Mineralia Slovaca, 45 (2013), 1 – 10
Web ISSN 1338-3523, ISSN 0369-2086

Paleoecological evaluation of calcareous nannofossils from the Eocene and Oligocene sediments of the Subtatric Group of the Western Carpathians

SILVIA OZDÍNOVÁ

Geological Institute of the Slovak Academy of Science,
Dúbravská cesta 9, SK-840 05 Bratislava 45

Abstract

The calcareous nannofossils assemblage was evaluated from the Middle Eocene to Upper Oligocene sediments of the Subtatric Group. The research intended to reveal the reaction of each species to changing environmental conditions (e.g. cooling, increased supply of terrestrial material, sufficient nutrients and partial isolation of the pool).

Lower Oligocene changes in the paleoecological conditions in the marine sedimentary area led to a change in body-proportion of placolith forms of calcareous nannofossils. This change was not only conditioned by cooling trend, but also by other changes in the marine environment, such as increased supply of continental material.

Key words: Calcareous nannofossils, cooling term, Lower Oligocene, Paleoecology, Western Carpathians

Introduction

Paleogene basin of the Subtatric group has developed as a part of Tethys Ocean. The process of isolation of the Paratethys Ocean from the Tethys Ocean began during Lower Oligocene and has been completed during Middle Oligocene (Köhler, 1998). During the Middle Eocene a relatively warm climate prevailed, which is characterized by an MECO (Middle Eocene Climatic Optimum) interval. The warm climate is characterized in the assemblage of the calcareous nannofossils by the occurrence of warm water species, such as *Discoaster barbadiensis* Tan Sin Hok and *Discoaster saipanensis* Bramlette & Riedel, which lived in symbiosis with species preferring the temperate water, for example *Dictyococcites bisectus* (Hay, Mohler & Wade) Bukry & Percival and *Reticulofenestra umbilica* (Levin) Martini & Ritzkowski. This symbiosis related on optimum nutritional value of the environment and optimal values of the salinity of seawater.

The cooling trend, which started during the Upper Eocene, has caused by the first glaciations of Antarctica. At the end of the Eocene, the transgression occurred due to the interconnection of the Buda Paleogene Basin and Central Carpathian Paleogene Basin (Gross, 1978; Nagymarosy, 1991). The massive sea transgression towards the south led to origin of one elongated basin. Sea connection existed in the area of the Central Slovakian fault system (Vass, 1995; Janočko et al., 2002). Climatic change culminated during the Upper Eocene, when the temperature of the world's oceans decreased on average by 2–5 °C on 12–15 °C (Shackleton and Kennett, 1975; Soták et al., 2002).

In the assemblage of the calcareous nannofossils this trend showed a visible increase in the number of small *Noelarhabdaceae,* which characterized cold season. The species *Blackites spinosus* (Deflandre & Fert) Hay & Towe and *Rhabdosphaera tenuis* Bramlette & Sullivan indicate short warm periods, which are supported by Milankovitch cycles (Krhovský et al., 1993). The Upper Eocene stage is also characterized by the last occurrence of warm water species as *Discoaster barbadiensis* Tan Sin Hok, *Discoaster saipanensis* Bramlette & Riedel and by the onset of the cold water species *Isthmolithus recurvus* Deflandre. These changes in the calcareous nannofossils assemblage occurred below or directly on the Eocene/Oligocene boundary (Krhovský et al., 1993; Nagymarosy, 1991; Švábenická et al., 2007).

The Lower Oligocene stage is characterized as a time of great cooling trend, which is in the calcareous nannofossil assemblage showed as expansion of the cold water placoliths forms with larger size of coccoliths (Blaj, 2009; Perch-Nielsen, 1985). Warm water genera *Discoaster* and *Sphenolithus* almost did not occur during the Oligocene time.

Decrease in salinity as a result of termination of Paratethys isolation has caused changes in assemblage of the calcareous nannofossils. A sudden drop in species diversity and the occurrence of endemic form *Reticulofenestra ornata* Müller is typical for the Nannoplankton zone NP 23 (for example Krhovský and Djurasinovič, 1994; Švábenická et al., 2007). The bloom of this endemic form is recorded in the Paleogene basins in the Western Carpathians, too (Ozdínová, 2010). Increase of this species indicated the decrease of the salinity and brackish paleoenvironment in the ocean. Together with *Reticulofenestra ornata* Müller there occur species *Braarudosphaera bigelowii* (Gran & Braarud) Deflandre and *Transversopontis fibula* Gheta, which also tolerate salinity fluctiations (Krhovský et al., 1993). Increased occurrence of the genera *Sphenolithus, Helicosphaera* and *Pontosphaera* indicates shallow water and warm water conditions in the sedimentary area (Švábenická et al., 2007).

Bloom of the calcareous nannofossils during the Upper Oligocene was caused by restoring of the sea connection and good communication of Paratethys with the open Ocean. This event caused rising the sea level, modifying the salinity, and an increase of supply of terrestrial material into the sea area, resulting in a rise of the proportion of nutrient in the photic zone (Krhovský and Djurasinovič, 1994).

Outline of geology

The calcareous nannofossils were examined from the sediments of three different Western Carpathians Paleogene basins (Fig. 1). The Veľké Kršteňany KRS-2 profile is located in the Hornonitrianska panva Basin and Vlachy-1 borehole is situated in the Liptovská kotlina Basin. Both basins have a common evolution and they belong to the Subtatric group of the flysch zone. Sediments of the Veľké Kršteňany KRS-2 profile and Vlachy-1 borehole belong to Zuberec Formation.

Zuberec Formation consists of the typical medium-rhythmical flysch, composed from alternating pelitic, aleuritic and psammitic sediments. Formation thickness ranges from tens of meters to 1 450 m. In the Liptovská kotlina Basin, the Zuberec Formation is represented by the flysch with dominating claystones and they cover larger areas with greater thickness. Their age of formation is Eocene to Oligocene (Priabonian; Gross et al., 1984).

Borehole Rapovce GTL-2 is located in the Lučenská kotlina Basin, belonging to the Buda Paleogene Basin development. The borehole sediments extend through *Číž* and *Lučenec Formation* (Pristaš et al., 2000).

Lučenec Formation is in major part of the borehole represented by *Szecsény Schlier,* which settled in the shelf up to deep-sea environments. It is composed mainly of the silt to siltstone with laminae of disintegrating fine-grained sandstone and sand. The small part of the borehole is composed from Panica Beds formed by sandstone, conglomerate and siltstone. This one represents a transgressive member of the Lučenec Formation (Vass et al., 2008).

In the borehole, the ***Číž Formation*** is represented by *Rapovce, Lenártovce, Hostišovce* and *Blh beds* (Vass et al., 2008).

Rapovce Beds are composed from the prograde basin sediments, such as sandstones with interbeds of siltstones and coal. ***Lenártovce Beds*** are formed of the grey calcareous siltstones with interbeds of fine-grained sandstones. They represent the deeper shelf sediments corresponding to a culmination of the marine transgression. The ***Hostišovce Beds*** are formed of sandstones with calcareous siltstones and coal. The environment of the formation of Hostišovce Beds was represented by the semi--enclosed lagoon, which occasionally communicated with an open sea. In the borehole, the ***Blh Beds*** are formed of

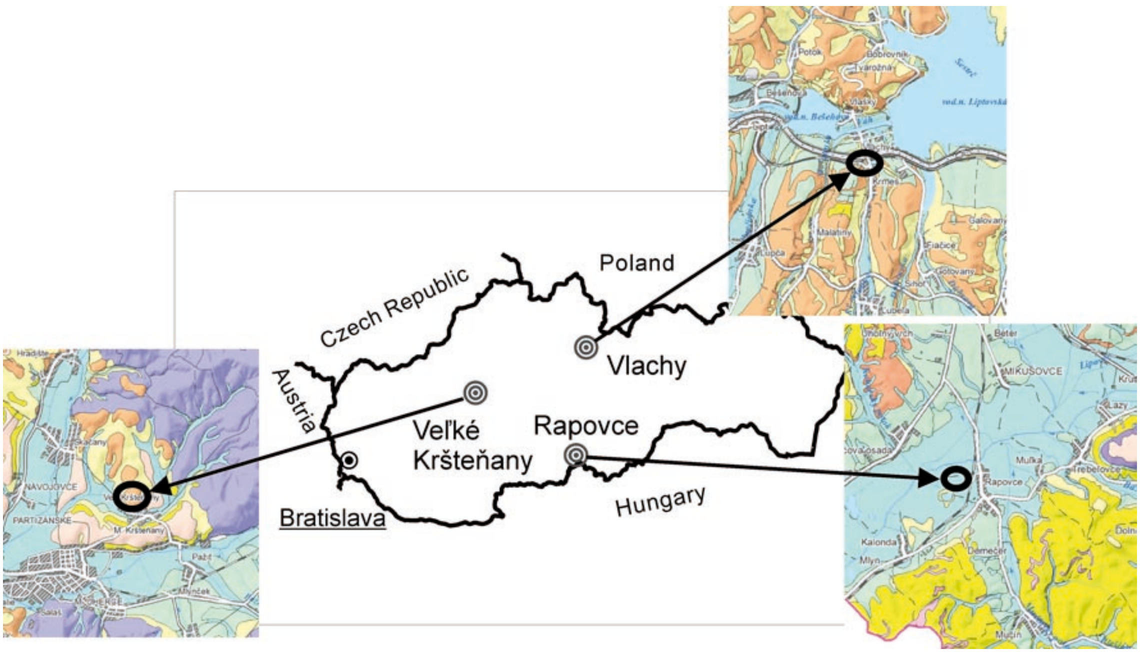


Fig. 1. Location of the boreholes Vlachy-1 and Rapovce GTL-2, as well as profile Veľké Kršteňany KRS-2. More detailed lithostratigraphy present in individual images of Fig. 1 and related to solved topic is shown in the lithostratigraphic columns in Figs. 2–4.

sandstone and sand with laminated calcareous siltstones (Vass et al., 2008).

Materials and methodology

Material

Samples for the study of calcareous nannofossils were taken from the Middle Eocene to Oligocene sediments of Paleogene basins of the Western Carpathians. From the Veľké Kršteňany KRS-2 profile there were taken 28 samples. The profile has been designed to the Middle Eocene nannoplankton zones NP 13/14 to NP 17 (according Martini, 1971), from which 8 samples were statistically evaluated, containing calcareous nannofossils from the zones NP 16 and NP 17 (Fig. 2).

In the Vlachy-1 borehole altogether 66 samples were taken from the range 1 140 m. All samples were used for the statistical research. The samples had determined the nannoplankton zones NP 21 to NP 23 (Ozdínová, 2009; Ozdínová et al., 2009; Fig. 3).

Altogether 78 samples were collected from the Rapovce GTL-2 borehole, encompassing an interval 55–770 m. Totally 48 samples were used for statistical evaluation, which contained calcareous nannofossils from the nannoplankton zone NP 23 and NP 24/25 (Fig. 4).

The research aimed to determine the changes of the dimensions of the species *Coccolithus pelagicus* (Wallich) Schiller, *Dictyococcites bisectus* (Hay, Mohler & Wade) Bukry & Percival and *Reticulofenestra umbilica* (Levin) Martini & Ritzkowski in relation to paleoclimatic conditions, especially temperature in the sedimentary area. The cold Upper Eocene and Lower Oligocene climate was significantly changed in comparison with the Middle Eocene warm period (Bohaty and Zachos, 2003; Krhovský and Djurasinovic, 1994). Therefore we have compared selected placolith forms of the calcareous nannofossils from the Middle Eocene warm period vs. the Upper Eocene to Lower Oligocene cold period.

Preparation of specimens

The samples for the study of calcareous nannofossils were taken mainly from pelitic rocks (clay and marly), containing $CaCO_3$. Samples were prepared by the classical method of decantation (Haq and Lohmann, 1976; Perch-Nielsen, 1985). Prepared samples were observed using a light microscope and documented with a digital camera.

The nanoplankton zones NP 16, NP 17, NP 21, NP 22, NP 23 and NP 24/25 were determined by biostratigraphic correlation according Martini´s zonation (1971), Perch--Nielsen (1985), Bown (1998) and Wise et al. (2002).

Morphometric analysis

The morphometric analysis applied the methodology by Blaj (Blaj, 2009). In this work in each sample there was measured the length of 30 specimens of the species *Coccolithus pelagicus* (Wallich) Schiller, *Dictyococcites bisectus* (Hay, Mohler & Wade) Bukry & Percival and *Reticulofenestra umbilica* (Levin) Martini & Ritzkowski. Length of individual objects was measured and from the data the arithmetic mean was calculated for each sample separately. The data were plotted applying the MS Excel software.

Biostratigraphic evaluation

In the Veľké Kršteňany KRS-2 profile we have determined the Middle Eocene nannoplankton zones NP 13/14 to NP 17 (Fig. 2). Zones NP 13/14 are evidenced by a very weak occurrence of the species *Tribrachiathus orthostylus* (Bramlette & Riedel) Shamrai, having its last occurrence at the base of the zone NP 13. The zone NP 14 was identified by the presence of the species *Rhabdospaera inflata* Bramlette & Sullivan. Zone NP 15 was established by the occurrence of the species *Reticulofenestra umbilica* (Levin) Martini & Ritzkowski and *Lanternithus minutus* Stradner, which have their first occurrence in this zone. Zone NP 17 was identified by the occurrence of the species *Discoaster saipanensis* Bramlette & Riedel and *Cyclicargolithus floridanus* (Roth et Hay) Bukry. In the zone NP 17 firstly appeared the species *Chiasmolithus oamaruensis* (Deflandre) Hay, Mohler & Wade (Ozdínová, 2009).

In the Vlachy-1 borehole we have determined nannoplankton zones NP 21, NP 22 and NP 23 (Fig. 3). Concerning biostratigraphy, important species for NP 21 zone in this borehole were: *Isthmolithus recuvus* Deflandre and *Lanternithus minutus* Stradner, together with the absence of the species of genera *Discoaster*. For NP 21 zone, found in this borehole, the important was the first occurrence of *Chiasmolithus altus* Bukry & Percival. The NP 23 zone was detected by the species *Reticulofenestra ornata* Müller and the sporadic occurrence of the species *Isthmolithus recuvus* Deflandre (Ozdínová, 2009).

In the Rapovce GTL-2 borehole we have determined the nannoplankton zones NP 23 to NN 2 (Fig. 4). Nannoplankton zone NP 23 was detected by the occurrence of the species *Reticulofenestra ornata* Müller. The NP 24 zone was determined by the first occurrence of the species *Cyclicargolithus abisectus* (Müller). Wise and the zone NP 25 was based on the occurrence of the species *Triquetrorhabdulus carinatus* Martini and *Triquetrorhabdulus milowii* Bukry. The Lower Miocene zone NN 1 was identified by the presence of the species *Sphenolithus conicus* Bukry and the zone NN 2 by the occurrence of the stratigraphic important species *Discoaster druggii* Bramlette & Wilcoxon (Halásová in Vass et al., 2008).

Paleoecological evaluation

The presence and distribution of calcareous nannofossils is conditioned by many factors, encompassing temperature, nutrients and depth of the sea water, as well as ocean circulation, transgression and salinity of the sea water. Different sizes can be associated with functions of coccoliths, which are light concentration and biochemical linkage of calcification to photsynthesis. Floriform species can easily fulfill these functions, especially the species with large coccospheres relative to cell size (Young in Winter and Siesser, 1994). The size of coccoliths affected depth of the ocean, too. Most species has a precise paleoecological parameters an environment for their survival. The most abundant placolith-form species of the calcareous nannofossils *Coccolithus pelagicus* (Wallich) Schiller, *Reticulofenestra umbilica* (Levin) Martini & Ritzkowski and *Dictyococcites bisectus* (Hay, Mohler & Wade) Bukry & Percival were statistically evaluated. These species responded on the change in paleoecological conditions of sedimentary environment by increasing or decreasing of the dimensions of their body (Blaj, 2009; Perch-Nielsen, 1985).

***Coccolithus pelagicus* (Wallich) Schiller** is a small elliptical placolith with dimensions of 5 to 13 μm, which has its first occurrence in the nannoplankton zone NP 1 during a lowermost Paleocene and occurs through the Paleogene, Neogene up to the Pleistocene nannoplankton zone NN 21. At present time, this species is considered as a cold water form, however during a Paleocene it preferred warm to

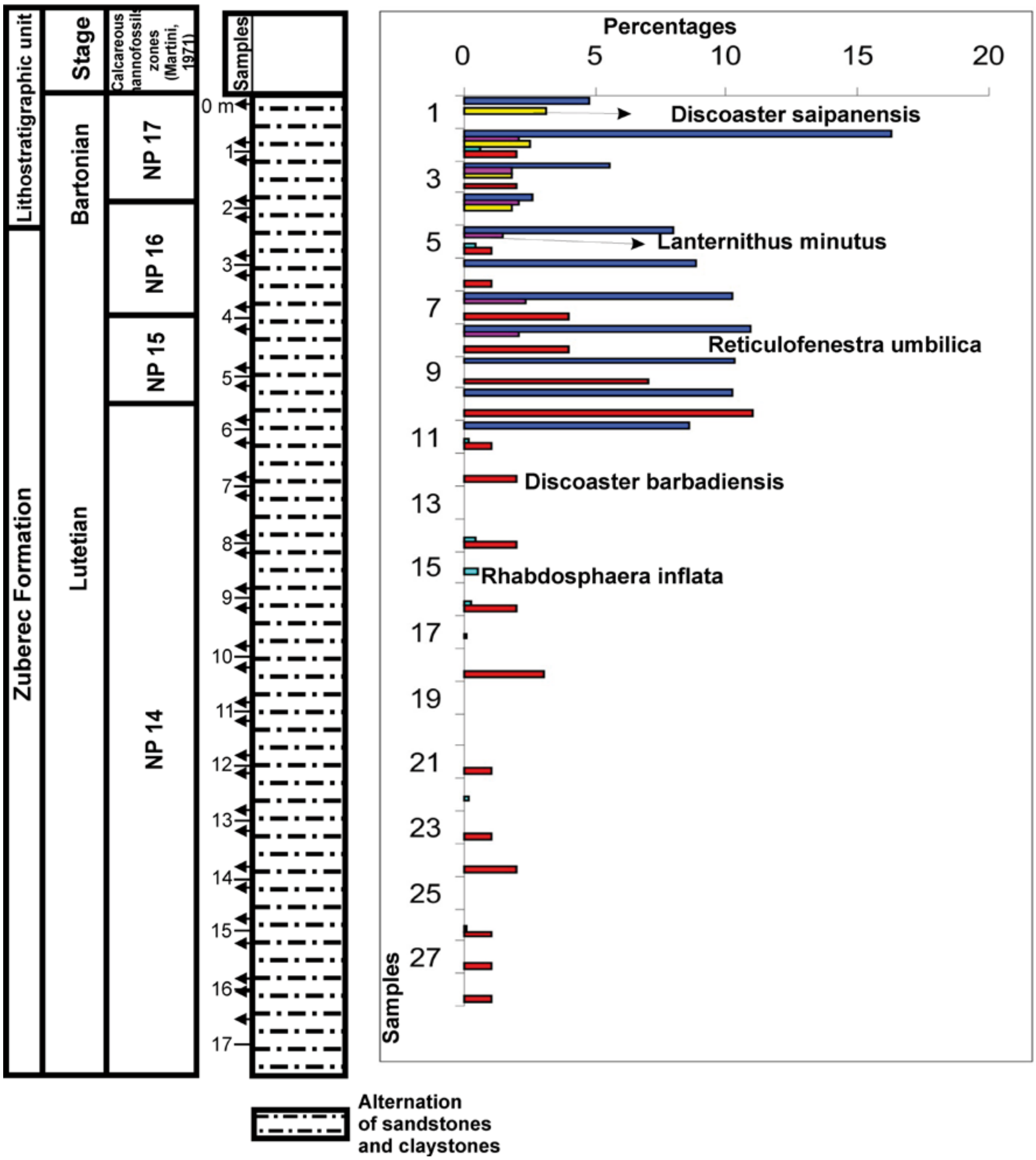


Fig. 2. Lithological and biostratigraphic evaluation of the Veľké Kršteňany KRS-2 profile.

moderate temperate water marine sedimentary conditions (Persico and Villa, 2004; Villa and Persico, 2006; Villa et al., 2008) and low latitudes (Perch-Nielsen, 1985).

During a cooling period the species *Coccolithus pelagicus* (Wallich) Schiller changed the dimensions of the body of coccolits as well as other placolith forms (e.g. Mita, 2001).

In our samples, in the zones NP 16 and NP 17 there was the largest abundance of the subjects with 5–7 µm size of the body, in the zones NP 21 to NP 23 the subjects with 7 to 8.5 µm of body-size had the major occurrence and in the zones NP 24/25 dominated subjects with 5–7 µm body-size. The graphic data from the statistical evaluation of the morphometric analyses show that a change of the body dimensions is the most significant in the zone NP 21 to NP 23, the largest subjects occurred in the zone NP 22 (Fig. 5).

Reticulofenestra umbilica **(Levin) Martini & Ritzkowski** is a large oval placolith with a body-size of 14–20 µm. The first occurrence is in the Middle Eocene

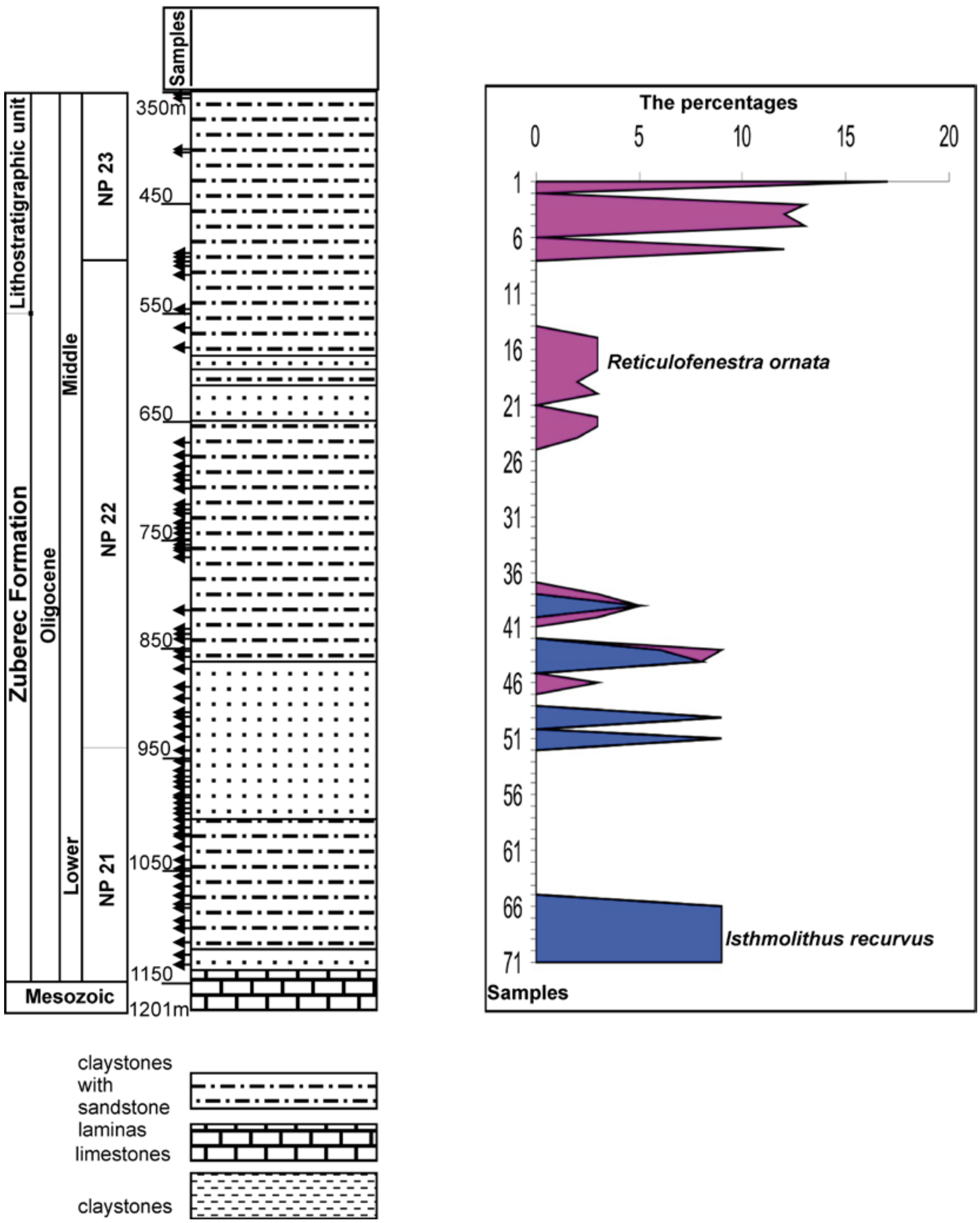


Fig. 3. Lithological and biostratigraphic evaluation of the Vlachy-1 borehole.

zone NP 15 and its last occurrence is in the Middle Oligocene zone NP 22. It is considered as a temperate water species (Wei and Wise, 1990; Persico and Villa, 2004; Villa et al., 2008).

In our samples from the nannoplankton zones NP 16 and NP 17, subjects with 14 to 15.5 μm of body-size have the most occurrence, in the zones NP 21 and NP 22 the largest abundance in the subjects with 16–18 μm of the body-size was found. The species *Reticulofenestra umbilica* (Levin) Martini & Ritzkowski has its last occurrence in the zone NP 22, even though it was found in other samples, it has not been evaluated. The statistics also show that the increase in dimensions of subjects was particularly noticeable in the zone NP 22 (Fig. 6).

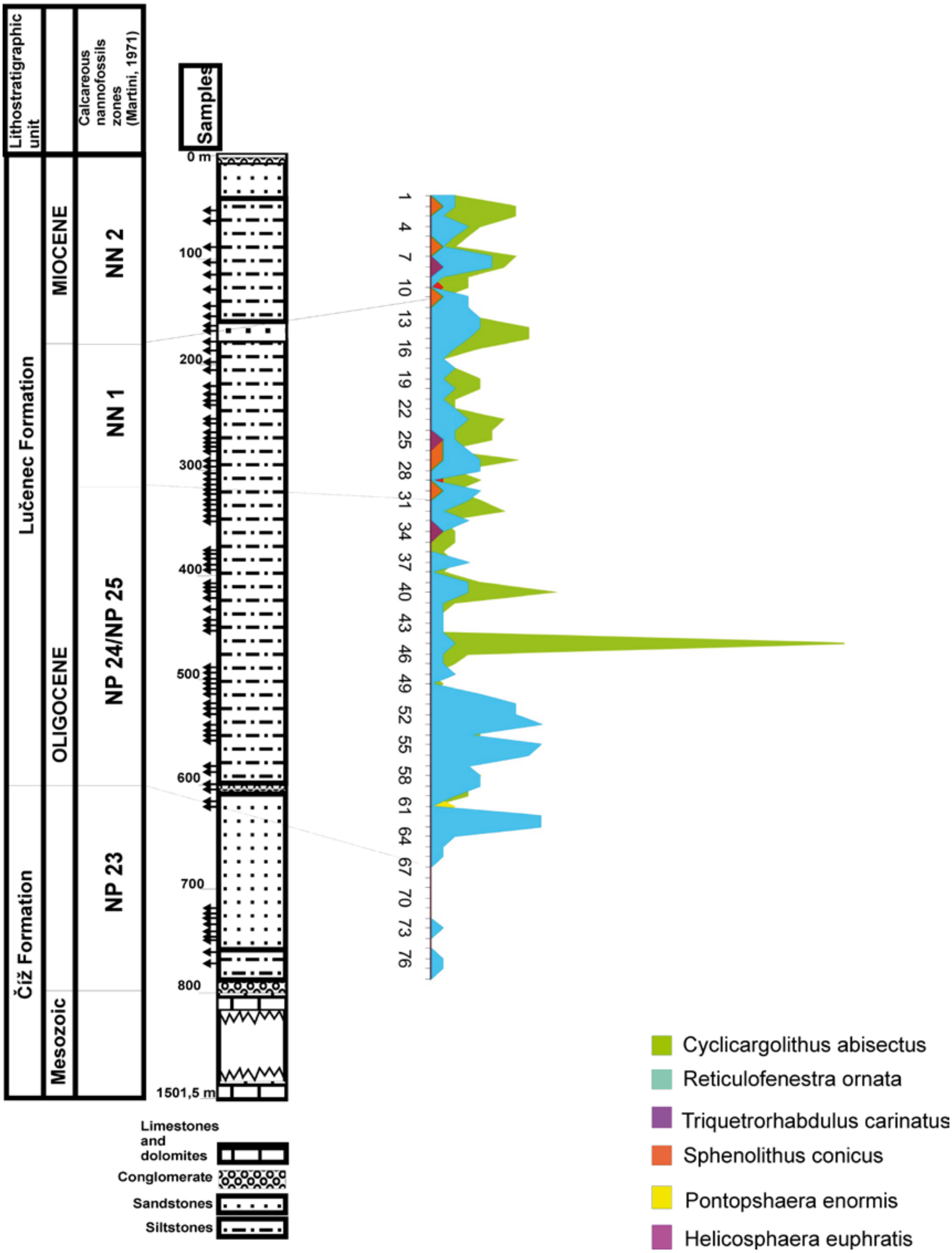


Fig. 4. Lithological and biostratigraphic evaluation of the Rapovce GTL-2 borehole.

Dictyococcites bisectus **(Hay, Mohler & Wade) Bukry & Percival** is a medium to large oval placolith with 8 to 18 μm body-size. Its first occurrence was observed in the zone NP 17 and its last occurrence in the zone NP 25. This species preferred eutrophic and temperate water sedimentary area (Persico and Villa, 2004; Villa and Persico, 2006; Villa et al., 2008).

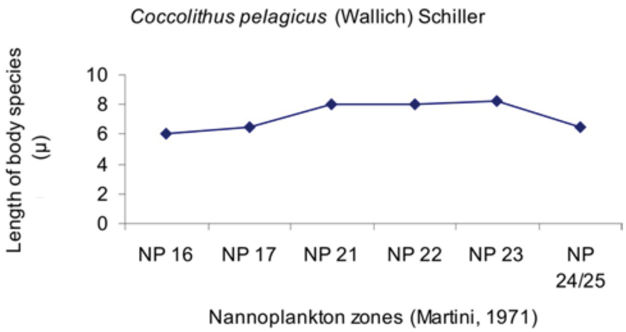


Fig. 5. Statistical evaluation of the length of the body species *Coccolithus pelagicus (Wallich) Schiller* (Wallich) Schiller.

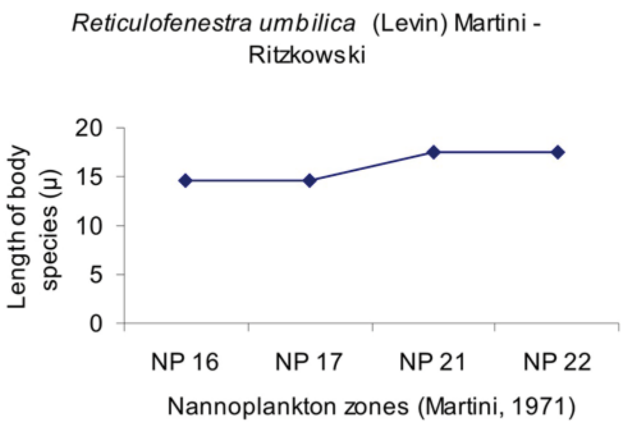


Fig. 6. Statistical evaluation of the length of the body species *Reticulofenestra umbilica (Levin) Martini & Ritzkowski* (Levin) Martini & Ritzkowski.

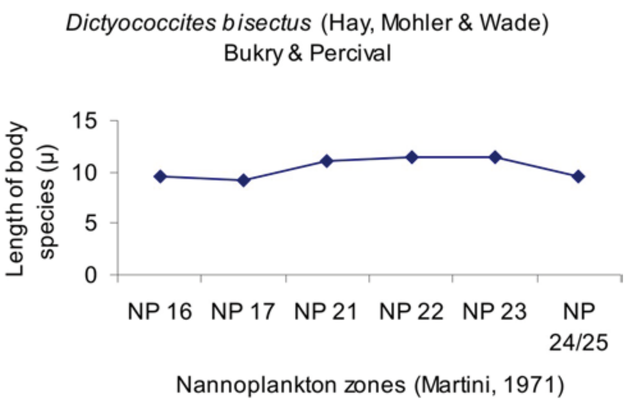


Fig. 7. Statistical evaluation of the length of the body species *Dictyococcites bisectus (Hay, Mohler & Wade) Bukry & Percival* (Hay, Mohler & Wade).

In the samples from the nannoplankton zone NP 17 the subjects with 8–9.5 μm of the body-size were the most common, in the zones NP 21 to NP 23 subjects with 10–12 μm of the body-size are the most numerous and in the zones NP 24/25 dominated subjects with 8–10 μm. The graphic data from the statistical evaluation of the morphometric analyses show that the dimension increase of the subjects occurred in the zone NP 22 (Fig. 7).

Discussion

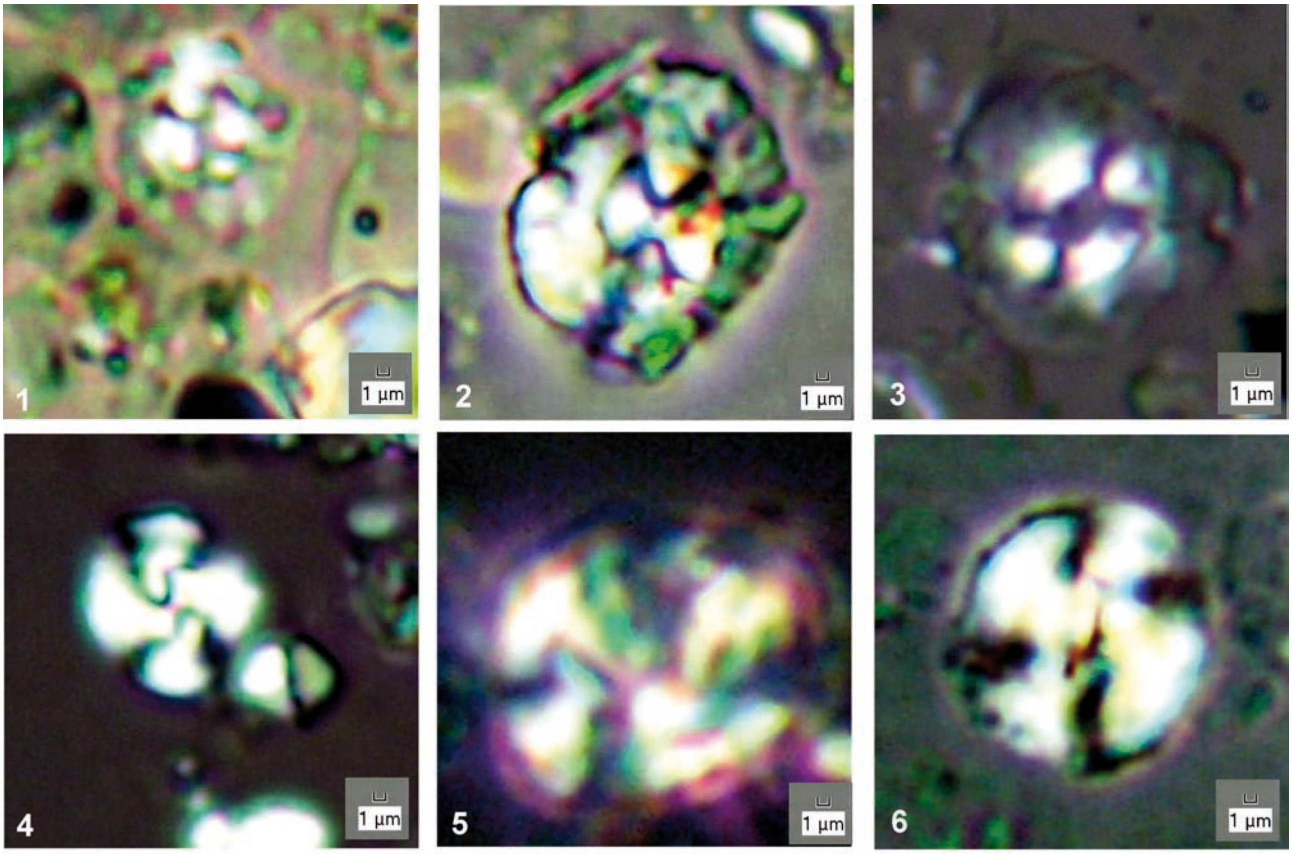
The statistical data obtained in this work show that species *Coccolithus pelagicus* (Wallich) Schiller, *Dictyococcites bisectus* (Hay, Mohler & Wade) Bukry & Percival and *Reticulofenestra umbilica* (Levin) Martini & Ritzkowski show larger body-sizes from the Lower Oligocene sediments than body-size of species coming from the Middle Eocene and Upper Oligocene sediments.

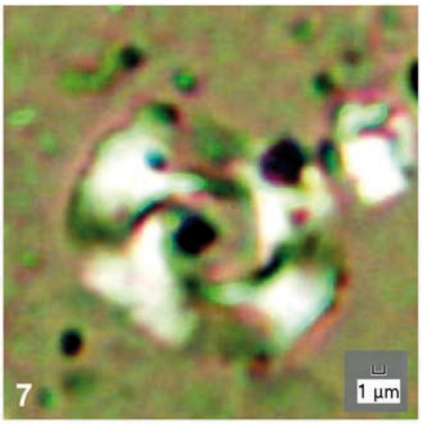
Increase of the body-size of placolith forms during this cooling time are described in the works e.g. Perch-Nielsen (1985), Blaj (2009) and Mita (2001). A similar trend was also observed in other species of organisms, for example sporomorphs.

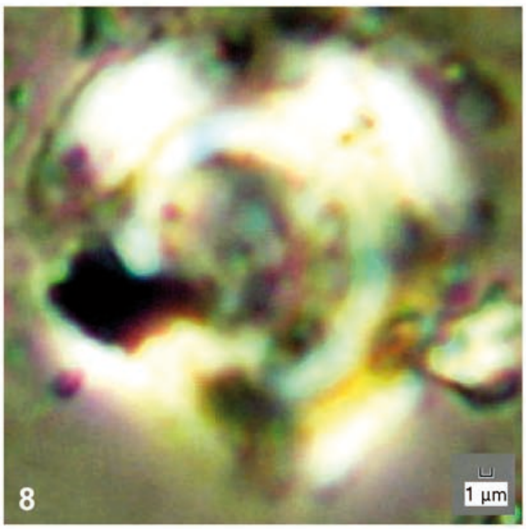
During Tertiary the species *Coccolithus pelagicus* (Wallich) Schiller prefers temperate water conditions in the sedimentary area (Persico and Villa, 2004; Narsico et al., 2006; Villa et al., 2008), but according Wei and Wise (1990) this species was preferring warm water environment. In the present time the species occupies cold water environment (Ziveri et al., 2004), this change was done on the development of its paleoecological claims to progressive preference for cold living conditions. During the Eocene period, different body-proportion variation of the species *Coccolithus pelagicus* (Wallich) Schiller is described by Narciso et al. (2006), which sets out various stages of its size-variation – small, medium and large. On the basis of their size these authors even earmarks a new kind of morphotypes. These variations in the body-size of subjects authors justify by convection of water masses, while in colder waters there occur specimens with larger body-size and in the warmer waters with smaller body-size of specimens. Similarly, Mita (2001) describes the change of the specimens of the genus *Coccolithus* by the influence of cold marine conditions.

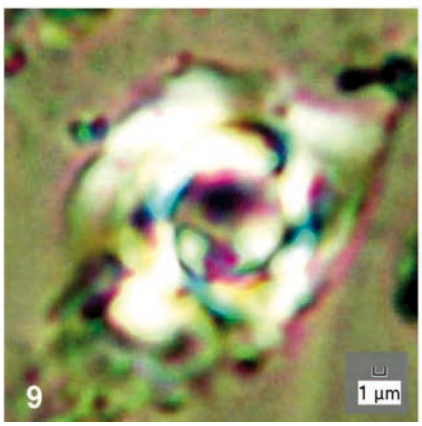
Parente et al. (2004) have earmarked three morphotypes variation *Coccolithus pelagicus* (Wallich) Schiller. Small form *Coccolithus pelagicus* ssp. *pelagicus* (Wallich) Schiller with dimensions of 6–10 μm characterized as cold water form, this form lived in arctic waters with temperatures less than 10 °C.

Middle variety forms *Coccolithus pelagicus* ssp. *braarudi* (Gaarder) Geisen et al. (2002) with dimensions of 10–13 μm lived in slightly warm waters in the oceans near Iberia and it is influenced by the position of coastal upwelling of Iberia.









Pl. I. 1 – *Coccolithus pelagicus* (Wallich) Schiller, Veľké Kršteňany KRS-2, NP 16 zone; 2 – *Coccolithus pelagicus* (Wallich) Schiller, Vlachy-1, NP 22 zone; 3 – *Coccolithus pelagicus* (Wallich) Schiller, Rapovce GTL-2, NP24/25 zone; 4 – *Dictyococcites bisectus* (Hay, Mohler & Wade) Bukry & Percival, Veľké Kršteňany KRS-2, NP 16 zone; 5 – *Dictyococcites bisectus* (Hay, Mohler & Wade) Bukry & Percival, Vlachy-1, NP 22 zone; 6 – *Dictyococcites bisectus* (Hay, Mohler & Wade) Bukry & Percival, Rapovce GTL-2, NP 24/25 zone; 7 – *Reticulofenestra umbilica* (Levin) Martini & Ritzkowski, Veľké Kršteňany KRS-2, NP 16 zone; 8 – *Reticulofenestra umbilica* (Levin) Martini & Ritzkowski, Vlachy-1, NP 22 zone; 9 – *Reticulofenestra umbilica* (Levin) Martini & Ritzkowski, Rapovce GTL-2, NP 24/25 zone.

Warm water variety forms represent subspecies *Coccolithus pelagicus* ssp. *azorinus* Parente & Cachão, which lived in waters with a temperature of 14–16 °C and has a size of 9 to 15 μm. Parente explains the different variety of the body-size by influence of NAO – North Atlantic Oscillation, which causes varying humidity of the atmosphere and also brings different water temperature.

The species *Dictyococcites bisectus* (Hay, Mohler & Wade) Bukry & Percival is considered as a warm water species (Wei and Wise, 1990; Monechi et al., 2000) and according Wei et al. (1992), Persico and Villa (2004), Villa and Persico (2006) and Villa et al. (2008) this species preferred temperate water conditions. Therefore, during cooling term there was recorded the decline in numbers of these specimens. The statistical data presented in this work show that the body-size of specimens of that species during the cooling period increased, which can be explained by changing paleoecological conditions in the Lower Oligocene sedimentary basins.

The species *Reticulofenestra umbilica* (Levin) Martini & Ritzkowski is considered as temperate water species (Wei and Wise, 1990; Persico and Villa, 2004; Villa et al., 2008), but according Monechi (in Monechi et al., 2000) this species prefers cool water conditions. According to our statistics, the body-size of specimens of this species increased, but it brings some difficulties in interpretation of these data. The size proportions of this species are increased during warm periods, such as MECO period. During the colder periods there is a reduction of body--size of species. Their small body-size is also associated with their adaptation to eutrophic conditions, because this species prefers oligotrophic conditions (Okada and Honjo, 1973; Winter et al., 1994). A similar phenomenon increase in the body-size of species *Reticulofenestra umbilica* (Levin) Martini & Ritzkowski described by Mita (2001), which, however, is not its cause.

Change of the body-size of the genera *Cyclicargolithus, Dictyococcites* and *Reticulofenestra* is stated by Blaj (2009), who described up to twice enlarge of these genera. He puts these changes in their body-size into the context with long term cooling trend that was continued during the Lower Oligocene. Similarly, Mita (2001) indicates the change of the body proportions of the species *Coccolithus, Reticulofenestra* and *Cribrocentrum* in the cooling term.

Based on the data collected in this article, there can be confirmed a response of the placoliths species of calcareous nannofossils on the change of paleoecological environment in the Central Carpathians Paleogene Basin by changing of their body-proportions. The reasons for the increase in the size of specimens of these species can not be exactly determined. As follows from the data obtained by the literature studying, there is no evidence that the mentioned placolith forms of calcareous nannofossils responded by changing its size only to cooling trend of the sea water.

Enlarging of the body-size of species can be caused by any of changes of paleoecological conditions, which is cooling trend, eutrophication, stratification of the water column, the supply of continental material, volcanic activity and semi-isolation of the basin (Soták, 2010).

Conclusion

In the Middle Eocene to Upper Oligocene sediments of the Subtatric group and Buda Paleogene of the Western Carpathians, the impact of changes of paleoecological conditions of the calcareous nannofossils was explored, specifically the impact on the size of studied objects.

Examined and statistically evaluated species were the placolith forms, being the most abundant in the assemblage of the calcareous nannofossils, and they are considered as the species responding to change of the temperature of paleoenvironment by the change of their body-size, as *Coccolithus pelagicus* (Wallich) Schiller, *Dictyococcites bisectus* (Hay, Mohler & Wade) Bukry & Percival and *Reticulofenestra umbilica* (Levin) Martini & Ritzkowski.

The results of the study show that calcareous nannofossils responded to changing paleoclimatic conditions and visibly enlarged their body-proportions. As the cause of changes in their body-proportions but can not be described by a cooling term, it can be caused by either paleoecological characteristics of the Lower Oligocene sediments of the Western Carpathians.

Acknowledgement. The author thanks to Doc. RNDr. Soták, DrSc., for the samples and for valuable information. RNDr. Lilian Švábenická, PhD. and RNDr. Katarína Žecová are gratefully acknowledged for their valuable comments on the manuscript. The research project was financed from the Vega 2/0145/11.

References

Blaj, T., 2009: Late Eocene through Oligocene calcareous nannofossils from the paleo-equatorial Pacific Ocean – taxonomy, preservation history, biochronology and evolution. Stockholm University.

Bohaty, S. M. & Zachos, J. C., 2003: A significant Southern Ocean warming event in the late Middle Eocene. *Geology, 31, 1 017 – 1 020.*

Bown, P. R., 1998: Paleogene: Calcareous Nannofossil Biostratigraphy. *Chapman et Hall, London, 204 – 217.*

Gross, P., Köhler, E. & Samuel, O., 1984: New lithostratigraphic division of the Central Carpathian Paleogene. *Geol. Práce, Spr., 81, 103 – 118. (In Slovak.)*

Gross, P., 1978: Paleogene beneath Central Slovakian neovolcanic rocks. *In: Vozár, J. (ed.): Paleogeographical evolution of the West Carpathians. Konf., Symp., Sem., GÚDŠ, Bratislava, 121 – 146.*

Haq, B. U. & Lohmann, G. P., 1976: Early Cenozoic calcareous nannoplankton biogeography of the Atlantic Ocean. *Mar. Micropaleontology, 1, 119 – 194*

Janočko, J., Jacko, S. & Žecová, K., 2002: Tectogenesis of the sedimentary basins of the Western Carpathians. *Report to geological task 130 – 01. ŠGÚDŠ, Bratislava. (In Slovak.)*

Köhler, E., 1998: The last occurrences of large numulites in the West Carpathian Eocene. *Zem. Plyn Nafta, 43, 1, 163 – 172.*

Krhovský, J., Adamová, M., Hladíková, J. & Maslovská, H., 1993: Paleoenviromental changes across the Eocene/Oligocene boundary in the Ždánice and Pozdřany units (Western Carpathians, Czechoslovakia): The long-term trend and orbitally forced changes in calcareous nannofossil assemblages. *In: Hamršid, B. & Young, J. R. (eds.): Nannoplankton research.*

Vol. II, Proc. 4th INA Conference, Prague 1991. Knih. Zem. Plyn Nafta, 14b, 105 – 155.

Krhovský, J. & Djurasinovič, M., 1994: The nannofossil chalk layers in the early Oligocene Šitbořice Member in Veľké Nemčice (the Menilitic Formation, Ždánice unit, south Moravia): Orbitaly forced changes in paleoproductivity. *Knih. Zem. Plyn Nafta, 15, 33 – 53.*

Martini, E., 1971: Standard Tertiary and Quaternary calcareous Nannoplankton zonation. *Proc. of the II. Planktonic Conference, Roma.*

Mita, I., 2001: Data Report: Early to late Eocene calcareous nannofossil assemblages of Sites 1051 and 1052, Blake Nose, northwestern Atlantic Ocean. *In: Kroon, D., Norris, R. D. & Klaus, A. (eds.): Proceedings of the Ocean Drilling Program, Scientific Results, College Station, TX (Ocean Drilling Program), 171B, 1 – 28, doi:10.2973/171B.122.2001*

Monechi, S., Buccianti, A. & Gardin, S., 2000: Biotic signals from nannoflora across the iridium anomaly in the Upper Eocene of the Massignano section: Evidence from statistical analysis. *Mar. Micropaleontology, 39, 219 – 237.*

Nagymarosy, A., 1991: From Tethys to Paratethys, a way of survival. *Acta geol. geophys. mont. hung., 25, 3 – 4, 373 – 385.*

Narciso, A., Cachao, M. & De Abreu, L., 2006: Coccolithus pelagicus (Wallich) Schiller subsp. pelagicus versus Coccolithus pelagicus (Wallich) Schiller subsp. braarudii (Coccolithophore, Haptophyta): A proxy for surface subarctic Atlantic waters off Iberia during the last 200 kyr. *Mar. Micropaleontology, 59, 15 – 34.*

Okada, H. & Honjo, S., 1973. The distribution of oceanic coccolithophorids in the Pacific. *Deep-Sea Research, 20, 355 – 374.*

Ozdínová, S., 2009: Oligocene nannofossils from the Paleogene basins of the Western Carpathians. *Miner. Slov., 41, 4, Geovest., 545. (In Slovak.)*

Ozdínová, S., Halásová, E. & Soták, J., 2009: Paleoecological interpretation of the Rapovce GTL-2 drilling (Lučenská kotlina depression). *In: Fossils – Darwin – Evolution: 10th Anniversary Conference of the Czech, Polish and Slovak Paleontologists. Abstracts and Guide of Excursion. Banská Bystrica, Faculty of Natural Sciences, Matej Bel University, 38 – 39.*

Ozdínová, S., 2010: Reticulofenestra ornata Müller – indigenous calcareous nannofossil from the Oligocene sediments of the Western Carpathians. *Miner. Slov., 42, 4, 429 – 438. (In Slovak with English resume.)*

Parente, A., Cachão, M., Baumann, K. H., Abreu, L. & Ferreira, J., 2004: Morphometry of Coccolithus pelagicus s.l. (Coccolithophore, Haptophyta) from offshore Portugal, during the last 200 kyr. *Micropaleontology, 50, 1, 107 – 120.*

Perch-Nielsen, K., 1985: Cenozoic calcareous nannofossils. *In: Bolli, H., Saunders, J. B. & Perch-Nielsen, K. (eds.): Plankton stratigraphy. Cambridge Univ. Press, Cambridge, 427 – 554.*

Persico, D. & Villa, G., 2004: Eocene-Oligocene calcareous nannofossils from Maud Rise and Kerguelen Plateau (Antartica): Paleoecological and paleooceanographic implications. *Mar. Micropaleontology, 52, 1 – 4, 153 – 179.*

Pristaš, J., Elečko, M., Maglay, J., Fordinál, K., Šimon, L., Gross, P., Polák, M., Havrila, M., Ivanička, J., Határ, J., Vozár, J., Tkáčová, H., Tkáč, J., Liščák, P., Jánová, V., Švasta, J., Remšík, A., Žáková, E. & Töröková, I., 2000: Explanations to geological map of the Danube Basin – Nitra Upland at a scale 1 : 50 000. *ŠGÚDŠ, Bratislava, 1 – 250. (In Slovak with English resume.)*

Shakleton, N. J. & Kennett, J. P., 1975: Paleotemperature history of the Cenozoic and the initiation of Antarctic glaciation: Oxygene and carbon isotope analyses in D.S.D.P. sites 272, 279 and 281. *Init. Reps. DSDP, 29, 743 – 755.*

Soták, J., Starek, D., Andreyeva-Grigorovič, A., Banská, M., Botková, O., Chalupová, B. & Hudecová, M., 2002: Climatic changes across the Eocene-Oligocene boundary: Paleoenviromental proxies from the Central Carpathian Paleogene Basin. *Geol. Carpath., 53, 28 – 30.*

Soták, J., 2010: Paleoenviromental changes across the Eocene--Oligocene boundary: Insights from the Central Carpathian Paleogene Basin. *Geol. Carpath., 61, 5, 393 – 418.*

Švábenická, L., Bubík, M. & Stránik, Z., 2007: Biostratigraphy and paleoenviromental changes on the transition from the Menilite to Krosno lithofacies (Western Carpathians, Czech Republic). *Geol. Carpath., 58, 3, 327 – 262.*

Vass, D., 1995: The origin and disappearance of Hungarian Paleogene Basins and short-term Lower Miocene Basins in Nothern Hungary and Southern Slovakia. *Slovak Geol. Mag., 2, 81 – 95.*

Vass, D., Soták, J., Dzúrik, J. & Halásová, E., 2008: New knowledge about Cenozoic fill of the Lučenská kotlina Basin. *Miner. Slov., 40, 1, 17 – 24. (In Slovak with English resume.)*

Villa, G. & Persico, D., 2006: Late Oligocene climatic changes: Evidence from calcareous nannofossils at Kerguelen Plateau Site 748 (Southern Ocean). *Palaeogeogr. Palaeoclimatol. Palaeoecol. (Amsterdam), 231, 110 – 119.*

Villa, G., Fioroni, C., Pea, L., Bohaty, S. & Persico, D., 2008: Middle Eocene-Late Oligocene climatic variability: Calcareous nannofossil response at Kerguelen Plateau, Site 748. *Mar. Micropaleontology, 69, 173 – 192.*

Wei, W. & Wise, S. W., 1990: Middle Eocene to Pleistocene calcareous nannofossils recorved by DSDP Leg 113 in the Weddell Sea. DSDP, Scientific Results, Florida.

Winter, A., Jordon, R. W. & Roth, P. H., 1994: Biogeography of living coccolithophores in ocean waters. *In: Winter, A. & Siesser, W. G. (eds.): Coccolithophores. Cambridge University Press, Cambridge, 161 – 177.*

Wise, S. W., Covington, J. M., Landner, B. & Wei, W., 2002: Electronic Calcareous nannofossils. Version 1.0: International nannoplankton Association. CD-Rom Series. No. 1.

Ziveri, P., Baumann, K. H., Böckel, B., Bollmann, J. & Young, J. R., 2004: Biogeography of selected Holocene coccoliths in the Atlantic Ocean. *In: Thiersten, H. R. & Young, J. R. (eds.): Coccolithophores: from Molecular Processes to Global Impact. Springer, 403 – 428.*

Manuscript received 21. 1. 2013
Revised form received 22. 5. 2013
Manuscript accepted by Editorial Board 27. 2. 2013