

Event and sequence stratigraphy of the Maastrichtian and Danian in Bulgaria

K. Stoykova¹, M. Ivanov²

¹Geological Institute, Bulgarian Academy of Sciences, 1113 Sofia, Bulgaria,

E-mail: stoykova@geology.bas.bg

²Sofia University "Sv. Kliment Ohridski", 1504 Sofia, Bulgaria,

E-mail: mivanov@gea.uni-sofia.bg

Introduction

The events (physical, geochemical, biological — in the modern sense of the event stratigraphy) in the Maastrichtian and Danian in Bulgaria recently have been a subject of several publications. The main part of them is concentrated on the impact event at the Cretaceous/Tertiary (K/T) boundary and its consequences.

After the discovery of the K/T boundary clay bed near Bjala (Stoykova, Ivanov, 1992), many authors had explored this locality and represented new data about the iridium anomaly in Bjala sections (Preisinger et al., 1993a, b; Rögl et al., 1996). Biological events and biostratigraphy across the K/T boundary in these sections are studied and discussed by Ivanov, Stoykova (1994), Stoykova, Ivanov (1995), Стойкова, Иванов (1996). The K/T boundary is located in the flysch section near Emona as well (Sinyovsky, Stoykova, 1995). Later on, СИНЬОВСКИ (1999) reported an iridium anomaly at the K/T boundary in a clay bed, situated in-between shallow-water carbonate sediments in Mezdra region (NW Bulgaria).

Many articles (or parts of articles) have been devoted to the problem of mass extinction and biological changes among the different fossil groups: calcareous nannoplankton — Preisinger et al. (1993a, b) Ivanov, Stoykova (1994, 1995), Rögl et al. (1996), Стойкова, Иванов (1996); planktonic foraminifera — Rögl et al. (1996), Adatte et al. (2002); benthic foraminifera — Вълчев (2001); macroinvertebrates — Ivanov,

Stoykova (1994), Stoykova, Ivanov (1995), Стойкова, Иванов (1996); Mileva-Ilieva (1998, 2000). There are two comprehensive studies on the K/T boundary in Bulgaria recently published — Стойкова и др. (2000), Adatte et al. (2002). These papers summarize all data, that had been obtained from the different studies (stratigraphical, sedimentological, paleontological, mineralogical, geochemical, isotope), as well as newly acquired data and interpretations.

The value of other types of event-markers in the Maastrichtian — Danian interval is still poorly examined. Until now, СИНЬОВСКИ (1999) documented slumps, tephra-markers (beds containing volcanic ash) and biological events (colonization and immigration of fauna) in Maastrichtian-Danian of Mezdra region. Unfortunately these event-markers are discerned in a restricted area and it's difficult to estimate their reliability for correlation.

The first attempts for sequence stratigraphy subdivision of the Maastrichtian-Danian interval are made in the last few years. СИНЬОВСКИ (1999) divided two sequence units in this interval in Mezdra region. Вангелов (2000) separated two units in the Maastrichtian and one in the Maastrichtian-Danian in the East Balkan, Central Balkan-Fore Balkan and East Moesian Platform.

The formulation of the present study is based of the choice of maximum informative for our purpose objects (sections). Therefore we discarded several well known to the geological

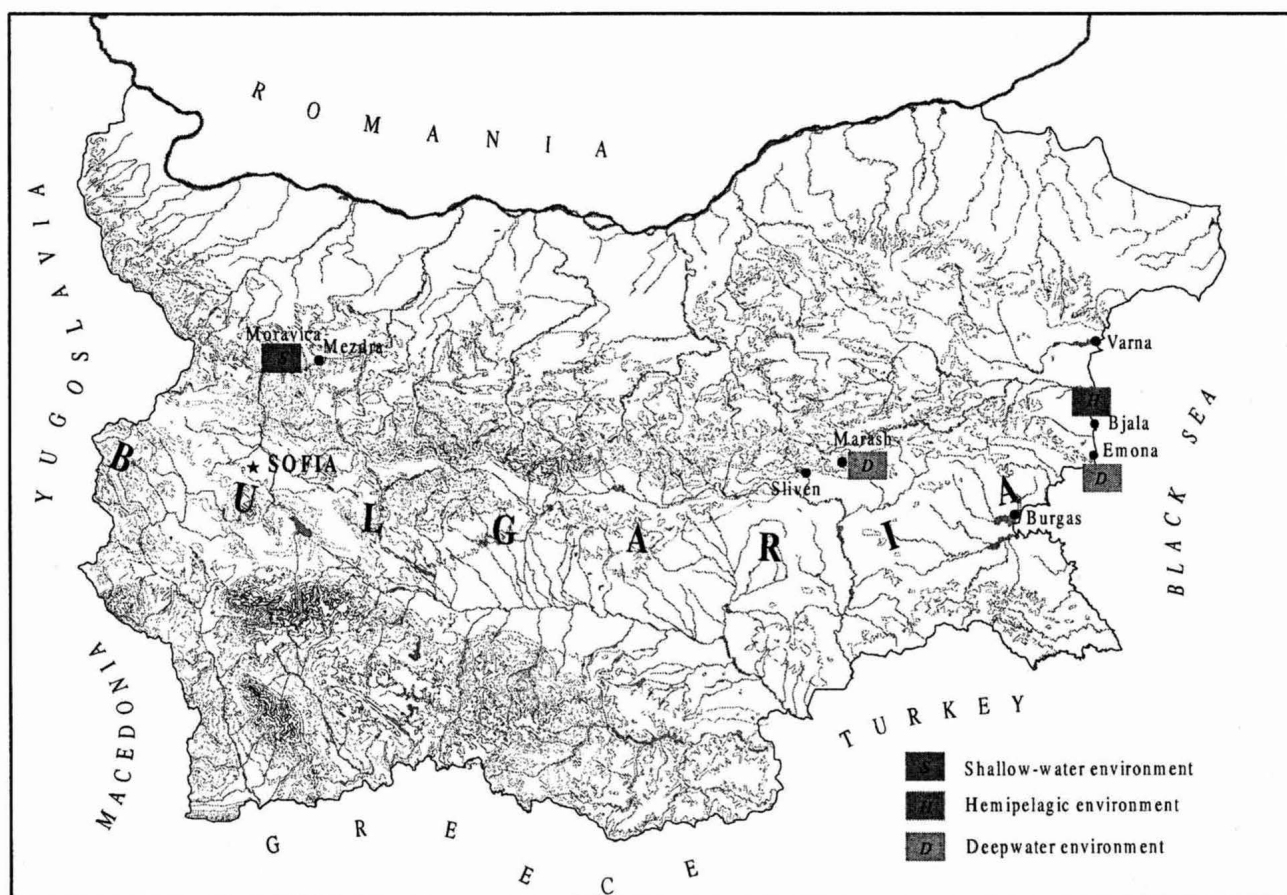


Fig. 1. Location of the studied sections

community sections. We used only sections, which meet the following requirements: a) to have relatively continuous sedimentation across the Maastrichtian-Danian, including the K/T boundary; b) to display different facial and bathymetrical zones in the basin. Three types of sections/environments can be distinguished: shallow-water, hemipelagic and deep-water (Fig. 1).

The main goals of the study are: 1) to summarize all available data on the K/T boundary studies in Bulgaria, as well as to reveal some newly obtained data for correlation of the event-markers in The Maastrichtian-Danian interval; 2) to produce a sequence stratigraphy subdivision and correlation of the third-order units in this interval.

Events and markers in the Maastrichtian—Danian sedimentary record in Bulgaria

Sedimentological

We distinguished two types of sedimentological events — the first, of global importance and the

second, of local one. Sedimentological marker of global importance is, of course, the Maastrichtian-Danian boundary clay bed. It is precisely located, using calcareous nannofossils as a main biostratigraphic tool, in almost all section studied. It marks the K/T boundary impact event, as indicated by the iridium anomaly, and is worldwide correlatable. Clay layer enriched in iridium of cosmic origin characterizes the K/T boundary globally.

The second type of marker is the one of local importance — the local and regional slumps. We documented slumps events in several stratigraphic levels — in Lower Maastrichtian of Bjala sections, Upper Maastrichtian of shallow-water sections (NW Bulgaria), as well as in Danian of Bjala and Liutidol section. These markers are useful for short-distance correlation and can be identified in the frame of the restricted area.

Mineralogical and geochemical

Mineralogical and geochemical peculiarities of the studied sediments display similar characteristics to the other K/T localities (including abrupt drop of calcite content at the Maastrichtian-Danian boundary, shock-quartz, iridium and PGE-anomaly, etc. — Preisinger et al., 1993a, b).

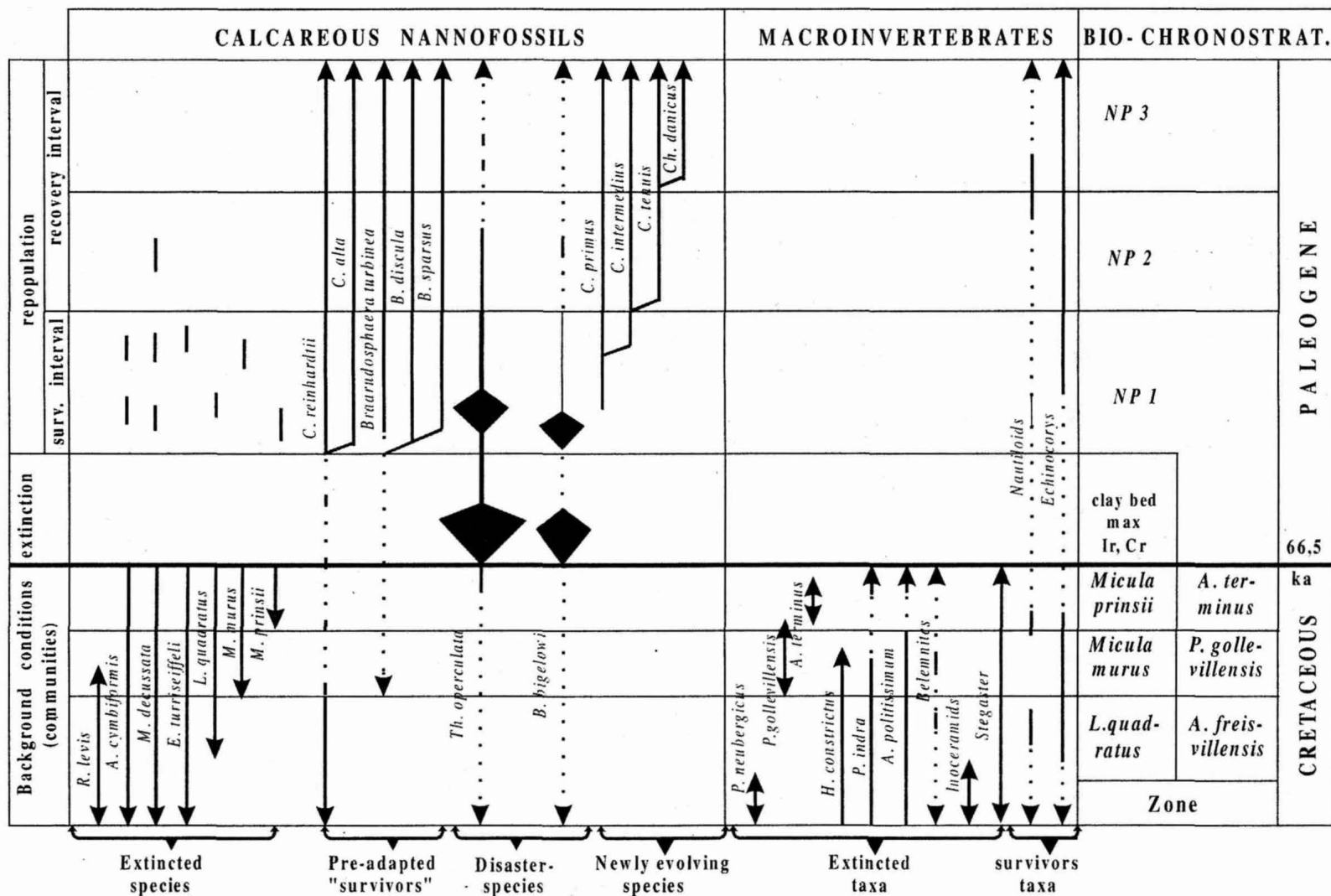


Fig. 2. Behavior of the marine macroinvertebrates and calcareous nannoplankton across the K/T boundary in Bulgaria

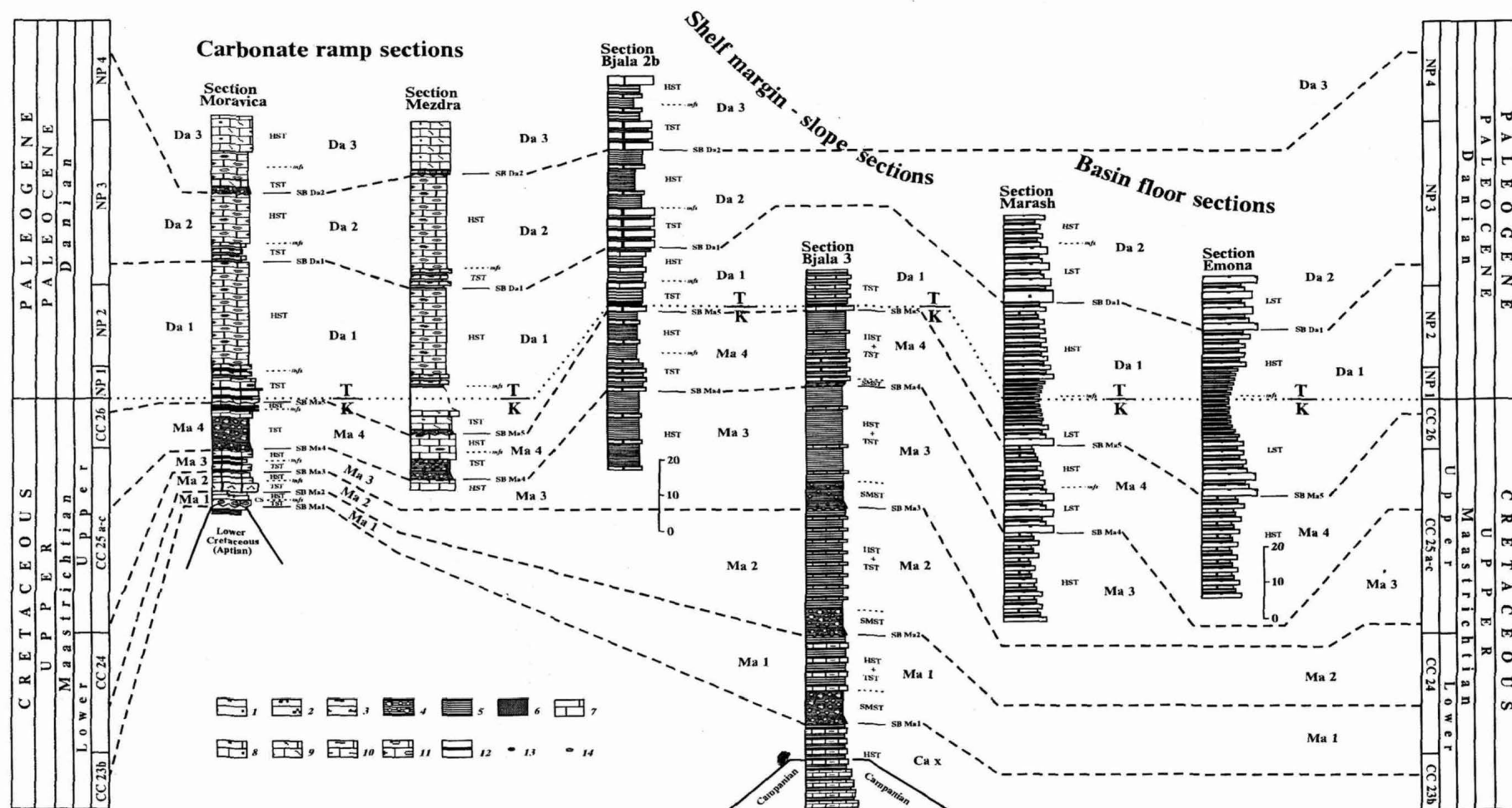


Fig. 3. Sequence stratigraphy correlation of the Maastrichtian – Danian sections in Bulgaria
 1 – sandstones; 2 – glauconitic sandstones; 3 – siltstones; 4 – slump; 5 – marls; 6 – black shales; 7 – limestones; 8 – sandy limestones; 9 – detritic limestones; 10 – clayey limestones; 11 – nodular limestones with cherts; 12 – boundary clay bed with Ir-anomaly; 13 – cherts; 14 – phosphoritic concretions; SB – sequence boundary; SMST – shelf margin system tract; TST – transgressive system tract; HST – highstand system tract; mfs – maximum flooding surface; CS – condensed section

A second (Lower Danian) clay bed in the Bjala section has been documented recently. It contains a small Ir anomaly and a major Pd anomaly that suggests a volcanic origin and respectively multiple events had occurred in the Danian (Adatte et al., 2002).

Paleomagnetic and paleoclimatic

Paleomagnetic data is acquired for only one section — Bjala 2b. They indicate a normal change of magnetic polarity across the Upper Maastrichtian and Danian (Preisinger et al., 1993a,b).

Oxygen isotope and clay mineral data indicate that climate cooling started at the end of Maastrichtian and accelerated across the K/T boundary, with generally cool climate in Early Danian (Adatte et al., 2002).

Biological

Biological events in the Maastrichtian-Danian interval, and especially the behavior of the marine invertebrates and calcareous nannoplankton are studied in detail (Fig. 2). It is found out that there is no relation between the K/T impact event and the gradual extinction of the ammonites and inoceramids, which occurred prior to the K/T boundary. On the contrary, calcareous nannoplankton assemblages are notably affected by the K/T catastrophic event. Four groups are separated: extinct, pre-adapted survivors, disasters and newly evolving species. Only the pre-adapted survivors and disaster species underwent the impact, giving rise to the new taxa during the recovery of the nanoflora (Fig. 2).

Sequence stratigraphy of the Maastrichtian and Danian in Bulgaria

Following the Exxon-model (Van Vagoner et al., 1988; Vail et al., 1991), several third order sequence stratigraphic units are distinguished in the Maastrichtian-Danian. They are bounded by unconformity surfaces or their correlative conformities. Relatively complete sections in different facial zones are chosen in order to recover the complete set of sequences (Fig. 3). The sequence boundaries often are washed-out surfaces, marked by parallel unconformity or (rarely) angular unconformity. In the present study we recognized four depositional sequences (DS) in the Maastrichtian and three in Danian (Fig. 3), briefly characterized below.

Depositional sequence Ma 1

Documented in two sections — Moravitsa and Bjala 3. Its lower boundary is a washout with parallel unconformity on the Campanian or older (Lower Cretaceous) sediments. In the basin slope sections, its lower part consists of shelf margin system tract (SMST). Later is represented by debris sediments (without extracasts), formed by gravity flows.

Transgressive system tract (TST) on the carbonate ramp is built up by thin glauconite-phosphorite sandstones (condensed sediments) with rare extracasts. On the slope it is hardly separated from the highstand system tract (HST).

HST in the shallow-water environment consists of thin packet of detrital, glauconitic limestones, and on the slope — of alternation of marls and marly limestones. The range of the Ma1 is lower part of the Lower Maastrichtian.

Depositional sequence Ma 2

This sequence is developed in the same sections as Ma 1. Its lower boundary is washout with a weak angular unconformity on the ramp and parallel unconformity on the slope.

On the basin slope it is similarly represented as Ma 1 (Fig. 3). On the carbonate ramp TST contains condensed sediments — limestones with large-sized bivalve detritus and abundant inoceramids. HST is dominated by marly limestones and its top — of micritic limestones with ammonites. Depositional sequence Ma 2 falls within the middle part of Lower Maastrichtian.

Depositional sequence Ma 3

It is identified in almost all sections studied. On the slope it is similarly developed as Ma 1 and Ma 2, with SMST (debris deposits) in the base.

In the shallow-water sections TST starts with a marl bed, followed by a packet of detritic and lithoclastic limestones with cross-bedding. HST includes micritic limestones with cherts and three marl beds, marking the maximum flooding surface (mfs). In the shelf-margin-slope sections TST+HST are dominated by marls with thin beds of marly limestones. In the basin floor (deep-water sections) HST is built up of distal flysh turbidites with clayey limestones.

DS Ma 3 occupies the topmost part of Lower Maastrichtian and lower part of Upper Maastrichtian.

System	Series	Stage	Substage	Calcareous nannofossils Zones	Ammonites Zones	Sinnyovsky, 1999	Vangelov, 2000	Present study	Haq et al., 1987	Hardenbol et al., 1998
C R E T A C E O U S	P A L E O C E N E	D a n i a n	Upper	NP 4		TST + LSW ST	ST 1	Da 3		Da 4
								SB Da 2		
								Da 2		
								SB Da 1		
			Lower	NP 3				Da 1	Da 1	Da 3
			Upper	NP 2						Da 2
			Lower	NP 1						Da 1
C R E T A C E O U S	P A L E O C E N E	D a n i a n	Upper	CC 26	<i>Anapachydiscus terminus</i>	HST	SK 6	SB Ma 5	Ma 5	Ma 5
								Ma 4	Ma 4	
								SB Ma 4		
								Ma 3	Ma 2	
			Lower	CC 25	<i>Pachydiscus gollevillensis gollevillensis</i>		SK 5	SB Ma 3		Ma 4
								Ma 2		
								SB Ma 2		
								Ma 1		
			Upper	CC 24	<i>Anapachydiscus freisvillensis</i>	TST		SB Ma 1		Ma 3
			Lower	CC 23						Ma 2

Fig. 4. Correlation of bio-, chrono- and sequence stratigraphic schemes

Depositional sequence Ma 4

Distinguished in all studied sections (Fig. 3). In the shallow-water localities TST is marked by slumps in the base and thin-bedded limestones in the upper part. The HST includes thin-bedded clayey limestones, interbedded by cherts.

In the shelf-margin and slope zone, TST+HST are very similar to those of Ma 3. In the deep-water sections the lowstand system tract (LST) is formed by proximal turbidite deposits. Thick rhythms dominated by sandstones are indicative for this system tract. HST in the basin floor is developed similarly to Ma 3. The range of the sequence is in the Upper Maastrichtian.

Depositional sequence Da 1

Recorded in all studied sections. Its lower boundary on the carbonate ramp is a washout, and in the other zones — conformity. In the shallow-water and shelf sections it has a thin TST in the base. The K/T boundary event marker falls within this sequence.

In the basin sections the LST is built up of proximal turbidites with thick and massive sandstones in the rhythms. HST consists of distal thin-bedded flysh in the lower part (mfs) and medium-bedded rhythms in the upper part.

HST on the carbonate ramp is represented by micritic limestones with chert nodules and beds. This sequence spans the topmost Maastrichtian to basal Danian.

Depositional sequence Da 2

Developed in all sections. Its lower boundary is a parallel unconformity or conformity. TST on the ramp and shelf is formed by alternation of nodular and clayey limestones, interbedded by marls. LST in the basin floor is similar to the previous (Da 1) sequence.

In the shallow-water environment HST includes clayey or micritic limestones with chert nodules. In the marginal and basin environment this tract is dominated by marls. The range of the sequence Da 2 is Lower Danian.

Depositional sequence Da 3

It is distinguished in shallow-water and hemipelagic sections only because in the deep-water ones is not studied. Its lower boundary on the carbonate ramp is a washout, marked by slumps or hard ground. TST consists of thin debris packets or phosphorite-glaucconite sediments, followed by grainstone packets.

In the hemipelagic environment TST is represented by alternation of thick-bedded marly limestones with marls. The HST is formed by periodites (Milankovich cyclicity), dominated by marls. The upper part of this unit as well as its upper boundary is insufficiently studied at present. Chronostratigraphic range of the sequence Da 3 is Upper Danian.

We should point that correlation of the proposed here sequence scheme to the other existing schemes in Bulgaria is rather hard (despite of some coincidences) (Fig. 4). This is mainly due to the different scale of study of СИНЬОВСКИ (1999) and Вангелов (2000), as well as to the specificity of the sections they were examined to draw their schemes.

Comparison of the recognized sequences with standard schemes indicates a relatively well fitting of the Bulgarian units to the scheme of Hardenbol et al. (1998) and Haq et al. (1987) (Fig. 4).

Conclusion

This complex study of Maastrichtian-Danian interval in Bulgaria resulted in elucidation and interpretation of the basic events affected organic and inorganic nature during this time.

The marine organisms' reaction of the events at the Maastrichtian-Danian boundary, as well as sedimentological, mineralogical-geochemical and paleomagnetic characteristics of the Bulgarian sections suggested their in-between paleogeographic position (between low and high latitudes).

A sequence stratigraphy subdivision (third-order units) and correlation of the Maas-

trichtian-Danian interval is proposed. It shows a good agreement partially with Western European scheme (Hardenbol et al. 1998) and/or with Exxon-scale (Haq et al. 1987).

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