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Quantitative analysis of calcareous nannofossil assemblages across the Campanian/Maastrichtian boundary interval at Kladorub (NW Bulgaria): preliminary results

Количествен анализ на асоциациите от варовити нанофосили в Кампан-Мастрихтския граничен интервал в Кладоруб (СЗ България): предварителни резултати

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Abstract. An investigation of the variations in calcareous nannofossil abundances across the Campanian/Maastrichtian boundary interval at Kladorub (NW Bulgaria) has been carried out. The section has an established detailed biostratigraphic framework, based on calcareous nannofossils, and also contains the Campanian–Maastrichtian Boundary Event. The analysis shows that the nannofloras are dominated by *Prediscosphaera cretacea*, followed by *Watznaueria barnesiae*, *Micula staurophora*, *Arkhangelskiella* spp. and *Cribrosphaerella ehrenbergii*.

Keywords: calcareous nannofossils, nannofossil abundance fluctuations, Campanian/Maastrichtian boundary interval, Kladorub, Bulgaria.

Introduction

Although the Late Cretaceous is known to be one of the warmest intervals in the last 200 million years of Earth's history, recent studies have shown that a long-term cooling trend commenced in the Campanian (see Razmjooei et al., 2020, and references therein). Over this trend, several short-term cooling and warming episodes were superimposed during the late Campanian–Maastrichtian (*ibid*.). Aside from stable isotope analyses, the abundant specialised literature shows that variations in calcareous nannofloras have also been a contributing factor in outlining these climatic episodes during the Late Cretaceous. Quantitative studies on Late Cretaceous calcareous nannofossil assemblages in Bulgaria, however, are still rare, which prompted the present investigation.

Recently, Granchovski (2019) provided a detailed, high-resolution calcareous nannofossil biostratigraphy for the Upper Cretaceous portion of the Kladorub Formation at Kladorub (NW Bulgaria), which spans the interval from the upper Campanian (UC15d^{TP}) to the end-Maastrichtian (UC20d^{TP}). Stoykova et al. (2020) published stable isotope curves, derived from benthic foraminifera, for the section and recognised the presence of the Campanian–Maastrichtian Boundary Event (CMBE). The present account is a continuation of these studies. Its aim is to give preliminary data on the quantitative analysis of calcareous nannofossil assemblages across the CMBE at Kladorub.

Geological setting

According to current geodynamic models, the sediments of the Kladorub Formation are thought to have been deposited on the continental slope of a deep-water back-arc basin in the western periphery of the Moesian Platform (Dabovski et al., 2009). In terms of tectonics, its distribution is restricted to the limits of the Kula tectonic unit of Dabovski and Zagorchev (2009), which is a para-autochthonous unit regarded as a part of the South Carpathian orogenic system (*ibid*.).

Section Kladorub is situated ~2.5 km to the south-east of Kladorub village. It is comprised of grey to grey-greenish silty to fine-sandy marlstones, interbedded with rare marly limestones and sandstones. It spans the interval from the upper Campanian (*pars*.) to the Ypresian (*pars*.) (see Granchovski, 2019, and references therein). Detailed calcareous nannofossil biostratigraphy of the Upper Cretaceous part of the

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section, together with illustrations of the majority of the identified species, was published by Granchovski (2019). Recently, Stoykova et al. (2020) documented the CMBE at Kladorub, based on stable isotope data derived from benthic foraminifera.

Material and methods

Out of 164 calcareous nannofossil samples investigated for biostratigraphic purposes (Granchovski, 2019), a total of 71 slides, taken with a 50-cm resolution, were chosen for the present study. They span the interval from 33.5 m to 75.5 m (upper part of UC15e^{TP}–top UC18), which encompasses the CMBE (Stoykova et al., 2020). Nannofloras were examined in simple smear-slides, made following the methodology described by Bown and Young (1998). These were viewed at 1250× magnification, using an oil-objective lens (×100) on a Zeiss Axioskop 40 transmitting light-microscope. Specimens were counted in randomly selected fields of view from both the central and the peripheral areas of the slides. In samples containing fragmented specimens, identifiable coccoliths were counted as one specimen only if at least one-half of the coccolith was preserved. Relative abundances for each taxon were estimated over 400 specimens. Relative abundances of selected taxa are shown in Fig. 1.

The biostratigraphic framework adopted herein is that of Granchovski (2019), which is based on Burnett's (1998) global UC zonation, as supplemented by Thibault (2016) for UC16.

Results and discussion

One hundred and nine calcareous nannoplankton species have been recognised in the studied interval. Per-sample species richness varies from 68 to 86 (avg. 77). Preservation is predominantly moderate, with some secondary calcite overgrowth and/or dissolution apparent. Holococcoliths and small coccoliths are reasonably consistently present, which suggests that diagenesis has not had a too deleterious impact on the assemblages.

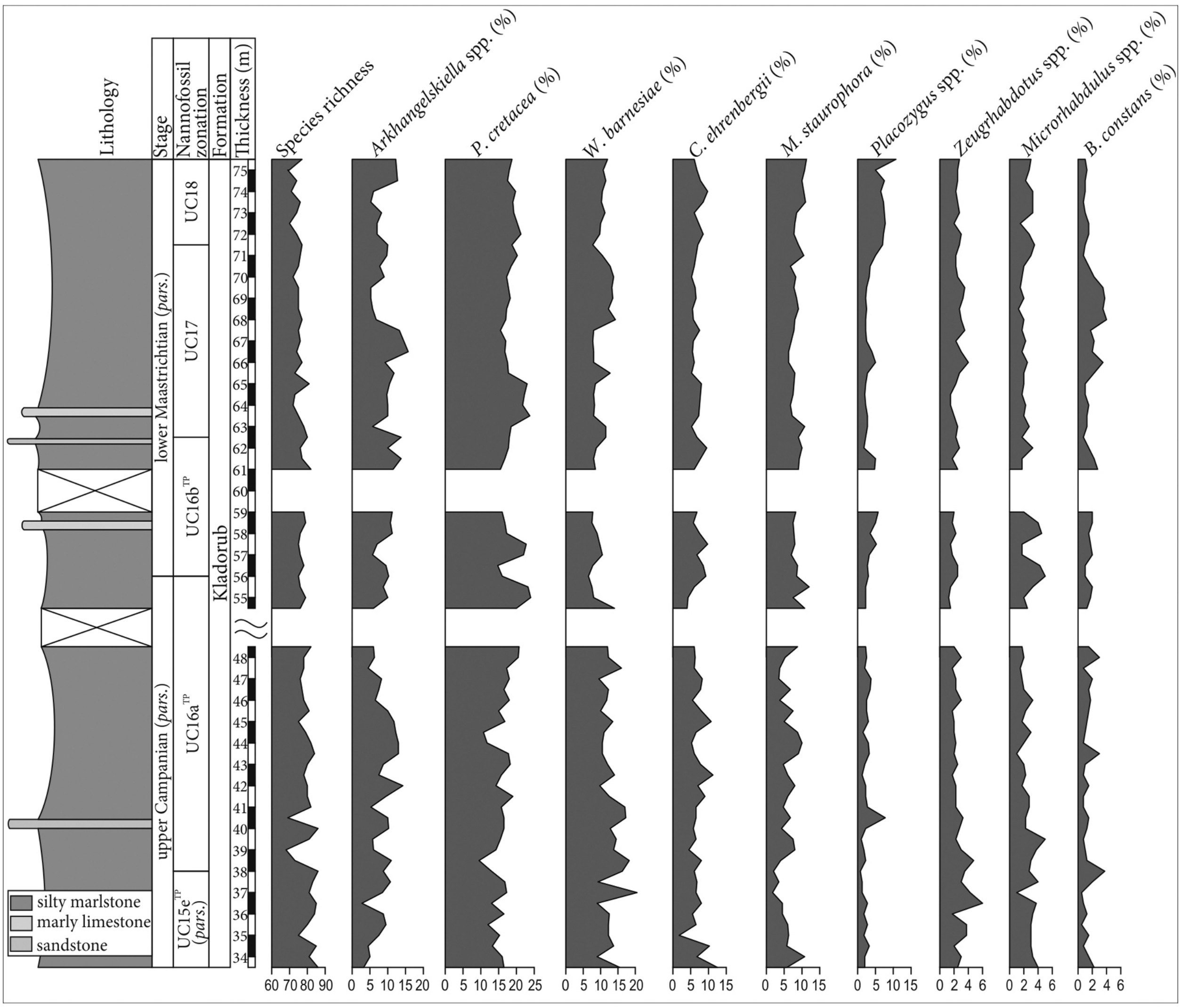

Fig. 1. Species richness and relative abundances (in %) of selected calcareous nannoplankton taxa from the Campanian/Maastrichtian boundary interval at Kladorub. Nannofossil biostratigraphy after Granchovski (2019).

The most abundant genus is *Prediscosphaera*, which accounts for 12.5% (at 44.5 m) to 27% (at 63.5 m) of the assemblages (avg. 20.79%). It is represented by *P. arkhangelskyi* (only in the lowest two samples), *P. cretacea*, *P. grandis*, *P. majungae*, *P. mgayae* (only from 57.5 m to 75.5 m), *P. microrhabdulina*, *P. ponticula*, *P. spinosa* and *P. stoveri*. Of these, *P. cretacea* distinctly dominates (avg. 17.48%), varying from 9.5% (at 38.5 m) to 24% (at 55 m). This species shows a trend towards slightly increased abundances in the lower Maastrichtian (avg. 18.61%) compared to the upper Campanian (avg. 16.31%) (Fig. 1).

Watznaueria comprises from 7.25% (at 56 m) to 22.25% (at 37 m) of the nannofossil assemblages, with an average of 12.14%. It includes *W. barnesiae*, *W. biporta*, *W. fossacincta*, *W. manivitiae* and *W. ovata*. The most abundant species is *W. barnesiae* (avg. 11.25%) and ranges from 6.5% (at 56 m) to 20.5% (at 37%). Its abundance slightly decreases in the lower Maastrichtian (avg. 10.05%, compared to an average of 12.49% in upper Campanian samples) (Fig. 1). There is a slight negative correlation between *W. barnesiae* and *P. cretacea*.

The third most abundant genus is *Arkhangelskiella*, which varies from 2.75% (at 36.5 m) to 15.75% (at 66.5 m), with an average of 8.97% (Fig. 1). It is represented by *A. confusa* (dominant; avg. 7.22%) and *A. cymbiformis* (avg. 1.75%). Their quantitative presence in lower Maastrichtian samples is slightly higher than in upper Campanian ones. *Arkhangelskiella confusa* reaches its peak abundance (13% at 66.5 m) in mid-UC17, whereas *A. cymbiformis* peaks in mid-UC18 (7% at 74.5 m). There is a slight negative correlation between *Arkhangelskiella* spp. and *P. cretacea*, whereas the negative correlation between *Arkhangelskiella* spp. and *W. barnesiae* is more pronounced.

The genus *Micula* is represented by *M. staurophora* (dominant), *M. concava*, *M. cubiformis* and *M. swastica*, with an average of 8.49% (Fig. 1). Its abundance varies from 3% (at 37 m) to 13% (at 34 m). *Micula staurophora*, ranging from 1.75% (at 37 m) to 12% (at 55.5 m, 50 cm below the Campanian/Maastrichtian boundary), averages at 7.42%. Its quantitative presence in Maastrichtian samples (avg. 8.48%) is higher than in Campanian ones (avg. 6.33%). There is a positive correlation between *M. staurophora* and *Arkhangelskiella* spp. and a relatively strong inverse correlation between *M. staurophora* and *W. barnesiae*.

Cribrosphaerella ehrenbergii (avg. 6.94%) varies from 1.75% (at 35 m) to 12.5% (at 35.5%) (Fig. 1). Recently, Razmjooei et al. (2020) considered this species, together with *Arkhangelskiella* spp., as the best cool-water indicator in the Zagros Basin (Iran). Interestingly, at Kladorub, *C. ehrenbergii* correlates negatively with *Arkhangelskiella* spp.

Other frequent taxa are *Placozygus* spp. (avg. 3.38%), *Microrhabdulus* spp. (avg. 2.54%), *Zeugrhabdotus* spp. (avg. 2.54%), *Uniplanarius* spp. (avg. 1.88%), *Reinhardtites levis* (avg. 1.81%) and *Biscutum constans* (avg. 1.6%). Of these, the most abundant species are *P. spiralis* (avg. 2.06%), *B. constans* (avg. 1.6%), *M. undosus* (avg. 1.51%) and *P. fibuliformis* (avg. 1.32%). There is a slight negative correlation between *B. constans* and *Placozygus* spp., whereas *B. constans* correlates positively with *Zeugrhabdotus* spp. A slightly negative correlation between *Zeugrhabdotus* spp. and *P. spiralis* and a negligibly positive correlation between *Zeugrhabdotus* spp. and *P. fibuliformis* are observed.

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