

NANNOFOSSIL SUBDIVISION AND STRATIGRAPHIC RANGE OF THE EMINE FLYSCH FORMATION IN EAST BALKAN, EAST BULGARIA

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ABSTRACT. The Campanian-Paleocene turbidite sequence known as Emine Flysch Formation is widely exposed in the East Balkan, East Bulgaria. Its boundaries and different stratigraphic levels have been described in many outcrops, but complete sequence of the unit is still not established due to great thickness and folded zones in different levels of the unit. A nannofossil zonation was applied here in order to estimate more precise stratigraphic range and total thickness of the unit. The Cretaceous part of the section includes 6 nannofossil zones, from older to younger: *Uniplanarius gothicus*, *Uniplanarius trifidus*, *Arkhangelskiella cymbiformis*, *Lithraphidites quadratus*, *Micula murus* and *Micula prinsii*. The Paleocene interval is subdivided into standard zones, well exposed along the Black Sea coast in the northern limb of the Banya syncline. Here are established 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 zones below and above the K/T boundary are described better than the others, due to their relatively short stratigraphic range, established in a singular section. In this study the nannofossil events are used as stratigraphic markers to choose appropriate outcrops, comprising full zonal intervals of at least one zone, in order to reconstruct a more complete composite section of the Emine Formation. On the basis of this reconstruction, the maximum thickness of the unit in its thickest near-shore part is calculated to be at least 1670 metres. Its stratigraphic range decreases to the west due to lateral transition into the coarse-grained deposits of Dvojnitza Formation. The thinnest part of the unit is near Kozichino Village, where its stratigraphic range is restricted to Upper Campanian - Maastrichtian.

НАНОФОСИЛНА ПОДЯЛБА И СТРАТИГРАФСКИ ОБХВАТ НА ЕМИНСКАТА ФЛИШКА СВИТА В ИЗТОЧНИЯ БАЛКАН, ИЗТОЧНА БЪЛГАРИЯ

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РЕЗЮМЕ. Кампан-палеоценската турбидитна последователност известна като Еминска флишка свита се разкрива широко в Източния Балкан, Източна България. Нейните граници и различни стратиграфски нива от нея са описани в много разкрития, но пълен разрез на единицата все още не е установен, поради голямата ѝ дебелина и гънковите зони в различни нейни нива. Предложеното тук нанофосилно зонироване е с цел да се оцени по-точно стратиграфският обхват на единицата и максималната ѝ дебелина. Кредната част от разреза включва 6 нанофосилни зони, отдолу нагоре: *Uniplanarius gothicus*, *Uniplanarius trifidus*, *Arkhangelskiella cymbiformis*, *Lithraphidites quadratus*, *Micula murus* и *Micula prinsii*. Палеоценският интервал е поделен на стандартните зони, разкрити добре по крайбрежието в северното бедро на Банянската синклинала. Тук са установени 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*. Зоните около границата К/Т са описани по-добре от другите, поради относително по-малкия им стратиграфски обем и установяването им в един разрез. В настоящото изследване нанофосилните събития са използвани като стратиграфски репери за установяване на подходящи разкрития, включващи пълни зонални интервали на поне една зона за да се реконструира пълен обобщен разрез на Еминската свита. Въз основа на това максималната дебелина на единицата бе изчислена на поне 1670 метра. Нейният стратиграфски обем намалява на запад поради латералния преход в грубозърнестите отложения на Двойнишката свита. Единицата е най-тънка при с. Козичино, където стратиграфският ѝ обхват е Горен Кампан - Мاستрихт.

Introduction

The Emine Flysch Formation is a thick turbidite sequence, widespread in the East Balkan Zone. It has been studied by many authors starting from Гочев (1932), who gave the unit its name - 'Emine beds'. One of the most comprehensive works devoted to the composition, genesis and age of the unit is that of Бошев et al. (1967). Later Караюлева & Костадинов (1977) called it "flysch formation". Its rank was determined by Джуранов & Пимпирев (1989). The unit is composed of regularly alternating thin to medium-bedded sandstones, siltstones, shales, marls and limestones forming classic turbidites. The thickness of the turbidite rhythms is 5-30 cm, with rare thicker beds up to 0.5-1 m, mainly in the Campanian part of the unit, giving it cyclic appearance. Characteristic structures are graded and convolute bedding, scour marks and

groove marks. Turbidite beds of sandy limestones more than 1 m thick are rarely encountered.

The lower boundary of the unit is a gradual transition from the volcanic rocks of the Draganovo Formation. It crops out near Tunkovo Village (Петрова et al., 1980). The lowest level belongs to the Upper Campanian (Синьовски & Синьовска, 1988; Sinnyovsky & Sultanov, 1994). The upper boundary is a fast lithological transition toward the rocks of Dvojnitza Formation. Wide lateral transitions are observed between the two units covering the entire Paleocene interval from the K/T boundary near Kozichino Village (Sinnyovsky, 2003) to the uppermost Paleocene near Irakli Resort at the Black Sea (Sinnyovsky & Sultanov, 1994; Синьовски, 1996). Campanian-Paleocene range of the Emine Formation has been reported by most authors (Бошев et al., 1967; Караюлева & Костадинов, 1977; Джуранов & Пимпирев, 1989; Nachev & Dimitrova, 1995).

Sinnyovsky & Sultanov (1994) gave a more precise stratigraphic range from the Upper Campanian to the Upper Paleocene with indications of several nannofossil zones.



Fig. 1. Outcrop of the Upper Campanian part of the Emine Formation, showing cyclic repetition of thick turbidite beds at the boundary between the nannofossil zones *Uniplanarius gothicus* and *Uniplanarius trifidus* on the eastern slope of Cape Emine

Present results

The present study is devoted to the nannofossil zonation of the Emine Formation in its near-shore outcrops between Emine and Kochan Capes. First exact data about the thickness of the unit is presented, based on successive description of 15 nannofossil zones from Upper Campanian to Upper Paleocene, from lower to upper: *Uniplanarius gothicus*, *Uniplanarius trifidus*, *Arkhangelskiella cymbiformis*, *Lithraphidites quadratus*, *Micula murus*, *Micula prinsii*, 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 Upper Cretaceous zones are established in different outcrops on the basis of characteristic nannofossil events, most of which are globally recognized as zonal boundaries. The Paleocene zones are recognized in one continuous section between Kochan cape and Irakli. Further information about their geographic distribution in Bulgaria is given in Sinnyovsky (this volume).

Upper Cretaceous

The Upper Cretaceous part of the unit is exposed mainly in the northern and southern limb of the Banya syncline. The most representative outcrops are located around Cape Emine and Emona Village (Figs. 1,2). Here are established several sections of uninterrupted and unfolded sequences, comprising six Upper Campanian-Maastrichtian nannofossil zones.

Uniplanarius gothicus Zone

Author: Martini (1976).

Definition: Interval from the first occurrence of *Uniplanarius gothicus* (Deflandre) Hattner & Wise to the first occurrence of *Uniplanarius trifidus* (Stradner) Hattner & Wise.

Age: Early Late Campanian.

Remarks: Martini (1976) defined the zone in the Pacific as a middle Campanian interval. Verbeek (1977) gave it a very restricted range confirmed by Stradner (1984) in site 530 in the Angola Basin, Atlantic Ocean. Late Campanian age of the zone was reported by Hattner & Wise (1980), Cepek (1981) and other authors.

Boundaries: The lower level of the zone is exposed north of Tunkovo Village (Sinnyovsky & Sultanov, 1994), but its lower boundary falls into the underlying volcanic-sedimentary deposits. In this study the upper part of the zone is established around Cape Emine.

Thickness: The zone includes more than 100 m of the section along the southern beach of Cape Emine.

Uniplanarius trifidus Zone

Authors: Bukry & Bramlette (1970).

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

Age: Late Campanian.

Remarks: This zone was originally defined as a Late Campanian - Early Maastrichtian interval: 'The range of *Tetralithus nitidus trifidus* defines the transitional zone between Maastrichtian and Campanian' (Bukry & Bramlette, 1970). Emendation of the Campanian-Maastrichtian boundary by Rawson et al. (1996) made the disappearance of both *Uniplanarius trifidus* (Stradner) Hattner & Wise and *Broinsonia parca* (Stradner) Bukry ssp. *constricta* Hattner et al. useful for definition of the Campanian-Maastrichtian boundary in sections with low sedimentation rate, where these datums are approximately synchronous. However, the disappearance of *B. parca constricta* in this section is 50 m above the disappearance of *U. trifidus*.

Boundaries: The reference section of the zone in Emine Formation is along the beach north of Cape Emine. The lower boundary is established 50 m north of the cape (Fig. 1). It is marked by three thick turbidite beds, traceable in the outcrops west of the cape. The upper boundary is among thin-rhythmic turbidites 500 m north of the cape.

Thickness: The zone includes 450 m of the section, perfectly exposed along the beach north of Cape Emine.

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. The most abundant species in this 'low diversity interval' is *Arkhangelskiella cymbiformis* Vekshina. In the zone disappear *Broinsonia parca constricta* Hattner et al. and *Reinhardtites levis* Prins & Sissingh.

Remarks: All previous authors referred the zone to the Lower Maastrichtian or lower Middle Maastrichtian when triple division is used.

Boundaries: Its lower boundary is recognized north of Cape Emine and immediately NW of Emona Village. The upper boundary crops out along the cliff east of 'St. Nikola' chapel, where the reference section of the zone is established.

Thickness: 160 m.

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.

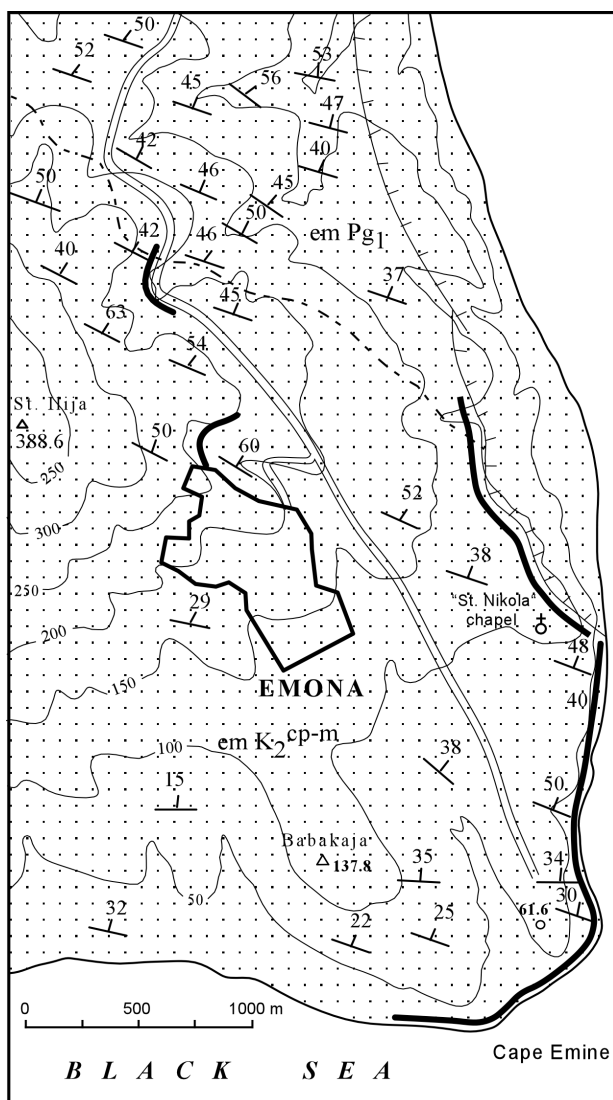


Fig. 2. Situation map in scale 1:25000 of the investigated outcrops in the southern limb of Banya syncline near Emona Village and Cape Emina (see explanation of Fig. 3)

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. Bukry & Bramlette (1970) emended the upper boundary after the first occurrence of *Micula murus* (Martini) Bukry.

Boundaries: Indications of the zone in the Emina Formation are recognized by the author during the geological mapping in the East Balkan area from 1993 to 1996 near Kozichino, Gilyovtsi, Kosharitsa, Rakovskovo, St. Vlas, Banya and Emona Villages.

Thickness: Between 35 and 45 m north of 'St. Nikola' chapel.

***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, *Prediscosphaera grandis* Perch-Nielsen, etc.

Remarks: This zone was initially considered to be the uppermost Cretaceous zone, according to the 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 (1979) defined the new species *Micula prinsii*, including in it the forms of *Micula murus* (Martini) "with distinct, long and sometimes bifurcated arms". Later 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 for emendation of the *Micula murus* Zone of Martini (1969) and original definition of *Micula prinsii* Zone by the total range of *Micula prinsii* Perch-Nielsen.

Boundaries: The boundaries of the zone are established along the road Emona – Irakli. Indications of the zone in the Emina Formation are recognized by the author during geological mapping of a part of the East Balkan in 1993-96 near Kozichino, Kosharitsa, Rakovskovo, Banya and Emona Villages.

Thickness: The thickness of the zone north of Cape Emina above the upper edge of the near-shore landslides, north of 'St. Nikola' chapel, is approximately 35 m.

***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). Definition of the lower boundary zone was discussed above.

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.

Boundaries: The boundaries of the zone are established 2 km north of Emona Village along the road Emona–Irakli. Indications of the zone in the Emina Formation are recognized by the author during the geological mapping in the East Balkan area from 1993 to 1996 south and north of Kozichino (Lekarnitsa River), Rakovskovo, Banya and Emona Villages, as well as Kochan Cape, north of Irakli.

Thickness: Thickness of 27 m is established in the K/T boundary section described by Sinnyovsky & Stoykova (1995), and 30 m in the K/T boundary section north of Cape Kochan (this study).

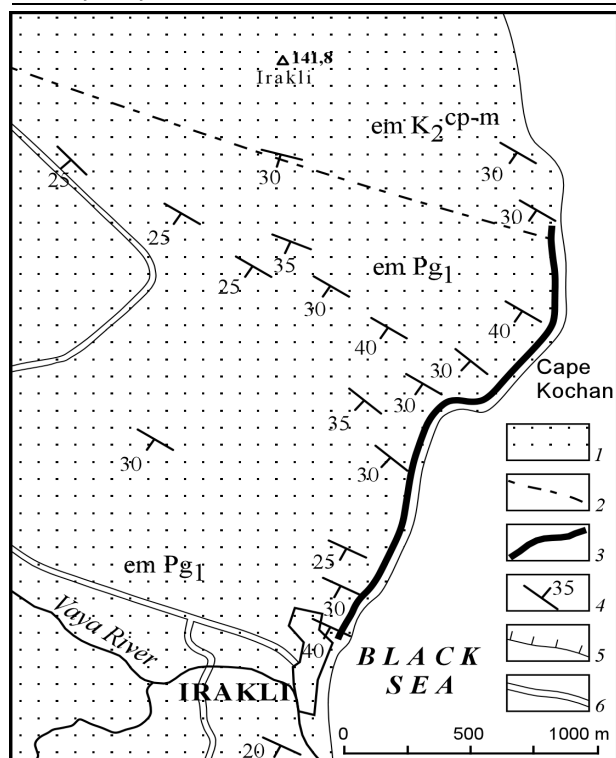


Fig. 3. Situation map in scale 1:25000 of the investigated outcrops in the northern limb of Banya syncline near Irakli Resort: 1 – Emine Formation; 2 – K/T boundary; 3 - studied outcrop; 4 – dip and strike; 5 – landslides; 6 – road

Cretaceous/Tertiary boundary

The Cretaceous/Tertiary boundary in the near-shore outcrops of Emine Formation was described by Sinnyovsky & Stoykova (1995) near Emona Village, Sinnyovsky (2003) near Kozichino Village and Stoykova & Ivanov (2004) near Marash River. In the section near Emona the boundary layer was not recognized, but in sample E 58-9 disappear most Cretaceous taxa and appears the marker species of the lowest Paleocene NP 1 Zone *Biantholithus sparsus* Bramlette & Martini, as well as *Cyclagelosphaera alta* Perch-Nielsen. The most common survivors encountered are *Braarudosphaera bigelowi* Gran & Braarud and *Thoracosphaera operculata* Bramlette & Sullivan. *Cyclagelosphaera reinhardtii* (Perch-Nielsen) Romein, *Markalius inversus* (Deflandre) and *Neocrepidolithus dirimosus* Perch-Nielsen are also relatively frequently encountered. Reworked specimens of the most abundant Cretaceous taxa *Micula decussata* (Vekshina), *Micula murus* (Martini), *Watznaueria barnesae* (Black), *Arkhangelskiella cymbiformis* (Vekshina), *Nephrolithus frequens* Gorka are also present. In the section south of Kozichino Village was observed a 4 cm dark boundary layer, marking the disappearance of most Cretaceous taxa and the appearance of *Biantholithus sparsus* Bramlette & Martini and *Cyclagelosphaera alta* Perch-Nielsen. K/T boundary is 8 m below the boundary between Emine and Dvoynitsa Formations. In the present study 5 cm thick, black K/T boundary layer is established 5 m above the sea level north of Cape Kochan with geographic coordinates N 42°46,179' and S 27°54,013' (Figs. 3,4).



Fig. 4. K/T boundary layer in fine-grained (mud) turbidites of the Emine Formation north of Cape Kochan (between arrows)

Paleocene

The studied Paleocene outcrops in the southern limb of Banya syncline are located 2 km north of Emona Village along the road to Irakli (Fig. 2) and in the northern limb of Banya syncline between Irakli and Cape Kochan (Fig. 3).

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 *Cruciaplacolithus tenuis* (Stradner) Hay & Mohler, (respectively *Cruciaplacolithus intermedius* van Heck & Prins).

Age: Earliest Paleocene.

Common taxa: *Biantholithus sparsus* Bramlette & Martini, *Cyclagelosphaera alta* Perch-Nielsen, *Braarudosphaera bigelowi* (Gran & Braarud) Deflandre, *Thoracosphaera operculata* Bramlette & Sullivan, *Cyclagelosphaera reinhardtii* (Perch-Nielsen) Romein, *Markalius inversus* (Deflandre) Bramlette & Martini, *Neocrepidolithus dirimosus* Perch-Nielsen. In the upper part of the zone appears *Cruciaplacolithus primus* Perch-Nielsen.

Remarks: This zone spans the base of the Paleocene. It is very thin and could be recognized only in continuous sequences through the K/T boundary. In the studied area it was described by Sinnyovsky & Stoykova (1995) 2 km north of Emona Village along the road to Irakli, and north of Cape Kochan (this study).

Thickness: The thickness of the zone in the section north of Emona Village is 12 m (Sinnyovsky & Stoykova, 1995). North of Cape Kochan crops out only the lowest 2 metres of the zone.

NP 2 *Cruciaplacolithus tenuis* Zone

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

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

Age: Lower Paleocene (Early Danian).

Common taxa: *Cruciplacolithus tenuis* (Stradner), *Cruciplacolithus intermedius* van Heck & Prins, *Cruciplacolithus asymmetricus* van Heck & Prins, *Cruciplacolithus primus* Perch-Nielsen, *Coccolithus cavus* Hay & Mohler, *Ericsonia subpertusa* Hay & Mohler.

Remarks: This zone was originally defined by the first occurrence of *Cruciplacolithus tenuis* (Stradner) Hay & Mohler. In 1987 van Heck & Prins 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. In the present study the zone is recognized north of Cape Kochan.

Thickness: 88 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).

Common taxa: *Neochiastozygus modestus* Perch-Nielsen appears in the lower part of the zone. Common taxa are the representatives of the genus *Cruciplacolithus*, and also *Coccolithus cavus* Hay & Mohler, *Braarudosphaera discula* Bramlette & Riedel, *Ericsonia subpertusa* Hay & Mohler. *Neochiastozygus modestus* Perch-Nielsen occurs in the lower part of the zone and *Neochiastozygus perfectus* Perch-Nielsen appears in the upper level. In the present study the zone is established near Cape Kochan.

Thickness: 60 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 occurrence of the marker species is 160 m above the K/T boundary. At this level the first representatives of *Neochiastozygus perfectus* Perch-Nielsen and *Ellipsolithus lajollaensis* Bukry & Percival are seen. Perch-Nielsen (1985) noted that in poorly preserved assemblages this species is missing. The first fasciculiths and *Sphenolithus moriformis* Perch-Nielsen occur in the upper part of the zone. It is established south of Cape Kochan.

Thickness: 155 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 *Fasciculithus ulii* Perch-Nielsen and *Fasciculithus janii* Perch-Nielsen is in the upper part of the former zone. The lower boundary is established 310 m above the K/T boundary by the first appearance of *Fasciculithus tympaniformis* Hay & Mohler. In the same sample appears *Toweius pertusus* Sullivan and *Toweius eminens* (Bramlette & Sullivan) 50 m higher.

Thickness: 125 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.

Common taxa: *Heliolithus kleinpellii* Sullivan, *Fasciculithus tympaniformis* Hay & Mohler, *Toweius eminens* (Bramlette & Sullivan), etc. *Fasciculithus clinatus* Bukry appears first in this zone.

Remarks: The upper zonal boundary defined by the first appearance of *Discoaster mohleri* Bukry & Percival is not established, because this marker species is missing.

Thickness: The total thickness of NP 6/NP 7 Zones is 180 m.

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: *Heliolithus kleinpellii* Sullivan, *Fasciculithus clinatus* Bukry, etc.

Remarks: The lower zonal boundary was discussed above. The upper boundary is placed by the first occurrence of *Heliolithus riedeli* Bramlette & Sullivan 620 m above the K/T boundary.

Thickness: The total thickness of NP 6/NP 7 Zones is 180 m.

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), *Coccolithus cavus* Hay & Mohler, *Fasciculithus tympaniformis* Hay & Mohler, *Fasciculithus clinatus* Bukry, *Bomololithus elegans* Roth, *Toweius eminens* (Bramlette & Sullivan), etc. 690 m above the K/T boundary is established co-occurrence of *Heliolithus riedeli* Bramlette & Sullivan, *Fasciculithus thomasi* Perch-Nielsen, *Fasciculithus tonii* Perch-Nielsen and *Fasciculithus richardii* Perch-Nielsen.

Thickness: 95 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 bolli* Perch-Nielsen, *Ellipsolithus distichus* Bramlette & Sullivan, *Coccolithus cavus* Hay & Mohler, *Fasciculithus tympaniformis* Hay & Mohler, *Fasciculithus thomasi* Perch-Nielsen, *Fasciculithus tonii* Perch-Nielsen, etc.

In the middle of the zone representatives of the genus *Pontosphaera* Lohmann first appear.

Thickness: The thickness is more than 150 m. The highest levels of the zone are in the core of the Banya syncline north of the entrance to the beach of Irakli.

Conclusion

This is the first detailed zonation of the continuous sequence of the Emine Formation, established on the basis of calcareous nannofossils. The investigated sections provide a good possibility to measure the real thickness of the unit in its thickest near-shore part. On the basis of present biostratigraphic results, the Cretaceous part of the unit is at least 820 m. It certainly exceeds this thickness since the lowermost zone is not entirely exposed in the investigated area. The upper part of the unit, investigated in a continuous section between Irakli Resort and Cape Kochan, provides even more reliable calculation for the Paleocene levels – the total thickness of the zones is 850 m, but the real thickness of the Paleocene is more than 850 m because of the incompleteness of the uppermost NP 9 Zone. Thus the total thickness of the Emine Formation should be at least 1670 m. The illusion for greater thickness is due to the folded zones in the unit. New outcrop of the Cretaceous/Tertiary boundary layer is established north of Cape Kochan, at the top of a complete section of Micula prinsii Zone.

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