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The Upper Cretaceous variegated shales in the Ropianka Formation of the Magura Nappe (Outer Carpathians) – age and lithostratigraphic position

Anna WAŚKOWSKA[1] and Mateusz SZCZĘCH[2,] *

[1] AGH University of Krakow Al. Mickiewicza 30, 30-059 Kraków, Poland; ORCID: 0000-0003-4090-8534

[2] Jagiellonian University, Institute of Geological Sciences, Gronostajowa 3a, 30-387 Kraków, Poland; ORCID: 0000-0001-9089-7947

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The lithological characteristics and age analysis of the variegated Farony Shale are presented for the first time. The Farony Shale occurs in the Lubomierz and Rabka areas in the Bystrica Subunit. It is located within medium- and thin-bedded sandy dominated turbidites of the Campanian–Paleocene Ropianka Formation. It is comprised of red shales laminated or interlayered with strongly bioturbated green shales. Exposures of the Farony Shale are observed along a distance of ~25 km, in the form of a narrow belt. The age of the variegated deposits is estimated based on agglutinated foraminifera to late Campanian–earliest Maastrichtian. Their deposition was associated with low-energy conditions and a temporary limitation of the supply of sandy material to the inner part of the Magura Basin.

Key words: Bystrica Unit, Campanian–Maastrichtian, red beds, lithostratigraphy, biostratigraphy, foraminifera.

INTRODUCTION

The Magura Nappe contains mostly deep-water deposits that originated in the Carpathian part of the Tethys Ocean. That deposits are predominated by turbidites and generally are built by sandstone or sandstone-shale deposits. Within the sedimentary log of the Magura Nappe, a few complexes of variegated shales are distinguished. These complexes stand out in the Magura Nappe lithostratigraphic profile because of the characteristic colour and predominance of shales. They contain a significant amount of red, muddy and clayey shales. The variegated shales were deposited in deep-water conditions with a share of suspension. They originated during periods of limited delivery of clastic material to the sedimentary basin and deposited in well-oxygenated environments (e.g., Leszczyński and Uchman, 1991; Waśkowska-Oliwa, 2000; Wetzel and Uchman, 2018). In the Carpathian sedimentary basin, dominated by turbiditic sedimentation, these conditions were not frequent.

The specificity of the variegated shales makes them important references in Carpathian lithostratigraphy. In the Magura Nappe, two intervals of variegated sedimentation are important: Turonian–Coniacian when the Malinowa Formation was formed, and late Paleocene–middle Eocene when the Łabowa Formation originated (e.g., Ślączka et al., 2006; Golonka and Waśkowska-Oliwa, 2007; Oszczypko and Oszczypko-Clowes, 2009; Oszczypko et al., 2015; Golonka et al., 2019). Apart from these, there are few other examples which are references within particular zones of the Magura Nappe. In the Bystrica Zone, in addition to the Malinowa and Łabowa formations, variegated shales are part of Santonian olistostrome deposits an occur in the Poręba Górna Formation (Burtan et al., 1978; Cieszkowski et al., 1998), and in an Eocene level within the Mniszek Member (Oszczypko et al., 2005, 2015). The next level belongs to the Upper Cretaceous–Paleocene Ropianka Formation. This unit was discovered by the late Marek Cieszkowski, who initiated research on these deposits. The aim of the research presented in this paper is to establish the range, lithostratigraphic position, and age of this variegated shale complex, tentatively called the Farony shale after personal communication with Marek Cieszkowski and notes published by him (Cieszkowski et al., 1998, 2015).

GEOLOGICAL SETTING

Geological field work was conducted in the Outer Carpathians on the Magura Nappe area. The Outer Carpathians originated in the Miocene as a result of the closing of the Tethys Ocean. They present typical externides and have a nappe structure. In the Polish western sector of the Outer Carpathians, the Magura Nappe is the innermost unit. From the south, it is tectonically bordered by the Pieniny Klippen Belt, located on the Outer and Inner Carpathians boundary. From the north, the Magura Nappe contacts with the Silesian Nappe and Fore-Magura Unites, and locally with the Subsilesian Nappe. It is thrusted over these nappes (Książkiewicz, 1977; Golonka et al., 2005, 2020; Ślączka et al., 2006; Fig. 1).

The Magura Nappe is comprised of deep-see deposits that originated within the Outer Carpathian basins, which functioned in the western part of Tethys. The lithological content of the

* Corresponding author, e-mail: mateusz.szczech@uj.edu.pl

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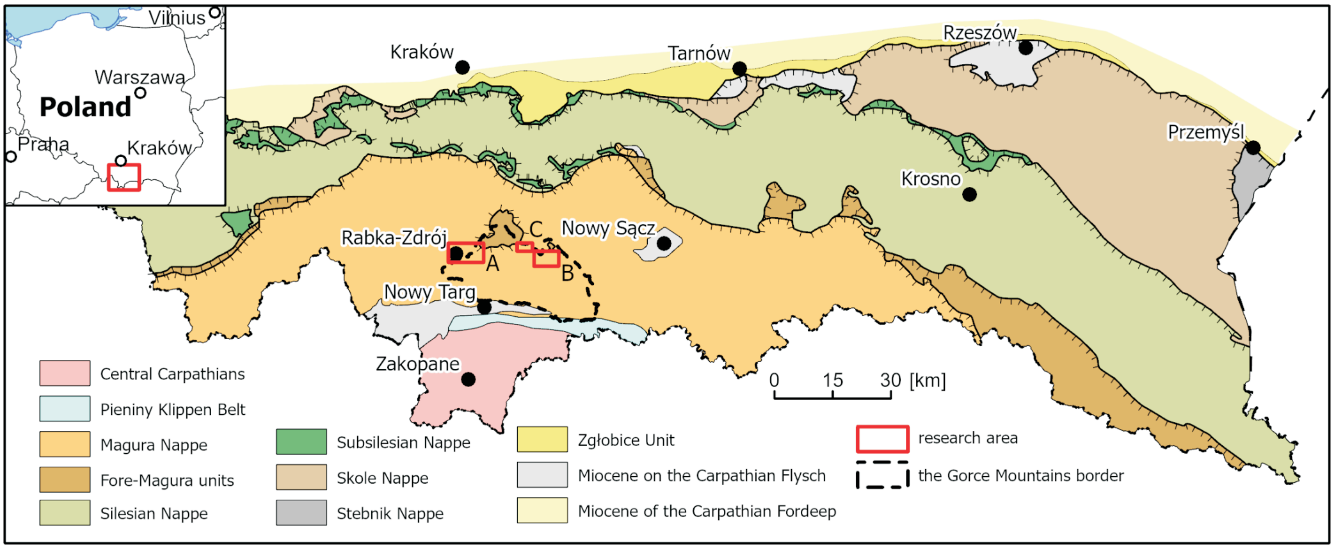

Fig. 1. Geological sketch map of the Polish sector of the Outer Carpathians (after Cieszkowski et al., 2017)

Magura Nappe corresponds to the sedimentary area of the Magura Domain related with Alpine Tethys (e.g., Ślączka et al., 2006; Oszczypko, 2006; Golonka et al., 2013, 2019 and references therein). A large part of this domain was occupied by the Magura Basin, which existed from the Jurassic up to the Miocene times. The lithological units tectonically included within the Magura Nappe correspond to deposits that formed in the Magura Basin. Differences in the lithological inventory and the internal structure allow the Magura Nappe to be subdivided into four tectonic-facies units. In order from the north to south, these are the Siary, Rača, Bystrica and Krynica subunits (after Koszarski et al., 1974). The Bystrica Subunit, in the study area, builds the northern slopes of the Gorce Mountains. It contains deposits of Albian to Oligocene? age (Fig. 2). The Cretaceous and Paleocene units were formalised by Oszczypko et al. (2005) and the Paleogene by Oszczypko (1992).

STUDY AREA

Geological analyses were carried out on the Bystrica Subunit of the Magura Nappe. The research area is located in the southern part of the Magura Nappe, 3 km north from the border with the more southern Krynica Subunit (Figs. 1 and 3), and is situated between Rabka Zaryte and Szczawa, 20 km north of Nowy Targ. According to geographical division, this area belongs to the Gorce Mountains (Solon et al., 2018). The Albian to the Oligocene? rock of the Bystrica Subunit in that area include the Ropianka Formation (Burtan et al., 1976, 1978; Cieszkowski et al., 1998; Szczęch et al., 2016), which is the subject of the current research. The outcrops form a belt 100–500 m wide, situated parallel to the main thrust lines (Fig. 3). The complex of variegated deposits occurs in the lower part of that formation. Its outcrops are exposed discontinuously over a distance of 25 km. Detailed observations of the lithological inventory and age analysis were carried out on outcrops located in the Lubomierz and Rabka Zaryte area (Figs. 1 and 3).

METHODS

The study area was covered by the cartographic, lithological and stratigraphic study. The cartographic work consisted of detailed geological mapping with the application of high-resolution digital elevation model analyses (Szczęch and Cieszkowski, 2021; Kania and Szczęch, 2023). A detailed study of the variegated deposits was conducted on the exposures mentioned above and included geological descriptions, lithology identification, observation of boundary sequences, sedimentary logging, field documentation, and sampling for age purposes.

The age of the variegated deposits was established using foraminiferal biostratigraphy. For this purpose, 17 rock samples were collected from four sections (Rabka Zaryte, Rabka, Lubomierz-Kamienica, Lubomierz-Mszanka; Fig. 3). Samples were taken from both red and green shales. The 0.5 kg portion of the mudstone was processed using standard micropalaeontological procedures. The first stage was maceration by multiple heating and cooling of the sample in a Glauber's salt solution (Na_2SO_4). In the next stage, the macerated sample was washed over 68 μm sieves and the residue was dried in an electric dryer at a temperature of 60°C. Fossils have been separated by hand from the obtained residue. Tests of agglutinated foraminifera and single fish teeth were found among the clastic grains. A group of foraminiferal tests from each sample is treated as a foraminiferal assemblage.

The state of microfossil preservation is poor, fossils are silicified and partly pyritized. Many of them are indeterminate owing to silicification and sediment sticking on the foraminifer tests. There are many broken tests, mostly tubular and uniserial forms are preserved as fragments. Foraminifera were identified taxonomicaly at the rank of species or genus, and the results of the determinations are presented in Table 1. A *Nikon VL 100POL* binocular microscope equipped with a *Nikon Digital Sight DS*-Fi1 camera and an *FEI QUANTA 200 FEG* scanning microscope were used for the taxonomic examination. Observations and documentation of foraminiferal assemblages were

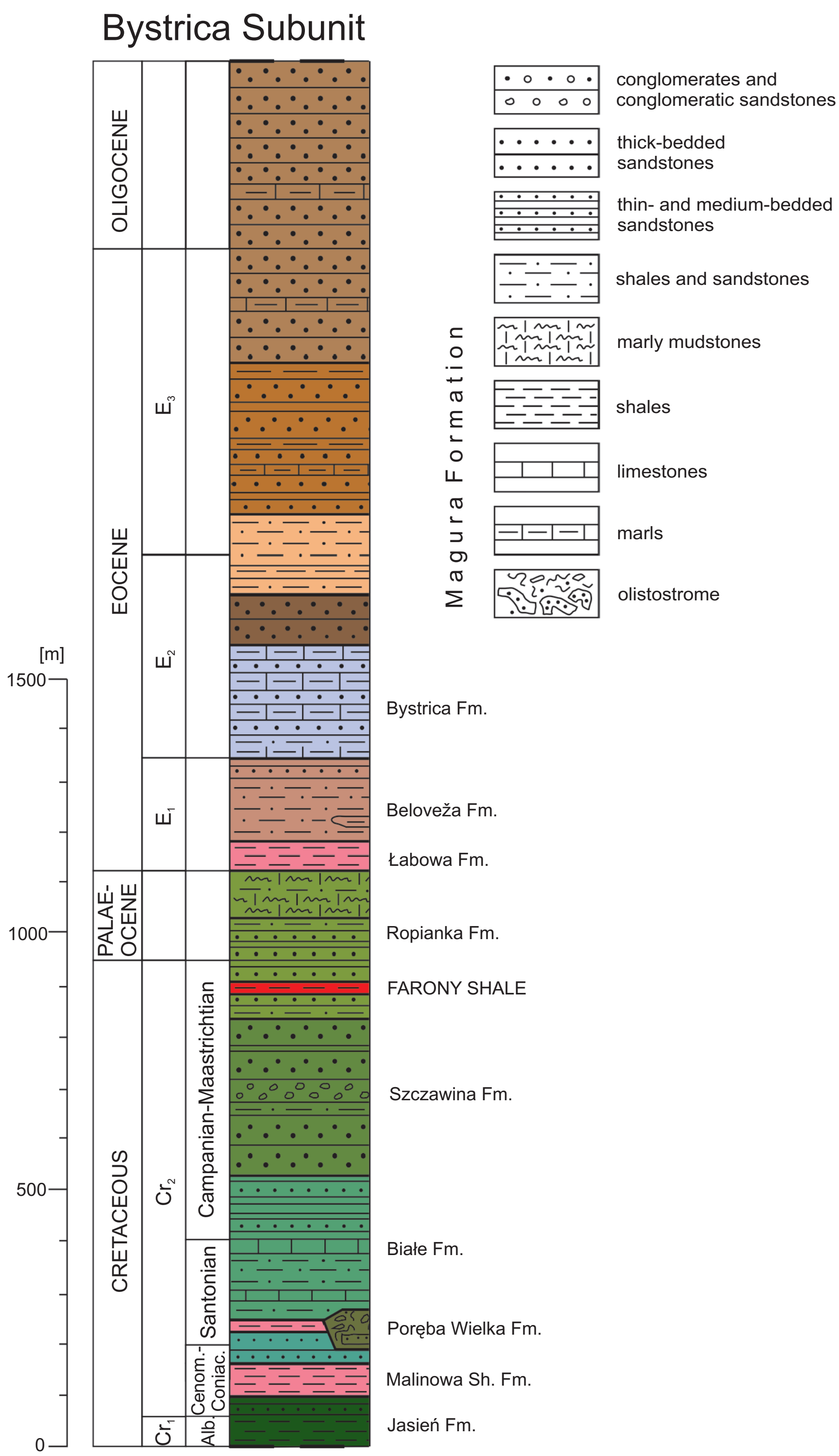

Fig. 2. Lithostratigraphic log of sedimentary succession of the Bystrica Subunit

conducted at the Department of General Geology and Geotourism and at the Scanning Microscopy Laboratory of the Faculty of Geology, Geophysics and Environment Protection AGH. The micropalaeontological material will be housed in the author's collection (A.W.) at the European Micropalaeontological Reference Centre of the Micropress Europe Micropaleontological Foundation (Kraków, al. Mickiewicza 30).

LITHOLOGY

The lithostratigraphic log of the Bystrica Subunit in the Lubomierz area has a thickness of 2.5 km and contains a full sequence of deposits from Albian up to Oligocene age (Fig. 2). In the middle part of the log, a 350 m thick Ropianka Formation occurs (Fig. 2). It consists of sandstone-dominated turbidites.

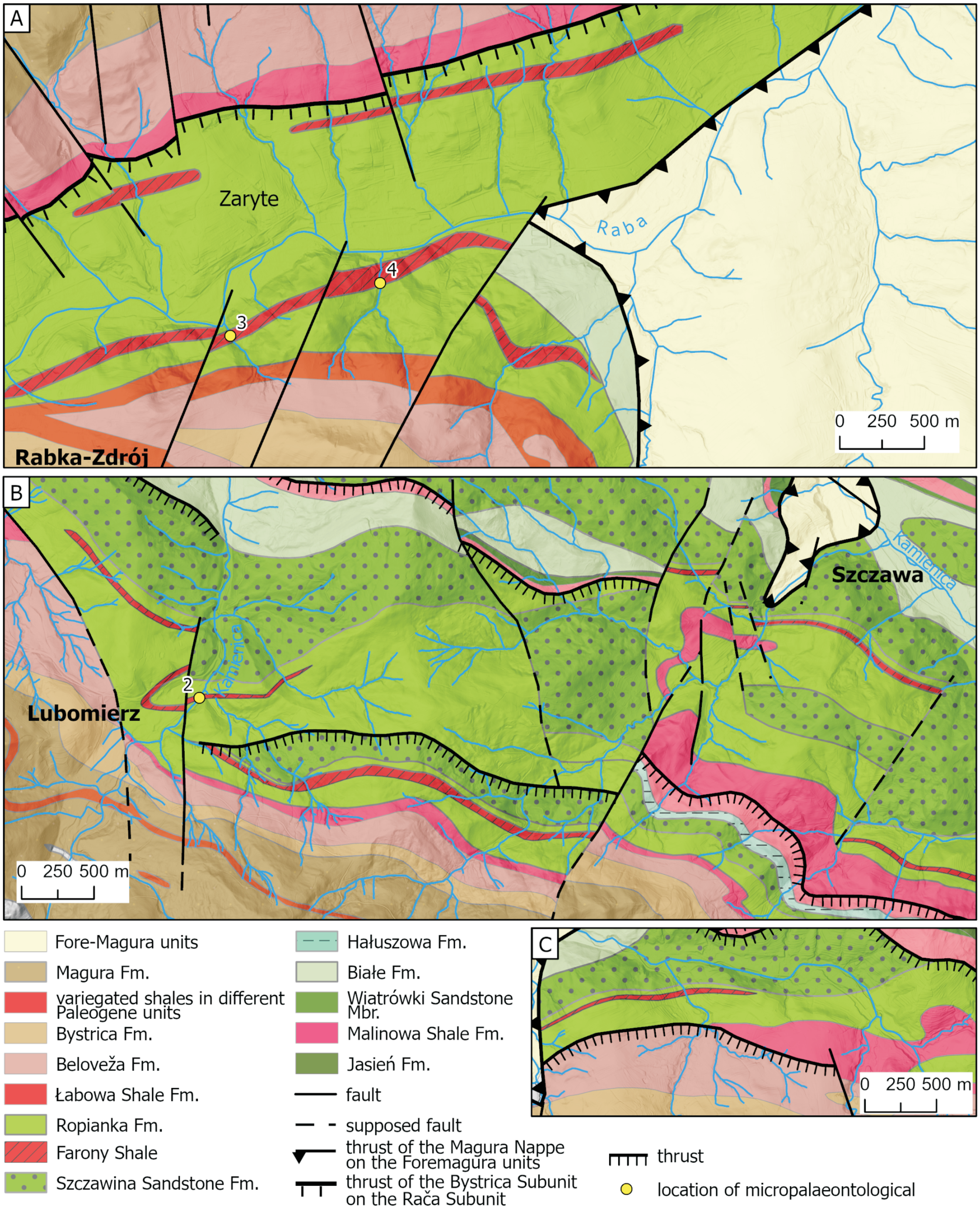

Fig. 3. Geological map of the research area (after Cieszkowski et al., 1998, modified)

Table 1

Taxonomic list of foraminifera from the Farony Shale

Section	Lubomierz-Mszanka **(1)**		Lubomierz-Kamienica **(2)**					**(3)**	Rabka Zaryte **(4)**								
Sample No.	20/FAR-1/20	21/FAR-2/20	22/FAR-3/20	23/FAR-4/20	24/FAR-5/20	25/FAR-6/20	26/FAR-7/20	Raba 176	47/RZ1/19	48/RZ2/19	49/RZ3/19	50/RZ4/19	51/RZ5/19	52/RZ6/19	53/RZ7/19	54/RZ8/19	55/RZ9/19
Ammodiscus cretaceus (Reuss)	1	2						1									
Ammodiscus peruvianus Berry		2				1											
Ammodiscus sp.		1				1											
Ammosphaeroidina pseudopauciloculata (Mjatliuk)		6				5							5				
Arthrodendron spp. (chambers)		20				20	4										
Buzasina pacifica (Krasheninnikov)								1									
Caudammina excelsa (Dylążanka) (chambers)		12				8		2									
Caudammina gigantea Geroch (chambers)								25									
Caudammina ovuloides (Grzybowski) (chambers)		1															
Caudammina ovulum (Grzybowski) (chambers)		3				2		27	3								
Conglophragmium irregularis (White)		9															
Glomospira charoides (Jones et Parker)		1			1	1			5								
Glomospira diffundens Cushman et Renz						1											
Glomospira gordialis (Jones et Parker)		3				2		1								10	
Glomospira sp.	1	1				1											
Haplophragmoides walteri (Grzybowski)						1		1									
Hormosina cf. *velascoensis? (Cushman)* (chamber)	1																
Hyperammina sp.						1											
Kalamopsis grzybowskii (Dylążanka) (fragments)		4															
Karrerulina conversa (Grzybowski)						1											
Karrerulina horrida (Grzybowski)													5				
Karrerulina sp.													4		2	4	
Nothia and *Batysiphon* div. sp. [mainly *N. excelsa* (Grzybowski)] (fragments)	440	874	510	486	640	924	1660	48	260	520	864	280	390	720	696	1220	472
Nothia latissima (Grzybowski) (fragments)		10		4		8		15									
Nothia robusta (Grzybowski) (fragments)	22	78			6		214	10									
Paratrochamminoides acervulatus (Grzybowski)		4				2											
Paratrochamminoides contortus (Grzybowski)	1	28			2	10											
Paratrochamminoides coronatus (Brady)		2															
Paratrochamminoides deflexiformis (Noth)		3						2									
Paratrochamminoides mitratus (Grzybowski)		3				3											
Paratrochamminoides multilobus (Dylążanka)		1															
Paratrochamminoides olszewskii (Grzybowski)		2				1											
Paratrochamminoides div. sp.	4	19	6		3	10		2									
Psammosiphonella, *Rhizammina* and *Rhabdammina* div. sp. [mainly *P. cylindrica* (Glaessner), *Psammosiphonella discreta* (Brady)] (fragments)		16	16	25	30	32		28					32				
Placentammina placenta (Grzybowski)	1	48		3		8											
Placentammina placenta (Grzybowski) var. *giagantea*	3	61	4		2	10		1									
Psammosphaera irregularis (Grzybowski)		14															
Recurvoides div. sp.	4	7	3	4	9	36		8	21							4	
Reophax duplex Grzybowski (fragment)		1															
Rzehakina inclusa (Grzybowski)								1									
Rzehakina sp.		1															
Saccammina grzybowskii (Schubert)	6	42			6	2											
Subreophax scalaris (Grzybowski)		7				6											
Subreophax pseudoscalaris (Samuel) (fragments)		3				2											
Trochammina umiatensis Tappan						5											
Trochamminoides subcoronatus (Brady)		4						2									
Trochamminoides cf. *proteus* (Karrer)						1											
Trochamminoides variolarius (Grzybowski)		5				2											

The sandstones are predominatly medium- and thin-bedded; thick-bedded sandstones occur rarely (Fig. 4A). They are quartzitic, fine-grained, and less frequently medium-grained, usually with normal grain gradation. Characteristic for the sandstones is lamination – wavy and convolute lamination is common, parallel lamination occurs in frequently, massive layers are subordinate. On the bottom of the sandstone layers, numerous trace fossils are present. The sandstones are grey when fresh. Weathered surfaces take a greyish-brown colouration. In their composition quartz is dominant, also mica is present, mica concentrations are observed on the surfaces of the layers and along the internal laminae. Between the sandstone layers, there are muddy shales. Their interbeds are usually a few centimetres thick. They are grey or greenish, with numerous trace fossils. In the lower part of the Ropianka Formation, the several metre thick package predominated by variegated shales occurs. It is informally called the variegated Farony Shale, after Farony hamlet, where these deposits were first noticed (e.g., Cieszkowski et al., 1998). The uppermost 100 m (Fig. 2) of the Ropianka Formation contains numerous marly shales and it is informally called as the Głębieniec Shale (Uchman and Cieszkowski, 2008; Szczęch et al., 2016).

The age of the Ropianka Formation was established based on the superposition and additionally confirmed by biostratigraphy. Oszczypko et al. (2005) indicated a Campanian/Maastrichtian–Paleocene age for it.

The Farony Shale is situated a several metres above the bottom of the Ropianka Formation. It consists of variegated deposits, dominated by shales, about a dozen metres thick. The shales are muddy and bioturbated (Fig. 4B–D). They are silicified, hard, and during breaking they disintegrate into sharp-edged fragments. The variegated shales consist of alternating red, green, and greenish-grey muddy shales. In general, the red shales are dominant; it forms 3 to 10 cm thick layers. Green and greenish-grey shales occur as thin and very thin intercalations from millimetres to single centimetres. The boundary layers are equal and parallel, or wavy. In particular, the upper boundary of the layers is uneven, deformed by bioturbation structures. Green shales also form continuous and discontinuous laminae with the character of elongated lenses. In the Farony Shale, there are intervals of several tens of centimetres thick built only of red mudstones, and several centimetres thick built only of green mudstones, or complexes of ~1 m thick where the proportion of red and green mudstones is comparable. The upper-

Fig. 4. Deposits of the Ropianka Fm.

A – thin- and medium-bedded sandstone-shale flysch of the Ropianka Fm. (Lubomierz Rzyki); **B** – variegated shales of the Farony Shale (Rabka Zaryte); **C, D** – variegated shales of the Farony Shale (Lubomierz Rzyki) most part of the Farony Shale is represented by the >1 m thick green shales, almost without red intercalations. Frequent bioturbation structures occur in the mudstones. They are most numerous and particularly pronounced in the green shales. Rare very thin-bedded and fine-grained sandstone layers occur within the shales. The discontinuous and continuous sandy laminae with blurred boundaries occur in the green shales. In the middle part of the Farony Shale, a 1 m thick intercalation of grey mudstone with rare very thin-bedded and very fine and fine-grained parallel laminated sandstones occurs.

Both boundaries, bottom and upper, of the Farony Shale are sharp. The underlying and overlying deposits have a similar character. They are grey shales, with rare very thin-bedded parallelly laminated fine-grained grey sandstones. In the underlaying deposits, the number and thickness of sandy intercalations decrease up section, towards the variegated deposits. Single cross-laminated sandstones are present in the above-lying deposits. The transition to the typical Ropianka-type, medium- and thin-bedded turbiditic deposits is gradual.

PALAEONTOLOGICAL STUDY

MATERIAL

Each sample contains foraminiferal tests. Most of foraminiferal assemblages are not numerous. The total number of specimens varies from 175 up to 1878 specimens per 0.5 kg of mudstone sample (Table 1). Only agglutinated, cosmopolitan forms are present. The taxonomic diversity ranges from 1 to >30 species (Table 1). Larger-size foraminifera specimens and higher taxonomic diversity is observed in the green shale samples. In samples from red shales mainly broken tubular forms are present. Most specimens represent fragments of tubular forms of the genus *Nothia*. Other tubular forms such as *Rhabdammina* and *Psammosiphonella* occur in smaller amounts. Furthermore, numerous are single-chambered foraminifera e.g., *Saccammina* and *Placentammina*, the uniserial multichambered forms *Caudammina*, *Arthrodendron*, and multichamberd *Paratrochamminoides* and *Recurvoides* (Figs. 5–7).

AGE ANALYSIS

A positive biostratigraphical record is obtained from samples Raba 176 taken from an unnamed stream located west of Polczakówka ski slope in Rabka Zaryte, and 21/FAR-2/20 taken from Lubomierz-Kamienica (Fig. 3). Sample Raba 176 contains *Rzehakina inclusa* (Grzybowski) (Table 1 and Fig. 6 F:1, 2), the index species indicative for Rzehakina inclusa zone *sensu* Olszewska (1997), which ranges from the upper Campanian up to the Maastrichtian/Paleocene boundary. Apart from tubular forms, the most numerous and characteristic specimens in that sample are *Caudammina*s (Table 1). They are represented mainly by *Caudammina gigantea* Geroch, *Caudammina ovulum* (Grzybowski) (Fig. 6M, N) and single *Caudammina excelsa* (Dylążanka). The share of *Caudammina* specimens, excluding tubular foraminifera, constitutes >70%, including *Caudammina ovulum* (Grzybowski) totalled 36.5% and *Caudamina gigantea* Geroch amounting to 34%. Those values are typical for acme assemblages. The *Caudammina gigantea* Geroch acme in the Outer Carpathians is dated to the uppermost Santonian–lowermost Maastrichtian and *Caudammina ovulum* (Grzybowski) acme to the Campanian-Danian (Waśkowska et al., 2019; Waśkowska, 2021). The co-occurrence of *Caudammina gigantea* Geroch and *Caudammina ovulum* (Grzybowski) acme assemblages together with *Rzehakina inclusa* (Grzybowski) points to a late Campanian-earliest Maastrichtian age for the Farony Shale. Such assemblage is typical for the lower part of the Rzehakina inclusa foraminiferal zone *sensu* Olszewska (1997).

The sample 21/FAR-2/20 includes the most diversified foraminiferal assemblage within the studied material. Its characteristic feature is the numerous occurrences of *Placentammina*, *Saccammina* and *Paratrochamminoides* div sp. (Table 1 and Fig. 5). The total amount of *Placentammina placenta* (Grzybowski) and *Saccammina grzybowskii* (Schubert), excluding tubular samples, is 47%. Such an amount is typical for an acme. In the Outer Carpathians, the *Placentammina*-*Saccammina* acme ranges from the Upper Campanian up to the Danian (Waśkowska, 2021). *Placentammina placenta* (Grzybowski) comprises a group of specimens which were tentatively divided into two types:

- smaller, ~0.3–0.6 mm in diameter with a distinct short neck (44% of all *Placentammina*) and
- larger, reaching 0.8 mm and more in diameter [*Placentammina* placenta (Grzybowski) var. *gigantea*] (56% of all *Placentammina*) (Table 1 and Fig. 5).

Larger *Placentammina placenta* (Grzybowski) features the Carpathian *Placentammina*-*Saccammina* acme assemblages (Waśkowska, 2021). In other Cretaceous and Paleogene assemblages, usually the first type (smaller specimens) of *Placentammina placenta* (Grzybowski) occurs. *Placentammina placenta* (Grzybowski) var. *gigantea* is also a component of the other studied assemblages from the Farony Shale that are rather poor in foraminiferal specimens (samples 20/FAR-1/20, 22/FAR-3/20, 24/FAR-5/20, 25/FAR-6/20, Raba 176, Table 1), sourced from 3 out of 4 sampled localities (Table 1). It can be a prerogative to belong to the same facies. In the sample, 21/FAR-2/20 *Caudammina excelsa* (Dylążanka) is present, which is another feature of the *Placentammina*-*Saccammina* acme (Waśkowska et al., 2018; Waśkowska, 2021).

Similar features, in terms of an increase in the number of *Saccammina*-*Placentammina,* and the presence of *Caudammina excelsa* (Dylążanka), occur in the sample 25/FAR-6/20. With a large probability, it corresponds to the *Saccammina*-*Placentammina* acme assemblage. *Glomospira diffundens* Cushman and Renz and *Trochammina umiatensis* Tappan also were found in this sample (Fig. 6). These species indicate a Maastrichtian–Danian age.

Taking into account the above, the *Caudammina gigantea* acme-*Caudammina ovulum* acme assemblage with *Rzehakina inclusa* (Grzybowski) as well as the *Saccammina*-*Placentammina* acme assemblage with *Placentammina placenta* (Grzybowski) var. *gigantea* and *Caudammina excelsa* (Dylążanka) were found in the Farony Shale. The age of the Farony shale is indicated as late Campanian–earliest Maastrichtian and it corresponds to the lower part of the Rzehakina inclusa Zone.

DISCUSSION

In the Bystrica Subunit in the Lubomierz area, within the Ropianka Formation, there is a several metre-thick compact package of variegated shales, dominated by red mudstone. It is clearly different from the typical deposits of the Ropianka Formation, which are grey-green coloured, thin- and medium-bedded sandy dominated turbidites. The variegated package has an extensive lateral range of 20 km. These deposits were previously marked in geological maps. On the Rabka sheet of De-

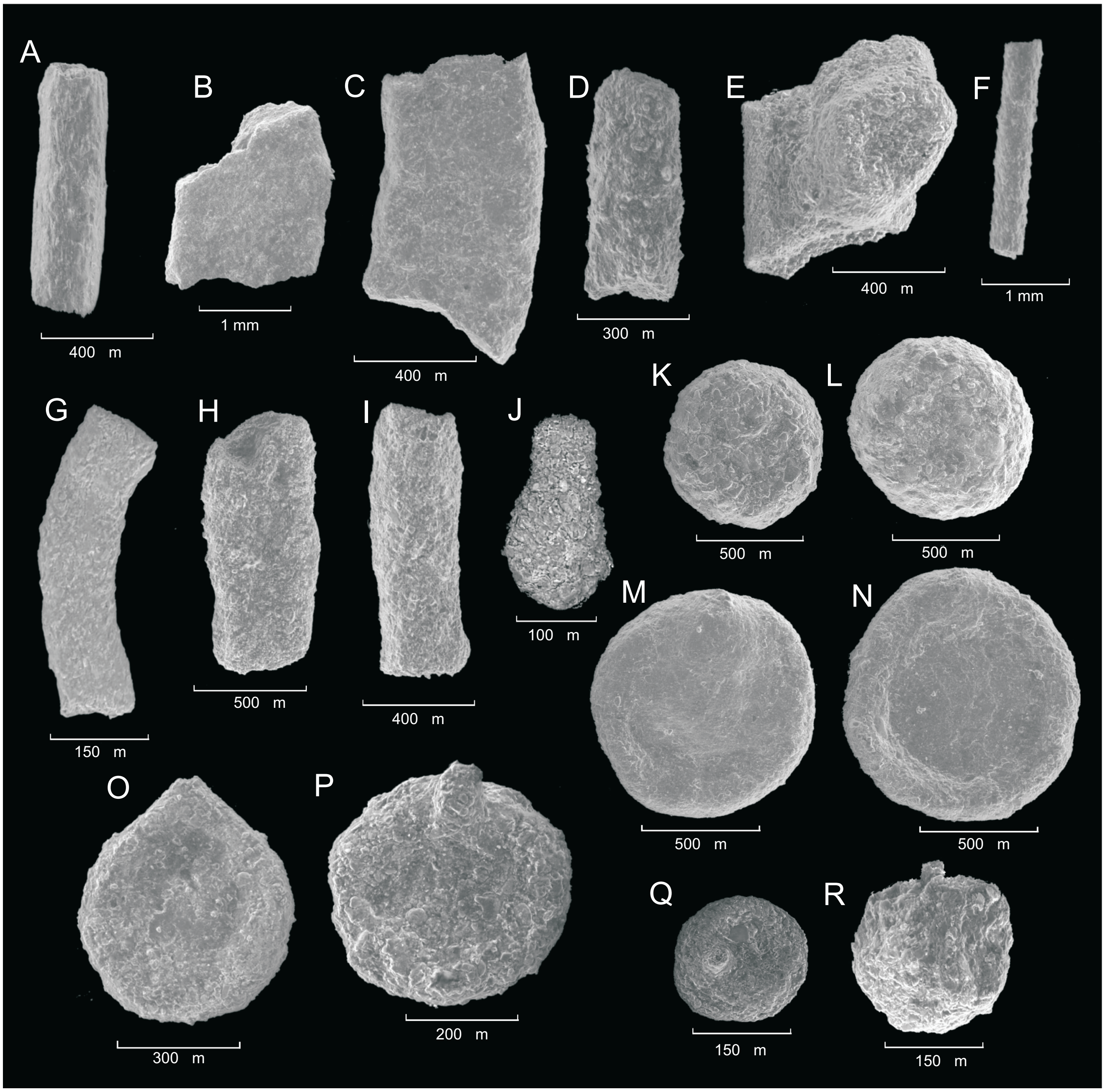

Fig. 5. SEM-images of agglutinated foraminifera from the Farony Shale

A – *Bathysiphon* sp. (sample – s. Raba 176); **B** – *Nothia latissima* (Grzybowski) (s. 21/FAR-2/20); **C** – *Nothia latissima* (Grzybowski) (s. Raba 176); **D** – *Rhabdammina/Psammosiphonella* sp. (s. 21/FAR-2/20); **E** – *Nothia excelsa* (Grzybowski) with attached form (s. 21/FAR-2/20); **F** – *Psammosiphonella cylindrica* (Glaessner) (s. Raba 176); **G** – *Rhizammina* sp. (s. Raba 176); **H** – *Rhabdammina/Psammosiphonella* sp. (Grzybowski) (s. 25/FAR-6/20); **I** – *Psammosiphonella discreta* (Brady) (s. 55/RZ9/19); **J** – *Hyperammina* sp. (s. 25/FAR-6/20); **K, L** – *Psammosphaera irregularis* (Grzybowski) (s. 21/FAR-2/20); **M, N** – *Placentammina placenta* (Grzybowski) var. *gigantea* (s. 21/FAR-2/20); **O** – *Placentammina placenta* (Grzybowski) (s. 21/FAR-2/20); **P** – *Placentammina placenta* (Grzybowski) (s. 25/FAR-6/20); **Q** – *Saccammina grzybowskii* (Schubert) (s. 21/FAR-2/20); **R** – *Saccammina grzybowskii* (Schubert) (s. 25/FAR-6/20)

tailed Geological Map of Poland (Paul and Ryłko, 1986, 1987) and in its new edition (Paul et al., 2022), the Farony Shale was included in the Malinowa Shale Formation of the Turonian-Cenomanian? age. Burtan et al. (1978), on the Mszana Górna sheet, marked the Farony Shale as an intercalation of variegated shales in the Ropianka Formation. Their affiliation within the Ropianka Formation was indicated on the geological map of the Gorce region (Cieszkowski et al., 1998, 2015; Cieszkowski, 2006; Uchman and Cieszkowski 2008; Szczęch et al., 2016) and on the lithostratigraphical log of the Bystrica Subunit in the Gorce Mountains (Oszczypko et al., 2005; Uchman and Cieszkowski, 2008). Until now, they have not been extensively characterized, other than marking the basic lithology and proposing a name which was suggested by Cieszkowski et al. (2015) and Szczęch et al. (2016). The present field studies indicated that the Farony Shale is a distinctive package, clearly visi-

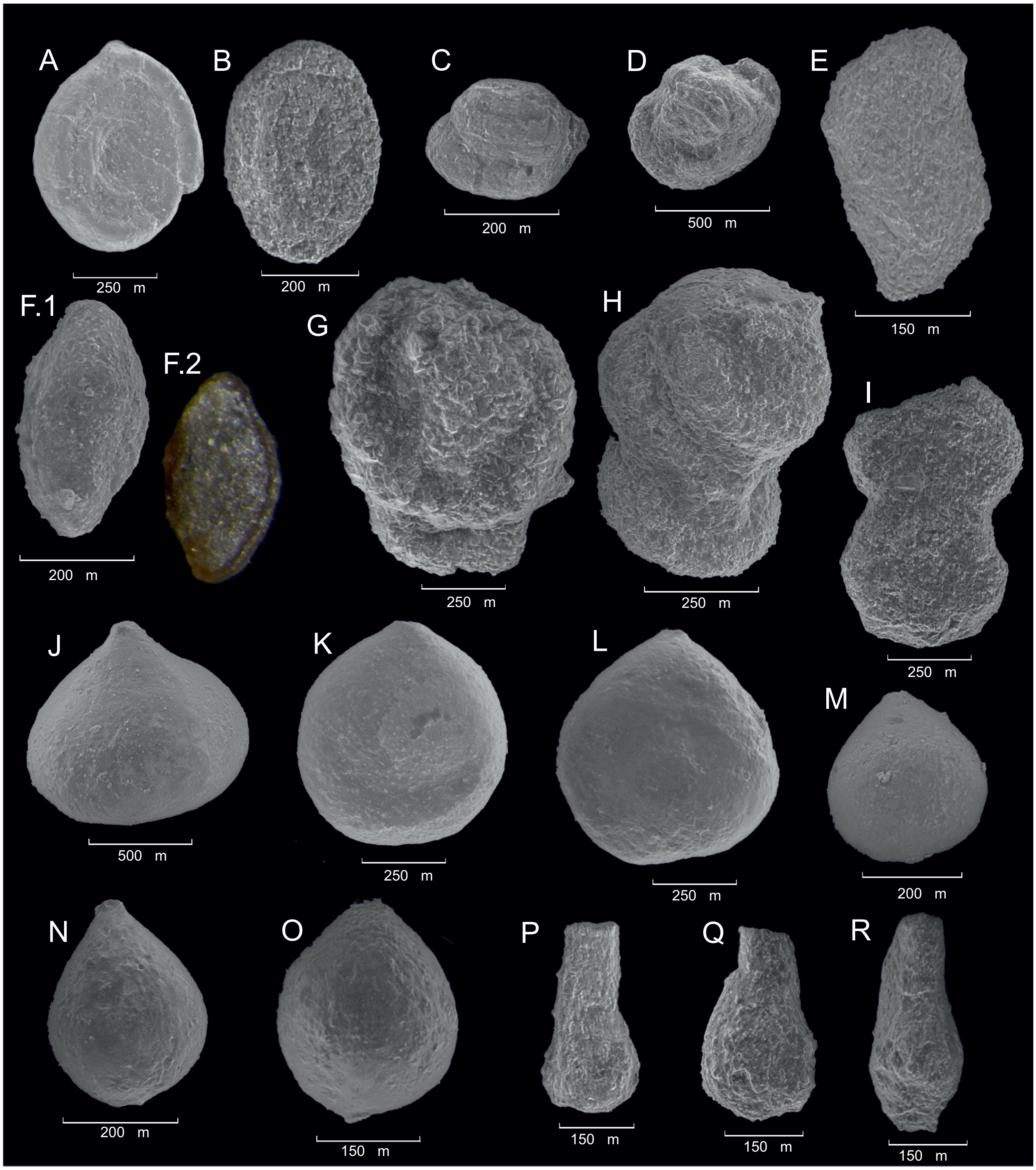

Fig. 6. SEM-images of agglutinated foraminifera from the Farony Shale

A – *Ammodiscus cretaceus* (Reuss) (s. 21/FAR-2/20); **B** – *Ammodiscus* sp. (s. 25/FAR-6/20); **C** – *Glomospira charoides* (Jones et Parker) (s. 21/FAR-2/20); **D** – *Glomospira charoides* (Jones et Parker) (s. 25/FAR-6/20); **E** – *Rzehakina* sp. (s. 21/FAR-2/20); **F (1, 2)** – *Rzehakina inclusa* (Grzybowski) (s. Raba 176); **G** – *Arthrodendron* sp. (s. 25/FAR-6/20); **H** – *Arthrodendron* sp. (s. 21/FAR-2/20); **I** – *Arthrodendron* sp. (s. 25/FAR-6/20); **J–L** – *Caudammina gigantea* (Geroch) (s. Raba 176); **M, N** – *Caudammina ovulum* (Grzybowski) (s. Raba 176); **P–R** – *Caudammina excelsa* (Dylążanka) (s. 25/FAR-6/20)

ble by its peculiar lithology, distinguishable cartographically, compact, and has distinct boundaries, so it can be regarded as an distinct lithostratigraphic unit. These deposits can be used as a correlation level in the Gorce Mountains.

The question of the age of the lower boundary of the Ropianka Formation remains in the Gorce Mountains. In formal description, a Maastrichtian age was reported (Oszczypko et al., 2005). The age of the Farony Shale, which is situated in the

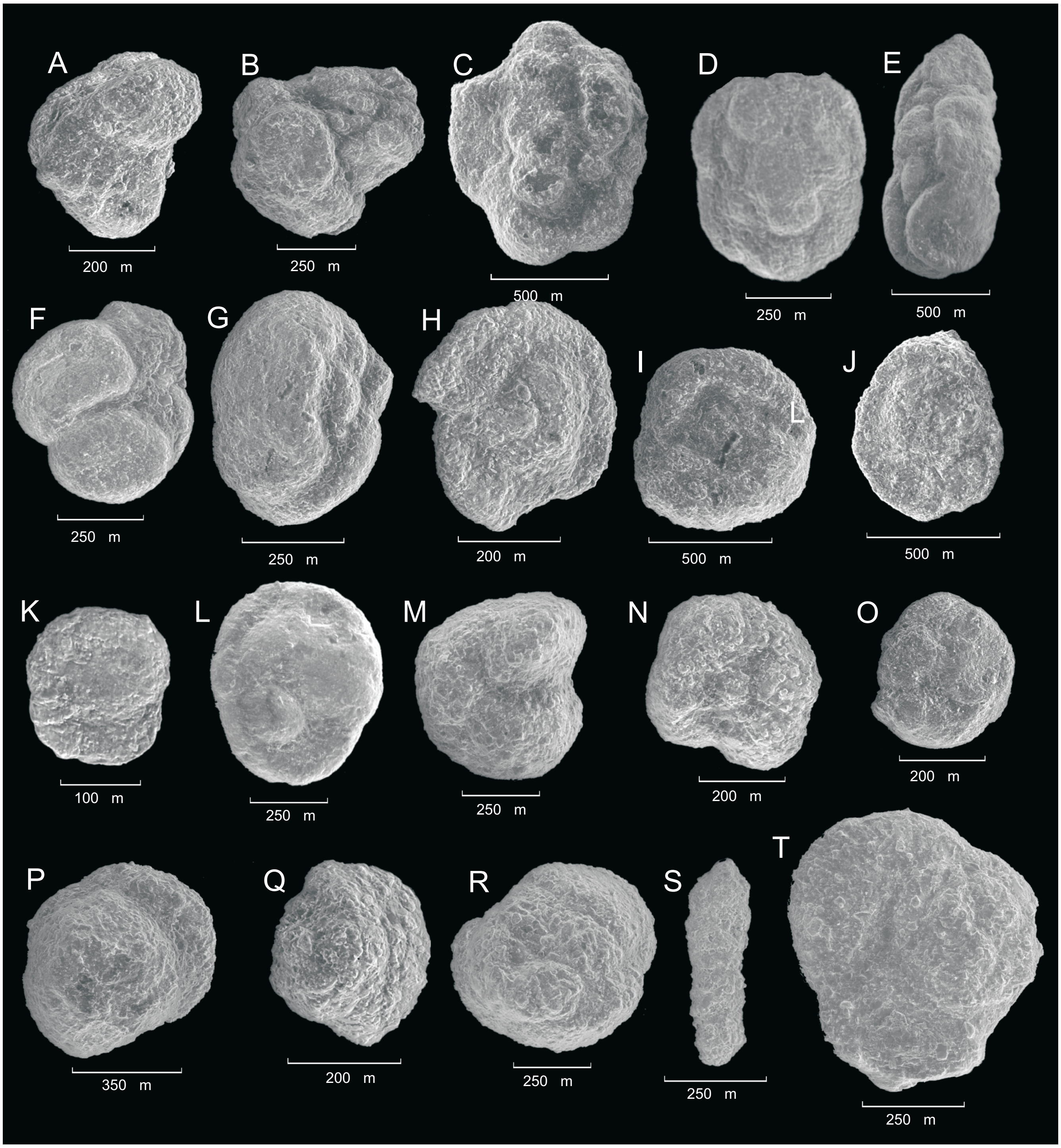

Fig. 7. SEM-images of agglutinated foraminifera from the Farony Shale

A – *Paratrochamminoides/Conglophragmium* sp. (s. 22/FAR-3/20); **B** – *Paratrochamminoides mitratus* (Grzybowski) (s. 21/FAR-2/20); **C** – *Paratrochamminoides acervulatus* (Grzybowski) (s. 21/FAR-2/20); **D** – *Paratrochamminoides* sp. (s. 21/FAR-2/20); **E, F** – *Trochamminoides subcoronatus* (Grzybowski) (s. 21/FAR-2/20); **G** – *Trochamminoides* cf. *variolarius* (Grzybowski) (s. 25/FAR-6/20); **H** – *Conglophragmium deformis* (Grzybowski) (s. 25/FAR-6/20); **I** – *Trochamminoides variolarius* (Grzybowski) (s. 21/FAR-2/20); **J** – *Haplophragmoides walteri* (Grzybowski) (s. 25/FAR-6/20); **K** – *Ammosphaeroidina pseudopauciloculata* (Mjatliuk) (s. 21/FAR-2/20); **L** – *Buzasina pacifica* (Krasheninnikov) (s. Raba 176); **M** – *Recurvoides* cf. *anormis* Mjatliuk (s. 21/FAR-2/20); **N** – *Recurvoides* cf. *nucleolus* (Grzybowski) (s. 21/FAR-2/20); **O** – *Recurvoides* sp. (s. 25/FAR-6/20); **P** – *Recurvoides* sp. (s. 21/FAR-2/20); **Q** – *Recurvoides walteri* (Grzybowski) (s. 21/FAR-2/20); **R** – *Recurvoides* sp. (s. 21/FAR-2/20); **S** – *Karrerulina conversa* (Grzybowski) (s. 21/FAR-2/20); **T** – *Trochammina umiatensis* Tappan (s. 25/FAR-6/20) lower part of this formation (Fig. 2), was estimated as late Campanian to earliest Maastrichtian. We wondered whether we could rule out the Campanian age, but data analysis in the paper by Oszczypko et al. (2005) indicates that, in principle, we cannot. Described in this paper foraminiferal samples taken from the lower part of the Ropianka Formation, there are no clear indicators that would constrain a Maastrichian age. Assemblages with abundant *Placentammina placenta* (Grzybowski), containing *Caudammina ovulum* (Grzybowski) and *Caudammina gigantea* Geroch begin in the upper Campanian. Biostratigraphical interpretation are different interpretations in the tables than in the text (Oszczypko et al., 2005). We have taken into account superposition and the age of the Szczawina Formation, directly underlying the Ropianka Formation, and we have not found any unambiguous Maastrichtian age markers. According to the micropalaeontological data presented in this study, as well as in the Oszczypko et al. (2005) paper, we cannot exclude late Campanian age for the lower part of the Ropianka Formation.

The foraminiferal assemblages of the Farony Shale correspond to the assemblages from the Cretaceous part of the Ropianka and Jaworzynka formations of the Magura Nappe. Assemblages with numerous *Caudammina gigantea* (acme assemblages) were noticed earlier by Blaicher (1958), Sikora and Żytko (1960), Bieda et al. (1963), Jednorowska (1966, 1975), Geroch et al. (1967), Malata (1981, 2002), Malata and Oszczypko (1996), Oszczypko et al. (1990, 2005), Stráník et al. (2000), Waśkowska (2021), Waśkowska et al. (2021), increased numbers of *Caudammina ovulum* (Grzybowski) with numerous *Caudammina gigantea* Geroch were described by Sikora and Żytko (1960), Malata (1981) and Oszczypko et al. (2005), and *Saccammina-Placentammina* rich assemblages were noticed by Jednorowska (1968) and Waśkowska et al. (2018, 2021). The species found in the Farony Shale are truly cosmopolitan, and as seen in a recent study of DWAF from an IODP site in the Tasman Sea (Kaminski et al., 2021). The similarity is marked at the levels: taxonomic composition and biofacies.

Generally, the foraminiferal assemblages preserved in the Farony Shale are characterized by low taxonomical diversity and a low number of specimens (Table 1). There is a disproportion between the red and green shales. In red shales exclusively sparse and undifferentiated assemblages are observed. In green shales the abundance and taxonomic diversity is higher. Only the agglutinated cosmopolitan species are present, and formed associations that are not complex. Most of the specimens represent primitive long-ranging foraminifera, generating a very simple test consisting of one or few chambers in a simple arrangement. These types of assemblages in deep water conditions are related to an environment not very favourable for the development of foraminifera. Environmental limitations influenced the structure of the assemblage. Foraminifera developed mostly on the sediment surface as evidenced by the occurrence of almost exclusively epifaunal taxa. They are represented by mobile and nonmobile forms and erect stabile forms. The most common specimens are tubular fragments of *Nothia,* which is a creeping form (Geroch and Kaminski, 1992). Its ecological requirements are extremely low, especially in relation to oxygenation. According to Bubik (2019), the number of *Nothia* specimens (tubular test fragments) does not reflect the true number of organisms, which is significantly (several hundred times) lower. In the assemblages with increased taxonomical diversity, abundant mobile epifauna occurs with the most numerous *Placentammina*, *Saccammina* and *Paratrochamminoides*. Infauna, when it occurs, is represented mainly by *Recurvoides,* which is a genus of high ecological tolerance, and other infaunal forms occur only occasionally. There was an episodic improvement in conditions as seen by occasional more complex and numerous assemblages.

The *Caudammina gigantea-ovulum* acme and the *Saccammina-Placentammina* acme assemblages developed in parallel in the Magura Basin. They have a different structure and developed under the influence of different environmental factors. The *Saccammina-Placentammina* acme occurs in grey mudstones with increased TOC values (0.4–0.5% TOC) (Waśkowska et al., 2018; Waśkowska, 2021). Larger-sized foraminifera that occur in this acme usually occur in low-energy environments with a significant delivery of organic matter. The *Caudammina gigantea* acme prefers carbonate-poor environments with low terrigenous detrital input (Kuhnt et al., 1992). This issue is poorly understood.

CONCLUSIONS

Variegated deposits, known as the Farony Shale, occur within the Ropianka Formation of the Bystrica Subunit in the Magura Nappe in the Rabka-Lubomierz area. They are represented by red shales laminated with green shales, composed of mudstones. The complex of variegated shales is several metres thick and its extend over a distance of 25 km. It stands out distinctly within the thin-medium turbidites of the Ropianka Formation.

The foraminiferal assemblages of the Farony Shale represent two different benthic foraminiferal biofacies: *Caudammina gigantea-ovulum* acme and *Saccammina-Placentammina* acme assemblages. A combined biostratigraphy of acmes and individual taxa ranges indicate a late Campanian–earliest Maastrichtian age (the lower part of the Rzehakina inclusa foraminiferal zone).

The Farony Shale was deposited during a break in the sandy and muddy turbidite sedimentation of the Ropianka Formation. During the period of a limited supply of sandy material to the central part of the Magura Basin, favourable conditions were created for the deposition of low-energy muddy sediments. This sedimentation occurred under conditions of good oxygenation in the bottom of the basin.

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