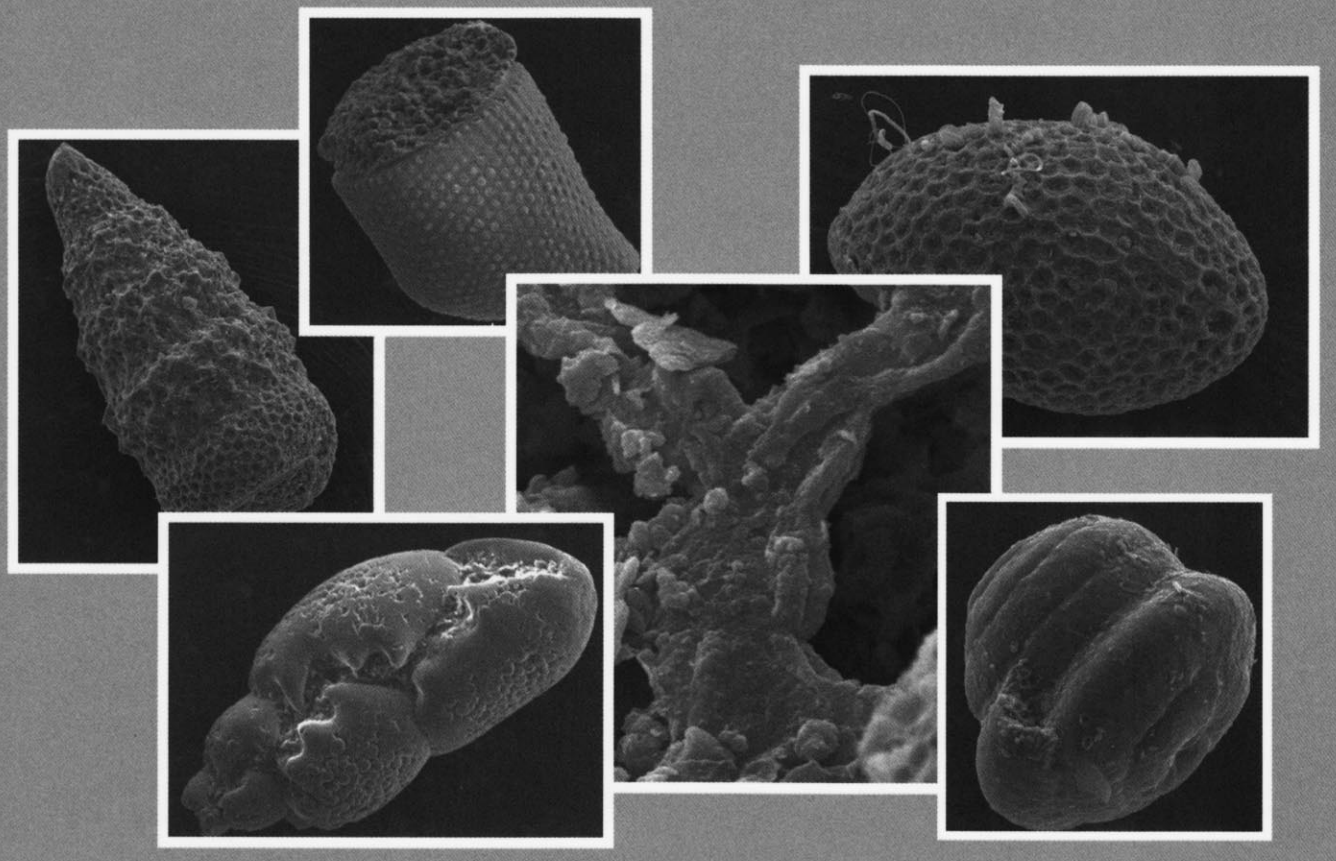
Integrating Microfossil Records from the Oceans and Epicontinental Seas



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Deep-water agglutinated foraminifera in Paleogene hemipelagic sediments of the Magura Basin in the Sucha Beskidzka area – variegated shales of the Łabowa Shale Formation

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ABSTRACT

Sedimentation of the variegated shales of the Łabowa Shale Formation in the Siary Zone of the Magura Basin commenced during the late Paleocene and lasted up to the middle Eocene. Quiet sedimentation of shales, mostly from a free fall suspension regime below the CCD, was favorable for the development of agglutinated foraminiferal communities. The Paleocene shales contain characteristic rich assemblages of the *Rzehakina fissistomata* Zone, followed by poor *Recurvoides* and *Glomospira* assemblages of the latest Paleocene and earliest Eocene connected with the LPTM crisis interval. These are followed by post-crisis *Karrerulina* assemblages, as well as assemblages of the *Saccamminoides carpathicus* Zone (Early Eocene) and the *Reticulophragmium amplectens* Zone (middle Eocene). Numerous very thin bentonite layers in the upper variegated shales subdivision of the Łabowa Shale Formation are found. The foraminiferal assemblages from these bentonite intercalations show low taxonomic diversity with numerous juvenile forms and increased numbers of *Glomospira charoides* (Jones & Parker).

Key words: Magura Basin, Łabowa Shale Formation, hemipelagic sedimentation, Late Paleocene–middle Eocene, agglutinated foraminifera

INTRODUCTION

The Łabowa Shale Formation is found within the middle and northern facies-tectonic zones of the Magura Nappe (Bystrica, Rača and Siary zones) in the Northern Outer Carpathians in Poland, Slovakia, and the Czech Republic (Fig. 1). The name "Łabowa beds" was firstly used by Węcławik (1986) with reference to the Paleocene–Eocene variegated shales of the Magura Series – the sedimentary succession of the Magura Nappe. This division was previously described as the "variegated Eocene" (e.g., Kozikowski, 1953) or "variegated shales" (Książkiewicz, 1948, 1951, 1953, 1958, 1962, 1966a, b, 1974a, b; Bieda *et al.*, 1967; Sikora & Żytko, 1959; Unrug, 1968, Węcławik, 1969; Sikora, 1970; Oszczypko, 1973;

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Burtan, 1973a, b; Golonka & Wójcik, 1976, 1978; Cieszkowski, 1992a, b and Kender *et al.*, 2005). In the Czech and Slovak republics the "variegated shales" have been included into the Beloveža Formation (Beloveža beds) as the lower part of this division (e.g., Pesl, 1963; Andrusov, 1965; Leško, & Samuel, 1968; Roth, 1967; Eliaš *et al.*, 1990, Pivko, 2002).

The Łabowa Shale Formation was named by Oszczypko (1991) in his paper presenting the new formal stratigraphy of the Paleogene sedimentary succession of the Bystrica Subunit (Zone) of the Magura Nappe. This lithostatigraphic division of the Magura Series consists of the Paleocene – Eocene variegated shales underlain by the Upper Cretaceous–Paleocene flysch deposits of the Ropianka Formation (Inoceramian beds) or Jaworzynka Formation (biotite facies of the Inoceramian beds), and overlain by the Lower and middle Eocene thin-bedded flysch of the Beloveža Formation. The author has chosen the type section of the discussed formation in Łabowa village in the Beskid Sądecki mountain range. There along the Uhryński Creek one of the best exposures of the Paleogene variegated shales of the Magura Nappe is located. The profile at Żeleźnikowski Stream in Żeleźnikowa village in the Beskid Sądecki has been proposed as the reference section. Others were chosen at Zbludza Stream flowing southward from the Beskid Wyspowy and Zasadne Stream flowing northeastward from the Gorce mountain range, both flowing into the Kamenica Gorczańska River in Kamienica village. Though Oszczypko (1991) focused on the sedimentary succesion of the Bystrica Subunit, in his paper he stated that the Łabowa Formation is widespread in the whole of the Magura Nappe with the only exception being the Krynica Subunit (Zone).

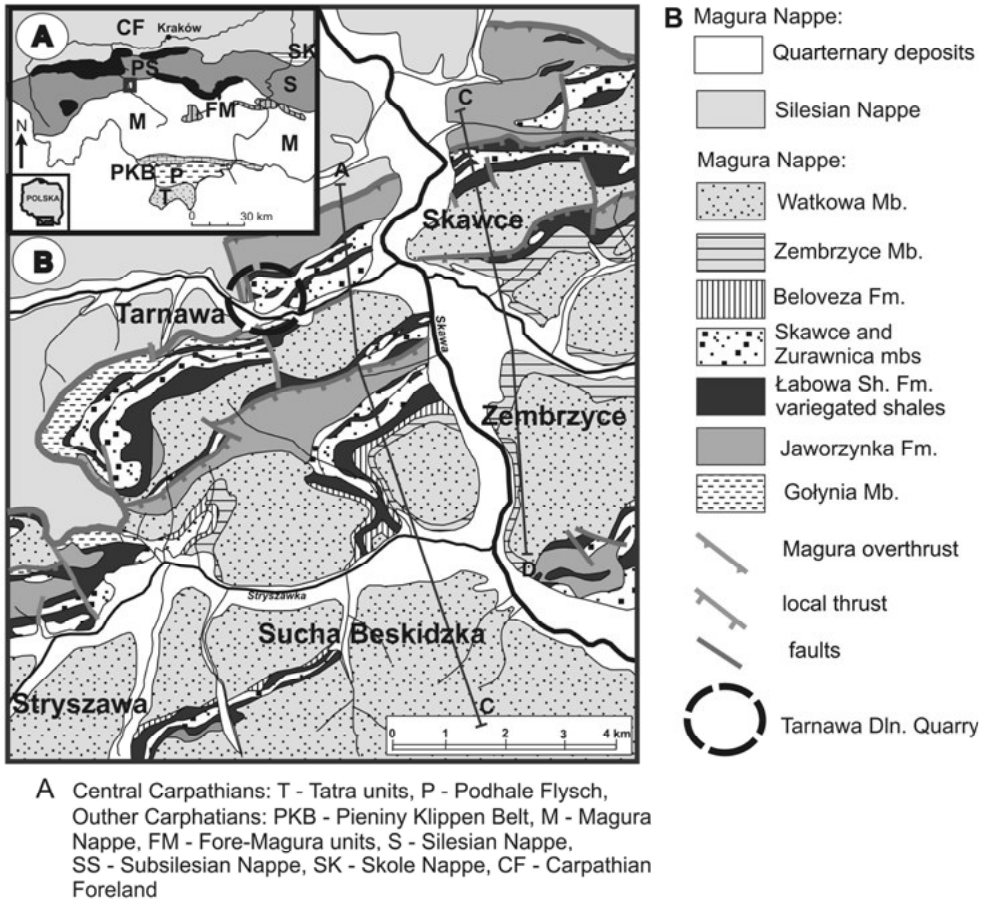

Figure 1. The geological setting of the Tarnawa Dolna quarry profile. **A** – Localization on the West Polish Carpathians tectonic-sketch map. **B** – The geological map of the Sucha Beskidzka area (modified after Książkiewicz, 1974a)

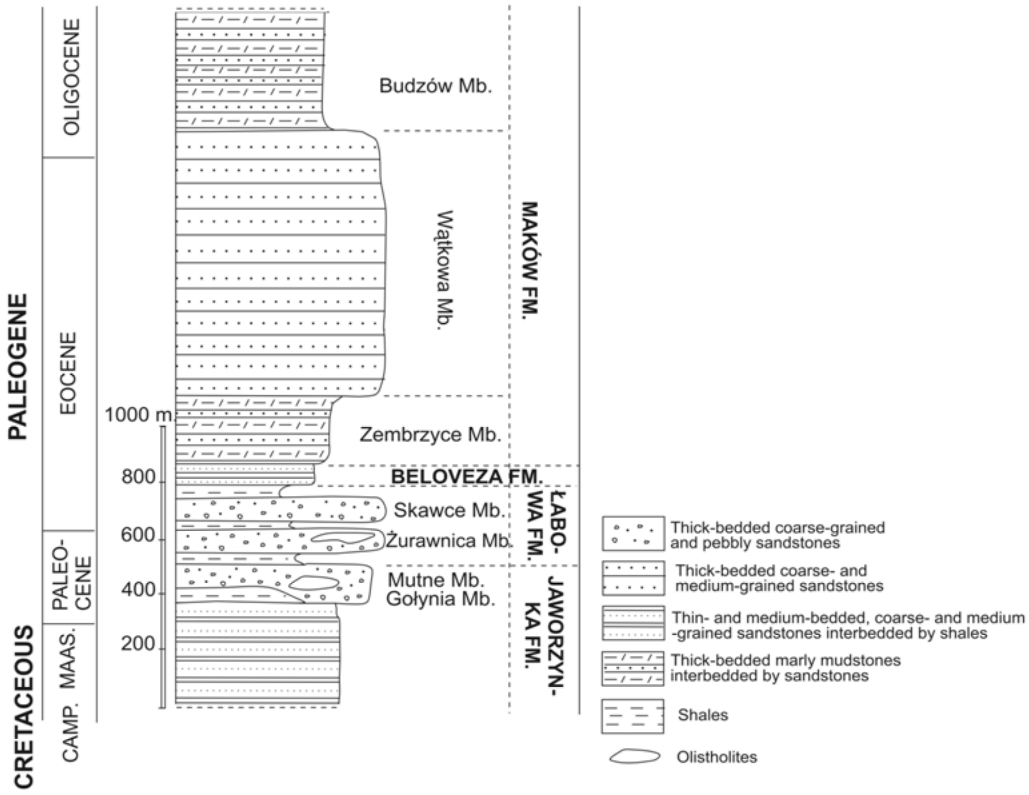

Figure 2. Lithostratigraphic log of the Siary Zone (Magura Nappe) in the Sucha Beskidzka area

Following Oszczypko (1991), the name "Łabowa Shale Formation" has been used in later publications (e.g., Oszczypko, 1992a, b; Oszczypko *et al*., 1999, 2005; Cieszkowski *et al*., 1999; Waśkowska-Oliwa & Malata, 1999; Waśkowska-Oliwa, 2000; Cieszkowski & Waśkowska-Oliwa, 2001). Cieszkowski & Waśkowska-Oliwa (2001) first used the formal name of the discussed lithostratigraphic division to describe the variegated shales from the Siary Subunnit of the Magura Nappe in the Sucha Beskidzka area. They proposed to consider outcrops of the Łabowa Shale Formation exposed in Sucha Beskidzka along the Stryszawka Creek as a further type section. Cieszkowski & Waśkowska-Oliwa (2001) concentrated especially on two of the thick-bedded sandstone levels interbedding the variegated shales and proposed to divide them as a new formal division with the rank of lithostratigraphic members of the Łabowa Shale Formation. The lower level was named the Żurawnica Sandstone Member, and the upper the Skawce Sandstone Member (cf. also: Cieszkowski *et al*., 2006, Cieszkowski & Waśkowska, this volume).

Lithological development of the Łabowa Shale Formation.

In its type area, the Łabowa Shale Formation is represented by clayey, red and cherry-red, noncalcareous, massive shales with intercalations of gray-bluish shales, with very thin-bedded silt-mud couplets, occasionally with very thin sandstone turbidites showing Bouma's Tcd subdivisions (Oszczypko, 1991). In the Sucha Beskidzka area a very similar development of shale complexes of this formation have been noticed, but here thick-bedded sandstone members occur (Fig. 2). In the lower part of the formation, below the Żurawnica Sandstone Member red clayey massive shales dominate. In the middle part between the discussed members and in the upper part above the Skawce Sandstone Member red shales are

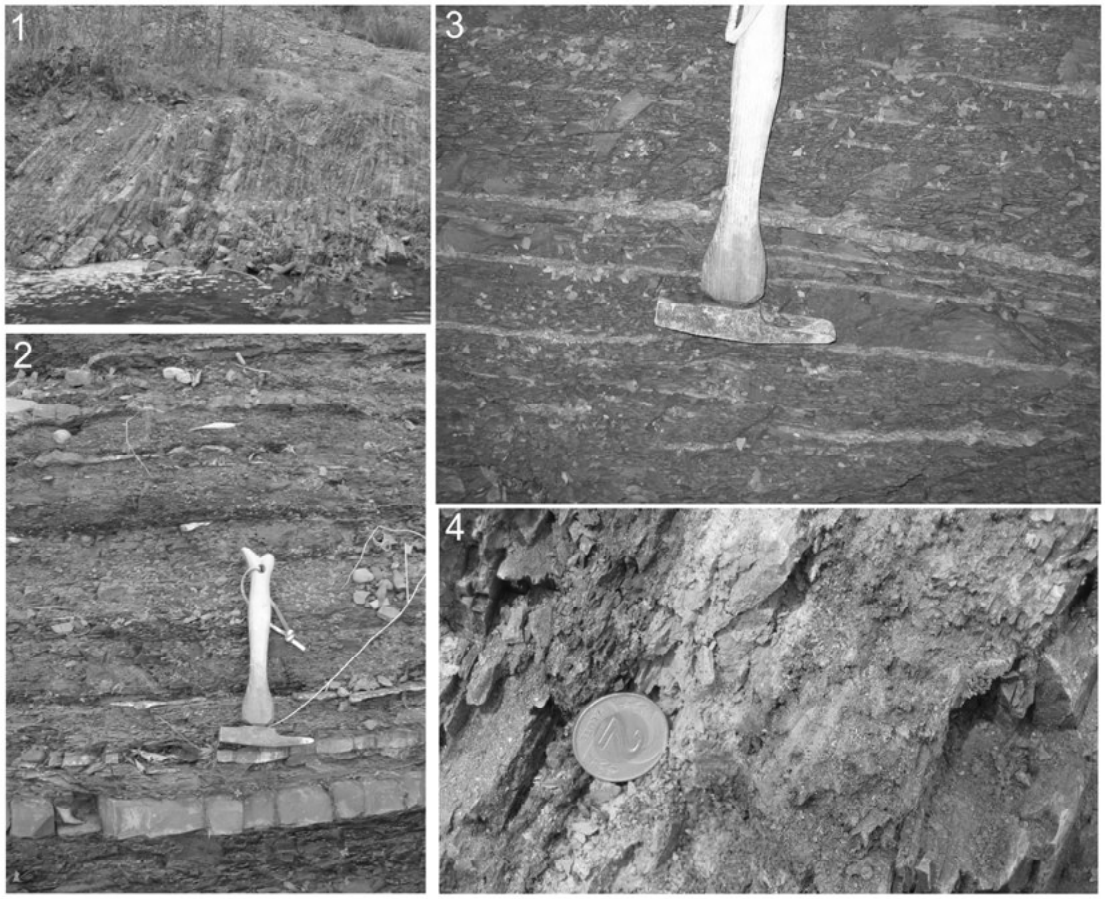

Figure 3. Outcrops of the Łabowa Shale Member – upper part in the Stryszawka section. **1** – General view. **2** – variegated (red, green and gray) shales with sandy intercalations. **3** – Cherry shales with very thin-bedded sandstones. 4 – Zone with bentonite intercalation

intercalated with a different frequency with thin layers of green shales and occasionally by thin- or very thin thin-bedded green quartz-glauconitic sandstones representing the turbidite Tcd subdivisions. Within the Łabowa Shale Formation occasional very thin intercalations of benthonites as well as manganiferous mineralizations have been recorded. In the surroundings of Sucha Beskidzka, this formation is underlain by the Ropianka Formation and overlain by the Beloveža Formation, but often directly by the Zembrzyce Shale Member (Submagura Shales) of the Maków Formation (Cieszkowski & Waśkowska-Oliwa, 2001; Cieszkowski *et al.*, 2006).

Sedimentation of the variegated shales of the Łabowa Shale Formation took place below the CCD, in quiet, hemipelagic conditions comparable to those of an abyssal plane. Occasional activity of low-density turbidite currents took place. Only in the northern part of the Magura Basin in the Siary Zone, an increasing flux of high-density turbidity currents formed two levels of thick-bedded sandstones-the Żurawnica and Skawce sandstone members-that formed a channel-lobe sedimentary system (Cieszkowski & Waśkowska, this volume).

The upper variegated shales of Łabowa Formation

Recently, outcrops of the Łabowa Formation in Sucha Beskidzka formed in the bed and banks of the Stryszawka River (Fig. 3). They are located in the central part of the Sucha Beskidzka, north of the railway station and in the eastern part between the hamlets Kotlinki and Głuszki. The second are

especially well exposed. During last several years, lowering of the erosional base of the river caused removal of aluvial gravels filling the river bed and the deposits of the Magura Series were exposed. Below the bridge in Głuszki at a distance of 0,5 km downriver it is possible to observe variegated shales of the upper part of the Łabowa Formation, folded and cut by a sequence of meso-scale faults. Red clayey massive shales pass up the section into red intercalated by green. Within the massive red shales lamina 1–5 mm thick of bentonites and manganese mineralisations occur. Manganese oxides occur in shales especially in places with intense tectonic fracture density. Traces of malachite have also been noticed. Occasional intercalations of thin- or very thin thin-bedded green quartz-glauconitic sandstones representing turbidite Tcd subdivisions are more frequent in the upper part of the section. In uppermost part of the formation, couplets of several thin-bedded sandstone layers intercalated by gray-green shales developed as a Hieroglyphic bed-like facies are observed.

Upsection, the Łabowa Shale Formation passes into the Beloveža Formation, middle–late Eocene in age, represented by light gray, thin- and medium-bedded, fine grained calcareous sandstones with parallel and cross laminated Bouma (Tbcd and Tcd) sequences, intercalated by gray-bluish marly shales. Thin or medium bedded intercalations of soft, light-gray marls and occasional thin layers of calciturbidites also occur. In one place thick-bedded sandstones of the Skawce Sandstone Member arrive from below the red shales. The contact between the red shales and the sandstones is not normal, but tectonic. The sandstones formed a kind of horst delimited by a few faults.

METHODS

The Łabowa Shale Formation has been studied in detail by the authors during the field investigation carried out in the Sucha Beskidzka area in the last several years. The area was mapped and the sampling for different analyses including also foraminifera. The material for biostratigraphical analysis (in number of 30 samples) was taken from variegated shales from Skawce, Sucha Beskidzka PKP, Grygle, Żurawnica and Błądzonka sections. Usually a few samples were picked from each locality in different parts of the outcropping section of the Łabowa Shale Formation, documenting the lower, middle and upper levels of the variegated shales. Additionally, the upper shales were sampled in more detail, especially the part of the sections containing bentonite intercalations in the Stryszawka section (10 samples from section is described above). The mudstones or muddy siltstone samples (about 0,5 kg) were prepared using standard micropaleontological methods (maceration in Glauber's salt solution, sieving over a 63 μm sieve, picking foraminiferal specimens from residue).

RESULTS

Foraminifera of the Łabowa Shale Formation from Sucha Beskidzka area

The Paleocene–Eocene time interval in the Magura Basin is associated with the sedimentation of variegated shales of the Łabowa Shale Formation (Oszczypko, 1991). The origin of this type of sedimentation is first seen in the Siary Zone, in northern marginal part of the Magura Basin. Later this sedimentation steeply covered other parts of the basin floor. The quiet sedimentation, mostly from free-fall suspension, was favorable for development of foraminiferal communities. Therefore, the Łabowa Shale Formation is known as a micropaleontologically well-documented lithostratigraphic subdivision (e.g., Bieda *et al*., 1967; Geroch *et al*., 1967; Jednorowska, 1966, 1968; Kender *et al*., 2005; Książkiewicz, 1974b; Jurkiewicz, 1967; Malata, 1981; Malata *et al*., 1996). Usually well-preserved, abundant specimens and taxonomically diversified assemblages are known from this deposits. Foraminiferal assemblages contain mainly agglutinated foraminifera, typical for deep water environments below the CCD (Cieszkowski & Waśkowska-Oliwa, 2001; Malata, 2000; Olszewska & Malata, 2006; Waśkowska-Oliwa, 2000), recognized as an autochtonous microfauna.

Deposits of the Late Paleocene–middle Eocene time interval include a complete foraminiferal record. In the lower variegated shale subdivision below the Żurawnica Sandstone Member, this is registered by

Paleocene assemblages with *Rzehakina fissistomata* (Grzybowski) and *Annectina grzybowskii* (Jurkiewicz). Assemblages of the middle variegated shale division are diverse and in stratigraphic order contain assemblages with numerous *Recurvoides*, followed by *Glomospira* and *Karrerulina*, and finally assemblages with *Saccamminoides carpathicus* Geroch. Such a succession of assemblages is connected with uppermost Paleocene to Early Eocene time interval. The Late Paleocene Thermal Maximum (LPTM) had a distinct affect on the composition of the deep water foraminiferal communities (Kennett & Stott, 1991; Miller *et al.*, 1987; Pak & Miller, 1992; Thomas, 1998; Thomas & Shackleton, 1996; Tjalsma & Lohman, 1983; Galeotti *et al.*, 2004). Foraminiferal communities reacted to changes in the deep-water environment caused by the mass extinction of benthic foraminifera. As a consequence, 16 species disappeared in the Magura Basin (Olszewska & Malata, 2006), and post LPTM-crisis assemblages are undifferentiated and dominated by *Glomospira charoides* (Jones & Parker). This oportunistic assemblage gives way to a more varied assemblage with numerous *Karrerulina conversa* (Grzybowski) and *Karrerulina coniformis* (Grzybowski) indicating more favorable life conditions (Bąk, 2004). The assemblages with numerous *Reticulophragmium amplectens* (Grzybowski) and *Reophax pilulifer* Brady are characteristic for the sub division of variegated shales placed in section above the Skawce Sandstone Member and indicate the middle Eocene age of shaly sedimentation. Westward in the Myślenice area, a single *Ammodiscus latus* Grzybowski was found in this upper division of variegated shales.

Foraminiferal record of the Łabowa Shale Formation (upper subdivision) in Stryszawka creek-*reference section*

The uppermost variegated shale subdivision of the Łabowa Formation is well exposed in the banks of Stryszwka creek in Stryszawa village. The foraminiferal assemblages from this locality are typical for the *Reticulophragmium amplectens* biozone (zones after Olszewska, 1997) and contain only agglutinated cosmopolitan deep-water forms. The index taxon is numerous and occurs together with *Ammodiscus* div. sp., *Ammolagena clavata* (Jones & Parker), *Bathysiphon* spp., *Glomospira* div. sp., *Karrerulina conversa* (Grzybowski), *Recurvoides* div. sp. and *Thalmannammina subturbinata* (Grzybowski), *Reophax pilulifer* Brady, and numerous *Pseudonodosinella elongata* (Grzybowski), *Paratrochamminoides* div. sp. (*P. subcoronatus* (Grzybowski)-common), *Rhabdammina*, *Haplophragmoides walteri* (Grzybowski), *Placentammina placenta* (Grzybowski), *Haplophragmoides kirki* Wickenden, *Cribrostomoides subglobosus* (Cushman), *Subreophax pseudoscalaris* (Samuel), *Karrerulina coniformis* (Grzybowski), and *Eggerella propinqua* (Brady). As additional components radiolaria and single fish teeth were found there. Rich and diversified assemblages developed in Magura Basin during slow deposition. The sedimentation rate is estimated to be on the order of 15-20m/mln years (Oszczypko & Oszczypko-Clowes, 2006).

In the Łabowa Shale Formation (upper shale subdivision) numerous epifaunal species *Ammolagena clavata* (Jones & Parker) attached to foraminiferal tests were found. Specimens of *Ammolagena clavata* are observed with foraminifera belonging to epifaunal *Rhabdammina*, *Ammodicus*, and *Paratochamminoides*, as well as it is attaching to some infaunal tests e.g., *Reticulophragmium*, *Reophax*, *Recurvoides* and *Karrerulina*. Probably *Ammolagena clavata* settled on infaunal tests (dead foraminifera) exposed on the surface of sediment (Kaminski *et al.*, 2009), during conditions of minimal delivery of sedimentary material depositing on the basin floor.

The low sedimentation rate was favourable for the deposition of bentonites, and intercalations of thin bentonite layers are observed within the variegated shales of the Łabowa Formation. These are connected with volcanic activity that produced volcanic ash falling to the sea floor in Eocene times. The upper variegated shales sub division contains the most numerous bentonite layers. Deposition of bentonite in the deep water of basin is reflected by very low supply of clastic material, consequently pyroclastics were not diluted by terrigenous material. Reduced foraminiferal assemblages were

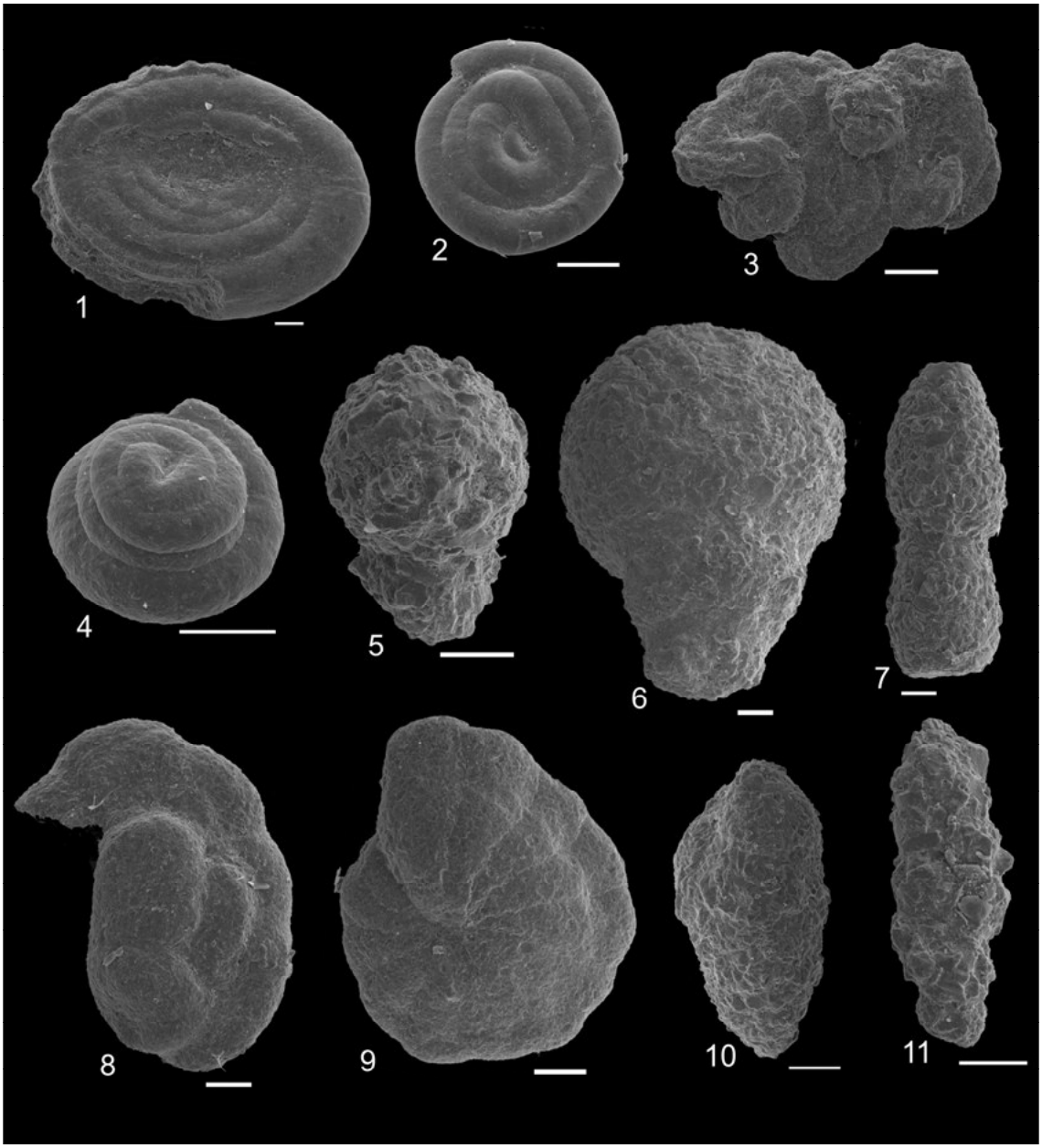

Plate 1. Foraminifera from the Łabowa Shale Formation (upper subdivision) in the Stryszawka section. **1** – *Ammodiscus cretaceus* (Reuss). **2** – *Glomospira gordialis* (Jones & Parker). **3** – *Glomospira glomerata* (Grzybowski). **4** – *Glomospira charoides* (Jones & Parker). **5** – *Reophax duplex* Grybowski. **6** – *Reophax pilulifer* Brady. **7** – *Pseudonodosinella elongata* (Grzybowski). **8** – *Paratrochamminoides heteromorphus* (Grzybowski). **9** – *Reticulophragmium amplectens* (Grzybowski). **10** – *Karrerulina coniformis* (Grzybowski). **11** – *Karrerulina conversa* (Grzybowski). Scale bar – 100μm

observed in samples taken from benthonite layers. Usually dwarfed foraminifera with low taxonomic diversity and numerous juvenile forms (especially many specimens of *Reticulophragmium amplectens* (Grzybowski)), with an increased number of *Glomospira charoides* (Jones & Parker) were observed. This type of assemblage is known as a crisis assemblage, reflecting local short-term environmental changes, and were observed in Lower Eocene bentonites of the Subsilesian Sedimentary Zone in the Outer Carpathians (Waśkowska, 2011).

In mudstone intercalations, a low diversity assemblage (represented by a few species only) is observed, with dominant *Reticulophragmium amplectens* (Grzybowski) and *Reophax pilulifer* Brady, occasionally rich *Karrerulina conversa* (Grzybowski). Generally the infaunal group dominates. Typical for this assemblage is the occurrence rather large-size specimens with coarse-grained tests and a lack of fragile foraminifera. This community reflects variable sedimentary conditions during the Łabowa Shale deposition and represents episodes with an increased supply of clastic material to the floor of the Magura Basin during the middle Eocene. Then, the barren samples with no microfauna correspond with intervals when the sea floor was not recolonized after a catastrophic higher energy turbidic flow. In the uppermost part of the Łabowa Formation the thin-bedded sandstone intercalations occur more frequently (Waśkowska-Oliwa, 2000).

CONCLUSIONS

In the Sucha Beskidzka area, the Łabowa Shale Formation is interbedded by two relatively thick sandy complexes. They subdivide the section of variegated shales to three levels: lower, middle and upper. The sedimentation of the Łabowa Shale Formation lasted from the late Paleocene (Rzehakina fissistomata zone – uppermost part) up to the middle Eocene (Reticulophragmium amplectens zone). The results of the global LPTM event are recorded in the middle variegated shales, though the sequence of *Recurvoides*, *Glomospira*, *Karrerulina* associations and assemblages are characteristic for Saccamminoides carpathicus zone. Low sedimentation rate during the deposition of the Łabowa Formation is reflected in sedimentary features of the sediments, especially in bentonites. It is likewise reflected in the very rich and taxonomically diversified foraminiferal assemblages and particularly numerous specimens of *Ammolagena clavata* Jones & Parker attached to the infaunal tests of other foraminifera. Detail sampling shows that environmental conditions during the Łabowa Shale Formation sedimentation were variable. Foraminiferal communities existing on the floor of the Magura Basin were subjected to numerous crises. Each episode (e.g., connected with the deposition of dilute pyroclastic material or a smalll amount of sandy material) modified the taxonomical structure of the assemblages.

ACKNOWLEDGEMENTS

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