Abstract

Foraminiferal assemblages rich in *Trochammina* are described from the uppermost part of the Istebna Beds within the Silesian Nappe (Polish Outer Carpathians). The percentage of *Trochammina* is 55% and 35% of all foraminifera, making this genus numerous in assemblages. Semi-specific *Trochammina* assemblages, dominated by the epifaunal eco-group, are represented by dwarf, thin-walled specimens of cosmopolitan taxa, suggesting they developed in a crisis condition. The late Paleocene age of these assemblages is established based on stratigraphic ranges co-occurring agglutinated and planktonic foraminifera, and on superposition of the host rocks.

INTRODUCTION

In the Outer Carpathians, the Paleocene deposits are dominated by turbiditic (so-called flysch) sedimentation. Thick-bedded sandstone complexes interbedded with sandy-shaley intervals are common. Such type of sedimentation resulted in the development of mostly agglutinated foraminiferal assemblages. The variability of these agglutinated assemblages is low, what is seen in biostratigraphic schemes dedicated to the Outer Carpathians (e.g., Geroch & Nowak, 1984; Olszewska, 1997) with only one zone – Rzehakina fissistomata – defining the whole of the Paleocene lasting 9.8 Ma.

During the Late Cretaceous, Paleocene, and Early or Early-Middle Eocene in the Silesian Basin a stage with the predominance of thick-bedded sandstone and conglomerate sedimentation took place (Książkiewicz, 1962; Golonka et al., 2006). This stage is especially well represented in the Istebna and Ciężkowice beds. Occasionally the sedimentation rate changed and thick-bedded sandstone deposits were substituted by shaley-sandstone or shale intervals. In the Upper Paleocene such a complex, developed as shale with intercalations of thin-bedded sandstones, make up the sediments of the Istebna Beds. This unit is called the Upper Istebna shales (a lithostratigraphic subdivision in the range of a member), which overlie the Upper Istebna sandstones and underlie the Ciężkowice sandstones. These Upper Istebna shales were sampled and are the subject of micropalaeontological studies. The foraminifera obtained here have a character of *Trochammina* semi-specific assemblages, which is unique to the Paleocene (Waśkowska et al., 2016).

The foraminiferal assemblages discussed here were first mentioned in a geotourist paper by Cieszkowski et al. (2010) concerning the geological attractions of Melsztyn Hill with the ruins of the medieval Melsztyn castle. The present paper contains wider *stricto sensu* micropalaeontological characteristics of the foraminiferal assemblages obtained from the Upper Istebna shales cropping out in the lower part of the Melszyn Hill slope. This study provides additional data about the palaeontological record of the upper Paleocene in the Polish Outer Carpathians.

Geological outline

The study area is located in the Outer Carpathians in Poland, on the territory of the central part of the Silesian Nappe (Książkiewicz, 1977; Golonka et al., 2006, Golonka & Waśkowska-Oliwa, 2007) (Fig. 1). This nappe contains mostly the rocks deposited in the Silesian Basin *sensu lato*, which were developed in the western part of the Tethys Ocean in the Outer Carpathian domain. The Silesian Basin was filled with flysch from the Late Cretaceous up to the Early Miocene even though a few stages of basinal evolution changed its tectonic structure and conditions of deposition (Cieszkowski et al., 2009, 2012). The different types of
clastic deposits are mainly an effect of turbidite sedimentation filling this area. During the Alpine orogenic movements these deposits were folded, uprooted from their basement, and uplifted. Then the Silesian Nappe was pushed tectonically to the north and overthrust onto the Subsilesian and Skole nappes as well as the Miocene deposits infilling the Carpathian Foredeep that transgressively onlap the North European Platform (Książkiewicz, 1976; Golonka et al., 2006).

The sampled deposits which represent the Upper Istebrna Beds (Upper Istebrna Shales) crop out on the slope of the Melsztyn Castle Hill, located in the Rożnów Foothills on the left bank of the Dunajec River in Melsztyn village (Fig.
Trochammina semi-specific assemblages from the Upper Paleocene

They occur there within the Jurków-Zakliczynczyn and Gwoździec thrust sheets *sensu* Cieszkowski *et al.* (2010). These deposits belong to the Istebna Beds, which form one of the thickest lithostratigraphic divisions of the Silesian Nappe, consisting of two complexes of thick- and very thick -bedded sandstones and conglomerates (Fig. 1). In the study area the thickness of the Lower Istebna sandstones is more than 1000 m and the Upper Istebna sandstones is about 250 m. Thin-bedded shaley-sandstone deposits with significant domination of the shales separate the Lower and Upper Istebna sandstones and some similar Upper Istebna shales overlie the Upper Istebna sandstones and from the top are covered in the section by the Ciężkowice sandstones. Such a section is observed in the study area (Burtan *et al*., 1981; Cieszkowski *et al*., 2010), though Koszarski & Kuciński (1966) and researchers who followed them (Leszczyński *et al*., 2005, 2012) classified the Ciężkowice Sandstones occurring there as a member of the Upper Istebna Beds. The presented geological image of the Silesian Nappe in Melsztyn and surrounding area follows Cieszkowski *et al.* (2010) and was established on the basis of detailed geological mapping carried out in 2009.

The samples were taken from the uppermost part of the Upper Istebna shales, close to the first thick-bedded sandy layer rich in rhodoids (Melsztyn sandstones subdivision *sensu* Cieszkowski *et al*., 2010) (Fig. 1), which belong to the Ciężkowice sandstones. The sampled deposits are represented mostly by muddy gray and gray-beige muddy shales with rare intercalations of very thin-bedded and thin-bedded, sporadically medium-bedded, gray quartzite fine-grained sandstones (Fig. 2). At present the studied outcrop is not accessible.

**METHODOLOGY AND MATERIAL**

Two samples, MELSZTYN 1/09 and MELSZTYN 2/09, were analysed. The samples were collected by Marek Cieszkowski in 2009 from shaley deposits outcropping on the southern slope of the Melsztyn Castel Hill in Melsztyn Village (Fig. 1). The sampled deposits were represented by gray muddy shales. Approximately 0.5 kg of rock was prepared using a standard micropalaeontological method – first macerated in saturated Glauber’s salt solution, and next washed over a 63 μm sieve. All microfossils from the resi-
Semi-specific Trochammina assemblages

The dominant genus is small-sized Trochammina (Fig. 3). Such a high proportion of one taxonomic group permits this assemblage to be regarded as semi-specific. Trochammina is represented mostly by compressed specimens, difficult to recognise, and not assigned to the species level. It seems that Trochammina is represented by at least by two species. The most numerous specimens are close to the dwarf Trochammina globigeriniformis (Parker & Jones), but there are specimens close to the Trochammina (Trochamminopsis) altiformis (Cushman & Renz). Most of the foraminiferal specimens are represented by dwarf, thin-walled and transparent foraminiferal tests which indicates the Liliputian effect. Similar, small-sized Trochammina assemblages were described from the Lower Eocene of the Silesian Basin, where the number of Trochammina specimens reaches up to 80% (Waśkowska, 2012, 2015a, b). They occur in the lowermost part of the Hieroglyphic Beds, deposited higher within lithostratigraphic column of the Silesian Nappe - above the Istebna Formation and Ciężkowice Sandstone. In other Carpathian lithostratigraphic divisions, Trochammina is accessory group of foraminifera (Waśkowska, 2015b).

**Spiroplectammina navarroana Cushman in Trochammina semi-specific assemblages**

In the sample MELSZTYN 2/09 the Spiroplectamminacea is represented only by one taxon - Spiroplectammina navarroana Cushman. Most specimens are broken, without the oldest-most fragile part of the test. They are red coloured and with red clay sediment infilling the chambers (Pl. 2). This suggests the first place of deposition within red shales, not within the gray muddy shales of the Upper Istebna Shales. In similar state of preservation is part of the specimens of Placentammina placenta (Grzybowski), Recurvoides, and Bathysiphon sp. All these tests belong to the large specimens in the studied samples and constitute the redeposited material. Despite of this, the rich occurrence of Spiroplectammina navarroana in the Carpathian deposits is interesting. It was observed in the Carpathian Paleogene of the Roźnów Lake Olistostrome (Waśkowska & Cieszkowski, 2013, 2014). Spiroplectammina navarroana occurred in the olistolithic clasts and in the olistostrome matrix, so represented also redeposited material. Usually, in the Outer Carpathians Spiroplectammina navarroana is relatively common, but it is an accessory component of foraminiferal assemblages. This taxon is a ubiquitous component of flysch-type assemblages, recognised in many sections around the world (Kaminski & Gradstein, 2005 and references therein). It is numerous in the Late Palaeocene–Early Eocene of Boreal seas (e.g. Gradstein & Kaminski, 1989; Kinsey, 2000; Nagy et al., 2004).

Micropalaeontological material contains the tests of agglutinated foraminifera 340 and 380 specimens per sample. The accessory components were: one specimen of a planktonic foraminifera test and three radiolarian steinkerns. Within this material 21 genera were recognised. The state of foraminiferal test preservation was various, generally not good, a portion of the fossils have poorly visible details of test morphology. The tubular forms and other long tests are usually broken. Most of the foraminifera are represented by dwarf specimens and thin-walled, transparent tests. In some cases test surfaces were partly covered by limonitic crusts. In sample MELSZTYN 2 the part of foraminiferal tests (only large specimens), belonging to the Spiroplectaminacea, Recurvoidacea, Astrorhizacea, and Saccamminacea, are red coloured or infilled with red clay sediment.

The foraminifera were analysed and photographed (Plates 1, 2) under a Nikon VL100POL binocular microscope in the Department of General Geology and Geotourism of WGióś AGH. The samples are housed in the Micropress Europe Foundation at the AGH University of Science and Technology in Kraków.

**RESULTS**

**Taxonomic composition**

In total, 32 species which belong to 21 genera were recognised. The dominance of Trochamminidae, which constitutes 35% and 55% of all foraminifera, is the characteristic feature (Fig. 3). The tubular forms of Astrorhizida are the next numerous group of foraminifera. They are preserved as fragments of tubes, and their number does not reflect the real number of specimens. The amount of Astrorhizida fragments is 39% and 28%. In fact, they represent at least several smaller groups of foraminifera. It needs to be highlighted that taking into account this fact, the real number of other groups in studied material is higher. Figure 3 presents the distribution of the taxonomic diversity for comparison with and without taking into account the Astrorhizida. The rest of the assemblages belongs to the Ammodiscidae, Recurvoidacea, Litulacea, Litutoebacea, Spiroplectaminacea, Rzhakinacea, Prolixopectidae, Hormosinellacea, and Saccamminacea among which the Recurvoidacea constitutes a rich (6-7%) group, and in one of the studied samples the Spiroplectaminacea comprises 13% of all foraminifera (Fig. 3).
Biostratigraphy

The foraminiferal assemblages are dominated by long-ranging and cosmopolitan forms typical for Cretaceous – Paleogene time with only single forms possessing biostratigraphical value. One of the most significant is the Rzehakina group. It is relatively rich (1–3% of all foraminifera in the sample) in the studied material. The genus is represented by four species: Rzehakina epigona (Rzehak), Rzehakina minima Cushman & Renz and Rzehakina lata Cushman & Jarvis which lived in latest Cretaceous and Paleocene time, and Rzehakina fissistomata (Grzybowski), which is limited only to the Paleocene (e.g., Jurkiewicz, 1967; Jednorowska, 1975; Olszewska et al., 1996; Olszewska, 1997; Kaminski & Gradstein, 2005 and references therein). The latter species is the marker and index taxon for the Outer Carpathian foraminiferal Paleocene biozone (e.g., Geroch & Nowak, 1984; Olszewska, 1997; Kaminski & Gradstein, 2005 and references therein). Moreover, in the studied assemblages single specimens of other Senonian – Paleocene species were found, such as Glomospira diffundens Cushman & Renz, Caudammina ovuloides? (Grzybowski), Haplophragmoides subbicoloris (Grzybowski), and Haplophragmoides stomatus (Grzybowski). This group of species is more common and numerous in the Upper Senonian – Lower Paleocene Carpathian deposits, in the Thanetian their number and diversity gradually decrease (Waśkowska-Oliwa, 2008). Most of them disappear above the Paleocene/Eocene boundary. Poorly preserved specimens of Subbotina were found among the agglutinated foraminifera. The species is closer to Subbotina velascoensis (Cushman), than to Subbotina linaperta (Finlay), which was first suggested by Cieszkowski et al. (2010). The species Subbotina velascoensis was noted from the upper Paleocene up to the Lower Eocene (e.g., Olszewska et al., 1996; Olsson et al., 1999; Premoli-Silva et al., 2003; Pearson et al., 2006, and references therein) or up to the end of Paleocene (Jednorowska, 1975). Taking into account the above data, the studied Trochammina-rich assemblages correspond to a Thanetian age. This age is consistent taking into account the superposition of the uppermost part of the Istebna shales.

DISCUSSION

The Trochammina acme is a widespread event in the Silesian Basin occurring in Ypresian time (Waśkowska, 2015a, b). It is after the Paleocene-Eocene Thermal Maximum (PETM). In the Paleogene sections it is found above the Glomospira acme or partly replacing the Glomospira as-
semblages, but above the last occurrence of *Rzehakina fissistomata* (Waśkowska, 2015a). In the studied assemblages, numerous *Trochammina* specimens co-occur with Paleocene *Rzehakina fissistomata* and other species that disappear after the PETM crisis. The Paleocene and Ypresian *Trochammina* assemblages display some similarity, however, is difficult to indicate their interrelationship. However, domination of one taxonomical type, domination of the epifaunal eco-group and the Lilliputian effect indicate the features of crisis assemblages. It is possible that the development of such type of assemblages was connected environmental changes that took place during the PETM.

A separate issue is raised by the presence of numerous *Spiroplectammina navarroana*. They are redeposited, however the phenomenon of *Spiroplectammina navarroana* rich assemblages is poorly known in other Carpathian sedimentary environments. *Spiroplectammina navarroana* is known from Upper Cretaceous – Lower Paleogene deposits of the Carpathians, where it is rather rare (e.g., Geroch, 1960; Morgiel & Szymakowska, 1978; Cieszkowski, 1992; Waśkowska-Oliwa, 2005, 2008). In the Silesian Nappe *Spiroplectammina navarroana*-rich assemblages were found in a large olistostrome in the Rożnów Lake area (Cieszkowski & Waśkowska, 2013; Waśkowska & Cieszkowski, 2014). The Melsztyn area is the second known locality in the Polish Carpathians where numerous redeposited *Spiroplectammina navarroana* can be found. This finding documents the development of assemblages rich in this taxon within the Silesian Basin, which took place in the shallower basin parts above the sedimentary area of the studied Upper Istebna Shales.

**CONCLUSIONS**

In the uppermost part of the Istebna Beds in the Silesian Nappe (Melsztyn area, Rożnów Foothills) the *Trochammina* semi-specific assemblages were recognised. The number of *Trochammina* is 35% and 55. The small sizes of agglutinated foraminifera tests indicate the Lilliputian effect.

The late Paleocene age of this assemblages was determined based on the presence of the Paleocene *Rzehakina fissistomata* (Grzybowski) with the co-occurrence other biostratigraphical marker species such as *Glommospira cf. diffundens* Cushman & Renz, *Caudammina ovuloides*? (Grzybowski), *Haplophragmoides suborbicularis* (Grzybowski), *Haplophragmoides stomatus* (Grzybowski), other species of *Rzehakina*, and poorly preserved *Subbotina velascoensis*?

The upper Paleocene *Trochammina* semi-specific assemblages have a similar structure to the Ypresian *Trochammina* assemblages from the Silesian Basin, but at present it is difficult to indicate their relationship.

The numerous specimens of *Spiroplectammina navarroana* Cushman in one of the samples is caused by redeposition. Redeposited foraminifera indicate the development of unknown *Spiroplectammina navarroana* - rich assemblages in the shallower parts of the Silesian Basin.

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**SYSTEMATICS**

The taxonomic documentation of all identified species from the uppermost Istebna Beds in the Melsztyn section is listed alphabetically.

**Ammodiscus cf. peruvianus Berry, 1928**

Ammodiscus *peruvianus* Berry, 1928, p. 342, pl. 27.

**Ammosphaeroidina pseudopauciloculata (Mjatliuk, 1966)**

Plate 1, Figs 15, 16

Cystaminellina *pseudopauciloculata* Mjatliuk, 1966, p. 264, pl. 1, figs 5-8, pl. 2, fig. 6, pl. 3, fig. 3.

**Ammosphaeroidina pseudopauciloculata** (Mjatliuk). – Bubik, 1995, p. 79, pl. 12, fig. 9.

**Annecetina sp. 1**

Plate 1, Figs 7-9

Description. Test free, circular or slightly elliptical in outline. The initial part of the tubular chamber (2 whorls) is miliolid-like coiled, followed part (4 whorls) is coiled planispirally. Diameter of tube increasing slowly. Aperture at the end of the tube. Test small, 200–300μm in diameter, thin-walled, transparent, finely agglutinated. Nine specimens in the studied material.

**Bathysiphon microrhaphidus Samuel, 1977**

Plate 1, Fig. 3

**Bathysiphon microrhaphidus** Samuel, 1977, p. 19, pl. 11, figs 3-6, pl. 12, figs 1-4.

**Caudammina aff. ovuloides** (Grzybowski, 1901)

Plate 1, Fig. 10

**Caudammina aff. ovuloides** Grzybowski, 1901, p. 268, pl. 7, fig. 3.

**Hormosina ovuloides** (Grzybowski). – Kaminski et al., 1988, p. 168, pl. 2, fig. 3-4.

**Caudammina ovuloides** Grzybowski). – Kaminski & Gradstein, 2005, p. 238, pl. 42.
Cribrostomoides cf. subglobosus (Cushman, 1910)  
Plate 2, Fig. 8
Haplophragmoides subglobosum (Sars). – Cushman, 1910, p. 105, figs 162-164.

Glomospira gordialis (Jones & Parker, 1860)  
Trophammina squamata Jones & Parker, 1860, p. 304.
Glomospira gordialis (Jones & Parker). – Geroch, 1960, p. 46, pl. 4, figs 2, 5, pl. 10, fig. 5.

Glomospira aff. diffundens Cushman & Renz, 1948
Glomospira diffundens Cushman & Renz, 1948, p. 15, pl. 1, fig. 30.

Haplophragmoides excavatus Cushman & Waters, 1927  
Plate 2, Fig 1
Haplophragmoides excavatus Cushman & Waters, 1927, p. 82, pl. 10, fig. 3.

Haplophragmoides kirki Wickenden, 1932
Haplophragmoides kirki Wickenden, 1932, p. 85, pl. 1, fig. 1.

Haplophragmoides horridus (Grzybowski, 1901)  
Haplophragmium horridum Grzybowski, 1901, p. 270, pl. 7, fig. 12.
Haplophragmoides horridus (Grzybowski). – Kaminski & Gradstein, 2005, p. 347, pl. 77.

"Haplophragmoides" stomatus (Grzybowski, 1898)  
Plate 2, Fig. 2
Trophammina stomata Grzybowski, 1898, p. 290, pl. 11, figs 26, 27.
Haplophragmoides stomatus (Grzybowski). – Kaminski et al., 1993, pl., 11, fig. 1.

Haplophragmoides suborbicularis (Grzybowski, 1896)  
Cyclammina suborbicularis Grzybowski, 1896, p. 284, pl. 9, figs 5, 6.
Haplophragmoides suborbicularis (Grzybowski). – Jednorowska, 1968, p. 48, pl. 5, fig. 4.

Haplophragmoides walteri (Grzybowski, 1898)  
Trophammina walteri Grzybowski, 1898, p. 290, pl. 11, fig. 31.
Haplophragmoides walteri (Grzybowski). – Geroch, 1960, p. 49, pl. 5, fig. 5.

Karrerulina aff. coniformis (Grzybowski, 1898)  
Gaudryina coniformis Grzybowski, 1898, p. 259, pl. 12, fig. 7.
Karrerulina coniformis (Grzybowski). – Kaminski et al., 1993, p. 269, pl. 13, figs 1-4.

Karrerulina conversa (Grzybowski, 1901)  
Plate 2, Fig. 13
Gaudryina conversa Grzybowski, 1901, p. 285, pl. 7, figs 15-16
Plectina conversa (Grzybowski). – Jednorowska, 1968, p. 60, pl. 8, figs 3-4.
Gerochammina conversa (Grzybowski). – Kaminski et al., 1993, p. 279, pl. 13, figs 5-11.

Paratrochamminoides olszewskii (Grzybowski, 1898)  
Plate 2, Figs 3-4
Trophammina olszewskii Grzybowski, 1898, p. 257, pl. 7, fig. 1.

In this group are placed the tubular tests, with constant diameter, occurring in fragments, with a thick coarse-grained wall and smooth interior.

Recurvoides aff. setosus (Grzybowski, 1896)  
Plate 2, Fig. 7
Cyclammina setosa Grzybowski, 1986, p. 284, pl. 9, fig. 9.

Recurvoides walteri (Grzybowski, 1898)  
Plate 2, Fig. 9
Haplophragmium walteri Grzybowski, 1898, p. 280, pl. 10, fig. 24.
Recurvoides walteri (Grzybowski). – Olszewska et al., 1996, p. 72, pl. 24, figs 6-7.

Rzehakina epigona (Rzehak, 1895)  
Plate 1, Fig. 12
Silicina epigona Rzehak, 1895, p. 214, pl. 6, fig. 1.
Rzehakina epigona (Rzehak). – Geroch, 1960, p. 62, pl. 4, figs 14-16, pl. 10, fig. 1.

Rzehakina lata Cushman & Jarvis  
Rzehakina epigona (Rzehak) var. lata Cushman & Jarvis, 1928, p. 28, pl. 13, fig. 11.
Rzehakina lata Cushman & Jarvis. – Kaminski & Gradstein, 2005, p. 212, pl. 34.

Rzehakina minima Cushman & Renz, 1946
Rzehakina minima Cushman & Renz, 1946, p. 24, pl. 3, fig. 5.

Rzehakina fissistomata (Grzybowski, 1898)  
Plate 1, Fig. 11
Rzehakina fissistomata (Grzybowski). – Geroch, 1960, p. 63, pl. 4, fig. 11.

Spirolectammina navarroana Cushman, 1932  
Plate 2, Figs 14-17
Spirolectammina navarroana Cushman, 1932, p. 96, pl. 11, fig. 14.

Subreophax pseudoscalaris (Samuel, 1977)  
**Subbotina aff. velascoensis** (Cushman, 1925)

*Globigerina velascoensis* Cushman, 1925, p. 19, pl. 3, fig. 6.

*Subbotina velascoensis* (Cushman). – Olszewska et al., 1996, p. 133, pl. 42, figs 1-2.

**Thallassammina subtorbinata** (Grzybowski, 1898)

Plate 2, Fig 8

*Haplophragmium subtorbinatum* Grzybowski, 1898, p. 280, pl. 10, fig. 23.

*Thallassammina subtorbinata* (Grzybowski). – Kamiński et al., 1993, p. 253, pl. 4, fig. 5.

**Trocchamminopsis aff. altiformis** (Cushman & Renz, 1946)

Plate 2, Fig. 11

*Trocchamminia altiformis* Cushman & Renz, 1946, p. 258, pl. 2, fig. 20.


**Trocchamminia aff. globigeriniformis** (Parker & Jones, 1865)

Plate 2, Fig. 12

*Lituola globigeriniformis* Parker & Jones, 1865, p. 407, pl. 15, figs 46-47, pl. 17, figs 96-98.

*Trocchamminia globigeriniformis* (Parker & Jones). – Geroch, 1960, p. 65, pl. 7, fig. 2.

**Trocchamminoides variolarius** (Grzybowski, 1898)

*Trocchammina variolaria* Grzybowski, 1898, p. 288, pl. 11, fig. 15.

*Paratrochamminoides variolarius* (Grzybowski). – Kamiński et al., 1993, p. 261, pl. 9, figs 5a-6c.

*Trocchamminoides variolarius* (Grzybowski). – Olszewska et al., 1996, p. 69, pl. 22, fig. 21.

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