Geological Quarterly, 2023, 67: 45
DOI: http://dx.doi.org/10.7306/gq.1715

New biostratigraphic data on the Ropianka Formation in the Przemyśl area (Skole Nappe, Polish Outer Carpathians) – a clue to understanding the timing of exotic material redeposition

Jan WOYDA[1,] *, Anna WAŚKOWSKA[2] and Zbyszek REMIN[1]

[1] University of Warsaw, Faculty of Geology, Żwirki i Wigury 93, 02-089 Warszawa, Poland; ORCID: 0000-0003-4735-8686 [J.W.], 0000-0003-4159-0126 [Z.R.]

[2] AGH University of Science and Technology, Al. Mickiewicza 30, 30-059, Kraków, Poland; ORCID: 0000-0003-4090-8534

Woyda, J., Waśkowska, A., Remin, Z., 2023. New biostratigraphic data on the Ropianka Formation in the Przemyśl area (Skole Nappe, Polish Outer Carpathians) – a clue to understanding the timing of exotic material redeposition. Geological Quarterly, 2023, 67: 45; http://dx.doi.org/10.7306/gq.1715

The geology of the Carpathian orogen in the Przemyśl area shows a diverse array of rock ages and tectonics. However, due to complicated tectonic settings and limited exposures, establishing the precise ages of selected sections and their structural arrangement is challenging. A particularly contentious aspect is the uncertain age of the exotic-bearing layers in the region, with previous age dates ranging from Neocomian to Miocene, leading to significant age discrepancies even for the same sections. Therefore, the need for well-defined age determinations is crucial. To address this issue we established precise biostratigraphic constraints on selected sections in the northern part of the Skole Nappe, specifically within the Ropianka Formation developed as marly and silty deposits with carbonate sandstones and exotic material including large olistoliths. Planktonic and calcareous benthic foraminifera from the exposures studied indicated the lower upper Maastrichtian, embracing the interval of the *Racemiguembelina fructicosa* and lower part of the *Abathomphalus mayaroensis* zones. Additionally, re-evaluation of the data of Bukowy and Geroch (1956) from the Iwanowa Hill section indicated its late Maastrichtian age, not the early Maastrichtian as previously inferred. Based on this new biostratigraphic data, the deposits of the Zielonka section are here reclassified to belong to the Leszczyny Member, and not the Paleocene Wola Korzeniecka Member as proposed by Gucik (Geroch et al., 1988). The sections studied seem to mark the lower age-limit of the redeposition of exotic material cropping out in the marginal part of the Gruszowa-Prałkowce Thrust Sheet.

Key words: Polish Outer Carpathians, Skole Nappe, Ropianka Fm., biostratigraphy, foraminifera, exotic-bearing layers, olistoliths, Maastrichtian.

INTRODUCTION

The geology of the Przemyśl area is directly linked to the evolution of the Carpathian orogen and reveals great complexity as regards both the age of the rocks and the tectonics. Numerous rock successions from various stratigraphic units have been recognized and documented within this relatively small region (Kotlarczyk, 1988a, b; Szajnocha, 1901; Gucik et al., 2005, 2017). Nevertheless, due to complicated tectonic settings, and a limited number of natural and artificial exposures, it has been difficult to establish continuous successions of well-constrained age and structural arrangement.

One of the most complex and controversial aspects is the problem of the uncertain age of the strata containing exotic rock fragments, here termed exotic-bearing layers, recognized in the Przemyśl area (with in some cases flysch successions as their host rock) (Wójcik, 1907, 1913–1914; Ney, 1956; Nowak, 1963; Kotlarczyk, 1978, 1988a, b; Geroch et al., 1979; Gucik et al., 2005, 2017). Up to now, different ages have been proposed for these, ranging from the Neocomian (Niedźwiedzki, 1876) through Turonian, Maastrichtian-Oligocene (Olszewska et al., 2011), late early Maastrichtian (Bukowy and Geroch, 1956), late Maastrichtian (Gaździcka, 1995, 2001); Maastrichtian and Paleocene (Geroch et al., 1988), Paleocene (Gucik in Geroch et al., 1988), early Oligocene (Wójcik, 1907) to Miocene (Jankowski, 1998, 2007). Because of such large discrepancies in the age of the exotic-bearing layers, even based on samples (at least in some cases) from the same localities, new well-constrained age determination was needed.

In the Skole Nappe, planktonic foraminifera are commonly used as a reliable biostratigraphic tool, especially in dating of the Cretaceous flysch deposits (e.g., Bukowy and Geroch, 1956; Geroch et al., 1988; Gasiński and Uchman, 2009; 2011; Gasiński et. al., 2013; Kędzierski et al., 2015; Kowalczewska and Gasiński, 2018; Waśkowska et al., 2019; Machaniec et al., 2020, 2022 and references therein).

This study provides insights into the biostratigraphic position of selected sections in the Przemyśl area, shedding light on the age of the exotic-bearing layers within the Ropianka Formation in the northern part of the Skole Nappe. The precise dating of these deposits has significant implications for reconstructing the tectonic and palaeoenvironmental history.

* Corresponding author, e-mail: j.woyda@student.uw.edu.pl
Received: August 21, 2023; accepted: October 9, 2023; first published online: January 5, 2023

GEOLOGICAL SETTING

LOCATION OF THE STUDY AREA

The study area is located in the Polish part of the Outer Carpathians in the vicinity of Przemyśl (Fig. 1A). Geographically it constitutes the eastern part of the Przemyśl Foothills (Richling et al., 2021). In a geological context, it belongs to the marginal part of the Skole Nappe – the northernmost part of the Western Outer Carpathians. The latter is overthrusted onto the autochthonous Miocene deposits in its basement or onto the Stebnik and Borysław-Pokucie Nappes in the eastern Polish part (Kotlarczyk, 1988a; Gucik et al., 2005, 2017). In the Przemyśl area, the Skole Nappe is built of Mesozoic flysch deposits belonging to the Ropianka Formation and to a lesser extent to the overlying Paleocene-Miocene Variegated Shale, Eocene Hieroglyphic Formation, Oligocene Menilite Formation and Oligocene-Miocene Krosno Formation (Fig. 1A; Kotlarczyk, 1978, 1988a, b; Gucik et al., 2005, 2017). The tectonics of the most external parts of the Skole Nappe are characterized by a stack of thrust sheets (Kotlarczyk, 1988b; Gucik et al., 2005, 2017). The sections analysed are located within the Gruszowa-Prałkowce Thrust Sheet (Fig. 1B).

The first lithostratigraphic documentation and subdivision of the flysch succession forming the Skole Nappe in the Przemyśl area was conducted in the 1870s by Paul and Tietze (1877), who distinguished the Ropianka beds in Prałkowce Village. Niedźwiedzki (1876), based on ammonites, dated this succession as of the Neocomian age. Uhlig (1894), after revision of the previous research, included these deposits into the Late Cretaceous "inoceramian beds". Based on comprehensive lithostratigraphic studies, Kotlarczyk (1978) proposed a new, formalized subdivision of the Skole Nappe succession in the Przemyśl area and included these deposits into the Ropianka Formation. The results of extensive fieldwork conducted in the late 1970s and 1980s were summarized in papers by Kotlarczyk (1978, 1988b) and the geological maps of Gucik (Geroch et al., 1988; Gucik et al., 2005).

LITHOSTRATIGRAPHY

The oldest deposits recognized in the Skole Nappe are dark mudstones of the Bełwin Mudstone included into the Spass Shale (Kotlarczyk, 1978, 1988a, b; Fig. 2A) and other deposits characteristic of deep environments (Douhe Shale) (Kotlarczyk, 1978, 1988a, b). The most important part of the entire succession of the Skole Nappe is the Ropianka Formation of Turonian to Paleocene age (Kotlarczyk, 1988a). It is built of siliciclastic rocks (thick-bedded sandstones), carbonate turbiditic sequences (marly shales, thick-bedded marls), and olistostromes (Kotlarczyk, 1988a). The Ropianka Formation has been subdivided into four members: the Cisowa Member, Wiar Member, Leszczyny Member, and Wola Korzeniecka Member (Fig. 2B). The presence of variegated shale units (dated biostratigraphically), located within or between these members, served as correlative horizons, enabling their correlation between various areas of the NE part of the Skole Nappe (Kotlarczyk, 1978).

The exotic-bearing beds constitute a distinct feature of the Ropianka Formation in the Przemyśl area, especially in the Wiar and Leszczyny members (Dżułyński and Kotlarczyk, 1988). They are represented either as olistostromes (Makówka Slump Debris, Babica Clays) or as huge olistoliths (e.g., Węgierka Marls; Geroch et al., 1979). The frequency of exotic-bearing deposits increases towards the external north-easternmost parts of the Skole Nappe (Nowak, 1963; Gucik, 1988).

PALAEOGEOGRAPHICAL REMARKS

The Skole Nappe comprises strata deposited in the Skole Basin (outer part of the Tethys Ocean) during Hauterivian to Miocene times (Kotlarczyk, 1978, 1988a, b; Poprawa and Malata, 2006). This basin developed on the thinned margins of the North European Platform (Poprawa et al., 2006; Jankowski, 2015). The main, long-lasting sediment supply area was located along its northern and northwestern margins (Książkiewicz et al., 1962; Bromowicz, 1986; Golonka et al., 2008; Cieszkowski et al., 2009; Salata and Uchman, 2013; Hoffman et al., 2021). According to Bukowy and Geroch (1956), this northern sediment supply area separated the Skole Basin from the epicontinental basin to the north (Polish Cretaceous Basin). These two basins were intermittently connected via a shallow marine zone (Bukowy and Geroch, 1956). Książkiewicz (1962) introduced the term North Marginal Cordillera for this palaeogeographic structure. Its general position was established on the basis of measurements of the palaeotransport directions of the uppermost Cretaceous detrital material (Książkiewicz, 1962; Bromowicz, 1974). To the south, the Skole Basin was bordered by elevations that separated it from other basinal areas of the Carpathian Basins (Żytko, 1961; Poprawa and Malata, 2006; Golonka et al., 2019).

MATERIAL AND METHODS

For the study, 12 rock samples were taken from mudstone and marlstone at four localities: Prałkowce I (Fig. 3C), Prałkowce II (Fig. 3B), Głęboki Potok, and Zielonka (Fig. 3A). In general, all sections studied are mainly characterized by alternating layers of marlstones, marly shales and calcareous sandstones typical of the Ropianka Formation (Nowak, 1963; Bromowicz, 1974, 1986; Kotlarczyk, 1978; Gucik et al., 2017).

PRAŁKOWCE I
(49°45'55.086"N, 22°43'1.836"E)

The section at Prałkowce I (prI) (Figs. 3C and 4) is developed in a 2 m-high bluff located near the beginning of the path from Prałkowce village to Wapielnica Hill (Fig. 1B). The Ropianka Formation at this site is characterized by marl- and shale-dominated flysch deposits with thin-bedded sandstones. Soil cover hinders access to the solid geology.

In the Prałkowce I section, a 15–20 cm thick breccia occurs within the grey marly shales. It is composed of angular clasts (up to 0.4 cm across) of mainly Stramberk-type limestones. One sample of grey marly shale was collected for micropalaeontological examination.

PRAŁKOWCE II
(49°45'37.154''N, 22°43'24.895''E)

This section is located on a 3 m-high bluff along the local path. The section consists of three exposures (prIIa, prIIb, prIIc), each ~2 m across. In the first exposure (prIIa), the marly

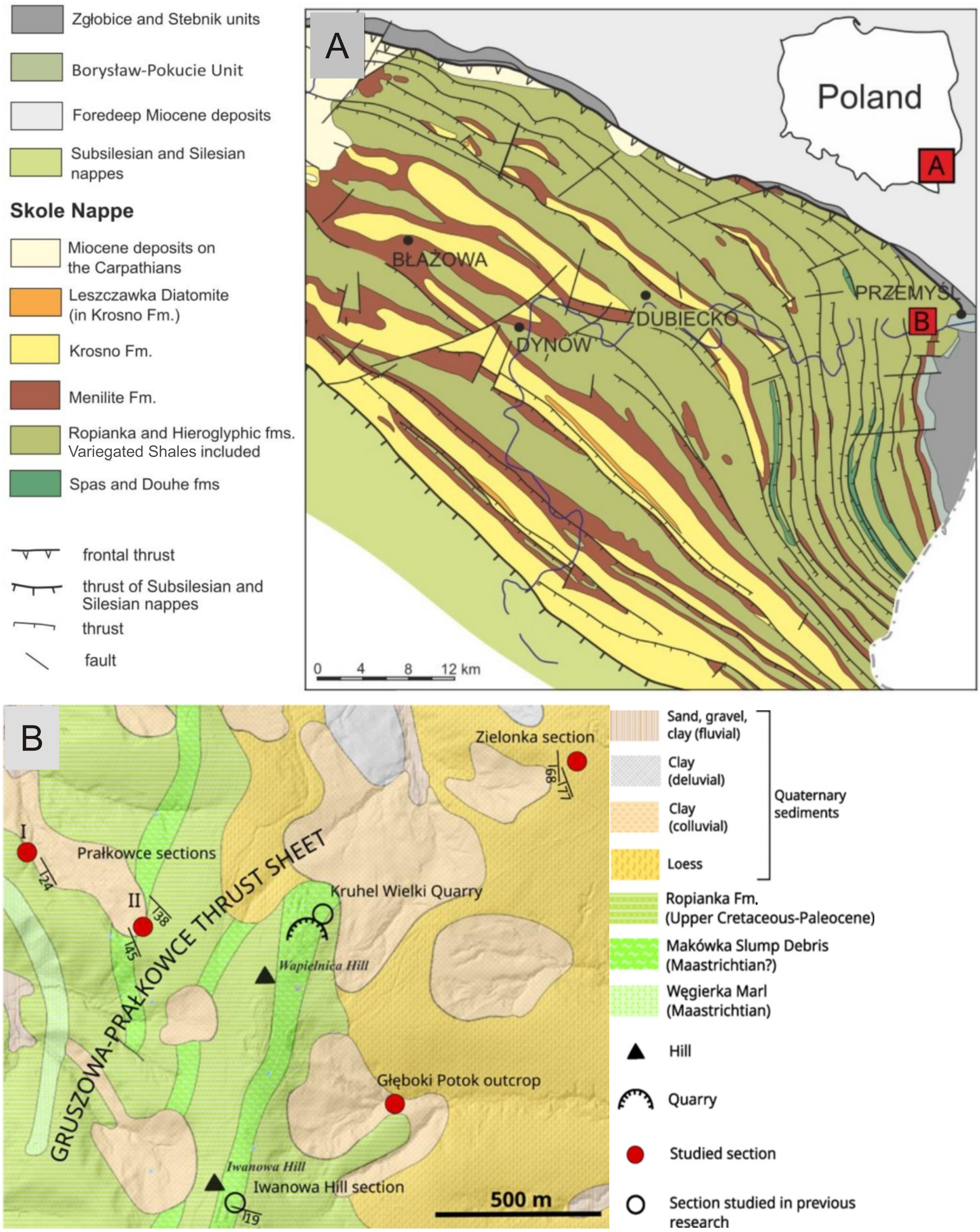

Fig. 1. Location of the study area on the eastern part of the Polish Skole Nappe (A) (map based on Kotlarczyk, 1988b; Waśkowska et al., 2019) and (B) simplified geological map of the study area (map based on Gucik et al., 2005)

shales include thin-bedded (0.5–2 cm) calcareous sandstones, 10–15 cm thick sandstones, and thick-bedded sandstones with wavy lamination (Figs. 3B and 4). Farther along the path (6 m from the first site), a well-preserved succession comprising grey marls and marly shales continues (prIIb; Fig. 4). The marls are rich in ichnofossils, mainly *Chondrites,* traditionally distinguished as fucoids. In the third exposure (prIIc), located 16 m from the beginning of the section (prIIc, Figs. 3B and 4), a contact of matrix-supported conglomerate with thin-bedded calcareous sandstone and marl is exposed. Single exotic clasts of igneous pebbles (25 cm across) occur within poorly consolidated calcareous sand and silt. Three samples were collected for micropalaeontological examination.

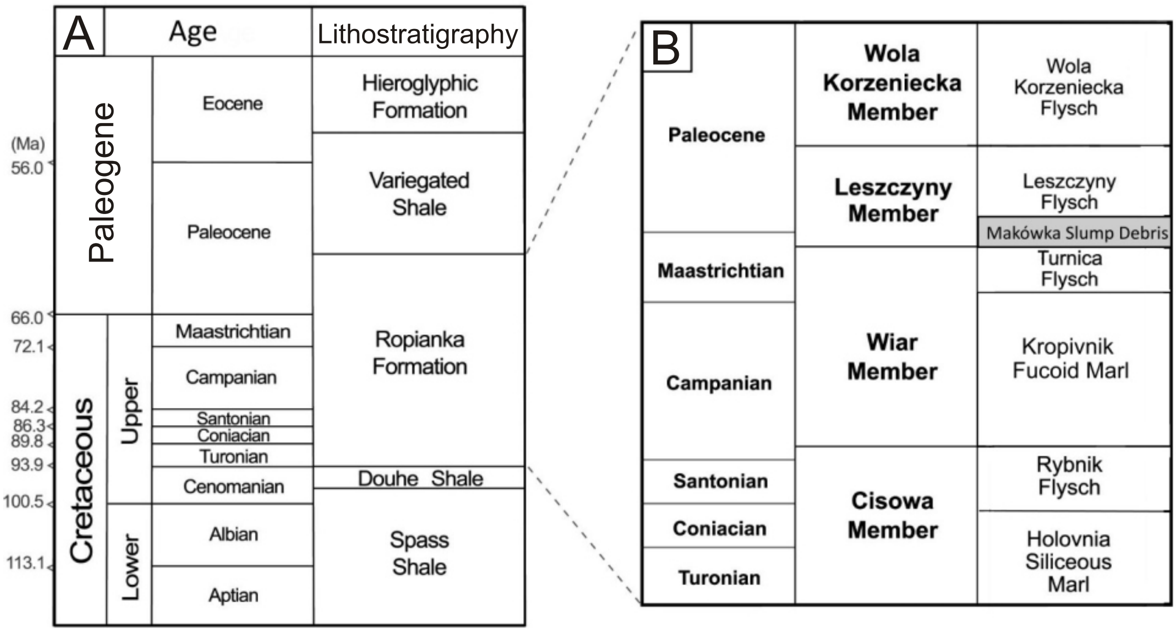

Fig. 2. Lithostratigraphic position of the Makówka Slump Debris in the study area (based on Geroch et al., 1988; Gucik et al., 2017)

A – lithostratigraphic subdivision of the Skole Nappe according to Kotlarczyk (1978), Gasiński and Uchman (2009); **B** – lithostratigraphic subdivision of the Ropianka Formation (after Kotlarczyk, 1978, 1988b)

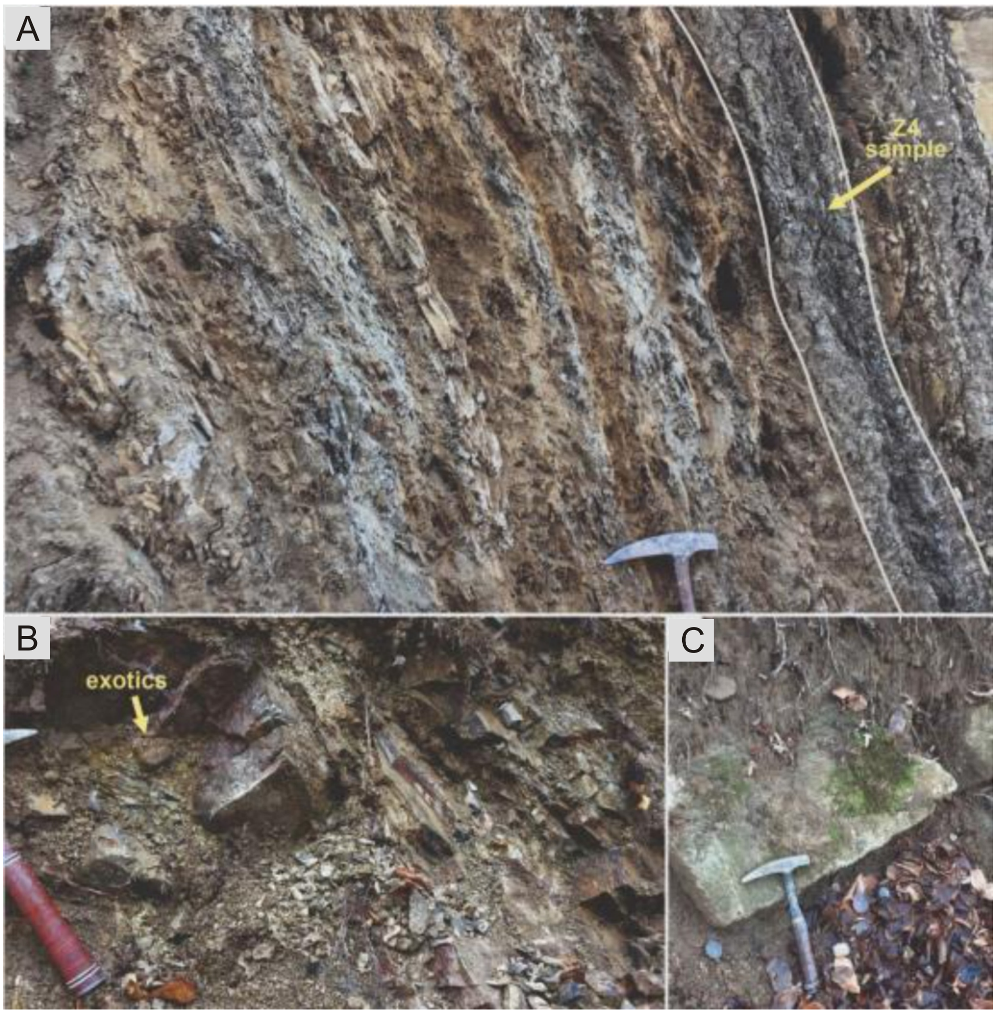

Fig. 3. Exposures of the Ropianka Formation in the study area: A – Zielonka section, Z4-layer rich in foraminifera; B – Prałkowce II section; C – Prałkowce I section

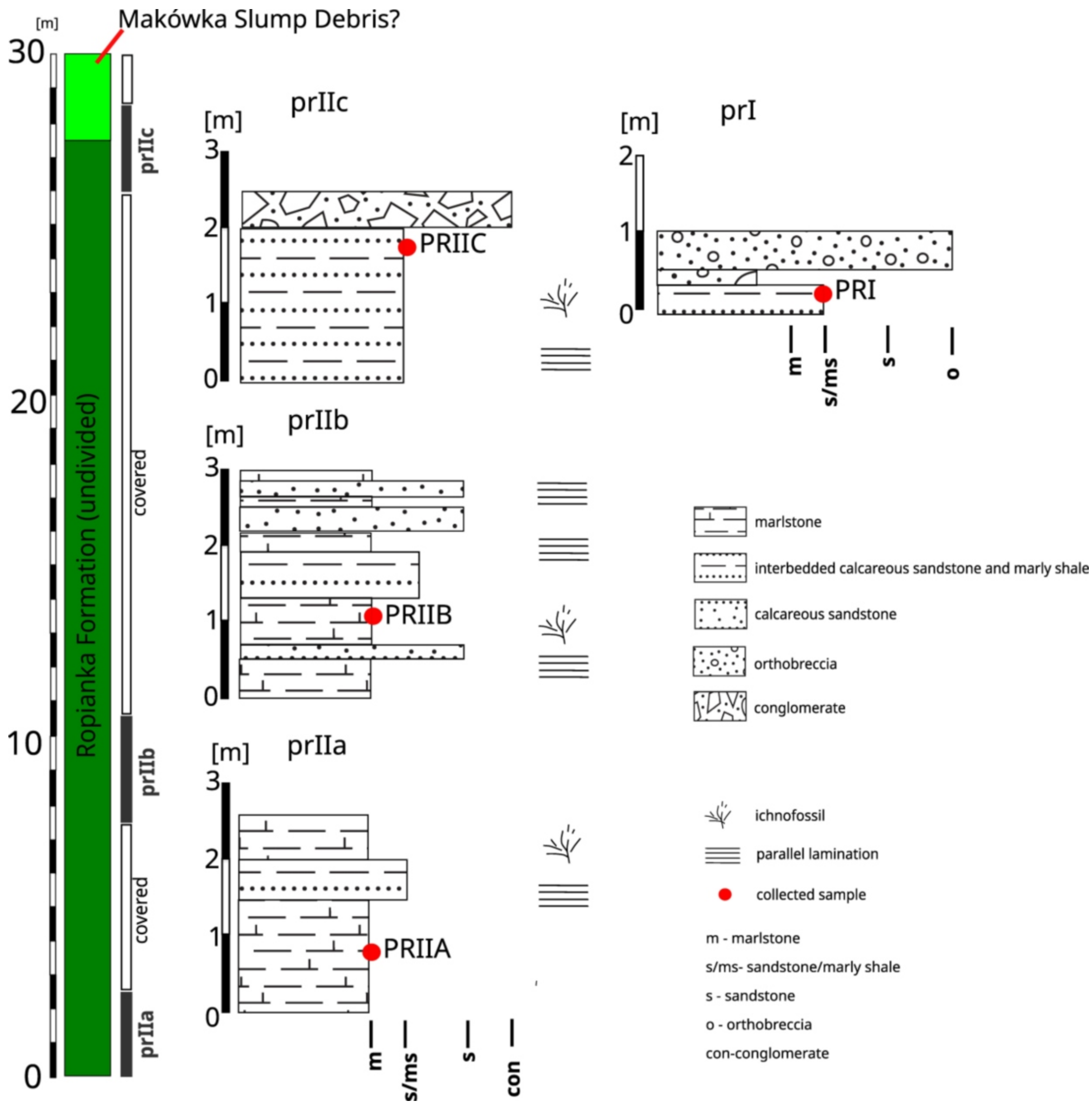

Fig. 4. Lithological logs of the Prałkowce I and II sections

Lithostratigraphy according to Gucik et al. (2005)

GŁĘBOKI POTOK
(49°45'16.153"N, 22°44'1.115"E)

This exposure was located in the gorge of the Głęboki Potok stream, in two temporary excavations, each ~1–1.5 m deep. The strata are now poorly exposed, and the original position of the layers is indecipherable, being covered by surficial clay containing crushed fragments of grey marl with fucoids. Only a ~50 cm thick segment of the original section was available to study, characterized by greenish clay; two samples were collected for biostratigraphic examination.

ZIELONKA
(49°45'56.523"N, 22°44'43.488"E)

The Zielonka section (Figs. 3A and 5) was a temporary man-made section, excavated through a 2 m-thick Quaternary cover (Fig. 1B). The Ropianka Formation is represented here by grey marly shales, mudstones, and thin- to thick-bedded calcareous sandstones. A few loose clasts, ~15 cm across, of Stramberk-type limestones, were found close to the exposure. The presence of such exotic clasts at Zielonka was also reported by Nowak (1963). Six samples of marly shale were collected for micropalaeontological examination.

MICROPALAEONTOLOGICAL METHODS

The dating was based on foraminifera, obtained by standard maceration of siltstone-marlstone deposits: crushing of very fine-grained rocks to obtain a partial suspension that is washed to remove the finest particles. Subsequently, samples (450 g each), were soaked in hot water and next washed through 0.063 mm sieves and dried. Foraminifera were hand-picked from the residue using a *Delta Optical IPOS-810* microscope. Subse-

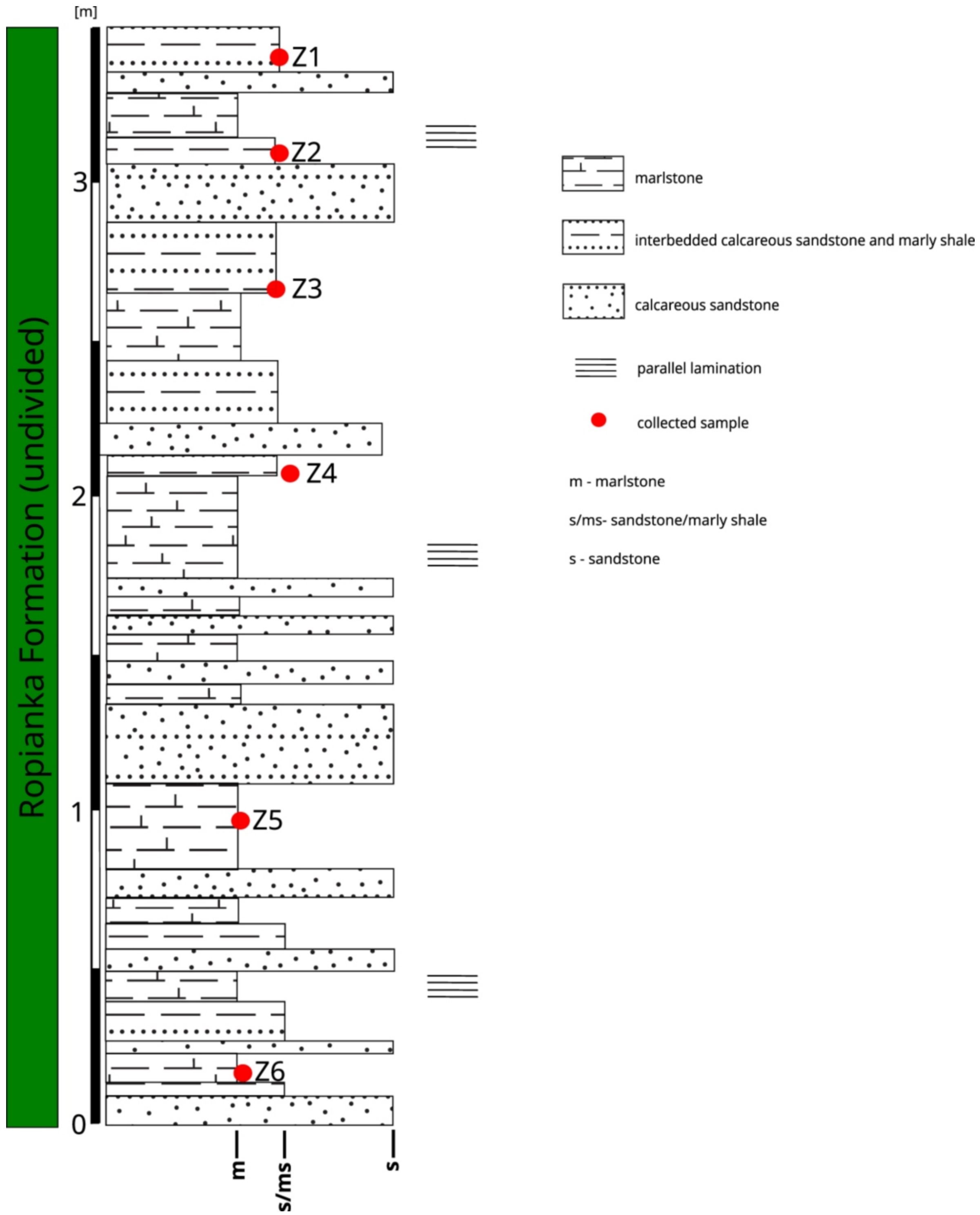

Fig. 5. Lithological log of the Zielonka sections

Lithostratigraphy according to Gucik et al. (2005)

quently, the foraminifera were identified and biostratigraphically interpreted; selected examples were photographed.

Laboratory analyses were conducted in the Microscopic Laboratory of the Department of Geochemistry, Mineralogy, and Petrology at the Faculty of Geology of the University of Warsaw. Taxonomic determination (at the rank of species or genus; Table 1) and photographic documentation (Figs. 6–10) were carried out at the Department of General Geology and Geotourism (*Nikon VL100POL* binocular microscope) and in the Laboratory of Critical Elements (*FEI Quanta 200 FEG* scanning electron microscope) at the Faculty of Geology, Geophysics and Environmental Protection, AGH, Kraków. The foraminiferal samples are housed at the Department of Historical Geology, Regional Geology, and Palaeontology at the Faculty of Geology of the University of Warsaw.

Table 1

Distribution of foraminifera in the samples studied

Section	ZIELONKA				PRAŁKOWCE				GŁĘBOKI POTOK
sample no.	Z1	Z3	Z4	Z5	PR I	PRIIB	PRIIC	PR IIA	GP1
PLANKTONIC FORAMINIFERA									
Abathomphalus spp. [*A. mayaroensis* (Bolli)?]								x	
Archaeoglobigerina australis Huber			x					x	x
Archaeoglobigerina spp.							x		
Contusotruncana patelliformis (Gandolfi)			x						
Contusotruncana cf. *plicata*? (White)		x							
Contusotruncana walfischensis (Todd)			x						
Contusotruncana spp.			x						
Ganserina ganseri (Bolli)			x						
Globotruncana aegyptiaca Nakkady	x		x						
Globotruncana arca (Cushman)	x		x				x		x
Globotruncana bulloides Vogler			x						
Globotruncana falsostuarti Sigal			x				x		
Globotruncana linneiana (d'Orbigny)									x
Globotruncana rosetta (Carsey)					x				
Globotruncana cf. *rosetta* (Carsey)	x		x						
Globotruncana spp.	x	x	x		x		x		x
Globotruncanella minuta Caron et Gonzalez Donoso									x
Globotruncanella petaloidea (Gandolfi)							x		
Globotruncanita insignis (Gandolfi)		x	x						
Globotruncanita pettersi (Gandolfi)			x						
Globotruncanita stuarti (de Lapparent)					x				
Globotruncanita stuartiformis (Dalbiez)		x	x						
Globotruncanita spp.	x	x	x						
Laeviheterohelix dentata (Stenestad)		x	x		x				
Laeviheterohelix glabrans (Cushman)			x				x		x
Laeviheterohelix spp.			x		x	x			
Muricohedbergella holmdelensis (Olsson)	x	x	x		x				x
Muricohedbergella spp.		x	x						
Planoglobulina acervulinoides (Egger)			x						
Planohedbergella circularis Huber et Petrizzo					x				x
Planohedbergella multispina (Lalicker)									x
Planohedbergella prairiehillensis Pessagno	x		x		x		x	x	x
Planohedbergella spp.			x		x	x			
Planoheterohelix globulosa (Ehrenberg)	x	x	x		x		x	x	x
Planoheterohelix planata (Cushman)			x		x		x	x	x
Pseudotextularia elegans (Rzehak)	x		x						x
Pseudotextularia intermedia De Klasz	x		x						
Pseudotextularia nuttalli (Voorwijk)			x		x				x
Racemiguembelina fructicosa (Egger)			x						
Racemiguembelina powelli Smith and Pessagno	x		x						
Rectoguembelina cretacea Cushman							x		
Rugoglobigerina rugosa (Plummer)									x
Rugotruncana circumnodifer (Finlay)									x
CALCAREOUS BENTHIC FORAMINIFERA									
Alabamina dorsoplana (Brotzen)			x						
Alabamina obtusa (Burrows et Holland)			x						
Anomalinoides minuta Mello			x						
Anomalinoides nobilis Brotzen			x						
Anomalinoides pinguis (Jennings)			x						x
Anomalinoides div. sp.		x	x		x		x		x

Tab. 1 cont.

Section	ZIELONKA				PRAŁKOWCE				GŁĘBOKI POTOK
sample no.	Z1	Z3	Z4	Z5	PR I	PRIIB	PRIIC	PR IIA	GP1
Bolivinoides draco (Marsson)			x						
Cibicides ventratumidus Myatlyuk			x						
Cibicidoides bembix (Marsson)									x
Cibicidoides succedens (Brotzen)			x						
Cibicidoides padella (Jennings)			x						
Cibicides and Cibicidoides div. sp.		x			x		x	x	x
Coryphostoma incrassatum (Reuss)			x	x					x
Gavelinella sandidgei (Brotzen)			x						
Gavelinella spp.							x		x
Gyroidinoides angustiumbilicata (Ten Dam)			x						
Gyroidinoides girardana (Reuss)		x	x	x					x
Gyroidinoides globosa (Hagenow)		x	x	x			x		x
Gyroidinoides nitida (Reuss)				x				x	
Gyroidinoides turgidus (Hagenow)			x						
Karreria fallax (Rzehak)			x						
Laevidentalina megalopolitana (Reuss)			x						
Nodosaria-Dentalina group of species		x	x						x
Nonionella troostae (Visser)			x						
Osangularia navarroana (Cushman)								x	
Parrelloides sibiricus (Nyetskaya)			x						
Praebulimina reussi (Morrow)			x						
Praebulimina sp.			x						
Pullenia dakotensis Mello									x
Quadrimorphina allomorphinoides (Reuss)			x						
Saracenaria triangularis (d'Orbigny)			x						
Siphonodosaria jacksonensis (Cushman et Applin)			x						
Stensioeina gracilis Brotzen			x						
Stensioeina pommerana Brotzen			x						
Stensioeina spp.			x						
AGGLUTINATED FORAMINIFERA									
Ammodiscus cf. *peruvianus* Berry	x								
Ammodiscus cretaceus (Reuss)	x		x	x					
Ammodiscus planus Loeblich	x								
Ammodiscus spp.			x						
Ammosphaeroidina pseudopauciloculata (Mjatljuk)	x								
Annectina sp.	x								
Glomospira gordialis (Jones et Parker)							x		
Hormosina velascoensis (Cushman) (chamber)							x		
Hyperammina kenmilleri Kaminski									x
Paratrochamminoides spp.							x		
Placentammina placenta (Grzybowski)							x		
Recurvoides sp.							x		
Rzehakina epigona (Rzehak)									x
Saccammina grzybowskii (Schubert)								x	
Saccammina/*Palcentammina* sp.								x	
Thalmannammina subturbinata (Grzybowski)							x		

RESULTS

Twelve samples were analysed biostratigraphically, and foraminifers were found in nine (Table 1). The frequency of specimens varied; only Z4 and GP1 contained numerous foraminiferal tests (>200 specimens). The foraminiferal assemblages were dominated by planktonic forms (Table 1), which were either the only component of the assemblage or accounted for >80%. They were represented mainly by small specimens of the Heterohelicidae, Globigerinelloididae and Hedbergellidae. Almost all planktonic forms are Late Cretaceous species with the last occurrences in the late Maastrichtian. Calcareous benthic foraminifera are dominated by small (~200 μm) specimens, mainly with convolute or planispiral coiling (*Cibicides*- and *Anomalina*-type shape); agglutinated foraminifera were an accessory component (Figs. 9 and 10). Foraminiferal tests are preserved in only a "satisfactory" state of preservation, and the apertural parts are broken or corroded by dissolution and commonly infilled or partly filled with sediment. Redeposition of the material from older and consolidated deposits is unlikely. The assemblage is taxonomically complementary with no traces of earlier lithification. Possible transport of foraminiferal tests from a shallow to deeper part of the basin was brief (if ever occurred), so the biostratigraphic dates obtained are assumed to determine the time of sedimentation.

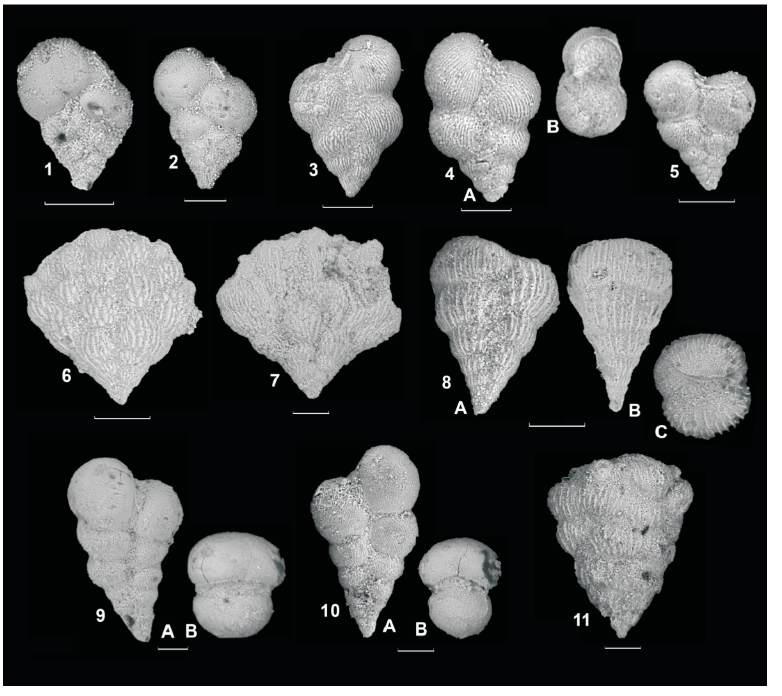

Fig. 6. Selected planktonic foraminiferids from the samples studied

1, 2 – *Laeviheterohelix dentata* (Stenestad); **3–5** – *Planoheterohelix globulosa* (Ehrenberg); **6, 7** – *Planoglobulina acervulinoides* (Egger); **8** – *Pseudotextularia elegans* (Rzehak); **9, 10** – *Pseudotextularia nuttalli* (Voorwijk); **11** – *Racemiguembelina fructicosa* (Egger); scale: 100 μm; **A, B, C** – the same specimen from different perspectives

BIOSTRATIGRAPHY

PRAŁKOWCE SECTION

The foraminiferal assemblages are dominated by poorly diverse and rare forms of mainly *Planoheterohelix globulosa* (Ehrenberg) (Fig. 6) and *Planohedbergella prairiehillensis* Pessagno (Fig. 7). Poorly-preserved specimens of *Abathomphalus* spp. (probably *Abathomphalus mayaroensis*? Bolli) were found in the prIIa sample. *Abathomphalus* spp. is a typical late Maastrichtian species (Robaszyński et al., 1984; Bolli et al., 1985) and determines the stratigraphic position of the sample. The upper-age limit is determined by the co-occurring *Planohedbergella prairiehillensis* Pessagno and *Archaeoglobigerina australis* Huber which ranged up to early late Maastrichtian (Premoli Silva and Sliter, 2002; Premoli Silva and Verga, 2004; BouDagher-Fadel, 2015; Microtax.org; Fig. 11).

Besides the cosmopolitan Campanian-Maastrichtian forms, sample PRIIC provided *Planohedbergella prairiehillensis* Pessagno and *Globotruncana orientalis* El Naggar. The two latter forms disappeared at the end of the Maastrichtian, within the upper Maastrichtian *Abathomphalus mayaroensis* Zone (Premoli Silva and Sliter, 2002; Premoli Silva and Verga, 2004; BouDagher-Fadel, 2015; Microtax.org). Additionally, one tiny specimen of *Rectoguembelina cretacea* Cushman was found. It belongs to a small group of forms that appeared in the Maastrichtian and survived the Cretaceous/Paleogene boundary (Olsson, 1999; Microtax, org). Unfortunately, it disintegrated before photographic documentation.

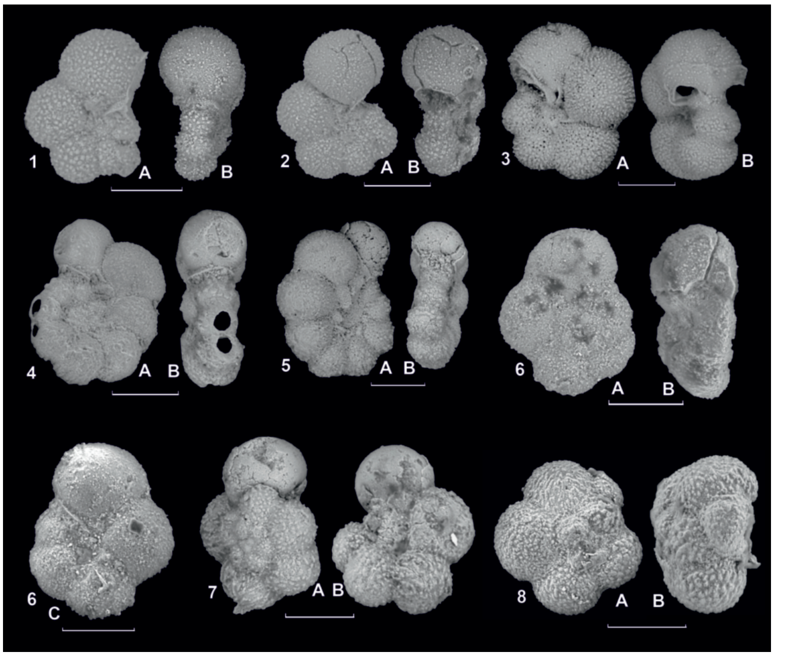

Fig. 7. Selected planktonic foraminiferids from the samples studied

1, 2 – *Planohedbergella prairiehillensis* Pessagno; **3** – *Planohedbergella multispina* (Lalicker); **4, 5** – *Planohedbergella circularis* Huber et Petrizzo; **6** – *Muricohedbergella holmdelensis* (Olsson); **7** – *Rugoglobigerina rugosa* (Plummer); **8** – *Archaeoglobigerina australis* Huber; scale: 100 μm; **A, B, C** – the same specimen from different perspectives

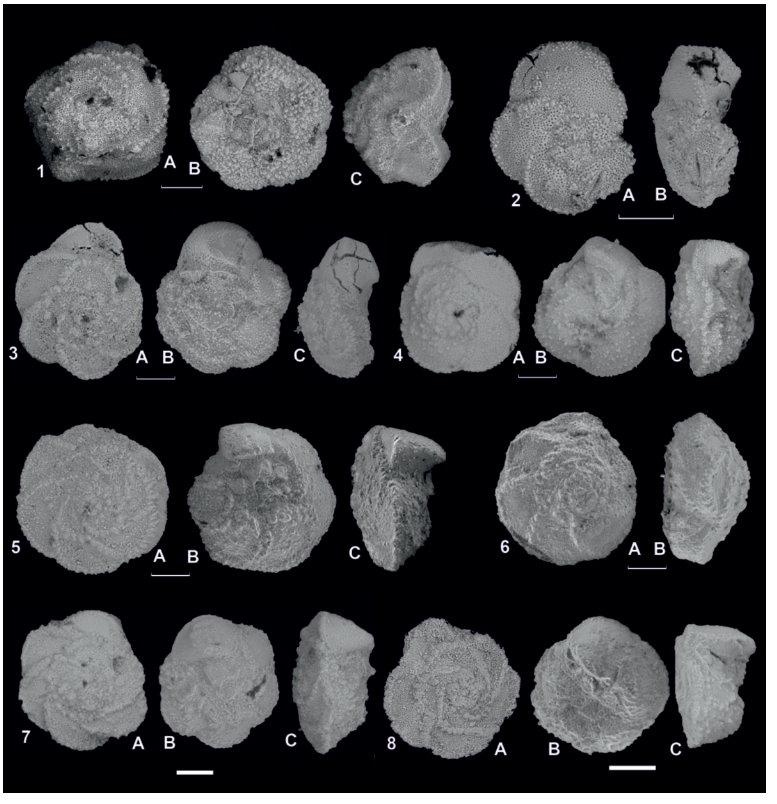

Fig. 8. Selected planktonic foraminiferids from the samples studied

1 – *Contusotruncana walfischensis* (Todd), **2** – *Globotruncana aegyptiaca* Nakkady; **3** – *Globotruncana arca* (Cushman); **4** – *Globotruncanita pettersi* (Gandolfi); **5** – *Globotruncanita stuartiformis* (Dalbiez); **6** – *Globotruncanita stuarti* (de Lapparent); **7** – *Globotruncanita insignis* (Gandolfi); **8** – *Gansserina ganseri* (Bolli); scale: 100 μm; **A, B, C** – the same specimen from different perspectives

GŁĘBOKI POTOK SECTION

Numerous and diverse planktonic foraminifera, dominated by biserial and planispiral forms, characterize the GPI sample. The presence of *Rugotruncana circumnodifer* (Finlay), which is recorded from the late Campanian to the late Maastrichtian, up to the lower part of the *Abathomphalus mayaroensis* Zone (Premoli Silva and Verga, 2004; BouDagher-Fadel, 2015) determines the age of the sample (Fig. 11). It co-occurs with *Globotruncana linneiana* (d'Orbigny) and *Planohedbergella prairiehillensis* (Pessagno) with a similar last occurrence dated to the lower *Abathomphalus mayaroensis* Zone (Robaszyński et al., 1984; Bolli et al., 1985; Premoli Silva and Sliter, 2002; Premoli Silva and Verga, 2004; BouDagher-Fadel, 2015; Microtax.org).

ZIELONKA SECTION

Six samples were collected from the Zielonka section (Fig. 5); two (Z2 and Z6) were barren.

In sample Z3 *Contusotruncana* cf. *plicata* (White) was identified, which is a late Maastrichtian species limited to the early late Maastrichtian (Robaszyński et al., 1984; BouDagher-Fadel, 2015; Microtax.org). However, it is poorly preserved, and so identification is not certain.

Sample Z4 contains the most numerous and diverse foraminiferal assemblage and provides the best biostratigraphic information. *Contusotruncana walfischensis* (Todd) (Fig. 8: 1) is dated to the middle and late Maastrichtian (Robaszyński et al., 1984; Premoli Silva and Sliter, 2002; Premoli Silva and Verga, 2004; BouDagher-Fadel, 2015; microtax.org) as is *Racemiguembelina fructicosa* (Egger) (Fig. 6: 11) with a range from middle to late Maastrichtian (Bolli et al., 1985; Premoli Silva and Sliter, 2002; Premoli Silva and Verga, 2004; BouDagher-Fadel, 2015). Both forms co-occur with *Globotruncana bulloides* Volger, *Globotruncanita insignis* (Gandolfi), *Ganserina ganseri* (Bolli), *Planoheterohelix planata* (Cushman) and *Planohedbergella prairiehillensis* Pessagno that extend from the Campanian to Maastrichtian with last occurrences in the early late Maastrichtian (e.g., Premoli Silva and Sliter, 2002; Premoli Silva and Verga, 2004; BouDagher-Fadel, 2015; Microtax.org). The common presence of these taxa coincides with the *Racemigumbelina fructicosa-Abathomphalus mayaroensis* zones. Among the benthic foraminifera, a few specimens of the late Maastrichtian *Bolivinoides draco* (Marsson) were recognized (Fig. 10: 14). This is a truly late Maastrichtian taxon – its range equates to the lower and middle part of the *Hoploscaphites constrictus crassus* ammonite Zone as recognized in the Polish Cretaceous Basin (Dubicka and Peryt, 2016; Walaszczyk et al., 2016).

DISCUSSION

The lithostratigraphic position of the exotic rocks in Kruhel Wielki area has been the subject of research since the second half of the 19th century. These strata are most often treated as part of the Ropianka Formation of Maastrichtian or Maastrichtian-Paleocene age (Bukowy and Geroch, 1956; Geroch et al., 1988; Gaździcka, 1995), but also as deposited within the Maastrichtian-Oligocene interval (Olszewska et al., 2011) or Miocene (Jankowski, 1998, 2007). The stratigraphy of the Ropianka Formation in the Gruszowa-Prałkowce Thrust Sheet has remained uncertain in several respects. Due to a lack of biostratigraphically well-documented exposures, complicated tectonic settings, and a subdivision of the Ropianka Formation based on sedimentary cycles (Kotlarczyk, 1978), the vast majority of deposits in the study area have been included into an undivided stratigraphic interval encompassing the entire Upper Cretaceous and part of the Paleocene (Gucik et al., 2005, 2017).

Up until now, the most precise biostratigraphic data based on foraminifera in the study area were published by Bukowy and Geroch (1956) (Fig. 12), who dated the marls exposed on Iwanowa Hill (Fig. 1B) to the upper lower Maastrichtian. The biostratigraphic analysis by Bukowy and Geroch (1956) was based on 20 samples. They distinguished three structural groups of foraminiferal assemblages: Group I dominated by agglutinated taxa typical of flysch deposits; Group II with poorly preserved calcareous planktonic forms, and Group III with abundant calcareous foraminifera. In one sample (no. 5) of Group I, Bukowy and Geroch (1956) noted a co-occurrence of the Late Cretaceous planktonic globotruncanids and *Rzehakina*

Fig. 9. Selected calcareous benthic foraminiferids from the samples studied

1 – *Pullenia dakotensis* Mello; **2** – *Cibicidoides* cf. *padella* (Jennings); **3** – *Gyroidinoides girardana* (Reuss); **4** – *Cibicides bembix* (Marsson); **5** – *Gyroidinoides angustiumbilicata* (Ten Dam); **6** – *Anomalinoides pinguis* (Jennings); **7** – *Anomalinoides minuta* Mello; **8** – *Anomalinoides nobilis* Brotzen; scale: 100 μm; **A, B, C** – the same specimen from different perspectives

inclusa (Grzybowski) the stratigraphic range of which is, however, from the Campanian to the end of the Maastrichtian (e.g., Morgiel and Szymankowska, 1978; Morgiel and Olszewska, 1981; Waśkowska et al., 2019), in addition to *R. fissistomata* (Grzybowski) which is considered to be Paleocene (Olszewska, 1997; Jurkiewicz, 1967; Malata et al., 1996).

In the Carpathians, single, small specimens of *R. fissistomata* (Grzybowski) have been occasionally observed in foraminiferal assemblages of the *A. mayaroensis* Zone *sensu* Caron, 1985 (Bubik et al., 1999; Waśkowska et al., 2021). All this data suggested a younger age of the deposits and indicated rather the uppermost Maastrichtian.

Bukowy and Geroch (1956) listed and illustrated stratigraphically important taxa. According to the present state of knowledge, it was possible to re-evaluate some taxa and their stratigraphic ranges. Consequently, *Pseudotextularia varians* Rzehak shown in their fig. 12, pl. XXVIII corresponds to *Pseudotextularia intermedia* De Klasz; *P. varians* Rzehak shown in their fig. 13, pl. XXVIII corresponds to *Racemiguembelina fructicosa* (Egger); *Globotruncana membranacea* (Ehrenberg) shown in their fig. 11, pl. XXVIII corresponds to *Globotruncana havanensis* (Voorwijk). Taking into account the recent range of *R. fructicosa* (Egger) (Bolli et al., 1985; Premoli Silva and Sliter, 2002; Premoli Silva and Verga, 2004; BouDagher-Fadel, 2015) this points to an upper Maastrichtian position of the sample.

Bukowy and Geroch (1956) also revised data provided previously by Wójcik (1907) from the Kruhel Wielki Quarry (Fig. 1B) and concluded that the age of the Wapielnica Hill deposits is not Oligocene but Maastrichtian (Fig. 12). However, based on the presence of *Abathomphalus* cf. *mayaroensis* (Bolli), the age of these deposits might be safely limited to the late Maastrichtian.

An additional stratigraphic study in Kruhel Wielki Quarry (Wapielnica Hill, Fig. 1B) was made by Geroch et al. (1988) who determined the Maastrichtian age (undivided) for the matrix of conglomerates based on planktonic and benthic foraminifera. They listed *Bolivinoides draco* (Marsson). *A. mayaroensis* (Bolli) and *Abathomphalus* cf. *intermedia* (Bolli) that are characteristic of the late Maastrichtian (Robaszyński et al., 1984; Bolli et al., 1985; Dubicka and Peryt, 2016) which might more precisely specify the age of these deposits. Gucik (in Geroch et. al., 1988), in turn, based on the tectonic setting of the marginal part

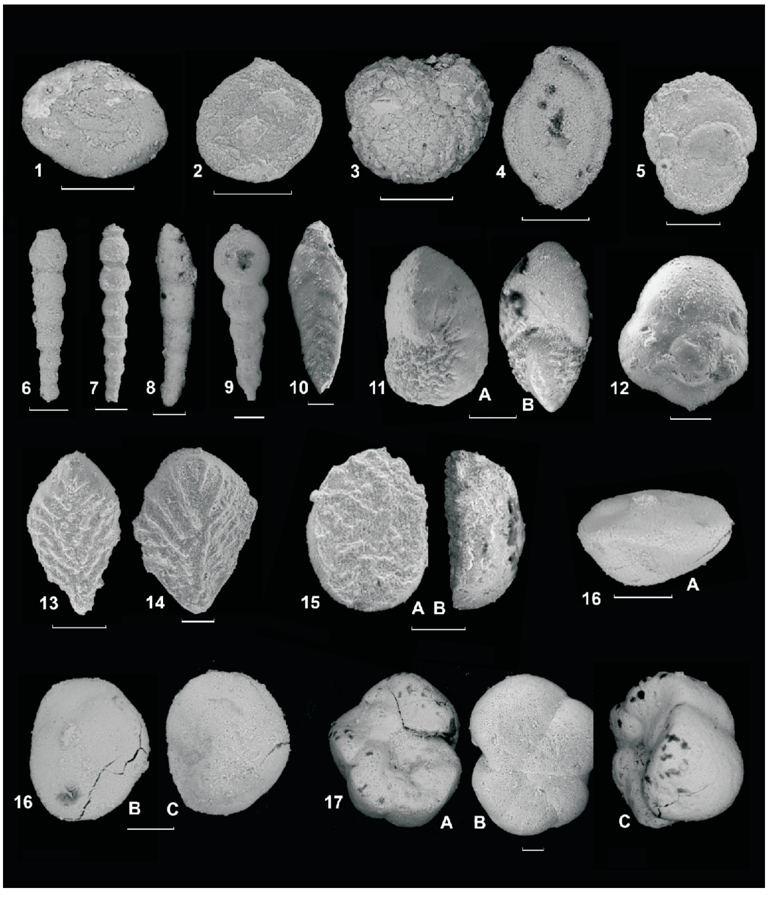

Fig. 10. Selected agglutinated (1–7) and calcareous benthic (8–17) foraminiferids from the samples studied

1 – *Glomospira gordialis* (Jones et Parker); **2** – *Placentammina placenta* (Grzybowski); **3** – *Recurvoides* sp.; **4** – *Rzehakina epigona* (Rzehak); **5** – *Ammosphaeroidina pseudopauciloculata* (Mjatljuk); **6, 7** – *Siphonodosaria* sp.; **8** – *Laevidentalina* sp.; **9** – *Nodosaria* sp.; **10** – *Coryphostoma incrassatum* (Reuss); **11** – *Nonionella troostae* (Visser); **12** – *Quadrimorphina allomorphinoides* (Reuss); **13, 14** – *Bolivinoides draco* (Marsson); **15** – *Stensioeina pommerana* Brotzen; **16** – *Alabamina dorsoplana* (Brotzen); **17** – *Karreria fallax* (Rzehak); scale: 100 µm; **A, B, C** – the same specimen from different perspectives

of the Skole Nappe in the Przemyśl area, inferred a Paleocene age for these conglomerates (Fig. 12).

Studies based on nannoplankton (Gaździcka, 1995) confirmed the late Maastrichtian age of the Makówka Slump Debris (upper part of the Ropianka Fm., Figs. 2B and 12). According to Olszewska et al. (2011), exotic rocks in the Kruhel Wielki area occur within Maastrichtian to Oligocene deposits (Fig. 12) and the Kruhel Wielki olistolith is located within Maastrichtian strata. Olszewska et al. (2011) identified also some Turonian forms (Fig. 12). These, however, might have been easily redeposited from older strata.

The newly sampled material from deposits of the Gruszowa-Prałkowce Thrust Sheet gave positive biostratigraphical results. The Zielonka and Głęboki Potok deposits contain foraminiferal assemblages typical of the lower and middle parts of the upper Maastrichtian. This new data corresponds to foraminiferal assemblages listed previously by Bukowy and Geroch (1956), Geroch et al. (1988) and Gaździcka (1995), although at least in some cases, variously interpreted.

SUMMARY AND CONCLUSIONS

The Ropianka Formation in the area of Przemyśl constitutes the host rocks for large olistoliths (e.g., Kruhel Wielki) in addition to beds of exotic conglomerates and breccias mainly composed of Stramberg-type limestones. The timing of redeposition of these exotic blocks has been greatly disputed in the literature.

Based on new finds of planktonic and calcareous benthic foraminifera, deposits from the sections analysed (also those hosting exotic-bearing layers) can be attributed to the lower/middle upper Maastrichtian, covering the interval of *R. fructicosa* up to the lower part of the A. mayaroensis foraminifera Zone.

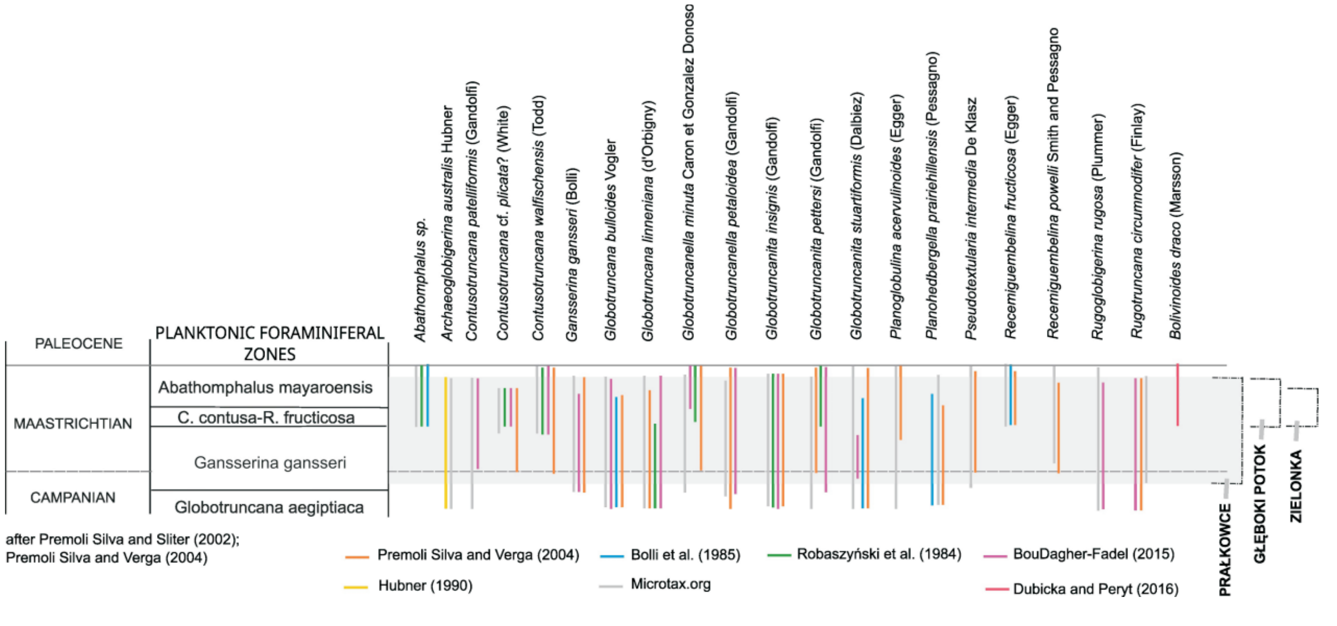

Fig. 11. Ranges of the planktonic foraminifera used for biostratigraphic analysis of the samples studied; the stratigraphic ranges (different colours) are based on various authors

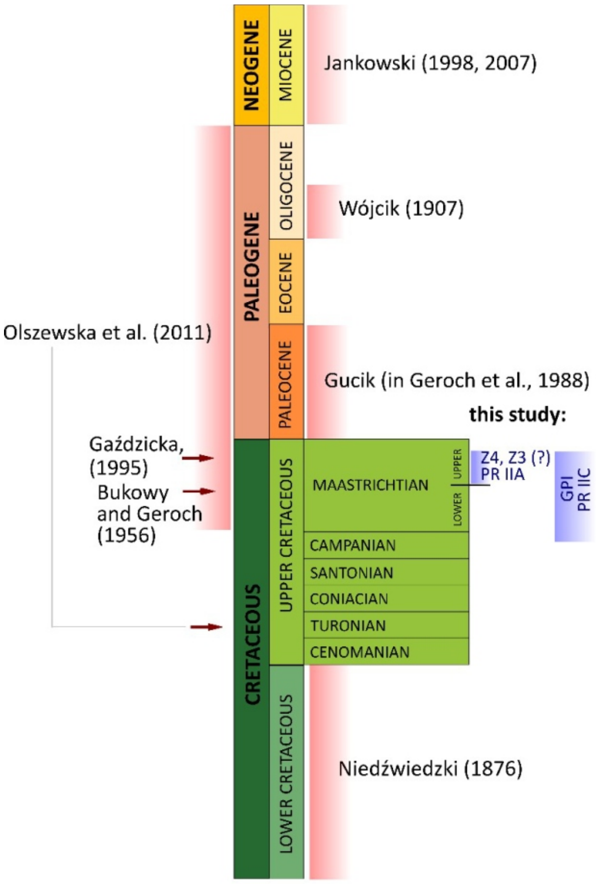

Fig. 12. The age of the exotic-bearing layers or adjacent flysch beds in the area of Kruhel Wielki obtained by different authors

The stratigraphic positions of the currently examined samples are in blue (right side)

The new stratigraphic results are in line with data based on a nannoplankton study (Gaździcka, 1995) and those obtained by re-evaluation of the taxonomic list and illustrations of foraminifera published by Bukowy and Geroch (1956) and Geroch et al. (1988).

Accordingly, the late Maastrichtian age of the Ropianka Formation at the Zielonka locality has some fundamental consequences. Formerly, it was included into the Paleocene Wola Korzeniecka Member. The new biostratigraphic data refute its Paleocene age. This has forced a change of its lithostratigraphic position from the Paleocene Wola Korzeniecka Member, as proposed by Gucik in Geroch et al. (1998), to the Leszczyny Member, as we propose here.

According to the inferred tectonic architecture, field observations and geological mapping, the deposits in the Zielonka section might constitute the lower stratigraphic age-limit of the vast exotic-bearing layers in the Wapielnica and Iwanowa hills (Fig. 1B), thus also for the Kruhel Wielki olistolith.

Moreover, it cannot be excluded that even higher levels (younger) of the Maastrichtian are present in the area of Zielonka, Kruhel Wielki Quarry and Prałkowce (Fig. 1B), thus potentially underlying the olistolith and olistostrome/s layer/s. Currently, it is a matter of speculation whether one or more depositional events were responsible for the emplacement of these exotic materials into the Ropianka Formation.

In conclusion, the exotic depositional event, its strata now within the marginal part of the Gruszowa-Prałkowce Thrust Sheet, took place not earlier than in the early late Maastrichtian.

A marked decrease in the exotic rocks towards the west from the Wapielnica and Iwanowa hills is documented both on available geological maps and in fieldwork results of the authors. However, since there is no correlation between exotic-bearing layers in the Gruszowa-Prałkowce Thrust Sheet with those in adjacent units, the time of redeposition of exotic material in surrounding units will be further explored by the authors.

Acknowledgements. This research has been supported by the IDUB Programme, grant number – BOB-661-786/2022 (J.W), AGH Subsidy Founds No. 16.16.140.315 (A.W), and Polish National Science Centre [Narodowe Centrum Nauki, Polska], grant number – UMO-2018/29/B/ST10/02947 (Z.R). The authors are grateful to reviewers, A. Uchman (Jagiellonian University, Kraków, Poland) and M.A. Kaminski (King Fahd University of Petroleum & Minerals, Saudi Arabia).

REFERENCES

Bolli, H.M., Saunders, J.B., Perch-Nielsen, K., 1985. Plankton Stratigraphy. **2**: Radiolaria, Diatoms, Silicoflagellates, Dinoflagellates and Ichthyoliths. Cambridge University Press, Cambridge.

BouDagher-Fadel, M.K., 2015. Biostratigraphic and Geological Significance of Planktonic Foraminifera. UCL Press, London.

Bromowicz, J., 1974. Facial variability and lithological character of Inoceramian Beds of the Skole-Nappe between Rzeszów and Przemyśl (in Polish with English summary). Prace Geologiczne, **84**: 1–83.

Bromowicz, J., 1986. Petrographic differentiation of source areas of Ropianka Beds east of Dunajec River (Outer Carpathians, Poland) (in Polish with English summary). Annales Societatis Geologorum Poloniae, **56**: 253–276.

Bubík, M., Bąk, M., Švábenická, L., 1999. Biostratigraphy of the Maastrichtian to Paleocene distal flysch sediments of the Rača Unit in the Uzgruň section (Magura group of nappes, Czech Republic). Geologica Carpathica, **50**: 33–48.

Bukowy, S., Geroch, S., 1956. On the age of exotic conglomerates at Kruhel Wielki near Przemyśl (Carpathians) (in Polish with English summary). Annales Societatis Geologorum Poloniae, **26**: 321–327.

Cieszkowski, M., Golonka, J., Krobicki, M., Ślączka, A., Oszczypko, N., Waśkowska, A., Wendorff, M., 2009. The Northern Carpathians plate tectonic evolutionary stages and origin of olistoliths and olistostromes. Geodinamica Acta, **22**: 101–126. https://doi.org/10.3166/ga.22.101-126

Dubicka, Z., Peryt, D., 2016. *Bolivinoides* (benthic foraminifera) from the Upper Cretaceous of Poland and western Ukraine: taxonomy, evolutionary changes and stratigraphic significance. Journal of Foraminiferal Research, **46**: 75–94. https://doi.org/10.2113/gsjfr.46.1.75

Dżułyński, S., Kotlarczyk, J., 1988. Zlepieńce we fliszu ogniwa z Leszczyn (in Polish). Przewodnik 59 Zjazdu Polskiego Towarzystwa Geologicznego w Przemyślu (eds. J. Kotlarczyk and K. Pękala): 92–94.

Gasiński, M.A., Uchman, A., 2009. Latest Maastrichtian foraminiferal assemblages from the Husów region (Skole Nappe, Outer Carpathians, Poland). Geologica Carpathica, **60**: 283–294. https://doi.org/10.2478/v10096-009-0020-5

Gasiński, M.A, Uchman, A., 2011. Foraminiferal assemblage and the Cretaceous-Paleogene boundary in turbiditic deposits of the Skole Nappe, Polish Outer Carpathians. Grzybowski Foundation Special Publication, **17**: 87–88.

Gasiński, M.A., Olshtynska, A., Uchman, A., 2013. A. late Maastrichtian foraminiferids and diatoms from the Ropianka Formation, Skole Nappe, Polish Carpathians: a case study from the Chmielnik-Grabówka section. Acta Geologica Polonica, **63**: 515–525. https://doi.org/10.2478/agp-2013-0022

Gaździcka, E., 1995. Stratygrafia warstw inoceramowych (formacji z Ropianki) w jednostce skolskiej w Karpatach, na podstawie nanoplankton wapiennego (in Polish). Narodowe Archiwum Geologiczne PIG-PIB, Warszawa. Nr. CBGD: 85937.

Gaździcka, E., 2001. Etapy rozwoju skolskiego basenu sedymentacyjnego w kredzie i wczesnym paleogenie – dokumentacja nanoplanktonowa (in Polish). Przegląd Geologiczny, **49**: 449–451.

Geroch, S., Krysowska-Iwaszkiewicz, M., Michalik, M., Prochazka, K., Radomski, A., Radwański, Z., Unrug, Z., Unrug, R., Wieczorek, J., 1979. Sedimentation of Węgierka marls (in Polish with English summary). Rocznik Polskiego Towarzystwa Geologicznego, **49**: 105–133.

Geroch, S., Gucik, S., Kotlarczyk, J., 1988. Pozycja „skałek" jurajskich Kruhela Wielkiego w profilu formacji z Ropianki (in Polish). Przewodnik 59 Zjazdu Polskiego Towarzystwa Geologicznego w Przemyślu (eds. J. Kotlarczyk and K. Pękala): 92–94.

Golonka, J., Krobicki, M., Waśkowska, A., Vasicek, Z., Skupien, P., 2008. Main paleogeographical elements of the West Outer Carpathians during Late Jurassic and Early Cretaceous (in Polish with English summary). Geologia, **34**: 61–72.

Golonka, J., Waśkowska, A., Ślączka, A., 2019. The Western Outer Carpathians: origin and evolution. Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, **170**: 229–254. https://doi.org/10.1127/zdgg/2019/0193

Gucik, S., 1988. Skałka wapienia jurajskiego (in Polish). Przewodnik 59 Zjazdu Polskiego Towarzystwa Geologicznego w Przemyślu (eds. J. Kotlarczyk and K. Pękala): 187–189.

Gucik, S., Wasiluk, R., Gaździcka, E., 2005. Szczegółowa mapa geologiczna Polski 1:50 000, arkusz 1026 Krzywcza (in Polish). Państwowy Instytut Geologiczny.

Gucik, S., Wasiluk, R., Gaździcka, E., 2017. Objaśnienia do szczegółowej mapy geologicznej Polski 1:50 000, arkusz 1026 Krzywcza (in Polish). Państwowy Instytut Geologiczny.

Hoffman, M., Kołodziej, B., Kowal-Kasprzyk, J., 2021. A lost carbonate platform deciphered from clasts embedded in flysch: Štramberk-type limestones, Polish Outer Carpathians. Annales Societatis Geologorum Poloniae, **91**: 203–251. http://dx.doi.org/10.14241/asgp.2021.15

Jankowski, L., 1998. Utwory olistostromowe Karpat polskich (in Polish). Posiedzenia Naukowe Państwowego Instytutu Geologicznego, **54**: 81–83.

Jankowski, L., 2007. Chaotic complexes in Gorlice region (in Polish). Biuletyn Państwowego Instytutu Geologicznego, **426**: 27–52.

Jankowski, L., 2015. A New History of the Evolution of the Carpathian Orogeny – Controversial Point of View (in Polish with English summary). Instytut Nafty i Gazu – Państwowy Instytut Badawczy.

Jurkiewicz, H., 1967. Foraminifers in the sub-Menilitic Palaeogene of the Polish Middle Carpathians (in Polish with English summary). Biuletyn Instytutu Geologicznego, **210**: 5–128.

Kędzierski, M., Gasiński, M.A., Uchman, A., 2015. Last occurrence of *Abathomphalus mayaroensis* (Bolli) foraminiferids index of the Cretaceous-Paleogene boundary: the calcareous nannofossil proof. Geologica Carpathica, **66**: 181–195. https://doi.org/1015151/geoca-2015-0019

Kotlarczyk, J., 1978. Stratigraphy of the Ropianka Formation or of Inoceramian beds in the Skole Unit of the Flysch Carpathians (in Polish with English summary). Prace Geologiczne, **108**: 1–82.

Kotlarczyk, J., 1988a. Zarys stratygrafii brzeżnych jednostek tektonicznych orogenu karpackiego (in Polish). Przewodnik 59 Zjazdu Polskiego Towarzystwa Geologicznego w Przemyślu (eds. J. Kotlarczyk and K. Pękala): 266–272.

Kotlarczyk, J., 1988b. Geology of the Przemyśl Carpathians – "a sketch to the portrait" (in Polish with English summary). Przegląd Geologiczny, **36**: 325–333.

Kowalczewska, O., Gasiński, M.A., 2018. Late Cretaceous foraminiferids from sections in the Zabratówka area (Skole Nappe, Outer Carpathians, Poland). Annales Societatis Geologorum Poloniae, **88**: 71–85. http://dx.doi.org/10.14241/asgp.2018.06

Książkiewicz, M., 1962. Atlas Geologiczny Polski. Zagadnienia stratygraficzno-facjalne(in Polish). Zeszyt 13-kreda i starszy trzeciorzęd polskich Karpat zewnętrznych. Instytut Geologiczny, Warszawa.

Machaniec, E., Kowalczewska, O., Jurgowiec, M., Gasiński, M.A., Uchman, A., 2020. Foraminiferal and calcareous nannoplankton bioevents and changes of the Late Cretaceous-earliest Paleogene transition in the northern margin of Tethys (Hyżne section, Polish Carpathians). Geological Quarterly, **64** (3): 567–588. https://doi.org/10.7306/gq.1536.

Machaniec, E., Uchman, A., Gasiński, A., 2022. A new late Maastrichtian zone based on benthic agglutinated benthic foraminifera: the Goessella rugosa/Remesella varians Zone. 11th International Cretaceous Symposium, Warsaw, Poland, 2022, August 22–26, Abstract Volume (eds. J.W.M. Jagt, E. Jagt-Yazykova, I. Walaszczyk and A. Żylińska): 257–258. Faculty of Geology, University of Warsaw, Warsaw.

Malata, T., 1996. Analysis of standard lithostratigraphic nomenclature and proposal of division for the Skole unit in the Polish Flysch Carpathians. Geological Quarterly, **40** (4): 543–554.

Morgiel, J., Szymakowska, F., 1978. Palaeocene and Eocene stratigraphy of the Skole Unit (in Polish with English summary). Biuletyn Instytutu Geologicznego, **310**: 39–91.

Malata, E., Malata, T., Oszczypko, N., 1996. Litho and biostratigraphy of the Magura Nappe in the eastern part of the Beskid Wyspowy Range (Polish Western Carpathians). Annales Societatis Geologorum Poloniae, **66:** 269–284.

Morgiel, J., Olszewska, B., 1981. Biostratigraphy of the Polish External Carpathians based on agglutinated foraminifera. Micropaleontology, **27**: 1–30.

Ney, R., 1956. On exotics of Jurassic limestones from the marginal Carpathian area and the foreland between the San and the Wiar river (In Polish with English summary). Acta Geologica Polonica, **7**: 259–270.

Niedźwiedzki, J., 1876. Spostrzeżenia geologiczne w okolicy Przemyśla (in Polish). Kosmos, **1**: 263–268, 317–328.

Nowak, W., 1963. Preliminary results of study on exotics from the inoceramian beds of the Skole series, of several sites in the Przemyśl and the Bircza Carpathians (in Polish with English summary). Kwartalnik Geologiczny, **7** (3): 421–430.

Olsson, R.K., Berggren, William, A., Hemleben, C., Huber, Brian, T., 1999. Atlas of Paleocene Planktonic Foraminifera. Washington, DC: Smithsonian Institution Press. https://doi.org/10.5479/si.00810266.85.1

Olszewska, B., 1997. Foraminiferal biostratigraphy of the Polish Outer Carpathians: a record of basin geohistory. Annales Societatis Geologorum Poloniae, **67**: 325–337.

Olszewska, B., Paul, Z., Ryłko, W., Garecka, M., 2011. Biostratygrafia olistolitów wapiennych zewnętrznego pasa skałkowego Karpat i skał otaczających (in Polish). AEM Studio Kraków 2011, 1–93.

Paul, K., Tietze, E., 1877. Studien in der Sandsteinzone der Karpathen. Jahrbuch der Geologischen Reichsanstalt, **27**: 33–130.

Poprawa, P., Malata, T., 2006. Model of late Jurassic to early Miocene tectonic evolution of the Western Outer Carpathians (in Polish with English summary). Przegląd Geologiczny, **54**: 1066–1080.

Poprawa, P., Malata, T., Oszczypko, N., 2002. Tectonic evolution of the Polish part of Outer Carpathian's sedimentary basins-constrains from subsidence analysis (in Polish with English summary). Przegląd Geologiczny, **50**: 1092–1108.

Poprawa, P., Malata, T., Oszczypko, N., Słomka, T., Golonka, J., Krobicki, M., 2006. Tectonic activity of sediment source areas for the Western Outer Carpathians basins – constraints from analysis of sediment deposition rate (in Polish with English summary). Przegląd Geologiczny, **54**: 878–887.

Premoli Silva, I., Sliter, W.V., 2002. Practical manual of Cretaceous planktonic Foraminifera. International School on Planktonic Foraminifera, Perugia 18–22 February 2002. Dipartimento di Scienza della Terra, Universitŕ di Perugia, Perugia.

Premoli Silva, I., Verga, D., 2004. Practical Manual of Cretaceous Planktonic Foraminifera. International School on Planktonic Foraminifera: 3rd Course: Cretaceous: Perugia, 16–20 February 2004. Universities of Perugia and Milano, Tipografia Ponte Felcino, Perugia, Italy.

Richling, A., Solon, J., Macias, A., Balon, J., Borzyszkowski, J., Kistowski, M., 2021. Regionalna geografia fizyczna Polski (in Polish). Bogucki Wydawnictwo Naukowe, Poznań 2021.

Robaszyński, F., Caron, M., Gonzales, D., Wonders, A.A.H., 1984. Atlas of the Late Cretaceous Globotruncanids. Revue de Micropaléontologie, **26**: 145–305.

Salata, D., Uchman, A., 2013. Conventional and high-resolution heavy mineral analyses applied to flysch deposits: comparative provenance studies of the Ropianka (Upper Cretaceous-Paleocene) and Menilite (Oligocene) formations (Skole Nappe, Polish Carpathians). Geological Qua*rterly*, **57** (4)**:** 649–664. https://doi.org/10.7306/gq.1119

Szajnocha, W., 1901. Atlas geologiczny Galicyi (in Polish). **13**: 1–54.

Uhlig, V., 1894. Bemerkungen zur Gliederung karpathischer Bildungen. Eine Entgegnung an Herrn C. M. Paul. Jahrbuch der Geologischen Reichsanstalt, **44**: 183–232.

Walaszczyk, I., Dubicka, Z., Olszewska-Nejbert, D., Remin, Z., 2016. Integrated biostratigraphy of the Santonian through Maastrichtian (Upper Cretaceous) of extra-Carpathian Poland. Acta Geologica Polonica, **66**: 313-350.

Waśkowska, A., Joniec, A., Kotlarczyk, J., Siwek, P., 2019. The Late Cretaceous fucoid marl of the Ropianka Formation in the Kąkolówka structure (Skole Nappe, Outer Carpathians, Poland) – Lithology and foraminiferal biostratigraphy. Annales Societatis Geologorum Poloniae, **89**: 259–284. https://doi.org/10.14241/asgp.2019.04

Waśkowska, A., Golonka, J., Starzec, K., Cieszkowski, M., 2021. Campanian-Paleocene Jaworzynka Formation in its type area (Magura Nappe, Outer Carpathians). Acta Geologica Polonica, **71**: 345–370.

Wójcik, K., 1907. Exotica fliszowe Kruhela Wielkiego koło Przemyśla (in Polish). Sprawozdanie Komisyi fizyograficznej Akademii Umiejętności w Krakowie, **42**: 3–24.

Wójcik, K., 1913–1914. Jura Kruhela Wielkiego pod Przemyślem. Część I, II, III (in Polish). Rozprawy Wydziału Matematyczno-Przyrodniczego Akademii Umiejętności, **53**: 141–182, 409–491, 543–618.

Żytko, K., 1961. Occurrence of variegated marls in the Upper Cretaceous and Eocene of the Skole Unit (Flysch Carpathians) (In Polish with English summary). Kwartalnik Geologiczny, **5** (3): 594–601.