

CALCAREOUS NANNOFOSSILS AND FORAMINIFERA FROM THE YOUNGEST DEPOSITS OF THE SIARY SUBUNIT (OLIGOCENE, MAGURA NAPPE, POLISH OUTER CARPATHIANS)

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Abstract: The calcareous nannoplankton and foraminifera from the Gładyszów Beds, regarded as the youngest deposits in the northern marginal Siary Subunit of the Magura Nappe in Poland, are characterized. The material investigated comes from outcrops in the vicinity of Gładyszów and from the Gładyszów PIG-1 borehole. The analysis allowed the establishment of the age of these deposits as not older than late Rupelian–early Chattian (the calcareous nannoplankton NP24 Zone). The taxonomic affiliations, environmental associations and preservation of the microfossils were analyzed to document the sedimentary processes and environmental conditions during the geotectonic transformation of the Magura Basin in the Oligocene. These microfossils also were compared with those reported from the terminal deposits of the Outer Carpathians and the Podhale Basin.

Key words: Calcareous nannoplankton, foraminifera, palaeoenvironment, Gładyszów Beds, Siary Subunit, Magura Nappe, Outer Carpathians, Oligocene.

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INTRODUCTION

The Siary Zone was the northernmost sedimentary area of the Magura Basin in the Polish Outer Carpathians. The Upper Cretaceous–Palaeogene deposits of this sedimentary zone (Fig. 1) were detached from their basement in the Maastrichtian, when the Inoceranian Beds were deposited in the Magura Basin; they formed a tectonic unit, distinguished as the Siary Subunit of the Magura Nappe (Świdziński, 1953; Koszarski and Koszarski, 1985). Since that time, the Magura Basin was separated into several facies zones with different rates of deposition. Facies changes in particular zones of the Magura Basin in the Palaeogene were associated with the migration of depocentres from the south to the north of the basin (Birkenmajer and Oszczypko, 1989; Oszczypko, 1999; Golonka *et al.*, 2000). The closure of the Neotethys, associated with global changes in sea level and palaeogeography (Hardenbol *et al.*, 1998; Snedden and Liu, 2010), led to a series of local tectonic and erosional processes in the Magura Basin (Poprawa *et al.*, 2002; Oszczypko, 1992, 2006).

The final stages of progressive shortening and closing processes in the part of the Magura Basin discussed led to the accumulation of the Gładyszów Beds (Kopciowski and Garecka, 1996; Kopciowski, 2007). Their strata have an ex-

tremely chaotic structure (Fig. 2), which makes their origin uncertain: it may be either sedimentary or tectonic. As a result, the position of the Gładyszów Beds and their relationship to the adjacent deposits are uncertain. In order to solve this problem, the authors describe calcareous nannoplankton and foraminifera from these youngest deposits of the Siary Zone and analyze them with regard to the reconstruction of sedimentary processes and environmental conditions during the terminal stages of the Magura Basin that led to its closure. They correlate the microfossils studied with coeval assemblages from the other Outer Carpathian basins that were rebuilding and from the Podhale Basin. Their previous micropalaeontological studies on the biostratigraphy of the Gładyszów Beds were presented in the form of short reports, as parts of archival materials (Garecka and Szydło in Kopciowski *et al.*, 1997) and scientific communications (Kopciowski and Garecka, 1996; Garecka *et al.*, 1998; Szydło, 2001; Garecka and Szydło, 2011). In this paper, the detailed micropalaeontological analysis of calcareous nannoplankton and foraminifera with photographic documentation and related discussion of these results with respect to sedimentary conditions and tectonic processes are presented for the first time.

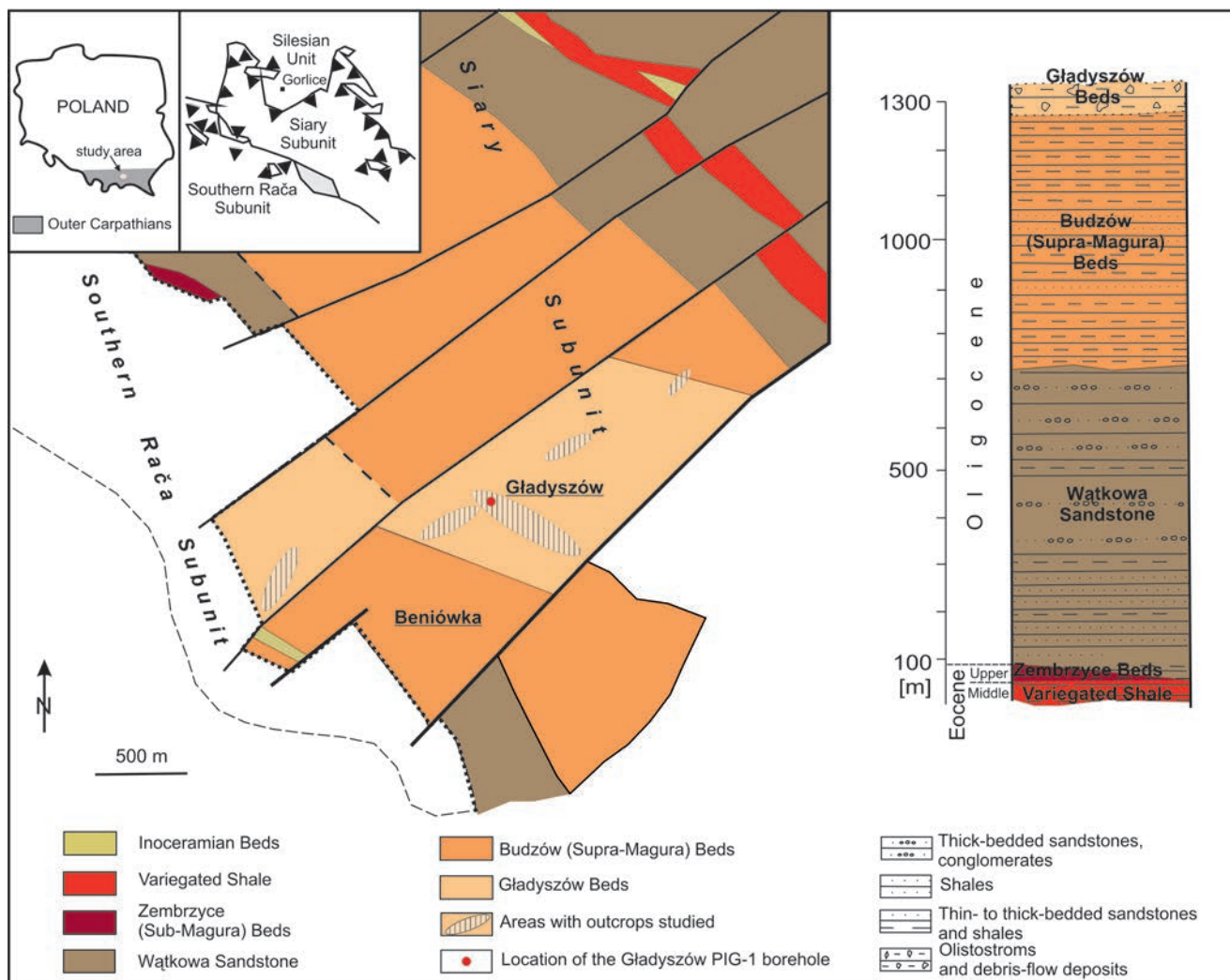


Fig. 1. Geological sketch-map and the general profile of the Siary Subunit in the vicinity of Gładyszów (after Kopciowski and Garecka, 1996, modified).

GEOLOGICAL SETTINGS

The Siary Subunit (North Rača Subunit) is usually distinguished as the most external, northernmost tectonic unit of the Magura Nappe (Fig. 1). Its source areas for sediments were located at the north and north-east margin of the Magura Basin (Kopciowski, 2007). Facies changes in particular zones of the Magura Basin were associated with the migration of sedimentary centres. As a consequence, thick sandstone series accumulated in the Magura Basin (Kopciowski, 1996; Fig. 1); this distinguishes the Magura Basin from the other Carpathian basins, which during this period of open connection with the world ocean, were characterized by unification of hemipelagic/pelagic sedimentation, leading to the accumulation of the Variegated Shale close to the CCD. Later, sedimentation from turbidity currents, associated with increased tectonic and volcanic activity, contributed to intensified circulation (upwelling), which led to oxygenation and fertilization of the surface waters in the basin (Oszczypko, 2004, 2006; Oszczypko and Oszczypko-Clowes, 2009). This process culminated across the Eocene–Oligocene boundary, when the pelagic Globigerina Marl

was deposited in the Outer Carpathian basins. In the northern marginal area of the Magura Basin (Siary Zone), sediments of this type have not been found, but shales containing calcareous foraminifers referable to this depositional event were noted (Garecka *et al.*, 1998).

The change in sedimentary conditions that took place during the earliest Oligocene brought to an end the deposition of the Globigerina Marl in the Outer Carpathian basins. The sea-level fall and isolation of the basins resulted in the formation of bituminous shales, which became the dominant facies in this area (Oszczypko, 1999; Poprawa *et al.*, 2002). The shallowing process in the Magura Basin was associated with the expansion of an accretionary prism in the southern part of the area. Initially, predominantly sandy turbidites were partly displaced by a mudstone series (Fig. 1) in the northern part of the basin (Kopciowski, 2007). The glauconitic sandstone facies (the Wątkowa Sandstone), associated with flows of higher density, were replaced by shales (the Budzów/Supra-Magura Beds), accumulated under conditions of low tectonic activity. After this sedimentary period, the chaotic deposits of the Gładyszów Beds were laid down as a result of syn- and post-tectonic processes (Kopciowski,

2007). In the Polish part of the Carpathian area, this process was initiated during the Oligocene and ended in the Miocene. It coincided with the formation of similar chaotic deposits, which were the result of closure of the other Outer Carpathian basins (Jankowski, 1997).

The Gładyszów Beds, which are the subject of this paper, were described for the first time in the vicinity of Gładyszów by Kopciowski (in: Kopciowski and Garecka, 1996). They are represented mainly by mudstones and marly clays, which include smaller clasts, blocks and even larger fragments of flysch series including various sandstones and shales (Fig. 2A, B). The thickness of the Gładyszów Beds is difficult to estimate, because of the lack of good exposures and the chaotic nature of the deposits; it may be assumed to range from 50 to 80 m (Kopciowski and Garecka, 1996; Kopciowski, 2007). The Gładyszów PIG-1 borehole was drilled to gain a complete profile, including the thickness of the Gładyszów Beds and their contact with the underlying Budzów Beds. Unfortunately, the transition between these two units was not found in this borehole (Kopciowski *et al.*, 2011).

MATERIAL AND METHODS

Rock material was sampled from the deposits exposed in Gładyszów Creek, to the east of the centre of Gładyszów village (18 samples; N49°30'59"–49°31'17", E021°15'15"–021°16'23") and 58 samples were collected from the Gładyszów PIG-1 borehole, located in Uście Gorlickie (N49°31'20", E021°16'10"; Fig. 1). The deposits sampled, described as “a block in a matrix”, were represented first of all by grey, grey green and green, strongly deformed calcareous, marly mudstones and claystones, in which fragments of fine- and medium-grained grey, calcareous sandstones occurred (Fig. 2; Kopciowski, 2007, Kopciowski and Garecka, 1996). The same type of rocks with brown, calcareous shales (Kopciowski *et al.*, 2011) was sampled from the interval 1.4–200 m in the Gładyszów PIG-1 borehole. The bottom of the Gładyszów Beds and their contact with underlying Budzów Beds was not reached in this borehole. For comparison, a few samples were taken from the uppermost part of the Budzów Beds, exposed in the vicinity of Gładyszów (Fig. 1)

The calcareous nannofossils and foraminifera studied were obtained from the same set of samples. The smear slides for nannofossils studies were prepared, according to the standard method described by Báldi-Beke (1984). A fine water suspension of the rock was spread out on a glass slide. After drying, the microscope slide was covered with Canada balsam and a cover glass. The slides were inspected and microfossils photographed with a light microscope Nikon Eclipse E400Pol at 1000× magnification. In the case of foraminifera, the rock material was subjected to mechanical and thermal crushing processes. Foraminifera were selected from sieved rock material, which previously had been washed and then was fragmented by an alternation of heating and freezing. Finally, the 63 µm fraction was used for observation under the stereoscopic optical microscope (Zeiss Stereo Discovery.V12). Photo documentation was

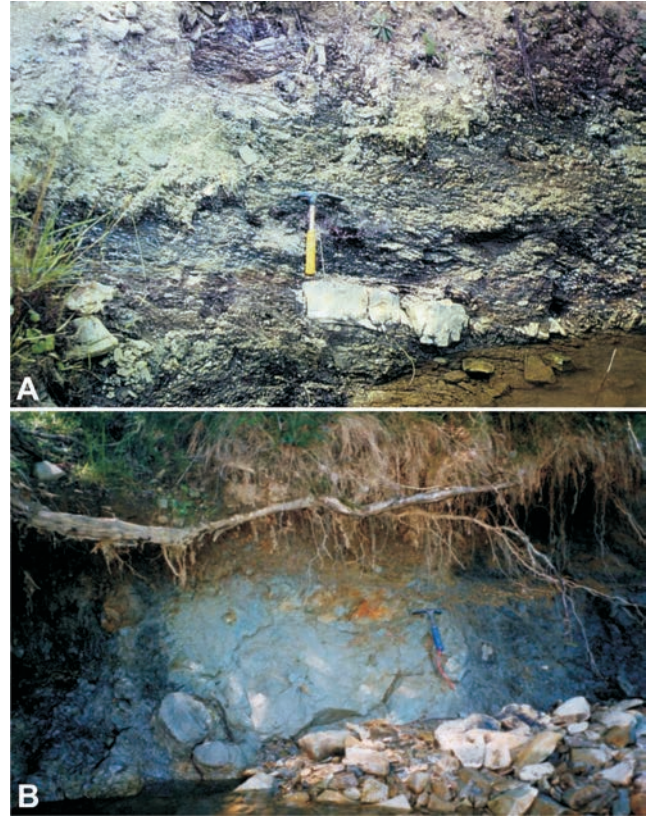


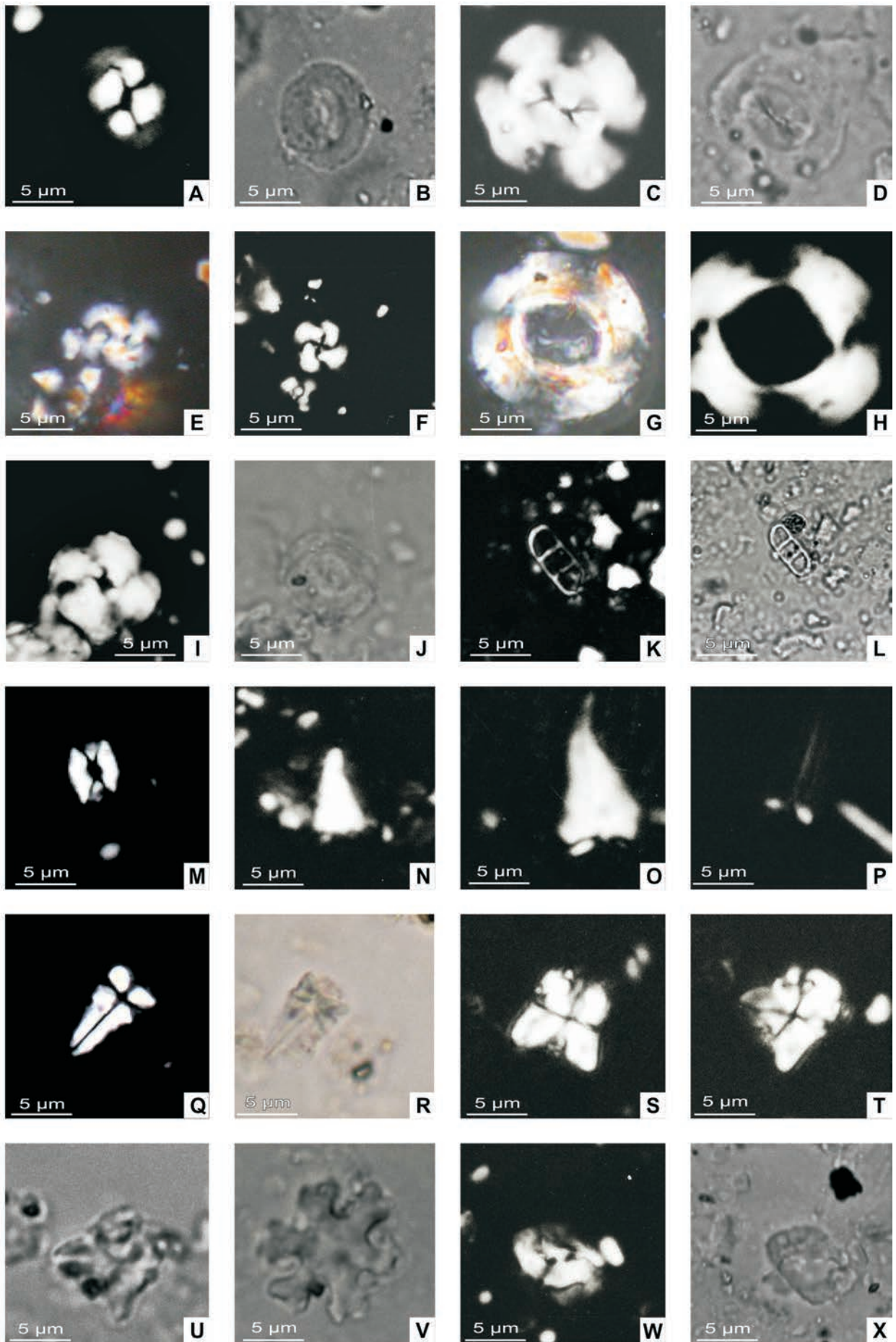
Fig. 2. Outcrops of the Gładyszów Beds in Gładyszów Creek. A, B. Multicolored mudstones incorporating sandstone blocks (photographs taken by R. Kopciowski).

carried out in the Scanning Electron Microscopy Laboratory of Biological and Geological Sciences Institute of the Jagiellonian University (JEOL-5410 and NORAN Voyager 3100). The microfossils were analyzed with respect to their number, diversity, and preservation.

RESULTS

Calcareous nannoplankton

The distribution of calcareous nannoplankton is shown in Tables 1 and 2; photographs of selected taxa are illustrated in Figures 3 and 4. The number, diversity and preservation of the calcareous nannoplankton specimens vary significantly from sample to sample. The most resistant to dissolution, according to Bukry's (1981) classification, long-ranging *Coccolithus*, *Dictyococcites*, *Reticulofenestra* and *Cyclicargolithus* specimens occur more frequently than the other, less resistant and sporadically found *Pontosphaera*, *Transversopontis*, *Braarudosphaera*, *Micrantholithus*, *Sphenolithus*, *Helicosphaera* and holococcoliths. The state of preservation can be determined as poor or, in some cases, very poor. The well preserved species occur sporadically. The large scale of the destruction is documented by the high frequency of indeterminate fragments of undefined morphological types and damaged specimens, e.g., broken arms of asteroliths, crushed fragments of shields, and the absence or fragmental preservation of diagnostic elements, espe-



cially in the samples taken from the borehole. Poor preservation and redeposition observed on a large scale (the latter being difficult to determine in the case of long-ranging species) created difficulties in the age dating of the sediments in question.

Reworked specimens are dominant elements of the calcareous nannofossil assemblages in the samples from both the outcrops and the Gładyszów PIG-1 borehole. They are mainly Eocene and Eocene–Oligocene and sporadically Cretaceous and Palaeocene taxa.

The youngest species, considered as autochthonous species, the presence of which allow the determination of an Oligocene age, are very rare. The following long-ranging placoliths dominate: *Coccolithus pelagicus* (Wallich) Schiller (Fig. 3A, B), *Dictyococcites bisectus* (Hay, Mohler et Wade) Bukry et Percival (Fig. 3C–E), *Cribozentrum reticulatum* (Gartner et Smith) Perch-Nielsen (Fig. 3F), *Reticulofenestra umbilica* (Levin) Martini et Ritzkowski (Fig. 3G, H) and small reticulofenestrids. Less commonly, quite unequally, but with constant frequency, the following species occur: *Cyclicargolithus floridanus* (Roth et Hay) Bukry (Fig. 3I, J), *Isthmolithus recurvus* Deflandre (Fig. 3K, L) and *Lanternithus minutus* Stradner (Fig. 3M). The warm-water *Sphenolithus* (*Sphenolithus predistentus* Bramlette et Wilcoxon (Fig. 3N–P), *S. pseudoradians* Bramlette et Wilcoxon (Fig. 3Q, R), *S. moriformis* (Brönnimann et Stradner) Bramlette et Wilcoxon, (Fig. 3S–U) and *Discoaster* (*Discoaster deflandrei* Bramlette et Riedel, (Fig. 3V), *D. tanii* Bramlette et Riedel, reworked Eocene forms) and nearshore *Helicosphaera* (*Helicosphaera compacta* Bramlette et Wilcoxon (Fig. 3W, X), *H. intermedia* Martini (Fig. 4A), *H. bramlettei* Müller (Fig. 4B, C), *Pontosphaera* (*Pontosphaera multipora* (Kamptner) Roth (Fig. 4D), *Transversopontis* (*Transversopontis obliquipons* (Deflandre) Hay, Mohler et Wade, Fig. 4E, F), pentoliths and *Zygrhablithus bijugatus* Deflandre (Fig. 4G, H) occurred sporadically. The Oligocene species occur mainly in the samples from Gładyszów Creek (Tab. 1): *Cyclicargolithus abisectus* (Müller) Wise (Fig. 4I–L), *Sphenolithus dissimilis* Bukry et Percival (Fig. 4M, N), *Reticulofenestra lockeri* Müller (Fig. 4O, P) and *Reticulofenestra ornata* Müller (Fig. 4Q, R). In the samples from the Gładyszów PIG-1 well, the only Oligocene species is *R. lockeri* (Tab. 2). The nannofossil association detected in the samples from the outcrops in Gładyszów Creek is

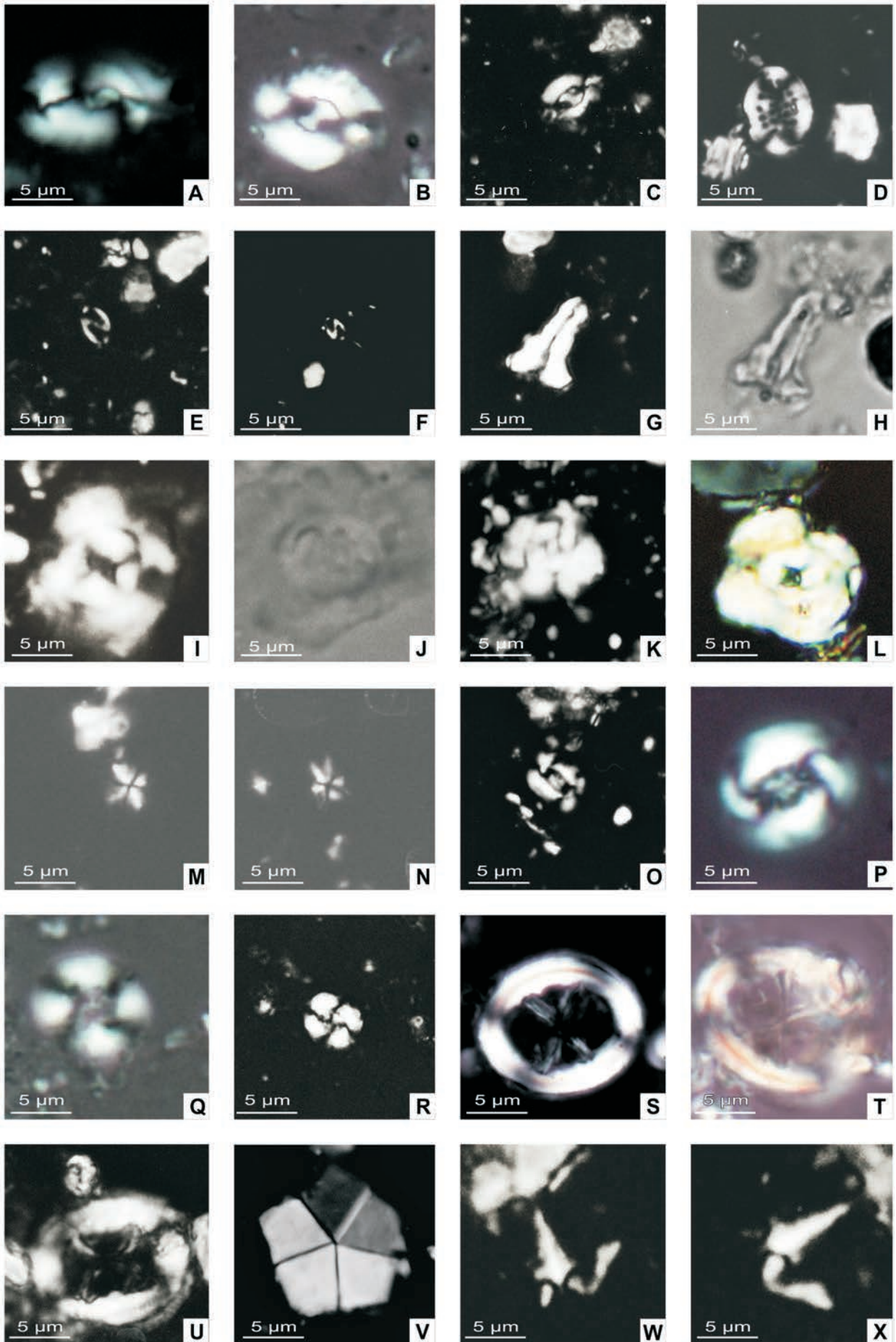
better preserved than the one from the borehole. In the case of large forms, such as *D. bisectus*, *R. umbilica*, *Chiasmolithus oamaruensis* (Deflandre) Hay, Mohler et Wade (Fig. 4S, T), *C. cf. grandis* (Bramlette et Riedel) Radomski (Fig. 4U) and also *Discoaster* sp., *Braarudosphaera bigelowii* (Gran et Braarud) Deflandre (Fig. 4V) and *I. recurvus*, the signs of mechanical damage are especially prominent.

Foraminiferal assemblages

The distribution of foraminifera is shown in Tables 1 and 2; SEM photographs of selected taxa are illustrated in Figure 5. In the samples studied, Paleocene–Eocene and Late Cretaceous planktonic or benthonic forms usually occur as separate assemblages in samples, which include only displaced and reworked rock material incorporated into the Gładyszów Beds during the syn-tectonic processes. Occasionally, these agglutinated benthos or plankton specimens occur as single forms in samples containing assemblages of Early Oligocene age (Tabs 1, 2). The latter are represented by opportunistic planktonic foraminifera representing *Chiloguembelina*, *Laterostomella*, *Globoquadrina*, *Globanomalina*, *Tenuitellinata*, *Parasubbotina*, *Catapsydrax*, *Globorotaloides* (Fig. 5A–H, J), *Testacarinata*, *Subbotina* and diversified calcareous benthic forms represented mainly by species of the *Bolivina-Brizalina* group [*B. cookie*, *B. crenulata*, *B. danvilensis*, *B. fastigia* (Fig. 5K–O), *B. aenariensisiformis*, *B. missisipiensis*, *B. subtilissima*] and the genus *Cibicides*: *C. lopjanicus* (Fig. 5P, Q), *C. amphisylenis*, *C. oligocenicus*. Some of them are known from the Budzów (Supra-Magura) Beds (Garecka *et al.*, 1998; Garecka and Szydło, 2011). Apart from the forms described, calcareous benthos, belonging to the genera *Globocassidulina*, *Cassidulina*, *Pullenia*, *Uvigerina* (Fig. 5R), *Bulimina* (Fig. 5V, W), *Fursenkoina* (Fig. 5X), and *Chilostomella* occur (Tab. 2). Among them, the latter three taxa occur as pyritized forms, which are more frequent in the upper part of the Budzów Beds (Szydło in Kopciowski *et al.*, 1997).

In addition, some samples from the Gładyszów Beds contain planktonic forms, belonging to the genera *Tenuitella* (*T. brevispira*), *Globigerinella* (*G. obesa*) and *Cassigerinella* (*C. chipolensis*), and also benthonic taxa (*Asterigerina*, *Protelphidium*).

Fig. 3. Calcareous nannofossils from the Gładyszów Beds. Abbreviations: CN – crossed nicols; NL – normal light. **A.** *Coccolithus pelagicus* (Wallich) Schiller – CN (crossed nicols). **B.** *Coccolithus pelagicus* (Wallich) Schiller – NL (normal light). **C.** *Dictyococcites bisectus* (Hay, Mohler et Wade) Bukry et Percival – CN. **D.** *Dictyococcites bisectus* (Hay, Mohler et Wade) Bukry et Percival – NL. **E.** *Dictyococcites bisectus* (Hay, Mohler et Wade) Bukry et Percival – CN. **F.** *Cribozentrum reticulatum* (Gartner et Smith) Perch-Nielsen – CN. **G.** *Reticulofenestra umbilica* (Levin) Martini et Ritzkowski – CN. **H.** *Reticulofenestra umbilica* (Levin) Martini et Ritzkowski – NL. **I.** *Cyclicargolithus floridanus* (Roth et Hay) Bukry – CN. **J.** *lang1033 Cyclicargolithus floridanus* (Roth et Hay) Bukry – NL. **K.** *Isthmolithus recurvus* Deflandre – CN. **L.** *Isthmolithus recurvus* Deflandre – NL. **M.** *Lanternithus minutus* Stradner – CN. **N.** *Sphenolithus predistentus* Bramlette et Wilcoxon – CN-0°. **O.** *Sphenolithus predistentus* Bramlette et Wilcoxon – CN-0°. **P.** *Sphenolithus predistentus* Bramlette et Wilcoxon – CN-45°. **Q.** *Sphenolithus pseudoradians* Bramlette et Wilcoxon – CN-0°. **R.** *Sphenolithus pseudoradians* Bramlette et Wilcoxon – NL-0°. **S.** *Sphenolithus moriformis* (Brönnimann et Stradner) Bramlette et Wilcoxon – CN-0°. **T.** *Sphenolithus moriformis* (Brönnimann et Stradner) Bramlette et Wilcoxon – CN-45°. **U.** *Sphenolithus moriformis* (Brönnimann et Stradner) Bramlette et Wilcoxon – NL-45°. **V.** *Discoaster deflandrei* Bramlette et Riedel – NL. **W.** *Helicosphaera compacta* Bramlette et Wilcoxon – CN. **X.** *Helicosphaera compacta* Bramlette et Wilcoxon – NL.



INTERPRETATION

Biostratigraphy

For the purpose of this work, the standard zonation of Martini, modified by e.g., Martini and Müller (1986) was used. The Oligocene zonation is based among others on the last (LO) and first occurrences (FO) of warm-water sphenoliths (*Sphenolithus distentus*, *Sphenolithus ciperoensis*), which are rare or even absent at high latitudes (Fig. 6). In the case where index species have not been used for the original boundary definition, it was necessary to use secondary species of established biostratigraphic position (Fig. 6). The first rare occurrence of *C. abisectus* closely corresponds to the first appearance of *Sphenolithus ciperoensis*, which originally defined the lower boundary of the NP24 Zone (and also the upper limit of the NP23 Zone) in Martini's scheme (1971). Its relation was used by Müller (1976) who created the substitute marker for the upper limit of the NP23 Zone and the lower limit of the NP24 Zone in mid and high latitudes. The FO of *C. abisectus* (and/or the FO of *Helicosphaera recta*) is used as a zonal marker by many authors (e.g., Roth *et al.*, 1971; Báldi-Beke and Báldi, 1973; Benedek and Müller, 1974; Stráník *et al.*, 1981; Martini and Müller, 1986; Krhovský *et al.*, 1992; Ślęzak *et al.*, 1995; Švábenická and Stráník, 2004; Van Simaëys *et al.*, 2004). The first rare individuals of *R. lockeri* (and *R. ornata*) were described already from the upper part of the Globigerina Marl of the Skole Unit, assigned to the NP22 Zone (Garecka, 2012). Dudziak (in Smoleńska and Dudziak, 1989) mentioned this species (as *R. cf. lockeri*) in the association of the NP22 Zone in the Sub-Cergowa Marl of the Dukla Unit. It confirmed information that *R. lockeri* appeared in the lower part of the Early Oligocene (NP22; Krhovský, 1981; Báldi *et al.*, 1984). According to Nagymarosy and Voronina (1992), the first rare specimens of *R. lockeri* appeared even close to the Eocene/Oligocene (NP21) boundary. At the boundary of NP22/NP23 zones, an increase in the number of *R. lockeri* individuals was observed (Nagymarosy and Báldi-Beke, 1988). The lower part of the Menilite Beds of the Skole Unit, on the basis of the mass occurrence of *R. ornata*, *Transversopontis fibula* and *R. lockeri*, were included in the NP23 Zone (Garecka, 2005, 2012). In the calcareous nannoplankton assemblage of the NP24 Zone, they occurred as one of the most resistant species with other *Reticulofenestra*, *Dictyococcites* and *Coccolithus* specimens. According to Perch-Nielsen (1985), *Sphe-*

nolithus dissimilis appeared in NP24 Zone. Oszczytko-Clowes (2001, 2010) mentioned this species in the assemblage of the Budzów Beds also assigned to the NP24 Zone. Already in sample 842/21/95 (Tab. 1), which was collected from the uppermost part of the Budzów Beds in the Gładyszów section (Kopciowski and Garecka, 1996; Garecka *et al.*, 1998; Garecka and Szydło, 2011), the occurrence of *R. lockeri* (common), *R. ornata*, *C. abisectus*, *S. distentus* and *C. floridanus* indicated the NP24 Zone (upper Rupelian–lower Chattian). It confirmed results achieved by Oszczytko-Clowes (2001, 2010), which on the basis of the occurrence *C. abisectus*, *S. dissimilis* and *H. recta* assigned the Budzów Beds of the Małastów and Olchowiec sections (Siary Zone) to the NP24 Zone. The scarcity of the Oligocene species and the common occurrence of redeposited forms indicate that the age of the investigated samples from the Gładyszów Beds may be younger than the discussed assemblage of nannofossils. They are not older than the NP24 Zone, whereas the poorer samples from the Gładyszów PIG-1 well are at least Early Oligocene in age; it is impossible to determine the nannofossil zone.

The presence of some planktonic genera in some of the samples studied (*Tenuitella brevispira*, *Globigerinella obesa* and *Cassigerinella chipolensis*) may indicate the upper part of the Early Oligocene (late Rupelian) and even the passage into the Late Oligocene (Fig. 6). However, it usually coincides with the presence of the planktonic foraminiferal genera *Globanomalina*, *Laterostomella* and *Chiloguembelina*. In this case, the age of the assemblages described could be placed within the range of the middle part of the P20 to P21 a/b boundary (Fig. 6; Berggren *et al.*, 1985, 1995). The extinction of chiloguembelinids, which usually corresponds to the boundary between the NP23/NP24 nannofossil zones, is closely linked with the Rupelian-Chattian boundary (Van Simaëys *et al.*, 2004). However, this event is not isochronous and as a result single forms of this genus could survive until the Late Oligocene (Fig. 6; Olszewska, 1984; Olszewska *et al.*, 1996; Van Simaëys *et al.*, 2004).

Palaeoenvironment

The microfossils from the Gładyszów Beds including mainly reworked forms reflect the changes in sedimentary conditions on the northern outer shelf of the Magura Basin (comp. Kopciowski, 2007). In the deposits studied, the skeletal elements of foraminifera and calcareous nannoplankton

Fig. 4. Calcareous nannofossils from the Gładyszów Beds. Abbreviations: CN – crossed nicoles; NL – normal light. **A.** *Helicosphaera intermedia* Martini – CN. **B.** *Helicosphaera bramlettei* Müller – CN. **C.** *Helicosphaera bramlettei* Müller – CN. **D.** *Pontosphaera multipora* (Kamptner) Roth – CN. **E.** *Transversopontis obliquipons* (Deflandre) Hay, Mohler et Wade – CN. **F.** *Transversopontis obliquipons* (Deflandre) Hay, Mohler et Wade – NL. **G.** *Zygrhablithus bijugatus* (Deflandre) Deflandre – CN. **H.** *Zygrhablithus bijugatus* (Deflandre) Deflandre – NL. **I.** *Cyclicargolithus abisectus* (Müller) Wise – CN. **J.** *Cyclicargolithus abisectus* (Müller) Wise – NL. **K.** *Cyclicargolithus abisectus* (Müller) Wise – CN. **L.** *Cyclicargolithus abisectus* (Müller) Wise – CN. **M.** *Sphenolithus dissimilis* Bukry et Percival – CN-0°. **N.** *Sphenolithus dissimilis* Bukry et Percival – CN-45°. **O.** *Reticulofenestra lockeri* Müller – CN. **P.** *Reticulofenestra lockeri* Müller – CN. **Q.** *Reticulofenestra ornata* Müller – CN. **R.** *Reticulofenestra ornata* Müller – CN. **S.** *Chiasmolithus oamaruensis* (Deflandre) Hay, Mohler et Wade – CN. **T.** *Chiasmolithus oamaruensis* (Deflandre) Hay, Mohler et Wade – CN. **U.** *Chiasmolithus cf. grandis* (Bramlette et Riedel) Radomski – CN. **V.** *Braarudosphaera bigelowii* (Gran et Braarud) Deflandre – CN. **W.** *Sphenolithus distentus* (Martini) Bramlette et Wilcoxon – CN-0°. **X.** *Sphenolithus distentus* (Martini) Bramlette et Wilcoxon – CN-45°.

Table 1

Distribution of calcareous nannofossils and foraminifers in samples collected from outcrops in the vicinity of Gładyszów

Calcareous nannoplankton	Gładyszów Beds																Foraminifera and other microfossils		
	Sample	857/18/95	858a	858b	858c/15/9	863/14/9	864b	902/10/9	905a/42/9	905b	905c/44/9	908/9/95	913/7/95	931/6/95	952a/4/95	952b/3/95	955/2/95	958/1/95	Sample
<i>Braarudosphaera bigelowii</i>	x(?)	o					x(?)							o	o			x	<i>Chiloguembelina gracillima</i>
<i>Chiasmolithus oamaruensis</i>	x o						x o	x		x	x			o	x o	x	x	x	<i>Laterostomella cubensis</i>
<i>Chiasmolithus</i> sp.		o					x o							x	x o	x	x		<i>Testacarinata rugosoacuelata</i>
<i>Clausicoccus subdistichus</i>		o	x				x	x						o				x	<i>Tenuitella brevispira</i>
<i>Coccolithus eopelagicus</i>	x						o(?)	x						o(?)	x	x			<i>Tenuitella gemma</i>
<i>Coccolithus pelagicus</i>	x	x	x	x	x	x	x	x		x	x			x	x	x	x	x	<i>Tenuitella obesa</i>
<i>Coronocyclus nitescens</i>	x		x		x	x	x	x		x	x			x	x o	x		x	<i>Tenuitella</i> sp.
<i>Cribocentrum coenurum</i>							x	x							x	x			<i>Tenuitellinata angustumbilicata</i>
<i>Cribocentrum reticulatum</i>	x	x	x		x	x	x	x		x	x			x	x	x	x	x	<i>Tenuitellinata denseconnexa</i>
<i>Cyclicargolithus abisectus</i>		o					x	xo(?)	x					o	x(?)o	x			<i>Globorotalides suteri</i>
<i>Cyclicargolithus floridanus</i>	x	x o	x	x			x	x	x		x	x		x	x	x	x	x	<i>Globoquadrina selli</i>
<i>Dictyococcites bisectus</i>	x o	x o	x	x	x	x	x o	x o		x	x			x	x	x	x	xo(?)	<i>Globanomalina micra</i>
<i>Dictyococcites callidus</i>		o								x				x					<i>Globanomalina naguewichensis</i>
<i>Discoaster barbadiensis</i>				x			x				x								<i>Cassigerinella chipolensis</i>
<i>Discoaster lodoensis</i>	o				x		x o							o	o			x	<i>Globigerina leroyi</i>
<i>Discoaster saipanensis</i>	x	o					o							x	x o			x	<i>Globigerina officinalis</i>
<i>Discoaster sublodoensis</i>				x			x o								o				<i>Parasubbotina karpatica</i>
<i>Discoaster tanii</i>	x			x	x		x	x		x	x			x o	x		x		<i>Bolivina aenariensisiformis</i>
<i>Discoaster</i> sp.	o		x				o			x					o			x	<i>Bolivina cookei</i>
<i>Ericsonia formosa</i>	x o	o(?)		x	x	x	x o	x			x			x	x o	x	x	x	<i>Bolivina crenulata</i>
<i>Helicosphaera bramlettei</i>							o(?)							o	x o	x		x	<i>Bolivina danvilensis</i>
<i>Helicosphaera compacta</i>							xo(?)								o(?)	x		x	<i>Bolivina mississippiensis</i>
<i>Helicosphaera intermedia</i>							x			x(?)				x o	x		x(?)		<i>Bolivina subtilissima</i>
<i>Isthmolithus recurvus</i>	o	x			x	x	x			x	x			x	x	x	x		<i>Brizalina fastigia</i>
<i>Lanternithus minutus</i>	x	x	x		x		x	x			x			x	x	x	x		<i>Cassidulina</i> sp.
<i>Pontosphaera latelliptica</i>	o		x				x							o					<i>Globocassidulina globosa</i>
<i>Pontosphaera multipora</i>			x		x									x		x(?)	x		<i>Bulimina ovata</i>
<i>Pontosphaera plana</i>	x o	x					x	x			x			o	x	x(?)	x		<i>Bulimina polymorphinoides</i>
<i>Reticulofenestra dictyoda</i>	o		x	x							x(?)				x	x	x		<i>Fursenkoina schreibersiana</i>
<i>Reticulofenestra hillae</i>					x		x	x						x	x		x		<i>Eponides binominatus</i>
<i>Reticulofenestra lockeri</i>	x o	x o		x	x	x	o	x		x	x(?)			x	o	x	x		<i>Cibicides amphysilensis</i>
<i>Reticulofenestra ornata</i>				x(?)		x o	x o	x		x				x o	o				<i>Cibicides lopjanicus</i>
<i>Reticulofenestra umbilica</i>	x	x	x	x	x		x	x		x	x			x o	x	x	x	x	<i>Asterigerina cf. bracteata</i>
<i>small reticulofenestrads</i>	x		x		x	x	x	x			x			x o	x	x	x		<i>Uvigerina multistriata</i>
<i>Sphenolithus dissimilis</i>		o						x						x					<i>Discorbis</i> sp.
<i>Sphenolithus editus</i>	o		x		x	x	x										x	x	<i>Protelphidium</i> sp.
<i>Sphenolithus mortiformis</i>	x o						x	x	x					x	x	x		x	<i>Rhabdammina</i> sp.
<i>Sphenolithus predistentus</i>	o							x								x	x	x	<i>Saccamina placenta</i>
<i>Sphenolithus radians</i>	x o			x			x	x						x					<i>Ammodiscus</i> sp.
<i>Sphenolithus spiniger</i>	x o		x				x			x	x					x	x	x	<i>Glomospira</i> sp.
<i>Transversopontis obliquipons</i>	x o						x				x					x			<i>Hormosina</i> sp.
<i>Transversopontis pulcher</i>	x o	x	x		x		x			x	x			x	x	x	x(?)		<i>Kalamopsis grzybowskii</i>
<i>Transversopontis pulcheroides</i>	x o	x	x				x	x			x			x	x	x	x	x	<i>Spiroplectammina</i> sp.
<i>Zygrhablithus bijugatus</i>	x o						x	o			x			x				x	<i>Haplophragmoides</i> sp.
<i>Thoracosphaera</i> sp.	x o						o	x o						o	o		o	x	E. Palaeogene planktonic taxa
Undistinguishable forms	x o		x	x	x	x		x	o		x			x	x	x	x	x	Diatoms
Cretaceous forms							x o		x		x			x	x				Skeletal elements of sponges

o – occurrence of calcareous nannoplankton, x – occurrence of foraminifera, (?) – indeterminate forms of calcareous nannofossils and foraminifers

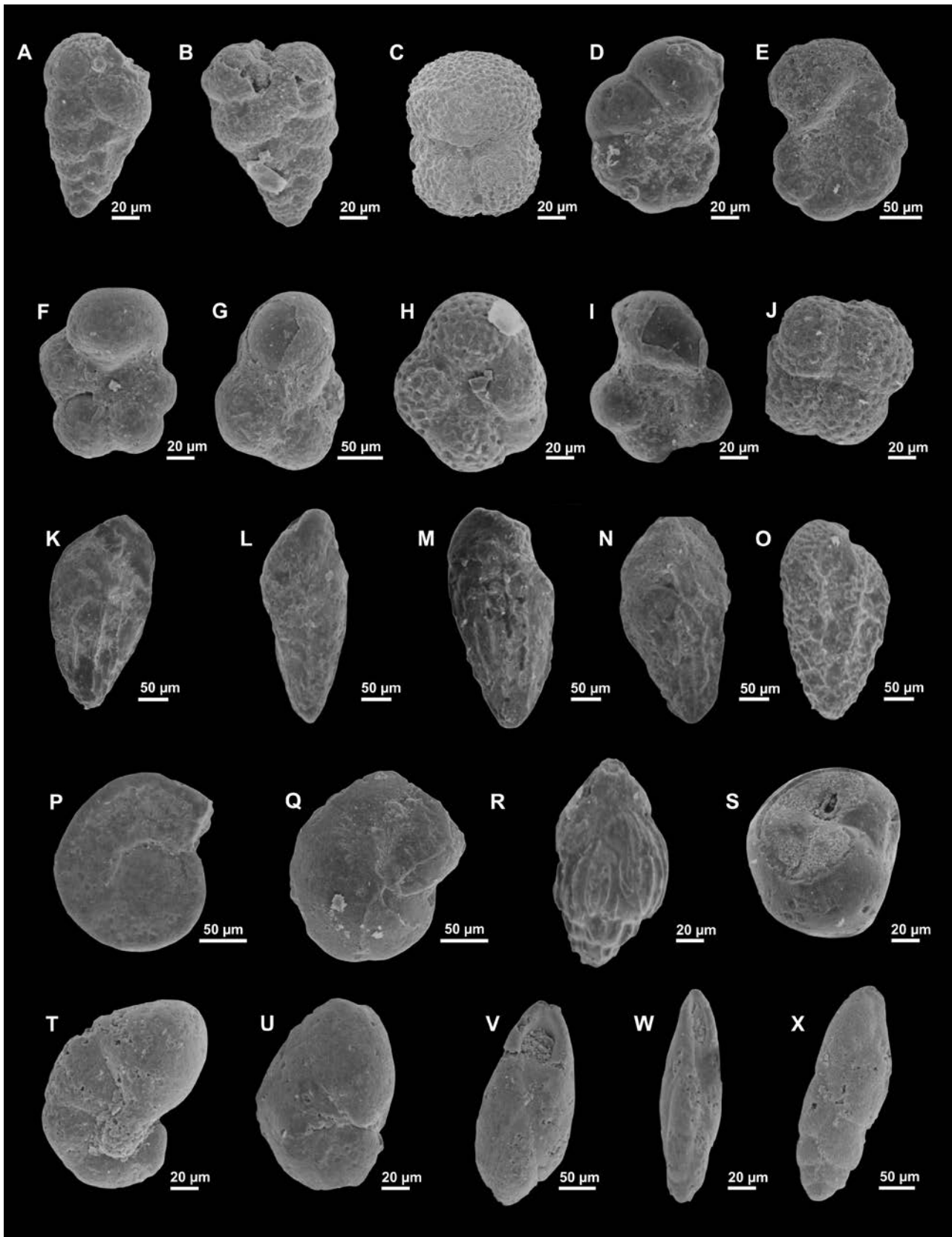


Fig. 5. Foraminifers from the Gładyszów Beds. **A.** *Chiloguembelina gracillima* (Andreae). **B.** *Laterostomella cubensis* (Palmer). **C.** *Globoquadrina selli* Borsetti. **D, E.** *Globanomalina micra* (Cole). **F.** *Tenuitellinata angustumblicata* Bolli. **G.** *Parasubbotina karpatica* Mjatluk. **H.** *Catapsydrax dissimilis* (Cushman and Bermudez). **I.** *Globigerinella obesa* (Subbotina). **J.** *Globorotaloides suteri* Bolli. **K.** *Brizalina* cf. *fastigia* (Cushman). **L.** *Bolivina* cf. *danvilensis* How et Wallace. **M.** *Bolivina cookei* Cushman. **N.** *Bolivina crenulata* Cushman. **O.** *B. crenulata* Cushman. **P, Q.** *Cibicides lopjanicus* Mjatluk. **R.** *Uvigerina multistriata* Hantken. **S.** *Globocassidulina globosa* (Hantken). **T, U.** *Nonionella liebusi* Hagn. **V, W.** *Bulimina polymorphinoides* (Yokoyama). **X.** *Fursenkoina schreibersiana* (Czjżek).

Table 2

in samples collected from the Gładyszów PIG-1 borehole

																Foraminifers and other microfossils												
1.9-2.0	3.3	5.7	6.96-8.96	9.6	10.0	14.2	18.6	20.5	23.3	27.8	29.4	32.7	34.5	38.8	39.2	41.9	52.0	59.9-60.0	61.9-62.0	65.0	67.0	68.9-69.0	69.9-70.0	74.0	81.9-82.0	87.3-87.4	92.0	Species
							x o							x														<i>Globanomalina micra</i>
							x o																					<i>Parasubbotina karpathica</i>
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	<i>Cassigerinella chipolensis</i>
																												<i>Catapsydrax dissimilis</i>
x	x		x o																									<i>Globigerina leroyi</i>
																												<i>Globigerina officinalis</i>
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	<i>Globigerina tapurensis</i>
																												<i>Subbotina angiporoides</i>
																												<i>Subbotina droogeri</i>
																												<i>Subbotina linaperta</i>
																												<i>Globigerina cryptomphala</i>
																												<i>Globoquadrina tripartita</i>
																												<i>Globigerinapsis index</i>
																												<i>Globigerinapsis kugleri</i>
																												<i>Globigerina hagni</i>
																												<i>Globigerina eoceana</i>
																												<i>Globigerina ampliapertura</i>
x																												<i>Chlostomella tenuis</i>
																												<i>Cibicides oligocenicus</i>
																												<i>Pullenia bulloides</i>
																												<i>Cassidulina sp.</i>
																												<i>Uvigerina costeliatta</i>
																												<i>Reusella tortusa</i>
																												<i>Angulogerina sp. (A. aff. yumuriana)</i>
																												<i>Rhizammina indivisa</i>
																												<i>Rhabdammina cylindrica</i>
																												<i>Hyperammina elongata</i>
																												<i>Kalamopsis grzybowskii</i>
x	x	x	x	x	x																							<i>Nothia latissima</i>
																												<i>Glomospira charoides</i>
																												<i>Glomospira glomerata</i>
																												<i>Glomospira gordialis</i>
																												<i>Glomospira irregularis</i>
																												<i>Hormosina velascoensis</i>
																												<i>Saccamina placenta</i>
																												<i>Trochamminoides coronatus</i>
																												<i>Haplophragmoides wateri</i>
																												<i>Haplophragmoides stomatus</i>
																												<i>Haplophragmoides suborbicularis</i>
																												<i>Recurvoides nucleolus</i>
																												<i>Recurvoides walteri</i>
																												<i>Recurvoidella lamella</i>
																												<i>Reticulophragmium amplexens</i>
																												<i>Radiolarians</i>
																												<i>Diatoms</i>
																												<i>Tubular feeding traces (pyritized tubes)</i>

o – occurrence of calcareous nannoplankton, x – occurrence of foraminifera, (?) – indeterminate of calcareous nannofossils and foraminifers

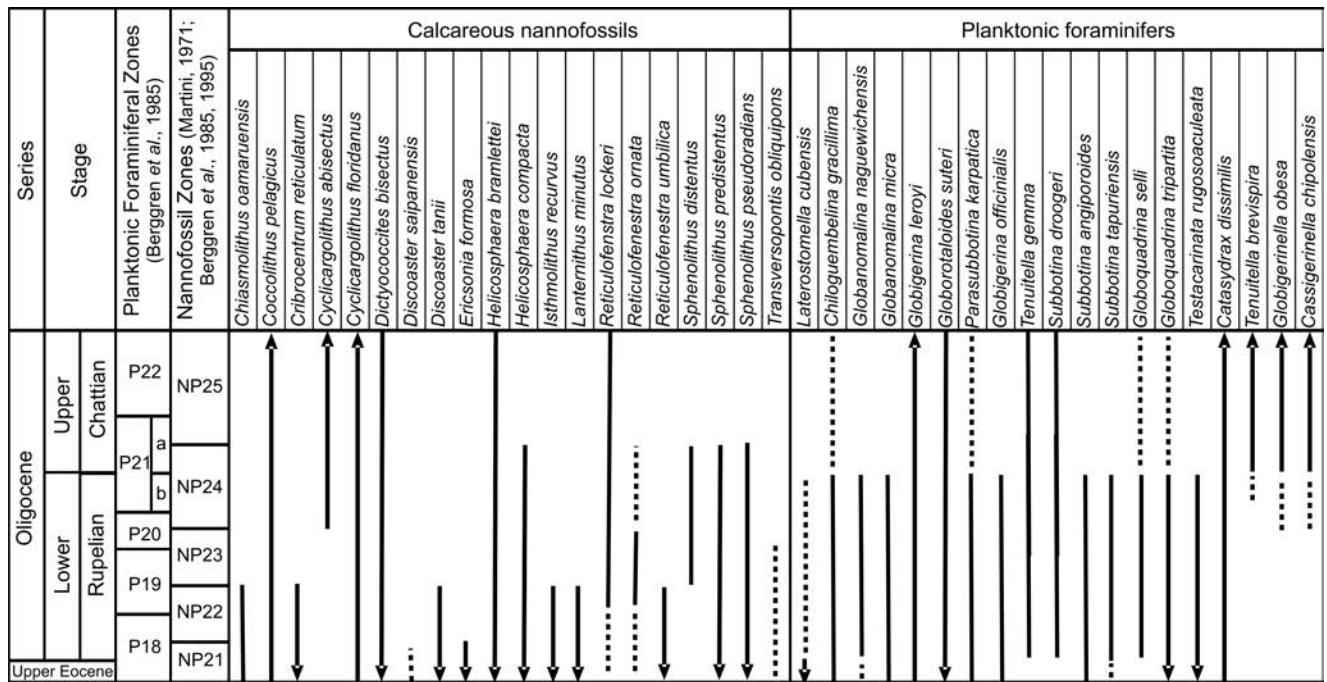


Fig. 6. The stratigraphic distribution of selected calcareous nannofossils (Báldi-Beke, 1984; Báldi *et al.*, 1984; Perch-Nielsen, 1985; Martini and Müller, 1986; Krhovský *et al.*, 1992; Nagymarosy and Voronina, 1992; Švábenicka and Stráník, 2004) and planktonic foraminifers (Postuma, 1971; Qianyu, 1987; Olszewska *et al.*, 1996) from the Gładyszów Beds.

had been subjected to mechanical crushing processes and often corrosion, solution and also mineralization. The increase in numbers of some species, especially in those of the *Bolvina-Brizalina* group, has been correlated with depletion in oxygen. On the continental slope, this event corresponds to the presence of oxygen minimum layers and stratification of the water (Boltovskoy and Wright, 1976; Fontanier *et al.*, 2002). The sediments mentioned contain pyritized and opportunistic forms, which are typical for the Menilite Shale and the lower part of the Krosno Beds in the Outer Carpathians, as well as for the Zakopane Beds of the Podhale Basin (Zakopane IG-1, Bańska IG-1 and Bukowina Tatrzańska IG-1 boreholes), in which these minimum-oxygen associations are more numerous (Blaicher, 1973; Olszewska, 1984; Olszewska and Wiczorek, 1998). Similar analogies can be observed in the case of the nannofossil associations (Garecka, 2005, 2008). It refers the composition, abundance, diversity and preservation of the assemblage and in particular the presence of redeposited specimens, which often predominate over autochthonous ones.

DISCUSSION

The calcareous nannoplankton and foraminifera from the deposits studied indicate a late Early Oligocene (late Rupelian) age, but an earliest Chattian age cannot be excluded (Fig. 6). A characteristic feature of these assemblages is the predominance of reworked specimens, whereas *in situ* ones are rare. They are associated with the skeletal elements of sponges, pyritized diatoms and radiolarians, and tubular pseudomorphs of trace fossils (Tables 1, 2). All these features of the microfossils from the Gładyszów Beds evidence

their similarity to coeval assemblages of the other Carpathian basins. This similarity is manifested in poor preservation and the occurrence of rare opportunistic forms, which are often the only autochthonous elements. The specific nature, poor preservation and irregular distribution of described nanno- and microfossils in the sediment, and their relationships can be attributed to the fact that the youngest deposits of the Magura Basin were displaced during syn- and post-tectonic erosion (Kopciowski, 2007; Oszczytko and Oszczytko-Clowes, 2009). The transformation of the basin was an effect of the expansion of the accretionary prism in the southern part of the basin and the shortening processes leading to its closure. It led to the formation of sediments with a chaotic structure, which included reworked and displaced rock material and microfossils. Parts of the sediments are similar to the ones in the immediate surroundings. In consequence, the same calcareous nannofossils and foraminiferal assemblages of the upper part of the Early Oligocene occur in the Budzów (Supra-Magura) Beds and in the Gładyszów Beds as well. According to Oszczytko-Clowes (2010) and other (Oszczytko-Clowes and Żydek, 2012), the Budzów Beds of the Siary Zone are an equivalent of the Malcov Formation of the Rača and Krynica/Pieniny Klippen Belt zones. In addition, the reworked Palaeocene–Eocene and Cretaceous forms that come from deposits, detached from the original basement, are also included in the Gładyszów Beds. Some samples contained reworked Eocene and Eocene–Early Oligocene microfossil assemblages. In general, the Eocene–Early Oligocene assemblages may be correlated with the Globigerina Marl, which are characteristic sediments for the Outer Carpathians, but are not present in the northern part of the Magura Basin. Kopciowski (1996, 2007), analyzing the microfossil

associations of the older part of the Siary Series and the overlying deposits, came to the conclusion that the Lower and Middle Eocene in the Siary Unit are preserved, while the time equivalents of the Globigerina Marl (i.e., the Upper Eocene) were eroded as a result of the abrupt changes in sedimentary conditions at the beginning of the Oligocene. After rapid sandstone deposition at the beginning of the Oligocene (Wątkowa Sandstone) the sediments including opportunistic plankton foraminifers and also numerous and diversified calcareous benthic forms (*Bolivina-Brizalina* group, *Cibicides*) were laid down. In general, unfavorable environmental conditions were reflected in the low numbers and diversity and the poor preservation of the nannofossil assemblages. Many species then appeared for the last time; the new taxa appeared sporadically and in the lower numbers. Only the more resistant, mostly long-ranging species occurred continuously. The occurrence of the mixed assemblage in the Gładyszów Beds, which is composed of numerous taxa that were resistant to mechanical damage or dissolution as well as of opportunistic, badly preserved taxa of the Oligocene (chiloguembelinids, globigerinids and tenuitellids) and reworked nanno- and microfossils, indicate displacement of the sediments. On the other hand, the scarcity and preservation of the Oligocene species may also indicate that these forms were redeposited and thus, the age of the sediments may be younger than the described forms. This was possible, because the sedimentary processes continued in the Magura Basin during the Oligocene and even lasted to the Early Miocene (Oszczypko and Oszczypko-Clowes, 2002; Kopciowski, 2007; Oszczypko-Clowes, 2012). Accordingly, the Gładyszów Beds may be regarded as syn-tectonic sediments, which formed as a result of submarine landslides triggered by the transformation of the basin and the intensive shortening process (Kopciowski, 2007).

CONCLUSIONS

The nanno- and microfossil assemblages described from the Gładyszów Beds are characterized by dominance of long-ranging and reworked taxa; taxonomically impoverished opportunistic taxa believed to be *in situ* are infrequent. Most of the latter represent species that disappeared during the Early Oligocene, while only a few appeared for the first time in this age. This indicates a late Rupelian age for the assemblages studied, although, owing to the increased occurrence of reworking, a younger, early Chattian age cannot be excluded.

A detailed analysis of the microfossils with respect to their origin, diversity, and also environmental associations and preservation indicates that the deposition of the Gładyszów Beds took place during the terminal tectonic transformations of the northern part of the Magura Basin (Siary Zone) in the late Rupelian and early Chattian.

However, according to the authors, the record of this process presented for the Siary Zone appears to indicate extensive erosion and as a consequence, deposition may have continued in the subbasin during the Late Oligocene.

The calcareous nannofossils and foraminifers described are associated with the last phases of a long-term transfor-

mation process, leading to the closure of the Outer Carpathian basins during the Oligocene–Miocene. It is confirmed by the similarity between microfossils from the Gładyszów Beds and the terminal deposits of the Outer (Menilite-Krosno Series) and the Inner (Podhale Basin) Carpathians.

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REFERENCES

- Báldi, T., Horváth, M., Nagymarosy, A. & Varga, P., 1984. The Eocene–Oligocene boundary in Hungary. The Kiscellian Stage. *Acta Geologica Hungarica*, 24: 41–65.
- Báldi-Beke, M., 1984. The nannoplankton of the Transdanubian Palaeogene formations. *Geologica Hungarica*, 43: 1–307.
- Báldi-Beke, M. & Báldi, T., 1973. Nannoplankton and macrofauna of the type section at Novaj (Kiscellian–Egerian). *Annales Universitatis Scientiarum Budapestinensis de Rolando Eötvös nominatae, Sectio Geologica*, 17: 59–103.
- Benedek, P. N. & Müller, C., 1974. Nannoplankton – Phytoplankton – Korrelation im Mittel- und Ober- Oligozän von Tönisberg (Niederrheingebiet). *Palaeontographica, Abteihung B*, 137: 1–71.
- Berggren, W. A., Kent, D. V. & Flynn, J. J., 1985. Paleogene geochronology and chronostratigraphy. In: Snelling, N. J. (ed.), *The Chronology of the Geological Record. Geological Society Memoir*, 10: 141–195.
- Berggren, W. A., Kent, D. V., Swisher C. C., III & Aubry, M.-P., 1995. A revised Cenozoic geochronology and chronostratigraphy. In: Berggren, W. A., Kent, D. V., Aubry, M.-P. & Hardenbol, J. (eds), *Geochronology, Time Scales and Global Stratigraphic Correlation. SEPM Special Publication*, 54: 129–212.
- Birkenmajer, K. & Oszczypko, N., 1989. Cretaceous and Palaeogene lithostratigraphic units of the Magura Nappe, Krynica Subunit, Carpathians. *Annales Societatis Geologorum Poloniae*, 59: 145–181.
- Blaicher J., 1973. Mikrofauna of the Podhale Flysch in the Zakopane IG-1 Borehole. *Biuletyn Instytutu Geologicznego*, 265: 105–133. [In Polish, with English summary.]
- Boltovskoy, E. & Wright, R., 1976. *Recent Foraminifera*. Dr W. Junk b. v. Publishers, The Hague, 515 pp.
- Bukry, D., 1981. Pacific coast coccolith stratigraphy between Point Conception and Cabo Corrientes, Deep Sea Drilling Project, Leg 63. In: Yeats, R. S., Haq, B. U., et al. (eds), *Initial Reports of the Deep Sea Drilling Project*, 63: 445–471.
- Fontanier, C., Jorissen, F. J., Licari, L., Alexandre, A., Anschutz, P. & Carbonel, P., 2002. Live benthic foraminiferal faunas from the Bay of Biscay: faunal density, composition and microhabitats. *Deep-Sea Research I*, 49: 751–785.

- Garecka, M., 2005. Calcareous nannoplankton from the Podhale Flysch (Oligocene–Miocene, Inner Carpathians, Poland). *Studia Geologica Polonica*, 124: 353–369.
- Garecka, M., 2008. Oligocene/Miocene boundary in the Polish Outer Carpathians based on calcareous nannoplankton. *Biuletyn Państwowego Instytutu Geologicznego*, 432: 1–54. [In Polish, with English summary.]
- Garecka, M., 2012. Record of the changes in the Oligocene–Miocene sediments of the Menilite-Krosno series of the Skole Unit based on calcareous nannoplankton studies-biostratigraphy and palaeogeographical implications (Polish Outer Carpathians). *Biuletyn Państwowego Instytutu Geologicznego*, 453: 1–22.
- Garecka, M. & Szydło, A., 2011. Nanoplankton wapienny i otwornice z najmłodszych utworów jednostki magurskiej (strefa raczańska północna, polskie Karpaty zewnętrzne). In: Boorová, D. (ed.), *Zborník príspevkov 12. česko-slovensko-polská paleontologická konferencia, Bratislava 20-21.10. 2011. Konferencie. Sympóziá. Simináré. Štátny geologický ústav D. Štúra, Bratislava*, pp. 40–41. [In Polish.]
- Garecka, M., Szydło, A. & Kopciowski, R., 1998. Nanoplankton wapienny i otwornice najmłodszych utworów jednostki magurskiej (strefa Siar). *Posiedzenia Naukowe Państwowego Instytutu Geologicznego*, 54: 83–86. [In Polish.]
- Golonka, J., Oszczytko, N. & Ślęczka, A., 2000. Late Carboniferous–Neogene geodynamic evolution and paleogeography of the circum-Carpathian region and adjacent areas. *Annales Societatis Geologorum Poloniae*, 70: 107–136.
- Hardenbol, J., Thierry, J., Farley, M. B., Jacquin, T., de Graciansky, P. C. & Vail, P. R., 1998. Mesozoic and Cenozoic sequence chronostratigraphic framework of European basins. In: Graciansky P. C., Hardenbol, J., Jacquin, T. & Vail, P. R. (eds), *Mesozoic and Cenozoic Sequence Stratigraphy of European Basins. SEPM Special Publication*, 60: 3–13.
- Jankowski, L., 1997. Gorlice Beds – the youngest deposits of the southern part of the Silesian Unit. *Przegląd Geologiczny*, 45: 305–308. [In Polish, with English summary.]
- Kopciowski, R., 1996. Geological structure of the Siary Zone between the Ropa and Branica rivers (Magura Nappe). *Biuletyn Instytutu Geologicznego*, 374: 21–39. [In Polish, with English summary.]
- Kopciowski, R., 2007. Paleogeography and facies development of the Siary Subunit in the Magura Unit, south of Gorlice. *Biuletyn Państwowego Instytutu Geologicznego*, 426: 91–114. [In Polish, with English summary.]
- Kopciowski, R. & Garecka, M., 1996. The youngest deposits of the Siary Zone – Magura Unit. *Przegląd Geologiczny* 44: 486–488. [In Polish, with English summary.]
- Kopciowski, R., Garecka, M. & Szydło, A., 2011. *Dokumentacja geologiczna badawczego otworu wiertniczego Gładyszów PIG-1*. National Geological Archive in Warszawa. [Unpublished, in Polish.]
- Kopciowski, R., Zimnal, Z. & Jankowski, L., 1997. *Objaśnienia do szczegółowej mapy geologicznej Polski, 1:50 000, arkusze Osiek*. National Geological Archive in Warszawa. [Unpublished, in Polish.]
- Koszarski, A. & Koszarski, L., 1985. Marginal zone of the Magura Nappe and its relation to lower units. In: Koszarski, L. (ed.), *Geology of the Middle Carpathians and the Carpathian Foredeep. Guide to Excursion 3. Carpatho-Balkan Geological Association, XIII Congress, Cracow, Poland*. Geological Institute, Kraków, pp. 216–219.
- Krhovský, J., 1981. Microbiostratigraphic correlations in the Outer Flysch Units of the southern Moravia and influence of the eustasy on their palaeogeographical development. *Zemní plyn a nafta*, 26: 665–688.
- Krhovský, J., Adamová, J., Hladíková, J. & Maslowská, H., 1992. Paleoenvironmental changes across the Eocene/Oligocene boundary in the Ždánice and Pouzdrány units (Western Carpathians, Czechoslovakia): the long-term trend and orbitally forced changes in calcareous nannofossils assemblages. In: Harmšmid, B. & Young, J. (eds), *Nannoplankton research. Proceedings 4th INA Conference, Praga, 1991. Knihovnička Zemního Plynu a Nafty*, 14b: 105–187.
- Martini, E., 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. In: Farinacci, A. (ed.), *Proceedings of the II Planktonic Conference, Roma, 1970*. Edizioni Tecnoscienza, Roma, pp. 739–785.
- Martini, E. & Müller, C., 1986. Current Tertiary and Quaternary calcareous nannoplankton stratigraphy and correlations. *Newsletters on Stratigraphy*, 16: 99–112.
- Müller, C., 1976. Tertiary and Quaternary calcareous nannoplankton in the Norwegian – Greenland Sea, DSDP Leg 38. *Initial Reports of the Deep Sea Drilling Project*, 38: 823–841.
- Nagymarosy, A. & Báldi-Beke, M., 1988. The position of the paleogene formations of Hungary in the standard nannoplankton zonation. *Annales Universitatis Scientias, Budapestinensis de Rolando Eötvös Nominatae Sectio Geologica*, 28: 3–25.
- Nagymarosy, A. & Voronina, A. A., 1992. Calcareous nannoplankton from the Lower Maykopian Beds (Early Oligocene, union of independent states). *Knihovnička Zemního Plynu a Nafty*, 14b/2: 189–221.
- Olszewska, B., 1984. A paleoecological interpretation of the Cretaceous and Paleogene foraminifers of the Polish Outer Carpathians. *Biuletyn Instytutu Geologicznego*, 346: 7–53. [In Polish, with English summary.]
- Olszewska, B., Odrzywolska-Bieńkowska, E., Giel, M. D., Pożaryska, K. & Szczechura, J., 1996. Foraminifera Order. In: Malinowska, L. & Piwocki, M. (eds), *Budowa geologiczna Polski. Atlas skamieniałości przewodnich i charakterystycznych. Część 3a. Kenozoik. Trzeciorzęd. Paleogen*. Polska Agencja Ekologiczna, Warszawa, pp. 45–216. [In Polish.]
- Olszewska, B. & Wieczorek, J., 1998. The Paleogene of the Podhale Basin (Polish Inner Carpathians) – micropaleontological perspective. *Przegląd Geologiczny*, 46: 721–728. [In Polish, with English summary.]
- Oszczytko, N., 1992. Late Cretaceous through Paleogene evolution of the Magura Basin. *Geologica Carpathica*, 43: 333–338.
- Oszczytko, N., 1999. From remnant oceanic basin to collision-related for land basin; a tentative history of the Outer Western Carpathians. *Geologica Carpathica*, 50: 161–163.
- Oszczytko, N., 2004. The structural position and tectonosedimentary evolution of the Polish Outer Carpathians. *Przegląd Geologiczny*, 52: 780–791.
- Oszczytko, N., 2006. Late Jurassic–Miocene evolution of the Outer Carpathian fold and thrust Belt and its foredeep basin (Western Carpathians, Poland). *Geological Quarterly*, 50: 169–194.
- Oszczytko, N. & Oszczytko-Clowes, M., 2002. Newly discovered Early Miocene deposits in the Nowy Sącz area (Magura Nappe, Polish Outer Carpathians). *Geological Quarterly*, 46: 117–133.
- Oszczytko, N. & Oszczytko-Clowes, M., 2009. Stages in the Magura Basin: a case study of the Polish sector (Western Carpathians). *Geodinamica Acta*, 22: 83–100.
- Oszczytko-Clowes, M., 2001. The nannofossils biostratigraphy of the youngest deposits of the Magura Nappe (east of Skawa River, Polish Flysch Carpathians) and their palaeoenviron-

- mental conditions. *Annales Societatis Geologorum Poloniae*, 71: 139–188.
- Oszczypko-Clowes, M., 2010. Calcareous nannoplankton biostratigraphy of the terminal sediments of the Magura basin – a case study of the Polish sector (Outer Western Carpathians). In: Christofides, G., Kantiranis, N., Kostopoulos, D. S. & Chatzipetros, A. (eds), *Proceedings of the XIX CBGA Congress, Thessaloniki, Greece, 23–26 September 2010. Scientific Annals of the School of Geology, Aristotle University of Thessaloniki, Faculty of Sciences, Special volume*, 100: 231–240.
- Oszczypko-Clowes, M., 2012. Reworked nannofossils from the Lower Miocene deposits in the Magura Nappe (Outer Western Carpathians, Poland). *Geologica Carpathica*, 63: 407–421.
- Oszczypko-Clowes, M. & Żydek, B., 2012. Paleocology of the Upper Eocene–Lower Oligocene Malcov Basin based on calcareous nannofossils: a case study of the Leluchów section (Krynica Zone, Magura Nappe, Polish Outer Carpathians). *Geologica Carpathica*, 63: 149–164.
- Perch-Nielsen, K., 1985. Cenozoic calcareous nannofossils. In: Bolli, H. M., Saunders, J. B. & Perch-Nielsen, K. (eds), *Plankton Stratigraphy*. Cambridge University Press, Cambridge, pp. 427–438.
- Poprawa, P., Malata, T. & Oszczypko, N., 2002. Tectonic evolution of the Polish part of Outer Carpathian's sedimentary basins – constrains from subsidence analysis. *Przegląd Geologiczny*, 50: 1092–1108. [In Polish, with English summary.]
- Postuma, J. A., 1971. *Manual of Planktonic Foraminifera*. Elsevier Publishing Company, Amsterdam, 420 pp.
- Qianyu, L., 1987. Origin, phylogenetic development and systematic taxonomy of the *Tenuitella plexus* (Globigerinitidae, Globigerinina). *Journal of Foraminiferal Research*, 17: 298–320.
- Roth, P. H., Baumann, P. & Bertolino, V., 1971. Late Eocene–Oligocene calcareous nannoplankton from the central and northern Italy. In: Farinacci, A. (ed.), *Proceedings of the Second Planktonic Conference Roma, 1970*. Edizioni Tecnoscienza, Rome, 2: 1069–1097.
- Smoleńska, A. & Dudziak, J., 1989. Age of the sub-Cergowa marls on the basis of calcareous nannoplankton studies. *Kwartalnik AGH, Geologia*, 15/3: 29–40. [In Polish, with English summary.]
- Snedden, J. W. & Liu, C., 2010. A Compilation of Phanerozoic Sea-Level Changes, Coastal Onlaps and Recommended Sequence Designations. AAPG, www. searchanddiscovery.com, Search and Discovery Article #40594 [entry: 09.02.2015.]
- Stráník, Z., Jurášová, F. & Peslová H., 1981. Šitbořické vrstvy ve vrtu Křepice-4. *Zemní plyn a nafta*, 26: 701–710. [In Czech.]
- Ślęzak, J., Koszarski, A. & Koszarski, L., 1995. Calcareous nannoplankton stratigraphy of the terminal flysch deposits from the Skole Nappe (Oligocene–Miocene, Polish Carpathians, Krosno Beds). In: Flores, J. A. & Sierro, F. J. (eds), *5th International Nannoplankton Association Conference, Salamanca 1993, Proceedings*. University of Salamanca Press, Salamanca, pp. 267–277.
- Švábenická, L. & Stráník, Z., 2004. Nannofloral changes in the Oligocene deposits of the Ždánice Unit, Křepice-5 borehole (Flysch Belt of Western Carpathians, Czech Republic). *Zprávy o geologických výzkumech*: 91–93. [In Slovak, with English summary.]
- Świdziński, H., 1953. Karpaty fliszowe między Dunajcem a Sanem. In: Książkiewicz, M. (ed.), *Regionalna geologia Polski, t.1, Karpaty, z. 2, Tektonika*. Polskie Towarzystwo Geologiczne, Kraków, pp. 362–422. [In Polish.]
- Szydło, A., 2001. Zespoły otwornicowe najmłodszych osadów jednostki magurskiej (strefa Siar). In: Bąk, K. (ed.), *Trzecie Ogólnopolskie Warsztaty Mikropaleontologiczne. Mikro-2001. Zakopane 31.05–02.06.2001. Streszczenia referatów i posterów*. Wyższa Szkoła Pedagogiczna, Kraków, p. 31. [In Polish.]
- Van Simaey, S., De Man, E., Vandenberghe, N., Brinkhuis, H. & Steurbaut, E., 2004. Stratigraphic and palaeoenvironmental analysis of the Rupelian– Chattian transition in the type region: evidence from dinoflagellate cysts, foraminifera and calcareous nannofossils. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 208: 31–58.