COMPOSITION AND STRATIGRAPHY OF AN OLISTOSTROME COMPLEX IN THE EOCENE DEEP-SEA DEPOSITS OF THE MAGURA NAPPE (OUTER CARPATHIANS, POLAND)

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Abstract: Within the Eocene turbidites of the Rača Zone of the Magura Nappe, a middle Eocene olistostrome complex approximately 200 m thick is present, containing redeposited middle Eocene, lower Eocene, and Paleocene deep-sea basinal deposits, as well as blocks of shallow-marine middle Eocene limestones and igneous rocks. It forms part of a large olistostrome horizon. The olistostrome originated through a series of individual gravitational slope failures. The displaced deposits occur in packets, separated by regular turbiditic deposits. In three sections, the following depositional units were identified: (1) a package of sedimentary mélange with blocks of metagabbro, serpentinite, and limestone; (2) a package of deformed turbidites; and (3) a package with olistoplaques of shales and marls, containing blocks of granitoid and limestone. The source area was located in the northern part of the basin and included a carbonate platform and basin slope. The material underwent relatively brief gravitational transport during the Bartonian. The age of the olistostrome was established on the basis of foraminifera: the *Haplophragmoides* acme and *Praesphaerammina subgaleata* (Vašíček) acme and Eocene marker taxa, e.g., *Reticulophragmium amplectens* (Grzybowski), *Ammodiscus latus* Grzybowski forma *ovoidalis,* as well as Eocene species of *Subbotina* and *Acarinina*. This olistostrome is one of several large ones that developed in the Carpathian part of the Tethys at that time.

Key words: Subaqueous mass movement, Bartonian, sedimentary mélange, biostratigraphy, Beloveža Formation.

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INTRODUCTION

Towards the end of the last century, systematic research began on the identification and description of olistostromes and olistoliths in the Polish Outer Carpathians (e.g., Książkiewicz, 1958; Unrug, 1968; Malik and Olszewska, 1984; Słomka, 1986, 2001; Cieszkowski, 1992; Bromowicz, 1998; Bubík *et al.,* 2000; Olszak, 2006; Jankowski, 2007, 2015; Cieszkowski *et al.,* 2009, 2012, 2017; Ślączka *et al.,* 2012; Waśkowska and Cieszkowski, 2014; Golonka *et al.,* 2015, 2022; Hnylko and Hnylko, 2016, 2019; Strzeboński *et al.,* 2017; Siemińska *et al.,* 2020; Hnylko *et al.,* 2021; Woyda *et al.,* 2023). These studies demonstrated that deposits, resulting from subaqueous mass movements, constitute a significant component of the Carpathian rocks and that sliding, which leads to slope stabilisation, is a typical process, accompanying the development of marine basins. Additionally, the motivation for detailed geological investigations of the Magura Nappe in the vicinity of Osielec Village prompted Cieszkowski (Cieszkowski *et al.,* 2017) to search for the olistolith of the ophiolite block described by Wieser (1952). During geological mapping of the Osielec area, a new outcrop, containing large blocks of metagabbro and smaller blocks of serpentinite, was discovered (Kysiak, 2010; Cieszkowski *et al.,* 2017; Gawęda *et al.,* 2021) and observations of the associated deposits were made. Field observations revealed the presence of a sedimentary mélange, consisting of debris flow deposits and chaotically deformed flysch layers, which encouraged the authors to increase their geological knowledge of the Osielec area, the olistostromes, and olistoliths present, and to produce a new detailed geological map of the area (Cieszkowski *et al.,* 2017). Olistoliths of igneous rocks were identified and subjected to separate analyses (Anczkiewicz *et al.,* 2016; Cieszkowski *et al.,* 2017; Gawęda *et al.,* 2019, 2023).

The primary objective of this paper is to characterise the structure, boundaries, and components of the Osielec olistostrome, as well as to determine the age of these subaqueous mass movements. This research continues the studies, initiated in this area by our friend and mentor, the late Marek Cieszkowski.

GEOLOGICAL SETTING

Osielec Village is situated on the boundary between the Maków Beskid Mountains and the Żywiec-Orava Beskid Mountains (Solon *et al.,* 2018). Geologically, it lies within the Outer Western Carpathians (Książkiewicz, 1977). The Outer Carpathians are predominantly composed of flysch rocks, deposited by turbidity currents in marine basins of the Northern Tethys from the Late Jurassic to the Miocene (e.g., Koszarski *et al*., 1974; Książkiewicz, 1977; Ślączka *et al.,* 2006; Golonka *et al.,* 2019, 2021, and references therein). These deposits were folded, detached from their original position, and thrust over the margin of the North European Platform, forming nappes that are now part of the orogen. The principal tectonic activity occurred during the Miocene, although prior to this, it was associated with the development of an accretionary prism.

The study area is located within the Magura Nappe, the innermost nappe of the Polish Outer Carpathians (Fig. 1). Due to its facies-tectonic differentiation, this nappe has been subdivided into four subunits; from south to north, these are the Krynica, Bystrica, Rača, and Siary subunits (Koszarski *et al.,* 1974). Olistostrome deposits of Late Cretaceous to late Eocene age have been identified within the Rača Subunit in the study area (Fig. 2). The sedimentary rocks, composing the Rača Subunit, belong to the Ropianka, Łabowa, Beloveža, and Magura formations. The Ropianka Formation (Campanian–Paleogene, thickness 100 m) consists of thin- to medium-bedded sandstones, interbedded with shales. Palaeocurrent measurements from flute marks at the base of the sandstone beds indicate transport from the east. The Łabowa Formation (uppermost Paleocene–lower Eocene, thickness 60 m) comprises shales, predominantly red, occasionally interbedded with greenish shales, collectively referred to as variegated shales (Fig. 3). These shales are intercalated with grey-greenish, glauconitic, fine-grained, thin- to very thin-bedded sandstones, the proportion of which increases upwards in the upper part of the formation. The Beloveža Formation (lower–middle Eocene, thickness 500 m), also known as the Hieroglyphic Beds in older literature, consists of thin- to medium-bedded shale-sandstone turbidites with a predominance of shales. The sandstones are grey-greenish, fine-grained, and exhibit numerous trace fossils and mechanoglyphs on the soles of beds. They are quartzose, with subordinate feldspar, muscovite, and glauconite (Cieszkowski *et al.,* 2017). The cement is siliceous-clayey or siliceous-carbonatic. Shales are greyish-greenish grey or dark grey. Mechanoglyphs (flute marks) indicate material transport from the east, with some layers suggesting transport from the NNE. In the lower part of the Beloveža Formation, the Pasierbiec Member (middle Eocene, thickness 350 m) is present (Figs 2, 3; division according to Golonka and Waśkowska, 2012). It comprises thick-bedded and very thick-bedded sandstones, conglomeratic sandstones, and conglomerates with granules, pebbles, and occasionally cobbles, irregularly intercalated with thin- to medium-bedded sandstone-shale deposits of the Beloveža Formation lithotype and, occasionally, marls of the Łącko Marl lithotype (Książkiewicz, 1966; Oszczypko, 1991; Fig. 4A–C). The sandstones are quartzose, with admixtures of feldspar, muscovite, and glauconite, and with carbonate cement (Książkiewicz, 1966). In the conglomerates, lithoclasts of organogenic limestones, single large foraminifera, siliceous sedimentary rocks, mudstones, claystones, sandstones, igneous rocks, and various metamorphic rocks occur among quartz grains (Cieszkowski *et al.,* 2017; Figs 4B–E, 5A–D). Flute marks in the conglomerates

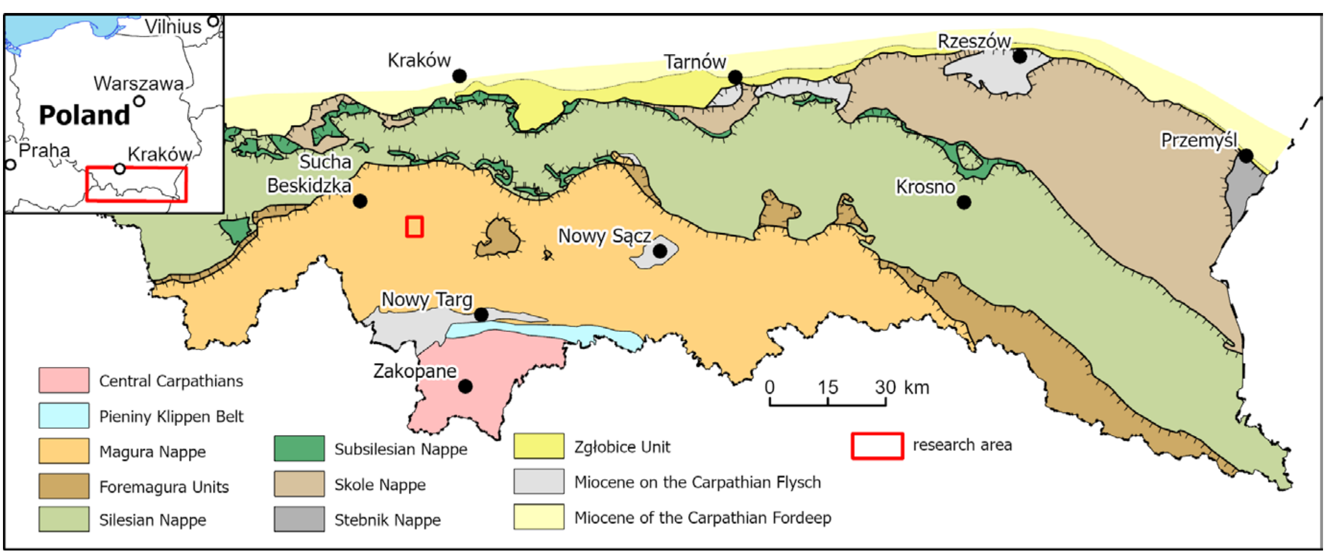

Fig. 1. Geological sketch map of the Polish sector of the Outer Carpathians (after Cieszkowski *et al*., 2017).

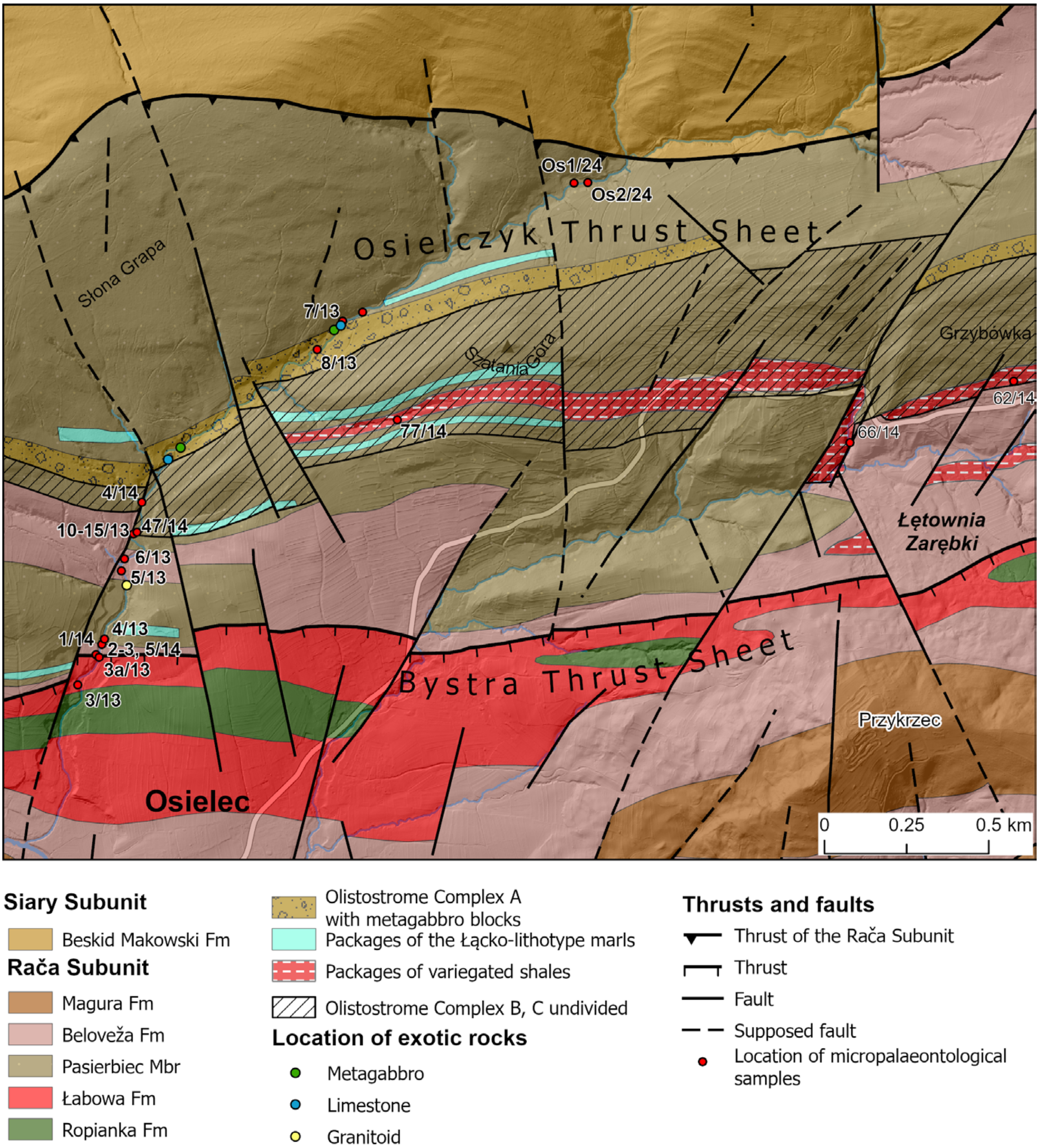

Fig. 2. Geological map of the Osielec area (after Cieszkowski *et al.*, 2017, modified).

indicate transport from the N, NNW, and NNE. The Magura Formation (upper Eocene–Lower Oligocene) comprises thick-bedded sandstones interbedded with shales. The sandstones are grey, light grey, or bluish-grey, massive, fine- to medium-grained, with parallel and cross-lamination in the upper parts of beds. They are dominated by quartz, with subordinate feldspars, muscovite, chlorite, and less frequent biotite, as well as clasts of volcanic rocks, pelitic rocks, and occasional coal grains (Cieszkowski *et al.,* 2017). The cement is carbonate or siliceous-carbonate, with an admixture of clay. The shales are represented by calcareous greenish-grey and brownish-grey siltstones or sandy siltstones. Palaeocurrent indicators show material transport from the SE and ESE.

In the Osielec area, two subunits of the Magura Nappe are present: the Siary Subunit, which forms only the northern marginal part of the study area, and the Rača Subunit. Within the Rača Subunit, Cieszkowski *et al.* (2017) distinguished two thrust sheets: the southern Bystra Thrust Sheet and the northern Osielczyk Thrust Sheet (Fig. 2). These

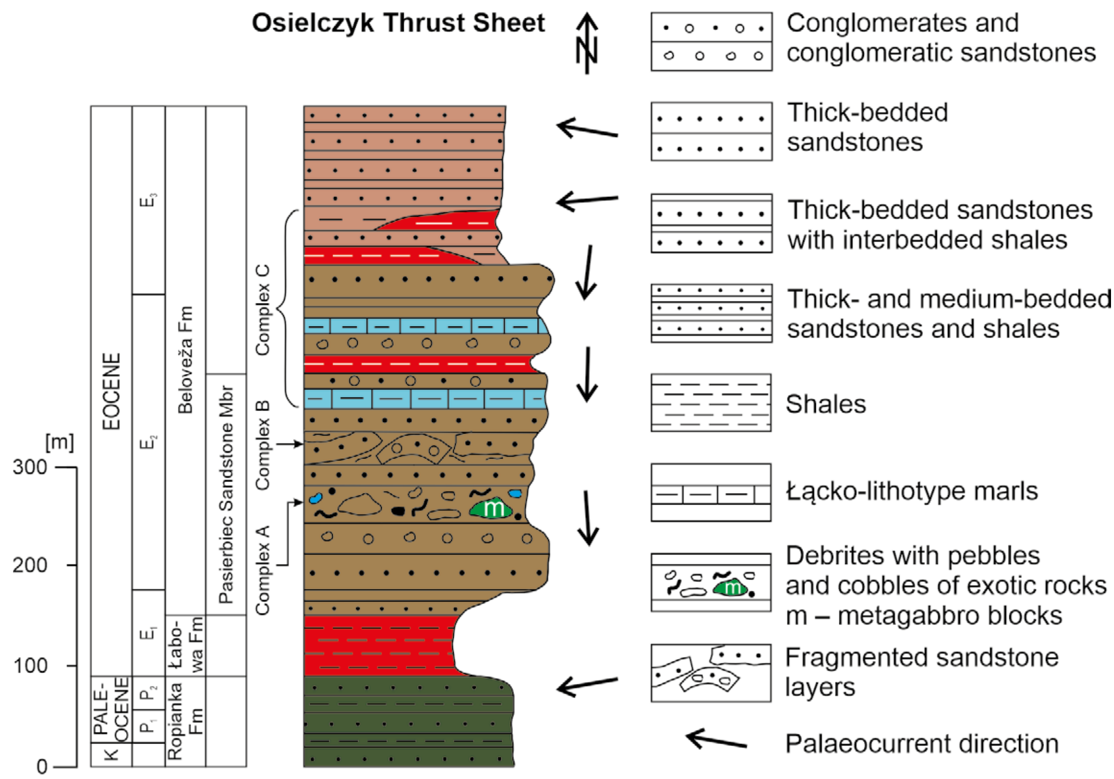

Fig. 3. Lithostratigraphic log of the Magura Nappe in the Osielec area (after Cieszkowski *et al.*, 2017, modified).

sheets exhibit significant differences in geological structure. Within the Osielczyk Thrust Sheet, the Grzybówka Anticline, moderately inclined northward, is present. Its core is composed of the Pasierbiec Member, enclosing the olistostrome. In its limbs, thin- to medium-bedded deposits of the Beloveža Formation and packages of variegated shales of the Łabowa Formation facies are found. In the north, the anticline is tectonically reduced and thrust over deposits of the Siary Subunit. In the southern part of the Osielczyk Thrust Sheet, the irregular Wronkówki Syncline is located (Cieszkowski *et al.,* 2017), with the Beloveža Formation deposits in its core. The southern Bystra Thrust Sheet is thrust over the northern Osielczyk Thrust Sheet. Strike-slip and oblique faults form a system, oriented N–S, NNW–SSE, NNE–SSW, and close to NW–SE and NE–SW (Cieszkowski *et al.,* 2017).

MATERIAL AND METHODS

The study was conducted, using traditional geological mapping techniques. During fieldwork, tectonic and lithological documentation of the olistostrome and its surroundings were carried out, along with sampling for biostratigraphic analysis. Detailed lithological descriptions, logging of continuous sections, measurements of layer bedding, and recording of point locations, using global navigation satellite systems, were carried out. Field data were supported by GIS methods, based on digital elevation model analyses in ArcGIS Pro (Cieszkowski *et al.,* 2017; Szczęch and Cieszkowski, 2021; Kania and Szczęch, 2023). All data were stored in a geodatabase.

To determine the age of the olistostrome, biostratigraphic studies, based on foraminifera, were conducted. Twenty-two samples were collected from mudstones and claystones (Tab. 1), and were subjected to maceration and washing. Maceration involved mechanical disintegration of the samples through crystallisation of Glauber's salt, achieved by repeatedly heating and cooling approximately 500 g of rock in a Na_2SO_4 solution. The macerate was then washed through 63 µm sieves to remove the finest-grained fraction, and the residue was dried. All foraminiferal tests were manually selected from the residue and placed in microslides. This material was subjected to taxonomic identification, using a Nikon VL 100POL binocular microscope with a Digital SIGHT DS-Fil camera, and documented, using an FEI QUANTA 200 FEG scanning electron microscope. Fifteen thin sections were prepared from hard rocks in the laboratory of the Faculty of Geology, Geophysics and Environmental Protection at the AGH University (FGGEP AGH). These were analysed and documented, using a Nikon Eclipse LV100 POL microscope. Analytical work was conducted at the Department of General Geology and Geotourism at FGGEP AGH, where the thin sections were deposited. Taxonomical determinations were made, using original and emended descriptions of taxa and subsequent diagnostic characteristics, e.g., Berggren and Pearson, 2005; Gawor-Biedowa et al., 1984; Holbourn *et al.*, 2013; Kaminski and Gradstein, 2005; Kaminski *et al.*, 1993; Olsson et al., 2006; Olszewska *et al.*, 1996; Waśkowska *et al.*, 2020). The palaeontological material from the washed samples was transferred and deposited at the European Micropalaeontological Reference Centre of the Micropress Europe Micropalaeontological Foundation.

Table 1

Distribution of foraminifera taxa in the samples from displaced deposits and the materials around them at Osielec (positions of samples are marked in Figure 2).

Sample no.	33/14	3/14	47/14	62/14	77/14	66/14	15/13	14/13	4/13	13/13	12/13	11/13	10/13	8/13	7/13	6/13	5/13	2/14	4/14	1/14	Os1/24	Os2/24
Benthonic foraminifera																						
Ammodiscus latus Grzybowski forma *ovoidalis* Waśkowska et Kaminski									I													
Ammobaculites agglutinans (d'Orbigny)				I																		
Ammodiscus cretaceus (Reuss)				I						I	I					I		I		I		
Ammodiscus pennyi Cushman et Jarvis																I						
Ammodiscus peruvianus Berry	I				I	I			V							I				Z		
Ammodiscus tenuissimus Grzybowski									V		X									I		
Ammodiscus sp. 1	X	Z		I		I																
Ammodiscus spp.						I			I							I				I		
Ammogloborotalia aff. *subvesicularis* (Hanzlikova)				I					I													
Annectina biedai Gradstein et Kaminski		X														I				I		
Annectina grzybowskii (Jurkiewicz)				X																I		
Ammolagena clavata Jones et Parker									I	I												
Ammosphaeroidina pseudopauciloculata (Mjatliuk)		X		I		I	X	I	I	V		I	I						I	V		I
Bathysiphon div. sp. and *Nothia* div. sp. (fragments)	L	L	X	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	V	Z
Buzasina pacifica (Krasheninnikov)									I	I										I		
Caudammina ovulum (Grzybowski)												I				I						
Chillostomelloides ovicula (Nuttall)							I								I							
Cribrostomoides sp.									I							X				I		
Cystammina sp.																I						
Dentalina/Nodosaria spp.														V								
Dolgenia sp.				I					V							X				I		
Eggerella propinqua (Brady)									V							I						
Glomospira charoides (Jones et Parker)	L	L		Z	Z	L			V						I	I				V		
Glomospira glomerata (Grzybowski)	I																			I		
Glomospira gordialis (Jones et Parker)		V		I		I			I	I		I								X		
Glomospira ex gr. *irregularis* (Grzybowski)	I	X														I						
Glomospira serpens (Grzybowski)					I															I		
Glomospira sp. 1				I							I					X						
Haplophragmoides kirki Wickenden							I	I	I	X						I				I		
Haplophragmoides horridus (Grzybowski)										I												
Haplophragmoides nauticus Kender, Kaminski et Jones												X				X						
Haplophragmoides parvulus Blaicher							I	I	I	V						I			I		I?	
Haplophragmoides stomatus (Grzybowski)		X							I	I	I	X										
Haplophragmoides walteri (Grzybowski)				I	I				Z	V	Z	X	X		I	Z			X	I		I
Haplophragmoides sp.							X		I	V						I						
Hormosina trinitaensis Cushman et Jarvis (chambers)									V													
Hormosina velascoensis (Cushman)																				I		
Hormosina sp.							I									I						

Sample no.	33/14	3/14	47/14	62/14	77/14	66/14	15/13	14/13	4/13	13/13	12/13	11/13	10/13	8/13	7/13	6/13	5/13	2/14	4/14	1/14	Os1/24	Os2/24
Hyperammina elongata Brady																I						
Hyperammina sp.				I																		
Kalamopsis grzybowskii (Dylążanka)				I		I														I		
Karrerulina coniformis (Grzybowski)				I	I	I			X										I			
Karrerulina conversa (Grzybowski)	X			I	V	I			V							I		I		X		
Karrerulina horrida (Miatlyuk)				I																		
Lenticulina sp.										I												
Nodosarella cf. *subnodosa* (Guppy)																		I				
Nodosaria monile (Hagenow)														I								
Paratrochamminoides/Trochamminoides div. sp.	V	X		V	L	V	I		V	X	X	I	I		V	L				V		X
Placentammina placenta (Grzybowski)	V	X		I			I		I	I				I						X		
Popovia beckmanni (Kaminski et Geroch)																I						
Praesphaerammina gerochi Hanzlikova																I						
Praesphaerammina subgaleata (Vašíček)							L	L								I			I			
Psammosphaera irregularis (Grzybowski)																I						
Pseudonodosinella elongata (Grzybowski)										I						I				I		
Pseudonodosinella nodulosa (Brady)	X									I	I	I				I			I			
Pyramidulina obscura (Reuss)														I								
Rhabdammina and *Psammosiphonella* div. sp. (fragments)	V	L		V	L	Z	Z			V	I				V	L				V		Z
Recurvoides div. sp. and *Thalmannammina subturbinata* (Grzybowski)	V	X		V	V	V	I	X	L	L	Z		I		X	V			V	L		I
Reophax guttifer (Brady)																						
Reophax duplex Grzybowski					I											I				I		
Reophax imitator Finaly					I																	
Reophax sp.				I																		
Reophax sp. – chambers				X															I	I		
Reticulophragmium amplectens (Grzybowski)				I										I		I			I	I		
Reticulophragmium sp.										I												
Rzehakina epigona (Rzehak)																				I		
Saccamina grzybowskii (Schubert)				I		I			X							I						
Spiroplectammina spectabilis (Grzybowski)																				I		
Spiroplectammina sp.				I																		
Subreophax scalaris (Grzybowski)	I					I						X				X				X		
Subreophax pseudoscalaris (Grzybowski)				I					I	I					I							
Subreophax spp.				I																		
Trochammina sp.				I					I	I						I						I
Trochammina umiatensis Tappan																I						
Planktonic foraminifera																						
Acarinina bullbrooki (Bolli)										I												
Acarinina boudreauxi Fleisher														I								
Acarinina primitiva (Finlay)																						
Subbotina cf. *gortanii* (Borsetti (mould)															I							
Subbotina corpulenta (Subbotina)										I												
Subbotina eocaena (Guembel)										I												
Subbotina linaperta (Finlay)										I												
Subbotina spp.										I				I								

Sample no.	33/14	3/14	47/14	62/14	77/14	66/14	15/13	14/13	4/13	13/13	12/13	11/13	10/13	8/13	7/13	6/13	5/13	2/14	4/14	1/14	Os1/24	Os2/24
Other fossils																						
fish teeth		X		X		X			I						V	I				I		
sponge spicules									+													
Radiolaria	V	L		X	L	V			+	I												
otoliths															I							
Echinoidea spines										+				+								

I: 1–4 specimens
X: 5–9 specimens
V: 10–19 specimens
Z: 20–49 specimens
L: 50 and more specimens
+: present in the sample

Age analyses were based on occurrences of diagnostic agglutinating foraminifera, and if they were present in the samples, also planktonic foraminifera, whose ranges were calibrated indirectly with other biostratigraphic data, i.e., nanoplankton, planktonic foraminifera, dinoflagellates, or directly with isotopic data, magnetostratigraphy or polarity.

RESULTS

Lithology

The succession of olistostrome deposits occurs within the lower part of the Beloveža Formation. It was identified in the Osielczyk valley section (GPS coordinates: base: N 49°41′10″, E19°45′41″; top: N49°41′30″, E19°48′45″; Figs 2, 3).

It comprises several packages of mass-transport deposits, separated by complexes of thick-bedded conglomeratic Pasierbiec Member in their normal position. In the uppermost part of the displaced deposits, thin- to medium-bedded shaly-sandy turbidites of the Beloveža Formation are present. Three olistostrome complexes are distinguished on the basis of their structure and composition within the succession.

A. The lowermost unit, approximately 30 m thick, contains dispersed blocks of metagabbro, serpentinite, and nummulitic-algal limestone, within a matrix of strongly plastically deformed, squeezed sandy mudstone, grey and greenish in colour, calcareous or non-calcareous, locally with red mudstone streaks (Fig. 4E). Due to poor exposure, the matrix characteristics are based on limited outcrops. The matrix contains sand and shales with pebbles and blocks of various rock types, including fine-grained sandstones, limestones, rounded quartz, fragments of metamorphic shales, and blocks of magmatic and carbonate rocks. The gabbro and serpentinite blocks, ranging from 10–350 cm in size, are poorly rounded. The organodetritic limestone blocks range from 10–80 cm in diameter and exhibit medium roundness. They are grainstones with large foraminifera, algal debris, rhodoliths, corals, bryozoans, and mollusc shells. This complex is overlain by a series of thick- to very thick-bedded conglomerates and gravelly sandstones with clasts, up to 20 cm in diameter and averaging 1–5 cm. Palaeotransport directions inferred from flute casts indicate material delivery from the north.

B. The second complex, also approximately 30 m thick, consists of mélanges of fractured packages of thin- to medium-bedded sandstones of the Beloveža Formation lithotype, rich in trace fossils, and fragments of thick sandstone beds of the Pasierbiec Member type, within a mudstone matrix (Fig. 5E–H). These chaotic deposits transition upwards into a complex of thin- to medium-bedded turbidites of the Beloveža Formation lithotype, deformed to varying degrees. Among these deformed turbidites, grey and green muddy deposits are locally squeezed together with red non-calcareous shales, brownish shales, and bluish and creamy mudstones. The proportion of bluish-creamy mudstone deposits increases towards the upper part of the complex. Palaeocurrent directions, measured from flute marks, indicate material delivery from the N, NNE, and NNW. Calcite veins are abundant in cracks. In places, the olistostrome extends into the lower part of the Beloveža Formation.

C. The third complex, approximately 150 m thick, occurs in the upper part of the Pasierbiec Member and in the lower part of the thin-bedded turbidites of the Beloveža Formation. It comprises deposits of the Pasierbiec Member and overlying thin-bedded turbidites of the Beloveža Formation, containing several packages with significant lateral extent, consisting of older variegated shales and grey marls, in the form of olistoplaques (Fig. 6C–E). The thickness of individual packages ranges from 1 to 10 m, with sharp boundaries. Their orientation aligns with the bedding of the Beloveža Formation deposits. These packages are not significantly internally deformed and preserve original sedimentary structures, such as laminations. The variegated shales consist of alternating red, green, and grey mudstone shales with occasional thin, fine-grained sandy beds, resembling the variegated shales of the Łabowa Formation. The marls are grey, pelitic, massive, and rarely exhibit parallel lamination, corresponding to the Łącko Marl lithotype (Cieszkowski *et al.,* 2017). Single angular, non-rounded blocks of pinkish granitoid (Fig. 6A), approximately 100 cm in diameter, and subangular to subrounded, grey pelitic limestone blocks (Fig. 6B), approximately 40 cm in size, are present in this complex.

The complex of displaced deposits is overlain by regular deposits of the Beloveža Formation (Fig. 6F).

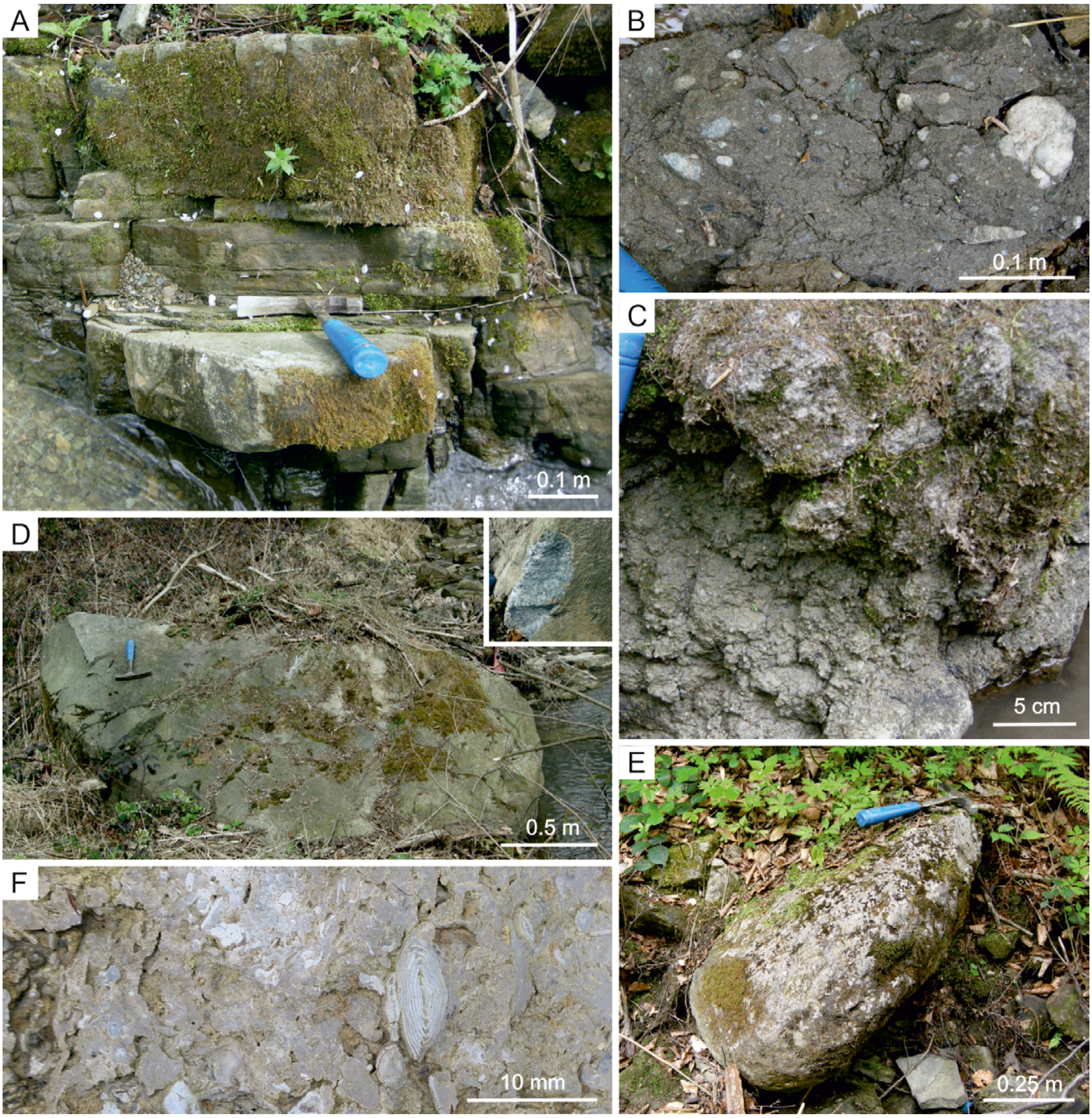

Fig. 4. Outcrops of the deposits of the Magura Nappe and clasts of exotic rocks in the study area. **A.** Pasierbiec Member – sandy facies (below olistostrome). **B, C.** Debrite in complex A. **D.** Ophiolite boulder. **E.** Organodetritic limestone boulder. **F.** Fragment of organodetritic limestone boulder.

BIOSTRATIGRAPHY

The biostratigraphic analysis is based on the foraminifers from 22 collected samples. The determined taxa are well-documented in the literature, which is cited in the Supplementary Material and was used as a basis for their identification.

Deposits below and above the olistostrome complexes

Three samples (nos. 1/14, Os1/24, Os2/24) were collected from deposits, underlying the olistostrome complexes. Sample no. 1/14 was taken from green mudstones of thin-bedded turbidites in the lowermost exposed part of the Beloveža Formation (Fig. 2). It contains a mixed assemblage, including Maastrichtian–Paleocene species, such as *Annectina grzybowskii* (Jurkiewicz), *Rzehakina epigona* Rzehak, and *Hormosina velascoensis* (Cushman), together with Eocene species, such as *Reticulophragmium amplectens* (Grzybowski) (Tab. 1). The youngest component, determining the age of the deposits, is *Reticulophragmium amplectens*, which was common in the Outer Carpathians during the middle Eocene and first appears in the uppermost Ypresian (Jurkiewicz, 1967; Jednorowska, 1968; Morgiel and Olszewska, 1981; Waśkowska, 2011, 2021; Waśkowska *et al.,* 2020).

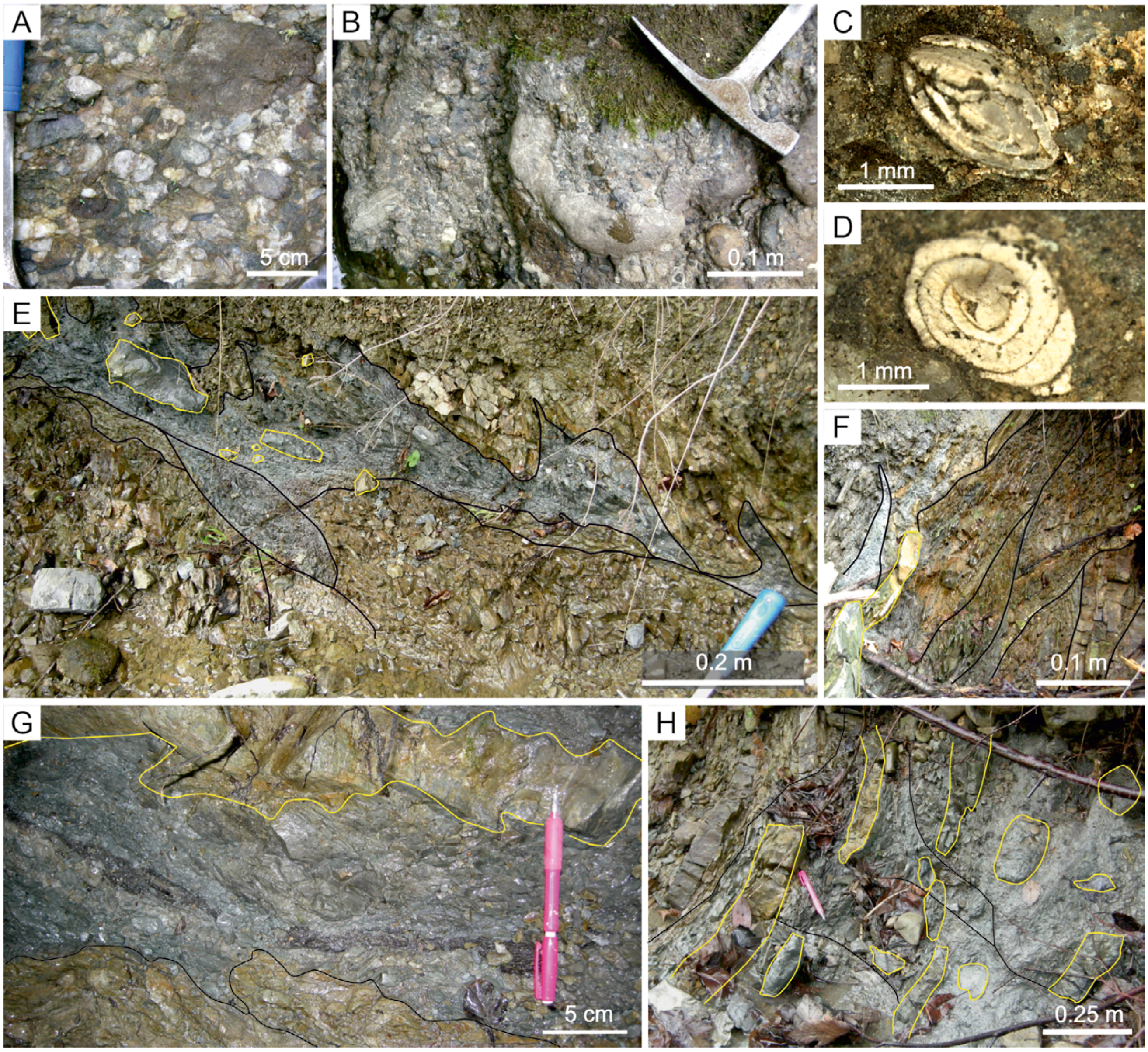

Fig. 5. Outcrops of the deposits of the Magura Nappe in the study area. **A, B.** Pasierbiec Member – conglomerate facies (above complex A). **C, D.** Large foraminifera in Pasierbiec conglomerates. **E–H.** Melange of complex B, shaly or packages of thin-bedded turbidites are outlined with black line, sandstones blocks are outlined with yellow line.

The presence of components of different ages, including both Beloveža Formation and Łabowa Formation deposits in a nearby thrust zone, where these units are in tectonic contact, indicates the occurrence of a tectonic mélange. However, a sedimentary origin for the mélange cannot be excluded. Foraminifera from the red shales of the upper Paleocene and lower Eocene Łabowa Formation constitute the majority of specimens in the sample. These are easily distinguishable, due to their red colouration, and include large specimens of *Paratrochamminoides* and *Trochamminoides*, tubular forms from the *Rhabdammina-Psammosiphonella* group, and large *Placentammina placenta* (Grzybowski), which are common in the upper Paleocene Łabowa Formation, as well as small and numerous *Glomospira charoides* (Jones and Parker), *Thalmannammina subturbinata* (Grzybowski), and *Karrerulina conversa* (Grzybowski), which are abundant in the lowermost Eocene assemblages (Jednorowska, 1966, 1968; Bieda *et al.,* 1967; Geroch *et al.,* 1967; Jurkiewicz, 1967; Malata, 1981; Waśkowska-Oliwa, 2000; Kender *et al.,* 2005; Cieszkowski *et al.,* 2011; Tab. 1; Fig. 7). The Beloveža Formation-type foraminifera are light grey, and in addition to *Reticulophragmium amplectens* (Grzybowski), they include tubular forms from the *Nothia* group, *Dolgenia* sp., *Haplophragmoides walteri* (Grzybowski), and *Buzasina pacifica* (Krasheninnikov).

Samples nos. Os1/24 and Os2/24 were collected from the lowermost Pasierbiec Member, from thin grey mudstone intercalations between thick- and very thick-bedded sandstones beneath complex A. Both contained very poor assemblages of non-diagnostic, long-ranging foraminifera, dominated by tubular forms of the genera *Nothia* and *Bathysiphon*.

Fig. 6. Outcrops of the deposits of the Magura Nappe in the study area. **A.** Granite block. **B.** Pelitic limestone block. **C, E.** Grey marls in complex C. **D.** Variegated shales in complex C. **F.** Beloveža Formation deposits above the olistostrome complex.

Samples nos. 5/13 and 6/13 were collected from grey-green mudstones within thin-bedded turbidites of the Beloveža Formation above the olistostrome complex. Sample 6/13 provided positive biostratigraphic results, containing *Pseudonodosinella elongata* (Grzybowski) and *Popovia beckmanni* (Kaminski et Geroch), which occur in Eocene deposits in the Carpathians (Kaminski and Geroch, 1987; Kaminski and Gradstein, 2005; Neagu *et al.,* 2011; Waśkowska, 2014; Waśkowska and Cieszkowski, 2014), as well as *Reticulophragmium amplectens* (Grzybowski) and *Praesphaerammina subgaleata* Vašíček, which co-occur in the middle and upper Eocene (Geroch, 1960; Jednorowska, 1969; Olszewska, 1996; Golonka and Waśkowska, 2011). The total proportion of *Haplophragmoides* (Tab. 1; Fig. 8) in the assemblage, excluding tubular forms, is 22%, which is typical of the middle Eocene *Haplophragmoides* acme (Waśkowska, 2021). The stratigraphic range of this fauna is Lutetian–Bartonian.

Biostratigraphic age of the olistostrome series

Each of the olistostrome complexes distinguished was sampled. Four samples were taken from the complex with olistoliths, seven from the olistolith debris, and six from the upper complex, which includes olistoplaques.

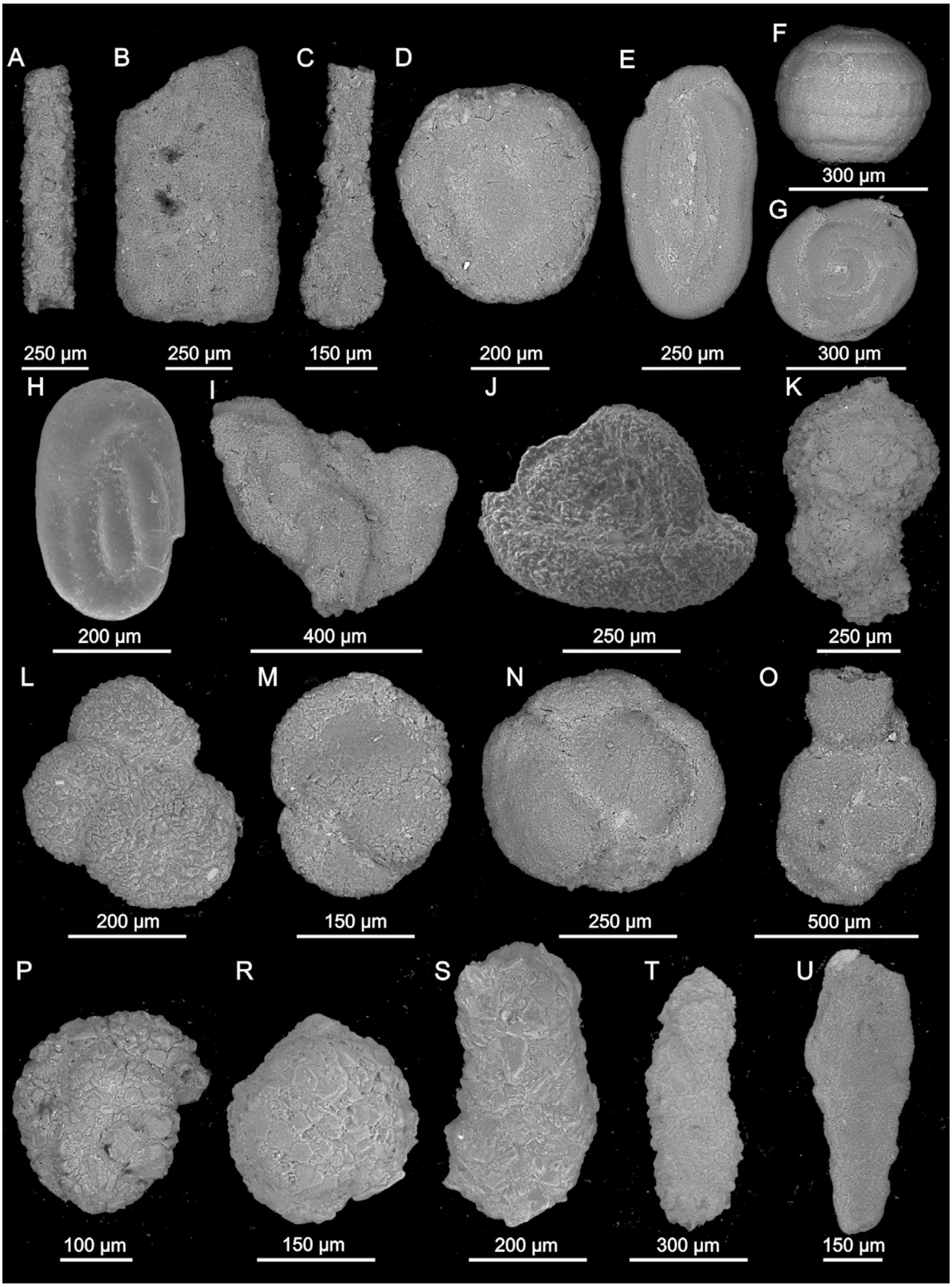

Fig. 7. The Paleocene and Eocene foraminifera of the variegated shale deposits. **A.** *Psammosiphonella cylindrica* (Glaessner) (sample (s.) 1/14). **B.** *Bathysiphon* sp. (s. 66/14). **C.** *Hyperammina* sp. (s. 62/14). **D.** *Placentammina placenta* (Grzybowski) (s. 3/14). **E.** *Ammodiscus peruvianus* Berry (s. 66/14). **F.** *Glomospira charoides* (Jones et Parker) (s. 1/14). **G.** *Glomospira gordialis* (Jones et Parker) (s. 1/14). **H.** *Annectina grzybowskii* (Jurkiewicz) (s. 62/14). **I.** *Glomospira* ex gr. *irregularis* (Grzybowski) (s. 1/14). **J.** *Glomospira* ex gr. *irregularis* (Grzybowski) (s. 3/14). **K.** *Reophax imitator* Finlay (s. 77/14). **L.** *Subreophax scalaris* (Grzybowski) (s. 66/14). **M.** *Ammosphaeroidina pseudopauciloculata* (Mjatliuk) (s. 62/14). **N.** *Trochammina* sp. (s. 62/14). **O.** *Paratrochamminoides vermetiformis* (Grzybowski) (s. 62/14). **P.** *Recurvoides* sp. (s. 60/14). **R.** *Thalmannammina subturbinata* (Grzybowski) (s. 62/14). **S.** *Ammobaculites agglutinans* (d'Orbigny) (s. 62/14). **T.** *Karrerulina conversa* (Grzybowski) (s. 77/14). **U.** *Spiroplectammina spectabilis* (Grzybowski) (s. 1/14).

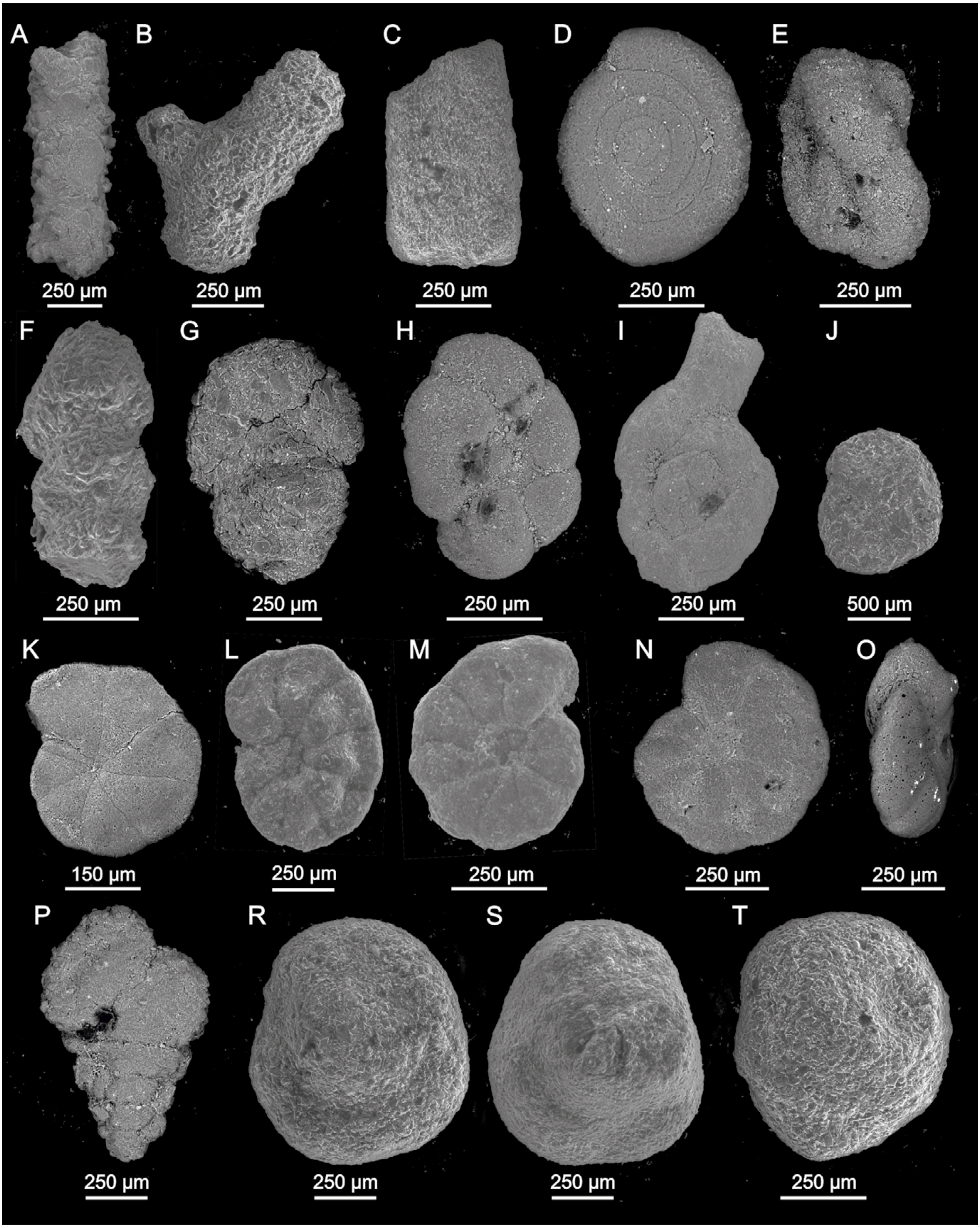

Fig. 8. Foraminifera from Beloveža Formation-lithotype deposits. **A.** *Psammosiphonella cylindrica* (Glaessner) (sample (s.) 6/13). **B.** *Nothia excelsa* (Grzybowski) (s. 4/13). **C.** *Bathysiphon* sp. (s. 6/13). **D.** *Ammodiscus cretaceus* (Reuss) (s. 6/13). **E.** *Glomospira* ex. gr. *irregularis* (Grzybowski). **F.** *Subreophax scalaris* (Grzybowski) (s. 6/13). **G.** *Reophax* sp. (s. 1/14). **H.** *Trochamminoides subcoronatus* (Grzybowski) (s. 6/13). **I.** *Paratrochamminoides vermetiformis* (Grzybowski) (s. 6/13). **J.** *Haplophragmoides parvulus* Blaicher (s. 6/13). **K.** *Haplophragmoides walteri* (Grzybowski). **L, M.** *Haplophragmoides nauticus* group Kender, Kaminski and Jones (s. 6/13). **N, O.** *Reticulophragmium amplectens* (Grzybowski) (s. 6/13). **P.** *Eggerella propinqua* (Brady) (s. 6/13). **R–T.** *Praesphaerammina subgaleata* (Vašíček) (s. 15/13).

Complex A – with metagabbro, serpentinite, and limestone blocks

Sample no. 33/14 (Tab. 1) was collected from the lower part of the complex, consisting of deformed red and green mudstones. It contains numerous small, red-coloured *Glomospira*, which, excluding tubular forms, exceed 53% of the assemblage. A significant group includes *Paratrochamminoides* and *Trochamminoides*, as well as *Recurvoides* with *Thalmannammina* (Tab. 1). The taxonomic features of the sample correspond to the lower Ypresian *Glomospira* acme (e.g., Olszewska, 1997; Waśkowska-Oliwa, 2000; Waśkowska, 2021; Kaminski *et al.,* 2024a, b), which, in biostratigraphic zonations for the Carpathians, defines the *Glomospira* div. sp. Zone (Olszewska, 1997; Waśkowska, 2021).

Two further samples, nos. 7/13 and 8/13, were collected from the strongly deformed mudstone matrix near olistolith blocks of gabbro, serpentinite, and nummulitic-algal limestone. These samples contained very few, poorly preserved foraminiferal specimens. Sample no. 7/13, associated with relatively numerous small fish teeth, contains a specimen of *Subbotina*. It is preserved as an internal mould without the final chamber, so identification could not include important diagnostic features. Morphological analysis indicates that it is closest to *Subbotina gortanii* (Borsetti) (Fig. 9), with a stratigraphic range from middle Bartonian (zone E13) to Oligocene (Berggren and Pearson, 2005; Olsson *et al.,* 2006). Sample 8/13 shows slightly greater taxonomic diversity, containing silicified nodosarids, a juvenile specimen of the Eocene *Reticulophragmium amplectens* (Grzybowski), and a specimen of *Acarinina boudreauxi* Fleisher, which ranges from mid to upper Ypresian to mid to upper Lutetian (Pearson *et al.,* 2006; Tab. 1; Fig. 9).

Sample no. 4/14 is characterised by low abundance, poor diversity, and poor preservation of foraminifera. Single specimens of *Haplophragmoides parvulus*? Blaicher, *Reticulophragmium amplectens* (Grzybowski), and *Praesphaerammina subgaleata* Vašíček were identified (Tab. 1), which co-occur from the late Bartonian through the Priabonian (Malata, 1981; Olszewska *et al*., 1996; Olszewska and Malata, 2006; Golonka and Waśkowska, 2011).

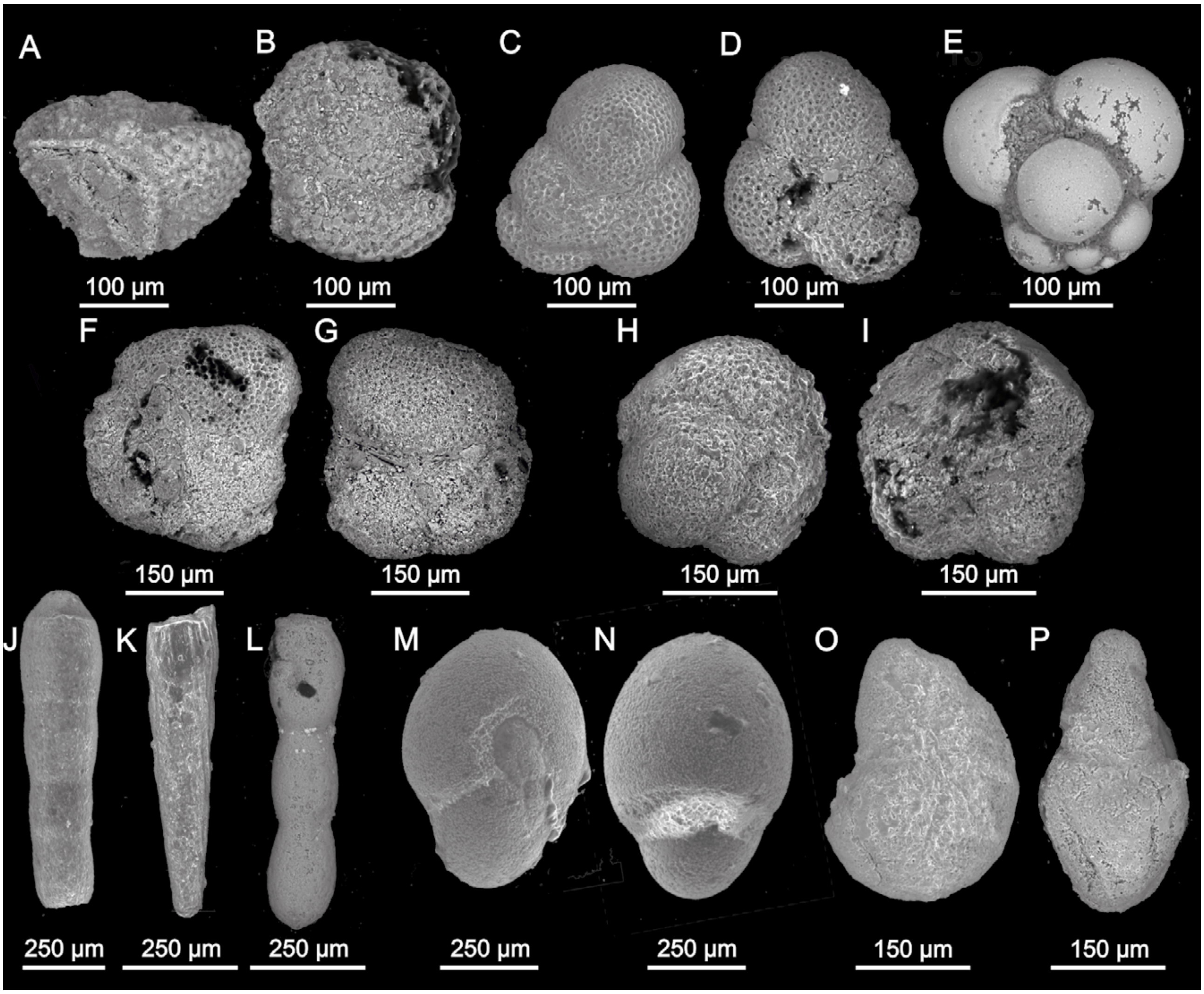

Fig. 9. Calcareous foraminifera from debrites. **A, B.** *Acarinina boudreauxi* Fleisher (sample (s.) 8/13). **C, D.** *Subbotina corpulenta* (Subbotina) (s. 13/13). **E.** *Subbotina* cf. *gortanii* (Borsetti) (s. 7/13). **F–I.** *Subbotina* spp. (from *linaperta* group) (s. 13/13). **J.** *Nodosaria* sp. (s. 8/13). **K.** *Pyramidulina obscura* (Reuss) (s. 8/13). **L.** *Nodosarella* cf. *subnodosa* (Guppy) (s. 2/14). **M, N.** *Chillostomelloides ovicula* (Nuttall) (s. 15/13). **O, P.** *Lenticulina* spp. (s. 13/13).

Complex B – deformed mudstone-sandstone turbidites

Samples nos. 10/13, 11/13, 12/13, and 47/14 were collected from the lower part of the complex. Samples nos. 10/13 and 12/13 were taken from deformed grey mudstones with intercalations of green shales, occasionally with red shales. Samples nos. 11/13 and 47/14, barren of foraminifera, were collected from red mudstone. Samples nos. 10/13 and 12/13 contained assemblages with low abundance and species diversity, where *Haplophragmoides* was a characteristic component, together with tubular forms (Tab. 1). These assemblages correspond to the *Haplophragmoides* acme, but the small number of specimens does not provide a sufficient basis for a definitive classification.

Samples nos. 13/13, 14/13, and 15/13 were collected from the upper part of the complex, containing grey mudstones, folded with soft, thinly laminated, blue and cream-coloured mudstones. In sample no. 13/13, from grey mudstones, foraminiferal specimens were relatively numerous, though the taxonomic diversity was low. Typical Eocene forms, such as *Pseudonodosinella elongata* (Grzybowski) and *Buzasina pacifica* (Krasheninnikov), were present, along with several specimens of *Haplophragmoides parvulus* Blaicher (Tab. 1), known from Bartonian and Priabonian deposits (Golonka and Waśkowska, 2011). The assemblage was dominated by *Haplophragmoides*, with *Haplophragmoides walteri* (Grzybowski) comprising 46% of benthic foraminifera, excluding tubular forms. This corresponds to the characteristics of the *Haplophragmoides* acme, occurring in Lutetian–Bartonian deposits of the Carpathians (Waśkowska, 2021). The sample contains isolated, poorly preserved planktonic foraminifera, including *Subbotina eocaena* (Guembel), *Subbotina corpulenta* (Subbotina), and *Subbotina linaperta* (Finlay) (Tab. 1). These taxa appear in the upper Ypresian and persist until the upper Oligocene, except for *Subbotina linaperta*, which does not extend into the Oligocene (Berggren *et al.,* 1995; Olsson *et al.,* 2006; Premoli-Silva *et al.,* 2008).

Samples nos. 14/13 and 15/13 were collected from deformed, soft, blue mudstones with beige lamination. They contained taxonomically poorly diversified assemblages, dominated by *Praesphaerammina subgaleata* (Vašíček), comprising 87% and 93% of the assemblages, respectively (Tab. 1; Fig. 7). *Praesphaerammina subgaleata* (Vašíček) is a typical Eocene species that in the Carpathians reaches its acme in the upper Lutetian and Bartonian, and assemblages dominated by it are common, particularly in the Magura Nappe (Blaicher, 1958; Jednorowska, 1966, 1968, 1969; Geroch *et al.,* 1967; Malata, 1981; Olszewska and Malata, 2006; Golonka and Waśkowska, 2011; Waśkowska, 2021). The presence of the Bartonian–Priabonian *Haplophragmoides parvulus* Blaicher in sample no. 15/13 narrows the age to the Bartonian.

Complex C – turbiditic deposits with layers of mudstones and marls

Samples were collected from the marl, variegated mudstone, and thin-bedded turbidites of the Beloveža Formation lithotype. Three samples (nos. 66/14, 77/14, and 3/14), taken from the variegated mudstone, contain fauna, characterised by the *Glomospira* acme. Together with numerous *Glomospira charoides* (Jones et Parker) and *Thalmannammina subturbinata* (Grzybowski), these samples include *Trochamminoides* and *Paratrochamminoides*, as well as radiolarians, which are particularly numerous in samples nos. 77/14 and 3/14 (Tab. 1). The character of these assemblages corresponds to the lowermost Ypresian of the variegated shales of the Łabowa Formation (Jednorowska, 1966, 1968; Bieda *et al.,* 1967; Geroch *et al.,* 1967; Jurkiewicz, 1967; Malata, 1981; Waśkowska-Oliwa, 2000; Kender *et al.,* 2005; Cieszkowski and Waśkowska, 2011). Sample no. 77/14 has a slightly different structure, with a few *Glomospira* accompanied by numerous radiolarians and small specimens of *Karrerulina conversa* (Grzybowski) (Tab. 1). Such assemblages are known from lower Eocene deposits and are associated with the post-crisis phase of the late Paleocene Thermal Maximum (Bąk, 2004; Waśkowska, 2021), representing an acme of *Karrerulina* (Kaminski, 2005; Kaminski *et al.,* 2024b).

Sample no. 62/14, collected from the mélange, containing variegated mudstones, contains red-stained foraminifera, dominated by *Recurvoides-Paratrochamminoides*, with a single *Annectina grzybowskii* (Jurkiewicz), typical of the Maastrichtian–Paleocene (e.g., Jurkiewicz, 1967; Jednorowska, 1975; Morgiel and Olszewska, 1981; Olszewska, 1997; Kaminski and Gradstein, 2005; Waśkowska *et al.,* 2014, 2020). The subordinate component consists of grey-coloured foraminifera, among which *Reticulophragmium amplectens* (Grzybowski) is present, occurring in the Carpathians since the late Ypresian (e.g., Jurkiewicz, 1967; Jednorowska, 1968; Morgiel and Olszewska, 1981; Waśkowska, 2011, 2021).

Samples nos. 2/14 and 4/13 were collected from Beloveža Formation lithotype deposits between two large slide blocks of Łabowa-like variegated shales. Sample no. 2/14 contains an uncharacteristic assemblage, dominated by tubular forms, whereas sample no. 4/13 yielded a diverse foraminiferal assemblage (Tab. 1). Diagnostic Eocene forms identified include *Ammogloborotalia* aff. *subvesicularis* (Hanzlíková), *Buzasina pacifica* (Krasheninnikov), *Reticulophragmium amplectens* (Grzybowski), and *Ammodiscus latus* Grzybowski forma *ovoidalis* Waśkowska et Kaminski, which occurs in the Carpathians from the Lutetian–Bartonian boundary (Jurkiewicz, 1967; Morgiel and Olszewska, 1981, 1997; Olszewska *et al.*, 1996; Kaminski and Gradstein, 2005). The sample also includes an elevated proportion of *Haplophragmoides*, constituting 10% of the assemblage (excluding tubular forms), with numerous *Haplophragmoides walteri* (Grzybowski), corresponding to its species acme in the Outer Carpathians during the Lutetian and Bartonian (Waśkowska, 2021). These data indicate that the sampled deposits accumulated during the Bartonian.

A biostratigraphic signal was obtained from a block of pelitic limestone. In thin sections, rare planktonic foraminifera, including *Subbotina* sp., *Dipsidripella danvillensis* (Howe and Wallace), and *Acarinina* species, were observed, including *Acarinina bullbrooki* (Bolli) (Fig. 10), ranging from the latest Ypresian to the end of the Lutetian, and *Acarinina primitiva* (Finlay), ranging to the earliest Bartonian (Berggren and Pearson, 2005; Berggren *et al.,* 2006; Premoli Silva *et al.,* 2008; BouDagher-Fadel, 2015).

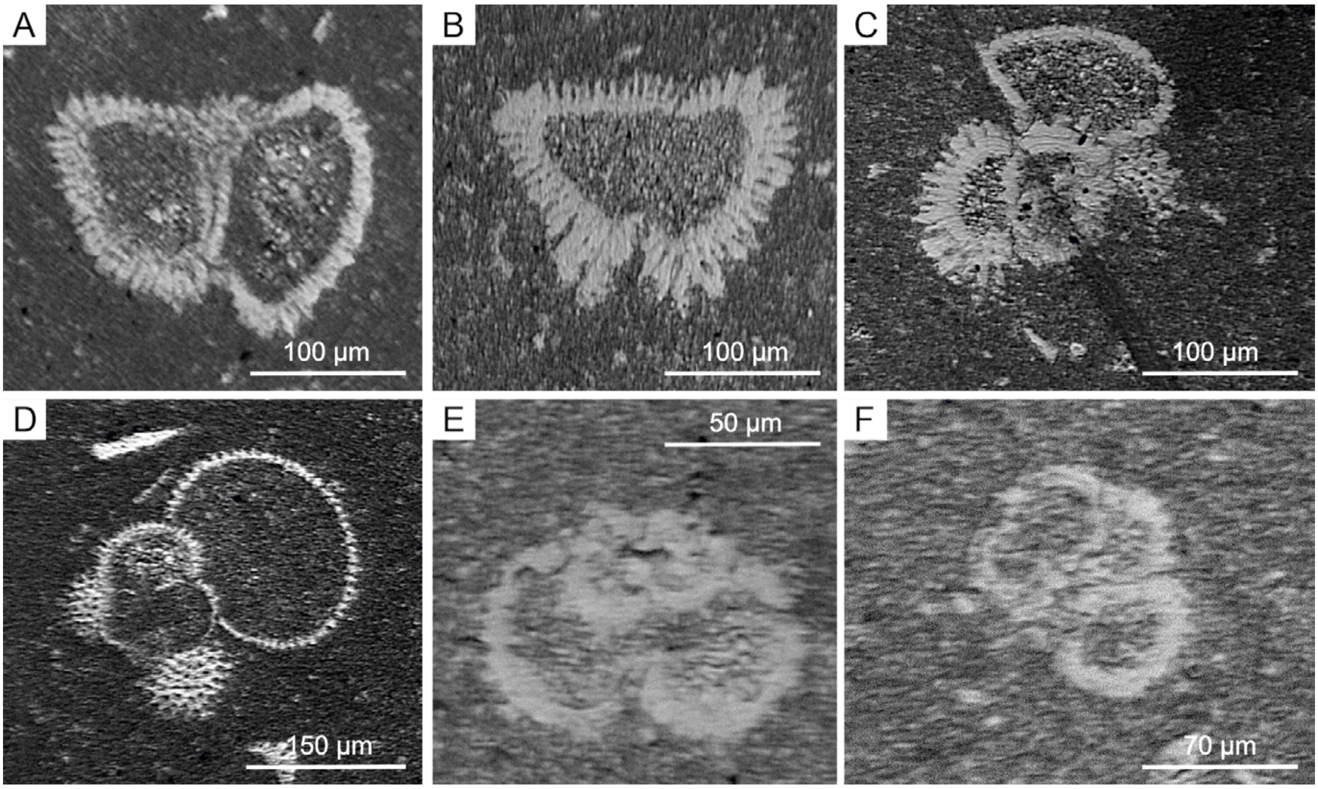

Fig. 10. Planktonic foraminifera in the thin-sections from the pelitic limestone. **A.** *Acarinina bullbrooki* (Bolli). **B.** *Acarinina* ex gr. *topilensis* (Cushman). **C.** *Acarinina topilensis* (Cushman). **D.** *Subbotina* sp. **E, F.** *Dipsidripella danvillensis* (Howe et Wallace).

Additionally, *Acarinina topilensis* (Cushman), with the shortest range, restricted to the middle Eocene (zones E10–E11 in the upper Lutetian; Berggren and Pearson, 2005; Berggren *et al.,* 2006), specifies the age of the limestone. According to the principle of inclusions, which states that a clastic component is as old as or older than the clastic rock in which it occurs, the age of the complex is not older than the middle Eocene.

Attempts to determine the age of the grey marls, using foraminifera, were unsuccessful, as neither the washing residues nor the thin sections contained foraminifera.

DISCUSSION

Olistostromes form due to gravitational submarine mass movements and are common components of deep-sea formations, deposited on slope or base-of-slope locations (Flores, 1959; Abbate *et al.,* 1970; Cieszkowski *et al.,* 2012). They are frequently deposited in the Carpathian basins, and current research highlights their significant role in the structure of the Outer Carpathians. Olistostromes of the Silesian domain are better documented (e.g., Ślączka, 1963; Unrug, 1968; Szymakowska, 1976; Malik and Olszewska, 1984; Ślączka and Gasiński, 1985; Słomka, 1986, 2001; Kotlarczyk, 1988; Cieszkowski, 1992; Bubík *et al.,* 2000; Cieszkowski *et al.,* 2009, 2012, 2017; Ślączka *et al.,* 2012; Waśkowska and Cieszkowski, 2014; Golonka *et al.,* 2015; Jankowski, 2015; Hnylko and Hnylko, 2016, 2019; Strzeboński *et al.,* 2017; Siemińska *et al.,* 2020; Hnylko *et al.,* 2021; Woyda *et al.,* 2023), while less information is available for those, formed in the Magura domain (Książkiewicz, 1958; Cieszkowski *et al.,* 1987; Bromowicz, 1998; Olszak, 2006). One such large olistostrome, examined in this paper, is located in the Rača Subunit of the Magura Nappe and is exposed in the Osielec area. It was deposited in the northern part of the Magura Basin.

Cyclic mass displacements of sediments occurred during the late Bartonian, during the sedimentation of the Beloveža Formation. These commenced, when coarse-grained sandy and gravelly turbidites of the Pasierbiec Member were deposited. Foraminiferal dating indicates that deposits below the olistostrome are not older than the late Ypresian, but late Bartonian components were identified in the first olistostrome complex. The same Bartonian age applies to components in the subsequent olistostrome complexes and the overlying Beloveža Formation deposits.

The displaced formations comprise three distinct complexes, characterised by different structures and lithological inventories, interbedded with regular turbidites, recording intervals of "normal" flysch sedimentation. The composite structure of the olistostrome complex results from a series of subaqueous displacements. As noted by Cieszkowski *et al.* (2017), elements of both endolithostromes and allolithostromes can be distinguished in the Osielec displaced deposits.

In complex A, variegated and grey muddy debris with sand, gravel, and blocks are present. Current conditions of poor exposure preclude detailed observations and sampling to determine precisely the structure of this complex or confirm whether it has a layered structure. Among the blocks, magmatic and limestone rocks occur, originating outside the turbiditic sedimentation environment (Fig. 3). Gabbros and serpentinite are unique in the Western Outer Carpathians and currently are known only from the Osielec locality (Wieser, 1952; Cieszkowski *et al.,* 2010, 2017; Kysiak, 2010; Gawęda *et al.,* 2023). Geochronological and geochemical studies indicate their Neoproterozoic age (Anczkiewicz *et al.,* 2016; Gawęda *et al.,* 2021), originating from mantle-derived rocks, modified by subduction with input of lithospheric mantle (Gawęda *et al.,* 2021). Blocks of nummulitic-algal limestone represent fragments of deposits, formed on the shelf, containing algal debris and rhodoliths, indicative of photic environments. Such limestones have been known in the Carpathians since the Paleocene (e.g., Bieda, 1931, 1946, 1962, 1968; Leszczyński *et al.,* 2012; Waśkowska *et al.,* 2014; Kowal-Kasprzyk *et al.,* 2021). In these limestones, a planktonic foraminifera of the large Eocene *Subbotina corpulenta* (Subbotina) group was identified (Tab. 1; Fig. 9), indicating its age. The blocks are embedded in mudstone or sandy mudstone debris. This deposit is underlain by predominantly red mudstone, containing foraminifera of early Ypresian age, corresponding to the Łabowa Formation, which is widely distributed in the Magura Basin. Other samples from this complex contain poorly preserved and dispersed planktonic and benthic calcareous foraminifera, possibly due to transport. Foraminifera from the grey mudstones in the upper part of the complex correspond to the Beloveža Formation lithotype foraminifera.

The next package (B) consists of slump deposits of deformed, thin- to medium-bedded turbidite packages, Bartonian in age, with fragments of thick-bedded sandstones. Macroscopically, these differ from *in situ* deposits primarily in the colour of the mudstones, with distinct differences also observed in the foraminiferal assemblages. Grey-coloured mudstones contain *Haplophragmoides* acme assemblages, resembling Beloveža Formation lithotype deposits, whereas blue mudstones, laminated with beige, contain assemblages, dominated by *Praesphaerammina subgaleata* (Vašíček) (Tab. 1), which developed in poorly oxygenated environments with increased input of organic matter and a higher supply of very fine-grained clastic material to the sea floor (Golonka and Waśkowska, 2011). These deposits originate from different environments, which explains the differences in lithology and foraminiferal associations.

The complex of deformed flysch deposits is overlain by Bartonian Pasierbiec Member and Beloveža Formation lithotype turbidites (C). These contain packages of non-fragmented and non-deformed grey marls and variegated shales (Fig. 5C–E), with interbedded turbidites of the Pasierbiec Member and Beloveža Formation. Together, they form a sequence of alternating deposits, dominated by middle Eocene, thin- to medium-bedded turbidites, with a few intercalations of older, variegated shales or the grey marls of different facies. These were considered olistoplaques, corresponding to isolated small packet displacements in the form of slabs that slid into the site of olistostrome deposition. The grey marls do not provide a biostratigraphic signal; their lithotype is similar to the marls, occurring in the Łącko Marl deposits of the Bystrica Formation (Cieszkowski *et al.,* 2017) or the Siary Subunit of the Magura Basin (e.g., Książkiewicz, 1974; Wójcik and Rączkowski, 1994; Ryłko, 2004; Cieszkowski *et al.,* 2006; Golonka and Waśkowska, 2012). The variegated shales originated from the Łabowa Formation, from its upper Paleocene, and lower and middle Eocene parts. In complex C, blocks of granite (Fig. 6A) and Lutetian limestone (Fig. 6B) were found. The granite is related to the late Variscan orogeny (Gawęda *et al.,* 2021).

The middle Eocene olistostrome in Osielec has a layered structure (Fig. 3), consisting of three distinct complexes, originating from different landslide niches. In the first stage, the niche developed on the slope and extended into the deposits of the Łabowa Formation, which, along with the overlying Beloveža Formation deposits, underwent gravitational displacement. This niche was supplied with material from shallower zones of the Magura Basin, containing Eocene blocks of algal-nummulitic limestone; possibly, the gabbro and serpentinite blocks, representing the eroded basement, also originated from these zones. In the subsequent landslide episode, complex B was formed, where Bartonian turbidites were redeposited. Within these, facies variability is observed. Both the *Haplophragmoides* and *Praesphaerammina subgaleata* facies developed adjacently or as successive biofacies.

In complex C, the number of bodies of displaced deposits is significantly smaller. This overburden formed above a compact olistostrome complex. These bodies were redeposited, together with blocks of hard rocks, originating from an eroded basement above the site, where the Beloveža Formation was deposited. Such blocks are represented by granitoid and Eocene limestone.

The structure of the olistostrome corresponds to the stages of its formation. During the main phase, massive displacement of slope material occurred. Initially, block displacements (complex A) from shallow areas of the basin initiated the movement of unconsolidated and weakly consolidated sediments on the slope. This niche developed within the middle Eocene Beloveža Formation and extended into the lower Ypresian mudstones of the underlying Łabowa Formation. In the subsequent stage, displacements of thin-bedded turbiditic mud-sand and mud deposits occurred. These were slumps of Bartonian complexes that underwent fragmentation and plastic deformation during transport (complex B), partly without significant fragmentation, typical for masses, transported by slides. After the main phase of massive displacements, stabilising slides occurred, involving small, isolated slide-displaced bodies of the Łabowa Formation variegated mudstones and the Łącko Marl lithotype marls. The niches supplying variegated mudstones deepened and reached the Paleocene formations, the oldest displaced basinal deposits in the olistostrome. Generally, a reversed arrangement is noted in the olistostrome colluvium, with the oldest components occurring in the upper part during advanced erosion of niches that were cut into the substrate during landslide episodes.

Allochthonous material provides insight into the geological structure of areas, located above the olistostrome deposition site. Lithologically, it is represented by two categories: (1) material, transported as blocks of a single rock type, and (2) packages of deposits. The first group comprises material, eroded from lithified rocks, including magmatic and sedimentary rocks. Magmatic rocks indicate the geological structure of the crystalline basement, while limestones document sedimentary environments, developing during the Eocene in shallow- marine parts of the Magura Basin. Among the displaced rocks, blocks of nummulitic-algal limestone, typical of photic zone facies, belonging to the Carpathian lithothamnian-bryozoan facies (Kowal-Kasprzyk *et al.,* 2021), are found, as well as pelitic limestone with planktonic foraminifera, typical of deeper environments, characterised by carbonate pelagic sedimentation. Future studies of these exotic materials will enable precise determination of the conditions in the carbonate sedimentation zones.

The second group of displaced rocks provides evidence of the sediments, located on the slope. In addition to the Beloveža Formation deposits in the *Haplophragmoides* acme facies, recognised from the olistostrome deposition area, the *Praesphaerammina subgaleata* acme facies, which developed in higher slope positions, have been identified. Progressive erosion within the basement of a submarine landslide encompassed deposits from the Łabowa Formation, which is widely distributed and underlies the olistostrome, as well as marly deposits of the Łącko Marl lithotype from more northern parts of the Magura Basin (Książkiewicz, 1974; Wójcik and Rączkowski, 1994; Cieszkowski *et al.,* 2006; Golonka and Waśkowska, 2011).

Material transport from the north is confirmed by the palaeocurrent directions (Fig. 3). Deposits both below and above, as well as within the olistostrome, contain flute marks, indicating delivery from the N, NNW, and NNE, which, after rotational adjustment, show the main supply area for the Rača and Siary subunits of the Magura Nappe. This supply was supplemented by blocks from shallow-water, marginal zones of the Magura Basin, located in the north.

Olistostromes, deposited in the Carpathian basins, formed during every stage of their evolution, with their intense development related to the basin's geodynamic regime (Cieszkowski *et al.,* 2009, 2012; Ślączka *et al.,* 2012). Depending on the stage of basin development, subaqueous mass movements were generated with varying intensities, and the scale of the phenomenon varied. Significant disturbances in slope stability during the middle Eocene triggered material displacement. In addition to the Osielec olistostrome, other large mass-displaced deposits of the same age are known from other areas of the Magura Nappe, described from the Bystrica Subzone by Bromowicz (1998) and Olszak (2006) and are related to the activity of the accretionary prism. Bartonian mass movements also occurred in the Silesian domain in the more northern part of the Tethys. A large-scale olistostrome is known from the Hieroglyphic Beds in the area of Rożnów Lake (Cieszkowski *et al.,* 2012; Waśkowska and Cieszkowski, 2014; Waśkowska, 2015) and is linked to the last major thrusting pulse of the second stage (Late Cretaceous–late Eocene) of tectonic evolution of the Outer Carpathian accretionary prism. Another large submarine slide occurred in the Skole Basin, forming the Popiele Beds in the Skole (Skiba) Nappe in eastern Poland and western Ukraine (Dżułyński and Kotlarczyk, 1965; Gedl, 2013; Waśkowska *et al.,* 2023), with sedimentation, associated with the Pyrenean orogenic phase (Dżułyński *et al.,* 1979; Kotlarczyk, 1988). The phenomenon of mass submarine movement is evident in all main sedimentary areas of the Carpathian basins. Their close stratigraphic position indicates that they originated from the same geotectonic episode.

CONCLUSIONS

In the Beloveža Formation, an approximately 200-m-thick complex of sedimentary mélange is present, commencing with mixed deposits of the Beloveža (middle–upper Eocene) and Łabowa formations (Paleocene–lower Eocene). The sedimentary mélange includes clastic deposits displaced from higher parts of the slope, ranging from Paleocene to middle Eocene in age, together with Neoproterozoic magmatic rocks and Eocene shallow-marine carbonate rocks. Three middle Eocene complexes were recognized within the olistostrome, each characterised by distinctive structures and lithological associations of displaced deposits, separated by the regular turbiditic deposits of the Beloveža Formation. The lowermost complex comprises a grey mudstone matrix, formed by a mixture of deposits of the Beloveža Formation lithotype and variegated mudstones of the lower Eocene Łabowa Formation, containing blocks of metagabbro, serpentinite, and nummulitic-algal limestones. The overlying complex consists of deformed middle Eocene packages of thin-bedded turbidites of the Beloveža Formation, exhibiting two different facies, with the variegated shales of the Łabowa Formation type. The uppermost complex, extending between regular turbiditic deposits of the Pasierbiec Member (middle Eocene) and the Beloveža Formation (upper Eocene), contains blocks of granite, pelitic limestone, and a few olistoplaques of Paleocene–lower Eocene variegated shales of the Łabowa Formation, as well as an olistoplaque of the Łącko Marl lithotype. Biostratigraphic analyses indicate that the displacement occurred in the Bartonian. The age of the olistostrome was established on the basis of foraminifera, the *Haplophragmoides* acme and the *Praesphaerammina subgaleata* (Vašíček) acme occur in deposits with Eocene marker taxa, e.g., *Reticulophragmium amplectens* (Grzybowski) and *Ammodiscus latus* Grzybowski forma *ovoidalis*. In the displaced limestones, the Eocene *Acarinina bullbrooki* (Bolli), *Acarinina primitiva* (Finlay), *Acarinina topilensis* (Cushman), *Dipsidripella danvillensis* (Howe and Wallace) and *Subbotina corpulenta* (Subbotina) are present. The material was delivered from the north and underwent short-distance transport. The olistostrome resulted from a thrusting pulse during the middle Eocene in the central Outer Carpathian Tethys, causing massive sediment displacement in the Magura and Silesian domains.

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