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CALCAREOUS NANNOPLANKTON BIOSTRATIGRAPHY OF THE CARPATHIAN TYPE UPPER CRETACEOUS-PALEOCENE DEPOSITS NEAR KLADORUB VILLAGE, VIDIN DISTRICT

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ABSTRACT. The siltstone sequence of the Kladorub Formation, covering almost the entire Upper Campanian – Paleocene stratigraphic interval, is exposed in a restricted area near Kladorub Village in the West Fore-Balkan, NW Bulgaria. Some biostratigraphic and lithologic studies were recently made about the discovery of the Cretaceous/Tertiary boundary in this area. In the present study, a nannofossil biostratigraphic zonation is proposed on the basis of relatively well preserved nannofossil assemblages. The Cretaceous part of the section includes 5 nannofossil zones, from older to younger: Uniplanarius trifidus, Arkhangelskiella cymbiformis, Lithraphidites quadratus, Micula murus and Micula prinsii. The Paleocene interval is subdivided into standard nannofossil zones NP-1 Biantholithus sparsus, NP-2 Cruciplacolithus tenuis, NP-3 Chiasmolithus danicus, NP-4 Ellipsolithus macellus, NP-5 Fasciculithus tympaniformis, NP-6 Heliolithus kleinpellii, NP-7 Discoaster mohleri, NP-8 Heliolithus riedeli and NP-9 Discoaster multiradiatus. The described section is the only uninterrupted Bulgarian outcrop providing a continuous sedimentary record of so long stratigraphic interval through the Cretaceous/Paleogene boundary. The beds are well exposed and contain rich nannofossil and foraminiferal assemblages that could be used for refined zonation and better paleogeographic characterization of this important stratigraphic interval.

БИОСТРАТИГРАФИЯ ПО ВАРОВИТ НАНОПЛАНКТОН НА КАРПАТСКИЯ ТИП ГОРНОКРЕДНО-ПАЛЕОЦЕНСКИ ОТЛОЖЕНИЯ ПРИ С. КЛАДОРУБ, ВИДИНСКА ОБЛАСТ

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РЕЗЮМЕ. Алевролитовата последователност на Кладорубската свита, покриваща почти целия горнокампанско-палеоценски стратиграфски интервал, се разкрива в една ограничена площ до с. Кладоруб в Западния Предбалкан, СЗ България. Напоследък бяха направени някои биостратиграфски и литоложки изследвания във връзка с установяването на границата Креда/Терциер в тази площ. В настоящата работа се предлага нанофосилна биостратиграфска подялба въз основа на сравнително добре запазени нанофосилни асоциации. Кредната част от разреза включва 5 нанофосилни зони, отдолу-нагоре: Uniplanarius trifidus, Arkhangelskiella cymbiformis, Lithraphidites quadratus, Micula murus и Micula prinsii. Палеоценският интервал е поделен на стандартните нанофосилни зони NP-1 Biantholithus sparsus, NP-2 Cruciplacolithus tenuis, NP-3 Chiasmolithus danicus, NP-4 Ellipsolithus macellus, NP-5 Fasciculithus tympaniformis, NP-6 Heliolithus kleinpellii, NP-7 Discoaster mohleri, NP-8 Heliolithus riedeli и NP-9 Discoaster multiradiatus. Описаният разрез е единственото непрекъснато разкритие в България на толкова широк стратиграфски интервал около границата Креда/Палеоген. Пластовете са добре разкрити и съдържат богати нанофосилни и фораминиферни асоциации, които могат да се използват за по-детайлна зониране и по-добра палеогеографска характеристика на този важен стратиграфски интервал.

Introduction

Calcareous nannoplankton assemblages, recovered from the biostratigraphically continuous Upper Campanian - Upper Paleocene sequence of the Kladorub Formation near Kladorub Village, provide a good possibility for nannofossil zonation. This outcrop includes one of the Bulgarian Cretaceous/Tertiary boundary sections, described by Sinnyovsky et al. (2002) and declared protected geosite (Sinnyovsky, 2003).

Modern investigation of the section has started in 1998 field season, when the mapping team of Geology and Geophysics Enterprise, Sofia, provided samples for nannofossil analyses and proved wider stratigraphic range of Kladorub Formation, from the Upper Campanian to the uppermost Paleocene (Sinnyovsky & Petrov, 2000). According to our recent investigations Kladorub Formation is generally composed of siltstones, hypo-rocks and rarely marls and limestone beds. The described outcrop is located in "Ciganskiya dol" valley, SE of Kladorub Village. The beds are vertical or overturned with orientation 200-220°/30-60°.

More detailed review of the previous investigations of Carpathian type Cretaceous-Paleocene deposits in North-West Bulgaria was made by Sinnyovsky et al. (2002).

The present investigation provides a nannofossil zonation that includes wide-spread zones used by most authors for the Campanian-Maastrichtian interval and standard Martini's (1971) Paleogene zonation. The total thickness of the section is 205 m. Most of the zones, known from different areas of the country, are described in a singular complete section (Fig. 1).

Present results

Upper Cretaceous

The sampling of the Upper Cretaceous portion of the section was made in every 5 m, and the uppermost part below the Cretaceous/Tertiary boundary – in every 0,5 m. Five

nannofossil zones have been established on the basis of well correlatable nannofossil events: Uniplanarius trifidus, Arkhangelskiella cymbiformis, Lithraphidites quadratus, Micula murus and Micula prinsii. The present zonation does not correspond to any of the published numerical zonal schemes as a whole. The main reason for not using 'standard' zonations is discrepancy between the ranges of some zonal markers not corresponding to their known ranges. For example the disappearance of *Uniplanarius trifidus* (Stradner) Hattner & Wise precedes the last occurrence of *Broinsonia parca* (Stradner) Bukry ssp. *constricta* Hattner et al. Many authors (see compilation of Burnett, 1998) reported earlier disappearance of the latter based on results from many sections all over the world. Bulgarian sections show a sustainable reverse order of disappearance in various facial types (epicontinental, hemipelagic and turbidite deposits). This investigation has added only little biostratigraphic detail, but confirms this trend, proved also in deep sea turbidites of the Emine Formation that crop out 500 km east of the examined section (see Sinnyovsky, this volume).

Rawson et al. (1996) recommend the first appearance of the ammonite species *Pachydiscus neubergicus* (Hauer) for definition of the Campanian-Maastrichtian boundary. This reduced the stratigraphic range of the Maastrichtian to 5 or 6 Ma and expanded the range of the Campanian to 8-12 Ma (see Burnett, 1998). This new stratigraphic boundary level corresponds better to more reliable nannofossil events, for example the disappearance of *Uniplanarius trifidus* (Stradner) Hattner & Wise. As a consequence, this datum level is used here for practical definition of the Campanian-Maastrichtian boundary.

Uniplanarius trifidus Zone

Authors: Bukry & Bramlette (1970).

Definition: Interval of the total range of *Uniplanarius trifidus* (Stradner) Hattner & Wise.

Age: Late Campanian.

Common taxa: Uniplanarius trifidus (Stradner), *Broinsonia parca* (Stradner), *Uniplanarius gothicus* (Deflandre), *Uniplanarius sissinghi* Perch-Nielsen, *Lucianorhabdus cayeuxii* Deflandre, *Reinhardtites levis* Prins & Sissingh, etc.

Remarks: This zone was originally defined as a Late Campanian-Early Maastrichtian interval: 'The range of *Tetralithus nitidus trifidus* defines this zone which is transitional between Maestrichtian and Campanian' (Bukry & Bramlette, 1970). This stratigraphic range has been accepted by most authors (including also many Bulgarian sections). After emendation of the Campanian-Maastrichtian boundary by Rawson et al. (1996), for practical reasons, the disappearance of both *Uniplanarius trifidus* (Stradner) Hattner & Wise and *Broinsonia parca* (Stradner) Bukry ssp. *constricta* Hattner et al. may be used for definition of the Campanian-Maastrichtian boundary in sections with low sedimentation rate.

Distribution: Up to now, indications of the zone have been established in many Bulgarian sections of both Epicontinental and Mediterranean type Upper Cretaceous.

Thickness: The zone includes 47 m of the section near Kladorub Village.

Arkhangelskiella cymbiformis Zone

Author: Perch-Nielsen (1972), emended by Martini (1976).

Definition: Interval from the last occurrence of *Uniplanarius trifidus* (Stradner) Hattner & Wise to the first occurrence of *Lithraphidites quadratus* Bramlette & Martini.

Age: Early Maastrichtian.

Common taxa: This zone is characterized by low diversity assemblages in many publications. Abundant species are *Arkhangelskiella cymbiformis* (Vekshina), *Eiffellithus turriseiffeli* (Deflandre), *Micula decussata* Vekshina, etc.

Remarks: All previous authors referred the zone to the Lower Maastrichtian or lower Middle Maastrichtian when triple division is used. It is well recognized in the section and includes the last occurrence of *Broinsonia parca* (Stradner) Bukry ssp. *constricta* Hattner et al. at 60 m and *Reinhardtites levis* Prins & Sissingh at 65 m.

Distribution: Indications of the zone are recognized in many sections of the epicontinental type Upper Cretaceous in Central and East North Bulgaria. The zone is present in the section of the Ljutidol Formation near Ljutidol Village in the West Fore-Balkan (Sinnyovsky, 2001) and in the East Balkan near Cape Emine (Sinnyovsky, this volume).

Thickness: The zone is 55 m thick, and occupies the sediments between 50 and 105 m of the Upper Cretaceous section.

Lithraphidites quadratus Zone

Authors: Čepek & Hay (1969), emended by Bukry & Bramlette (1970).

Definition: Interval from the first occurrence of *Lithraphidites quadratus* Bramlette & Martini, 1964 to the first occurrence of *Micula murus* (Martini) Bukry.

Age: Early Late Maastrichtian.

Remarks: This zone was originally defined as an interval between the first occurrence of *Lithraphidites quadratus* Bramlette & Martini and *Nephrolithus frequens* Gorka. Later Bukry & Bramlette (1970) emended the upper boundary after the first occurrence of *Micula murus* (Martini) Bukry.

Distribution: Indications of the zone are recognized in several South Bulgarian sections because the Upper Maastrichtian part of the epicontinental type Upper Cretaceous in North Bulgaria contains little or no nannofossils. So far the zone has been recognized in the West Srednogorie sections near Gurlo Village, East Balkan sections near Kosharitsa, Kozichino, Vlas, Banya and Emona Villages (Sinnyovsky, this volume), in the West Fore Balkan near Ljutidol Village (Sinnyovsky, 2001b).

Thickness: The thickness of the zone in the studied section is 15 m between 105 and 120 m.

Micula murus Zone

Author: Martini (1969), emended by Perch-Nielsen (1985).

Definition: Interval from the first occurrence of *Micula murus* (Martini) Bukry to the first occurrence of *Micula prinsii* Perch-Nielsen.

Age: Late Maastrichtian.

Common taxa: Lithraphidites quadratus Bramlette & Martini, *Micula murus* (Martini), *Nephrolithus frequens* Gorka, *Arkhangelskiella cymbiformis* (Vekshina), *Prediscosphaera microrhabdulina* Perch-Nielsen, *Prediscosphaera majunga* Perch-Nielsen, etc.

Remarks: This zone was initially considered to be the uppermost Cretaceous zone, according to Martini's (1969) definition as a total range of *Tetralithus murus* Martini ('Intervall vom ersten Auftreten von *Tetralithus murus* Martini bis zum Erlöschender Maastricht-Arten'). Perch-Nielsen (1985)

stated that 'the FO of *Micula murus* and the subsequent FO of *Micula prinsii* can be used to subdivide the interval between the FO of Lithraphidites quadratus (base CC 25c) and the top of the Maastrichtian'. This statement should be used as emendation of the Micula murus Zone of Martini (1969) and original definition of the Micula prinsii Zone by the total range of *Micula prinsii* Perch-Nielsen.

Distribution: In Bulgaria Micula murus Zone in the means of its earlier definition was recognized in the East Balkan section near Bjala Town (Синёвски, 1990; Preisinger et al., 1993a) and Kochan Cape (Sinnyovsky & Sultanov, 1994). Later the uppermost part of the Maastrichtian is subdivided into two zones – Micula murus and Micula prinsii (Perch-Nielsen, 1985). Following the new definition Micula murus Zone is established near Bjala Town (Ivanov & Stoykova, 1994, 2004), Emona Village (Sinnyovsky & Stoykova, 1995; Stoykova & Ivanov, 2004) and Kladorub Village (Sinnyovsky, this volume).

Thickness: The thickness of the zone in the studied section is 10 m between 120 and 130 m from the base.

Micula prinsii Zone

Author: Perch-Nielsen (1985).

Definition: Interval from the first occurrence of *Micula prinsii* Perch-Nielsen to the last occurrence of 'unreworked, non-survivor Cretaceous taxa' (Burnett, 1998).

Age: Latest Maastrichtian.

Common taxa: Same species as in the preceding zone and *Micula prinsii* Perch-Nielsen.

Remarks: This zone includes a very short stratigraphic interval at the top of the Cretaceous and could be easily missed in condensed epicontinental sections.

Distribution: It has been recognized in the East Balkan near Bjala Town (Stoykova & Ivanov, 1992; 2004; Preizinger et al., 1993b), Emona Village (Sinnyovsky & Stoykova, 1995; Stoykova & Ivanov, 2004), Aytos Pass (Sinnyovsky & Vangelov, 1997), Kozya River and Chudnite skali (Vangelov & Sinnyovsky, 2000; Sinnyovsky, 2001a), Kozichino Village (Sinnyovsky, 2003), Marash (Stoykova & Ivanov, 2004).

Thickness: 5 m between 130 and 135 m in this section; 18 m near Bjala Town, and 30 m near Kochan Cape (Sinnyovsky, this volume).

Cretaceous/Tertiary boundary

The K/T boundary in the section was described by Sinnyovsky et al. (2002) and illustrated by Sinnyovsky (2003). It is characterized by a 2 cm thin dark layer, marking 'the great change in calcareous nannoplankton fossils', first described by Bramlette & Martini (1964). At this level disappear most Cretaceous taxa and appears the marker species of the lowest Paleocene NP 1 Zone *Biantholithus sparsus* Bramlette & Martini. The first tens of centimetres above the boundary layer are very poor, with predominant representatives of the surviving genera *Thoracosphaera*, *Braarudosphaera, Cyclagelosphaera, Markalius and Neocrepidolithus*.

Paleocene

The sampling of the lowest 2,5 m of the Paleocene was made in every 5 cm, and the rest of the section up to 70 m above the K/T boundary – in every meter. This has allowed complete zonation using Martini's (1971) zones from NP 1 to NP 9.

NP 1 Biantholithus sparsus Zone

Author: Perch-Nielsen (1971), emended by Romein (1977).

Definition: Interval from the first occurrence of *Biantholithus sparsus* Bramlette & Martini to the first occurrence of *Cruciplacolithus tenuis* (Stradner) Hay & Mohler, (respectively *Cruciplacolithus intermedius* van Heck & Prins).

Age: Earliest Paleocene.

Common taxa: Braarudosphaera bigelowi (Gran & Braarud), *Thoracosphaera operculata* Bramlette & Sullivan, *Cyclagelosphaera reinhardtii* (Perch-Nielsen), *Markalius inversus* (Deflandre), *Biantholithus sparsus* Bramlette & Martini, *Neocrepidolithus dirimosus* Perch-Nielsen. The marker species is first recognized 5-10 cm above the boundary layer, *Cyclagelosphaera alta* Perch-Nielsen at +30 cm (lower than reported by Sinnyovsky et al., 2002), *Placozygus sigmoides* (Bramlette & Sullivan) at +50 cm, *Lanternithus duocavus* Locker at +1 m, *Cruciplacolithus primus* Perch-Nielsen and *Coccolithus cavus* Hay & Mohler at 2,4 m.

Remarks: This zone includes the base of the Paleocene. It is very thin and could be recognized only in continuous sequences through the K/T boundary. It could be easily missed in sections with low sedimentation rate.

Distribution: In the East Balkan the zone is recognized in the section near Byala Town (Синёвски, 1990, under the name Markalius inversus; Stoykova & Ivanov, 1992; 2004; Preizinger, 1993a,b; Ivanov & Stoykova, 1994; Sinnyovsky, 2001a), Emona Village (Sinnyovsky & Stoykova, 1995; Stoykova & Ivanov, 2004), Aytos Pass (Sinnyovsky & Vangelov, 1997), Kozichino Village (Sinnyovsky, 2003), Marash (Stoykova & Ivanov, 2004). In the West Fore Balkan it was established near Perchovtsi Village (Синьовски, Христова-Синьовска, 1993), Mezdra Town (Синьовски, 1998) and Ljutidol Village (Sinnyovsky, 2001b).

Thickness: 2,7 m (Sinnyovsky et al., 2002).

NP 2 Cruciplacolithus tenuis Zone

Author: Mohler & Hay in Hay et al. (1967), emended by Martini (1970).

Definition: Interval from the first occurrence of *Cruciplacolithus intermedius* van Heck & Prins to the first occurrence of *Chiasmolithus danicus* (Brotzen) Hay & Mohler.

Age: Lower Paleocene (Early Danian).

Remarks: This zone was originally defined by the first occurrence of *Cruciplacolithus tenuis* (Stradner). Van Heck & Prins (1987) separated from the former two new species - *Cruciplacolithus intermedius* and *Cruciplacolithus asymmetricus.* Thus the lower boundary of the zone should be defined by the first occurrence of the earlier form which is *Cruciplacolithus intermedius* van Heck & Prins. It appears at +2,7 m together with *Cruciplacolithus asymmetricus* van Heck & Prins, *Cruciplacolithus tenuis* (Stradner) at +3,10 m, and *Chiasmolithus edwardsii* (Romein) at + 8 m.

Distribution: In Bulgaria it has been recognized in the East Balkan sections near Bjala Town (Синёвски, 1990; Ivanov & Stoykova, 1994; Sinnyovsky, 2001a), Emona Village (Sinnyovsky & Stoykova, 1995; Stoykova & Ivanov, 2004), Aytos Pass (Sinnyovsky & Vangelov, 1997), Kozya River (Sinnyovsky, 2001a), Marash (Stoykova & Ivanov, 2004). In the West Fore Balkan it was established near Perchovtsi Village (Синьовски, Христова-Синьовска, 1993), Moravitsa Village (Синьовски, 1998; Stoykova & Ivanov, 2004) and Ljutidol Village (Sinnyovsky, 2001b).

Thickness: 7,3 m.

NP 3 Chiasmolithus danicus Zone

Author: Martini (1970).

Definition: Interval from the first occurrence of *Chiasmolithus danicus* (Brotzen) Hay & Mohler to the first occurrence of *Ellipsolithus macellus* (Brotzen) Hay & Mohler.

Age: Early Paleocene (Late Danian).

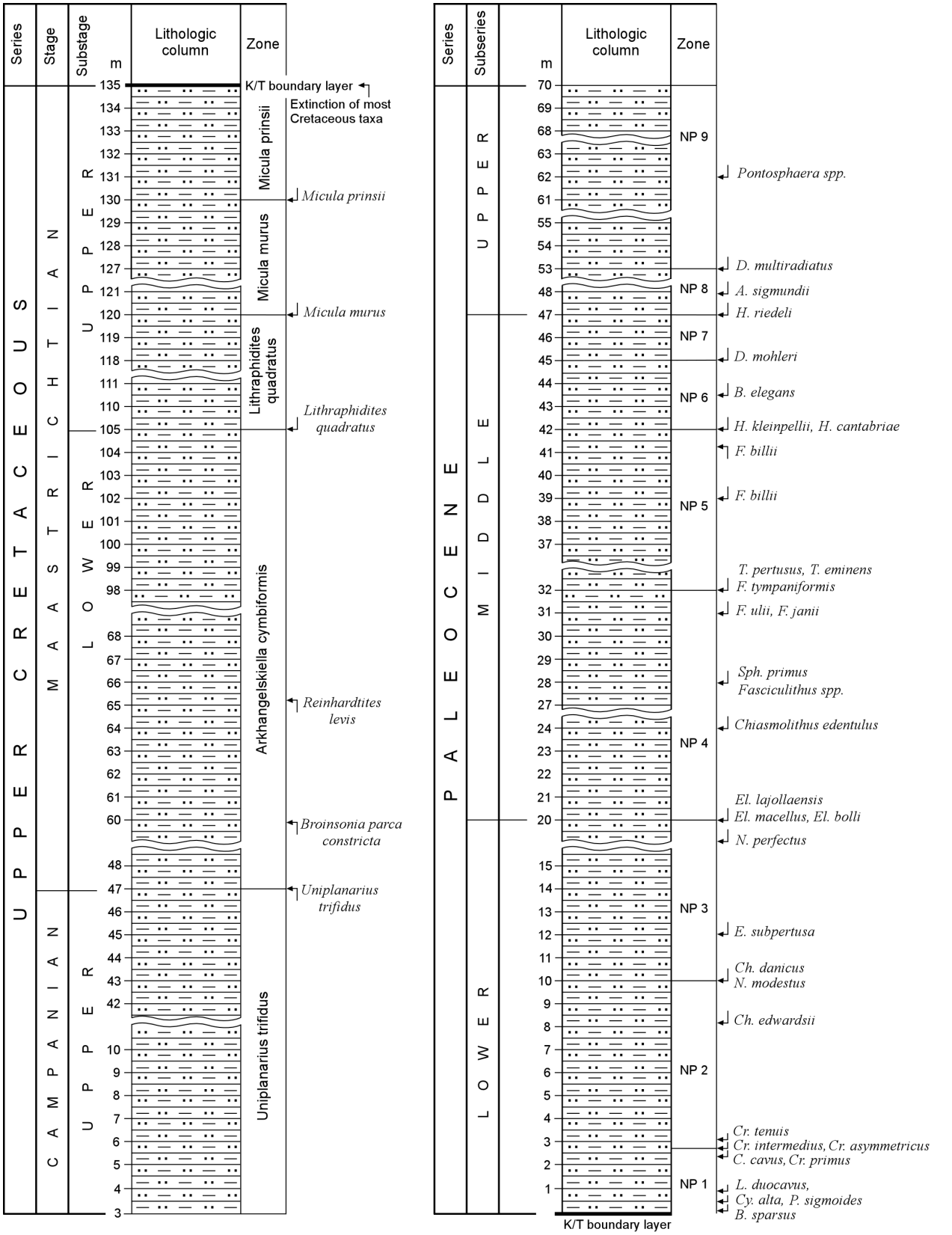

Fig. 1. Section of the Kladorub Formation in Ciganskiya dol SE of Kladorub Village, Vidin District, composed of carbonate siltstones, silty marls and mixed silty-clayey-carbonate rocks, showing the stratigraphic position of the nannofossil zones and nannofossil events, established in this study

Common taxa. In the lowest part of the zone early forms of *Neochiastozygus modestus* Perch-Nielsen appear. Common taxa are the representatives of the genus *Cruciplacolithus,* and also *Coccolithus cavus* Hay & Mohler, *Braarudosphaera discula* Bramlette & Riedel, *Ericsonia subpertusa* Hay & Mohler. Early forms of *Neochiastozygus modestus* Perch-Nielsen occur in the lowermost sample of the zone and *Neochiastozygus perfectus* Perch-Nielsen appears in the uppermost sample.

Distribution: In Bulgaria the zone has been recognized near Moravitsa (Stoykova & Ivanov, 2004) and in East Balkan near Bjala (Синёвски, 1990; Ivanov & Stoykova, 1994; 2004; Sinnyovsky, 2001a), Emona and Marash (Stoykova & Ivanov, 2004), Cape Kochan (Sinnyovsky, this volume).

Thickness: 10 m between +10 and +20 m.

NP 4 Ellipsolithus macellus Zone

Author: Martini (1970).

Definition: Interval from the first occurrence of *Ellipsolithus macellus* (Brotzen) Hay & Mohler to the first occurrence of *Fasciculithus tympaniformis* Hay & Mohler.

Age: Early Paleocene (Late Danian).

Common taxa: The first rare occurrence of the marker species is in sample +20 m above the K/T boundary along with *Ellipsolithus lajollaensis* Bukry & Percival and *Ellipsolithus bolli* Perch-Nielsen. Perch-Nielsen (1985) noted that in poorly preserved assemblages the marker species is missing. *Chiasmolithus edentulus* van Heck & Prins appears 24 m above the K/T boundary. First fasciculiths and sphenoliths occur in the sample +28.

Distribution: The zone was recognized in the section of Bjala Fm near Bjala (Ivanov & Stoykova, 1994; Sinnyovsky, 2001a) and north of Irakli in Emine Fm (Sinnyovsky, this volume).

Thickness: 12 m between +20 and +32 m.

NP 5 Fasciculithus tympaniformis Zone

Authors: Mohler & Hay in Hay et al. (1967).

Definition: Interval from the first occurrence of *Fasciculithus tympaniformis* Hay & Mohler to the first occurrence of *Heliolithus kleinpellii* Sullivan.

Age: Early Middle Paleocene.

Remarks: The first representatives of the fasciculiths occur in the upper part of the former zone. *Fasciculithus ulii* Perch-Nielsen is regularly encountered in the sample +31 m, whereas *Fasciculithus janii* Perch-Nielsen is very rare in the same sample. First rare specimens of the marker species *Fasciculithus tympaniformis* Hay & Mohler are seen in the sample +32 m together with *Toweius pertusus* Sullivan and *Toweius eminens* (Bramlette & Sullivan). One of the most abundadt fasciculiths in the upper part of the zone is *Fasciculithus billii* Perch-Nielsen, encountered in samples +39 to +41 m.

Distribution: The zone is established in the Emine Fm near Cape Kochan, north of Irakli (Sinnyovsky, this volume).

Thickness: 10 m, between +32 and +42 m.

NP 6 Heliolithus kleinpellii Zone

Authors: Mohler & Hay in Hay et al. (1967) emended by Bykry & Percival (1971).

Definition: Interval from the first occurrence of *Heliolithus kleinpellii* Sullivan to the first occurrence of *Discoaster mohleri* Bukry & Percival.

Age: Middle Paleocene.

Remarks: The upper zonal boundary was originally defined by the first occurrence of *Discoaster gemmeus* Stradner, but later Bukry & Percival (1971) showed that this is an Eocene species and erected *Discoaster mohleri* on the basis of the specimen illustrated by Hay & Mohler (1967). The nannofossil assemblage in sample +42 m, where the first appearance of the marker species is established, is very poor. First representatives of *Heliolithus cantabriae* Perch-Nielsen and *Bomolithus elegans* Roth are seen in this zone (Fig. 1).

Distribution: Indications of the zone are recognized in the sandstone unit near Ljutidol Village in West Fore-Balkan (Синьовски & Христова-Синьовска, 1993) and Emine Formation (Sinnyovsky, this volume).

Thickness: The zone is recognized only in 3 m of the section.

NP 7 Discoaster mohleri Zone

Authors: Mohler & Hay in Hay et al. (1967) emended by Bykry & Percival (1971).

Definition: Interval from the first occurrence of *Discoaster mohleri* Bukry & Percival to the first occurrence of *Heliolithus riedeli* Bramlette & Sullivan.

Age: Late Middle Paleocene.

Common taxa: The zone contains rich nannofossil assemblages with predominant *Coccolithus cavus* Hay & Mohler, *Ericsonia subpertusa* Hay & Mohler, *Heliolithus kleinpellii* Sullivan, *Bomolithus elegans* Roth, *Toweius eminens* Perch-Nielsen, *Toweius tovae* Perch-Nielsen, many fasciculiths, cruciplacoliths, small *Princiacea*, etc. In this interval is the first occurrence of *Fasciculithus clinatus* Bukry and *Amithalithina sigmundii* Pospichal & Wise.

Remarks: The lower zonal boundary was discussed above. The upper boundary should be placed also by the first appearance of *Discoaster nobilis* Martini (Perch-Nielsen, 1972).

Thickness: 2 m, probably due to condensation.

NP 8 Heliolithus riedeli Zone

Authors: Bramlette & Sullivan (1961).

Definition: Interval from the first occurrence *Heliolithus riedeli* Bramlette & Sullivan to the first occurrence of *Discoaster multiradiatus* Bramlette & Riedel.

Age: Late Paleocene.

Common taxa: *Heliolithus riedeli* Bramlette & Sullivan, *Chiasmolithus bidens* (Bramlette & Sullivan), *Ellipsolithus bolli* Perch-Nielsen, *Coccolithus cavus* Hay & Mohler, *Fasciculithus tympaniformis* Hay & Mohler, *Fasciculithus clinatus* Bukry, *Bomolithus elegans* Roth, *Toweius eminens* (Bramlette & Sullivan), small *Prinsiacea*, etc.

Distribution: Indication of the zone is reported from Emine and Dvoynitsa Formations in the East Balkan (Sinnyovsky & Sultanov, 1994; Синьовски, 1996) as well as from Bjala Fm.

Thickness: It is difficult to establish the exact thickness of the zone because samples 50-54 are barren. It is maximum 6 m.

NP 9 Discoaster multiradiatus Zone

Authors: Bramlette & Sullivan (1961).

Definition: Interval from the first occurrence *Heliolithus riedeli* Bramlette & Sullivan to the first occurrence of *Discoaster multiradiatus* Bramlette & Riedel.

Age: Late Paleocene.

Common taxa: Discoaster multiradiatus Bramlette & Riedel, *Discoaster lenticularis* Bramlette & Sullivan,

Discoaster falcatus Bramlette & Sullivan, Chiasmolithus bidens (Bramlette & Sullivan), *Ellipsolithus bollii* Perch-Nielsen, *Ellipsolithus distichus* Bramlette & Sullivan, *Coccolithus cavus* Hay & Mohler, *Fasciculithus tympaniformis* Hay & Mohler, *Fasciculithus thomasii* Perch-Nielsen, *Fasciculithus tonii* Perch-Nielsen, *Pontosphaera plana* Bramlette & Sullivan, etc. In the middle of the zone first appear representatives of the genus *Pontosphaera* Lohmann.

Remarks: The lower zonal boundary is not exactly established, for the reasons discussed above. The zonal marker is present in the sample 55 m above the K/T boundary.

Distribution: Indication of the zone is reported from Emine and Dvoynitsa Formations in East Balkan (Sinnyovsky & Sultanov, 1994; Синьовски, 1996, Sinnyovsky, this volume).

Thickness: More than 16 m.

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