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The Cretaceous/Paleogene (K/Pg) boundary in the Mezdra and Lyutidol syncline, Vratza District (West-Fore Balkan, Bulgaria)

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Abstract. This paper discusses the unjustified assignment (based on calcareous nannofossils) of a large portion of the Maastrichtian strata in the Mezdra and Lyutidol synclines (West Fore Balkan, Bulgaria) to the Paleogene. The co-occurrence of Paleocene nannofossils, reported by some authors, and Maastrichtian macrofossil taxa in these sections indicates diachronism in the appearance of macro- and nannofossils across the K/Pg boundary. Thus, this boundary cannot be precisely localised except if the Maastrichtian fossils are assumed to have been redeposited, but there is no evidence of resedimentation. Maastrichtian macrofossils are found not only within the range of the Paleogene nannofossil zones, but also in sections overlying them in the Kajlâka Formation where new Maastrichtian macrofossil taxa, such as the echinoid *Hemipneustes striatoradiatus* (Leske), appear and some inoceramid and cephalopod taxa range into this unit. These facts shed doubt over the applicability of nannofossils in determining the K/Pg boundary where this has already been firmly documented by macrofauna.

Key words: Cretaceous/Paleogene boundary, Maastrichtian strata, nannofossils, foraminifers, inoceramids, ammonites, echinoids, West Fore Balkan, Bulgaria.

Апстракт. У раду се расправља о неоправданом приписивању (на основу кречњачких нанофосила) великог дела мастрихтског профила у синклиналама Мездре и Љутидола (западни Предбалкан, Бугарска) палеогену. Истовремено појављивање палеоценских нанофосила, о којима пишу неки аутори, са мастрихтским макрофосилним таксонима у овим профилима указује на диахронизам у појави макрофосила и нанофосила на граници K/Pg. Према томе, ова граница се не може прецизно утврдити осим ако се не претпостави да су махстритски фосили били преталожени, али не постоје докази преталоживања. Мастрихтски нанофосили су нађени не само у оквиру вертикалног простирања палеогених нанофосилних зона, већ и у формацији Кајлака где се јављају нови мастрихтски макрофосилни таксони као што је *Hemipneustes striatoradiatus* (Leske) и неки иноцерамски и цефалоподски таксони. Ове чињенице бацају сенку сумње на применљивост нанофосила у одређивању границе K/Pg где је она већ поуздано доказана на основу макрофауне.

Кључне речи: граница креда–палеоген, мастрихтски слојеви, нанофосили, фораминифери, иноцерамуси, амонити, ехиниди, западни Предбалкан, Бугарска.

Inroduction

Upper Cretaceous sediments in the Mezdra and Lyutidol synclines in the Vratza District, West Fore Balkan, Bulgaria are widely distributed and of essential tectonic importance. For a long time, based on erroneously identified fossils, these were assumed to be of Cenomanian age (Zlatarski, 1904, 1905, 1910). This author (Zlatarski, 1905) assigned only a portion of the limestones exposed at the village of Varbeshnitza, northwest of Mezdra and those around the village of Lyuta (now Vladimirovo) to the Senonian. Later, Zlatarski (1910) pointed out that the limestones at Lyuta were certainly of Senonian age but those at Varbeshnitza were of doubtful Senonian age, although he cited some Senonian fossils found earlier by him. He assumed these sediments to be of Cenomanian age but later again referred them to the Senonian (Zlatarski, 1927). The same author (Zlatarski, 1904) assigned a Cenomanian age also to Eocene sandstones resting upon the "Cenomanian" limestones which, as he pointed out, were easily distinguished from the Lower Cretaceous sandstones in the Vratza area. For the first time, Bončev (1932) proved that the Upper Cretaceous sediments in the Fore Balkan to the south of the Iskar River were of Maastrichtian, not Cenomanian, age. Simultaneously, Bončev & Kamenov

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(1932) extended the studies of this stage to the north of the Iskar River – between Mezdra and Roman, and later they (BONČEV & KAMENOV, 1934) continued these to the west – between the rivers of Iskar and Ogosta. Based on inoceramids, cephalopods, echinoids and other macrofossil taxa, they documented in detail the biostratigraphy of the Maastrichtian Stage in the western Fore Balkan. The Maastrichtian age of the Upper Cretaceous sediments in this area was confirmed by all subsequent investigators, based on macrofossil fauna (COHEN, 1946; TZANKOV, 1968; JOLKIČEV, 1982, 1986, 1989, and others).

During recent years, calcareous nannofossils have been assumed to be of extreme importance for the subdivision of Upper Cretaceous and Cenozoic sediments – an importance that, seemingly, cannot be put in question. However, NAIDIN (2002, p. 46) has recently pointed out that "nevertheless we should have some doubts" of the applicability of nannofossils.

Under the influence of nannoplankton euphoria, a number of publications have recently appeared in which the Cretaceous/Paleogene boundary in the study area was traced without taking into account the presence of characteristic macrofauna in the same sections that were subdivided by means of nannoplankton. The Cretaceous/Paleogene boundary as determined by macrofauna was disregarded in these papers.

The macrofaunal data presented below raise questions about the applicability of nannofossils in defining the Cretaceous/Paleogene boundary in the study area.

Facts and discussion

This paper discusses the Maastrichtian strata in the southern limb of the Mezdra syncline and the same deposits in the northern and southern limb of the Lyutidol syncline in the southern parts of the West Fore Balkan (Fig. 1).

The stratigraphic section in these two structures comprises the following lithostratigraphic units in ascending order (JOLKIČEV, 1986): Dârmanci Formation – Lower Maastrichtian; Kunino Formation – Lower Maastrichtian; Mezdra Formation – Lower Maastrichtian and Kajlâka Formation – Upper Maastrichtian (Fig. 2).

The studies of SINNYOVSKY (1991, 1993, 1998, 2001), SINNYOVSKY & CHRISTOVA-SINNYOVSKA (1993) and STOYKOVA *et al*. (2000) all focused on the Dârmanci, Kunino and Mezdra Formations. It is unexplainable why they did not discuss the age of the overlying Kajlâka Formation.

The Mezdra Formation in the two structures comprises three lithological units of variable thickness: the lower unit – microgranular limestones with flint concretions; the middle unit – argillaceous limestones without flint concretions with interbeds or in alternation with marls and the upper unit – microgranular limestones with flint concretions (Figs. 2–4). SINNYOVSKY & CHRISTOVA-SINNYOVSKA (1993, p. 32) referred to the middle unit in the Lyutidol syncline as the "Limestone Formation". In this unit EK. DIMITROVA (Geological Institute, Bulgarian Academy of Sciences (BAS), unpublished data) identified a foraminiferal assemblage (see Fig. 3). From the same strata at the southerly limb of the Mezdra syncline (at the village of Chelopeck), Y. MALIAKOV (Geological Institute, BAS) collected eighteen echinoid tests (now housed at the museum of the Geological Institute, BAS No F.002525 to 002542). Among these, the following taxa have recently been identified (Fig. 2): *Echinocorys conoidea* GOLDFUSS as well as several *Echinocorys* sp. which belong to a group of species morphologically close to *E*. gr. *marginata/subglobosa* (of early to late Campanian age; compare ERNST, 1972, 1975; JAGT *et al*., 2004); this may represent a continuation into, or recurrence(?) during the Maastrichtian of such test morphologies (compare JAGT, 2000). In the Maastrichtian type area, these forms occur as well, and are nearly always associated with typical

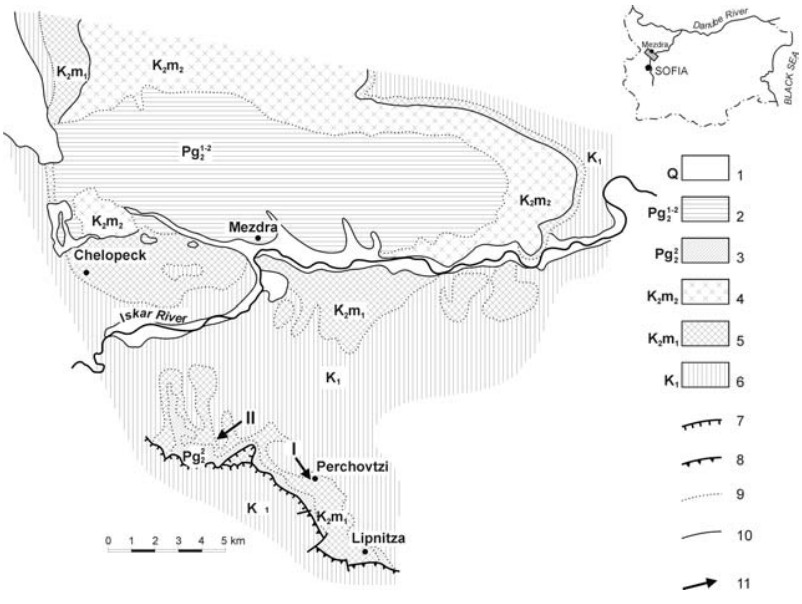

Fig. 1. Sketch map (inset) of Bulgaria with location and geological map of the study area (after TZANKOV *et al*., 1991, modified). **1**, Quaternary; **2**, Lower–Middle Eocene; **3**, Middle Eocene; **4**, Kajlâka Formation – Upper Maastrichtian; **5**, Dârmanci, Kunino, Mezdra formations – Lower Maastrichtian; **6**, Lower Cretaceous; **7**, thrust; **8**, reverse fault; **9**, transgressive boundary; **10**, boundary of Quaternary sediments; **11**, stratigraphic sections (sections I and II, shown in Figs, 3, 4, respectively).

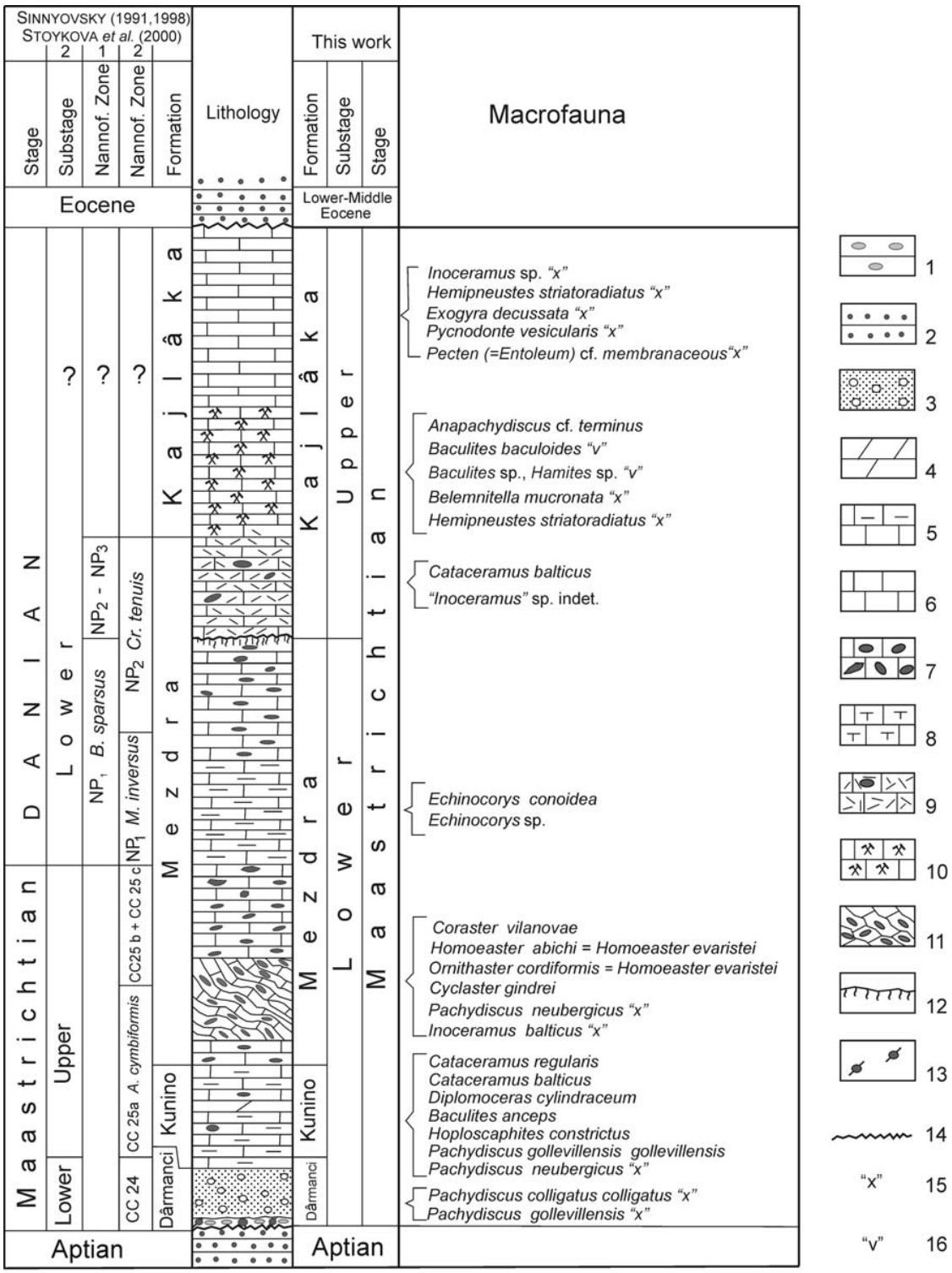

Fig. 2. Generalized stratigraphic section of the Mezdra syncline. **1**, conglomerates; **2**, sandstones; **3**, glauconitic sandstones; **4**, marls; **5**, clayey limestones; **6**, medium- to coarse-grained limestones; **7**, limestones with flints; **8**, chalky limestones; **9**, biomorphic limestones; **10**, "quarry type" limestones; **11**, megaslump; **12**, hardground; **13**, phosphorites; **14**, transgressive boundary; **15**, "x", fossils discovered by BONČEV & KAMENOV (1934) and probably some of them misidentified; **16**, "v", fossils discovered by ZLATARSKI (1910) and probably some of them misidentified. The meaning of the question marks "?" in Figs. 2, 3 and 4 is as follows: Fig. 2 – part of the section unstudied by SINNYOVSKY (1998) and STOYKOVA *et al*. (2000); Fig. 3 – the upper part of Mezdra Fm is not shown in the paper of SINNYOVSKY & CHRISTOVA-SINNYOVSKA (1993, fig. 8); Fig. 4 – the middle part of Mezdra Fm is not shown in the section of SINNYOVSKY (2001, fig. 3).

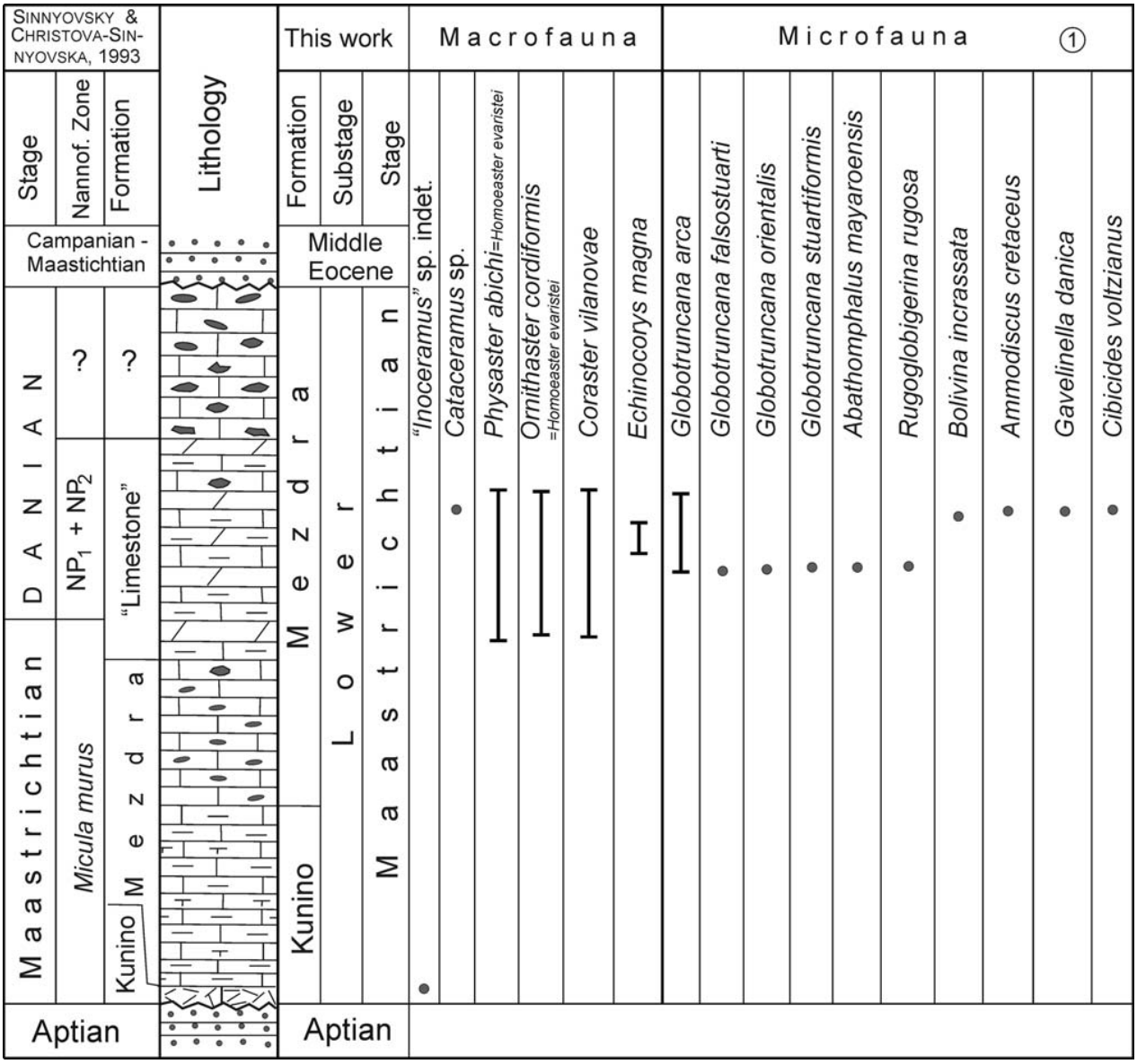

Fig. 3. Schematic stratigraphic section of the Maastrichtian Stage south of the village of Perchovtzi (Section I in Fig. 1). (**1**) - EK. DIMITROVA, unpublished data. For legend see Fig. 2.

Echinocorys gr. *conoidea,* hence a Maastrichtian age is not in doubt (J.W.M. JAGT, pers. comm., April 2006).

In outcrops south of the village of Perchovtzi (Section I in Fig. 1; Fig. 3) and at the Malata reka River (Section II in Fig. 1; Fig. 4), SINNYOVSKY & CHRISTOVA-SINNYOVSKA (1993, p. 38, fig. 8) and SINNYOVSKY (2001, p. 15, fig. 3) did not include the normal and complete magnitude of the Mezdra Formation. Furthermore, in the "Paleocene nannofossil zone" in these sections, single specimens of *Cataceramus* sp. and *Cataceramus* cf. *regularis* (Figs. 5A, B), and a juvenile ammonite undeterminable to the species level cf. Pachydiscidae (Figs. 5C, D) have been found. Ammonites are common in the "limestone formation" along the southern limb of the Lyutidol syncline, SW of the village of Lipnitza (Fig. 1).

In my opinion, the upper portion of the Mezdra Formation in the southern limb of the Mezdra syncline (Fig. 2) above the hardground (SINNYOVSKY, 1991, p. 264, fig. 2; 1998, p. 12, fig. 4; p.14, fig. 6), which comprises bioclastic, medium- to coarse-grained limestones, in fact belong to the base of the Kajlâka Formation. These limestones are analogous to the limestones of Unit 9 in the northern limb of the Mezdra syncline (JOLKIČEV, 1982, pp. 18–19, fig. 7). From these, in the eastern centricline of the Mezdra syncline, a single specimen of *Cataceramus balticus* BÖHM and one of "*Inoceramus"* sp. indet. have been found.

The transitional limestones are followed upwards by whitish (with beige), indistinctly bedded micro- to medium-grained quarry limestones – the so-called "Vratza

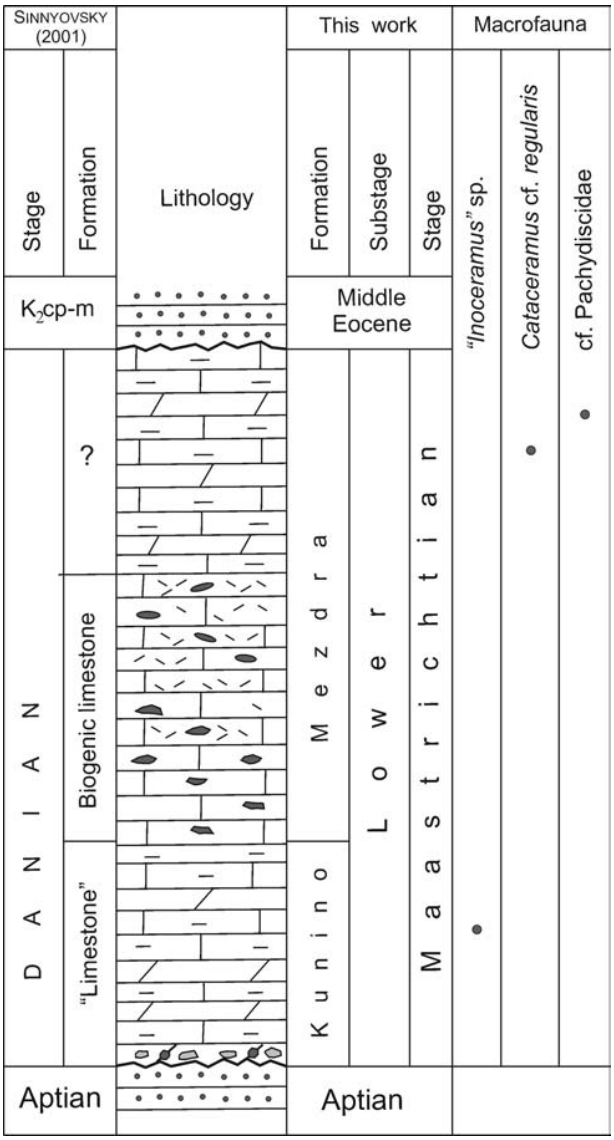

Fig. 4. Schematic stratigraphic section of the Maastrichtian Stage near to the village of Lyutidol – on the left bank of the Malata River (Section II in Fig.1). For dating the "Danian" strata SINNYOVSKY refers to the nannofosil taxa mentioned in the same paper (SINNYOVSKY, 2001, p. 12). For legend see Fig. 2

Stone". From these limestones, ZLATARSKI (1910) mentioned *Baculites baculoides* ROEMER (probably misidentified ammonite), *Baculites* sp., *Hamites* sp.; while BONČEV & KAMENOV (1934, p. 81) reported *Hemipneustes striatoradiatus* (LESKE) and *Belemnitella mucronata* (SCHLOTHEIM) (probably misidentified *Belemnitella*), and JOLKIČEV (1982, p. 18 – packet 9; p. 19, fig. 7) noted a *Pachydiscus gollevillensis gollevillensis* (D'ORBIGNY), = *Anapachydiscus* cf. *terminus* WARD & KENNEDY, 1993 which is figured here (Fig. 5E).

These sediments are overlain by light grey to whitish fine-, medium- to coarse-grained limestones from which BONČEV & KAMENOV (1934, p. 82) collected *Hemipneustes striatoradiatus*, "*Inoceramus*" sp., *Pycnodonte vesicularis* (LAMARCK), *Exogyra decussata* COQUAND and *Pecten* (=*Entolium*) cf. *membranaceus* (NILSSON) (Fig. 2).

In the area of the Lyutidol syncline, the Kajlâka Formation is preserved only in the southern limb of the structure – along the left bank of the Malata River, at the southern end of the village of Lyutidol. There, different horizons of Maastrichtian strata are transgressively overlain by terrigenous Middle Eocene deposits (TZANKOV *et al*., 1991), which SINNYOVSKY & CHRISTOVA-SINNYOVSKA (1993) and SINNYOVSKY (1993, 2001) assumed to be in allochthonous position and of Campanian–Maastrichtian age, as defined by nannofossils (Figs. 3, 4). I subscribe to the transgressive, but not allochthonous, position of the terrigenous sediments upon the Maastrichtian ones. The nannofossil samples have presumably been collected from Upper Cretaceous blocks, included as a common component within Middle Eocene terrigenous sediments.

Disregarding the presence of inoceramids, cephalopods and characteristic Maastrichtian echinoid fauna in the whole section of the Upper Cretaceous series in these structures, SINNYOVSKY & CHRISTOVA-SINNYOVSKA (1993), SINNYOVSKY (1991, 1993, 1998, 2001) and STOYKOVA *et al*. (2000), on the basis of nannofossils, defined the Paleocene age for most of this section (Figs. 2–4). They assumed (pers. comm., 2004) the Maastrichtian inoceramid, cephalopod and echinoid fauna, which occurs in the range of their "nannofossil zones", as well as the macrofauna from the Kajlâka Formation, to have been redeposited. I assert that this does not correspond to the fossil sequences in the section and there is no physical evidence of resedimentation of Maastrichtian macrofossils.

The outcrops of the Mezdra Formation continue into the Fore Balkan and to the west of the Mezdra syncline as far west as the valley of the Ogosta River. There, in a quarry at the village of Lyuta (now Vladimirovo), Vratza District, BONČEV & KAMENOV (1934, p. 80) found *Pachydiscus neubergicus* (VON HAUER) together with numerous echinoids, analogous in specific content to those from the Mezdra Formation in the area of Mezdra (determined also by the present author). SINNYOVSKY (2003, p. 152) analysed the limestones in this quarry for nannoplankton and "proved" that they are of Paleocene and not of Maastrichtian age. SINNYOVSKY is well aware of the presence of Maastrichtian macrofossil taxa at this locality, cited by him in this paper (p. 149), but fails to comment on this fact.

Conclusion

The normal superposition of lithostratigraphic units, which form the limbs of the Mezdra and Lyutidol synclines, as well as their macro- and microfossil content unambiguously confirm their Maastrichtian age.

The co-occurrence of Paleocene nannofossils and Maastrichtian macrofossil taxa in the sections of these

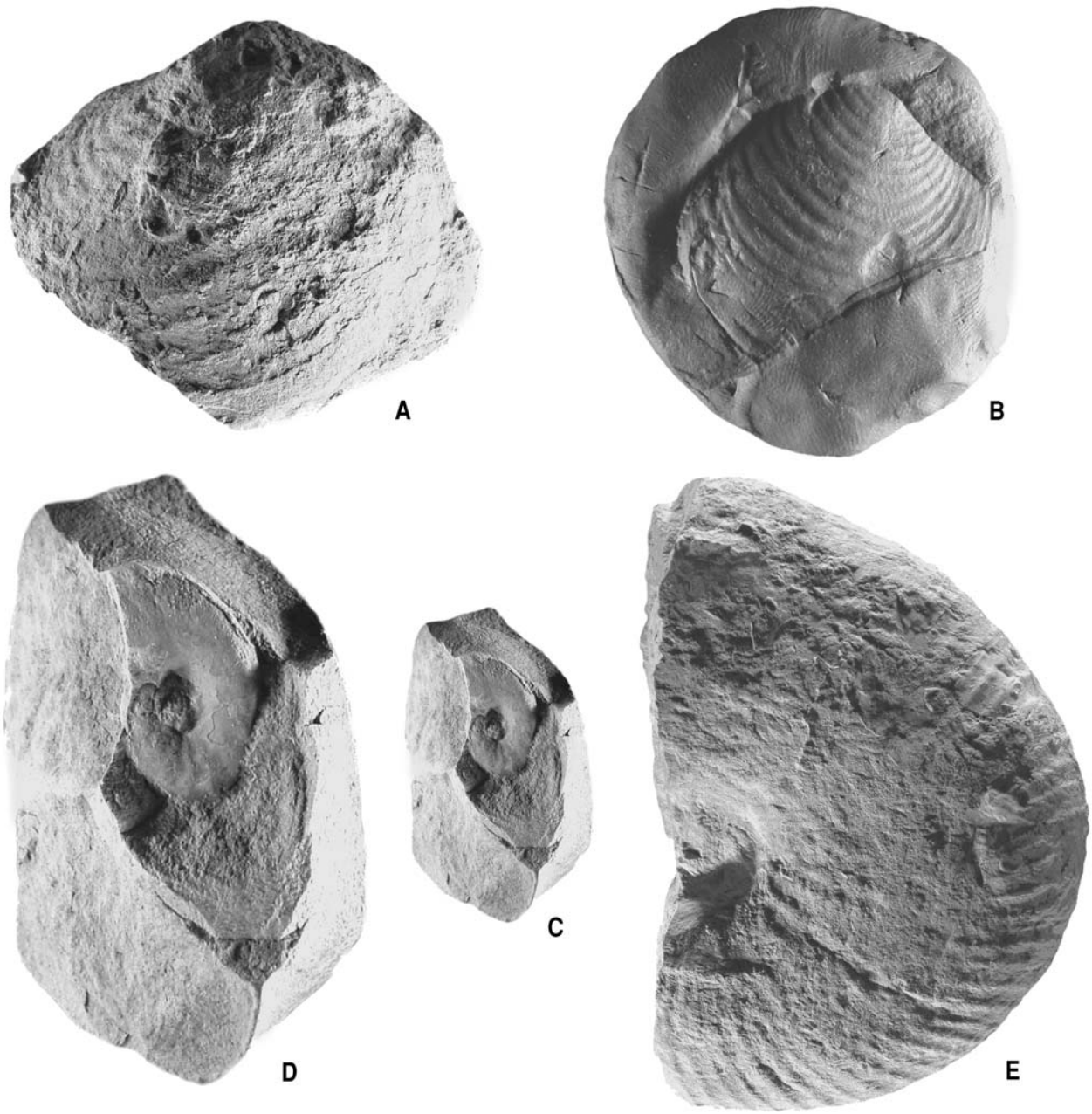

Fig. 5. **A**. *Cataceramus* sp., specimen No SU6030, Mezdra Formation, south of the village of Perchovtzi (section I from Fig. 1; Fig. 3); x 1. **B**. *Cataceramus* cf. *regularis* D'ORBIGNY, specimen No SU6029 (plaster cast), Mezdra Formation, on the left bank of Malata River, near the village of Lyutidol (section II from Fig. 1, Fig. 4); x 1. **C**, **D**. A juvenile ammonite undeterminable to the species level cf. Pachydiscidae, specimen No SU6028, Mezdra Formation, on the left bank of Malata River, near the village of Lyutidol (section II from Fig. 1, Fig. 4); C, × 1; D, × 2. **E**. *Anapachydiscus* cf. *terminus* WARD & KENNEDY, specimen No SU267, found in Kajlâka Formation, the quarry at the village of Varbeshnitza, NW from Mezdra (mentioned in JOLKIČEV, 1982, p. 18, packet 9, p. 19, fig. 7 as *Pachydiscus gollevillensis gollevilensis* (D'ORBIGNY), x 0.5. SU – collection numbers from the Museum of Paleontology at Sofia University "St. Kliment Ohridski".

structures indicates the diachronic appearance of macro- and nannofossils at the Cretaceous/Paleogene boundary. From this viewpoint, the respective boundary cannot be fixed by nannofossils except if it is assume the Maastrichtian macrofossils to have been re-deposited, but this is not the case. Furthermore, the Maastrichtian macrofauna is found not only within the ranges of the "nannofossil zones" but also in the sections overlying them – in the Kajlâka Formation, where a number of new Maastrichtian taxa, such as *Hemipneustes stria-*

toradiatus, appear. Accompaning to this taxon, inoceramids and cephalopods continue to occur (Fig. 2). These facts call into question the applicability of nannofossils for defining the Cretaceous/Paleogene boundary.

This recalls the situation in the type area of the Maastrichtian Stage, where all nannofossil taxa except one (*Biantholithus sparsus*), including the ones held to be indicative of the lower Paleocene, already occur in the underlying Maastricht Formation [(MAI *et al*, 1994; MAI *et al*, 1997a; MAI *et al*, 1997b; MAI, 1999; MAI *et al*, 2003), yet in a different size category], which is well dated by macrofossil taxa as late Maastrichtian (J.W.M. JAGT, pers. comm., 2005).

Diachronism in the occurrences of macro- and nannofossils is observed not only at the boundary Cretaceous/Paleogene, but also at other boundaries, e. g. the Campanian/Maastrichtian boundary in some European outcrops (JAGT & FELDER, 2003; KÜCHLER & WAGREICH, 1999; WAGREICH *et al*., 2003). ROBASZYNSKI *et al*. (1985) also expressed some doubts on the applicability of nannofossils in determining the Campanian–Maastrichtian boundary and pointed out that "the Campanian–Maastrichtian boundary is somewhat difficult to recognize with nannoplankton because of problems in determining the index species and possible diachronism of their appearances and extinctions from the Tethyan to the Boreal realms". WAGREICH (1987, p. 85) stated that "no exact correlation of nannoplankton and macrofossil zonation at the Campanian/Maastrichtian boundary for low and high latitudes exists". According to BURNETT (1998, p. 137) "stages have been historically defined onshore using macrofossils. In the absence of macrofossil data from oceanic cores, stages boundaries started to be "defined" using microfossil events". Finally, BURNETT (1998, p. 137) concluded: "Nannofossils do not define the bases of any Upper Cretaceous stages." This evidence, as well as the data presented above, shows that nannofossils should be used in biostratigraphy with more care in the case of chronostratigraphic boundaries already fixed by macrofauna.

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Резиме

Граница креде и палеогена у синклиналама Мездре и Љутидола у области Враца (западни Предбалкан, Бугарска)

У раду се говори о неоправданом приписивању (на основу кречњачких нанофосила) великог дела мастрихтског профила у синклиналама Мездре и Љутидола (западни Предбалкан, Бугарска) палеогену. Горњокредни седменти у синклиналама Мездре и Љутидола врацке области западног дела Предбалкана у Бугарској широко су распрострањени и великог су тектонског значаја. BONČEV

(1932) је први доказао да су горњокредни седименти Предбалкана јужно од реке Искар мастрихтске старости. Мастрихтску старост су потврдили сви каснији истраживачи на основу макрофосилне фауне (Cohen, 1946; Tzankov, 1968; Jolkičev, 1986, 1989; и други).

За кречњачке нанофосиле се последњих година претпоставља да су изузетно важни за расчлањавање горњокредних и кенозојских седимената – важност коју изгледа не можемо да доведемо у питање. Под утицајем нанопланктонске еуфорије недавно се појавило неколико публикованих радова у којима се граница креде и палеогена у проучаваном подручју прати не узимајући у обзир присуство карактеристичне макрофауне у истим слојевима који су расчлањени на основу нанопланктона. Граница креде и палеогена одређена помоћу макрофауне занемарује се у тим радовима.

Макрофаунистички подаци приказани у овом раду покрећу питање применљивости нанофосила за дефинисање границе креда–палеоген у датој области. Занемарујући присуство иноцерамуса, цефалопода и карактеристичне мастрихтске ехинидске фауне у целом профилу горњокредне серије у овим структурама, Synnovsky & Christova-Synnovska (1993), Synnovsky (1991, 1993, 1998, 2001) и Stoykova *et al*. (2000) одредили су на основу нанофосила палеоценску старост највећег дела профила (сл. 2–4). Они претпостављају (усмено саопштење, 2004) да су мастрихтска иноцерамска, цефалоподска и ехинидска фауна, која се јавља у границама њихових "нанофосилних зона", као и макрофауна формације Кајлака, преталожене. Ја тврдим да то одговара фосилној секвенци у профилу и да не постоји материјални доказ преталоживања мастрихтских макрофосила.

Нормална суперпозиција литостратиграфских јединица које формирају крила синклинала Мездра и Љутидол, као и њихов макро и микрофосилни садржај недвосмислено потврђују њихову мастрихтску старост. То је приказано у овом раду бројним чињеницама.

Истовремена појава палеоценских нанофосила и мастрихтских макрофосилних таксона у профилима ових структура указује на дијахроничну појаву макро и нанофосила на граници креде и палеогена. Са овог становишта одговарајућа граница се не може утврдити помоћу нанофосила осим ако не предпоставимо да су мастрихтски макрофосили били преталожени, али то овде није био случај. Осим тога, мастрихтска макрофауна је нађена не само у границама "нанофосилних зона" већ и у слојевима изнад њих – у формацији Кајлака, где се јавља више нових мастрихтских таксона као што је *Hemipneustes striatoradiatus*. Поред овог таксона и даље се јављају иноцерамуси и цефалоподи (сл. 2). Ове чињенице доводе у питање применљивост нанофосила за дефинисање границе креда–палеоген.

То потсећа на ситуацију у типској области мастрихтског ката, где се сви нанофосилни таксони осим једног (*Biantholithus sparsus*) укључујући и оне за које се сматра да указују на доњи палеоцен, јављају у подини Мастрихтске формације [(Mai, 1999; Mai *et al*., 1994, 1997a, 1997b, 2002), мада другачијих димензија], која је пouздано одређена на основу макрофосилних таксона као горњомастрихтска (Jagt, усмено саопштење, 2005).

Дијахронизам у појавама макро и нанофосила запажен је не само на граници креде и палеогена, већ и на другим границама, напр. граници кампана и мастрихта у неким инданцима у Европи (Jagt & Felder, 2003; Küchler & Wagreich, 1999; Wagreich *et al*., 2003). Robaszynski *et al*. (1985) такође су изразили сумњу у применљивост нанофосила за одређивање границе кампан–мастрихт и указали да је "границу кампан–мастрихта донекле тешко препознати на основу нанопланктона због проблема утврђивања водеће врсте и могућег дијахронизма њиховог појављивања и изумирања од Тетиса до бореалних области". Wagreich (1987, стр. 85) констатује да "не постоји тачна корелација нанопланктонског и макрофосилног зонирања на граници кампан–мастрихт за мање и веће географске ширине". Према Burnett-у (1998, стр. 137), "катови су историјски дефинисани на копну помоћу макрофосила. У недостатку макрофосилних података из океанских језгара, границе катова су почеле да се "одређују" помоћу микрофосила". На крају, Burnett (1998, стр. 137) закључује: "Нанофосили не одређују базе било којих катова горње креде". Овај доказ као и подаци приказани у овом раду показују да у биостратиграфији нанофосиле треба користити са више пажње у случају хроностратиграфских граница које су већ утврђене помоћу макрофауне.