LOWER CRETACEOUS CALCAREOUS NANNOFOSSILS OF THE ROMANIAN CARPATHIAN BEND

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Abstract. We have studied two successions located at the southern end of the Eastern Carpathians. Lithologically, the investigated sections are represented by calcareous turbidites. These successions have been thoroughly sampled (3 samples/1m) for calcareous nannofossil investigations. The oldest studied section is Berriasian in age, while the youngest was sedimented during the late Valanginian-early Hauterivian interval. Across the Valanginian-Hauterivian boundary interval, we identified several nannofossils such as *Rucinolithus wisei*, *Rucinolithus pinnatus*, *Eiffellithus windii*, *Diloma galiciense*, and *Lithraphidites bollii*, with biostratigraphic significance. The observed calcareous nannofossil assemblages are mainly composed of *Watznaueria barnesiae* and taxa largely confined to the Tethyan Realm, such as *Nannoconus* spp., *Cruciellipsis cuvillieri*, *Calcicalathina oblongata*, *Diazomatholithus* spp. and *Rucinolithus* spp.

Key words: Berriasian-Hauterivian; nannofossil biostratigraphy; Eastern Carpathians

1. INTRODUCTION

The calcareous nannoplankton represents a major component of the oceanic phytoplankton. Nowadays, coccolithophores are abundant throughout the oceans, and can be found from tropical to sub-arctic waters, even where the water temperature drops below 0°C. The coccolithophores life is related to the photic zone, the maximum abundance being recorded at 50 m water depth (Tappan, 1980). As most of the planktonic organisms, this group highly reflects environmental changes, i.e., light, salinity, temperature, sea-level, ocean productivity, nutrients, and geochemistry modifications on the surface-waters (Perch-Nielsen, 1985; Young, 1994; Rost and Riebesell, 2004, among many others).

The calcareous nannofossils were firstly identified in Upper Triassic sediments (i.e., Bown, 2005a; Gardin *et al.*, 2012), but this group of organisms started to substantially contribute to the biogenic carbonate production in the oceans since the Middle Jurassic (i.e., Roth, 1989). Several authors, such as Deflandre (1970), Pirini Radrizzani (1971), Gartner and Gentile (1972), and Shumenko (2001), reported the presence of this phytoplankton group since the Palaeozoic, but there is no certain evidence of such old calcifying haptophytes. These algae diversify upwards the Jurassic-Cretaceous boundary interval, and since then they are responsible for a huge accumulation of biogenic $CaCO_3$ on the ocean floor (i.e., Erba and Tremolada, 2004; Suchéras-Marx *et al.*, 2019).

From the Tithonian-Berriasian boundary interval, an important radiation took place in the nannoplankton world, expressed in the occurrence of new genera and species (Roth, 1978; Perch-Nilesen, 1985; Bown *et al.*, 1998, among many others). The Lower Cretaceous nannofossils showed a significant palaeolatitudinal provincialism related to the two Cretaceous realms, the Tethys and the Boreal. (i.e., Bralower *et al.*, 1989; Mutterlose, 1991; Aguado *et al.*, 2000; Erba, 2004; Mutterlose *et al.*, 2005).

These associations are known to occur in the Eastern Carpathians broad sedimentary successions, covering the whole Early Cretaceous interval (Murgeanu *et al.*,1963; Patrulius and Avram, 1976; Patrulius *et al.*, 1976; Săndulescu, 1988), but only a few of them have been studied for their calcareous nannofossil content. The previous investigated turbidites of the Eastern Carpathians, along with the hemiplegic sediments of the Southern Carpathians were proved to contain well preserved and diversified nannofossil assemblages, covering several Early Cretaceous intervals (Avram and Melinte, 1998; Melinte and Mutterlose, 2001; Barragán and Melinte, 2006; Melinte-Dobrinescu and Jipa, 2007).

This paper aims to complete the data concerning the Lower Cretaceous distribution pattern of calcareous nannofossil from the Romanian Carpathian Bend (Fig. 1). A palaeogeographic approach is also accomplished herein.

2. GEOLOGICAL BACKGROUND

The Romanian Carpathians are part of the Alpine system, extending on more than 1,300 km. The nappes of the Romanian Carpathians were grouped into several major units, based on the age of their deformation and mutual areal position (Săndulescu, 1984 and 1994), as it follows: (i) the Transylvanides and the Dacides (both nappe systems mainly deformed during Late Cretaceous times), (ii) the Moldavides (which were mainly folded during the Early Miocene), and (iii) the Pienides (which underwent the effects of two main tectonic phases, during Late Cretaceous and Early Miocene times) (Fig. 1).

The Eastern Carpathian chain represents an arched orogen with a complex structure wherein the flysch nappes modify their trend with 200° from the northernmost area (Poland) down to the south, in the belt zone of Romania. This belt consists of thin-skinned nappes, basement nappes in its western part, and mainly Cretaceous to Paleogene turbidites, followed by Miocene to Quaternary molasse deposits in their central and eastern parts. Imbrication and internal deformation of the nappes took place in several periods of deformation from the Late Cretaceous to Quaternary times (Săndulescu, 1984; Jipa, 1984; Ştefănescu and Micu, 1987; Maţenco *et al.*, 1997, 2007; Roban *et al.*, 2020, Jipa *et al.*, 2020).

The nappes cropping out in the Eastern Carpathians are comprised in the Outer Dacides (inner, western part) and Moldavides (outer, eastern part - Fig.1). The Outer Dacides are represented by two nappes (from W towards E): Ceahlău and Bobu (Săndulescu,1988; Bădescu, 2005). The former tectonic unit occurs from the N part of Romania, in the whole Eastern Carpathian bend, while the latter crops out only in the southern part of the Eastern Carpathians.

The most widespread tectonic unit of the Outer Dacides is the Ceahlău Nappe (Fig. 2), which consists of several tectonic subunits, such as (from W to E) Bratocea, Comarnic,

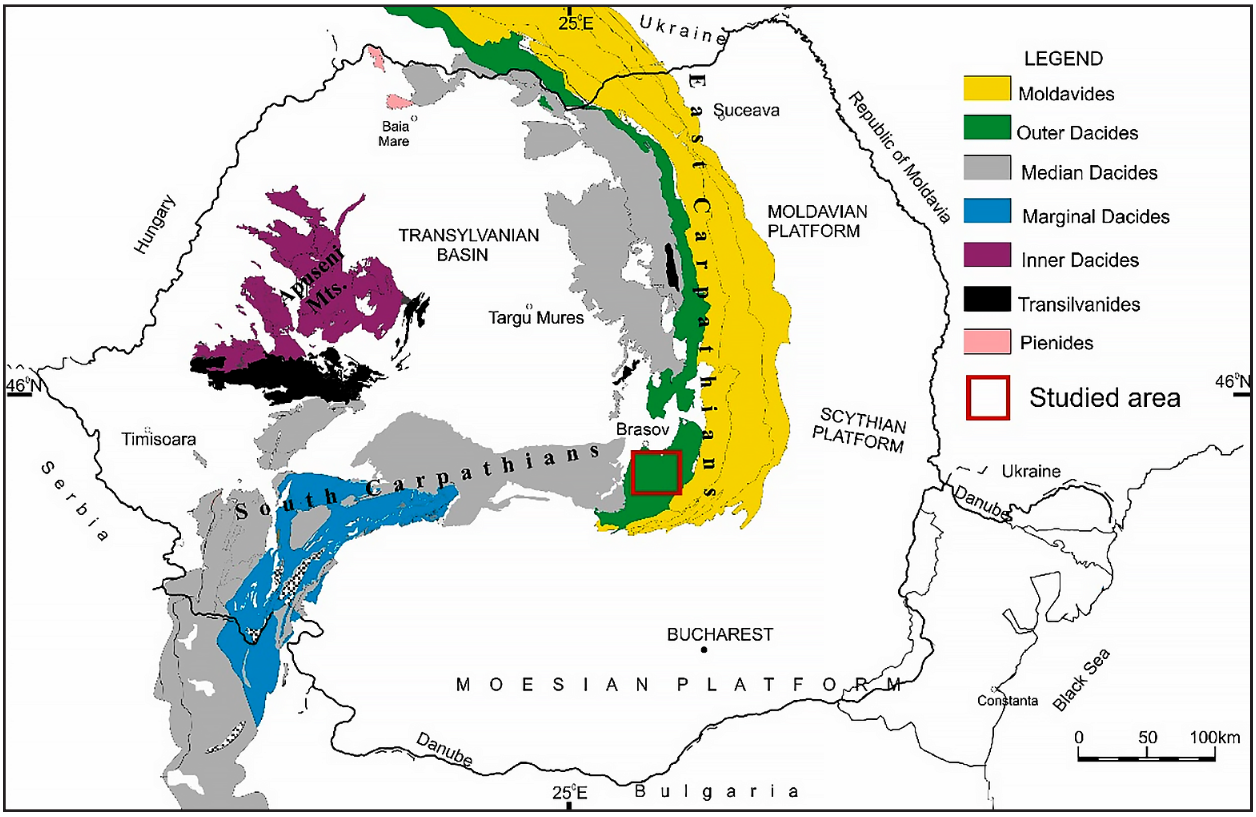

Fig. 1. Tectonic map of Romania (modified and simplified after Săndulescu, 1984), showing the location of the studied area.

Secăria, Ciuc, and Bodoc (Săndulescu, 1994; Ştefănescu, 1995). Bratocea, the innermost (western) tectonic subunit of the Ceahlău Nappe, largely occurs in the southern Eastern Carpathians, especially in the Prahova Valley basin (Fig. 2), and contains several Cretaceous lithostratigraphic units.

The Upper Jurassic-Lower Cretaceous depositional interval defines the Sinaia Formation, which is divided into three members (Murgeanu *et al.*, 1963; Patrulius, 1969; Patrulius *et al.*, 1976): (1) the Lower Member ('Shaly' Member); (2) the Middle Member ('Sandy-Calcareous' Member); (3) the Upper Member ('Lamellaptychus angulicostatus' Member). Towards the base of the Sinaia Formation, red and green shales are occurring, usually bearing mafic igneous rocks of the Azuga Formation. This unit interfingers with the upper part of the Lower Member and the lower part of the Middle Member of the Sinaia unit. According to micropalaeontological studies, i.e., foraminifers, calpionellids, and calcareous nannofossils (Patrulius, 1969; Neagu, 1972; Pop, 1997; Melinte and Jipa, 2007), the Tithonian-Berriasian boundary is placed in the Lower Member of the Sinaia Formation (Fig. 3).

The Sinaia unit is covered by the Piscu cu Brazi Formation (Fig. 3), consisting of sandstones, alternating with shales, which occurs only in the inner part of the Bratocea tectonic subunit. In the outer part of Bratocea tectonic subunit, within the stratigraphic interval corresponding to the sedimentation of the Piscu cu Brazi Formation, the facies underwent several changes leading to three lithostratigraphic entities that could be distinguished: Comarnic, Vârful Rădăcinii, and the 'Sandy Shaly Flysch' unit (Fig. 3). All lithostratigraphic units above-described are siliciclastic turbidites.

The Lower Cretaceous turbidites are discordantly covered by a pile of conglomerates and coarse sandstones, namely the Bucegi Formation. Frequently breccia levels were deposited at the base of the conglomerates.

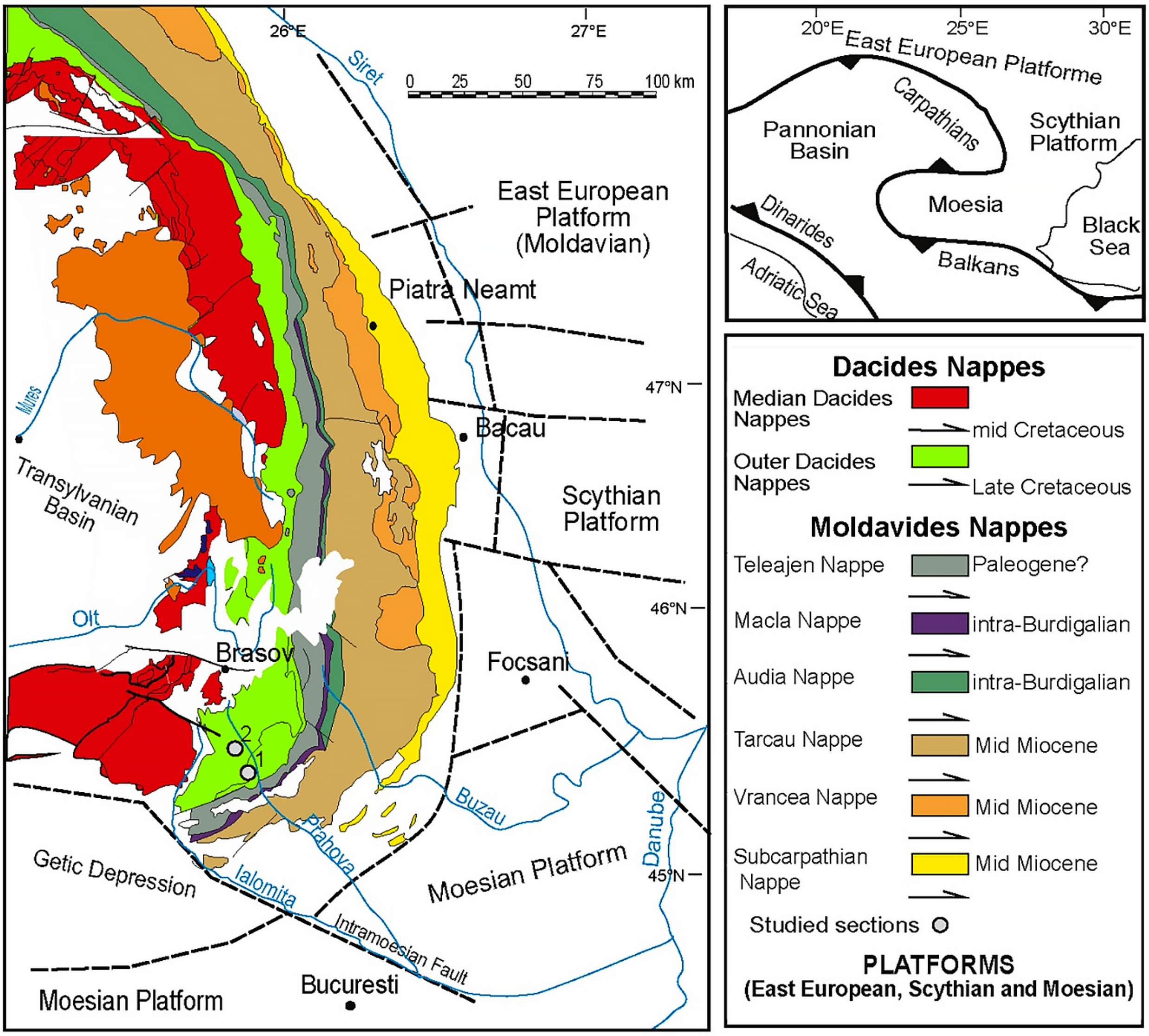

Fig. 2. Location of the studied section along the Prahova Valley; **1** - Podul lui Neag; **2** - Sinaia Penny. Geological map after Săndulescu, 1984 and Bădescu, 2005.

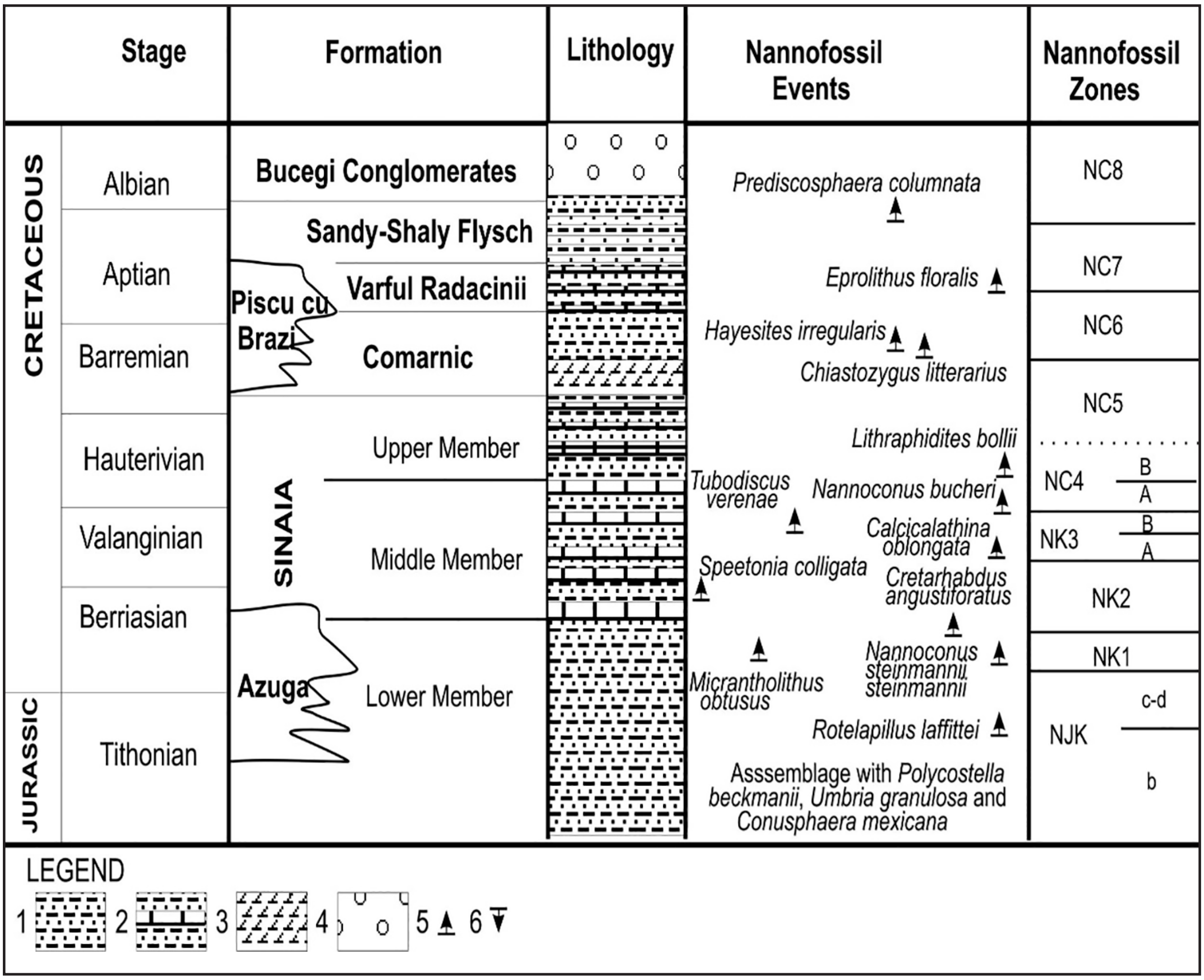

Fig. 3. Lithology and biostratigraphy of the Lower Cretaceous of the Ceahlău Nappe cropping out in the Eastern Carpathians. *Legend*: **1** - turbidites; **2** - limestones; **3** - marlstones; **4** - conglomerates; **5** - first occurrence; **6** - last occurrence. Calcareous nannofossil zones NJK and NK after Bralower *et al.* (1989); NC after Roth (1983) – modified after Melinte and Jipa, 2007.

The conglomerates of the Bucegi unit were initially regarded as molasse deposits, i.e., the oldest post-tectonic cover, occurring due to Meso-Cretaceous tectonics (Săndulescu, 1984). Recent studies (Olariu *et al.*, 2014) assumed that this unit was syntectonical sedimented in a shallow to deep-water basin regime.

3. MATERIAL AND METHODS

We have studied two successions of the Sinaia unit, situated in the Prahova Valley (southern Eastern Carpathians) (Fig. 2). The two successions presented herein are placed in the right bank of the Prahova Valley. The southern one – Podul lui Neag (Section 1 in Fig. 2) is made of strongly folded 6.8 m-thick turbidites, a feature of the Middle Member of the Sinaia Formation encountered in all the Eastern Carpathian chain (Fig. 4). Truncated Bouma sequences, consisting of cm to dm-thick grey calcareous sandstones, showing horizontal- and cross-laminated structures, along with claystones and marlstones, are present. The succession grades-up from sandy turbidites to the topmost turbidites, capped by marlstones and even limestones.

The northern investigated section (Section 2 in Fig. 2) is situated at the N exit of the Sinaia town, along the route. It exposes almost vertical strata, composed of 13.7 m of turbidites that encloses cm-thick calcareous sandstones, along with grey claystones and marlstones. Several cm-thick black shales are also present (Fig. 5).

The two sections were sampled thoroughly for calcareous nannofossil investigation. In general, 3 samples/1m have been collected; altogether, we have analysed 19 samples from Section 1 and 45 sampled from Section 2. Smear slides have been studied at LM (light microscope), with x1,500 magnification, in both crossed-nicols and polarized light. Qualitative and semi-quantitative analyses (by counting at 250 specimens/sample in longitudinal transverses, randomly distributed) have been carried out.

Fig. 4. The investigated succession of the Sinaia Formation at Podul lui Neag (right bank of Prahova Valley, N Comarnic town).

Fig. 5. The investigated succession of the Sinaia Formation Sinaia-Penny (N exit of the Sinaia town).

4. RESULTS

4.1. Calcareous nannofossil assemblages

In both studied sections, the calcareous nannofossil assemblages are dominated by *Watznaueria barnesiae*; commonly, *Watznaueria ovata* and *Watznaueria britannica* have been observed. Nannoconids show high diversity. This genus is represented by *N. bronnimannii*, *N. colomii*, *N. globulus*, *N. dolomiticus*, *N. kamptneri kamptneri*, *N. kamptneri minor*, *N. steinmannii steinmannii* and *N. steinmannii minor*. Other commonly encountered taxa are the genera *Micrantholithus* (*M. hoschulzii* and *M. obtusus*), *Retecapsa* spp., and *Cretarhabdus* spp. Rarely, taxa of the genus *Conusphaera*, as well as *Biscutum constans*, *Discorhabdus ignotus*, *Manivitella pemmatoidea*, *Staurolithites stradneri*, *Cruciellipsis cuvillieri*, *Cyclagelosphaera brezae, Cyclagelosphaera margerelii*, *Cyclagelosphaera deflandrei*, *Zeugrhabdotus embergeri*, and *Haqius circumradiatus* have been observed. Overall, the preservation varies from moderate to good.

The above-mentioned features were encountered in both of our studied sections. In Section 1 - Podul lui Neag, 33 taxa were observed, while in Section 2 - Sinaia-Penny, 56 taxa have been identified (Table 1). Some of the taxa, such as *Watznaueria barnesiae*, *W. britannica*, *Conusphaera mexicana* ssp. *mexicana*, *Cruciellipsis cuvillieri*, Manivitella pemmatoidea, *Micrantholithus* spp., *Percivalia fenestrata*, *Retecapsa*, spp. *Nannoconus* spp., and *Zeugrhadotus* spp., show a consistent occurrence throughout the investigated succession (Table 1 and Fig. 6). Other taxa, especially species of the genera *Braarudosphaera*, *Rucinolithus*, *Staurolithites*, *Tubodiscus*, sporadically occur. *Biscutum* spp. (including *Biscutum constans* and *Biscutum ellipticum*) have an almost continuous occurrence with an overall low abundance.

4.2. Biostratigraphy

In the nannofossil assemblages of Section 1, besides the long-ranging taxa, important biostratigraphic species occur, such as *Retecapsa angustiforata* and *Retecapsa* crenulata having their FO (first occurrence) towards the base of Berriasian and respectively in the upper part of this stage (Black, 1971; Applegate and Bergen, 1988).

Table 1. Distribution chart of the identified nannofossils in studied Section 2 – Sinaia-Penny in the late Valanginian-early Hauterivian interval. Nannofossil zones/subzones after Applegate and Bergen (1988).

STAGE	NO. SAMPLE	*Assipetra infracretacea*	*Axopodorhabdus dietzmannii*	*Biscutum* spp.	*Braarudosphaera primula*	*Calcicalathina oblongata*	*Conusphaera mexicana mexicana*	*Cretarhabdus conicus*	*Cruciellipsis cuvillieri*	*Cyclagelosphaera brezae*	*Cyclagelosphaera deflandrei*	*Cyclagelosphaera margerelii*	*Diazomatolithus lehmanii*	***Diloma galiciense***	*Discorhabdus ignotus*	***Eiffellithus striatus***	*Eiffellithus windii*	*Haqius circumradiatus*	*Helenea chiastia*	*Helenea quadrata*
HAUTERIVIAN	45	R		R	R	P	R	R	F	F		F	P	R	P	F		F	R	
	44	R	P	F		P	R		F			F	R	R	P	F		F		P
	43	P	P	F	R	F	P	P	F	F		F	P	P	P	F		F	R	P
	42	P	P	F	R	F	P	P	F	R		F	R		P	R		F	R	P
	41	P		F	P	F			P				R	P	P	R			R	
	40		P	P	P	F	P		F	R			R		R	P		R	R	P
	39			P			P	P	P	F		F	R	P	R	R		R	P	P
	38	R	P	P		R		P	P	R		P			P	P		R	P	
	37	P		P			R		P			R	R			R	P	R	P	P
	36	R	P	P			R		P				R		P	P	R	F		
VALANGINIAN	35	F		P		R	R		P			R	R		P	R	R			P
	34	F		P		R		P	P	F			R			R	R		P	
	33	F		P	P	R	F		P				R			R	R	F		
	32	F		P	P			P	P		P	R				P	R			
	31			F		F	P		F				P			P	P		P	
	30	R				F	P		R							P	F	R		P
	29	F		R		F	P	F	F							R			P	
	28	R		F			P	F	F			P	P		R	R	P	R		
	27	P		P		P		F	F							P	P			
	26	F				P	F		F	P		R				P	R			

STAGE	NO. SAMPLE	*Hemipodorhabdus gorkae*	***Lithraphidites bollii***	*Lithraphidites carniolensis*	*Manivitella pemmatoidea*	*Micrantholithus hoschulzii*	*Micrantholithus obtusus*	*Nannoconus bermudezii*	*Nannoconus bronnimannii*	*Nannoconus bucheri*	*Nannoconus circularis*	*Nannoconus globulus*	*Nannoconus kamptneri*	*Nannoconus steinmannii* ssp. *steinmannii*	*Nannoconus wassalii*	*Percivalia fenestrata*	*Rhagodiscus asper*	*Rhagodiscus infinitus*	*Retecapsa angustiforata*	*Retecapsa crenulata*
HAUTERIVIAN	45		P		C	R	R		R	F		C	C	C	F	P	R		R	
	44	F	P	P	F	R	F	F		F	F		C	C	F	P	F	R		F
	43		R		F	P	F		F	R		C	C	C	F	P	F	R	P	F
	42		P		F	F		F		C	F	F	C	C	F	P	F	R	P	F
	41				R	R	F		P	F		F	F	C	F	P	F		R	
	40					F	F			F		F	F	C	F		R		P	F
	39	F			R	F	F	P	P	F			F	R		P	P	R		F
	38				P	F	F			F			F	F		P	P			
	37			P		P		F	P	R		F	F	C			F			F
	36					R	R			R	F		P	C	R	P	R			F
VALANGINIAN	35					P	R			R		F	R	C	R	F	R			
	34	P			F	R	R		R	R			R	C		F	R			F
	33				F	R	R		R	R		F		C	P	F	P	R	R	F
	32					P		F				F	F	C		F	F			F
	31	F				P	F	P	P				R	F		F	R		P	F
	30				F	F	F	F					R	R		R	R			R
	29				R	F	F						F	C		R	R	P	P	R
	28				R	R	F				F		F	C		R	F		P	R
	27	P		P	R	F	R		R		P	P	F	F		R	R		P	R
	26	P				F	R				P	P	F	F			R	P	P	

STAGE	NO. SAMPLE	*Rucinolithus* sp.	***Rucinolithus pinnatus***	***Rucinolithus wisei***	*Speetonia colligata*	*Staurolithites mutterlosei*	*Staurolithites stradneri*	***Tegulalithus septentrionalis***	*Tegumentum stradneri*	*Tubodiscus jurapelagicus*	*Tubodiscus verenae*	*Watznaueria barnesiae*	*Watznaueria britannica*	*Watznaueria ovata*	*Watznaueria manivitae*	*Zeugrhabdotus diplogrammus*	*Zeugrhabdotus embergeri*	*Zeugrhabdotus erectus*	*Zeugrhabdotus xenotus*	NANNOFOSSIL ZONES/SUBZONES
HAUTERIVIAN	45					P		P				A	P				P	P		CC 4 b
	44					P	P	P	P		P	A	R				P	P		
	43											A	R	P			P	R	P	
	42											A	R	P		P	P	P	P	
	41					P			P			A	R				C	F	P	CC 4 a
	40					P					P	A	R				C	F	P	
	39	P			P		P					A	R	R			C	R		
	38	P							R			A		R			C	P		
	37	P			P				R			A	R	R		P	F	P	R	
	36								R			A	R	R		F	F	P	R	
VALANGINIAN	35	P										A	R			F	F	R	R	
	34					P					P	A	R			F	F			
	33				P				P			A				F	F	P	R	
	32						P		P		P	A	R	R		F	F		R	
	31									P		A	R	R		F	F		R	
	30								P			A	R	R			F	P	R	
	29	R			P				R			A	R	R			F	P	P	
	28											A	R	R		P			P	
	27	P					P			P		A				P	P		P	
	26						R		R			A	P				P			

Tabel 1 (continued)

NO. SAMPLE	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6
STAGE	VALANGINIAN																			
Assipetra infracretacea		P	P	P	P			P	P					R	R	R	R	R	R	R
Axopodorhabdus dietzmannii	P										P			P				P		
Biscutum spp.			P		P	F	P	F	F		P	F	F	F	R	P	F	F	F	R
Braarudosphaera primula																				
Calcicalathina oblongata	P	P		P	P	P	P	P			P		R	R	F	F	F	F	F	F
Conusphaera mexicana mexicana			F	F	F	F			R	R	R		R							R
Cretarhabdus conicus			P	P			R	R					P		P	P		P		P
Cruciellipsis cuvillieri	R	P	P	P	P	P	P	P	F	F	F	R	R	R	R	R	R	R	R	R
Cyclagelosphaera brezae					P		R		P	R	P		R	P	R	F	P	P	P	P
Cyclagelosphaera deflandrei	P								P	F	P		R							
Cyclagelosphaera margerelii			P			P			P		P			R	F	R		F	F	R
Diazomatolithus lehmanii		P							P	P		P	P	P			R	F	R	P
Diloma galiciense																				
Discorhabdus ignotus						R	F	F	R	P	F	P	F	F	F	P	P	F	P	P
Eiffellithus striatus	R	P	P	P	P	P		P		P	R	R	P	R	P	P	R	R	F	F
Eiffellithus windii	R	R	R	R	F	F	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Haqius circumradiatus	F		F						P	R						F	P	P	P	P
Helenea chiastia		P						P			F		R	R	R	R		F	R	R
Helenea quadrata	P				P									P					P	
Hemipodorhabdus gorkae				P		P		P						P	R		R	R	P	
Lithraphidites bollii																				
Lithraphidites carniolensis					R		R		R	R			P	R	R				P	
Manivitella pemmatoidea		R				R			P					P	R	R	R	P	P	P
Micrantholithus hoschulzii	F		P	P	P					R						P	P	P	F	P
Micrantholithus obtusus	R	F	F	F		P			P		P				R		F	F	F	R
Nannoconus bermudezii										F			F	F					R	F
Nannoconus bronnimannii	R	P	P	P		F			F			F						P	P	R
Nannoconus bucheri											F			F		R	P		P	R
Nannoconus circularis	P	P					R					R	R	R	R	R		P	P	P
Nannoconus globulus	P	P	R	R	R	R	R	F	F	F	F	F	F	F	F	F	F	F	F	C
Nannoconus kamptneri	R	P	P	R	R	R	R		R		R	R	R	P	R	F	C	C	C	C
Nannoconus steinmannii ssp. *steinmannii*	F	F	P		P		P		F	F	C	C	C	C	F		R	F	F	F
Nannoconus wassalii																R	P	P	R	P
Percivalia fenestrata		R	R	R	R	R			P	P	P	P			F	R	P	R	R	F
Rhagodiscus asper	F	F	F	F	F	R	F	F	F	F	F	R	R	F	F	F	F	F	R	F
Rhagodiscus infinitus		P									P				P			P	P	
Retecapsa angustiforata		P	P	P	P	F	F	F		F				R	R		R	R		
Retecapsa crenulata		R	R		R	R	P	P	P		R	R	R	F	F		F	F	F	R
Rucinolithus sp.	P	P						P		P										
Rucinolithus pinnatus					P			P	P				P			P			P	P
Rucinolithus wisei																				
Speetonia colligata				P										P			R			P
Staurolithites mutterlosei	P				P					P			P;			P		P		
Staurolithites stradneri									P									P		
Tegulalithus septentrionalis																				
Tegumentum stradneri								P			R						P	R	R	
Tubodiscus jurapelagicus			P			R					R									R
Tubodiscus verenae				P	P			P		P						P	P		P	
Watznaueria barnesiae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Watznaueria britannica	P	P	P	P	P	P	P		P	P	R	R						P	P	P
Watznaueria ovata																P	P		P	P
Watznaueria manivitae															P	P	P	P	P	P
Zeugrhabdotus diplogrammus	F	F	F	F	F	F		R	P	P		P	P	P	R	P	R	R	R	R
Zeugrhabdotus embergeri	P	P			C	C	C	C	C	C	P	P	P	R	R	R	P	P	P	F
Zeugrhabdotus erectus		P	F	R	R	R	R	F	R	R	F	P	F	P	P	P	P	P	P	F
Zeugrhabdotus xenotus		R	R	R	R	R		P	R	P	R	P	P		P	P	P	P		P
NANNOFOSSIL ZONES/SUBZONES	CC 4 a																			

Tabel 1 (continued)

STAGE	VALANGINIAN				
NO. SAMPLE	1	2	3	4	5
Assipetra infracretacea	R	R	R	R	R
Axopodorhabdus dietzmannii			P		
Biscutum spp.	R	R	R	R	R
Braarudosphaera primula					
Calcicalathina oblongata	F	F	F	F	
Conusphaera mexicana mexicana	R	R	R	F	F
Cretarhabdus conicus		P	P		P
Cruciellipsis cuvillieri	R	R	R	R	R
Cyclagelosphaera brezae	R	P	R	P	P
Cyclagelosphaera deflandrei	R	R	P	P	
Cyclagelosphaera margerelii	R	R			R
Diazomatolithus lehmanii	P	P	P	P	R
Diloma galiciense					
Discorhabdus ignotus	R	P	P	P	P
Eiffellithus striatus	F	F	F	F	F
Eiffellithus windii	F	F	C	R	C
Hagius circumradiatus	F		F	R	P
Helenea chiastia	R	R	R	R	R
Helenea quadrata	P		P	P	
Hemipodorhabdus gorkae	R				R
Lithraphidites bollii					
Lithraphidites carniolensis	R	R		P	
Manivitella pemmatoidea		P	R	P	P
Micrantholithus hoschulzii	F	F	F	F	R
Micrantholithus obtusus	F	R	F	F	R
Nannoconus bermudezii		R		R	R
Nannoconus bronnimannii	R		P	R	R
Nannoconus bucheri				P	R
Nannoconus circularis	F	F	P	P	P
Nannoconus globulus	F	P	R	R	C
Nannoconus kamptneri	C	F	C	C	C
Nannoconus steinmannii ssp. *steinmannii*	F	F	F	F	F
Nannoconus wassalii	F	R	P	R	P
Percivalia fenestrata	R	P	R	F	P
Rhagodiscus asper	F	R	R	F	R
Rhagodiscus infinitus			P	P	
Retecapsa angustiforata			F	F	F
Retecapsa crenulata	R	R		R	R
Rucinolithus sp.	R	P		P	
Rucinolithus pinnatus	F	R	R	P	P
Rucinolithus wisei	R	R	R		
Speetonia colligata	R	P	R	R	
Staurolithites mutterlosei	R	R		R	
Staurolithites stradneri	R	R	R	R	
Tegulalithus septentrionalis					
Tegumentum stradneri			R		
Tubodiscus jurapelagicus		R	R		R
Tubodiscus verenae		P			P
Watznaueria barnesiae	A	A	A	A	A
Watznaueria britannica	P	P			
Watznaueria ovata	R		P		
Watznaueria manivitae		R		R	R
Zeugrhabdotus diplogrammus	F	F	F		R
Zeugrhabdotus embergeri	F	F	F	F	F
Zeugrhabdotus erectus	P	R	P	P	P
Zeugrhabdotus xenotus	R	R	P	P	P
NANNOFOSSIL ZONES/SUBZONES	CC 4 a				

Legend:

P (present) = 1-3 specimens/8 FOVs;
F (few) = 4-7 specimens/5 FOVs;
A (abundant) = >10 specimens/5 FOVs;
R (rare) = 1-3 specimens/5 FOVs;
C (common) = 7-10 specimens/5 FOVs;
FOV: field of view.

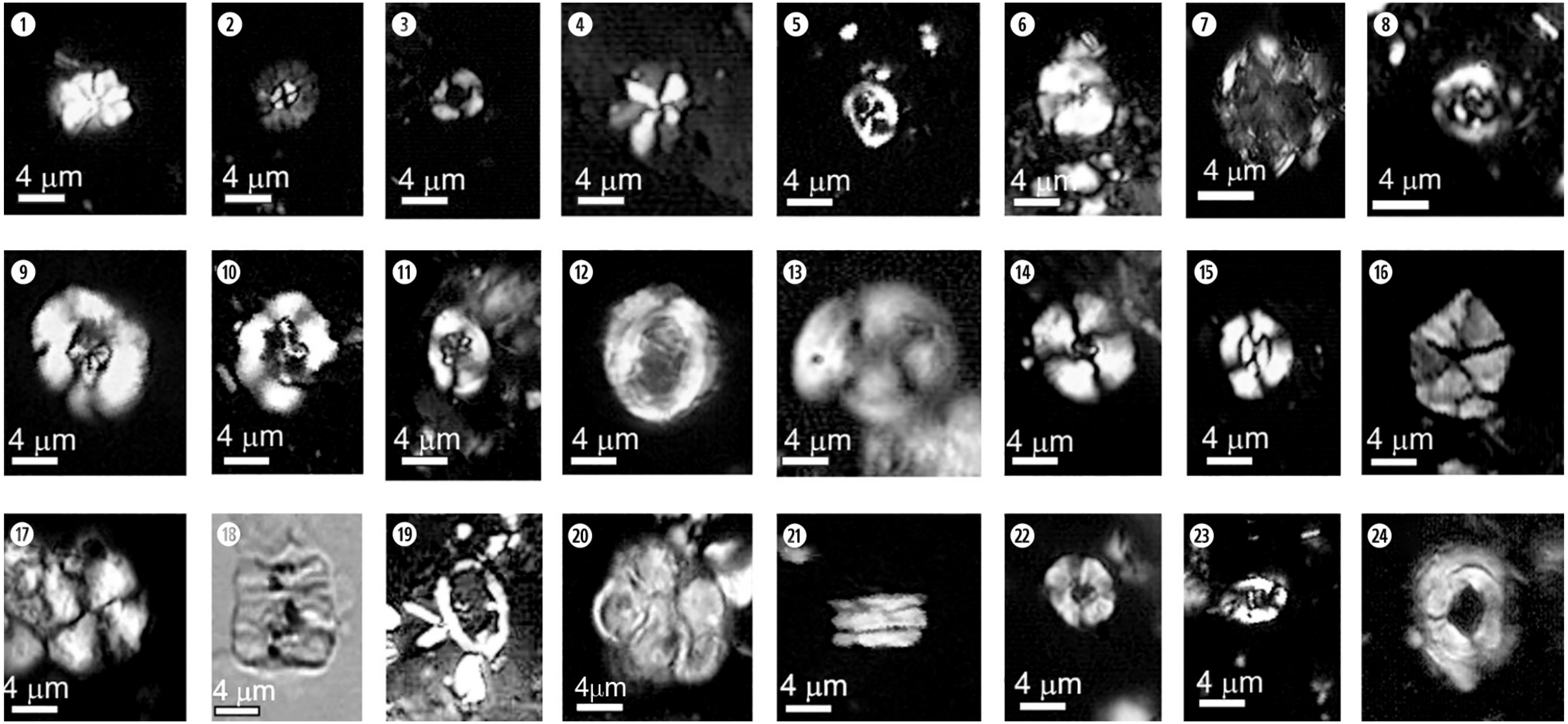

Fig. 6. Microphotographs of Valanginian calcareous nannofossils identified of studied Section 2 (Sinaia-Penny) taken under LM - light microscope, in N+ - crossed nicols, except no. 18 in NII – polarized lights; **1**. *Rucinolithus sp*; Sample 35. **2**. *Biscutum constans* (Górka, 1957) Black *in* Black and Barnes, 1959; Sample **11. 3**. *Diazomatolithus lehmanii* Noël, 1965; Sample 11. **4** *Rucinolithus pinnatus* Bergen, 1994; Sample 21. **5.** *Staurolithites mutterlosei* Crux, 1989; Sample 21**. 6**. *Assipetra infracretacea* (Thierstein, 1973) Roth, 1973; Sample 15. **7**. *Calcicalathina oblongata* (Worsley, 1971) Thierstein, 1971; Sample 15. **8**. *Helenea chiastia* Worsley, 1971; Sample 44. **9**. *Cruciellipsis cuvillierii* (Manivit, 1966) Thierstein, 1971; Sample 28. **10**. *Cretarhabdus conicus* Bramlette & Martini, 1964; Sample 28. **11**. *Retecapsa angustiforata* Black, 1971; Sample 40. **12**. *Tubodiscus jurapelagicus* (Worsley, 1971) Roth, 1973; Sample 2. **13**. *Haqius circumradiatus* (Stover, 1966) Roth, 1978; Sample 40. **14.** *Watznaueria britannica* (Stradner, 1963) Reinhardt, 1964; Sample 29. **15.** *Watznaueria barnesiae* (Black *in* Black & Barnes, 1959) Perch-Nielsen, 1968; Sample 29. **16**. *Micrantholithus hoschulzii* (Reinhardt, 1966) Thierstein, 1971; Sample 29. **17**. *Cyclagelosphaera brezae* Applegate & Bergen, 1988; Sample 40**. 18**. *Nannoconus kamptneri* Brönnimann, 1955; Sample 17. **19**. *Diloma galiciense* Bergen, 1994; Sample 43. **20**. *Braarudosphaera primula* Black, 1973; Sample 18. **21**. *Conusphaera mexicana* subsp. *mexicana* Trejo, 1969; Sample 17. **22**. T*egulalithus septentrionalis* (Stradner, 1963) Crux, 1986; Sample 45. **23**. *Eiffellithus windii* Applegate & Bergen, 1988; Sample; 24. *Tubodiscus verenae* Thierstein, 1973; Sample 2.

Rucinolithus wisei, where the FO is placed in the NK2A subzone of Bralower *et al.* (1989) in Tethyan sections (Aguado *et al.*, 2000), is also present, along with *Speetonia colligata*, which firstly occurred in the Berriasian (Applegate and Bergen, 1988; Bown, 2005b).

Based on the above-mentioned findings, the calcareous nannofossil assemblages of Section 1 belong to the NK2 biozone of Bralower *et al.* (1989), extending within the late Berriasian to basal Valanginian interval. *Percivalia fenestrata*, for which its FO is used by the above-mentioned authors to divide their NK2 nannofossil zone in subzones NK2A and NK2B, was not encountered in our studied succession.

According to the nannofossil distribution of Section 2, the covered interval is late Valanginian-early Hauterivian. Most part of this section belongs to the NC4a nannofossil zone of Applegate and Bergen (1988). These authors divided their NC4 biozone in NC4a and NC4b, based on the FO of *Lithraphidites bollii*, which occurs towards the upper part of the investigated successions, in the youngest 4 samples. Within the whole studied succession of Section 2, *Tubodiscus* taxa (*T. verenae* and T. *jurapelagicus*) occur, but they show a discontinuous and rare occurrence. Some former studies indicate that the LO is placed in the latest Valanginian (i.e., Bralower,1987; Channell *et al.*, 1995), while other authors found it throughout the Hauterivian (Bulot *et al.*, 1996). At the GSSP of the Hauterivian, Mutterlose *et al.* (2021) identified a sporadical occurrence of *T. verenae* and T. *jurapelagicus* up to the late Hauterivian interval. Also in this section, with a continuous presence, *Eiffellithus windii* occurs with a moderate abundance, disappearing towards the upper part of the investigated succession. This nannofossils can accurately approximate the Valanginian-Hauterivian boundary in the section La Charce, France, the GSSP of the Hauterivian stage (Mutterlose *et al.*, 2021), where the boundary is defined based on the FO of the ammonite genus *Acanthodiscus* which marks the base of the *A. radiatus* Ammonite Zone. Another event encountered in Section 2 is FO of *Diloma galiciense* (calcareous nannofossil), slightly above the LO of *Eiffellithus windii*. This is followed by successive FOs of *Diloma galiciense*, *Lithraphidites bollii*, and *Tegulalithus septentrionalis*.

5. DISCUSSION

The semi-quantitative analysis of calcareous nannofossil taxa reveals fluctuations throughout the studied Section 2 (Fig. 7). The nannofossil assemblages are mainly made of *Watznaueria barnesiae* and *Nannoconus* spp., which jointly represent up to 45% in each studied sample.

The calcareous nannofossil assemblages are dominated by *Watznaueria barnesiae,* which represents between 18.7% and 32.6% of total assemblages. No more than 40% of *Watznaueria barnesiae* was observed in the studied succession, indicating that there are no heavy alterations of nannofossil assemblages (Roth and Krumbach, 1986). There are contradictory hypotheses concerning the palaeoecology of this species, being considered either as an oligotrophic taxon, regarded as a K-strategist species (Mutterlose and Kessels, 2000), or it is possibly more related to mesotrophic up to eutrophic surface waters (Lees *et al.*, 2005).

The nannoconids represent an important compound of the found assemblages, covering a total from 9.2% up to 21.3%. The lowest abundance is recorded at the lower part of the section, in the late Valanginian, while the highest was observed at the topmost section, in the early Hauterivian. The nannoconids are in general linked to the warm surface waters of the Tethyan Realm (Busson and Noël, 1991; Street 2000; Lees *et al.*, 2005; Mattioli *et al.*, 2014), even though there are species mainly occurring in the Boreal Realm (i.e., Covington and Wise, 1987; Mutterlose *et al.*, 2005), such as *Nannoconus abundans* (probably synonym with *Nannoconus inornatus* of Rutledge and Bown, 1996) and *Nannoconus borealis* (i.e., Street and Bown, 2000)

Micrantholithus taxa (including *M. obtusus* and M. *hoschulzii*) varies between 2.7 and 12% of the total assemblages. The palaeoecology of these nannofossils is unclear, the taxa being present in low- to mid-palaeolatitudes and in high ones, but some species, such as *M. speetonensis*, seem to be restricted to the Boreal Realm (Jakubowski, 1996; Bown *et al.*, 1998; Mutterlose *et al.*, 2005).

Rhagodiscus asper consistently occurs throughout the studied section, showing a maximum of 11.8% of the total assemblages covering the middle part of the succession. *R. asper* is confirmed to be a warm-water taxon, of a Tethyan affinity (*e.g.* Roth and Krumbach, 1986; Mutterlose 1989, 1991; Hardas and Mutterlose, 2007).

Biscutum spp.*,* including mainly *B. constans* (75-80%) of the total representative of the genus and *B. ellipticum,* occurs with a consistent presence and low abundance (up to 5.8%) in the lower part of the section (upper Valanginian) and sporadically throughout the rest of the succession, showing a slight recovery towards the top (early Hauterivian). *B. constans* is believed to indicate high-fertility surface-water conditions (Linnert *et al.*, 2011; Aguado *et al.*, 2016), probably being more associated with a mesotrophic surface-water palaeosetting, rather than an eutrophic one (Watkins, 1989).

Discorhabdus ignotus, indicator of high-fertility surface water and regarded as an eutrophic species (*e.g.*, Roth and Krumbach, 1986; Premoli Silva *et al.*, 1989; Linnert *et al.*, 2011; Bottini and Erba, 2018), occurs with a low abundance (up to 3.7%) in the studied succession, with higher values in the lower and upper part of the section. It shows a sporadic occurrence, disappearing in the middle part of the section, within the Valanginian-Hauterivian boundary interval.

Zeugrhabdotus erectus is another proxy of high-fertility conditions; probably, it prefers mesoeutrophic surface-waters, with high input of nutrients (Herrle, 2003; Bornemann *et al.*, 2005; Mutterlose *et al.*, 2005; Aguado *et al.*, 2014; 2016).

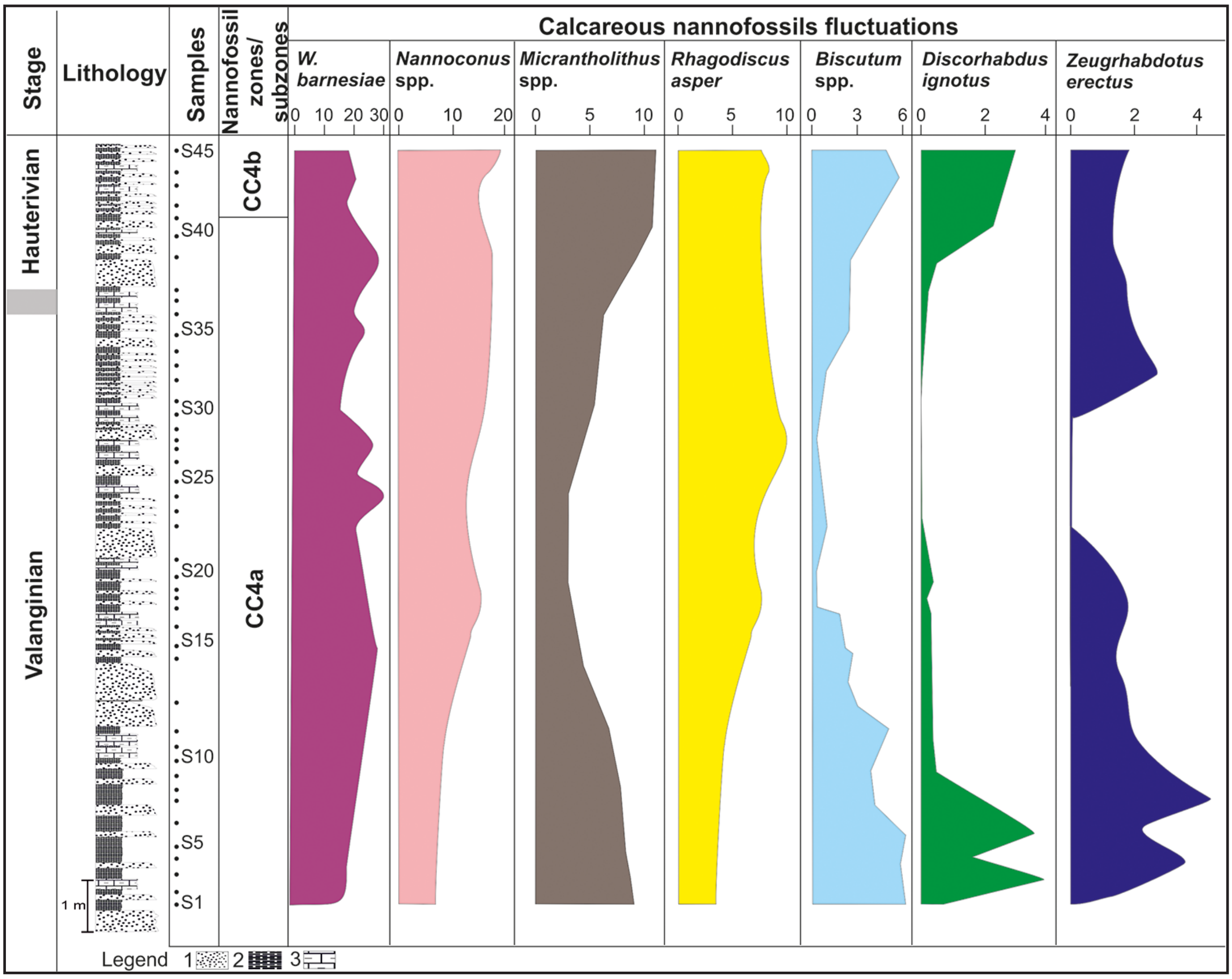

Fig. 7. Calcareous nannofossil fluctuation in the studied Section 2 (Sinaia-Penny), southern end of the Eastern Carpathians. *Legend*: **1** - sandstones; **2** - dark grey and black shales; **3** - sandstones.

Like the other high fertility proxies, identified in Section 2, i.e., *Biscutum constans* and *Discorhabdus ignotus*, *Zeugrhabdotus erectus* show a low abundance (up to 4%) and a more consistent presence within the lower and upper parts of Section 2.

The studied samples contain diversified nannofossil assemblages, dominated by Tethyan taxa, such as *Nannoconus* spp., *Tubodiscus* spp., *Calcicalathina oblongata*, *Cruciellipsis cuvillieri*, and taxa showing a preference for warmer surface-water, i.e., *Rucinolithus* spp. and *Rhagodiscus asper*. The low- to mid- palaeolatitudes taxa prevail in the assemblages, a normal feature for the studied area, which during Early Cretaceous times was situated in the Tethyan Realm, at around 30°N palaeolatitude (Roban *et al.*, 2020).

To note that in the Early Cretaceous interval of the Eastern and Southern Carpathians, an influx of Boreal nannofossils was observed, but this is restricted to the early Valanginian, within the Saynoceras verrucosum Ammonite zone (Melinte and Mutterlose, 2001). The studied successions are older (Section 1 – Berriasian) and respectively younger (late Valanginian-early Hauterivian); therefore, they do not encompass the early Valanginian interval. Only one Boreal nannofossil was encountered in Section 2, *Tegulalithus septentrionalis*, in the uppermost two studied samples, early Hauterivian in age; this occurrence could be a signal of the global cooling, including of surface-waters in the last stages of the Weissert event, which possibly reflects substantial CO_2 drawdown (Weissert and Erba, 2004; Baudin *et al.*, 2015; Price *et al.*, 2018), but further investigations are needed in the studied area.

The nannofossils indicating high-fertility, i.e., *Biscutum constans*, *Discorhabdus ignotus*, and *Zeugrhabdotus erectus* almost continuously occur through the studied successions, but with a low abundance. Their highest frequency was recorded in the latest Valanginian (NC4a nannofossil zone), possibly related to early phase of the Valanginian Weissert Event, but again more studies are needed for confirming this hypothesis. As the lithological signal, i.e., dark-grey and black shales, indicate at least a dysoxic setting, the low productivity may be indicative for a restricted water circulation during Early Cretaceous times in the southern end of the Carpathian depositional area.

6. CONCLUSIONS

Two successions of turbidites belonging to the Sinaia unit, located at the southern end of the Eastern Carpathians have been studied. The oldest one (Section 1 – Podul lui Neag) is situated in the Berriasian, within the biozone NK2a of Bralower *et al.* (1989), while the youngest studied section (Sinaia-Penny) is placed in the Valanginian-Hauterivian boundary interval, covering the subzones CC4a and CC4b of Applegate and Bergen (1988).

The nannofossil succession events throughout the late Valanginian-lower Hauterivian interval is the following (oldest first):

1. The LO of *Rucinolithus wisei*
2. The LO of *Rucinolithus pinnatus*
3. The LO of *Eiffellithus windii*
4. The FO of *Diloma galiciense*
5. The FO of *Lithraphidites bollii*
6. The FO of *Tegulalithus septentrionalis*

The identified calcareous nannofossil assemblages are in general Tethyan in character, including common nannoconids, along with consistent occurrence of *Tubodiscus* spp., *Rucinolithus* spp., *Calcicalathina oblongata*, *Rhagodiscus asper* and *Lithraphidites bollii*, the later occurring in the topmost section. Most of the other encountered nannofossils are cosmopolitan, except *Tegulalithus septentrionalis*, a Boreal species, which was identified only in the two uppermost samples of Section 2.

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REFERENCES

Aguado, R., Company, M., Tavera, M. (2000). The Berriasian/Valanginian boundary in the Mediterranean region: new data from the Caravaca and Cehegín sections, SE Spain. *Cretac. Res.,* **21**: 1-21.

Aguado, R., de Gea, G.A., O'Dogherty, L. (2014). Integrated biostratigraphy (calcareous nannofossils, planktonic foraminifera, and radiolaria) of an uppermost Barremian– lower Aptian pelagic succession in the Subbetic Basin (southern Spain). *Cretac. Res*., **51**: 153-173.

Aguado, R., Reolid, M., Molina, E. (2016). Response of calcareous nannoplankton to the Late Cretaceous Oceanic Anoxic Event 2 at Oued Bahloul (central Tunisia). *Palaeogeogr., Palaeoclimat., Palaeoecol.*, **459**: 289-305

Bodin, S., Meissner, P., Janssen, N.M.M., Steuber, T., Mutterlose, J. (2015). Large igneous provinces and organic carbon burial: Controls on global temperature and continental weathering during the Early Cretaceous. Glob. Planet. Change, **133**: 238-253.

Bornemann, A., Pross, J., Reichelt, K., Herrle, J.O., Hemleben, C., Mutterlose, J. (2005). Reconstruction of short-term palaeoceanographic changes during the formation of the Late Albian 'Niveau Breistroffer' black shales (Oceanic Anoxic Event 1d, SE France). *J. Geol. Soc. Lond.*, **162**: 623-639.

Bottini, C., Erba, E. (2018). Mid-Cretaceous paleoenvironmental changes in the western Tethys. *Clim. Past*, **14**: 1147-1163.

Aguado, R., Reolid, M., Molina, E. (2016). Response of calcareous nannoplankton to the Late Cretaceous Oceanic Anoxic Event 2 at Oued Bahloul (central Tunisia). *Palaeogeogr., Palaeoclimat., Palaeoecol.*, **459**: 289-305.

Applegate, J.L., Bergen, J.A. (1988). Cretaceous calcareous nannofossil biostratigraphy of sediments recovered from the Galicia Margin, ODP Leg 103. *Proceedings of the Ocean Drilling Program, Scientific Results,* **103**: 293-348.

Barragán, R., Melinte, M.C. (2006). Palaeoenvironmental and palaeobiologic changes across the Barremian/Aptian boundary interval in the Tethys Realm, Mexico, and Romania. *Cretaceous Research*, **27**: 529-541.

Bădescu, D. (2005). Evoluţia tectono-stratigrafică a Carpaţilor Orientali în decursul Mesozoicului şi Neozoicului. Editura Economică, 308 p.

Bornemann, A., Pross, J., Reichelt, K., Herrle, J.O., Hemleben, C., Mutterlose, J. (2005). Reconstruction of short-term palaeoceanographic changes during the formation of the Late Albian 'Niveau Breistroffer' black shales (Oceanic Anoxic Event 1d, SE France). *J. Geol. Soc. Lond.* **162**: 623-639.

Bottini, C., Erba, E. (2018). Mid-Cretaceous paleoenvironmental changes in the western Tethys. Clim. Past, **14**: 1147-1163.

Bown, P.R., Rutledge, D.C., Crux, J.A., Gallagher, L.T. (1998). Lower Cretaceous. *In*: Bown, P.R. (Ed.) Calcareous Nannofossil Biostratigraphy. *British Micropalaeontological Society Publication Series*: 86-131.

Bown, P. R. (2005a). Calcareous nannoplankton evolution: a tale of two oceans. *Micropal.*, **51**: 299-308.

Bown, P.R. (2005b). Early to Mid-Cretaceous Calcareous Nannoplankton from the Northwest Pacific Ocean, Leg 198, Shatsky Rise. *Proceedings of the Ocean Drilling Program, Scientific Results,* **198**: 1-82

Black, M. (1971). Coccoliths of the Speeton Clay and Sutterby Marl. *Proceedings of the Yorkshire Geological Society,* **38**: 381-424.

Bralower, T.J. (1987). Valanginian to Aptian calcareous nannofossils stratigraphy and correlation with the Upper M-sequence magnetic anomalies. *Mar. Micropal*., **11**: 293-310.

Bralower, T.J., Monechi, S., Thierstein, H.R. (1989). Calcareous nannofossil zonation of the Jurassic-Cretaceous Boundary Interval and Correlation with the Geomagnetic Polarity Timescale. *Marine Micropaleontology*, **14**: 153-235.

Bulot, L.G. (reporter), Blanc, E., Company, M., Gardin, S., Hennig, S., Hoedemaeker, P.J., Leereveld, H., Magniez-Jannin, F., Mutterlose, J., Pop, G., Rawson, P.F. (1996). The Valanginian stage. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique*, *Sciences de la Terre*, **66**: 11-18.

Busson, G., Noël, D. (1991). Les nannoconidés indicateurs environnementaux des océans et mers épicontinentales du Jurassique terminal et du Crétacé inférieur. *Oceanol. Acta,* **14**: 333-356.

Channell, J.E.T., Cecca, F., and Erba, E. (1995). Correlations of Hauterivian and Barremian (Early Cretaceous) stage boundaries to polarity chrons. *Earth Planet. Sci. Let.*, **134**: 125-140.

Covington, J.M., Wise, S.W. (1987). Calcareous nannofossil biostratigraphy of a Lower Cretaceous deep-sea fan complex: Deep Sea Drilling Project Leg 93 Site 603, lower continental rise off Cape Hatteras. *Initial Reports of the Deep Sea Drilling Project,* **93**: 617-660.

Deflandre, G. (1970). Présence de nannofossiles calcaires (coccolithes et Incertae sedis) dans le Siluro-dévonien d'Afrique du Nord. *Sci. Comptes Rendues,* **270**: 2916–2921.

Erba, E. (1992). Middle Cretaceous calcareous nannofossils from the Western Pacific (Leg129): evidence for paleoequatorial crossings. *Proc. ODP Sci. Results,* **129**: 189-201.

Erba, E. (2004). Calcareous nannofossils and Mesozoic oceanic anoxic events. *Mari. Micropal.*, **52**: 85-106.

Erba, E., Tremolada, F. (2004). Nannofossil carbonate fluxes during the Early Cretaceous: phytoplankton response to nutrification episodes, atmospheric CO2, and anoxia. *Paleocean.*, **19**: PA1008.

Gardin, S., Krystyn, L., Richoz, S., Bartolini, A., Galbrun, B. (2012). Where and when the earliest coccolithophores? *Lethaia*, **45**: 507-523.

Herrle, J.O. (2003). Reconstructing nutricline dynamics of Mid-Cretaceous oceans: Evidence from calcareous nannofossils from the Niveau Paquier black shale (SE France). *Mar. Micropaleontol*., **47**: 307-321.

Jakubowski, M. (1986). New calcareous nannofossil taxa from the Lower Cretaceous of the North Sea. *INA Newsletter,* **8**(*1*): 38-42

Jipa, D. (1980). Orogenesis and Flysch Sedimentation. Critical Remarks on the Alpine Model. *Sed. Geol.*, **27**(*3*): 229-239.

Jipa, D. (1984). Large scale progradation structures in the Romanian Carpathians; facts and hypothesis. *An. Instit. Geol. Geofiz.*, **64**: 455-463.

Jipa, D.C., Melinte-Dobrinescu, M., Rutka, M. (2020). Large-scale progradation and sediment gravity flow in a deep-sea basin: Albian deposits in the south Carpathians (Ialomița-Dâmbovița area, Romania). *Geo-Eco-Marina*, **56**: 41-73.

Lees, J.A., Bown, P.R., Mattioli, E. (2005). Problems with proxies? Cautionary tales of calcareous nannofossil palaeoenvironmental indicators. *Micropaleontol*., **51**: 333-343.

Linnert, C., Mutterlose, J., Mortimore, R. (2011). Calcareous nannofossils from Eastbourne (South-eastern England) and the paleoceanography of the Cenomanian-Turonian Boundary Interval. *Palaios*, **26**: 298-313.

Mațenco, L., Bertotti, G., Dinu, C., Cloetingh, S.C. (1997). Tertiary tectonic evolution of the external South Carpathians and the adjacent Moesian Platform (Romania). *Tectonics*, **16**: 896-911.

Mațenco, L., Bertotti, G., Leever, K., Cloetingh, S., Schmid, S., Tărăpoancă, M., Dinu, C. (2007). Largescale deformation in a locked collisional boundary: Interplay between subsidence and uplift, intraplate stress, and inherited lithospheric structure in the late stage of the SE Carpathians evolution. *Tectonics*, **26**: TC4011.

Melinte, M., Mutterlose, J. (2001). A Valanginian (Early Cretaceous) 'boreal nannoplankton excursion' in sections from Romania. *Mar. Micropal.* **43**: 1-25.

Melinte-Dobrinescu, M., Jipa, D. (2007). Stratigraphy of the Lower Cretaceous sediments from the Romanian Carpathian Bend area. *Acta Geologica Sinica English Edition*, **81**: 949-956.

Murgeanu, G., Patrulius, D., Contescu, L., Jipa, D., Mihailescu, N., Panin, N. (1963). Stratigrafia şi sedimentogeneza terenurilor cretacice din partea internă a curburii Carpaţilor. *Geological Carpatho-Balkan Association*, Congress V, **III**(*2*): 31-58.

Mutterlose, J. (1991). Biostratigraphy and palaeobiogeography of Early Cretaceous calcareous nannofossils. *Cretac. Res.*, **13**: 167-189.

Mutterlose, J., Kessels, K. (2000). Early Cretaceous calcareous nannofossils from high latitudes: implications for palaeobiogeography and palaeoclimate. *Palaeogeogr., Palaeoclimatol., Palaeoecol*., **160**: 347-372.

Mutterlose, J., Bornemann, A., Herrle, O. (2005). Mesozoic Calcareous-Nannofossils – State of the Art. *Paläontol. Zeitsch.*, **70**: 113-133.

Mutterlose, J., Rawson, F.P., Reboulet, S. (2021). The Global Boundary Stratotype and Point (GSSP) for the base of the Hauterivian Stage (Lower Cretaceous), La Charce, southeast France. *Episodes*, **44**:129-130.

Neagu, T. (1972). The Eo-Cretaceous foraminiferal fauna from the area between the Ialomiţa and Prahova Valleys (Eastern Carpathians). *Revista Española de Micropaleontologia,* **4**: 181-224.

Olariu, C., Jipa, D., Steel, R., Melinte-Dobrinescu, M.C. (2014). Genetic significance of an Albian conglomerate clastic wedge, Eastern Carpathians (Romania). *Sedimentary Geology*, **299**: 42-59.

Patrulius, D. (1969). Geologia Masivului Bucegi şi a Culoarului Dîmbovicioara. Editura Academiei R.S.R., 321 p.

Patrulius, D., Neagu, T., Avram, E., Pop, G. (1976). The Jurassic-Cretaceous boundary Beds in Romania. *Anuarul Institutului de Geologie şi Geofizică*, **50**: 71-125.

Perch-Nielsen, K. (1985). Mesozoic calcareous nannofossils. *In*: Bolli, H.M., Saunders, J.B. and Perch-Nielsen, K. (Eds.), Plankton Stratigraphy, Cambridge Earth Science, Cambridge Univ. Press: 329-426.

Pirini Radrizzani, C. (1971). Coccoliths from the Permian deposits of eastern Turkey. *In*: Farinacci, A. (ed.) *Proceedings of the Second Planktonic Conference Roma 1970*. Edizioni Tecnoscienza, Rome **2**: 993-1001.

Pop, G. (1997). Tithonian to Hauterivian praecalpionellids and calpionellids: bioevents and biozones. *Mineral. Slovac.*, **29**: 304-305.

Premoli Silva, I., Erba, E., Tornaghi, M.E. (1989). Palaeoenvironmental signals and changes in surface water fertility in mid Cretaceous Corg-rich pelagic facies of the Fucoid Marls (Central Italy). *Geobios Memoir Special*, **11**: 225-236

Price, G.D., Janssen, M.N.N., Martinez, M., Company, M., Vandevelde, J.H., Grimes, T.S. (2018). A high-resolution Belemnite geochemical analysis of Early Cretaceous (Valanginian-Hauterivian) environmental and climatic perturbations. *Geochem*. *Geophys*. *Geosyst*., **19**: 3832-3843.

Roban, R.D., Maţenco, L., Ducea, M., Melinte-Dobrinescu, M., Kreszek, C., Panaiotu, C., Anastasiu, N., Profeta, L., Francovschi, I. (2020). Lower Cretaceous provenance and sedimentary deposition in the Eastern Carpathians: Inferences for the evolution of the subducted oceanic domain and its European passive continental margin. *Tectonics*, **39**: e2019TC005780.

Roth, P.H. (1978). Cretaceous nannoplankton biostratigraphy and oceanography of the northwestern Atlantic Ocean. *Initial Reports DSDP*, **44**: 731-760.

Roth, P.H. Krumbach, K.R. (1986). Middle Cretaceous calcareous nannofossil biogeography and preservation in the Atlantic and Indian oceans: implications for paleoceanography. *Mar. Micropaleontol*., **10**: 235-266.

Roth, P.H. (1989). Ocean circulation and calcareous nannoplankton evolution during the Jurassic and Cretaceous. *Palaeogeogr., Palaeoclimat., Palaeoecol*., **74**: 111-126.

Rost, B., Riebesell, U. (2004). Coccolithophores and the biological pump: response to environmental changes. *In*: Thierstein H.R., Young J.R. (Eds.), Coccolithophores. From Molecular Processes to Global Impact: 99-127, Springer-Verlag Berlin Heidelberg.

Rutledge, D., Bown, P.R. (1996). New names for old: taxonomic clarification of some Early Cretaceous nannofossil marker-species. *Journ. Nannopl. Res.,* **18**(*2*): 53-59

Săndulescu, M. (1984). Geotectonica României. Editura Tehnică Bucureşti, 336 p.

Săndulescu, M. (1988). Cenozoic tectonics history of the Carpathians. *In*: Royden, L.H., Horwath, F. (eds.), The Pannonian Basin: a study in basin evolution. *AAPG Memoirs*, **45**: 17-26.

Săndulescu M. (1994). Overview on Romanian Geology. *Romanian Journal of Tectonics and Regional Geology*, **75**: 3-15.

Shumenko, S.I. (2001). To the study of Early Mesozoic, Palaeozoic, and Precambrian nannofossils. *Int. Journ. Algae,* **3**: 90-94.

Street, C., Bown, P.R. (2000). Palaeobiogeography of Early Cretaceous (Berriasian–Barremian) calcareous nannoplankton. *Mar. Micropal*., **39**: 265-292.

Suchéras-Marx, B., Henderiks, J. (2019). Downsizing the pelagic carbonate factory: Impacts of calcareous nannoplankton evolution on carbonate burial over the past 17 million years. *Global and Planetary Change*, **123**: 97-109.

Ştefănescu, M., Micu M. (1987). Flysch deposits in the East Carpathians. *In*: Ştefănescu M. (Ed.), Flysch deposits from the Hartz, the Thuringian and Vogtlandian Slate Mountains, the Carpathians, the Balkans and the Caucasus: 65-69, Editura Academiei RSR, Bucureşti.

Ştefănescu, M. (1995). Stratigraphy and structure of Cretaceous and Paleogene flysch deposits between Prahova and Ialomiţa valleys. *Rom. Journ. Tecton. Reg. Geol.*, **76**: 4-49.

Tappan, H. (1980). Haptophyta, Coccolithophores and other calcareous nannoplankton. The Paleobiology of Plant Protista: 678-803, Freeman San Francisco.

Young, J.R. (1994). Function of coccoliths. *In*: Winter A., Siesser W.G. (Eds.): Coccolithophores: 63-82, Cambridge University Press, Cambridge.

Watkins, D.K. (1989). Nannoplankton productivity fluctuations and rhythmically-bedded pelagic carbonates of the Greenhorn Limestone (Upper Cretaceous). *Palaeogeogr., Palaeoclimat., Palaeoecol*., **74**: 75-86.

Weissert, H., Erba, E. (2004). Volcanism, CO_2 and palaeoclimate: a Late Jurassic – Early Cretaceous carbon and oxygen isotope record. *J. Geol. Soc.* **161**: 695-702.