# FIVE PROTECTED OUTCROPS OF THE CRETACEOUS/TERTIARY BOUNDARY IN BULGARIA

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#### ABSTRACT

According to the famous 'impact theory', 65 million years ago a great meteorite caused explosion exceeding 10 000 times the present day nuclear weapon potential. This impact is considered to be one of the major disasters in the Phanerozoic history of the Earth. As a result, great quantity of ash material rose up into the atmosphere and covered the Earth for months. The subsequent fallout produced thin, globally traceable layer, enriched in iridium and other rare elements, oxides, minerals, shocked quartz and microtectites. This catastrophic event is probably responsible for disappearance of many typical Mesozoic animals and plants - dinosaurs, marine reptiles, ammonites, belemnites, over 90% of calcareous nannoplankton and planktonic foraminifera, 60% of angiosperm species, etc. In the present study geoconservation characteristics of five nominated for protection outcrops of this geological phenomenon in Bulgaria are proposed: geosite "Belite skali" in limestone-marl periodites near Byala Town, Varna District; geosite "Kozya reka" in cyclic limestone near Asparoukhovo village, Varna District; geosite "Kozichino" in turbidite sequence near Kladorub village, Vidin district.

#### INTRODUCTION

During the recent 20 years the Cretaceous/Tertiary boundary has been examined in the light of the 'impact theory' (Alvarez et al., 1980), proclaiming a giant impact of Earth with a great meteorite (the Chicxulub Crater) 65 million years ago. It caused explosion exceeding 10 000 times all the present day nuclear weapon potential. As a consequence great quantity of ash material rose up into the atmosphere and covered the Earth for months.

The fallout after the impact produced thin layer, enriched in Ir and other rare elements, shocked quartz, microtektites, and rare minerals. This event is considered to be one of the major disasters in the Phanerozoic history of the Earth that caused catastrophic changes in the organic world. This level marks the final extinction of many typical Mesozoic animal groups like dinosaurs, marine reptiles, ammonites, belemnites, rudistid and inoceramid bivalves, actaeonellid gastropods. Deep taxonomic reduction underwent many other groups of molluscs, planktonic foraminifers, echinoids, corals, and primitive mammals. The change of atmospheric and water parameters caused disappearing of nearly 100% unicellular calcareous nannoplankton and 60% of angiosperm species.

This geological phenomenon of global scientific value has been established in several places on the territory of Bulgaria. Due to its unique character, some of them are proposed for protected geosites. Geoconservation assessment and protection measures are proposed in this study for five of the outcrops, described in different facial types and environments: geosite "Belite skali" in limestonemarl periodites near Byala town, Varna District; geosite "Kozya reka" in cyclic limestone near Asparoukhovo village, Varna District; geosite "Kozichino" in turbidite sequence near Kozichino village, Bourgas District; geosite "Kamenitsa" in limestone sequence near Mezdra town and geosite "Kladorub" in marl-silty sequence near Kladorub village, Vidin district.



Figure 1. Regional disposition of the geosites representing the K/T boundary in Bulgaria

#### **PREVIOUS WORKS**

Data about Maastrichtian-Danian deposits in Bulgaria was first reported during the first half of 20<sup>th</sup> century, but the boundary itself was not examined since the Danian Stage was considered part of the Cretaceous System. Later was proved that most of these sections contain significant hiatus including the uppermost Maastrichtian and lowermost Paleocene.

Purposeful investigation of the potential transitional sequences through the K/T boundary started during the latest 80s of the last century. Continuous sedimentary sequences through the K/T boundary in Bulgaria have been established

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in several facial types: limestone-marl periodites near Byala town, Varna District (Stoykova, Ivanov, 1992) and Lyutidol village, Vratsa District (Стойкова и др., 2000; Sinnyovsky, 2001b); turbidite deposits near Emona village, Burgas District (Sinnyovsky, Stoykova, 1995), Kozichino village and Aytos Pass (Sinnyovsky, Vangelov, 1997) and along Marash river S of Kotel town (Stoykova et al., 2000); cyclic limestone sequences near Moravitsa (Синьовски, 1998) and Mezdra town (Стойкова и др., 2000), Kozya river, Razkrachenitsa river and Wonderful Rocks (Вангелов, Синьовски, 2000; Sinnyovsky, 2001a); marl-siltstone sequence near Kladorub village, Vidin District (Sinnyovsky et al., 2002).



Figure 2. Section of limestone-"marl" periodites near Byala town, with actual thickness of the beds in scale 1:100 (after Preisinger et al., 1993ab and Sinnyovsky, 2001): In different parts of the section are represented cycles of different order: cycles between 32,20 and 48,20 m (mean thickness 0,8 m) are of average duration 28 ka and may be compared with the precessional 21 ka Milankovitch cycles (see Fig. 4); cycles between 3,7 and 10 m (mean thickness 0,315 m) correspond to 11 ka sub-Milankovitch cycles; cycles below K/T boundary from -8 to 0 m (mean thickness less than 1 m) are of duration 33,33 ka and probably correspond to the 41 ka Milankovitch cycles; 1 - robust limestone, 2 - clayey limestones ("marls" in field determination) and marls, 3 - K/T boundary iridium layer, 4 - meters from the K/T boundary (+ above; - below), 5 - correlation to the absolute time scale in million years, 6 - reversal magnetopolarity chron, 7 - normal magnetopolarity chron, 8 - zonal boundary based on calcareous nannoplankton



Figure 3. Iridium layer marking the K/T boundary near Byala town

Figure 4. Limestone-marl couplets (between 32,20 and 48,20 m) with periodicity ~0,8 m, corresponding probably to 21 ka Milankovitch cycles (scale line 30 cm)

Nevertheless, the boundary is proved geochemically only in the outcrops near Byala (Preisinger et al., 1993a,b), Moravitsa (Синьовски, 1998) and Коzya river (Вангелов, Синьовски, 2000; Sinnyovsky, 2001a).

Due to its unique character as geological phenomenon of global value, five of the K/T boundary outcrops are proposed for protected areas in the frame of the Project for Register and Cadastre of the geological phenomena in Bulgaria of the Ministry of Environment and Water. The present study is devoted to the geoconservation characteristics of these five outcrops (Fig. 1), nominated for geosites of scientific value.

## PROTECTED GEOSITES

#### Geosite "Belite skali"

This geosite is situated on the Black Sea coast and is now in procedure for protection. It is developed into the limestone-marl sequence of the Byala Formation (Джуранов, Пимпирев, 1989). The boundary layer near Byala town (Fig. 3) was found for the first time north of the entrance to the beach (Stoykova, Ivanov, 1992) in the frame of Bulgarian-Austrian project, led by Prof. Anton Preisinger. His team proved geochemically the iridium anomaly of 6 ppb at the boundary between the uppermost Cretaceous nannofossil zone Micula prinsii (the uppermost Paleogene NP 1 Biantholithus sparsus Zone (= Markalius inversus Zone) (Preisinger et al., 1993a,b). They established magnetostratigraphical subdivision of the boundary interval.

Later Preisinger (1996) recognized periodicity of about 100 cm in the Cretaceous part and 50 cm in the Paleocene part of the section. He presumed climatic change at the K/T boundary and correlated the cycles above with 20 ka Milankovitch cycles. However, the thickness of the couplets in different levels of the section shows most likely cycles of different order (Sinnyovsky, 2001a). The interval 32,20-48,20 m (Fig. 2) contains 20 well-expressed couplets of mean thickness 0,8 m with supposed duration 28 ka, corresponding approximately to the precessional 19-23 ka Milankovitch cycles (Fig. 4). The interval 3,7-10 m contains 20 cycles with mean thickness 0,315 m corresponding exactly to 11 ka sub-Milankovitch cycles.

Geosite Belite skali is a wonderful place on the Black Sea Coast. Its geoconservation characteristics, including stratigraphical cycles and events of global scientific value, combined with its tourist significance and easy access, make this place geosite of global significance.

Protection measures according to the protection ordinance may be resumed briefly as follows:

 conservation activities - scientific research; establishment of visitor centre, paths for access to the geosite and placement of information signboards; strengthening the cliff and the beech; • forbidden activities - any kind of building; geological prospecting and quarry excavation; alpine and deltaplane sports.



Figure 5. Section of the boundary interval between the Cretaceous and Paleogene along Kozya River: 1 – sandy limestone; 2 – limestone; 3 – limestone with chert; 4 – clayey-silty interbeds; 5 – Ir layer at the K/T boundary



Figure 6. The outcrop of the K/T boundary along Kozya River: the Ir layer between the boundary nannofossil zones Micula prinsii (uppermost Maastrichtian) and NP 1 Biantholithus sparsus (lowermost Paleocene) with 5 ppb Ir content

## Geosite "Kozya River"

The geosite is situated along Kozya River, S of Tsonevo dam and 4 km SE of Asparoukhovo village, Varna District. The iridium layer is localized on the basis of the great change in taxonomical composition of the calcareous nannoplankton.

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It is situated between two lithostratigraphical units – the Asparoukhovo Formation (Upper Maastrichtian) and the cyclic limestone sequence, which is related to the "Mezdra Formation" (Lower Paleocene).

The boundary layer is 5 cm dark-gray calcareous argillite with 5 ppb Ir content, composed of 35% CaCO<sub>3</sub> and 65% insoluble residue (Sinnyovsky, 2001a). It is very well expressed on the background of the more robust limestone below and above (Fig. 6). The stratigraphical interval below the K/T boundary is massive clayey-silty limestone with 63-80% CaCO<sub>3</sub> (Figs. 5,6). The nannofossil content is rather poor but along with common Upper Cretaceous forms are encountered typical for the Upper Maastrichtian nannofossils *Lithraphidites quadratus* Bramlette & Martini, *Micula murus* (Martini) and *Micula prinsii* Perch-Nielsen. The latter is the zonal marker of the uppermost Maastrichtian nannofossil zone Micula prinsii.

The nannofossil assemblage above the boundary is extremely poor, but it differs significantly from the Maastrichtian one. In the lowest 0.98 m only survivors are encountered belonging to the genera *Thoracosphaera* and *Braarudosphaera*, as well as small Paleocene forms of *Princiaceae* and *Coccolithus cavus* Hay & Mohler. *Cyclagelosphaera alta* Perch-Nielsen, *Cruciplacolithus primus* Perch-Nielsen and *Cruciplacolithus intermedius* van Heck & Prins are found in a relatively rich sample at +0,98 m. The latter is one of the zonal markers for the next Paleocene nannofossil zone NP 2 Cruciplacolithus tenuis.

The Danian interval is represented by typical bed-scale periodites. Totally 32 couplets with mean thickness 23,60 cm are investigated. The mean thickness of the limestone beds is 19,22 cm with 86-97% CaCO<sub>3</sub>. The mean thickness of the siliciclastic interbeds is 4,38 cm with 46-81% CaCO<sub>3</sub> (Sinnyovsky, 2001a).

The outcrop itself is a place of exceptional beauty. It is named "Skoka" and is located just next to Tsonevo dam, near a forestry house with a high debit karst water source. The access is by narrow, asphalt forest road, 17 km east of the geosite 'Chudnite skali' ('Wonderful rocks'). It is necessary to put signboard near the resthouse 'Chudnite skali' at the branch from the main road Shumen – Aytos.

The iridium layer is located in an outcrop on the left riverside, just after the bridge on the forest road. It needs marking and signboards with information about the geological event that caused formation of this layer and its scientific importance.

Proposed forbidden activities in the area are: quarrying and other activities that change the natural landscape and water regime; building around the geosite except strengthening the bridge; disturbing the rock outcrops.

The place is near the geosite 'Chudnite skali' and it could be included in the routs of organized groups from the Varna resorts. This makes the place a geosite of continental significance.

#### Geosite "Kozichino"

The section near Kozichino village is the only place in the country where the boundary layer is established in turbidite sequence (top of the Emine Formation). It is situated in the Eastern Balkan and is first described in this paper. This is about 4 cm thick layer (Fig. 7) overlying a hard ground resembling surface, similar to the outcrop near Byala (Fig. 3).

The boundary is localized biostratigraphically on the basis of nannofossils. So far the presence of iridium anomaly has not been proved geochemically.

Micula prinsii and NP 1 Biantholithus sparsus boundary zones are present with their characteristic elements. The change at the boundary is very clear, which is not typical for the turbidite sequences. It is probably due to the short hiatus marked by the presence of *Cyclagelosphaera alta* Perch-Nielsen in the lowermost Paleocene sample. This is one of the first Paleocene species, appearing slightly above the K/T boundary.



Figure 7. The boundary layer in the turbidites of the Emine Formation near Kozichino village (scale line 30 cm)

The outcrop is of rather large dimensions and the layer could be traced in several meters. The turbidites are finegrained, with rare sandstone beds. Granulometric analysis show that the boundary layer could be classified as silty marl: 47,35% CaCO<sub>3</sub>, 32,55% clay, 20,05\% silt and only 0,055 % psammite.

The close proximity of the geosite to the southern Black Sea resort Sunny Beach is a good prerequisite for popularization among the tourists. It could be included in the tourist route Slanchev Bryag - Kozichino for visiting the ostrich farm. This could be combined with visiting the other geological phenomena in the area – Cape Emine east of Sunny Beach and Dobrovan mushrooms, north of Prosenik village. For this purpose, signboards should be put with information about the geological development of the area and the Cretaceous/Tertiary boundary near Kozichino village and indicative signboards near the road through Dyulino Pass and Bourgas-Varna.

#### Geosite "Kamenitsa"

The Kamenitsa study interval is situated in the West Fore Balkan, SE of Moravitsa village. It is in a cyclic carbonate sequence of the Mezdra Formation. The K/T boundary in the outcrop south of Moravitsa village is 1-2 cm thin, dark colored, iridium enriched layer containing 7-11 ppb Ir (Синьовски, 1998). It is situated just below a welldeveloped major bedding plane, representing short hiatus (Fig. 8). The underlying soft interbed contains poor nannofossil assemblage with *Lithraphidites quadratus* Bramlette & Martini, and *Micula murus* (Martini). The uppermost Maastrichtian nannofossil marker *Micula prinsii* Perch-Nielsen has not been found in this assemblage. The interbed located 80 cm above the boundary contains one of the first Paleocene nannofossils *Cyclagelosphaera alta* Perch-Nielsen. The layer is not laterally traceable because of the diagenetic deformation of the interbed below the major bedding plane.



Figure 8. The boundary layer in the limestone sequence of the Mezdra Formation near Moravitsa village (scale line 30 cm)

Comparable results for the mineralogical content of the boundary layers near Byala and Moravitsa are published by Костов и Цанкарска (2000).

Along with the K/T boundary layer, Geosite Kamenitsa represents many stratigraphical cycles and events of scientific value and is classified as geosite of global significance. This place does not need any special protective measurements because the outcrops are of erosion-resistant robust limestones. The only necessary protective activities are to put signboards along the international road E-79 near Mezdra, Vratza and Moravitsa and information signboard in the place with data on the geological history of the region and the geological event, responsible for this layer, and its scientific importance.

## Geosite"Kladorub"

This geosite is situated near Kladorub village in the West Fore Balkan in sedimentary rocks belonging to the Kladorub Formation, known as "Sinaya" or "Karpathian type Cretaceous". It was described by Sinnyovsky et al. (2002). Three nannofossil zones are present in the investigated boundary interval – the top of the uppermost Maastrichtian Micula prinsii Zone, the lowermost Paleocene NP 1 Biantholithus sparsus Zone and NP 2 Cruciplacolithus tenuis Zone (Fig. 10). The presence of the two boundary zones allowed finding dark, up to 4 cm thick layer, marking sharp change in the calcareous nannoplankton assemblages (Fig. 9).



Figure 9. The K/T boundary layer in the marl-siltstone sequence of the Kladorub Formation, 2 km SE of Kladorub village, along Ciganskiya dol (Photo after Boris Valchev)

The samples below this layer contain rich nannofossil association represented by more than 50 Cretaceous species, including the Upper Maastrichtian markers *Lithraphidites quadratus* Bramlette & Martini, *Nephrolithus frequens* Gorka, *Micula murus* (Martini) and *Micula prinsii* (Perch-Nielsen).





The composition of the Paleocene nannofossil association is entirely different. The taxonomical diversity in the first samples +5 and +10 cm above the boundary is drastically reduced and represented by survivors *Braarudosphaera bigelowi* Gran & Braarud and *Thoracosphaera operculata* Bramlette & Sullivan.

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The new Paleocene species Biantholithus sparsus (Bramlette & Martini) appears immediately above the boundary layer between +5 and +10 cm. Thus, the lower boundary of NP 1 Biantholithus sparsus is marked by both disappearance of the Cretaceous species and appearance of the zonal marker. Cyclagelosphaera alta Perch\_Nielsen is another Paleocene species appearing in this interval. The first specimen was found at +0.75 m. The thickness of the NP 1 Biantholithus sparsus Zone is 2.40 m (Fig. 10). The first appearance of Cruciplacolithus intermedius (van Heck & Prins) marks the lower boundary of the NP 2 Cruciplacolithus tenuis Zone. The lower level of the zone is characterized by the presence of another cruciplacoliths Cruciplacolithus primus Perch Nielsen, appearing just below the zonal Cruciplacolithus tenuis boundary, (Stradner), Cruciplacolithus asymmetricus (van Heck & Prins) and Coccolithus cavus Hay & Mohler.

This geosite is difficultly accessible even on foot, so it is necessary to cut path or dirt road with suitable markers of the route. At the crossroad to Rabisha village and Magurata Cave in the center of Kladorub village indicative signboard have to be placed with data about the distance and location of the geosite. Such signboards have to be placed also on the highway E-79 near the cross road to Kladorub in Dimovo Town. The outcrop itself needs marking by resistant markers and putting signboard with information of the event, responsible for the layer formation and its scientific significance.

The place is far from the large towns in the district, but it could be popularized along with the other famous geological phenomena in the region - Belogradchik rocks and Magurata Cave. In close proximity to the geosite is situated another interesting geological phenomenon of aesthetic and scientific value – "Chuturite" ("The Mortars"). It is easy accessible from Gramada village and represents "stone forest".

## CONCLUSION

Although representing the same event, the proposed geosites are of different geoconservation value, mainly because of their different tourist and educational value and different degree of study. "Belite skali" and "Kamenitsa" are estimated as geosites of global significance because they represent complex geological events rather than K/T boundary only, and have higher degree of study.

The visitor centre in Byala and its position on the Black Sea coast are major premises for high attendance of the place.

The museum in the field campus of the University of Mining and Geology in Ljutibrod village contains all types of rocks that crop out along Kamenitsa River. It is visited every year by tens of students and is of high educational value. As part of the future geopark "Iskar Gorge", this place is very convenient for international practices and workshops. The most interesting geological routes are described in a geological guide in English and Bulgarian including the other geological phenomena in this part of the Iskar Gorge – the rock dolls and "Kamarata" near the villages Kameno pole and Reselets, "Strupanitsa" and "Provartenika" near Karlukovo village, Lakatnik rocks, the rock bridges near Lilyache village, "Ritlite" in Ljutibrod village, Cherepish rocks and Vratsa karst field with Ledenika Cave and "Vratzata" near Vratsa town.

The other outcrops – Kozya River, Kozichino and Kladorub are of continental and regional significance, because of their difficult access and low degree of study.

In making comparative assessment of a type of phenomenon to identify the best example, it is generally appropriate to identify more than a single example. The identification of multiple examples of a class of geological phenomena is known as "replication". This approach is important because a single example could easily become degraded.

The proposed geosites are national treasure, because of the rare exposures of the K/T boundary in global scale. They could be used for popularisation not only of this phenomenon of global significance, but also of the other geological phenomena of Bulgaria.

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