Paleocene “flysch-type” agglutinated foraminifera from the northern part of the Eastern Carpathians (Romania)

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Abstract. Representative assemblages of agglutinated foraminifera from the Paleocene deposits of the Suha outcrop in the Tarcău Nappe (Eastern Carpathians, Romania) were analyzed using diversity indices, morphogroups and foraminiferal biofacies in order to describe the paleoenvironmental and palaeobathymetrical conditions of the studied area. The results suggest bathyal environments, close to the Carbonate Compensation Depth (CCD) and a flysch type biofacies. The assemblages are dominated by coarsely agglutinated flysch-type taxa: tubular (*Nothia*, *Rhizammina*, *Rhabdammina*), globular (*Saccammina*), flattened planispiral and streptospiral (*Rzehakina*) and flattened streptospiral forms (*Paratrochamminoides* and *Trochamminoides*). The agglutinated foraminifera morphogroups display variations through the section suggesting changes in the amount of organic matter, oxygen and seafloor disturbance caused by the local influence of the turbiditic flows. Based on the presence of the index taxa *Rzehakina fissistomata* throughout the entire section, the deposits were assigned to the Paleocene Izvor Formation.

Keywords: Paleocene, agglutinated foraminifera, biostratigraphy, palaeoecology, Eastern Carpathians.

INTRODUCTION

Paleocene assemblages of agglutinated foraminifera from the Eastern Carpathians (Romania) were mentioned in the Tarcău Nappe (between Suceava and Bistrița valleys) by Ionesi and Todorjescu (1968), Săndulescu (1973), Dicea (1974), Ionesi (1974), Bindiu and Filipescu (2011) and Mare (2014). Similar assemblages from equivalent formations in other areas of the Carpathians were studied by Szczechura and Pozaryska (1974), Morgiel and Olszewska (1981, 1982), Geroch and Nowak (1984), Bubík (1995), Olszewska (1997), Cieszkowski and Waśkowska-Oliwa (2002), Bąk (2004), Oszczyk et al. (2005), Waśkowska-Oliwa (2008), Cieszkowski et al. (2012), Waśkowska et al. (2014).

The aim of this study is to point out the biostratigraphical and paleoenvironmental conditions during the Paleocene based on detailed sampling of a representative section displaying the deposits of the Tarcău Nappe from the northern Moldavides (Săndulescu, 1984). The deposits belong to the Izvor Formation (Ionesi, 1961) of the Tarcău Nappe (Fig. 1) developed along the Suha Valley (Fig. 2), close to its confluence with the Moldova River, near Frasin locality (N 47°31'05.2"; E 25°48'09.6"). The Paleocene turbidites of the Tarcău Nappe are overlapping the Hangu Formation – Upper Cretaceous (Atanasiu, 1939) having the source area in the foreland (Bădescu, 2005).

MATERIAL AND METHODS

The succession consists of alternating centimetric sandstones and silty clays; Tb-c and Tc-e divisions of Bouma sequence were observed on the sandstones. Seventeen samples were collected

from the shales intercalations (Fig. 3) and 250 g of sediment were processed from each sample by standard micropaleontological methods (boiling in water with sodium carbonate, washing over a 63 µm sieve and drying, re-treating with 0.3% hydrogen peroxide in some cases to further disintegrate the clay minerals). Where possible, more than 300 foraminifera were picked from the >63 µm fraction. Two tubular specimens were counted as one individual in order to consider fragmentation.

Primary identification was done under the stereomicroscope, while several specimens were examined in detail with a scanning electron microscope (Hitachi S-4700 - Institute of Geological Sciences, Jagiellonian University, Krakow, Poland).

In order to obtain palaeoecological information, quantitative data (Fisher's α , Shannon, Simpson and Equitability indices – detailed by Murray, 2006) were calculated for the foraminiferal assemblages using the computer software PAST (Hammer et al., 2002).

Palaeoecological methods also included the analysis of agglutinated foraminifera morphogroups (Nagy et al., 1995; Van der Akker et al., 2000; Kaminski & Gradstein, 2005; Cetea et al., 2011; Murray et al., 2011; Setoyama et al., 2011, 2013).

The lithologic log was drawn using the StratDraw application (Hoelzel, 2004) and the abundance of agglutinated morphogroups and calcareous benthic foraminifera graphics with GpalWin application (Goeury, 1997).

Biostratigraphical interpretations are based on several deep-water agglutinated foraminifera zonal schemes (Morgiel and Olszewska, 1981, Geroch and Nowak, 1984; Neagu et al., 1992; Olszewska, 1997). Additional information was provided by planktonic foraminifera (only for sample 1).

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TARCĂU NAPPE					Age		
TARCĂU LITHOFACIES		TAZLĂU LITHOFACIES	DOAMNA LITHOFACIES				
Ardeluța Formation		Lupoaia Formation	Lucăcești sandstone Formation and Globigerina Marls		EOCENE	PRIABONIAN	
Secu Formation		Plopu Formation		Bisericani Formation		BARTONIAN	
<div>Tarcău Formation</div> <div>"basal member"</div>				Doamna - Viteu Limestone			
		"Asterocyclina sandstone"					
		Tazlău Formation		Sucevița Formation			LUTEȚIAN
Sucevița Fm.							
Straja Formation						YPRESIAN	
Izvor Formation		Runcu Formation			PALEOCENE		
Studied section							

Fig. 1. Paleogene lithostratigraphic scheme of the Tarcău Nappe with the location of the studied section (after Ionesi, 1971; Juravle, 2007; Bindiu et al., 2016).

Fig. 2. Simplified geological map and location of the studied section in the investigated area (after Ionesi, 1971).

Fig. 3. Sedimentary log and biostratigraphy of the Suha section.

RESULTS AND DISCUSSIONS

About 98% of the foraminiferal assemblages from the Suha Valley are dominated by deep-water species. Most samples (except for the barren sample 13) contain abundant, well to moderately preserved foraminifera. 92 taxa were identified (Table 1) representing all agglutinated foraminifera morphotypes (Setoyama et al., 2011, 2013).

Types of foraminiferal assemblages

Two different assemblages of foraminifera have been identified in the Suha Valley section:

- Assemblages with agglutinated foraminifera (samples 2-8, 11 and 15) represented by *Nothia excelsa* (Grzybowski), *Psammosiphonella cylindrica* (Glaessner), *Placentamina placenta* (Grzybowski), *Ammolagena clavata* (Johnes & Parker), *Rzehakina fissistomata* (Grzybowski), and *Karrerulina conversa* (Grzybowski).

- Mixed assemblages consisting mostly of agglutinated benthics and rare calcareous benthics and planktonics. Calcareous benthic foraminifera (*Cibicidoides*, *Dentalina*, *Nuttallides*) are sparse (1-2 %) and appear in samples 1, 9, 10, 12, 14, 16, and 17 (Fig. 3). Planktonic foraminifera occur only in the first sample as a few individuals of *Eoglobigerina eobulloides* (Morozova) and *Parasubbotina* spp.

Paleobathymetry

The composition of the assemblages from Suha Valley is similar to those identified in the Polish Carpathians by Cieszkowski and Waśkowska-Oliwa (2002, 2005), and Gasiński and Uchman (2009) and in the Lizard Springs by Kaminski et al. (1988). They seem to be associated with small fluctuations of the CCD level as presence of planktonics and benthics suggest positions just above the CCD, while exclusively agglutinated assemblages lived below the CCD.

The depositional settings were middle to lower bathyal as indicated by the bathymetrically useful species *Ammolagena clavata* (Plate I). This taxa is typical for middle and lower bathyal settings (Kuhnt et al., 2000; Fontanier et al., 2008; Alve et al., 2011; Waskowska, 2014) and has been described from high diversity foraminiferal assemblages from the turbiditic deposits with low terrigenous supply, moderate organic matter flux, as suggested by the relatively high proportions of tubular forms and flysch-type species (Kaminski & Gradstein, 2005). Similar foraminiferal assemblages (dominated by agglutinated forms with low

percentages of calcareous ones) were identified in the Paleocene deposits of the Skole Nappe – Polish Carpathians (Gasinski and Uchman, 2009) which is well known to be stretched in the Ukrainian Carpathians – Skyba Nappe and in the Eastern Romanian Carpathians – Tarcău Nappe (Słaczka et al., 2006). Micropaleontological similarities were also noticed in the Paleocene of the Subsilesian Unit of the Polish Carpathians (Waskowska-Oliwa, 2005, 2008). Based on the micropaleontological analyses and the geological context an affinity of the investigated section with the Skole Nappe is more plausible.

Table 1. Distribution of foraminifera in the examined samples. *R* = rare, 1-3 specimens; *F* = frequent, 4-9 specimens; *C* = common, 10-29 specimens; *A* = abundant, 30 or more specimens.

Litostratigraphic unit	Izvor Formation																
Epoch	lower Paleocene																
Agglutinated foraminifera Zone	<i>Rzehakina fissistomata</i>																
Samples	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Agglutinated foraminifera																	
<i>Ammobaculites agglutinans</i>																	R
<i>Ammobaculites</i> sp.					R		R			F		R					R
<i>Ammodiscus glabratus</i>		F			R		R	F	C	F	R			F	R	F	F
<i>Ammodiscus cretaceus</i>	R						R	R	R	R							
<i>Ammodiscus peruvianus</i>	F	F		F	F	F	F		F	R	R			F	R	F	R
<i>Ammodiscus</i> sp.		F	R						F			F			F		
<i>Ammodiscus tenuissimus</i>	R	F		F	F	F	F	R	F	F	F	R				F	R
<i>Ammolagena clavata</i>					F	F			F	R	R				C		
<i>Ammolagena</i> sp.							R		R					R	C	R	F
<i>Ammosphaeroidinia pseudopauciloculata</i>		C	C	C	C	F	C	F	C	F	C	C		C	C	A	C
<i>Annectina grzybowskii</i>		R					F		R	R					R		
<i>Aschemocella</i> sp.										R							
<i>Bathysiphon</i> sp.	C	F	R	F	R	F			C	F		F		F	F	F	
<i>Budashevaella trinitatensis</i>				F			R					R					
<i>Caudammina excelsa</i>		C	R	C	F	C	C	F	C	F	C	R		F	F	C	R
<i>Caudammina ovula</i>	F	F	R	C	C	R	F	R	F					R			
<i>Caudammina ovuloides</i>		R															
<i>Conglophragmium irregularis</i>					R												
<i>Gaudryina</i> sp.	R																
<i>Gaudryinopsis</i> sp. aff. <i>filiformis</i>	R																
<i>Glomospira charoides</i>							F	R									
<i>Glomospira diffundens</i>		R		F	F		F	R	R	F		R		R	R	R	
<i>Glomospira gordialis</i>	F	R		R	R				F	F	F				F		R
<i>Glomospira irregularis</i>							R					R					
<i>Glomospira serpens</i>	F	R		C	F			R	F	R	R	R			R	R	
<i>Glomospira</i> sp.						F								R		R	R
<i>Haplophragmoides</i> sp.				R				R	R			R			R		
<i>Haplophragmoides stomatus</i>				R													
<i>Haplophragmoides walteri</i>	R				R						R					F	
<i>Hormosina</i> sp.															F	R	F
<i>Hormosina trinitatensis</i>				F				R	R								
<i>Hormosina velascoensis</i>	F	F		R	R	R	F		F	F	R				F		
<i>Hormosinella distans</i>	C			F													
<i>Hormosinella fusiformis</i>				F	F			F									
<i>Hormosinella gutifer</i>									R								
<i>Hyperammina dilatata</i>	F	R		R		R				R		R				F	R
<i>Hyperammina elongata</i>	F													R			R
<i>Hyperammina rugosa</i>	F					F					F				F		
<i>Kalamopsis grzybowskii</i>	R	F	R	F	F		R	F	F	F	C	F			F	F	C

<i>Karrerulina conversa</i>	C	C		C	A	C	C	A	C	C	A	C		C	C	A	C
<i>Karrerulina horrida</i>	F			R	R		F		F		F						F
<i>Lituotuba lituiformis</i>	R			R					R		R				R		
<i>Nothia excelsa</i>	C	C		C	F	C	F	C	C	C	F	C		F	R		
<i>Paratrochamminoides acervulatus</i>	R			F		F	R				R				R		
<i>Paratrochamminoides deflexiformis</i>	R	F		F	R	F	C		F		R			R	F		F
<i>Paratrochamminoides heteromorphus</i>	F	R		C		F			R		F				R		R
<i>Paratrochamminoides mitratus</i>		F	R	F			F		R		R						R
<i>Paratrochamminoides olszewskii</i>	C	F		R	R		F		F		R			R	R		R
<i>Paratrochamminoides sp.</i>		R	R									C		F	R	R	R
<i>Placentamina placenta</i>	A	C	F	C	C	C	C	F	C	C	A	A		F	C	C	C
<i>Protomarssonella sp.</i>			R									F		R			R
<i>Psammosiphonella cylindrica</i>					C	C	C	F	A	A	A				A	A	A
<i>Psammosiphonella discreta</i>					F	F	F	F	C	C	F				F	F	F
<i>Psammosphaera irregularis</i>	C	C	R	F	F	F	F	R	C	F	C	F		F	C	F	F
<i>Psammosphaera sp.</i>																	R
<i>Pseudonodosinella elongata</i>			R	F			R		R	F		R		R			R
<i>Recurvoides anormis</i>		R				F	C		C	F					C		
<i>Recurvoides sp.</i>		C			F	C	R	R	F	R		C		F	R	F	F
<i>Recurvoides walteri</i>	F	C		C	R	C	F	F	F	F				F	R		
<i>Reophax duplex</i>		R		R	R	R	F	R	R		R	R		R	R		F
<i>Reophax globosus</i>					R	R	R	R							R		
<i>Reophax pilulifer</i>				R		R									F		
<i>Reophax subfusiformis</i>											R						
<i>Rhabdammina linearis</i>					R	F			F	F	F				C	F	F
<i>Rhabdammina sp.</i>		F	F	C	C	C	A	C	F	C	C	A		A	C	C	F
<i>Rhizammina indivisa</i>	A			C													
<i>Rhizammina sp.</i>		C			C	C	C	C		C	F	F		C	F		
<i>Rzehakina epigona</i>	R			R		R			R	R							
<i>Rzehakina fissistomata</i>	F	R	R	F	F	R	R		R		R	R		R		R	R
<i>Rzehakina inclusa</i>	R							R									
<i>Rzehakina minima</i>		R	R						R	R	R				R		
<i>Rzehakina sp.</i>												R		F	R	F	F
<i>Saccammina grzybowski</i>	F			C	F	R	F	R	R	R	F				F		R
<i>Saccammina sphaerica</i>		R				F	R				R			R	F		R
<i>Spiroplectammina sagittula</i>										R	R	R		R		R	
<i>Spiroplectammina sp.</i>			R									R		R			F
<i>Spirosgmoilinella compressa</i>												R					
<i>Subreophax longicameratus</i>										F							
<i>Subreophax scalaris</i>	F				R	F	R		F	R	R			R	F		
<i>Textularia sp.</i>										R		R					
<i>Thalmannammina subturbinata</i>	C								F								
<i>Trochammina sp.</i>	F									R							
<i>Trochamminoides dubius</i>				R		R	F			F					R		
<i>Trochamminoides sp.</i>		R										F			R		
<i>Trochamminoides subcoronatus</i>	C	C	C	C		F	C	R	C	R	F			R	F	F	F
<i>Trochamminoides variolarius</i>	C	C					C		F		F			R	R		F
Calcareous benthic foraminifera																	
<i>Cibicidoides velascoensis</i>									R	R		R				R	R
<i>Dentalina sp.</i>	R								R								R
<i>Nuttalides truempy</i>												F		F		F	R
<i>Valvulabamina lenticula</i>																	F
Planktonic foraminifera																	
<i>Eoglobigerina eobulloides</i>	R																
<i>Parasubbotina sp.</i>	R																

The “flysch-type” agglutinated foraminifera biofacies (described by Kaminski et al., 1988 and summarized in Kaminski & Gradstein, 2005) was used to describe bathyal to abyssal environments. For the studied section the deep-water environments are confirmed by the presence of the flysch-type taxa *Rzehakina* spp. and *Caudammina* spp., reported only for this type of environments (Kaminski et al., 1988; Kaminski & Gradstein, 2005; Cetean, 2009; Setoyama et al., 2011).

Agglutinated Foraminiferal Morphotypes & Diversity

All the agglutinated foraminiferal morphotypes are present in the studied section (Fig. 4). M1 (tubular forms – *Nothia* spp., *Rhizammina* sp., *Rhabdammina* sp.), M2a (globular forms – *Placentammina placenta* (Grzybowski), *Saccammina grzybowskii* (Schubert), M3c (flattened streptospiral – *Ammosphaeroidina pseudopauciloculata* (Mjatluk), *Paratrochamminoides* spp., *Trochamminoides* spp.), and M4b (elongate subcylindrical/tapered – *Karrerulina conversa* (Grzybowski), *K. horrida* (Mjatluk)) consistently dominate the assemblages and have a uniform distribution along the section. The only exception is sample 3 where M3c morphotype records high values. The other morphotypes (M2b, M2c, M3a, and M4a) display low values throughout the section. An important event can be observed in sample 15 where the flattened irregular *Ammolagena* (M3b) shows a peak.

The diversity values (Fisher's α , Shannon, Simpson, and Equitability) show a positive correlation throughout the section (Fig. 5). Higher values of these indices (samples 2, 9, 15, and 17) suggest favorable conditions with high supply of organic matter and low energy of the bottom water; this is also supported by the presence of all the morphotypes in high proportions at these intervals (Fig. 4). The *Ammolagena clavata* (Jones & Parker) taxa is an attached form and it was found on the surface of the tests of tubular and planispiral agglutinated forms such as *Rhabdammina* sp. and *Ammodiscus* sp. The taxa was found in samples (Table 1) where the diversity indices displayed relatively high values (Fig. 5) suggesting favourable environmental conditions with a low terrigenous supply (Waskowska, 2014). Similar paleoenvironmental conditions reflected by high diversity assemblages with *Ammolagena clavata* (Jones & Parker) together with *Psammosiphonella*, *Bathysiphon*, *Placentammina* and *Paratrochamminoides* were described by Waskowska (2014) from the Polish Carpathians (Magura Nappe and Skole Nappe).

Average values of the diversity (values between 10–14) in four samples (4, 5, 6, 7, 11, and 12) corresponds to transitional intervals and indicate moderate organic matter flux, energy and oxygen content at the sea floor. Low diversity values (as seen in samples 3, 8, 14, and 16) correspond to “stressed” environmental conditions with high organic carbon content and low oxygenated bottom sediments; this is confirmed by the darker color of the sediments. A high abundance of M3c (dominated by *Ammosphaeroidina pseudopauciloculata* (Mjatluk)) can be observed in sample 3 (Fig. 4) corresponding to a low diversity. A similar situation was described from the lower Paleocene deposits of Lizard Springs (Kaminski et al., 1988) and was assigned to a deepening of the deposition, near the CCD.

Biostratigraphy

Several stratigraphical zonations based on DWAF were proposed for the Cretaceous to Paleogene deposits of the Outer (Flysch) Carpathians by Morgiel and Olszewska (1981), Geroch and Nowak (1984), Neagu et al. (1992), and Olszewska (1997). These zones can be well applied to the Suha Valley section (clearly dominated by agglutinated foraminifera). The presence of *Rzehakina fissistomata* (Grzybowski) – Plate II was observed in all of the studied samples and allows framing the studied section to the *Rzehakina fissistomata* Zone of the Paleocene interval. The occurrence of the index taxa represents a clear indicative of the Paleocene interval and it is commonly used in micropaleontological biozones of deep water Tethyan deposits (Jurkiewicz, 1967; Săndulescu, 1973, 1975; Ionesi, 1974; Neagu et al., 1992; Malata et al., 1996; Bąk et al., 1997; Bubik et al., 1999; Bąk, 2004; Oszczyk et al., 2005; Waskowska-Oliwa, 2005, 2008; Bindiu and Filipescu, 2011; Waskowska, 2014). Individuals of *Recurvoides* div. sp., *Paratrochamminoides* div. sp., *Trochamminoides* div. sp., *Hormosina velascoensis* (Cushman), *Glomospira diffundens* Cushman & Renz, *Kalamopsis grzybowskii* (Dyląganka), *Haplophragmoides walteri* (Grzybowski),

Fig. 4. Agglutinated foraminifera morphotypes (M1 - tubular; M2a - globular; M2b - rounded trochospiral and streptospiral/planconvex trochospiral; M2c - elongate keeled; M3a - flattened trochospiral/flattened planispiral and streptospiral; M3b - flattened irregular; M3c - flattened streptospiral; M4a - rounded planispiral; M4b - elongate subcylindrical/elongate tapered) and relative abundance (% of the assemblage) of calcareous benthic foraminifera.

Fig. 5. Diversity indices at the Suha Valley section.

Karrerulina conversa (Grzybowski), *Ammosphaeroidina pseudopauciloculata* (Mjatliuk) resemble similar Paleocene assemblages from Lizard Springs (Kaminski et al., 1988) and Outer Polish Carpathians (Cieszkowski and Waškowska-Oliwa, 2002).

The species *Eoglobigerina eobulloides* (Morozova) and *Parasubbotina* sp. have been recognized among the sparse and poorly preserved planktonic forms from sample 1. Their presence is typical for assemblages of early Paleocene (Olsson et al., 1999; Premoli-Silva et al., 2003) and confirms that the lowermost part of the studied deposits belong to the Paleocene Izvor Formation. Unfortunately, the low percentages of planktonic foraminifera do not allow more precise biostratigraphical interpretation.

CONCLUSIONS

New biostratigraphical and paleoenvironmental data were provided for the northern part of the Tarcău Nappe (Izvor Formation) based on agglutinated foraminifera.

The age of the analysed foraminiferal assemblages from the Izvor Formation of the Tarcău Nappe was established on the basis of the occurrence of the *Rzehakina fissistomata* (Grzybowski) taxa in all the samples. Therefore the data allow correlation support for the Izvor Formation by assigning the deposits to the Paleocene *Rzehakina fissistomata* Zone.

The alternating intervals containing only agglutinated taxa and intervals with rare calcareous benthic and planktonic foraminifera suggest bathyal environments with small fluctuations of the CCD level.

The variable morphotypes distribution together with oscillating diversity throughout the section suggests changes in the amount of oxygen, organic matter and energy at the sea floor probably caused by the local influence of the turbiditic flows.

The occurrence of *Ammolagena clavata* (Jones & Parker) in rich and relatively well diversified assemblages together with the presence of characteristic representatives of “flysch type” biofacies indicate middle to lower bathyal settings for the studied deposits.

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REFERENCES

- Alve, E., Murray, W. & Skei, J., 2011, Deep sea benthic foraminifera, carbonate dissolution and species diversity in Hardangerfjord, Norway: An initial assessment. *Estuarine, Coastal and Shelf Science*, 92: 90-102. <http://dx.doi.org/10.1016/j.ecss.2010.12.018>
- Atanasiu, I., 1939, Contributions á la stratigraphie et la tectonique du flysch marginal moldave. *Annalele Ştiinţifice ale Universităţii A. I. Cuza Iaşi*, 25 (1): 320-327.
- Bădescu, D., 2005, *Tectono-stratigraphical evolution of the Eastern Carpathians in the Mesozoic and Neozoic*. Editura Economică, Bucureşti, 311 p. (In Romanian).

- Båk, K., 2004, Deep-water agglutinated foraminiferal changes across the Cretaceous/Tertiary and Paleocene/Eocene transition in the deep flysch environment; eastern Carpathians (Bieszczady Mts, Poland). In *Proceedings of the 6th International Workshop on Agglutinated Foraminifera* (Bubík, M., Kaminski, M.A., Eds.). *Grzybowski Foundation Special Publication*, 8: 1-56.
- Båk, K., Båk, M., Geroch, S. & Manecki, M., 1997, Biostratigraphy and paleoenvironmental analysis of benthic foraminifera and radiolarians in Paleogene variegated shales in the Skole Unit, Flysch Carpathians. *Annales Societatis Geologorum Poloniae*, 67: 135-154. http://www.asgp.pl/sites/default/files/volumes/67_2-3_135_154.pdf
- Bindiu, R. & Filipescu, S., 2011, Agglutinated foraminifera from the Northern Tarcău Nappe (Eastern Carpathians, Romania). *Studia UBB, Geologia*, 56 (2): 31-41. <http://dx.doi.org/10.5038/1937-8602.56.2.4>
- Bindiu, R., Filipescu, S., Bălc, R., Cociș, L. & Gligor, D., 2016, The Middle/Late Eocene transition in the Eastern Carpathians (Romania) based on foraminifera and calcareous nannofossil assemblages. *Geological Quarterly*, 60 (1): 38-55. <http://dx.doi.org/10.7306/gq.1237>
- Bubík, M., 1995, Cretaceous to Paleogene agglutinated foraminifera of the Bile Karpaty Unit (West Carpathians, Czech Republic). In *Proceedings of the 4th International Workshop on Agglutinated Foraminifera* (Kaminski, M.A., Geroch, S. & Gasiński, M.A., Eds.). *Grzybowski Foundation Special Publication*, 3: 71-116.
- Bubík, M., Båk, M. & Svabenická, L., 1999, Biostratigraphy of the Maastrichtian to Paleocene distal flysch sediments of the Raca Unit in the Uzgrun section (Magura Group of nappes, Czech Republic). *Geologica Carpathica*, 50: 33-48.
- Buzas, M.A. & Gibson, T.G., 1969, Species diversity: benthonic foraminifera in Western North Atlantic. *Science*, 163: 72-75. <http://dx.doi.org/10.1126/science.163.3862.72>
- Cetean, C.G., 2009, *Cretaceous foraminifera from the southern part of the Eastern Carpathians, between Stoenesti and Cetățeni. Paleoecology and biostratigraphy*. Unpublished PhD Thesis, Universitatea "Babes-Bolyai", Cluj-Napoca, 212 p.
- Cetean, C., Balc, R., Kaminski, M.A. & Filipescu, S. 2011, Integrated biostratigraphy and palaeoenvironments of an upper Santonian – upper Campanian succession from the southern part of the Eastern Carpathians, Romania. *Cretaceous Research*, 32: 575-590. <http://dx.doi.org/10.1016/j.cretres.2010.11.001>
- Cieszkowski, M. & Waśkowska-Oliwa, A., 2002, Development and biostratigraphy of the Paleogene Gorzeń beds, Subsilurian Unit, Outer Carpathians, Poland. *Geologica Carpathica*, 53: 57-59.
- Cieszkowski, M., Golonka, J. & Waśkowska, A., 2012, An olistolith interpretation for the Paleocene Szydłowiec sandstones in the stratotype area (Outer Carpathians, Poland). *Austrian Journal of Earth Sciences*, 105 (1): 240-247. http://www.univie.ac.at/ajes/archive/volume_105_1/cieszkowski_et_al_ajes_v105_1.pdf
- Dicea, O., 1974, The geological study of the Voroneț - Suha Mică – Platonîța area. *Studii tehnice și economice., Seria J, Stratigrafie*, 11: 1-143.
- Fontanier, C., Jorissen, F.J., Lansard, B., Mouret, A., Buscail, R., Schmidt, S., Kerherve, P., Buron, F., Yaragosi, S., Hunault, G., Ernoult, E., Artero, C., Anschutz, P. & Rabouille, C., 2008, Live foraminifera from the open slope between Grand Rhone and Petit Rhone Canyons (Gulf of Lions, NW Mediterranean). *Deep Sea Research*, 55: 1532-1553. <http://dx.doi.org/10.1016/j.dsr.2008.07.003>
- Geroch, S. & Nowak, W., 1984, Proposal of a zonation for the late Tithonian-late Eocene, based upon arenaceous foraminifera from the outer Carpathians, Poland. In *Benthos '83: 2nd International Symposium on Benthic Foraminifera, Pau (France)*, (Oertli, H., Ed.), April 11-15, 1983, Elf Aquitaine, ESSO REP and TOTAL CFP, Pau and Bourdeaux, 225-239.
- Goeury, C., 1997, GpalWin: gestion, traitement et représentation de la paléocéologie. *XV-ème Symposium de l'APLF (Association des Palynologues de Langue Française)*, Université Claude Bernard, Lyon, 31 p.
- Ślaczka, A., Kruglov, S., Golonka, J., Oszczytko, N. & Popadyuk, I., 2016, Geology and hydrocarbon resources of the Outer Carpathians, Poland, Slovakia and Ukraine. General geology. In *The Carpathians and their foreland geology and hydrocarbon resources*. (Golonka J. & Picha, F.J., Eds.). American Association of Petroleum Geologists, 84: 221-258.
- Hammer, O., Harper, D.T., Ryan, P.D., 2002. PAST-Palaeontological Statistics software package for education and data analysis, ver. 0.93, *Palaeontologica Electronica*, 4 (1): 1-9.
- Hoelzel, M., 2004, StratDraw: automatic generation of stratigraphic sections from tabulated field data. *Computers & Geosciences*, 30 (7): 785-789. <http://dx.doi.org/10.1016/j.cageo.2004.05.004>
- Ionesi, L., 1961, The geology of the Gura Humorului–Poiana Micului area. *Analele Științifice ale Universității "A. I. Cuza" Iași*, 7 (2): 355-382. (In Romanian)
- Ionesi, L., 1971, *The Paleogene from the Moldova Valley Basin*. Editura Academiei Republicii Socialiste România. 250 p. (In Romanian).
- Ionesi, L., 1974, The Paleocene from the External Carpathian Flysch. *Analele Științifice ale Universității "A. I. Cuza" Iași*, XX: 93-100. (In Romanian).
- Ionesi, L. & Tocorjescu, M., 1968, Microfaunistic data on the Upper Cretaceous-Paleogene boundary in the External Flysch from the Moldova Valley basin. *Analele Științifice ale Universității "A. I. Cuza" Iași*, 18 (2): 61-68. (In Romanian).
- Juravle, D.T., 2007, *The geology between the Suceava and Putna valleys*. Casa Editorială Demiurg, Iași, 319 p. (In Romanian).
- Jurkiewicz, H., 1967, Foraminifers in the sub-Menilitic Paleogene of the Polish Middle Carpathians. *Biuletyn Instytutu Geologicznego*, 210: 5-116.
- Kaminski, M.A., Gradstein, F.M., Berggren, W.A., Geroch, S. & Beckmann, J.P., 1988, Flysch-type agglutinated foraminiferal assemblages from Trinidad: taxonomy, stratigraphy and paleobathymetry. In *Proceedings of the 2th Workshop on Agglutinated Foraminifera* (Rögl, F. & Gradstein, F.M., Eds.), Vienna 1986: *Abhandlungen der Geologischen Bundesanstalt*, 41: 155-228.

- Kaminski, M.A. & Gradstein, F.M. and collaborators, 2005, Atlas of Paleogene cosmopolitan deep-water agglutinated foraminifera. *Grzybowski Foundation Special Publication*, 10, 574 p.
<http://dx.doi.org/10.2113/gsmicropal.52.6.555>
- Kuhnt, W., Collins, E. & Scott, D. B., 2000, Deep water agglutinated foraminiferal assemblages across the Gulf Stream: Distribution patterns and taphonomy. In *Proceedings of the 5th International Workshop on Agglutinated Foraminifera* (Hart, M.B., Kaminski, M.A. & Smart, C.W., Eds.). *Grzybowski Foundation. Special Publication*, 7: 261-298.
- Malata, E., Malata, T. & Oszczykko, 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.
http://www.asgp.pl/sites/default/files/volumes/66_3-4_269_284.pdf
- Mare, S., 2014, The Paleocene assemblages of agglutinated foraminifera from deep-water deposits of the northern Tarcu Nappe (Eastern Carpathians, Romania). *Acta Mineralogica-Petrographica, Abstract Series*, 8: 80.
- Morgiel, J. & Olszewska, B., 1981, Biostratigraphy of the Polish external Carpathians based on agglutinated foraminifera. *Micropaleontology*, 27 (1): 1-24.
<http://dx.doi.org/10.2307/1485376>
- Morgiel, J. & Olszewska, B., 1982, Uniformity of the Tethyan faunas from Cretaceous and Palaeogene as shown by foraminifera from Morocco and Polish Flysch Carpathians. *Cahiers du Micropaléontologie*, 3: 45-33.
- Murray, J., 2006, *Ecology and applications of benthic foraminifera*. Cambridge University Press, 462 p.
<http://dx.doi.org/10.1017/CBO9780511535529>
- Murray, J., Alve, E. & Jones, B., 2011, A new look at modern agglutinated benthic foraminiferal morphogroups: their value in palaeoecological interpretation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 309: 229-241.
<http://dx.doi.org/10.1016/j.palaeo.2011.06.006>
- Nagy, J., Gradstein, F.M., Kaminski, M.A. & Holbourn, A.E., 1995, Foraminiferal morphogroups, paleoenvironments and new taxa from Jurassic to Cretaceous strata of 41 Thakkhola, Nepal. In *Proceedings of the 4th International Workshop on Agglutinated Foraminifera* (Kaminski, M.A., Geroch, S., Gasinski, M., A., Eds.). *Grzybowski Foundation Special Publication*, 3: 181-209.
- Neagu, T.H., Platon, E., Dumitrescu, G. & Seale, L., 1992, The biostratigraphical significance of agglutinated foraminifera in the Eastern Carpathians (Upper Cretaceous). *Analele Universității București*, 15-16: 45-49.
- Olsson, R.K., Hemleben, C., Berggren, W. & Huber, C., 1999, Atlas of paleocene planktonic foraminifera. *Smithsonian Contributions to Paleobiology*, 85: 1-252.
- Olszewska, B., 1997, Foraminiferal biostratigraphy of the Polish Outer Carpathians: a record of basin geohistory. *Annales Societatis Geologorum Poloniae*, 67 (2-3): 325-337.
http://www.asgp.pl/sites/default/files/volumes/67_2-3_325_337.pdf
- Oszczypko, N., Malata, E., Bąk, K., Kędzierski, M. & Oszczypko-Clowes, M., 2005, Lithostratigraphy and Biostratigraphy of the Upper Albian–Lower / Middle Eocene flysch deposits in the Bystrica and Rača subunit of the Magura Nappe (Beskid Wyspowy and Gorce Ranges; Poland). *Annales Societatis Geologorum Poloniae*, 75: 27-69.
http://www.asgp.pl/~asgp/sites/default/files/volumes/75_1_027_069.pdf
- Premoli-Silva, I., Rettori, R. & Verga, D., 2003, Practical Manual of Paleocene and Eocene planktonic Foraminifera. In *International School on Planktonic Foraminifera, 2^o Course: Paleocene and Eocene* (Rettori, R., Verga, D., Eds.). Dipartimento di Scienze della Terra, Università di Perugia, 152 p.
- Săndulescu, J., 1973, Étude micropaléontologique et stratigraphique du flysch du Crétacé supérieur – Paléocène de la région de Brețcu – Comandău (Secteur intern meridional de la Nappe de Tarcău – Carpates Orientales). *Memoriile Institutului Geologic*, XVII: 1-52.
- Săndulescu, J., 1975, Microbiostratigraphie, associations et zones a foraminifères du Crétacé du Flysch Externe des Carpates Orientales (Roumanie). *Revista Espagnola de Micropaleontologia*, VII (1): 99-111.
- Săndulescu, M., 1984, *Geotectonics of Romania*. Editura Tehnică, Bucharest, 334 p. (In Romanian).
- Setoyama, E., Kaminski, M.A. & Tyska, J., 2011, The Late Cretaceous–Early Paleocene palaeobathymetric trends in the southwestern Barents Sea - Palaeoenvironmental implications of benthic foraminiferal assemblage analysis. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 307 (1-4): 44-58. <http://dx.doi.org/10.1016/j.palaeo.2011.04.021>
- Setoyama, E., Radmacher, W., Kaminski, M.A. & Tyska, J., 2013, Foraminiferal and palynological biostratigraphy and biofacies from a Santonian - Campanian submarine fan system in the Voring Basin (offshore Norway). *Marine and Petroleum Geology*, 43: 396-408.
<http://dx.doi.org/10.1016/j.marpetgeo.2012.12.007>
- Szczuchura, J. & Pozaryska, K., 1974, Foraminifera from the Paleocene of Polish Carpathians (Babice Clays). *Paleontologica Polonica*, 31: 1-142.
http://palaeontologia.pan.pl/Archive/1974_31.pdf
- Van Der Akker, T., Kaminski, M.A., Gradstein, F.M. & Wood, J., 2000, Campanian to Palaeocene biostratigraphy and palaeoenvironments in the Foula Basin, west of Shetland Islands. *Journal of Micropalaeontology*, 19: 23-43.
<http://dx.doi.org/10.1144/jm.19.1.23>
- Wąskowska-Oliwa, A., 2005, Foraminiferal palaeodepth indicators from the lower Palaeogene deposits of the Subsilesian Unit (Polish Outer Carpathians). *Studia Geologica Polonica*, 124: 297-324.
http://sgp.ing.pan.pl/124_pdf/SGP124_285-295.pdf
- Wąskowska-Oliwa, A., 2008, The Paleocene assemblages of agglutinated foraminifera from deep-water basin sediments of the Carpathians (Subsilesian Unit, Poland) – biostratigraphical remarks. In *Proceedings of the 7th International Workshop on Agglutinated foraminifera* (Kaminski, M.A. & Coccioni, R., Eds.). *Grzybowski Foundation, Special Publication*, 13: 227-265.

- Waśkowska, A., 2014, Distribution of the agglutinated foraminifera *Ammolagena clavata* (Jones & Parker) in Western Tethyan Upper Cretaceous and Paleogene deep-water deposits (Outer Carpathians, Poland). *Micropaleontology*, 60 (1): 77-88.
- Waśkowska, A., Cieszkowski, M., Golonka, J. & Kowal-Kasprzyk, J., 2014, Paleocene sedimentary record of ridge geodynamics in Outer Carpathians basins (Subsilesian Unit). *Geologica Carpathica*, 65 (1): 35-54.
<http://dx.doi.org/10.2478/geoca-2014-0003>

Plate I.

Fig. 1. - *Rhabdammina* sp. – Sample 2;

Fig. 2. - *Rhabdammina linearis* Brady, 1879 – Sample 15;

Fig. 3. - *Placentamina placenta* (Grzybowski, 1898) – Sample 6;

Fig. 4. - *Saccammina grzybowskii* (Schubert, 1902) – Sample 4;

Fig. 5. - “*Hyperammina dilatata*” Grzybowski, 1896 - Sample 2;

Fig. 6. - *Ammodiscus cretaceous* (Reuss, 1845) – Sample 12;

Fig. 7. - *Ammolagena clavata* (Jones & Parker, 1860) on *Ammodiscus* sp. – Sample 7;

Fig. 8. - *Ammodiscus peruvianus* Berry, 1928 – Sample 7;

Fig. 9. - *Annectina grzybowskii* (Jurkiewicz, 1960) – Sample 5;

Fig. 10. - *Glomospira* sp. – Sample 5;

Figs. 11 – 13. - *Ammolagena clavata* (Jones & Parker, 1860) on *Rhabdammina* sp. - Sample 15. Scale bar: 200 microns.

Plate II.

Figs. 1 – 4. - *Rzehakina fissistomata* (Grzybowski, 1901) – Samples 1, 3, 16, 17;

Fig. 5. - *Hormosina velascoensis* (Cushman, 1926) – Sample 2;

Fig. 6. - *Kalamopsis grzybowskii* (Dyląganka, 1923) – Sample 4;

Fig. 7. - *Reophax globosus* Sliter, 1968 – Sample 15;

Fig. 8. - *Reophax duplex* Grzybowski, 1896 – Sample 8;

Fig. 9. - *Subreophax scalaris* (Grzybowski, 1896) – Sample 15;

Fig. 10. - *Lituotuba lituiformis* (Brady, 1879) – Sample 3;

Fig. 11. - *Paratrochamminoides mitratus* (Grzybowski, 1901) – Sample 4;

Fig. 12. - *Paratrochamminoides deflexiformis* (Noth, 1912) – Sample 12;

Fig. 13. - *Trochamminoides variolarius* (Grzybowski, 1898) – Sample 10;

Fig. 14. - *Recurvoides* sp. – Sample 6;

Fig. 15. - *Karrerulina* sp. – Sample 16. Scale bar: 200 microns