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BENTONITIZED TUFFITES IN THE LOWER EOCENE DEPOSITS OF THE SUBSILESIAN UNIT (WESTERN OUTER CARPATHIANS, POLAND): LITHOLOGY, STRATIGRAPHIC POSITION AND MINERAL COMPOSITION

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Abstract: New occurrences of bentonitized tuffites were described from numerous outcrops of the Lower Eocene flysch rocks of the Subsilesian Unit. These deposits crop out in the Żywiec tectonic window and in the tectonic windows of the Lanckorona – Żegocina Structural Zone. The bentonitized tuffites, composed of almost pure dioctahedral motmorillonite, form numerous thin layers and laminae, only occasionally exceeding 5 cm. The age of the tuffites is estimated as the Early Eocene (*Glomospira* div. sp. and *Saccamminoides carpathicus* zones) on the basis of foraminiferal assemblages. They occur in the upper part of green shales and in the lower part of the Lipowa beds that consist mainly of muddy turbidites represented by green or green-brownish shales with rare intercalations of sandstones. The sedimentary sequences with the tuffite intercalations form a lithostratigraphic level in the Subsilesian Unit called in the present paper "the Glichów Tuffite Horizon". This tuffite horizon could probably be correlated with deposits of similar age containing tuffites which are known from the Magura, Silesian and Skole nappes.

Key words: Polish Outer Carpathians, Subsilesian Unit, Early Eocene, bentonitized tuffites, foraminiferal assemblages.

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INTRODUCTION

Tuffites have been reported in several tectonic units of the Polish Outer Carpathians. 31 levels of tuffites were described within the sedimentary sequences younger than the Hauterivian (Wieser, 1985). Within the Subsilesian Unit Wieser (1985) distinguished 4 levels: no. 5 – Upper Cenomanian, no. 7 – Upper Turonian, no. 11 – Lower Eocene, no. 21 – Lower Oligocene.

The lower Paleogene pyroclastic sediments were described from the Żegocina surroundings (Skoczylas-Ciszewska, 1956), Poznachowice Dolne (Burtan, 1978) and Las Bachowicki (Książkiewicz, 1956; Liszkowa, 1959; Wieser, 1952). Similar deposits of the same age were also noticed in the Silesian (Koszarski & Wieser, 1960) and Skole Units (Koszarski & Koszarski, 1985; Kotlarczyk, 1988; Rajchel, 1990; Rajchel, 1994; Wieser, 1970).

During field investigations, the authors found several new occurrences with numerous intercalations of bentonized tuffites within the lower Paleogene deposits of the Subsilesian Unit. The thickness of some of these intercalations exceeds several centimeters, which is unusual in the flysch deposits of the Subsilesian Unit in the Polish Outer Carpathians. In this contribution, some new occurrences are described, including foraminiferal stratigraphy and mineral composition.

Position and characteristics of Subsilesian Unit

The Outer Carpathian sedimentary basins are characterized by marked lateral facies changes that highlight complex paleogeography, where deep subsiding troughs were separated by shallow or even emergent geanticlinal structures – ridges. From the south to the north the following main sedimentary basins and ridges (Książkiewicz, 1972), each with distinctive lithostatigraphic succession, are identified: the Magura Basin, the Dukla Basin, the Bukowiec Ridge, the Silesian Ridge, the Silesian Basin, the Subsilesian Ridge, and the Skole Basin. In the troughs up to a few thousands meters, thick sequences of flysch type sediments were deposited. In many cases, the sedimentation of these deep-sea deposits took place below the local calcite compensation depth (CCD).

The deposits of the Subsilesian Series are not as thick as those in others Outer Carpathian units and part of them represent deposition above CCD. Some of them, deposited during the Late Cretaceous, Paleocene and Eocene, have been developed as non-flysch marly deposits. This fact shows that the Subsilesian sedimentary area was relatively shallower and included an elevated zone, even with some periodically emerging parts. The Subsilesian and Silesian sedimentary areas were interconnected. Towards the north and northeast, the Cretaceous and Paleogene clastic deposits,

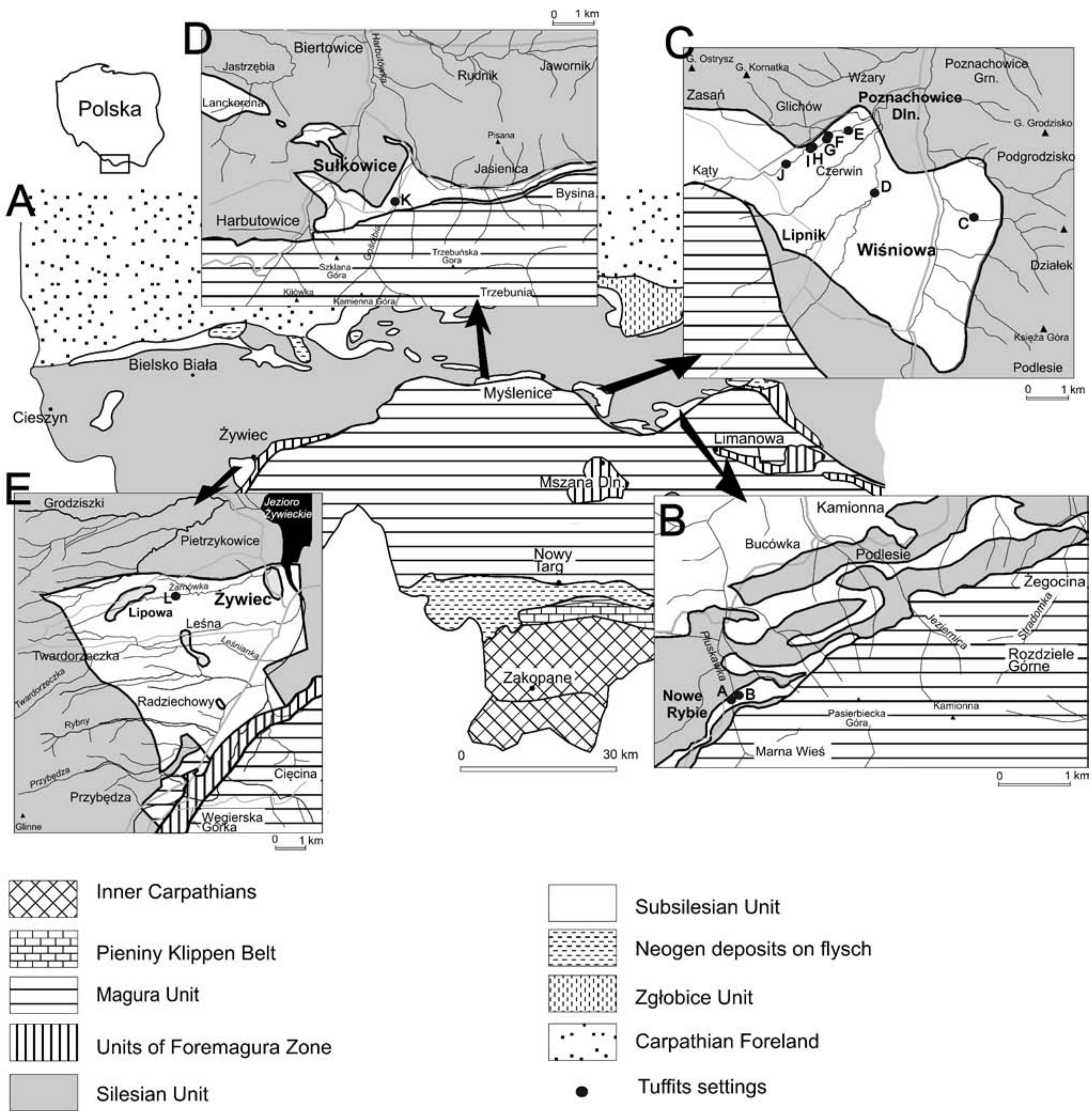

Fig. 1 Tuffite exposures settings (sketches after: A – Malata *et al.,* 1996; B – Skoczylas-Ciszewska, 1960; C – Burtan, 1978; D – Burtan, 1966; Burtan & Szymakowska, 1966; E – Nowak, 1966; Żytko, 1966)

typical of the Silesian Basin, were gradually replaced in the Subsilesian sedimentary area; at first by variegated shales, and eventually by the marls. Occasionally, in the Paleogene time, the sedimentation of variegated deposits continued up to the end of the Middle Eocene. Later, marls and shales and the Lower Oligocene Menilite Beds were deposited.

In the Neogene, the sediments filling the basins were folded and detached from their substratum and several uprooted nappes were created. The nappes' composition partially reflects the origin of sequences of deposits within the basins (Książkiewicz, 1977). During the folding and thrusting, the main nappes were partly differentiated and subdivided into smaller tectonic units. The Outer Carpathian nappes thrusted one upon another, were all together displaced onto the European platform. They covered the Miocene molasse deposits, which filled the Carpathian Foredeep that was formed in front of the northward advancing nappes. The Subsilesian Nappe underlies tectonically the Silesian Nappe, which is overthrust from the south by the Magura and Fore-Magura nappes. In the western sector of the Polish Carpathians the Silesian and Subsilesian nappes were thrust over the Miocene molasse of the Carpathian Foredeep, and in the eastern sector over the Skole Nappe. The deposits of the Subsilesian Nappe crop out in the northern part in a narrow zone in front of the Silesian thrust as well as in the numerous tectonic windows. The biggest one is the Żywiec tectonic window situated in the south-western part of the Silesian Nappe. Many tectonic windows are grouped in the Lanckorona-Żegocina Zone, stretched between Wadowice town in the west and Rajbrot village in the east. The Subsilesian Nappe sediments were found beneath the Silesian Nappe in many wells.

Lithology

The paper describes tuffites occurring within the Lower Paleogene deposits: green and variegated shales or the Lipowa beds of the Subsilesian Unit. Green and variegated shales are usually developed as green, green-brownish or occasionally variegated – red and green, muddy and clayey shales. Rare (up to 15%) intercalations of fine-grained sandstone turbidites also occur there. The Lipowa Beds consist mainly of clayey shales and mudstones with rare sandstone intercalations. They have been described as green or green-brownish shales in the Wiśniowa tectonic window (Leśniak *et al.*, 2001), while on the geological map of the area (Burtan, 1974; Burtan, 1978; Burtan, 1993), they were grouped together with Czerwin Sandstones. The same deposits were described as grey-greenish and variegated shales (Leśniak & Waśkowska-Oliwa, 2001a; Cieszkowski *et al.*, 2001) or as Lipowa Beds (Nescieruk, 1998) from the Żywiec tectonic window. In the exposures investigated, the discussed tuffites form numerous thin layers and laminae typically 0.5–5.0 cm thick, in the extreme cases reaching 10–17 cm. Tuffites are easy to identify macroscopically, because their properties are very different from the surrounding shales. They are much lighter than shales white or creamy, occasionally light grey or pink, and also soft, plastic, fat touched, and swelling in water. Thicker layers display subtle parallel lamination. The laminae usually occur in groups. In some places, shaly sediments with tuffite laminae are strongly tectonically deformed, mainly folded and ductily squeezed. The tuffite laminae form discontinuous streaks of different length and thickness. In some outcrops, thin layers of fine-grained calciturbidites (syderitic carbonate rocks) accompany the tuffites.

DETAILED DESCRIPTION OF SELECTED OUTCROPS

Twelve selected, best exposed and spectacular outcrops of the deposits with bentonitized tuffites are described below.

Żegocina Zone

The so-called Lanckorona – Żegocina Zone forms a composite anticlinal tectonic structure built of the Silesian and Subsilesian nappes thrust one upon another and refolded together. The northern limb of this undulated anticlinal structure is cuted by an inverse fault, uplifted and partly removed by the subsequent erosion. The Subsilesian Unit is visible in numerous tectonic windows of the Silesian Nappe.

The Żegocina Zone (Skoczylas-Ciszewska, 1960) represents the most eastern part of this tectonic structure. Two bentonized tuffites settings have been found there. They occur in the valley of the Pluskawka Creek and its tributaries in Nowe Rybie village (Fig. 1).

Exposure A

This setting is located in the left bank of a tributary, about 260 meters up from its junction with the Pluskawka Creek (Fig. 1). A 5 cm thick tuffite layer and two irregular streaks can be found in variegated shales (Fig. 2) of this outcrop.

Exposure B

This setting was found in the bank of Pluskawka Creek, about 60 meters up the creek from the mouth of the tributary described above (Fig. 1). Three thin layers of light-creamy bentonized tuffites of 1–5 cm thick occur in the outcrop of grey, clayey shales.

Wiśniowa Tectonic Window

Numerous high-quality exposures have been observed in the Czerwin Creek. Isolated outcrops were also found in the Foszczówka and Lipnik Creeks (Fig. 1) (Leśniak *et al.*, 2001). The eight best exposed localities in the central part of the Lanckorona – Żegocina Zone, in the Wiśniowa Tectonic Window are described below.

Exposure C

Exposure C is located in the Foszczówka Creek about 1 km from its junction with the Krzyworzeka Creek (Fig. 1). The 1,5 m long exposure of grey clayey shales in the bank of the creek contains 10 irregularly distributed intercalations of white tuffite layers of 0.5–3 cm thickness (Fig. 2).

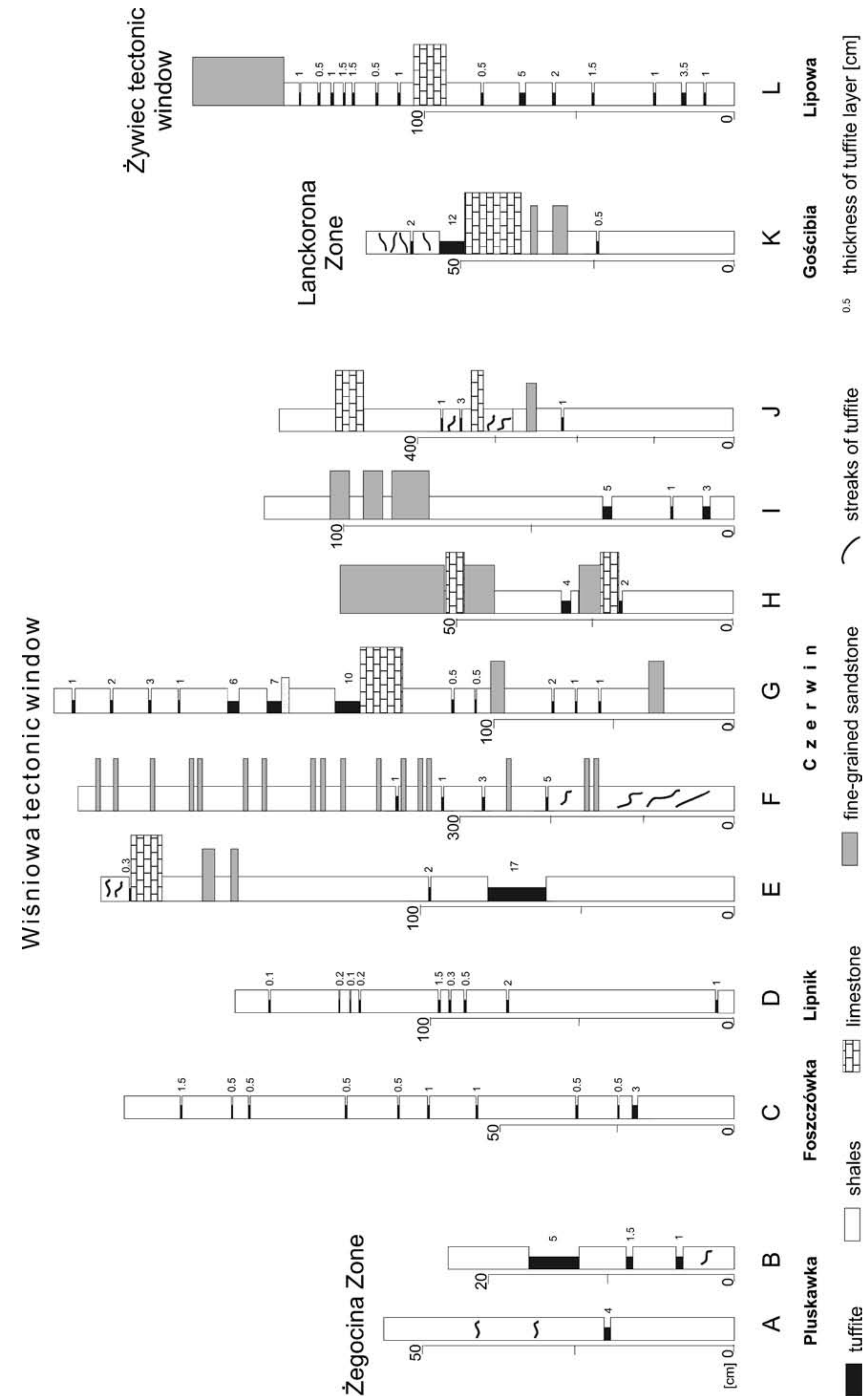

Fig. 2. Lithological logs of deposits with intercalations of tuffite layers

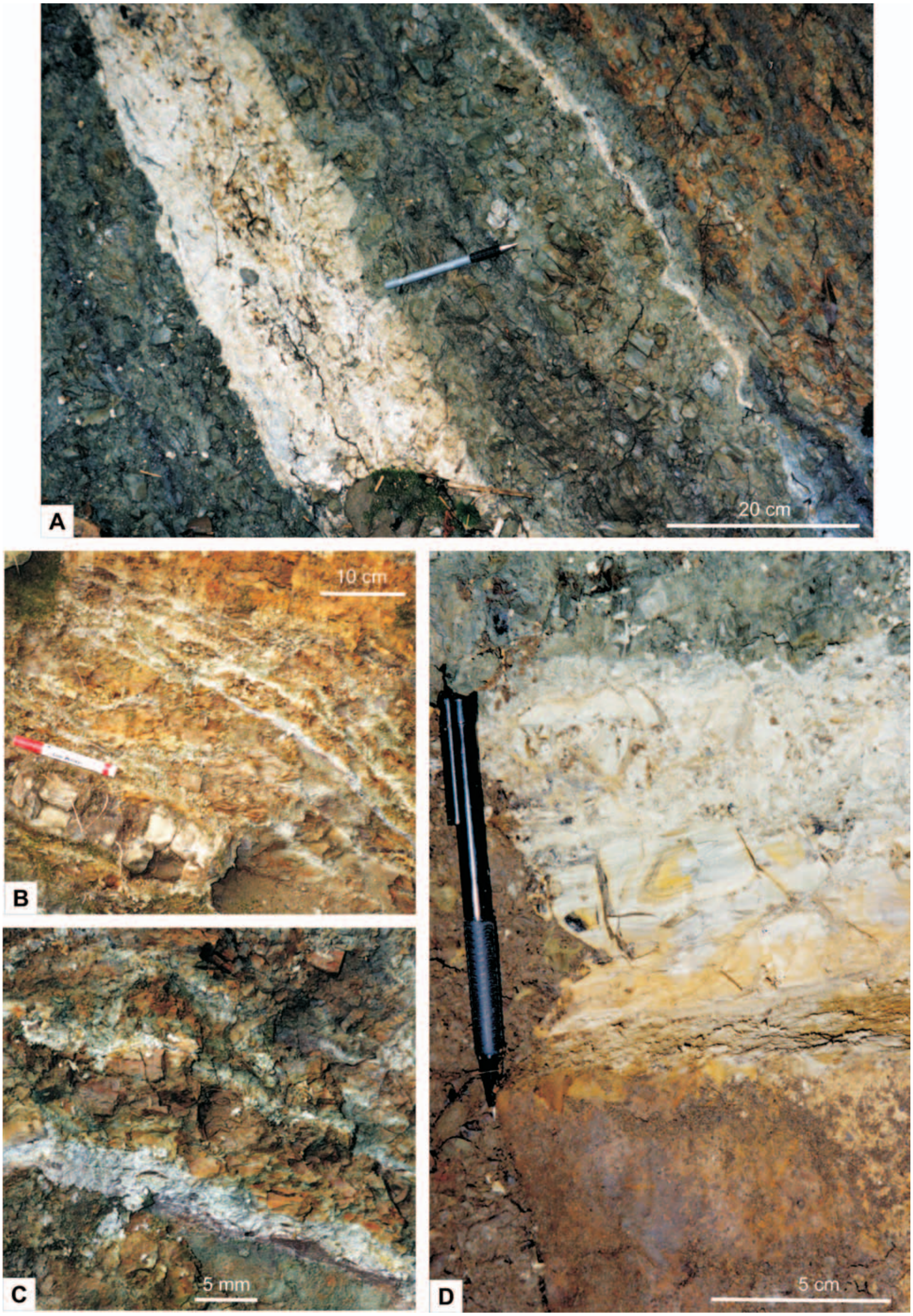

Fig. 3 Tuffites: **A** – in Czerwin creek – the thickest layer (17 cm) (Wiśniowa tectonic window), **B**, **C** – in Lipowa creek (Żywiec tectonic window), **D** – Sedimentary structures within tuffite layer (Czerwin creek – Wiśniowa tectonic window)

Exposure D

This setting was found in the Lipnik Creek, 45 m above its first tributary in Lipnik village (Fig. 1). Nine thin layers of light-creamy tuffites occur in the outcrop of grey clayey shales. These layers are distributed irregularly within the shale section. Their thickness ranges from 1 mm to 2 cm.

Exposure E

This setting is situated in Glichów village, in the right bank of the Czerwin Creek (Fig. 1). The exposure of tuffites is located about 450 m up, the creek from the small bridge, not far from the local fire-station situated at the road from Glichow to Poznachowice. Three white tuffite layers occur there within grey-bluish shales with occasional thin-bedded fine-grained sandstone intercalations (Fig. 2). One of them is 17 cm thick (Fig. 3 A). It is one of the thickest tuffite layer described from the Subsilesian Unit in the Polish sector of the Outer Carpathians until now. It is built of white and light-creamy bentonized tuffite with a fine slightly marked parallel lamination. The tuffite color changes upwards from white, creamy to more grayish at the top of the layer. Mineralogical data show, that this tuffite layer is rich in montmorillonite (Salata *et al.*, 2001). About 20 cm above is a 2 cm thick layer of tuffite and 90 cm up the section 10 cm calciturbidite layer is located. 0,3 cm tuffite lamina can be found at the top of the carbonate layer. 5 cm above the carbonate layer, there are next two very thin, tectonically deformed tuffite streaks.

Exposure F

Setting F is located about 350 m up the creek from setting E (Fig 1). Grey-greenish shales with numerous thin-bedded, fine-grained sandstone intercalations crop out there in the bank of the creek. Four layers of tuffites of 1–5 cm thickness occur in this section (Fig. 2). Below them, five thin tuffite streaks of various thicknesses are visible.

Exposure G

The next exposure G is located 50 m up the creek from the setting F (Fig. 1). It contains 12 layers of bentonized tuffites intercalating gray an gray-greenish shales with occasional intercalations of thin bedded sandstones. The thickness of tuffite layers ranges from 0.5 cm to 10 cm. The three thickest layers (10, 7 and 6 cm) are situated in the central part of the section (Fig. 2). Some tuffite layers are rusty and some light-gray, but more of them are white or light-creamy. In general, they are very similar to those described above. Thickest, 10 cm tuffite layer is laminated in its lower part (Fig. 3 D). It displays gently interleaved white and light-grayish parallel laminae. In lower part of the layer, the tuffite is massive and is yellowish at the bottom. In the upper part of the layer the lamination disappears and the tuffite becomes more crumbly and white with grayish shadow growing up to top. This tuffite is directly underlain by a layer of sideritic carbonate rock of 35 cm thickness. It is a calciturbidite with Bouma intervals sequence T_{abcd}, light-gray when fresh, and yellowish or rusty on weathered surface.

Exposure H

Next 90 m up the creek, in its right bank there is located another setting (H) (Fig. 1). Two layers of tuffites (2 and 4 cm thick) and two layers of sideritic carbonate rock (4 and 5 cm thick) (Fig. 2) occur here within gray-green shales with intercalations of fine-grained, medium-bedded sandstones.

Exposure I

About 100 m from the setting H there is an outcrop of shales and tuffites resembling those described in the previous outcrops (Fig. 1). A few thin sandstone layers occur there at top of the cropped out section. Within the shales, three layers of white tuffites 1–5 cm thick have been noticed (Fig. 2).

Exposure J

Following the section 600 m up the creek, it is possible to find three thin layers 1–3 cm thick and a few streaks of tuffites within the shales. Two layers of sideritic carbonate rock 10 and 14 cm thick also crop out here (Fig. 2).

Lanckorona Zone

Lanckorona Zone (Książkiewicz, 1951a, b) extends west of Myślenice up to Wadowice. Between Myślenice and Wadowice the Subsilesian Unit is exposed in several tectonic windows in the area of Sułkowice, Lanckorona and Kalwaria Zebrzydowska.

Exposure K

This setting is located in the Gościbia Creek about 0.5 km up the dam which is situated by the road connecting Jasienica and Harbutowice villages (Fig. 1). There is an outcrop of gray-greenish clayey shales with layers and a few streaks of bentonized tuffites (Fig. 2). Two of tuffite layers are thin (0.5 cm and 2 cm) and the central one is of 12 cm thickness. The bottom tuffite is directly underlain by 20 cm thick layer of a turbiditic limestone. 30 cm below the limestone there is another layer of white tuffite. The thickest one is creamy or somewhere rusty in lower part, upward passing steeply to light-gray. Softly marked parallel lamination is visible within this layer. Within the shales above, a few very thin streaks below a gray colored tuffite layer can be seen.

Żywiec Tectonic Window

Żywiec Tectonic Window is the biggest among the Silesian Nappe windows, filled with the deposits of Subsilesian Unit (Geroch & Gradziński, 1955).

Exposure L

Setting L is located in the north-western part of the Żywiec Tectonic Window in the Lipowa village (Fig. 1). There in the left bank of Żarnówka Creek, crops out about 1.8 m long section of gray-green shales intercalated by fourteen thin layers of bentonized tuffites of the thickness from 0.5 cm up to 5 cm (Leśniak & Waśkowska-Oliwa, 2001b) (Figs.2, 3 B). In the central part of this section, 9 cm thick layer of turbiditic limestone is visible, and, at the top of the section, 40 cm thick layer of fine-grained sandstone is situ-

Table 1

Results of X-ray diffraction examination. For illite-smectite and smectite, positions of diagnostic peaks are given

Sample	Lithology	< 0.2 μm fraction, glycolated												
		Diagnostic peaks of illite-smectite			%S	Diagnostic peaks of i-s		%S	K	Ch	I	Anatase	Quartz	Apatite
Glichów 1	variegated shale	16.22		31.88	50				+	tr	+	+		
Glichów 2	bentonite	15.78	26.46	31.82	96	43.00	48.50	95	+			+		
Glichów 3	shale between bent.	16.24		31.86	50				+	tr	+	tr		
Glichów 4	bentonite	15.80	26.48	31.84	98	43.00	48.58	100	+			tr		
Glichów 5	bentonite	15.80	26.48	31.80	98	43.00	48.56	100	tr			tr		
Glichów 6	shale	16.20	26.58	31.88	50				+	tr	+	+		
Glichów 7	bentonite	15.78	26.48	31.78	100	42.98	48.52	100	tr			tr		
Glichów 8	shale	16.26		31.96	50				+	tr	+	+		
Glichów 9	siderite layer	16.68			30					+++	++	tr	tr	
Glichów 10	siderite concretion	16.70			30					+++	++	tr		+

Sample	Lithology	Bulk rock								
		K	CH	I	Anatase	Calcite	Pyrite	Quartz	Apatite	Siderite
Glichów 1	variegated shale	+	+	++		++	+	+++		
Glichów 2	bentonite	++			++			++		
Glichów 3	shale between bent.	+	+	++				+++		
Glichów 4	bentonite	+			++	tr		+		
Glichów 5	bentonite	+			++			tr		
Glichów 6	shale	+	+	++		tr		+++		
Glichów 7	bentonite	+			++	tr		tr		
Glichów 8	shale	+	+	++	+			+++		
Glichów 9	siderite layer					tr		+		++++
Glichów 10	siderite concretion							+	+	++++

%S – percent of smectite in mixed-layer illite-smectite (for bentonites % S by two techniques); K – kaolinite, CH – chlorite; I – illite, tr – trace. Number of crosses reflects relative abundance of a given mineral.

ated. Tuffites are white or creamy and occasionally light-gray. Their colors contrast markedly with the shales surrounding them. At the bases of some tuffitic layers, cherry-red, 1–3 mm thick laminae are visible (Fig. 3 D). The tops of tuffite layers are sharply grayish. This gray color is well visible especially in the thickest layers.

MINERAL COMPOSITION

Since all described outcrops contain very similar rocks, their mineral composition was studied in the best exposed locality from the Wiśniowa Tectonic Window. 10 samples were investigated from exposures E–I, located in the banks of Czerwin Creek. 4 samples represent shales, 4 bentonites, and 2 Fe-carbonates. Their approximate positions in the profile are given in Table 1.

All samples were studied by X-ray diffraction (XRD) both as bulk rocks and in <0.2 μm fractions separated from these rocks. Bulk rocks were studied as side-loaded random preparations of powders, prepared by wet grinding in McCrone mill. <0.2 μm fractions were separated using the complete Jackson (1975) procedure, applied in order to dissolve carbonates and remove organic matter and iron oxides. They were studied as oriented preparations, sedimented on glass slides, both in air-dry and ethylene glycol-saturated form. A Philips diffractometer, equipped with a Cu lamp, and a graphite monochromator were used.

Mixed-layer illite-smectite and smectite were identified in glycolated preparations using the positions of appropriate pairs of basal reflections (Środoń 1980, 1981, 1984; Dudek & Środoń, 1996).

The mineral composition of all shale samples is very similar, typical of the Carpathian shales of the Subsilesian Unit (comp. Kotarba, 2003): mixed-layer illite-smectite, illite + mica, kaolinite, chlorite, quartz, plagioclase, calcite, and in individual samples pyrite or anatase (Tab. 1). Illite-smectite is randomly interstratified and in all shale samples contains ca. 50%S (smectite layers; Fig. 4: Glichów 1).

The composition of bentonite samples is characteristic of altered pyroclastics: a very low amount of quartz, the lack of dioctahedral mica, and the predominance of clay. The major clay mineral is pure or almost pure dioctahedral smectite (100–95%S). It is accompanied by a small amount of kaolinite (Fig. 4: Glichów 2). Chlorite is absent. Some samples contain trace amounts of calcite.

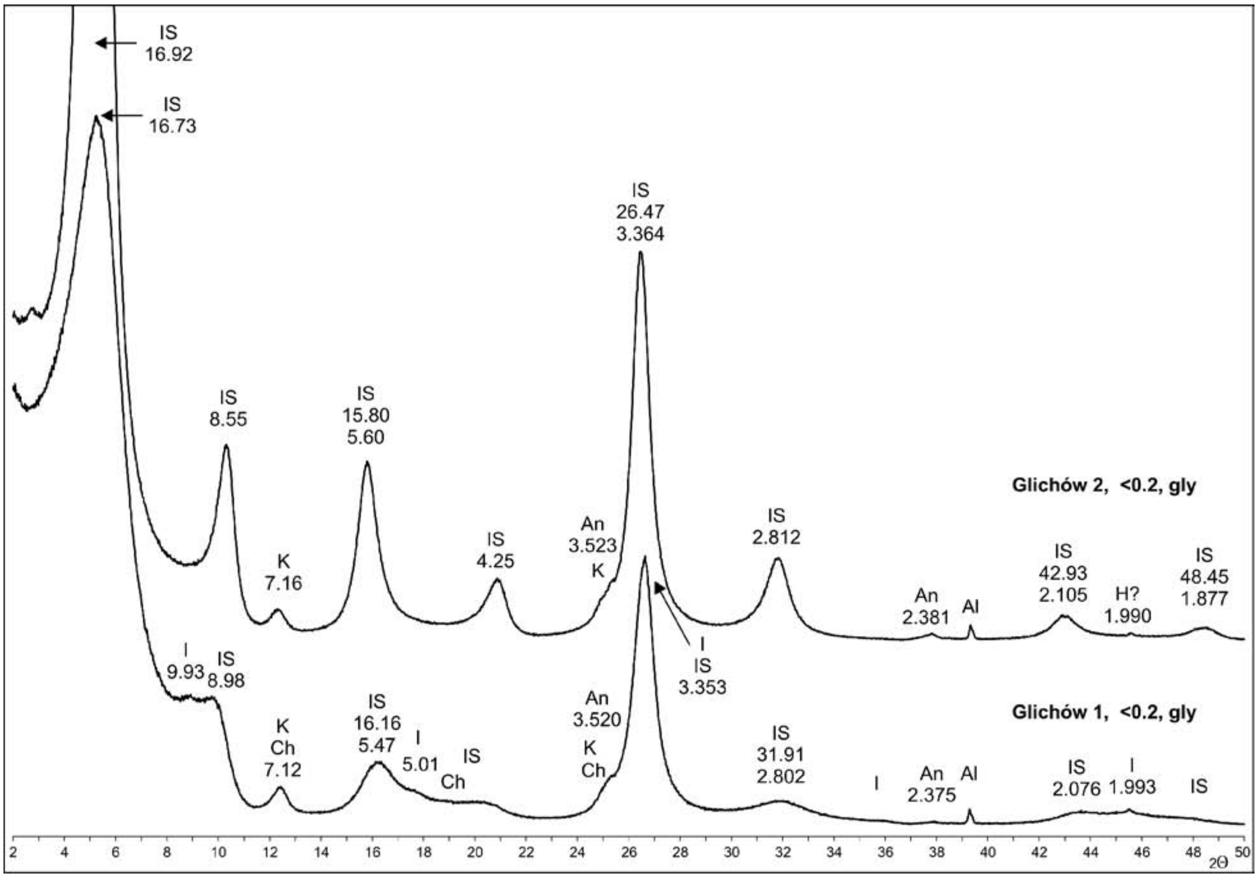

Fig. 4. Examples of XRD patterns of glycolated, oriented preparations of <0.2 µm fractions of a shale (Glichów 1) and a bentonite (Glichów 2). IS – illite-smectite, I – illite, K – kaolinite, Ch – chlorite, An – anatase, Al – aluminum from the Al foil blocking the primary beam

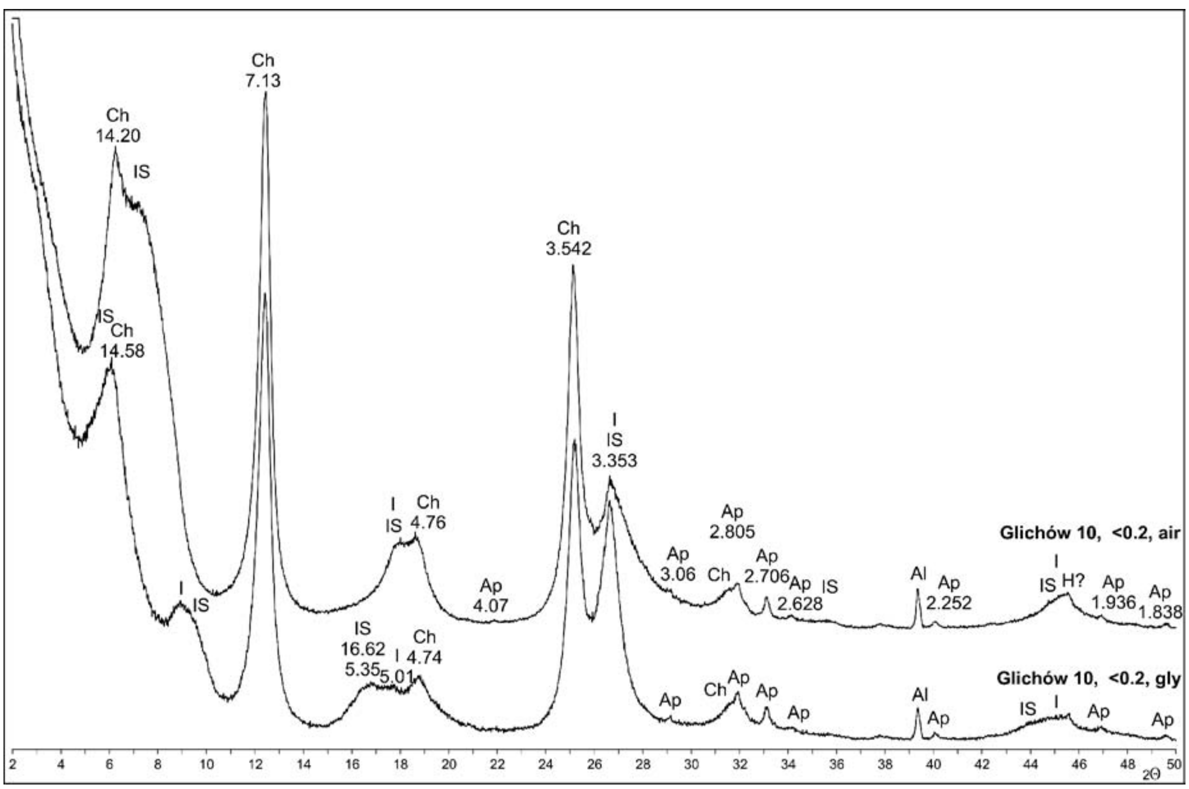

Fig. 5. Examples of XRD patterns of air dry and glycolated, oriented preparations of <0.2 µm fraction of a carbonate rock. IS – illite-smectite, I – illite, Ch – chlorite, Ap –apatite, H? – probably halite, Al – aluminum from the Al foil blocking the primary beam

A characteristic component of the investigated bentonites, almost absent from the surrounding shales, is anatase, present in all samples in quantities comparable to quartz. It is so fine grained that it can be detected even in <0.2 µm fraction (Fig. 4).

The carbonate samples are composed almost exclusively of siderite. Trace amounts of quartz and calcite or apatite were recorded in the bulk samples. A trace amount of clay fraction was detected after dissolving siderite in the course of Jackson treatment. The composition of the clay fraction is very different from the surrounding shales (Fig. 5), characterized by dominant Fe-rich chlorite, subordinate illite and ordered illite-smectite, with 30%S (more illitic than in the shales). A trace of anatase was found in the clay fractions from both carbonate samples, as well as some apatite in one of them.

FORAMINIFERAL STRATIGRAPHY

57 samples used for the biostratigraphical study have been taken from tuffites as well as from the surrounding shales. Minimum 3 samples from each exposure were thoroughly investigated. Table 2 presents the list of foraminiferal taxa from one typical sample from each exposure. Microfossils were separated using standard micropaleontological methods. Well preserved foraminifera are represented mainly by agglutinated forms (Figs 6, 7, 8).

Frequent occurrence of *Glomospira* genus is typical for the assemblages from each sample. Such microfauna from the Polish sector of the Outer Carpathians was described as Early Eocene assemblage (Bąk *et al.*, 1997; Jednorowska, 1968; Jurkiewicz, 1967; Malata *et al.*, 1996; Morgiel & Olszewska, 1981; Morgiel & Szymakowska, 1978; Waśkowska-Oliwa, 2000; Waśkowska-Oliwa & Leśniak, 2003). Independent Acme Zone *Glomospira* div. sp. distinguished by Olszewska (1997) was used in the biostratigraphic zonation presented in this paper.

Based on taxonomical composition, the foraminiferal assemblages from the tuffites were divided into two groups:

– group 1 – assemblages typical for the *Glomospira* div. sp. Zone with numerous examples of *Glomospira. Glomospira* genus is represented by 5 species (Tab. 1). The most frequent *Glomospira charoides* (Jones et Parker) and *Glomospira gordialis* (Jones et Parker), taken together compose 70% of the assemblage. Tubular forms: *Rhabdammina*, *Rhizammina*, *Nothia* and *Recurvoides* div. sp., as well *Paratrochamminoides* div. sp are also relatively frequent. Single specimens of typical Eocene species *Glomospirella biedai* Samuel, *Reophax elongatus* Grzybowski, *Reophax pilulifer* Brady, *Saccamminoides carpathicus* Geroch occasionally occur. Besides these species, other common components of the discussed assemblages include: *Aschemocella carpathica* (Neagu), *Ammodiscus* div. sp., *Ammosphaeroidina pseudopauciloculata* (Mjatliuk), *Gerochammina conversa* (Grzybowski), *Haplophragmoides walteri* (Grzybowski), *Hyperammina elongata* Brady, *Praecystammina sveni* Gradstein et Kaminski, *Saccammina placenta* (Grzybowski), *Spiroplectammina spectabilis* (Grzybowski), *Thalmannammina subturbinata* (Grzybowski), *Trochammina* div. sp. Poorly preserved calcareous forams occur together with agglutinated forms. The benthic genus *Nuttallides truempyi* (Nuttall) is common. The other benthic forams *Abysammina poagi* Schnitker et Tjalsma, *Abysammina quadrata* Schnitker et Tjalsma, *Eponides subcandidulus* (Grzybowski), *Eponides umbonatus* (Reuss), *Dentalina* sp., *Nodosaria* sp., *Osangularia* div. sp., *Quadrimorphina profunda* Schnitker et Tjalsma, as well planktonic forms e.g. *Acarinina*, *Globigerina*, *Subbotina*, sporadically occur in the assemblage. Such assemblages were found in the exposures A, C, D, E, G, H, L (Fig. 1). The composition of assemblages from localities F, G, H (Fig. 1) is the same as described above, but the authors noticed a single occurrence (one example/sample) of *Rzehakina fissistomata/minima*, *Haplophragmoides* cf. *mjatliukae* (Masłakowa), and *Glomospirella grzybowskii* (Jurkiewicz).

– group 2 – assemblages of the *Saccamminoides carpathicus* Zone – the specimens of *Glomospira*, *Paratrochamminoides* and *Recurvoides* genus are common, but less numerous than in the assemblages typical for the *Glomospira* div. sp. Zone. More frequent are index taxa *Saccamminoides carpathicus* and *Reophax* genus and also calcareous benthic forams, with *Nuttallides truempyi* (Nuttall) as most common. In these assemblages, a single *Reticulophragmium amplectens* (Grzybowski) was found. The first occurrences of *Reticulophragmium amplectens* (Grzybowski) and *Reophax elongatus* (Grzybowski) were noticed above the *Glomospira* acme, in the late Early Eocene (Olszewska, 1997). These assemblages were found in the exposures B, J (Fig. 1).

Described foraminiferal assemblages bear features of the *Glomospira* div. sp. Zone. The occurrence of single specimens of foraminifera, typical for the Paleocene could indicate a lower part of the *Glomospira* div. sp Zone, or the assemblages from the Paleocene /Eocene boundary. On the boundary between the Eocene and the Paleocene the sedimentation could be condense, and, therefore, the Paleocene and Eocene species could be taken together in the same sample. The authors didn't find traces of redeposition in the studied material there. Taxonomic composition of foraminiferal assemblages suggests that the deposition of tuffites in the Subsilesian Unit took place in the Early Eocene. The samples taken from bentonized tuffites and surrounding shales display similar age, but some individual features differentiating foraminifera assemblages have been observed.

DISCUSSION

The Lower Eocene deposits, while widespread in the Subsilesian Unit and occurring in many settings, have been poorly described until now. This contribution fills such gap, by characterizing the sequence of tuffite bearing deposits in the Subsilesian Unit, occurring in the upper part of green shales and lower part of so called Lipowa Beds *sensu* Nescieruk (1998) (Lower Eocene).

It seems that the tuffites characterized in this paper could be equivalent to the bentonitized tuffites described from the Subsilesian Unit in Żegocina by Skoczylas-Cieszewska (1956), from Poznachowice Dolne by Burtan

Table 2

Occurrence of small foraminifera in tuffites and surrounding deposits

Foraminifera / Tuffites outcrops	Żegocina zone	Wiśniowa tectonic window									Lanckorona Zone	Żyiec window
	A	B	C	D	E	F	G	H	I	J	K	L
Abysammina poagi Schnitker et Tjalsma	+					+				+		
Abysammina quadrata Schnitker et Tjalsma						+				+		+
Acarinina soldadoenis (Brünnimann)					+							
Acarinina nitida (Martin)							+					
Acarinina primitiva (Finaly)												+
Acarinina sp.		+	+				+				+	
Ammobaculites sp.					+							+
Ammodiscus cretaceus (Reuss)	+	+			+	+	+	+	+	+	+	+
Ammodiscus incertus (d'Orbigny)					+	+	+		+	+	+	
Ammodiscus peruvianus Berry	+		+	+	+	+	+			+	+	
Ammodiscus planus Loeblich	+	+			+	+	+	+	+		+	+
Ammodiscus tenuissimus Grzybowski	+				+		+		+	+	+	
Ammolagena clavata (Jones et Parker)	+	+				+						
Ammosphaeroidina pseudopauciloculata (Mjatliuk)	+	+	+	+	+	+	+	+		+	+	+
Anomalina preacuta Vasilenko						+	+					
Anomalina acuta (Plummer)		+								+		+
Arenobulimina dorbignyi (Reuss)		+				+			+			
Aschemocella carpathica (Neagu)	+		+		+	+		+		+		
Bathisiphon sp.	+			+	+				+	+		
Caudammina ovulum (Grzybowski)	+			+		+	+	+			+	
Cibicides sp.						+	+			+		
Clinapertina complanata Tjalsma et Lohman										+		
Dentalina sp.						+			+	+		
Ellipsoglandulina sp.		+								+		+
Eponides subcandidulus (Grzybowski)					+	+				+		
Eponides umbonatus (Reuss)	+	+				+				+		+
Eponides sp.		+					+		+			
Gavelinella sp.	+									+		
Gerochammina conversa (Grzybowski)	+	+	+		+	+	+	+	+	+	+	+
Gerochammina lenis (Grzybowski)	+	+			+	+					+	+
Globigerina turgida Finaly					+							
Globocassidulina inexculpta (Franzenau)										+		
Glomospira charoides (Jones et Parker)	+	+	+	+	+	+	+	+	+	+	+	+
Glomospira glomerata (Grzybowski)		+			+	+	+			+		+
Glomospira gordialis (Jones et Parker)	+	+	+	+	+	+	+	+	+	+	+	+
Glomospira irregularis (Grzybowski)	+	+		+	+	+	+				+	+
Glomospira serpens (Grzybowski)					+		+			+		
Glomospirella biedai Samuel	+	+			+							
Glomospirella grzybowskii (Jurkiewicz)							+				+	
Gyroidinoides sp.										+		
Haplophragmoides kirki Wickenden	+					+	+					+
Haplophragmoides cf. *mjatliukae* (Masłakowa)						+					+	
Haplophragmoides porrectus Masłakowa							+					
Haplophragmoides walteri (Grzybowski)			+	+		+	+	+	+	+		+
Hormosina velascoensis (Cushman)	+			+	+	+	+		+		+	
Hyperammina elongata Brady		+		+	+	+	+	+		+	+	+
Hyperammina gaultina Dam								+				
Hyperammina sp.	+	+										
Kalamopsis grzybowskii (Dylążanka)			+		+	+		+		+		

Table 2 continued

Foraminifera \ Tuffites outcrops	Żegocina zone	Wiśniowa tectonic window									Lanckorona zone	Żywiec window
	A	B	C	D	E	F	G	H	I	J	K	L
Karrerulina coniformis (Grzybowski)					+	+	+	+		+	+	
Karrerulina horrida (Mjatliuk)					+		+				+	
Lenticulina sp.										+		
Lituotuba lituiformis (Brady)					+	+	+	+	+			+
Nodosaria sp.	+			+		+				+		+
Nonion cf. *havanense* Cushman et Bermudez										+		
Nothia excelsa (Grzybowski)	+	+	+	+	+	+	+	+	+	+	+	+
Nuttallides truempyi (Nuttall)	+				+	+	+	+		+		+
Osangularia plummerae Brotzen						+				+		
Paratrochamminoides div. sp.	+	+	+		+	+	+	+	+	+	+	+
Pleurostomella cf. *eocena* Gümbel						+				+		
Psamminopelta gradsteini Kaminski et Geroch						+	+					+
Pseudonodosaria sp.										+	+	
Psamosphaera sp.					+		+					
Pullenia sp.						+						
Quadrimorphina profunda Schnitker et Tjalsma	+					+				+		
Praecystammina sveni Gradstein et Kaminski	+	+	+			+	+			+	+	+
Recurvoides div. sp.	+	+	+	+	+	+	+	+	+	+	+	+
Reophax duplex Grzybowski						+	+			+		+
Reophax elongatus Grzybowski	+				+	+		+		+	+	+
Reophax nodulosus Brady	+		+		+	+	+	+		+	+	+
Reophax pilulifer Brady	+	+	+	+	+	+	+	+	+	+	+	+
Reticulophragmium amplectens (Grzybowski)		+								+		
Rhabdammina div. sp.	+	+	+	+	+	+	+	+	+	+	+	+
Rhizammina indivisa Brady	+	+	+		+		+	+	+	+	+	+
Rzehakina fissistomata/minima ?						+	+					
Saccammina grzybowskii (Schubert)					+	+	+	+	+		+	+
Saccammina placenta (Grzybowski)	+	+	+	+	+	+	+	+	+	+	+	+
Saccamminoides carpathicus Geroch		+			+			+		+		+
Spiroplectammina spectabilis (Grzybowski)				+	+	+		+			+	+
Stilostomella sp.										+		
Subbotina linaperta (Finaly)					+	+	+		+			+
Subbotina hagni (Gohrbandt)												+
Subbotina velascoensis (Cushman)					+		+					+
Subbotina triangularis (White)					+							
Subbotina sp.	+											
Subreophax splendidus (Grzyzbowski)					+	+						
Thalmannammina subturbinata (Grzybowski)	+	+	+	+	+	+	+	+	+	+	+	+
Trochammina altiformis Cushman et Renz				+								
Trochammina globigeriniformis (Jones et Parker)	+				+	+				+	+	+
?*Trochammina qadriloba* (Grzybowski)			+		+	+	+	+				+
Trochammina sp.				+								
Trochamminoides coronatus (Brady)	+					+						+
Trochamminoides proteus (Karrer)		+								+		

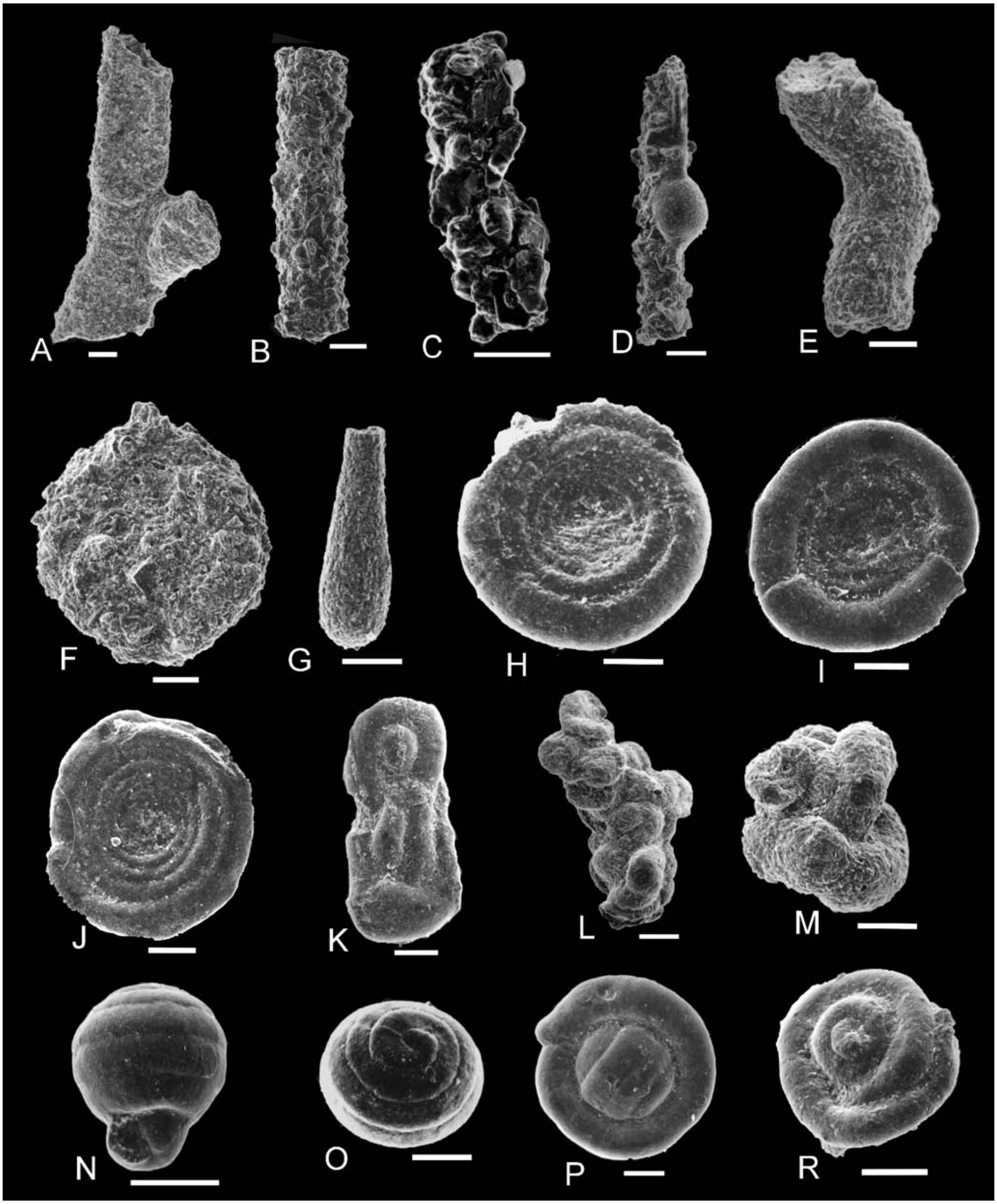

Fig. 6. Small foraminifera from tuffites and surrounding deposits. **A** – *Nothia excelsa* (Grzybowski), **B**, **C** – *Rhabdammina cylindrica* Glaessner, **D** – *Rhabdammina cylindrica* Glaessner and *Ammolagena clavata* (Jones et Parker), **E** – *Rhizammina indivisa* Brady, **F** – *Saccammina placenta* (Grzybowski), **G** – *Hyperammina kenmilleri* Kaminski, **H**, **I** – *Ammodiscus cretaceus* (Reuss), **J** – *Ammodiscus tenuissimus* Grzybowski, **K** – *Glomospira serpens* (Grzybowski), **L** – *Glomospira glomerata* (Grzybowski), **M** – *Glomospira irregularis* (Grzybowski), **N**, **O**, **P** – *Glomospira charoides* (Jones et Parker), **R** – *Glomospira gordialis* (Jones et Parker). SEM scale bar = 100 μm

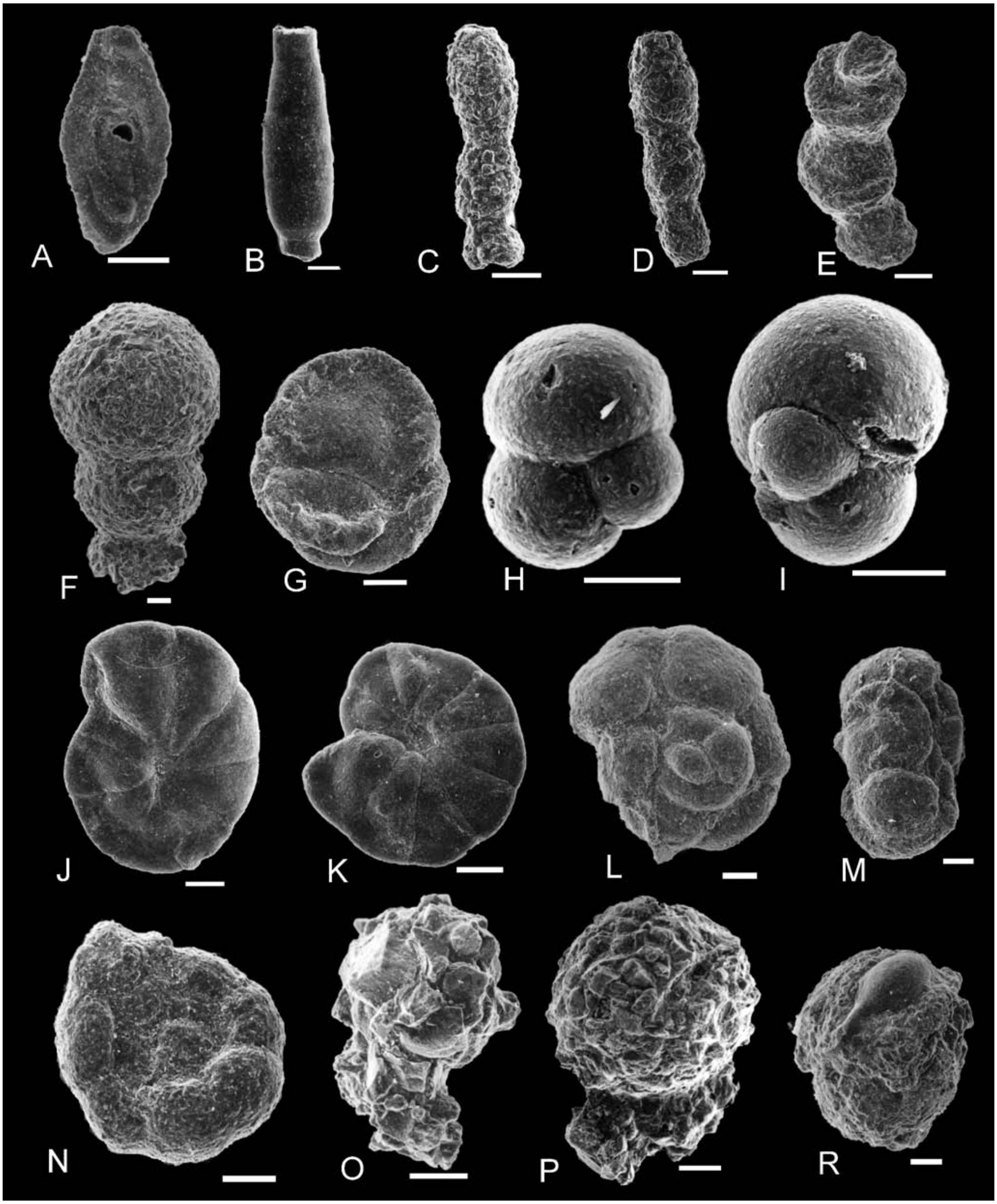

Fig. 7. Small foraminifera from tuffites and surrounding deposits. **A** – *Psamminopelta gradsteini* Kaminski et Geroch, **B** – *Kalamopsis grzybowskii* (Dylążanka), **C**, **D** – *Reophax elongatus* Grzybowski, **E** – *Reophax scalaris* Grzybowski, **F** – *Reophax pilulifer* Brady, **G** – *Ammosphaeroidina pseudopauciloculata* (Mjatliuk), **H**, **I** – *Praecystammina sveni* Gradstein et Kaminski, **J**, **K** – *Haplophragmoides walteri* (Grzybowski), **L** – *Paratrochamminoides* sp., **M** – *Paratrochamminoides contortus* (Grzybowski), **N** – *Trochamminoides* sp., **O**, **P** – *Saccamminoides carpathicus* Geroch, **R** – *Recurvoides* with *Ammolagena clavata* (Jones et Parker). SEM scale bar = 100 µm

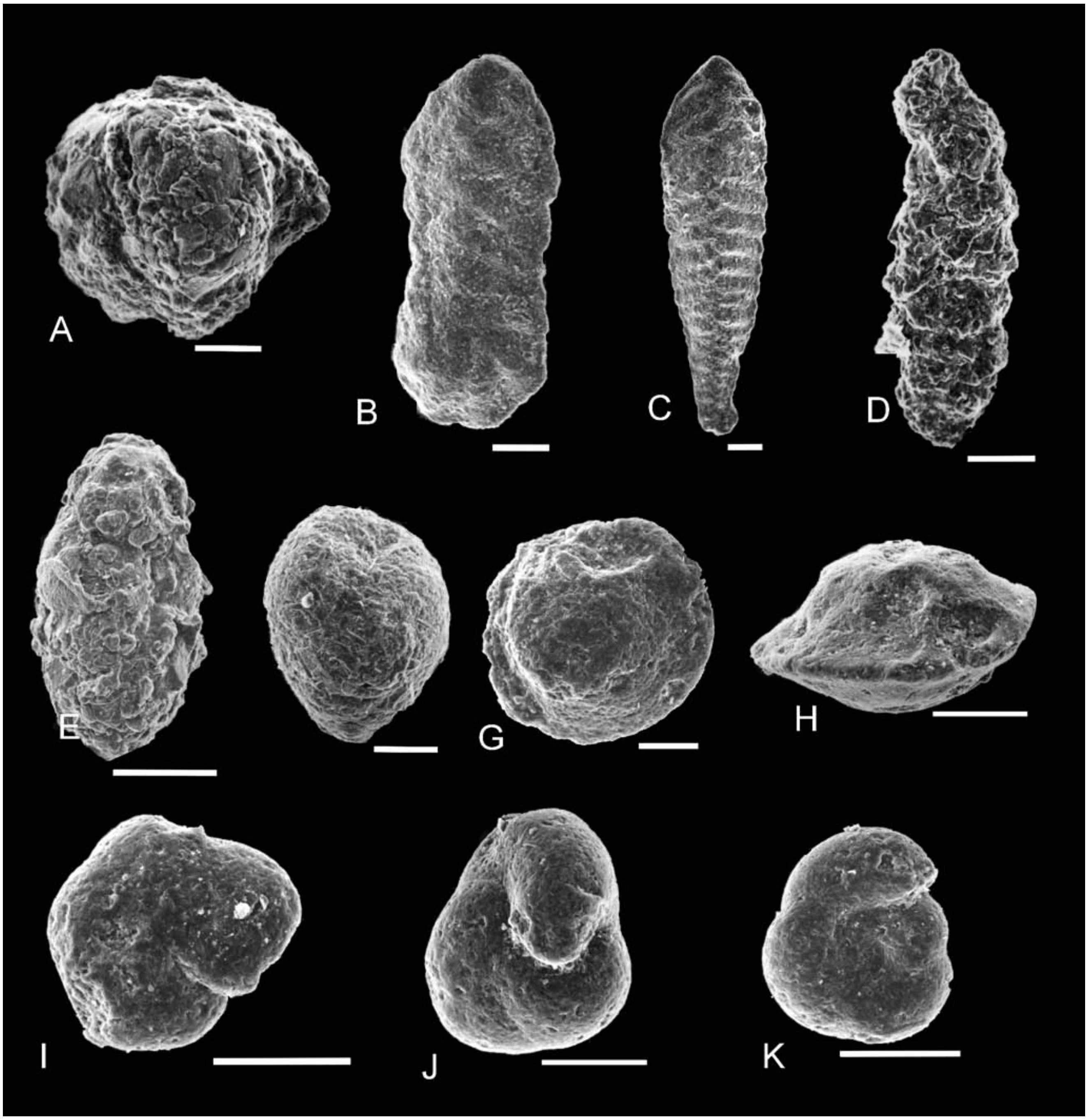

Fig. 8. Small foraminifera from tuffites and surrounding deposits. **A** – *Recurvoides nucleolus* (Grzybowski), **B**, **C** – *Spiroplectammina spectabilis* (Grzybowski), **D** – *Gerochammina horrida* (Grzybowski), **E** – *Karrerulina conversa* (Grzybowski), **F** – *Arenobulimina dorbignyi* (Reuss), **G**, **H** – *Nuttallides truempyi* (Nuttall), **I**, **J** – *Abysammina poagi* Schnitker et Tjalsma, **K** – *Quadrimorphina profunda* Schnitker et Tjalsma. SEM scale bar = 100 µm

(1978), and from Las Bachowicki (Książkiewicz, 1956; Liszkowa, 1959; Wieser, 1952). All those tuffites belong to the tuffite level No 11, *sensu* Wieser (1985). They form a clearly visible widespread correlation level in the Subsilesian Unit in the Polish sector of the Outer Carpathians. The authors propose to identify the sedimentary complex with described tuffites as a special correlation level. We suggest calling it "the Glichów Tuffite Horizon", because the best outcrops occur in the Glichów Village along Czerwin creek (Fig. 1).

We suspect that the pyroclastic material of the tuffite horizons of the same age from Silesian (Koszarski & Wieser, 1960), as well from the Skole Nappe (Koszarski & Koszarski 1985; Kotlarczyk, 1988; Rajchel, 1990; Rajchel, 1994; Wieser, 1970) could be derived from the same volcanic eruptions. Likewise, in the Paleocene or Lower Eocene variegated shales from the Magura Nappe (Sikora & Wieser, 1959a, b), bentonitized tuffites are known and are interpreted as representing the peak of the Early Paleogene volcanic activity (Książkiewicz, 1974).

It is not easy to pinpoint the exact location of the active volcanoes during the Early Eocene that produced ashes constituting the original material of the bentonized tuffites that occur in the Subsilesian Unit. The numerous, not less than thirty, tuffite intercalations, testify to the frequency of eruptions. So many of them, some even very thin, could be preserved thanks to the relatively quiet sedimentation, dominated by the deposition of thin-bedded mudstone or rarely fine-grained sandstone turbidites. The turbidites originated from low density suspension gravity flows that formed distal fans. Such turbiditic currents' energy was quite low, so their erosion activity has been minimal, and common intercalations of hemi-pelagic claystone are preserved between the individual mud-turbidite layers.

Very similar deposits of Early Eocene age with the intercalations of bentonized volcanic ashes (the setting known to Cieszkowski) were described from the Ultrahelvetic Unit of Eastern Alps in the Antherin section in Austria close to Salzburg (Egger *et al.*, 1997; Egger *et al.,* 2000). Based on micropaleontological and petrological investigations, these tuffites from the Anthering section were correlated with tuffites of the same age of the main ash series in the North Sea region (Egger *et al.*, 2000). The westernmost Subsilesian and the Helvetic sedimentary areas probably were connected (Golonka, *et al.* 2003). Perhaps the tuffites from all these regions could eventually be correlated based on detail lithological, micropaleontological, petrological and geochemical investigations.

The dominance of Fe-chlorite in siderites can be explained, assuming their early diagenetic crystallization, partially at least at the expense of kaolinite, in such Fe-rich environment. Lower %S in the illite-smectite from siderite than from shale is not easy to explain. Perhaps future K-Ar dating will solve this puzzle.

The presence of elevated quantities of anatase in bentonites is unusual. Anatase is not a mineral common in bentonites (comp. Grim & Guven, 1978). In his study of the Carpathian bentonites Kłapyta (1975) noted anatase only in the Eocene. Probably this mineral reflects more mafic character of the primary Eocene piroclastics.

Age examinations of tuffite bearing deposits are based on detail micropaleontological investigations of foraminiferal microfauna. These studies prove the Early Eocene age of the investigated sedimentary sequence. The fossil foraminiferal data shows that assemblages from tuffite rich sequences are typical for the biostratigraphic levels: *Glomospira* div. sp. or *Saccamminoides carpathicus*.

Taking into account the same lithology, development and stratigraphic position, the tuffites form a clearly visible and widespread correlation level in the Subsilesian Unit, called here the Glichów Tuffite Horizon. The Lower Eocene deposits, including thin tuffitic layers, are also known from other main tectonic units of the Outer Carpathians, e.g. from the Skole, Silesian and Magura nappes. Perhaps these deposits are correlable to the Glichów Horizon of the Subsilesian Unit.

CONCLUSIONS

Finding and describing in the present paper, such great number of layers and laminae of pyroclastic origin in the Lower Eocene deposits of the Subsilesian Unit completes the list of tuffite settings in the Polish sector of the Outer Carpathians. It is usual that the Carpathian tuffites in the flysch sedimentary successions form very thin layers and laminae, ranging from a few millimeters up to 3 cm. The exposures described by the authors also contain much thicker layers reaching up to 17 cm, i.e. the thickest tuffite layer known from flysch of the Subsilesian Unit in Poland. In some outcrops separated layers of fine calciturbidites (of sideritic composition) accompany the tuffites. These siderites have not been observed in the Lower Paleogene sedimentary section of the Subsilesian Unit below the deposits with tuffites. The tuffites occur in the shaly sediments of the upper part of green shales and/or in the Lipowa beds.

Tuffite layers could have been preserved so well thanks to the relatively quiet sedimentation, dominated by thin-bedded mudstone or rarely fine-grained sandstone turbidites, deposited from low density suspension gravity flows.

The %S in the illite-smectite from shales indicates early stage of burial diagenesis (the maximum paleotemperatures below 100°C, according to the approach of Środoń and Clauer (2001). The presence of pure smectite in bentonites is consistent with this conclusion (comp. Šucha *et al.*, 1993). This result confirms the evaluation of the degree of diagenesis in the Subsilesian Unit, made for the same area by Kotarba (2003).

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Streszczenie

ZBENTONITYZOWANE TUFITY W DOLNOEOCEŃSKICH OSADACH JEDNOSTKI PODŚLĄSKIEJ (POLSKIE ZACHODNIE KARPATY ZEWNĘTRZNE): LITOLOGIA, POZYCJA STRATYGRAFICZNA I SKŁAD MINERALNY

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W osadach dolnopaleogeńskich jednostki podśląskiej w strefie lanckorońsko-żegocińskiej oraz w oknie tektonicznym Żywca zlokalizowane zostały nowe stanowiska zbentonityzowanych tufitów (Fig. 1). W niniejszej pracy zamieszczono charakterystykę litologiczną, mineralogiczną oraz biostratygraficzną ich wybranych odsłonięć. Strefę żegocińską reprezentują odsłonięcia w potoku Pluskawka w Nowym Rybiu (A i B); okno tektoniczne Wiśniowej – odsłonięcia w potoku Foszczówka w Wiśniowej (C), w potoku Lipnik w Lipniku (D), w potoku Czerwin w Glichowie (E–J); strefę lanckorońską – odsłonięcie w potoku Gościbia w Jasienicy (K) oraz okno tektoniczne Żywca – odsłonięcie w potoku Żarnówka w Lipowej (L) (Figs. 1, 2).

W zbadanych profilach tufity występują w formie warstewek o przeciętnej miąższości od 0,5 do 5 cm, wyjątkowo są to warstewki grubsze (10–17 cm) (Figs. 2, 3). Miejscami wkładki tufitowe są silnie zdeformowane tektonicznie wskutek plastycznego wyciskania, nie tworzą wtedy regularnych lamin, lecz występują w formie smug o nieregularnej miąższości i długości. Warstewki tufitowe są zgrupowane blisko siebie, w liczbie od kilku do kilkunastu. W bezpośrednim kontakcie z tufitami lub w ich pobliżu występują warstwy pelitycznych syderytów o miąższości od 10 do 35 cm (Fig. 2). Tufity są barwy białej lub kremowej, a czasem jasnopopielatej lub różowawej. Charakteryzują się słabą zwięzłością, są tłuste w dotyku, na mokro plastyczne, pęczniejące w wodzie. Osad tufitowy jest przeważnie pozbawiony struktur sedymentacyjnych, jedynie w grubszych warstewkach można zaobserwować subtelnie zarysowaną płaską laminację równoległą (Fig. 3 D). Tufity występują w obrębie poziomu łupków zielonych i pstrych oraz warstw z Lipowej. Łupki są zielone i zielonobrunatne, miejscami czerwone i zielone, mułowcowe lub łupki z pojedynczymi wkładkami cienkoławicowych, drobnoziarnistych piaskowców. Warstwy z Lipowej złożone są głównie z brunatnych i zielonych mułowców i iłowców z rzadko występującymi wkładkami piaskowców. Duża ilość nawet bardzo cienkich wkładek tufitów mogła się zachować dzięki bardzo spokojnej sedymentacji mułowych turbidytów deponowanych z rozrzedzonych prądów zawiesinowych.

Badaniami mineralogicznymi objęto trzy typy litologiczne skał: łupki ilaste, bentonity oraz płaskury i konkrecje syderytowe. Bentonity mają skład przeobrażonych osadów piroklastycznych, charakterystyczna jest dla nich bardzo mała zawartość kwarcu, a bardzo duża materiału ilastego (Fig. 4). Dominującym minerałem ilastym jest niemal czysty dioktaedryczny smektyt (0 do 5% pakietów illitowych). Nikły stopień illityzacji potwierdza słabe zaawansowanie diagenezy badanej serii skalnej. Smektytowi towarzyszy podrzędny kaolinit, brak jest natomiast chlorytu i illitu. W niektórych próbkach zostały stwierdzone śladowe ilości pirytu lub kalcytu. Charakterystycznym składnikiem bentonitów jest anataz, występujący we wszystkich próbkach w ilościach porównywalnych z kwarcem. Łupki otaczające tufity mają skład mineralny typowy dla łupków karpackich (por. Kotarba 2003) minerał mieszanopakietowy illit-smektyt, illit (mika), kaolinit, chloryt, kwarc, plagioklaz, piryt. (Tab. 1, Fig. 4). Próbki z syderytów są niemal monomineralne. Stwierdzono w nich tylko niewielką

domieszkę kwarcu, a także niewielką ilość substancji ilastej, o składzie odmiennym niż w bentonitach i łupkach (Fig. 5) oraz śladowe ilości kalcytu i apatytu (Tab. 1).

Wczesnoeoceński wiek depozycji tufitów został określony na podstawie analiz autochtonicznych zespołów małych otwornic z osadów tufitowych oraz ich otoczenia. Typową cechą dla tych zespołów jest występowanie otwornic aglutynujących, którym towarzyszą nieliczne formy wapienne (Tab. 2, Figs. 6, 7, 8).

Ze względu na skład taksonomiczny zespoły występujące w bentonitach zostały podzielone na 2 grupy:

– zespoły typowe dla poziomu *Glomospira* div. sp., dla których charakterystyczną cechą jest liczne występowanie okazów z rodzaju indeksowego, oraz obecność otwornic powszechnie występujących w eocenie tj. *Glomospirella biedai* Samuel, *Reophax elongatus* Grzybowski, *Reophax pilulifer* Brady;

– zespoły poziomu *Saccamminoides carpathicus*, gdzie relatywnie licznie reprezentowanemu taksonowi indeksowemu towarzyszą otwornice z rodzaju *Reophax*, pojedyncze okazy *Reticulophragmium amplectens* (Grzybowski) oraz otwornice wapienne bentoniczne, w obrębie których najliczniej reprezentowany jest *Nuttallides truempyi* (Nuttall), ilość otwornic z rodzaju *Glomospira*, *Recurvoides* oraz *Paratrochamminoides* jest mniejsza w stosunku do grupy pierwszej.

Opisane w niniejszej pracy tufity, występujące w dolnoeoceńskich utworach jednostki podśląskiej, należą do poziomu tufitowego nr 11 *sensu* Wieser (1985) i mogą być odpowiednikiem tufitów tego samego wieku, opisywanych z innych stanowisk i jednostek Karpat fliszowych (Skoczylas-Ciszewska, 1956; Burtan, 1978; Książkiewicz, 1956: Liszkowa, 1959; Wieser, 1952, 1960, 1970; Koszarski, 1985; Koszarski & Wieser, 1960; Koszarski & Koszarski, 1985; Kotlarczyk 1988; Rajchel 1990, 1994).

Biorąc pod uwagę szerokie rozprzestrzenienie, ten sam wiek depozycji, podobne wykształcenie litologiczne, stwierdzono, że łupki z wkładkami tufitów tworzą horyzont szeroko rozprzestrzeniony, wyraźnie wyodrębniający się w profilach jednostki podśląskiej. Autorzy proponują, aby nazwać go horyzontem tufitowym z Glichowa.