

UPPER TITHONIAN – BERRIASIAN CALCAREOUS NANNOFOSSIL ZONATION OF THE TURBIDITE DEPOSITS OF KOSTEL FORMATION NEAR BERENDE VILLAGE, PERNIK DISTRICT

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ABSTRACT. Bobovo Member of the Kostel Formation crops out near Berende Village, Pernik District. The sampled section is more than 400 m thick. During the present study relatively well preserved Upper Tithonian–Berriasian nannofossil assemblages are recovered, represented by coccoliths and nannoconids. The boundary Jurassic-Cretaceous interval is subdivided into zones and subzones, according to previous investigations in the West Atlantic, Italy, France, Spain and Bulgaria. The lowest 50 m of the section belong to *Hexalithus noelae* Subzone (Upper Tithonian) of the *Microstaurus chisti* nannofossil Zone (Upper Tithonian - Lower Berriasian). The next interval between 50 and 76 m including the Jurassic-Cretaceous boundary belongs to *Umbria granulosa granulosa* Subzone (Upper Tithonian) and *Rotelapillus laffitei* Subzone (uppermost Tithonian – lowermost Berriasian) of the same nannofossil zone. The lowermost Cretaceous Subzone *Nannoconus steinmanni minor* (lower Lower Berriasian), characterized by the presence of small representatives of *Nannoconus camptneri* Brönnimann and *Nannoconus steinmanni* Kamptner known as "minor" subspecies, is established between 76 and 115 m. The large forms appear 115 m above the base and mark the bottom of *Nannoconus steinmanni steinmanni* nannofossil Zone (upper Lower Berriasian) with thickness 100 m. The rest of the section belongs to *Cretarhabdus angustifloratus* nannofossil Zone (Upper Berriasian) more than 200 m thick.

ЗОНАЛНА ПОДЯЛБА НА ГОРНОТИТОНСКО-БЕРИАСКИТЕ ТУРБИДИТНИ ОТЛОЖЕНИЯ НА КОСТЕЛСКАТА СВИТА ПРИ С. БЕРЕНДЕ, ПЕРНИШКА ОБЛАСТ

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РЕЗЮМЕ. Бобовският член на Костелската свита се разкрива при с. Беренде, Пернишка област. Опробваният разрез е с дебелина над 400 m. При настоящото изследване бяха установени относително добре запазени горнотитонско-бериаски нанофосилни асоциации, представени от коколити и нанокопуси. Граничният интервал между Юрата и Кредата е поделен на зони съгласно предшествващи изследвания в Западния Атлантик. Италия, Франция, Испания и България. Най-долните 50 m от разреза принадлежат на подзона *Hexalithus noelae* (Горен Титон) от нанофосилна зона *Microstaurus chisti* (Горен Титон – Долен Бериас). Следващият интервал между 50 и 76 m, включващ границата Юра-Креда принадлежи на подзона *Umbria granulosa granulosa* (Горен Титон) и подзона *Rotelapillus laffitei* (най-горен Титон – най-долен Бериас) от същата нанофосилна зона. Най-долната кредна подзона *Nannoconus steinmanni minor* (долен Долен Бериас), характеризира се с присъствието на малки представители на *Nannoconus camptneri* Brönnimann и *Nannoconus steinmanni* Kamptner известни като подвидове "minor", е установена между 76 и 115 m. Големите форми се появяват на 115 m над основата и маркират долната граница на нанофосилна зона *Nannoconus steinmanni steinmanni* (горен Долен Бериас) с дебелина 100 m. Останалата част от разреза принадлежи на нанофосилна зона *Cretarhabdus angustifloratus* (Горен Бериас) с дебелина над 200 m.

Introduction

During the recent 15 years many publications devoted to the problems of the stratigraphic boundaries between Phanerozoic systems and series have appeared. Calcareous nannofossils are among the most useful groups for determination of these boundaries from Jurassic to recent. One of the most comprehensive works concerning the problems of the nannofossil distribution in the Jurassic-Cretaceous boundary interval is that of Bralower et al. (1989). They stated that the Jurassic-Cretaceous boundary interval is a crucial time in nannofossil evolution, when a rapid increase of the nannofossil diversity and abundance started. In fact the abundance of the nannofossil assemblages depends upon their living conditions. For example in the Bajocian sediments of Bov Formation in Belogradchik region (NW Bulgaria) very abundant but low diversity nannofossil associations occur, represented almost entirely by species of the genus

Watznaueria Reinhardt, 1964. However the bloom of new taxa across this boundary interval is really remarkable. Most of the common Cretaceous taxa appear in the Tithonian and Berriasian.

The first characteristics of the calcareous nannoplankton occurrence across the Jurassic-Cretaceous boundary in Bulgaria was made by Стойкова (1995) in Ginci, Glozhene and Salash Formations in the West Balkan near Burlya and Komshtitsa Villages, Sofia District. She recognized three successive nannofloral associations: *Conusphaera mexicana* (Upper Tithonian), *Nannoconus camptneri minor* (Lower Berriasian) and *Cretarhabdus angustifloratus* (Upper Berriasian). These associations were correlated with the ammonite zonation after Bralower et al. (1989) and calpionellid zonation of Lakova (1993). Lakova et al. (1997, 1999) established an integrated zonation of the Tithonian-Valanginian interval in the sections near Barlya and Gorno Belotinci Villages based on calpionellids, nannofossils and

calcareous dinocysts. They recognised many bioevents and established a chronostratigraphic subdivision of the investigated stratigraphic interval. Stoykova subdivided the Tithonian-Berriasian interval into three zones: *Conusphaera mexicana* (Tithonian), *Microstaurus chisti* (Upper Tithonian – Lower Berriasian) and *Nannoconus steinmannii steinmannii* (Upper Berriasian – Lower Valanginian).

In the present investigation a more detailed nannofossil subdivision of the Tithonian-Berriasian interval is proposed, based on reliable nannofossil assemblages in the turbidite sequence of the Kostel Formation near Berende Village, Pernik District. The section is not permanently exposed but provides a series of outcrops along Berende River between Berende and Svetlya Villages in an undisturbed sequence with relatively permanent dip and strike.

Previous investigations

The Tithonian flysch deposits in Kraishte (SW Bulgaria) were described by Nachev (1969a,b) as “coarse flysch”, “sandstone flysch” and “normal flysch”. Начев & Николов (1968) described 1000-2000 m thick “postflysch” Berriasian deposits near Berende Village. These deposits were referred to the Kostel Formation (Николов & Сапунов, 1970) by Сапунов et al. (1985), Сапунов & Чумаченко (1986) and Зарорчев (1993). Сапунов et al. (1985) introduced three new members of the Kostel Formation in Kraishte area: Antovo, Gorochevo and Bobovo Members. The Bobovo Member is composed of alternating sandstones, conglomerates, gravelites, shales and marls. The studied section was described by Сапунов et al. (1985) as a supplementary section for the upper part of the Bobovo Member of Kostel Formation with thickness 600 m. In their original description the authors described three packets from upper to lower: packet 3 (Berriasian, middle part) – 300 m sandstones, conglomerates and “conglomerate shales”; packet 2 (Berriasian, lower part – upper Upper Tithonian) – 150 m grey sandstones, gravelites and conglomerates with graded bedding, alternating with grey marls and “conglomerate shales”; packet 3 (lower Upper Tithonian – upper Lower Tithonian) – 150 m medium to thin-bedded grey sandstones with graded bedding alternating with thin packets of calcareous shales and marls.

Present results

This work is a part of the paleontological investigation of samples, collected by the mapping team in SW Bulgaria, performing the task of the Ministry of Environment and Water for mapping of Bulgaria in scale 1:50 000. Section sampled and measured is more than 400 m thick (Fig. 1). It is situated along Berende River between “lower hamlet” of Berende Village and half distance to Svetlya Village. The lower 315 m are described south of the road. It is practically impossible to compare this section with the section of Сапунов et al. (1985) because no lithologic marker levels were pointed in the previous description and the packets are not recognisable. In the present study a prominent terrigenous sandstone-gravelite-conglomerate packet is established between 52 and 65 m from the base of the section. Another sandstone level is

between 39 and 42 m, and a 1 m thick gravelite bed 130 m above the base. As a whole this lower portion of the section, probably corresponding to the packet 3 of Сапунов et al. (1985), is characterized by predominance of sandstones. However the present results show that only the lowermost about 60-70 m of the section belong to the Upper Tithonian without nannofossil evidence for Middle or Lower Tithonian deposits.

The nannofossil content in most of the samples is rather poor however some samples contain relatively abundant and well preserved nannofossil assemblages. The nannofossil diversity is low, including some persistently represented species as *Watznaueria barnesae* (Black in Black & Barnes, 1959) Perch-Nielsen, 1968, *Watznaueria britannica* (Stradner, 1963) Reinhardt, 1964, *Watznaueria fossacincta* (Black, 1971) Bown in Bown & Cooper, 1989, *Cyclagelosphaera margerellii* Noël, 1965, *Cyclagelosphaera deflandrei* (Manivit, 1966) Roth, 1973 and *Nannoconus* sp. discs (sensu Crux, 1989). The last taxon is represented by rare large forms and abundant medium and small sized forms. In the Cretaceous part of the section the common taxa increase with several nannoconid species *Nannoconus steinmannii* (Kamptner, 1931) ssp. *minor* Deres & Achéritéguy, 1980, *Nannoconus steinmannii* Kamptner, 1931, ssp. *steinmannii*, *Nannoconus kamptneri* Brönnimann, 1955 ssp. *minor* Bralower in Bralower et al., 1989, *Nannoconus kamptneri* Brönnimann, 1955 ssp. *kamptneri*, *Nannoconus globulus* Brönnimann, 1955 ssp. *minor* Bralower in Bralower et al., 1989 and *Nannoconus globulus* Brönnimann, 1955 ssp. *globulus*. *Nannoconus kamptneri* Brönnimann, 1955 ssp. *kamptneri*, is especially abundant in *Nannoconus steinmannii* *steinmannii* and *Retecapsa angustiforata* nannofossil Zones.

The stratigraphically important taxa are rather rare. Most important species are figured on Plate 1 and 2. Many of the nannofossil species appearing in the Jurassic-Cretaceous boundary interval have not been found. On the basis of the determined nannofossils three nannofossil zones have been recognised: *Microstaurus chisti* Zone, *Nannoconus steinmannii steinmannii* Zone and *Retecapsa angustiforata* Zone, the first one being subdivided into subzones.

Microstaurus chisti Zone (NJK)

Authors: Bralower et al. (1989).

Definition: Interval from the first occurrence of *Microstaurus chisti* (Worsley, 1971) Grün in Grün & Allemann, 1975 to the first occurrence of *Nannoconus steinmannii* Kamptner, 1931, ssp. *steinmannii*.

Age: Upper Tithonian – Early Berriasian.

Remarks: Bralower et al. (1989) subdivided this zone into four subzones: *Hexalithus noelae* (NJK-A), *Umbria granulosa granulosa* (NJK-B), *Rotelapillus laffittei* (NJK-C) and *Nannoconus steinmannii minor* (NJK-D). The upper part of *Hexalithus noelae* Subzone is established in the samples from the lowermost 50 m of the section. Its upper boundary is established in the sample 50 m above the base after the first appearance of *Umbria granulosa* Bralower & Thierstein in Bralower et al., 1989, ssp. *granulosa*. The next interval between 50 and 76 m belongs to both *Umbria granulosa granulosa* and *Rotelapillus laffittei* Subzones,

although the base of the latter is not established because the marker species is not found. Its upper boundary is put after the first appearance of the small representatives of *Nannoconus steinmannii* Kamptner and *Nannoconus kamptneri* Brönnimann known as 'minor' subspecies. The interval between 76 and 115 m belongs to the uppermost subzone of *Microstaurus chiastius* Zone - *Nannoconus steinmannii* minor Subzone (NJK-D).

***Hexalithus noelae* Subzone (NJK-A)**

Authors: Bralower et al. (1989).

Definition: Interval from the first occurrence of *Microstaurus chiastius* (Worsley, 1971) Grün in Grün & Allemann, 1975 to the first occurrence of *Umbria granulosa* (Bralower & Thierstein in Bralower et al., 1989, ssp. *granulosa*).

Age: Upper Tithonian.

Characteristic taxa: *Nannoconus* discs (sensu Crux, 1989), *Nannoconus quadratus* Deres & Achéritéguy, 1980, *Conusphaera mexicana* Trejo, 1969 ssp. *mexicana*, *Conusphaera mexicana* Trejo, 1969 ssp. *minor* Bralower in Bralower et al., 1989, *Zeugrhabdotus erectus* (Deflandre in Deflandre & Fert, 1954) Reinhardt, 1965, *Zeugrhabdotus embergeri* (Noël, 1958) Perch-Nielsen, 1984. *Umbria granulosa* Bralower & Thierstein in Bralower et al., 1989, ssp. *minor*, *Polycostella senaria* Thierstein, 1971, *Polycostella beckmannii* Thierstein, 1971, *Microstaurus chiastius* (Worsley, 1971) Grün in Grün & Allemann, 1975.

Remarks. *Nannoconus compressus* Bralower & Thierstein in Bralower et al., 1989 is very rare in the lowest samples of the section. Obviously it disappears in this subzone. *Nannoconus globulus* Brönnimann, 1955 ssp. *minor* Bralower in Bralower et al., 1989 appears 45 m above the base of the section.

Boundaries: The lower boundary is not exposed. The upper boundary is established 50 m above the base of the section.

Thickness: 50 m.

***Umbria granulosa granulosa* Subzone (NJK-C)**

+ *Rotelapillus laffittei* Subzone (NGK-D)

Authors: Bralower et al. (1989).

Age: uppermost Tithonian – lowermost Berriasian

Characteristic taxa: *Nannoconus* discs (sensu Crux, 1989), *Nannoconus quadratus* Deres & Achéritéguy, 1980, *Nannoconus globulus* Brönnimann, 1955 ssp. *minor* Bralower in Bralower et al., 1989, *Conusphaera mexicana* Trejo, 1969 ssp. *mexicana*, *Zeugrhabdotus erectus* (Deflandre in Deflandre & Fert, 1954) Reinhardt, 1965, *Zeugrhabdotus embergeri* (Noël, 1958) Perch-Nielsen, 1984. *Umbria granulosa* Bralower & Thierstein in Bralower et al., 1989, ssp. *minor*, *Umbria granulosa* Bralower & Thierstein in Bralower et al., 1989, ssp. *granulosa*, *Polycostella senaria* Thierstein, 1971, *Rotelapillus laffittei* (Noël, 1957) Noël, 1973, *Genus et species* indet. (Pl. 2, figs. 26-30).

Remarks. The interval between sample 50 and 76 m above the base includes 13 m thick terrigenous sandstone-gravelite-conglomerate packet between 52 and 65 m, barren of nannofossils. The first specimen of the subzonal marker of *Umbria granulosa granulosa* Subzone - *Umbria granulosa* Bralower & Thierstein in Bralower et al., 1989,

ssp. *granulosa* is found 50 m above the base in sample Be 263 but it is very rare. It is rare also in the next two samples Be 250 and Be 247 above the terrigenous packet. The subzonal marker of the younger *Rotelapillus laffittei* Subzone *Rotelapillus laffittei* (Noël, 1957) Noël, 1973 is found in the sample 65 m above the base of the section. Thus the boundary between *Umbria granulosa granulosa* Subzone and *Rotelapillus laffittei* Subzone falls into the terrigenous packet between 52 and 65 m above the base. For that reason these two zones are united. Another characteristic feature of this interval is the presence of *Umbria granulosa* Bralower & Thierstein in Bralower et al., 1989, ssp. *minor*. Regularly encountered in the sample Be 263 below the terrigenous packet are *Polycostella senaria* Thierstein, 1971 and *Polycostella beckmannii* Thierstein, 1971. These species are not present in the samples Be 250 and Be 247, so they obviously disappear in the terrigenous packet. Unknown *Genus et species* indet. (Pl. 2, figs. 26-30) is common in these samples. It is characteristic only for these samples. The first occurrence of *Cruciellipsis cuvillieri* (Manivit, 1966) Thierstein, 1971, which is very rarely encountered is in the sample Be 250. The Jurassic-Cretaceous boundary as defined by Bralower et al. (1989) falls into the *Rotelapillus laffittei* Subzone, so it is supposed to be into the interval between samples Be 250 and Be 239.

Boundaries: The lower boundary of this interval is 50 m above the base and the upper one is 76 m above the base.

Thickness: 26 m.

***Nannoconus steinmannii minor* Subzone (NJK-D)**

Authors: Bralower et al. (1989).

Definition: Interval from the first occurrence of *Nannoconus steinmannii* (Kamptner, 1931) ssp. *minor* Deres & Achéritéguy, 1980 to the first occurrence of *Nannoconus steinmannii* (Kamptner, 1931) ssp. *steinmannii*.

Age: Earliest Berriasian.

Characteristic taxa: *Nannoconus steinmannii* Kamptner, 1931 ssp. *minor*, Deres & Achéritéguy, 1980, *Nannoconus kamptneri* Brönnimann, 1955 ssp. *minor* Bralower in Bralower et al., 1989, *Conusphaera mexicana* Trejo, 1969 ssp. *mexicana*, *Umbria granulosa* Bralower & Thierstein in Bralower et al., 1989, ssp. *granulosa*, *Zeugrhabdotus erectus* (Deflandre in Deflandre & Fert, 1954) Reinhardt, 1965, *Zeugrhabdotus embergeri* (Noël, 1958) Perch-Nielsen, 1984, *Nannoconus* discs (sensu Crux, 1989), *Cruciellipsis cuvillieri* (Manivit, 1966) Thierstein, 1971.

Remarks: *Nannoconus kamptneri* Brönnimann, 1955 ssp. *minor* Bralower in Bralower et al., 1989 appears in the bottom of the zone simultaneously with the marker subspecies. This subspecies is common and could be also used for determination of the lower boundary of the subzone.

Boundaries: The lower boundary is 76 m above the base and the upper one - 115 m above the base of the section.

Thickness: 39 m.

***Nannoconus steinmannii steinmannii* Zone (NK-1)**

Authors: Bralower et al. (1989).

Definition: Interval from the first occurrence of *Nannoconus steinmannii* Kamptner, 1931 ssp. *steinmannii* to the first occurrence of *Retecapsa angustiforata* Black, 1971.

Age: Early Berriasian.

Fig. 1. Section of the Bobovo Member of Kostel Formation near Berende Village: 1 – conglomerates; 2 – gravelites; 3 – sandstones; 4 – thin rhythmic turbidite deposits; sandy marls, carbonate shales

Thickness: More than 200 m.

Discussion

The nannofossil assemblages contain some of the marker species characteristic for the investigated stratigraphic interval. Establishment of the zonal boundaries is made on the basis of appearance levels of the zonal markers, although most of the characteristic species have not been found. Some of them are rarely encountered. One of the reliable marker species *Nannoconus compressus* Bralower & Thierstein in Bralower et al. 1989 is extremely rare in the lowest samples of the section and disappears in Hexalithus noelae Subzone. *Nannoconus wintereri* Bralower & Thierstein in Bralower et al. 1989 is also very rare encountered in the sample 130 m above the base of the section. *Umbria granulosa* Bralower & Thierstein in Bralower et al., 1989, ssp. *minor*, is very rare in the lower 60-70 m of the section. *Umbria granulosa* Bralower & Thierstein in Bralower et al., 1989, ssp. *granulosa* first appearing in sample Be 260 m is also very rare. In this sample these two species occur together. One of the most characteristic nannofossils for the Tithonian Stage *Faviconus multicolumnatus* Bralower in Bralower et al., 1989 is very rare encountered in the lowermost three samples. *Rhagodiscus asper* (Stradner, 1963) Reinhardt, 1967 and *Diadorhombus rectus* Worsley, 1971 have not been found. *Cruciellipsis cuvillieri* (Manivit, 1966) Thierstein, 1971 has been found sporadically in several samples.

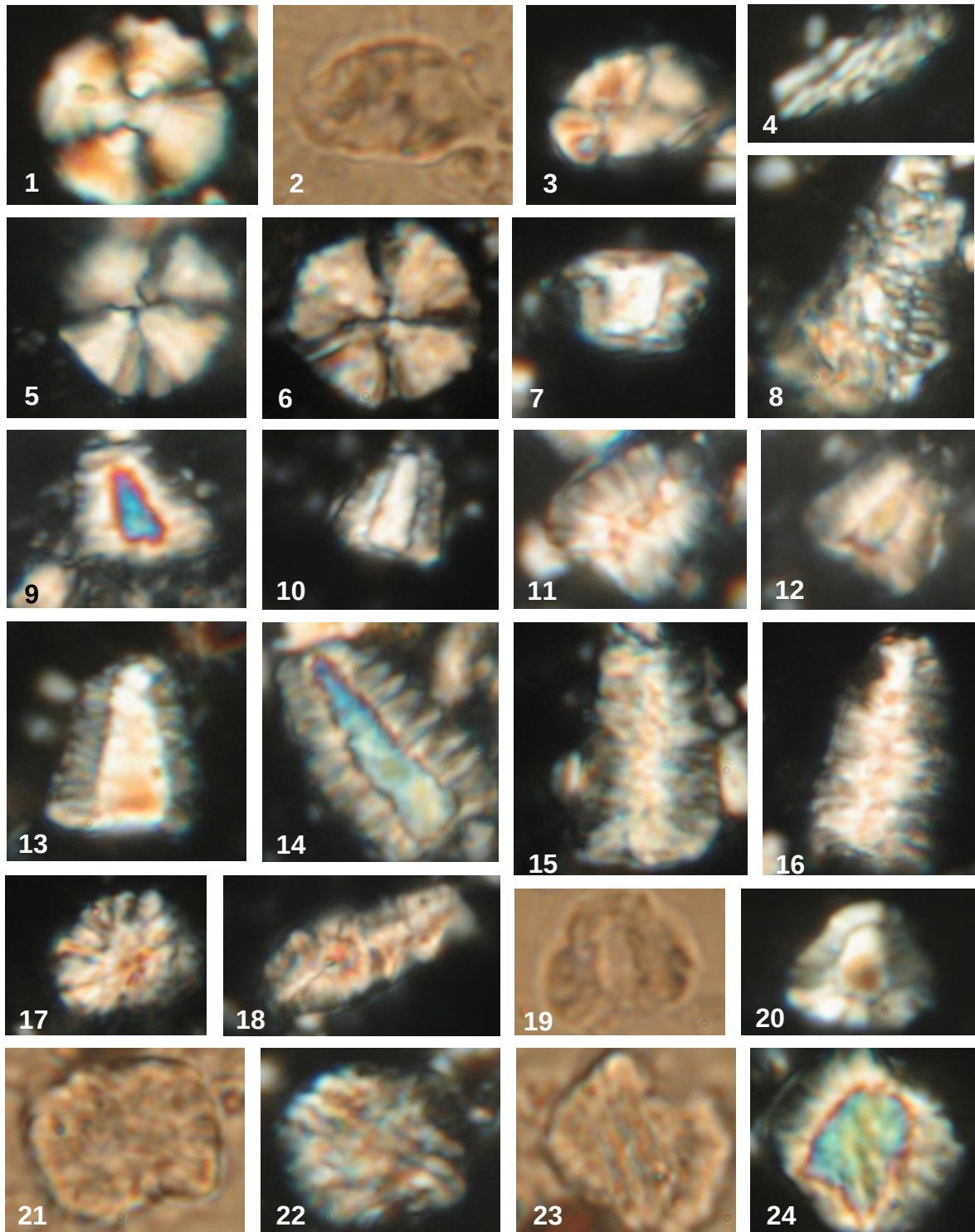
Conclusion

On the basis of the recognized nannofossil zones and subzones the stratigraphic range of the section is restricted in the frame of uppermost Tithonian - Upper Berriasian. No nannofossil evidence for the presence of Middle or Lower Tithonian rocks has been obtained. The lowermost 50 m of the section belonging to the upper part of Hexalithus noelae Subzone and the lower part of the interval Umbria granulosa granulosa – Rotelapillus laffittei Subzones are referred to the Upper Tithonian. The Jurassic-Cretaceous boundary falls above the sandstone packet between 50 and 76 m, barren of nannofossils. The rest of the section up to the sandstone levels north of Berende Village belong to the Berriasian Stage. It includes the uppermost nannofossil subzone Nannoconus steinmannii minor of the Microstaurus chiasmus Zone, Nannoconus steinmannii steinmannii Zone and Retecapsa angustiforata Zone. The turbidite deposits of the Kostel Formation contain well preserved nannoflora which is a reliable biostratigraphic tool for subdivision of the Jurassic-Cretaceous boundary interval. The present results provide an appropriate correlation of this important stratigraphic interval with the other investigated sections in West Bulgaria.

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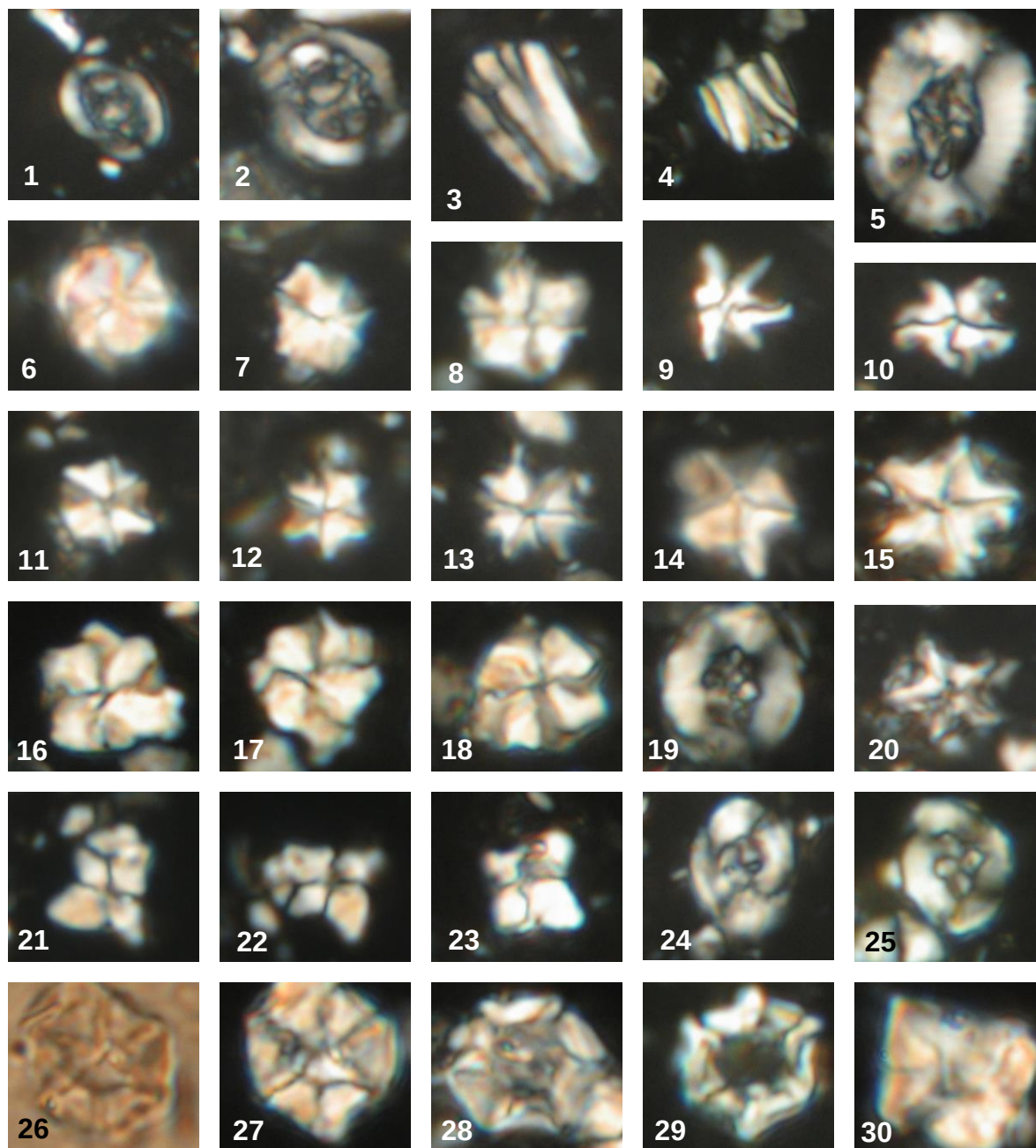
PLATE 1



1 – *Cyclagelosphaera deflandrei* (Manivit, 1966) Roth, 1973, Be 1, XPL; 2, 3 – *Nannoconus compressus* Bralower & Thierstein, 1989, Be 283, 2 – TL, 3 – XPL; 4-6 – *Nannoconus* discs (sensu Crux, 1989), 4 – side view, Be 307, 5, 6 – top view, Be 283, XPL; 7 – *Nannoconus quadratus* Brönnimann, 1955 XPL, Be 285, XPL; 8 – *Faviconus multicolumnatus* Bralower in Bralower et al., 1989, 9, 10 – *Nannoconus kamptneri* Brönnimann, 1955 ssp. *minor* Bralower in Bralower et al., 1989, Be-235, XPL; 11, 12 – *Nannoconus steinmannii* Kamptner, 1931 ssp. *minor*, Deres & Achéritéguy, 1980, Be 235, XPL; 13, 14 – *Nannoconus kamptneri* Brönnimann, 1955 ssp. *kamptneri*, 13 – Be 20, 14 – Be 1, XPL; 15, 16 – *Nannoconus steinmannii* Kamptner, 1931 ssp. *steinmannii*, Be 200, XPL; 17 – *Nannoconus globulus* Brönnimann, 1955 ssp. *minor* Bralower in Bralower et al., 1989, Be 291, XPL; 18 – *Nannoconus bermudezii* Brönnimann, 1955, Be 235, XPL; 19, 20 – *Nannoconus* sp. 1, Be 283, 7 – TL, 8 – XPL.; 21-24 – *Nannoconus* sp. 2, Be 270, 21, 23 – TL, 22, 24 – XPL.

Magnification: X 3390

PLATE 2



1 – *Umbria granulosa* Bralower & Thierstein in Bralower et al., 1989, ssp. *minor*, Be 260, XPL; 2 – *Umbria granulosa* Bralower & Thierstein in Bralower et al., 1989, ssp. *granulosa*, Be 263, XPL; 3 – *Conusphaera mexicana* Trejo, 1969 ssp. *mexicana*, Be 296, XPN; 4 – *Conusphaera mexicana* Trejo, 1969 ssp. *minor* Bralower in Bralower et al., 1989, Be 296, XPN; 5 – *Cruciellipsis cuvillieri* (Manivit, 1966) Thierstein, 1971, Be 20, XPL; 6-8 – *Polycostella beckmannii* Thierstein, 1971, Be 283, XPL; 9 – *Polycostella* sp. 1, Be 283, XPL; 10 – *Polycostella* sp. 2, Be 283, XPL; 11-13 – *Polycostella senaria* Thierstein, 1971, Be 283, XPL; 14,15 – *Micrantholithus obtusus* Stradner, 1963, Be 20, XPL; 16-18 – *Assipetra infracretacea* (Thierstein, 1973) Roth, 1973; Be 190, XPL; 19 – *Retecapsa angustiforata* Black, 1973, Be 20, XPL; 20 – *Micrantholithus obtusus* Stradner, 1963, ssp. *minor*, new subspecies, Be 20, XPL; 21-23 – *Tetralithus* sp., 21, 22 – Be 1, 23 – Be 20, XPL; 24 – *Microstaurus chiastius* (Worsley, 1971) Grün in Grün & Allemann, 1975; 25 – *Microstaurus quadratus* Black, 1971, Be 307, XPL; 26-30 – Genus et species *indet.*, Be 263, XPL, 26-29 top view, 30 – side view

Magnification: X 3390