GEOLOGICA CARPATHICA, FEBRUARY 2014, 65, 1, 35–54 doi: 10.2478/geoca-2014-0003

Paleocene sedimentary record of ridge geodynamics in Outer Carpathian basins (Subsilesian Unit)

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(Manuscript received March 7, 2013; accepted in revised form October 16, 2013)

Abstract: The stratigraphic position of the Goryczkowiec Sandstone reflects the Paleocene ridge geodynamics in the Outer Carpathian basins. The Goryczkowiec Sandstone was deposited on the slope of a ridge, known as the Subsilesian Sedimentary Area that originated during reorganization of the Outer Carpathian realm. A Paleocene age of this sandstone, documented clearly by autochthonous foraminiferal and algal assemblages indicates the time of the final formation of the Subsilesian Ridge. Abundant calcareous material of biogenic origin was transported by turbidity currents into deeper zones. This material includes fragments of carbonate buildups represented by algae, bryozoans and other organisms growing in the shallower part of the ridge. The Goryczkowiec Sandstone, previously known as the Szydłowiec Sandstone, is here redefined as a new lithostratigraphic unit within the Subsilesian Sedimentary Area in the marginal Outer Carpathians in Poland. The new name clarifies the ambivalence in the lithostratigraphic nomenclature.

Key words: Paleocene, Outer Carpathians, Subsilesian Sedimentary Area, paleoenvironmental study, stratigraphy, red algae, foraminifera.

Introduction

As part of a program to study the geodynamic of ridges (Golonka et al. 2005b) within the Outer Carpathians in southern Poland and adjacent countries, we have undertaken a new study of the Goryczkowiec Sandstone. Generally these sandstones are associated with intrabasinal uplifts. Carbonate facies developed in the upper parts of the ridges while the slopes were dominated by flysch deposition. The number and configuration of the ridges within the Outer Carpathian basins changed over time. The uplifts were subjects of intense geodynamic evolution (Golonka et al. 2005b; Cieszkowski et al. 2009a, 2011). The present-day Outer Carpathians were reorganized tectonically by the Miocene Alpine movements, and the ridges were largely destroyed. Their original existence is recorded by the sedimentary rocks deposited on uplifted slopes and within the basins. The Goryczkowiec Sandstone represents uplift-slope deposits classified recently as part of the Subsilesian Unit inventory. The available lithological material is limited by isolated surface outcrops; nevertheless the sandstone provides an important and valuable record of the Paleocene phase of the evolution of the Subsilesian Ridge within the Outer Carpathian basins. The Goryczkowiec Sandstone belongs to the flysch deposits rich in redeposited material represented by crystalline rocks as well as by calcareous fragments, which document paleoenvironmental conditions in the shallower part of the ridge. The purpose of this paper is to determine the paleogeographical position of this ridge within the Outer Carpathian flysch. We also clarify the ambivalence in the lithostratigraphic nomenclature investigating the litho- and chronostratigraphy of the ridge deposits.

Outline of geology of the study area

The Polish Outer Carpathians form a complex structure built from Upper Jurassic–Neogene flysch deposits that are strongly imbricated due to thrusting (Limanowski 1905; Ślączka et al. 2006). The Outer Carpathian nappes are thrust over the southern part of the North European Platform which is covered by autochthonous Miocene deposits of the Carpathian Foredeep for a distance of at least 70 km. The northern Carpathian nappes became uprooted from the basement during their overthrusting movement and only their basinal parts were preserved. The following Outer Carpathian nappes have been distinguished: the Magura Nappe, Fore-Magura group of nappes, Silesian, Subsilesian and Skole Nappes (Fig. 1). The Subsilesian Nappe was distinguished by Książkiewicz (1951a,b) in the Wadowice area. It underlies tectonically the Silesian Nappe. In the western sector of the Western Carpathians both nappes are thrust over the Miocene molasse of the Carpathian Foredeep and in the eastern sector they are thrust over the Skole Nappe (Książkiewicz 1972, 1977; Golonka et al. 2005a; Ślączka et al. 2006). The presence of the Subsilesian Nappe was also confirmed in numerous boreholes beneath the Silesian and the Magura Nappes (Fig. 2). On the surface it is usually exposed within tectonic windows, connected with the border zone of the

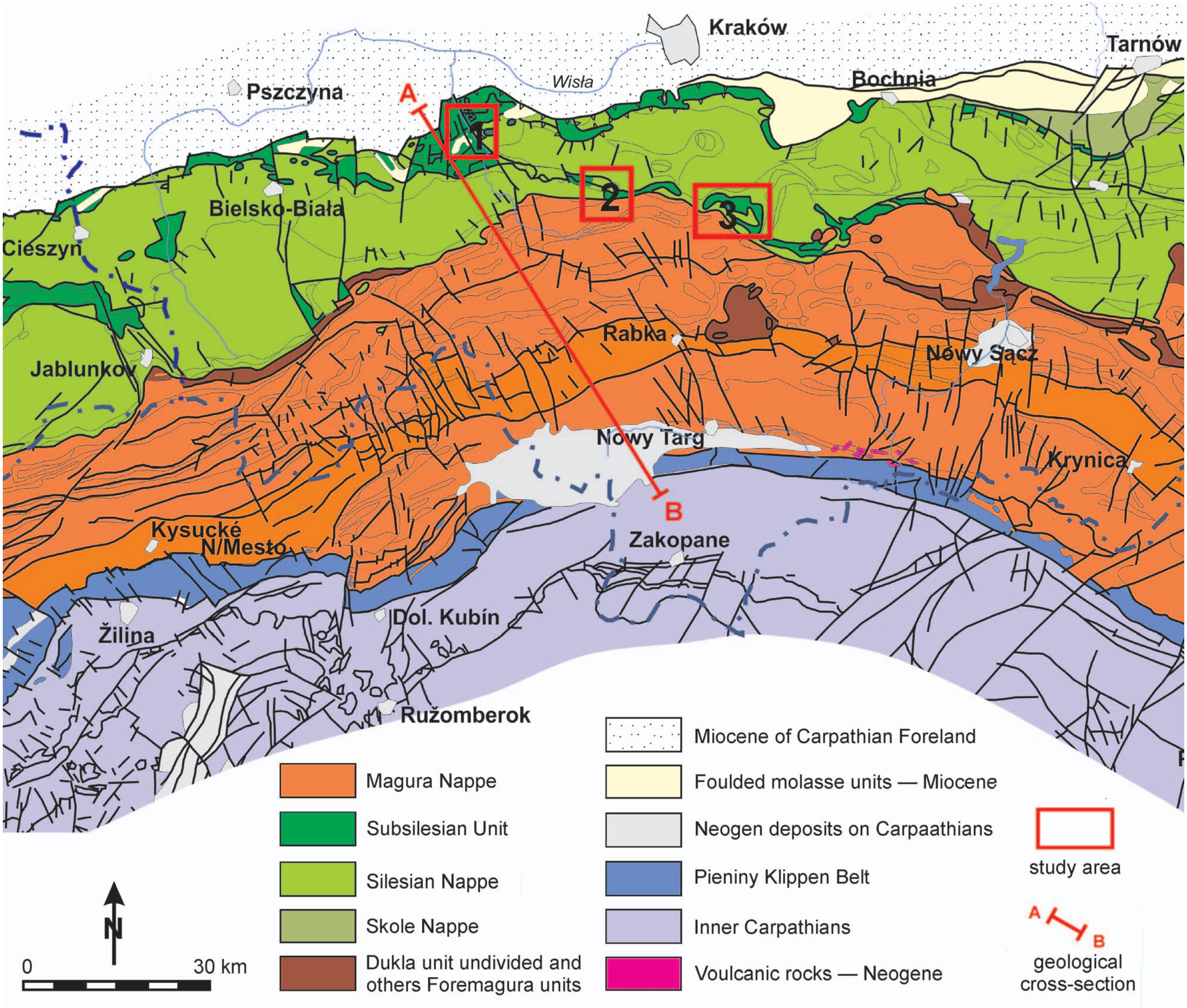

Fig. 1. Location of study area on a tectonic sketch-map of the Western Carpathians in Poland (map after Lexa et al. 2000). **1** — Wadowice area with stratotype locality; **2** — Gościbia Tectonic Window; **3** — Wiśniowa Tectonic Window.

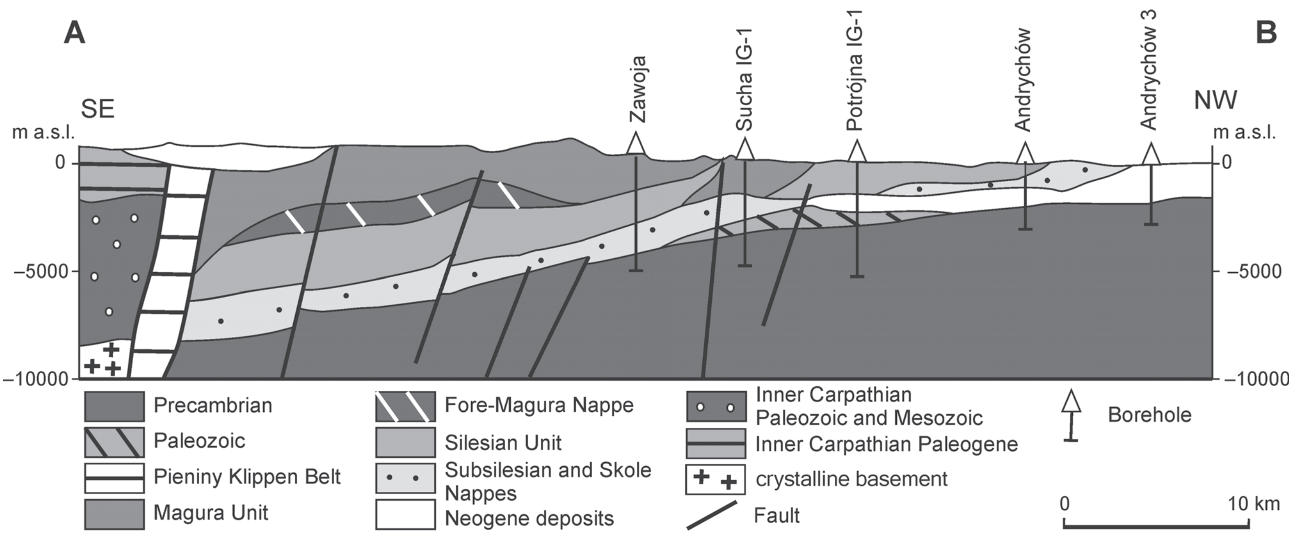

Fig. 2. Cross-section through the Outer Carpathians and their foreland (map after Golonka et al. 2011, modified) (cross-line on Fig. 1).

Silesian Nappe. In the Western Carpathians, along the thrust zone of the Magura Nappe over the Silesian Nappe, it forms a long and discontinuous belt with outcrops of the Subsilesian rocks, known as the Lanckorona-Żegocina Zone. The zone consists of small tectonic windows in different configurations. A large tectonic window known as the Wiśniowa Tectonic Window is located south of Kraków, another one in the west, in the Żywiec area. Between Żywiec and Wadowice, surface exposures of Subsilesian deposits disappear (Książkiewicz 1951a,b, 1972, 1977; Geroch & Gradziński 1955; Burtan 1974, 1978; Cieszkowski et al. 2001; Leśniak et al. 2001). The position of the Subsilesian outcrops connected with the northern border of the Silesian Nappe is uncertain, and constitutes a subject of discussion. In many cases, deposits of mixed character occur close to rocks belonging, according to the lithostratigraphic schemes, to the Skole and Subsilesian Nappes. The Goryczkowiec (Szydłowiec) Sandstone deposits are distinguished as a lithostratigraphic unit that is characteristic for this zone. We studied this unit in the Western Carpathians, including the Wiśniowa Tectonic Window and the Lanckorona Zone (Figs. 3 and 4), taking into special consideration the stratotype profile located in Wadowice near Goryczkowiec Hill (Figs. 4 and 5). A similar sandstone unit described from the Żywiec Tectonic Window (Geroch & Gradziński 1955) is now poorly exposed.

Previous studies

"The Szydłowiec bryozoan-lithothamnium sandstone" was originally described by Książkiewicz (1951a,b) as a sandstone complex that forms Szydłowiec Hill (recently renamed Goryczkowiec Hill) located in the southern part of the town of Wadowice, north of Gorzeń Dolny village. Książkiewicz (1951b) reported that this sandstone was also known to Hohenegger (1861) and Dunikowski (1885). Książkiewicz established the Szydłowiec Sandstone as a new lithostratigraphic division of the Subsilesian Series. The bryozoan-lithothamnium Szydłowiec Sandstone was also observed by Burtan (1974, 1978) in the Subsilesian Unit cropping out in the Wiśniowa and Skrzydlna Tectonic Windows, ESE of Myślenice and in the west in the Żywiec Tectonic Window (Geroch & Gradziński 1955). Książkiewicz (1951a,b, 1953, 1972, 1977) also stated that the Szydłowiec and Gorzeń Sandstones in Wadowice area form a separate tectonic structure, and called it the Szydłowiec scale (thrust-sheet), a different tectonic element of the Silesian Unit.

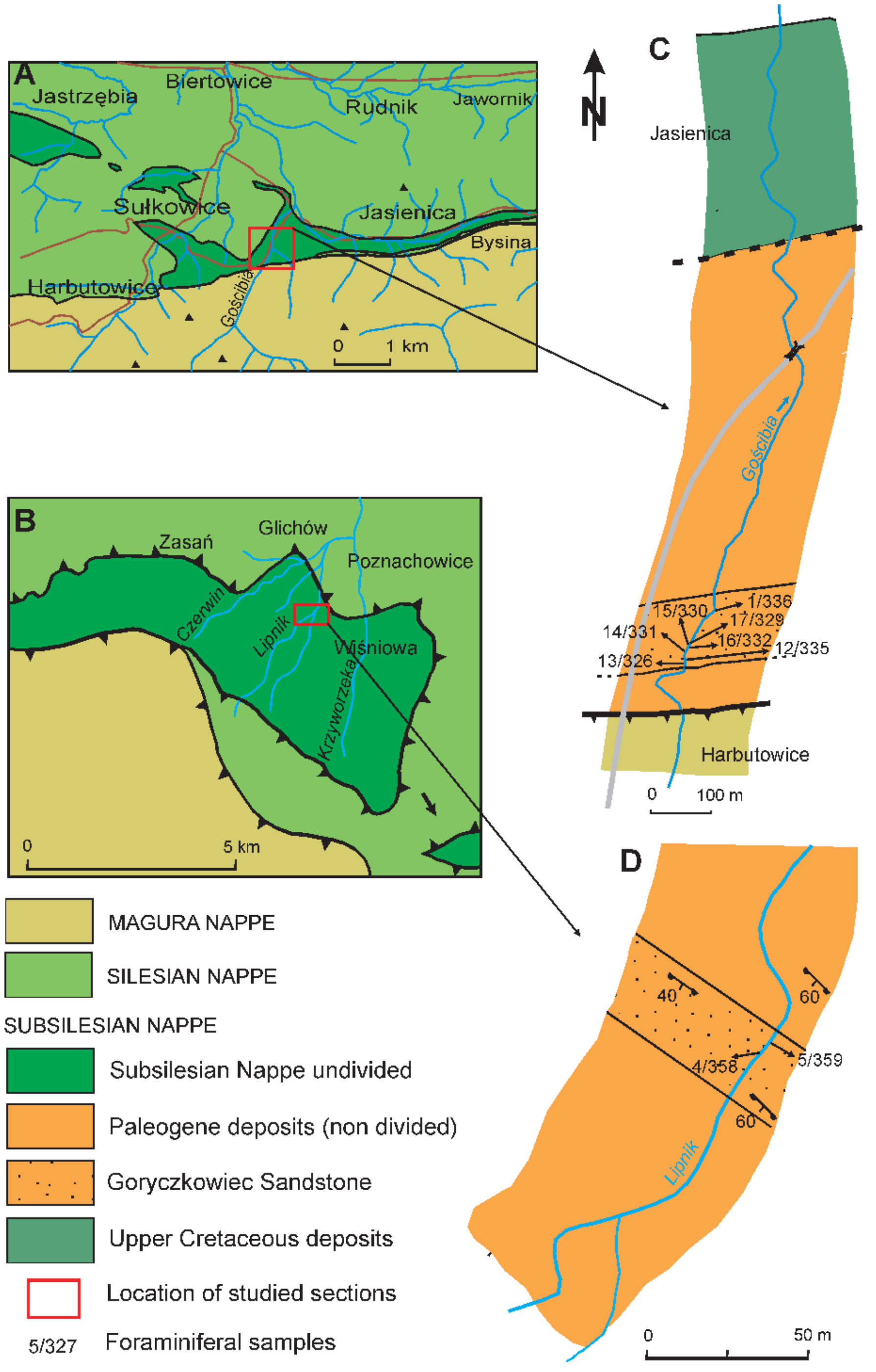

Fig. 3. A, B — tectonic sketch-maps of: A — Sułkowice Area (after Burtan 1966 and Burtan & Szymakowska 1966, simplified), B — Wiśniowa Tectonic Window (after Burtan 1974, simplified); **C, D** — sampled sections.

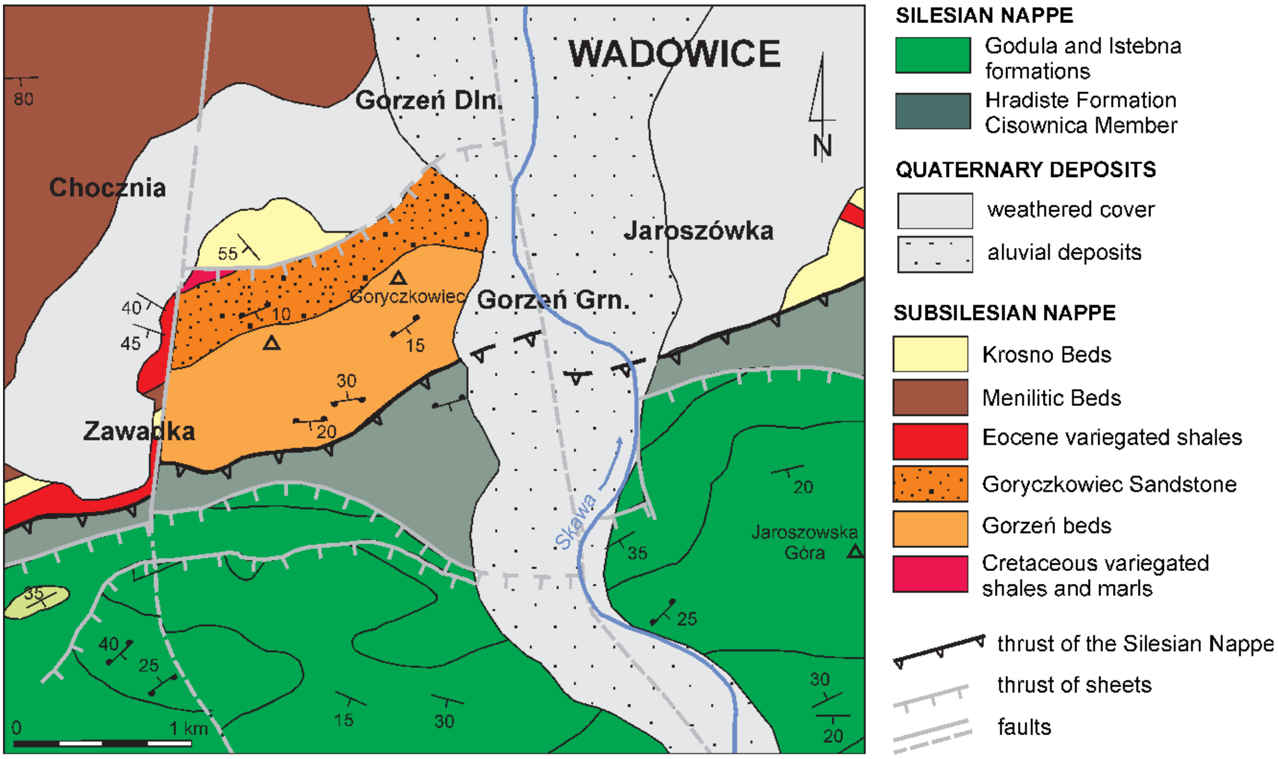

Fig. 4. Geological map of the Wadowice area with stratotype locality (map after Nowak 1963; Szymakowska & Żytko 1965, modified).

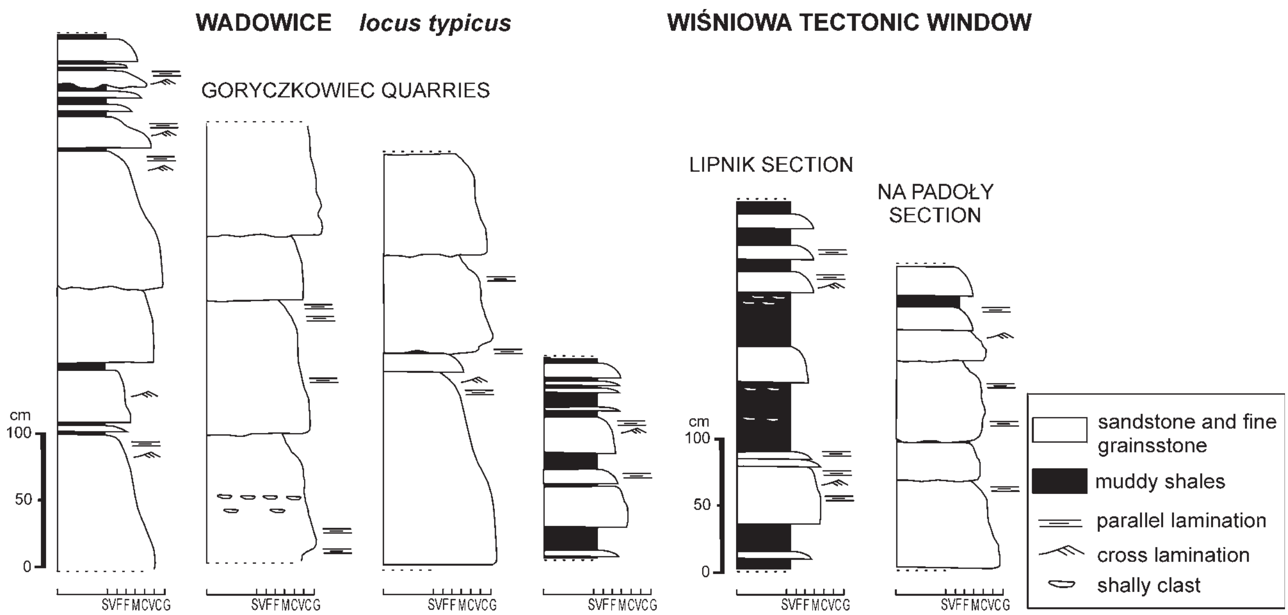

Fig. 5. Lithological logs of the Goryczkowiec Sandstone.

This idea was adopted by other authors (Nowak 1963). Balcer & Koszarski (1992, see also Koszarski et al. 1974; Koszarski 1985; Żytko 1985) suggested that the Szydłowiec beds should be included in the Skole Nappe and emphasized their similarities to the Inoceramian Beds of the Skole Series. Cieszkowski et al. (2011, 2012b) presented the first results of new detailed investigations of the geology of the Wadowice area and concluded that so-called "the Szydłowiec thrust-sheet" has in fact an olistostrome origin. A block consisting of the Goryczkowiec Sandstone is covered by the Gorzeń beds and underlain by grey shales, representing a large olistolith in the highest part of the Krosno Formation section. The various grey and variegated marls also represent olistoliths within the Krosno Beds matrix, so the position of the Szydłowiec and Gorzeń Sandstones is analogous to the olistostrome blocks known as the Andrychów Klippes (Cieszkowski et al. 2009b, 2011, 2012a,b). While the olistolithic origin of the block located south of Wadowice is well documented, the positions of similar rocks in the Wiśniowa and Sułkowice areas are still under investigation. It is possible that the present sequence of these deposits reflects their original position within the Subsilesian Sedimentary Area.

The older papers suggested a Maastrichtian age of this lithostratigraphic division (Książkiewicz 1951b). Książkiewicz cited the micropaleontological investigations of Bieda (1948), who studied samples of calcareous sandstones from the type locality. The larger foraminifera that Bieda (1948) extracted represented the genera *Simplorbites* and *Siderolites* and are known from the Maastrichtian. A Maastrichtian age was preferred in other papers (Bieda et al. 1963; Geroch et al. 1967), the table listings, however, also suggested a Paleocene age. Geroch & Gradziński (1955) defined the age of the bryozoan-lithothamnium sandstones in the Żywiec Tectonic Window as Maastrichtian to Paleocene based on smaller foraminifera assemblages that indicated a transitional age between the Maastrichtian and Paleocene. They noted that the small foraminiferal assemblages were very similar to those quoted by Książkiewicz (1956). Burtan (Burtan et al. 1974; Burtan 1978) preferred a Maastrichtian age, indicating that the sedimentation lasted from the Maastrichtian until the end of the Danian. The Szydłowiec Sandstone was mentioned in the "Mesozoic" volumes of the "Geology of Poland" (Koszarski & Ślączka 1973).

The ambivalence in the lithostratigraphic nomenclature

The name Szydłowiec Sandstone was used in lithostratigraphic nomenclature to describe two independent lithostratigraphic units, located within two separate geological realms. One — more popular — is typical of the Holy Cross Mountains and consists of a Jurassic white sandstone of continental origin. The second Szydłowiec Sandstone is typical of the Outer Carpathians, and constitutes thickly-bedded flysch deposits connected with the Tethys Ocean now located within the Subsilesian Nappe. These deposits are widespread between Żywiec and Wiśniowa, and their outcrops are dismembered, small, and rare. The Carpathian Szydłowiec Sandstone contains numerous calcareous clasts, in most cases of biogenic origin (Cieszkowski et al. 2012a; Waśkowska et al. 2012). Coralline red algae and remnants of bryozoa are common, together with other fossils typical of shallow marine environments. The position of this sandstone unit within the Silesian or Subsilesian lithological profiles is not clear. It crops out as isolated exposures among deposits characteristic for the Subsilesian Sedimentary Area.

The formal lithostratigraphic nomenclature of the Outer Carpathians is still in the process of reorganization according to stratigraphic code rules (see Alexandrowicz et al. 1975; Racki & Narkiewicz (Eds.) 2006). The lithostratigraphic units of the Subsilesian Nappe are not formalized, and the traditional informal names like the Paleocene Green Shales, the Szydłowiec Sandstone, the Frydek-type Marls or the Czerwin Sandstone are still being used in the Polish literature (e.g. Cieszkowski et al. 2005a; Leśniak et al. 2005; Ślączka et al. 2006; Waśkowska-Oliwa 2008). The formalization process requires the precise detailed description of lithology, chronostratigraphy, and well defined formational boundaries. The lithostratigraphic inventory of the Upper Cretaceous and Paleogene deposits of the Subsilesian Nappe is still a subject of discussion (Burtan 1974; Koszarski (Ed.) 1985; Balcer & Koszarski 1992; Waśkowska-Oliwa 2008; Cieszkowski et al. 2010). Some units are distinguished locally, without lateral continuity. The deposits are often strongly tectonically deformed and the natural, sedimentary boundaries are not well exposed. The individual tectonic windows have their own lithostratigraphic schemes, constructed on the basis of stratigraphic sequence, without formalization. The name Szydłowiec Sandstone is in conflict with lithostratigraphic code, as every lithostratigraphic name should be unique. Since 1951, when the Carpathian sandstones were described, two independent divisions using the same names have been in use. The Holy Cross Mountains Szydłowiec Sandstone was defined in 1887 by Siemiradzki, while the Carpathian one was described in 1951 (Książkiewicz 1951a,b). The law of priority, respected in the natural sciences, would suggest suppression of the younger name. The name Carpathian Szydłowiec Sandstone originates from the hill south of Wadowice, where Książkiewicz (1951a,b) found and described these deposits exposed in numerous quarries. The name Szydłowiec Hill functioned as an equivalent to Goryczkowiec Hill before the 2nd World War, but the name later disappeared from the maps and only Goryczkowiec is now used. We therefore decided to introduce the name Goryczkowiec Sandstone for this lithostratigraphic unit to avoid confusion with the Holy Cross Mountains Szydłowiec Sandstone.

Lithology

Thickly-bedded coarse-grained sandstones, pebbly sandstones and fine-pebble conglomerates predominate within the Goryczkowiec Sandstone (Figs. 5 and 6). The sandstones have a well-sorted grain framework, while the conglomerates are poorly sorted and contain more cement. In many cases the sandstones are amalgamated. Occasionally, the sandstone complexes are intercalated by thin layers of shales or thin- and medium-bedded shaly sandstone flysch. Medium- and thickly-bedded coarse sandstones within green calcareous shales were observed in the Wiśniowa and Sułkowice areas. The lithological development is variable. The thickness of the thickly-bedded layers oscillates from 0.8–2.5 m and amalgamated complexes can reach even 5–6 m. A massive structure dominates within the thickly-bedded sandstone layers. Parallel or/and cross laminations occur in the upper parts, and occasionally parallel lamination is observed in the middle part of the layer. Coarser material in the lower part of layers is common. In some cases coarse-grained sandstone passes gradually to fine-pebble conglomerates.

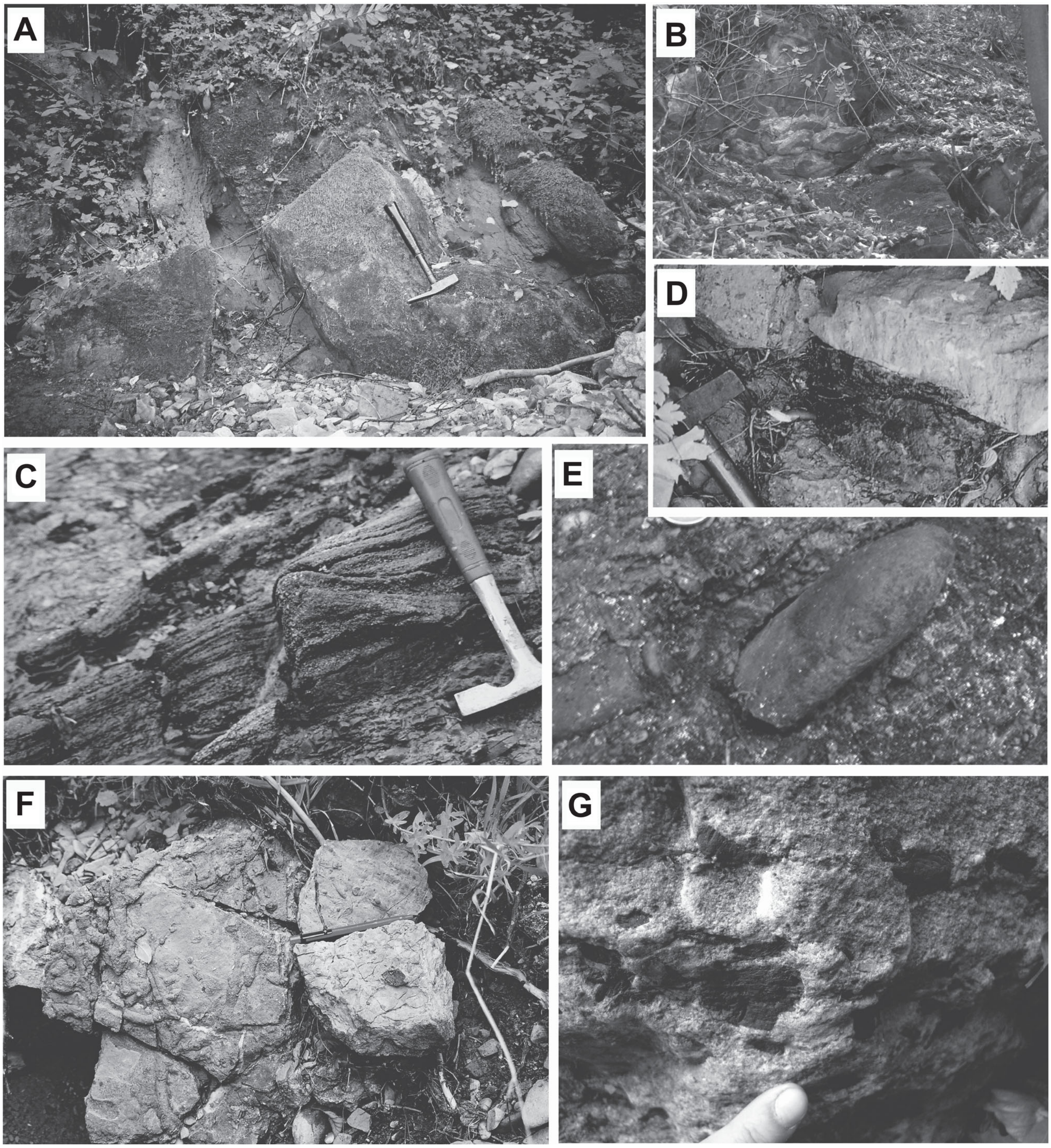

Fig. 6. Outcrops of the Goryczkowiec Sandstone: **A** — thick-bedded sandstones intercalated green shales in Gościbia tectonic window; **B** — thick-bedded sandy complex in Wadowice — stratotype Goryczkowiec Hill; **C** — coarse-grained sandstones in Lipnik section; **D** — coal clast in sandstone, Krzyworzeka section; **E** — sandstone with pebbles, Goryczkowiec Hill; **F** — organic trace-fossils; **G** — sandstone with coal clasts, Na Padoły stream, Wiśniowa.

Grains measuring 2–7 mm occur within fine- and medium-grained matrix in coarser sandstones, but isolated pebbles reach up to 11 cm. Grey shaly mudstone clasts that reach up to several centimeters in length form local levels within the sandstone layers. Thinly- and medium-bedded sandstone layers (2–35 cm thick) are fine- and/or medium-grained, occasionally coarser, fractional, with parallel and cross laminations, sometimes with concentrations of muscovite that highlight the lamination. Thinly-bedded sandstones are fine- and very fine-grained and cross-laminated. The presence of glauconite gives the fine-grained sandstones a greenish colour. Current marks and organic trace-fossils are observed on the bottoms of sandstone layers.

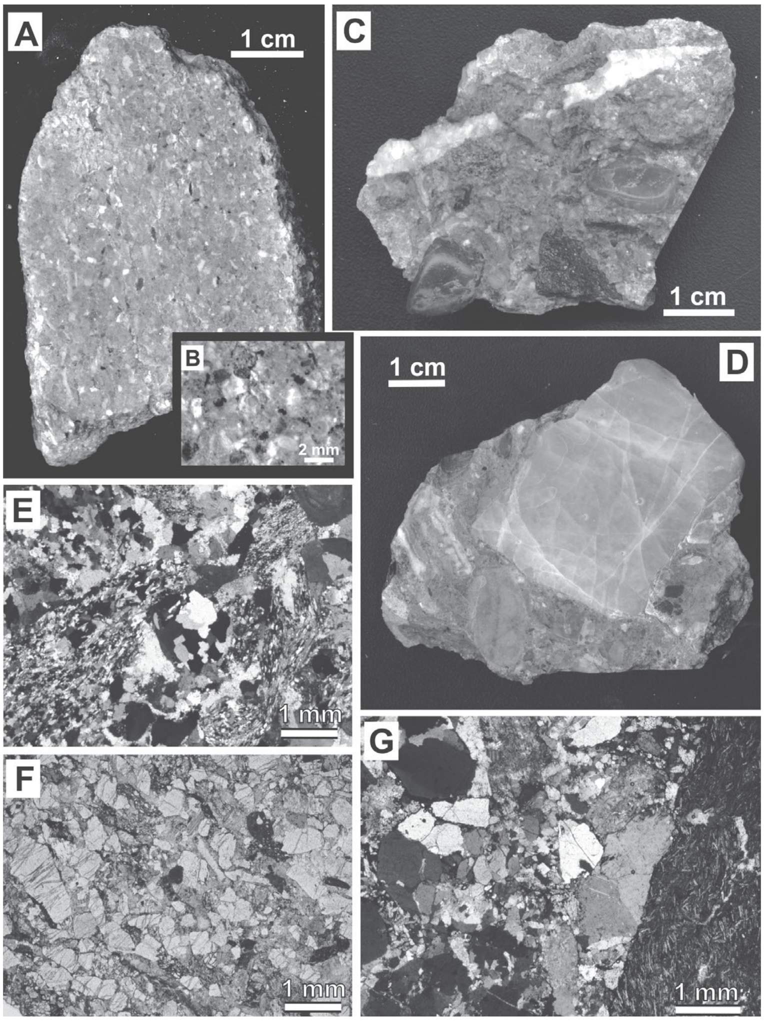

Fig. 7. Lithology of the Goryczkowiec Sandstone: **A, B** — sandstone with light calcareous clasts; **C** — pebbly sandstone; **D** — conglomerate with a big quartz grain; **E** — sandstone with quartz grains, clasts of gneisses and sparry cement (microphotograph, XPL); **F** — sandstone with quartz grains, as well as glauconite and fragments of red algae (microphotograph, PPL); **G** — pebbly sandstone with quartz grains, bigger clast of volcanic basic rock and sparry cement (microphotograph, XPL).

The most abundant grain type is quartz, which occurs in a monocrystalline, polycrystalline and/or stretched metamorphic form. Lithoclasts are an important constituent of these rocks. The volcanic basic rocks, granitoids, gneisses, sandstones with quartz and micas, siliceous rocks, mudstones, and shales can be identified within these lithoclasts (Fig. 7). Single grains of micas and glauconite occur as secondary components. Quartz grains are predominantly angular to subangular; the roundness of other grains is slightly better. Calcite cement occurring between the composite grains is usually fairly coarse-grained, especially in the conglomerates.

In addition to the detrital material, carbonate bioclasts constitute an important component of the Goryczkowiec Sandstone (Fig. 8). These rocks are especially rich in fragments of the coralline algae. The fragments are usually very fine, but single specimens can reach 1 cm in size. Fragments of bryozoan colonies and echinoderm plates, and in particular echinoid spines belong to the other frequently occurring bioclasts. Planktonic and benthic foraminifera, serpulid worms, and fragments of bivalves are also present. Most of these bioclasts originated in a shallow marine environment, especially the coralline algae that live within the photic zone.

Sandstones are interbedded with noncalcareous green-grey clayey-muddy shales or occasionally marly shales, often with psammite admixture.

Age of the Goryczkowiec Sandstone

Material and methods

Micropaleontological investigations determined the age of the Goryczkowiec Sandstone. These investigations used mainly foraminiferal assemblages, but also attempted to use the algal remains that are present in the sandstones as bioclasts. The micropaleontological samples for studies of foraminiferal assemblages were taken from the grey-greenish muddy shales that are intercalated with the sandstone layers in outcrops of the Goryczkowiec Sandstone. The type locality section is located in old abandoned quarries on the northern slope of the Goryczkowiec (Szydłowiec) Hill south of Wadowice. The samples were also collected from sections of the Gościbia creek valley cropping out in the Jasienica-Sułkowice Tectonic Window, and from the Krzyworzeka and Lipnik creeks sections in the Wiśniowa Tectonic Window.

Field samples consisted of muddy shales (about 0.5 kg each). They were prepared using standard micropaleontological methods using Glauber's salt, and washed on small dimension sieve. The foraminifera were picked from the >63 μm residue. The amount and quality of micropaleontological items was variable, and some samples contain only a small number of specimens. The foraminifera consist mainly of agglutinated forms. The abundance of accompanying calcareous forms was variable in different samples.

Organic remains contained in pieces of carbonate rocks were studied in thin sections of samples collected from the sandstones. Fragments of skeletons of calcareous coralline algae were also useful for estimating the age of the rocks.

Foraminiferal assemblages

The micropaleontological samples studied here are dominated by agglutinated foraminifera (Figs. 9–11; Table 1). Single specimens of strongly corroded *Lenticulina* sp. were found in a sample from the Lipnik section. This state of preservation of specimens may suggest their redeposition from shallow parts to deeper zones of the sedimentary basin. In some samples from the Gościbia section, the admixture of

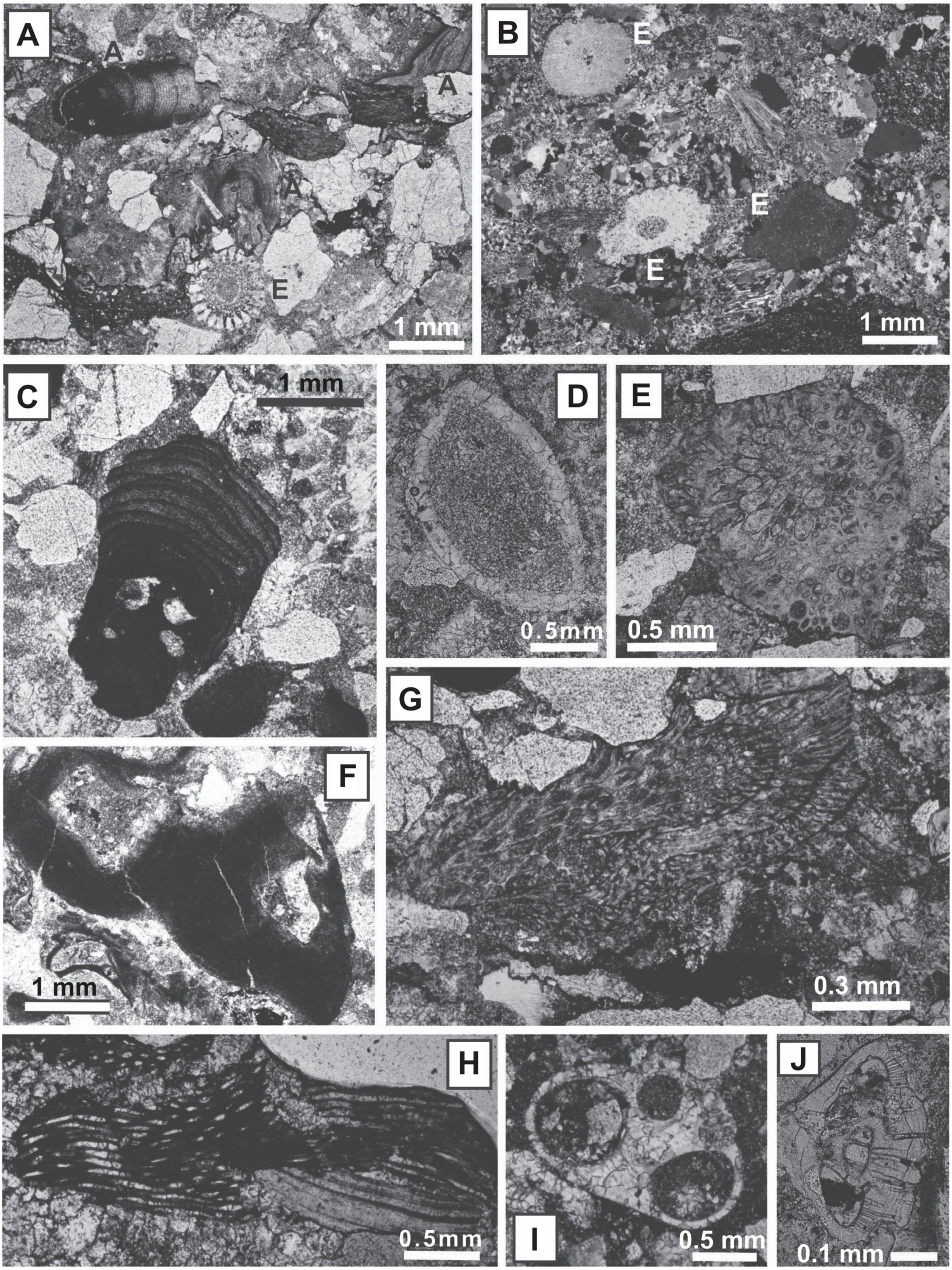

Fig. 8. Bioclasts of the Goryczkowiec Sandstone (microphotographs): **A** — sandstone with fragments of red algae (A) and transverse section of an echinoid spine (E) (PPL); **B** — sandstone with echinoderm plates (E) (XPL); **C, F, H** — red algae (PPL); **D** — shell (PPL); **E, G** — bryozoans (PPL); **I, J** — benthic foraminifera (PPL).

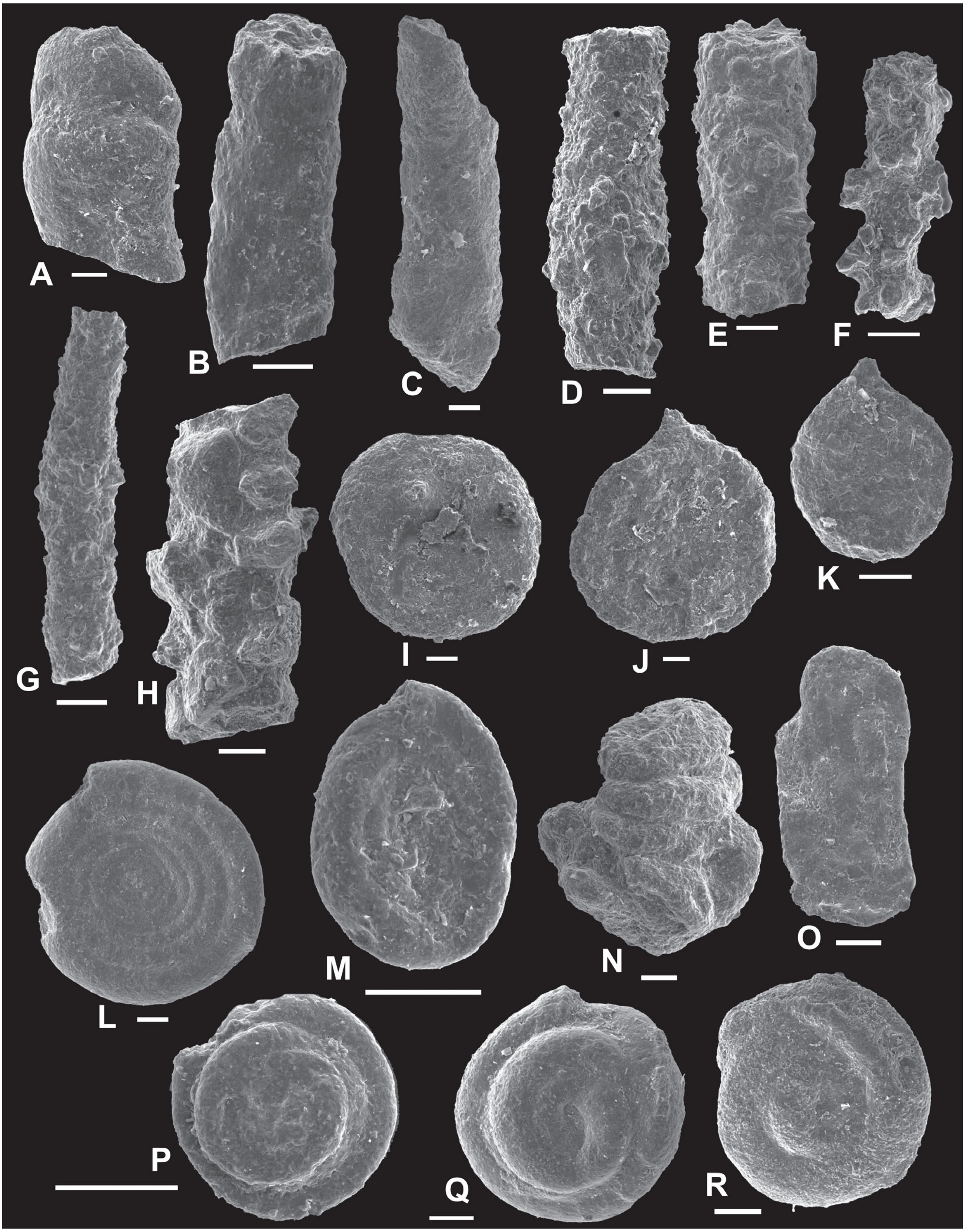

Fig. 9. SEM photographs of foraminifera from the Goryczkowiec Sandstone: **A, B** — *Bathysiphon* sp.; **C** — *Nothia excelsa* (Grzybowski); **D, G** —*Psammosiphonella discreta* (Brady); **E, H** — *Psammosiphonella cylindrica* (Glaessner); **F** — *Psammosiphonella* sp.; **I, J, K** — *Placentammina placenta* (Grzybowski); **L** — *Ammodiscus cretaceus* (Reuss); **M** — *Ammodiscus peruvianus* Berry; **N** — *Glomospira irregularis* (Grzybowski); **O** — *Annectina grzybowskii* (Jurkiewicz). **P, Q** — *Glomospira charoides* (Jones & Parker); **R** — *Glomospira gordialis* (Jones & Parker). Scale bar = 100 μm.

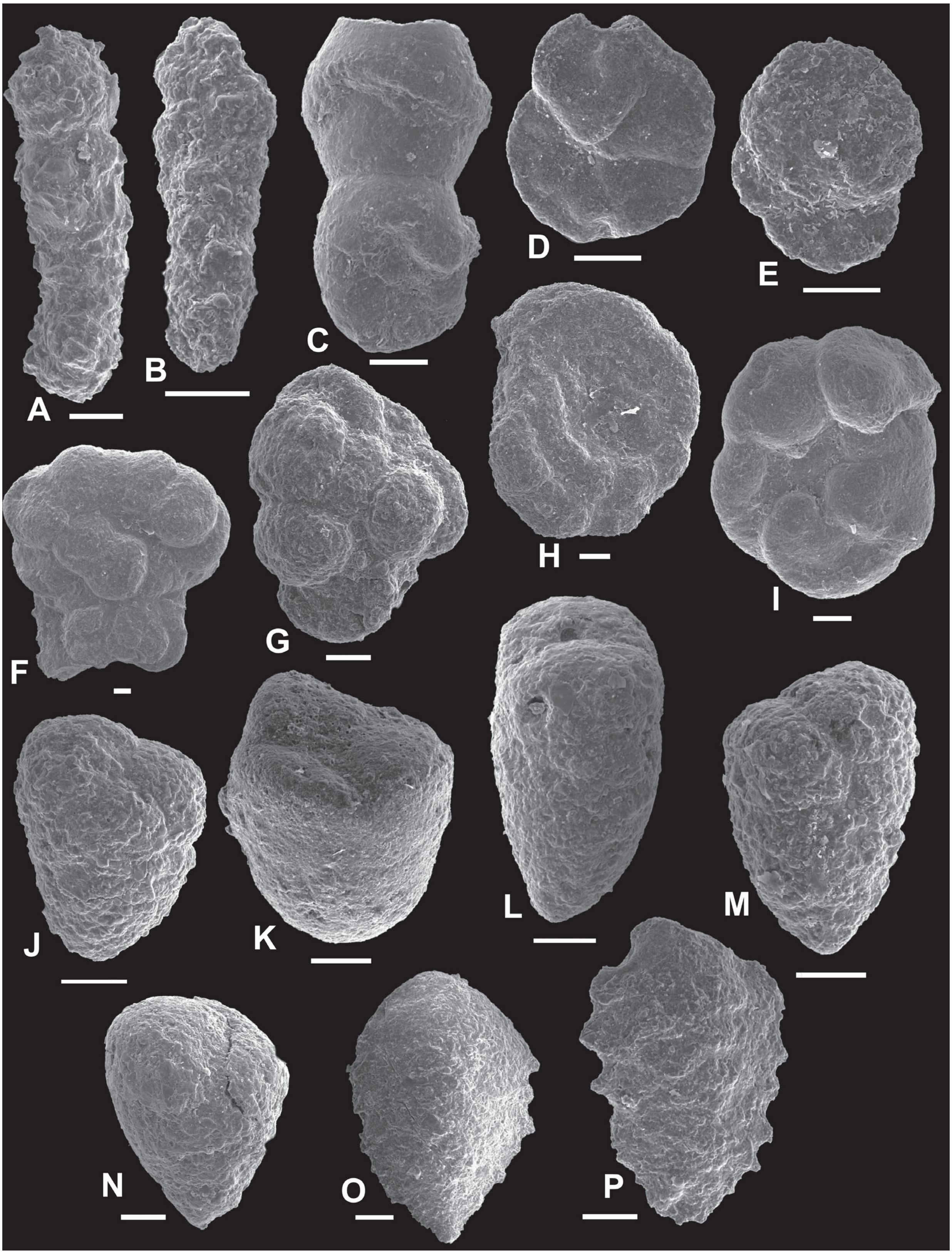

Fig. 10. SEM photographs of foraminifera from Goryczkowiec Sandstone: **A** — *Ammobaculites* sp.; **B** — *Karrerulina conversa* (Grzybowski); **C** —*Hormosina velascoensis* (Cushman); **D** — *Haplophragmoides walteri* (Grzybowski); **E** — *Ammosphaeroidina pseudopauciloculata* (Mjatliuk); **F** — *Paratrochamminoides* sp.; **G** — *Paratrochamminoides mitratus* (Grzybowski); **H** — *Paratrochamminoides dubius* (Grzybowski); **I** — *Trochamminoides subcoronatus* (Grzybowski); **J** —*Remesella varians* (Glaessner); **K** — *Dorothia crassa* (Marsson); **L, M** — *Dorothia retusa* (Cushman); **N** — *Dorothia* sp.; **O, P** — *Spiroplectammina dentata* (Alth). Scale bar = 100 μm.

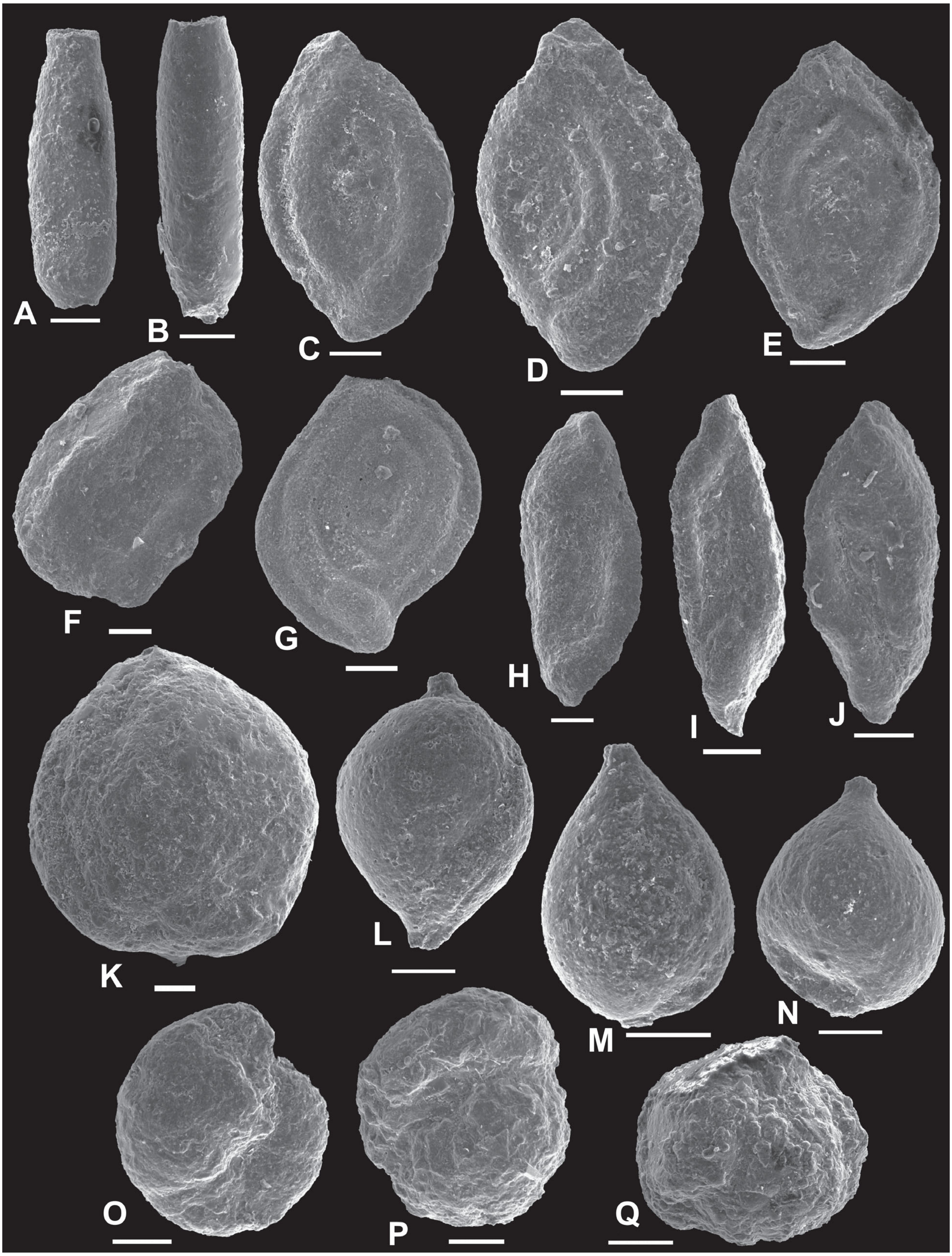

Fig. 11. SEM photographs of foraminifera from the Goryczkowiec Sandstone: **A, B** — *Kalamopsis grzybowskii* (Dylążanka); **C, D, E, G** — *Rzehakina fissistomata* (Grzybowski); **F** — *Rzehakina lata* Cushman & Jarvis; **H–J** — *Rzehakina minima* Cushman & Renz; **K** — *Caudammina gigantea* (Geroch); **L, M, N** — *Caudammina ovula* (Grzybowski); **O** — *Haplophragmoides mjatliukae* Maslakova; **P, Q** — *Recurvoides* sp. Scale bar = 100 μm.

Table 1: Taxonomic list of foraminifera from the Goryczkowiec Sandstone. *Continued on the next page.*

	Szydłowiec (Goryczkowiec) Hill					**Gościbia section**							**Krzyworzeka section**	**Lipnik valley**	
Sample number	**63/1/05 Sz**	**18/2/05 Sz**	**19/1/05 Sz**	**16/4/05 Sz**	**17/3/05 Sz**	**12/ 335 G**	**13/ 326 G**	**14/ 331 G**	**15/ 330 G**	**16/ 332 G**	**17/ 329 G**	**1/ 336 G**	**10/311 K**	**4/358 L**	**5/359 L**
Abyssamina quadrata Schnitker & Tjalsma								I							
Ammobacuites midwayensis (d'Orbigny)		I	I												
Ammobaculites sp.								I							I
Ammodiscus cretaceus (Reuss)	I		II			I		I			I	I	I		
Ammodiscus peruvianus Berry	I	II	II			I		I	I		I	I			
Ammodiscus planus Loeblich	II	II	II					I			I		II		
Ammodiscus sp.	I		I			I		I	I	I	II	I	II		
Ammodiscus tenuissimus Grzybowski	I	II								I	I		I		
Ammolagena clavata (Jones & Parker)			I			I						I			
Ammosphaeroidina pseudopauciloculata (Mjatliuk)	II	I	II			II	II	II		II	II	II	V	II	
Annectina grzybowskii (Jurkiewicz)		II	I			I		II	I		I	I	II		
Anomalina sp.											I				
Aragonia ouezzanenzis (Rey)									I						
Arthrodendron grandis Grzybowski		I	I			I		I		I	I		II		
Bathysiphon div. sp.	VI	V	V	II	II	II								I	II
Caudammina excelsa (Dylążanka)						II		II		II	II		II		
Caudammina gigantea (Geroch)	I														
Caudammina ovula (Grzybowski) (chambers)	II	I	II	I		I		II	I	I	II	II	II		
Caudammina ovuloides (Grzybowski)	I		I			II		I			I	II	I		
Chiloguembelina morsei (Kline)								I							
Cribrostomoides subglobosus (Cushman)	I	I	II	I											
Cystammina sveni Gradstein & Kaminski								I						II	
Dentalina div. sp.								I	II	I	II				
Dorothia crassa (Marsson)	II		I		I										
Dorothia indentata Cushman & Jarvis									I						
Dorothia retusa (Cushman)		II	II		II										
Dorothia sp.		I	I			I		I	II	I	II				
Ellipsoglandulina conicana Olbertz									I						
Ellipsoglandulina obesa Hanzlikova									I						
Eponides subcandidulus (Grzybowski)									I						
Gavelinella sp.											I				
Globanomalina sp.								I							
Globobulimina sp.									I						
Glomospira charoides (Jones & Parker)	I	II	II		II	II	V	I			II	I	V	II	I
Glomospira diffundens Cushman & Renz			II	I	I	I		I	I			II	I		
Glomospira glomerata (Grzybowski)			I						I						
Glomospira gordialis (Jones & Parker)	I	I	II				II	II		I			II		II
Glomospira irregularis (Grzybowski)			I								I				
Glomospira serpens (Grzybowski)			I	I				I							
Guttulina sp.											I				
Haplophragmoides mjatliukae (Masłakowa)	I	I	II					I							
Haplophragmoides sp.	I	II						I							
Haplophragmoides walteri (Grzybowski)			I								I				
Hormosina sp. I						II		I			II				
Hormosina velascoensis (Cushman)	I	I	II			II		II	I	I	II	II	II		
Hyperammina sp.				I											
Kalamopsis grzybowskii (Dylążanka)		II	II			I			I		II		II		
Karrerulina conversa (Grzybowski)	I	II	II					II	I	I	II		II		
Karrerulina horrida (Mjatliuk)	II	I						II	I				I		
Karrerulina sp.		I	I					II							
Lagena sp.											I				
Lenticulina sp.														I	
Lenticulina velascoensis White									I						
Lituotuba lituiformis (Brady)															I
Morozovella sp.								I							
Nodosaria sp. and *Nodosarella* sp.									II	I					
Nothia div. sp. (mainly *N. excelsa* (Grzybowski))		II				V	V	VI	V	V	V	V	II	V	V
Nuttallides truempyi (Nuttall)							I				II				
Nuttallinella florealis (White)								I							
Osangularia velascoensis (Cushman)									I						
Paratrochamminoides div. sp. (e.g. *P. irregularis* (White), *P. mitratus* (Grzybowski), *P. dubius* (Grzybowski), *P. acervulatus* (Grzybowski))	II	III	III	I	I	II	II	II	II	I	I	II	II	II	I
Placentammina placenta (Grzybowski)	I	I	II		II	I		I		I	I	II	I		
Praesphaerammina gerochii Hanzlikova			I												
Psammosiphonella div. sp. (mainly *P. cylindrica* (Glaessner), *P. discreta* (Brady))		I	II		II	V	V	VI	V	VI	V	VI	V	VI	V
Psammospera fusca Schultze				I											

Table 1: *Continued.*

	Szydłowiec (Goryczkowiec) Hill					Gościbia section							Krzyworzeka section	Lipnik valley	
Sample number	63/1/05 Sz	18/2/05 Sz	19/1/05 Sz	16/4/05 Sz	17/3/05 Sz	12/ 335 G	13/ 326 G	14/ 331 G	15/ 330 G	16/ 332 G	17/ 329 G	1/ 336 G	10/311 K	4/358 L	5/359 L
Pseudonodosinella nodulosa (Brady)								I	I			I	I		
Pseudonodosinella parvula (Huss)					I										
Pullenia coryelli White									I						
Recurvoides div. sp., *Thalmannammina subturbinata* (Grzybowski)	V	V	V	II	II	II	II	II	II	I	II	II	V	II	
Remesella varians (Glaessner)		I							I	II	I			I	
Reophax sp.						I			I			I			
Reophax duplex Grzybowski			I												
Reophax pilulifer Brady		I						I	I						
Rhizammina sp.						V		V			II	V	I	V	
Rzehakina epigona (Rzehak)			I			I		I	I	I	I		II		
Rzehakina fissistomata (Grzybowski)		II	I			I	I	II		I	I	II	I		
Rzehakina minima Cushamn et Renz		II	I					I							
Saccammina grzybowskii (Schubert)		II	I			I		II					I		
Saccammina scabrosa Mjatliuk		I	II	I				I	II		I		I		
Saccammina sp.			I			I			I		I		II	II	
Saracenaria sp.									I						
Spiroplectammina navarroana Cushman						I		I		II	I				
Spiroplectammina sp.											I				
Spiroplectammina spectabilis (Grzybowski)	I							I			II				
Spiroplectinella dentata (Alth)	II														
Subbotina triloculinoides (Plummer)								I							
Subreophax splendidus (Grzybowski)		I													
Subrepohax scalaris (Grzybowski)			I					I	I						
Trochammina globigeriniformis (Jones & Parker)	II		I			I		I					I		
Trochammina sp.	I		I			I				I		I	I	II	I
Trochamminoides proteus (Karrer)			I					I							
Trochamminoides subcoronatus (Grzybowski)	I	I	I												
Trochamminoides variolarius (Grzybowski)		II	II										I		
Trochamminopsis altiformis (Cushman & Renz)													I		

Specimens (per sample): **I** — 1–4 specimens; **II** — 5–9 specimens; **III** — 10–19 specimens; **V** — 20–99 specimens; **VI** — 100 and more.

calcareous benthic forms is much higher, though their preservation varies. Taking into account these observations and the taxonomic composition with identified deep-water genera, the calcareous microfauna appear to be an autochthonous component of the foraminiferal assemblages.

The foraminiferal assemblages from the stratotype section of the Goryczkowiec Sandstone on the slope of Goryczkowiec (Szydłowiec) Hill contain the typical Paleocene taxon *Rzehakina fissistomata* (Grzybowski) (Fig. 11C,D,E,G). This species is typical for the deep-sea flysch deposits, noted from many deposits of Late Cretaceous-Early Paleogene age. Its total stratigraphic range was approximated as Maastrichtian-Paleocene (mostly Paleocene) (Kaminski & Gradstein 2005 and references therein). In the Carpathian region, the species *Rzehakina fissistomata* (Grzybowski) occurs exclusively in the Paleocene, so it is used as an index taxon for regional Carpathian biostratigraphic divisions (Geroch & Nowak 1984; Olszewska 1997). *Haplophragmoides mjatliukae* (Maslakova) (Fig. 11O) identified from the Goryczkowiec Sandstone section also indicates a Paleocene age. Olszewska (1997) applies its extent as a supplementary parameter defining the Paleocene *Rzehakina fissistomata* Biozone. Additionally, cosmopolitan forms are found in the assemblages: Maastrichtian–Paleocene *Remesella varians* (Glaessner) (Fig. 10J), *Glomospira diffundens* Cushman & Renz; Senonian–Paleocene *Caudammina gigantea* (Geroch) (Fig. 11K), *C. ovuloides* (Grzybowski), *C. excelsa* (Dylążanka), *Pseudonodosinella parvula* (Huss), *Rzehakina epigona* (Rzehak), *R. minima* Cushman & Renz (Fig. 11H,I,J), *Dorothia crassa* (Marsson) (Fig. 10K), *Spiroplectammina dentata* (Alth) (Fig. 10O,P), as well as Senonian–Eocene *Caudammina ovulum* (Grzybowski), *Spiroplectammina spectabilis* (Grzybowski), *Annectina grzybowski* (Jurkiewicz) (Fig. 9O), *Hormosina velascoensis* (Cushman) (Fig. 9C). The composition of foraminiferal assemblages from other localities in the Sułkowice-Jasienica and Wiśniowa Tectonic Windows is very similar. *Spiroplectammina navarroana* Cushman, and *Dorothia indentata* Cushman & Jarvis (the Senonian-Paleocene forms) as well as *Cystammina sveni* Gradstein & Kaminski (noted in the Early Paleogene) are found in the Gościbia section. Assemblages of calcareous benthos, relatively rich in taxa as well as the Early Paleocene planktonic forms including *Subbotina triloculinoides* (Plummer) occur there. Benthic calcareous foraminifera are represented by *Ellipsoglandulina*, *Nuttallides, Eponides*, *Nodosaria*, *Gavelinella* and *Pullenia.* Cretaceous–Paleocene calcareous benthic species such as *Nuttallinella florealis* (White), *Osangularia velascoensis* (Cushman), *Pullenia coryelli* White, *Ellipsoglandulina obesa* Hanzlikova, *Aragonia ouezzanenzis* (Rey) as well as Paleocene–Eocene taxa, such as *Nuttallides truempyi* (Nuttall) and *Abysammina* are the most common.

The frequency of various species commonly known from Senonian assemblages, (especially relatively numerous specimens of *Caudammina ovulum* (Grzybowski) or *Caudammina excelsa* (Dylążanka) and *Rzehakina*) together with the presence of restricted Paleocene foraminifera can suggest that the Goryczkowiec Sandstone was formed in the Early Paleocene. This type of faunal diversity was observed in Paleocene assemblages from deposits of the Subsilesian Nappe. The frequency of relatively numerous and taxonomically diversified agglutinated foraminifers, which survived the extinction event at the Cretaceous/Paleogene boundary, is typical for the Lower Paleocene deposits of the Subsilesian Nappe. In the Upper Paleocene deposits the abundance of tests and their diversity significantly decreased (Waśkowska-Oliwa 2001, 2004, 2008). Moreover, the frequency of sporadic typically Cretaceous *Caudammina gigantea* (Geroch) is noted exclusively from the Early Paleocene (Liszkowa 1959; Sztejn et al. 1984; Waśkowska-Oliwa 2008). The taxon *Chiloguembelina morsei* (Kline), which occurs in the Early Paleocene (Olsson et al. 1999) was identified in one sample that also contained planktonic *Subbotina triloculinoides* (Plummer).

The recently collected micropaleontological material indicates an undisputed Paleocene age for the Goryczkowiec Sandstone, based mainly on the taxonomic composition of the agglutinated foraminiferal assemblages, the preserved calcareous forms, and algal material from thin sections. A Paleocene age was determined based on the total range of commonly occurring species, in particular *Rzehakina fissistomata* (Grzybowski) and *Haplophragmoides mjatliukae* Maslakova, as well as the coexisting Senonian–Paleocene and Paleocene–Eocene agglutinated, calcareous benthic, and planktonic species. The foraminiferal assemblages have been assigned to the *Rzehakina fissistomata* Biozone (zone after Olszewska 1997), and in particular to the earlier Early Paleocene part of that zone. Other papers dealing with the micropaleontological stratigraphy contain age estimates based on the state of knowledge that existed sixty years ago. This material requires reevaluation. The modern sedimentological models of the Outer Carpathian Flysch emphasize resedimentation of the shallow water older rocks from ridges into the younger deposits formed within deep-water basins. The larger foraminifera as well as other calcareous organic remnants were redeposited by gravity flows together with siliciclastic material from the shelf or upper basin slope (cf. Książkiewicz 1956). The flysch deposits are never older than their younger components. The age determination based on examination of small foraminifera assemblages from shales that consist of muddy or clayey material deposited mainly by free suspension is more reliable. The autochthonous microfauna recently evaluated do not contain any index species of Maastrichtian age within the Goryczkowiec Sandstone deposits.

Lithostratigraphic position

The upper boundary of the Goryczkowiec Sandstone is well documented in the type locality south of Wadowice as well as in the reference section in Wiśniowa and Sułkowice (Figs. 3 and 4). The thin- and medium-bedded quartzitic sandstones intercalated by green shales cover the Goryczkowiec Sandstone in the area between Goryczkowiec Hill and Gorzeń village. The green shales contain micropaleontological assemblages documenting a Paleocene age (e.g. Balcer & Koszarski 1992; Cieszkowski & Waśkowska-Oliwa 2002). The sandstones are greenish in colour. They contain a considerable amount of glauconite and also carbonate clasts. These flysch deposits covering the Goryczkowiec Sandstone were named the Gorzeń Sandstone by Książkiewicz (1951a,b). The name is derived from the nearby Gorzeń village. Burtan (1974, 1978) found similar deposits in the Wiśniowa area and named them the Czerwin Sandstone. They are represented by green shales with thin- and medium-bedded sandstones containing calcareous clasts (most of them have biogenic origin) and glauconite. They are the equivalent of the Gorzeń Sandstone defined by Książkiewicz (1951a,b).

The lower boundary of the Goryczkowiec Sandstone in the Wadowice area is not so clear due to the olistostrome character of the rocks. In most cases, grey and grey-green shales with very sporadic intercalations of thin-bedded calcareous sandstones constitute the lower part of the large olistolith just below the Goryczkowiec Sandstone. A similar sequence is well documented in the reference sections in the Sułkowice and Wiśniowa areas. The shales contain foraminiferal assemblages with *Rzehakina fissistomata* (Grzybowski) documenting a Paleocene age (Waśkowska-Oliwa 2002). The above described complex separates the Goryczkowiec Sandstone from the Cretaceous Frydek-type marls. The traditional lithostratigraphic scheme of the Subsilesian Unit (see e.g. Waśkowska-Oliwa 2005, 2008; Ślączka et al. 2006 and references therein) in which the Goryczkowiec (Szydłowiec) Sandstone covers the Frydek marls is no longer valid.

Similar clastic rocks are known from the Subsilesian Unit in the Outer Carpathians in the Czech Republic. They are usually called Stráž-type Sandstone (type locality Choryňská Stráž Hill near Choryně). Elias (1988) also distinguished the Lower Paleocene Klokočov Beds at the top of the Frydek Formation, without giving, however, any detailed diagnostic characters that would help to distinguish the Klokočov and Stráž-type Sandstones. All calcareous biodetritic (algal) sandstones and conglomerates within the Czech Republic are called the Stráž-type Sandstone and are marked accordingly on the geological maps from the 1960s until now, indicating a rock type (in particular petrography) rather than a well-defined lithostratigraphic unit. The field survey in the Czech Republic indicated laterally equivalent facies (variegated, grey and black grey shales, biodetritic sandstones etc.) in the Subsilesian Unit are just laterally passing facies (Menčík et al. 1983). The Goryczkowiec Sandstone would perhaps fit into the Czech lithostratigraphic scheme as a member within the Frýdlant Formation (Picha et al. 2006). This new lithostratigraphic scheme requires further consideration in cooperation with Czech geologists.

Paleogeography and paleoenvironment

The Outer Carpathian realm originated during Jurassic times as two separate paleogeographical units: the Alpine Tethys and the Protosilesian Basin (Hsü 1975; Książkiewicz

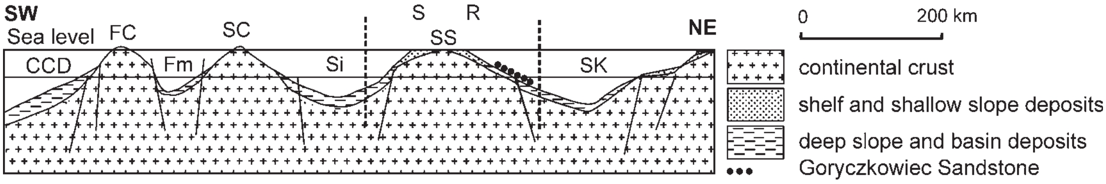

Fig. 12. Palinspastic cross-section showing the Outer Carpathian basins during the Paleocene. **Abbreviations:** FC — Fore-Magura Ridge, Fm — Fore-Magura Basin, Si — Silesian Basin, SK — Skole Basin, SC — Silesian Ridge, SS — Subsilesian Ridge, SR — Subsilesian Sedimentary Area (after Waśkowska et al. 2009).

1977; Golonka et al. 2005a,b, 2006, 2011; Waśkowska et al. 2009). The Paleogene paleogeography of the Outer Carpathians reflects the series of continental break-ups, rifts and collisions (e.g. Golonka et al. 2009; Golonka 2011) (Fig. 12). Each basin had a specific type of clastic deposits, and sedimentation commenced at different times (Bieda et al. 1963; Ślączka et al. 2006). The Magura Basin originated as part of the Alpine Tethys created during Mesozoic times between the Tethyan terranes and Eurasia. The other Outer Carpathian basins developed in the process of rifting and fragmentation of the European platform. During the Cretaceous compression the Magura Basin joined the Outer Carpathian realm. Within this realm in the foreland of the folded Inner Carpathians area, several basins divided by ridges and underwater swells became distinctly separated. In the Paleogene the movement of Adria and ALCAPA terranes resulted in gradual closing of the flysch basins and development of an accretionary prism. The ridges dividing the flysch basins in the Outer Carpathians became more distinguished providing favourable conditions for development of shallow banks with carbonate platform sedimentation.

The Late Cretaceous–Paleocene orogenic processes in the northern Outer Carpathians produced an enormous amount of the clastic material that started to fill the Carpathian basins. The material was derived from the northern and southern margins as well as from the inner ridges and elevated areas. The Silesian Ridge separated the Magura and Silesian basins. The Marmarosh Ridge was the extension of the Silesian Ridge (Bąk & Wolska 2005). It was also the alimentation center for detrital material during the Paleocene. Carbonate detritus was transported to the north into the Silesian Basin and to the south into the Magura Basin. The Subsilesian uplifted area was located between the Silesian and Skole Basins. The shallow banks with the carbonate platform sedimentation developed on this ridge. Carbonate detritus was transported to the surrounding slopes and basins contributing to the development of accretionary prism deposits. The Goryczkowiec Sandstone belongs to these deposits. It represents the coarse-grained type of flysch dominated by psammite-psephitic deposits separated by shale complexes. These rocks were deposited on the slope of the Subsilesian uplifted area (Figs. 12 and 13). The allogenic material, present within sandstones and conglomerates was transported from the shallower parts on the slopes. The petrographic inventory is diversified representing crystalline as well as sedimentary rocks. During the maximal stage of ridge uplift the basement was eroded, providing crystalline rocks belonging originally to the North European Platform. Proterozoic, Vendian (Cadomian), Early Paleozoic (Caledonian), Late Paleozoic (Hercynian) fragments can be distinguished within the folded and metamorphosed basement of this plate (Golonka et al. 2004, 2006; Ślączka et al. 2006).

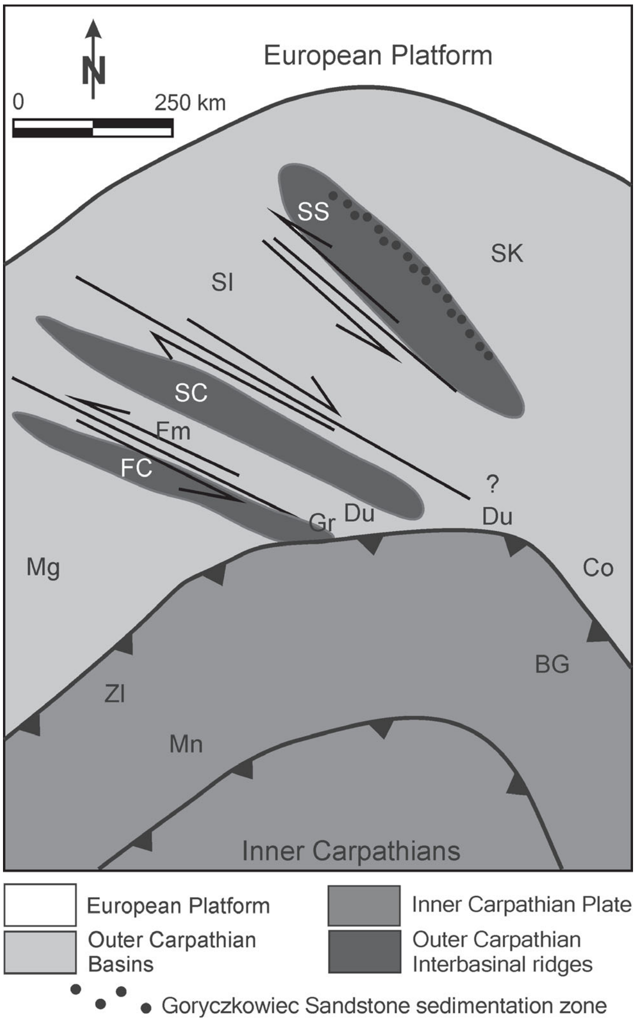

Fig. 13. Paleogeography of the Outer Carpathian basins during the Late Cretaceous. **Abbreviations:** BG — Bucovinian-Getic, Co — Cornohora, Porkulec, Audia, Teleajen, Du — Dukla, FC — Fore-Magura Ridge (cordillera), Fm — Fore-Magura Basin, Gr — Grybów Basin, Mg — Magura Basin, Mn — Manin Basin, SI — Silesian Basin, SK — Skole Basin, SC — Silesian Ridge (cordillera), SS — Subsilesian Ridge, Zl — Zlatna (after Golonka et al. 2011, modified).

The sedimentary fragments are represented mainly by carbonates, the clastic rocks are not so frequent. The carbonate clasts occur within medium-thick layers of the Goryczkowiec Sandstone. They also dominate the flysch layer constituting the allodapic limestone. Originally they were deposited within the sublittoral, mainly reefal facies. The uplifted part of the ridge was surrounded by shallow water, probably a narrow shelf locally dominated by coralline algae; other reef species are not so frequent. In smaller amounts there were bryozoans, brachiopods and foraminifers. The patchy distribution of these bioclasts is confirmed by the local occurrence of redeposited organic limestones within the siliciclastic material. The algal material is quite similar in all the Carpathian Paleocene carbonates. Numerous calcareous red algae have been found in Paleocene flysch and olistostrome deposits within all the Outer Carpathian subbasins (e.g. Cieszkowski et al. 2005b; Golonka et al. 2005a; Ślączka et al. 2006). The calcareous algae play a major role in ecological and paleogeographical reconstructions, as they are only derived from shallow and littoral zones. The character of algal assemblages closely follows the facies paleoenvironment. These paleoenvironments include reefs, patch reefs, reef talus, shallow water platforms, lagoons, and others.

In older works several algal genera (*Lithothamnium*, *Lithophyllum*, *Mesophylum*, *Arhaeolithothamnium*, *Paleothamnium*, *Ethelia* among the others) were distinguished in the so-called *Lithothamnium* limestones and sandstones within the Outer Carpathian Flysch (Golonka 1974). Recently fossil red algae species are often considered artificial (e.g. Rasser & Piller 1999; Rasser 2000) and the algal material requires reevaluation. Nevertheless, the strong development of the Corallinaceae family occurred during Paleocene (Thanetian) times (Perrin 2002). The Corallinaceae and Squamariaceae algae artificial species assemblages also known from the Goryczkowiec Sandstone include *Paleothamnium iorii* Maslov, *Lithothamnium abrardi* Lemoine, *L. andrusowi* Lemoine, *L. contraversum* Lemoine, *L. densum* Lemoine, *L. quadrangulum* Lemoine, *Lithophyllum carpathicum* Lemoine, *Ethelia alba* Pfender, and *Distichoplax bisserialis* (Dietrich). These assemblages are similar within olistoliths and organodetritical sandstones within the Paleocene formations of all Outer Carpathian and Pieniny Klippen Belt units. They are not known from the Cretaceous deposits.

The algae occurring in flysch sediments indicate the existence of intrabasinal ridges and carbonate platforms along the basin margins. The abundance of algae in flysch deposits indicates the time of geotectonic activity, development of rifted basins and/or closing of flysch basins. Well-preserved reefs are known from the olistolithic limestones found in Eastern and Western Slovakia (e.g. Kambühel Kalk, see Köhler et al. 1993; Köhler & Buček 2005) the Haligovce and Velký Lipnik olistolithic limestones (e.g. Cieszkowski et al. 2004; Köhler & Buček 2005; Krobicki et al. 2005; Cieszkowski et al. 2009a), which provide excellent example of coral-algal reefal facies. These limestones were also found as olistoliths within the fore-arc flysch deposits of the Žilina Formation. The fore-arc Złatne (Klape, Myjava) Basin was formed during Late Cretacaeous times as a result of subduction of the southern part of the Alpine Tethys (Cieszkowski et al. 2009a). The huge Mesozoic Haligovce Klippen olistoliths and Paleocene limestone reefs blocks were sliding during Paleocene–Eocene times as repetitive events during the formation of the Złatne accretionary prism.

During Paleocene time narrow carbonate platforms originated, in some places full of coral-algal reefs, which are now known as Kambühel-type limestones (see Köhler et al. 1993; Köhler & Buček 2005 and references therein).

The organogenic limestones are formed by *Scleractini*a corals together with numerous red algae from the Corallinaceae family Corallinaceae, Melobesiideae subfamily, algae (genera *Lithothamnium*, *Lithophyllum*, *Arhaeolithothamnium*, *Paleothamnium*, *Ethelia*), bryozoans, sponges, brachiopods, gastropods and foraminifera.

The typical Paleocene sandstones with algal reef material were described from numerous locations in the Outer Carpathian nappes. The eastern part of the Silesian Ridge was made up mainly of sedimentary rocks, a source for the mature, siliciclastic material. This part of the ridge was surrounded by shallow water, probably narrow shelf locally dominated by *Lithothamnium,* but other reef species were absent. There were smaller numbers of bryozoans, brachiopods and foraminifera. Patchy distribution of *these faunas* is confirmed by local occurrence of redeposited organic limestones within siliciclastic material. The best known rocks containing the redeposited shallow carbonates are the Skalnik Limestone (Ślączka & Walton 1992) and exotic-bearing shales from Bukowiec and Roztoki (Ślączka 1961; Golonka et al. 2005a,b; Bąk & Wolska 2005). The Skalnik Limestone is a megaturbidite within the Oligocene bituminous fish-shales (Menilite beds) from the western part of the Dukla Basin and its adjacent foreland. It shows changes from the NW towards the SE in structures and contents of bioclasts. Its proximal part is composed of graded and laminated limestones, towards the SE amount of quartz grains increases and the Skalnik Limestone eventually passes into calcareous sandstones. Everywhere the calcareous algae *Lithothamnium* is predominant, with smaller amounts of bryozoans and foraminifera. The more proximal part also contains fragments of echinoderms, brachiopods, ostracods and Balanidae. The Czerwin Sandstone known from outcrops in the Wiśniowa Tectonic Window east of Wadowice (Burtan 1974, 1978; Cieszkowski et al. 2001) also belongs to the Paleocene sandstones with algal reef material. They contain numerous calcareous clasts. Locally, these clasts prevail and were described as allodapic limestones with *Lithothamnium* (Cieszkowski et al. 2009b). Carbonate material with coralline red algae was also found within sandstones typical for the Silesian Basin in the Upper Istebna Beds and the Ciężkowice Sandstone (Leszczyński 1978), especially its local facies known as the Melsztyn Sandstone (Cieszkowski et al. 2010). The Bircza Sandstone deposited in the eastern part of the Skole Basin contains a *Lithothamnium*-limestone bed, which is a typical example of the limestone formed by material that originated on the shallow-water margin of the North European Platform and was redeposited in the Carpathian flysch. The Bircza Sandstone was deposited on the northern margin of the Skole Basin, while the Goryczkowiec Sandstone was deposited on its southern margin within the Subsilesian Sedimentary Area, mainly in a reef talus paleoenvironment (Fig. 12). The Subsilesian Ridge (Golonka et al. 2005b, 2011), which separated the Silesian and Skole Basins, was the main provider of detrital material during the Paleocene (Golonka et al. 2004). It was the source of carbonate material to the Goryczkowiec Sandstone, which represents a huge olistolith on the border of the Subsilesian Unit. The carbonate sediments with coralline red algae are well preserved in the area of Adrychow, in the Targanice and Pańska Góra olistoliths. They represent more proximal facies of reef talus, compared with the Goryczkowiec sediments. The paleogeographical position of the Goryczkowiec Sandstone confirms the Paleocene age of this lithostratigraphic unit.

Agglutinated forms predominate in the autochthonous assemblages of foraminifera. Foraminifera that agglutinated grains with carbonate cement also occur within these assemblages (e.g. *Dorothia*, *Remessella*). A typical admixture of calcareous forms within the foraminiferal assemblages of mainly benthic forms, representing a deep-sea bathyal paleoenvironment, is around 2–10 %, occasionally reaching 20 % (Geroch & Gradziński 1955; Waśkowska-Oliwa 2005). The taxonomic composition of the calcareous benthos is diversified. Planktonic foraminifera are occasional, usually not surpassing 1 %. This composition of microfauna confirms the deep-sea conditions of sedimentation in this part of the Subsilesian Sedimentary Area, where the Goryczkowiec Sandstone was deposited, most likely at a depth between the CCD and lysocline (Waśkowska-Oliwa 2005). Coarse-grained suspension-feeding foraminifera with massive test walls predominate, for example, *Rhabdammina* — a genus typical for the high-energy turbiditic paleoenvironments. Other morphotypes, epifaunal to shallow and deep sea infaunal, are well developed. The presence of diverse morphotypes suggests good conditions for the development of foraminifera with respect to organic matter as well as good oxygenation of the bottom water and the surface of the sediment. In the deep basinal zones, organic life was apparently the richest, and the foraminifera were accompanied by macrofauna that produced diversified trace fossils preserved on the bottoms of sandstone layers and within the shales.

The Miocene tectonic movements within the Outer Carpathian accretionary prism caused final folding flysch deposits and created several imbricate nappes. The Subsilesian Ridge deposits were partially included in the Subsilesian Nappe, the ridge's basement rocks and part of its deposits form olistostromes and exotic pebbles within the upper part of the Menilite-Krosno flysch and the following Lower Miocene Molasse deposits (Cieszkowski et al. 2009a). The olistoliths, slid down into the basin situated in front of the Silesian Nappe from the Subsilesian Ridge during Late Oligocene or Early Miocene times.

Conclusions

The proximal flysch units from the marginal Outer Carpathians containing the Paleocene bryozoan-coralline algae sandstones reflect the geodynamics of the ridges within the Outer Carpathians. The Goryczkowiec Sandstone was deposited on the slope of an uplifted intrabasinal structure known as the Subsilesian Sedimentary Area, at depths between the CCD and lysocline. Lithological investigations revealed abundant calcareous material of biogenic origin representing reef and its talus, containing red algae and bryozoans as the leading organic group. This material was transported by turbidity currents into deeper zones.

A Paleocene age for the Goryczkowiec Sandstone is documented on the basis of the autochthonous foraminiferal assemblages from shale intercalations and algae identified in the thin sections.

The larger foraminifera, which suggested a Late Cretaceous (Maastrichtian) age are the allochthonous component, redeposited by turbidity currents from eroded parts of the Subsilesian Ridge. The Goryczkowiec Sandstone is underlain by Paleocene grey shales and covered by the Gorzeń and Czerwin Sandstones.

We revise and redefine here the lithostratigraphic position of the Goryczkowiec Sandstone, but further work needs to be carried out in cooperation with Czech geologists leading to the formalization of the Goryczkowiec and Gorzeń Sandstones as members within the Frýdlant Formation.

Acknowledgments: This research has been financially supported by AGH University of Science and Technology in Krakow Grant No. 11.11.140.173. and Grant MNiSW/NCN No. N N307 249733. We thank Miroslav Bubík (ČGS) for helpful discussions. Mike Kaminski (KFUPM) and Ján Soták (GI SAS) are thanked for reviewing the manuscript.

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