Kuwait J. Sci. **47 (4)** pp. 92-105, 2020

تحليل بيواستراتجرافي لحدود K/Pg باستخدام حفرية نانو كلسية (جيرية) من منطقة السليمانية، إقليم كردستان، العراق

[1]باسم أ. القيم، [1]سوران أو. أ. خهراجياني، [2]شيروود دبليو. وايز

[1]جامعة السليمانية، كلية العلوم- قسم الجيولوجيا، كردستان، العراق

[2]جامعة فلوريدا، فلوريدا، الولايات المتحدة الأمريكية

الملخص

يشير البحث إلى أن الحدود الباليوجينية/ الطباشيرية في إقليم كردستان في العراق بوجه عام هي موضع خلاف، بيد أن دراسة الحدود عند محليات كلبهزة Qalbza ودارتو Dartw في منطقة السليمانية بإقليم كردستان، تُظهر نتائج متباينة فيما يتعلق بالاستراتجرافية الحيوية عند منطقة الحدود. تُركز الدراسة الحالية على مجموعات حفريات النانو الكلسية والاستراتجرافية الحيوية عبر حدود K/Pg في منطقة السليمانية بكردستان. تتسم الطبقات الصخرية في منطقة الدراسة بترددات طبقات الطفل العضوي، والحجر الغريني، حجر رملي دقيق الحبيبات، وحصى الجَراوِل، الحجر الجيري العضوي داخل تكوين تانجرو Tanjero (Maastrichtian المتأخر) ومايعلوه من تكوين كولوش Kolosh (البالوسينَ- الأيوسين الباكر). تم تخطيط الحدود من الناحية البيوستراتجرافية عن طريق البروزات الأولى *Cruciplacolithus* spp.، *Biantholithus sparsus* و *Coccolithus pelagicus*. ويشير البحث إلى أن هناك علامة بيواستراتجرافية إضافية مهمة وهي ذروة *Thoracosphaera operculata* للمنطقة الحيوية *NP1* فوق المنطقة الحيوية *CC26* والتي تتكون بشكل عام من *Micula Prinsii*، *Micula murus* و *Lithraphidites*. يوضح التحليل البيواستراتجرافي عدم وجود فجوات بالرغم من أنه يظهر تصنيف طباشيري طرأ عليه تغيير وتم تسجيله فوق حدود K/Pg داخل مناطق NP2 و NP1

Biostratigraphic analysis of the K/Pg boundary using calcareous nannofossils from the Sulaimani Area, Kurdistan Region, Iraq

Basim A. Al-Qayim[1,*], Soran O. A. Kharajiany[1], Sherwood W. Wise, Jr.[2]

[1]Dept. of Geology,College of Science, University of Sulaimani, Kurdistan, Iraq

[2]Florida State University, Tallahassee, Florida 32306-4100, USA

[*]Corresponding author: soran.muhammad@univsul.edu.iq

Abstract

The Cretaceous/Paleogene boundary in the Kurdistan region of Iraq in general is still debatable; however, examination of the boundary at the Qalbaza and Dartw localities in the Sulaimani area of the Kurdistan Region shows different results regarding the biostratigraphy of the boundary zone. In the current study, the calcareous nannofossil assemblages and biostratigraphy across the K/Pg boundary in the Sulaimani area of Kurdistan were focused on. The rock strata in the study sections are characterized by alternations of organic shale, siltstone, fine-grained sandstone, gravel and organic limestone interlayers within the Tanjero Formation (Late Maastrichtian) and the overlying Kolosh Formation (Paleocene-early Eocene). The boundary is biostratigraphically delineated by the first occurrences of *Biantholithus sparsus, Cruciplacolithus* spp. and *Coccolithus pelagicus*. An additional important biostratigraphic marker is plus an acme of *Thoracosphaera operculata* of biozone NP1 above biozone CC26 which generally consisted of *Micula murus, Micula Prinsii* and *Lithraphidites quadratus*. This biostratigraphic analysis indicates no hiatus, although it shows that reworked Cretaceous taxa are recorded above the K/Pg boundary within zones NP1 and NP2.

Keywords: Tanjero; Kolosh; K/Pg boundary; *Biantholithus sparsus*; Sulaimani; Kurdistan of Iraq.

1. Introduction

The Cretaceous/Paleogene boundary (K/Pg) in northeast Iraq has been studied by many authors using planktonic foraminifera, e.g., Kassab 1974, Abdel- Kareem (1986), Al-Shaibani *et al.*, (1986) and Sharbazheri (2009). Most of these studies concluded that this boundary is unconformable and in many cases missing the Danian deposits, except the section of the Kalaka Smaq locality near Shaqlawa, which shows a conformable sequence (Sharbazheri, 2007). The current study examines the stratigraphic sequence across this boundary at two localities, using calcareous nannofossils. This globally important boundary is characterized in the study area by a sequence of flysch sediments of the foreland basin of the Northeast Arabian Plate margin. The flysch sequence includes the Maastrichtian Tanjero Formation and the overlying Paleogene Kolosh Formation (Al-Qayim *et al.*, 2012).

The Qalbaza and Dartw sections are selected as a case study to re-evaluate the age of the boundary sequence. The Qalbaza section is 110 meters thick and lies inside the village of Qalbaza, about 700 meters from the western bank of the Sirwan River and 15 kilometers southwest of the city of Halabja (Figure 1). The section is the closest to the type section of the Tanjero Formation in Sirwan Valley, which was studied by Bellen *et al.* (1959) at the intersection of coordinates 35°15’51”N and 45°48’43”E. The section is eroded by a small water spring above the village, which exposes fresh outcrops of the succession. The Dartw section extends to the south of Dartw Village at the foot of the Piramagroon Mountain Series, and northwest of the town of Tasluja. The section lays out parallel to the Sulaimani-Tasluja highway at the intersection of coordinates 35°38’50”N and 45°16’15”E (Figure 1). The purpose of the study is to investigate the biostratigraphy of the K/Pg boundary in the Sulaimani area of the Kurdistan Region/ Iraq using calcareous nannofossils.

2. Geologic Setting

The study area is located within the High Folded Zone of the Zagros orogenic belt, which is characterized by numerous folds and faults with major trending northwest-southeast. The folds of this zone are linear, curvilinear, asymmetrical, doubly-plunging, high-amplitude, and arranged in an en-echelon pattern on the surface (Buday and Jassim, 1987). To the northeast of this belt, the Zagros Imbricate and Suture Zones have too complicated geology. To the southwest of the High Folded Zone, folds become low in elevation with broader synclines characterizing the Low Folded Zone (Jassim and Goff, 2006).

The study area represents the foredeep part of the Zagros foreland basin, which was filled by thick flysch, pelagic marlstone succession of the passive Arabian margin (Al-Qayim *et al.*, 2012). The K/Pg boundary in this area is recognized between the flysch succession of the Tanjero Formation (Maastrichtian) and the Kolosh Formation (Paleogene). Bellen *et al.* (1959) first describe the Tanjero Formation from the type section in the Sirwan Valley. It comprises two divisions. The lower division is pelagic marl with occasional beds of argillaceous limestone and siltstone beds in its upper part. The upper division includes silty marls with sandstones, conglomerate horizons and occasional sandy or silty organic limestones.

Shiranish Formation Underlay underlies the Tanjero Formation with a gradational and conformable contact. The overlying sequence of the Tanjero Formation is the Kolosh Formation. The Kolosh Formation was deposited in a deep marine trough with flysch sediment type (Buday, 1980). The Formation was first described by Bellen *et al.* (1959) at the village of Krozh, to the north of Koya town (northwest of the city of Sulaimani). It basically consists of cyclic alternating of shale and sandstones. In the Sirwan Valley, Bellen *et al.* (1959) found that the Kolosh Formation unconformably overlies the Tanjero Formation.

3. Material and Method

Field studies were conducted to examine, measure, and sample both sections. Eighty samples were collected and all yielded calcareous nannofossils. Standard smear slides were prepared to study the calcareous nannofossils. The nannofossil identification is accomplished using a cross-polarized light microscope at magnifications of 400X, and biostratigraphic zonation charts were prepared using standard range overlapping format. The zonation schemes for calcareous nannofossils used here are following Martini (1971), Okada and Bukry (1980) for the Danian, and Sissingh (1977) in Perch-Nielsen 1985a) for the Maastrichtian.

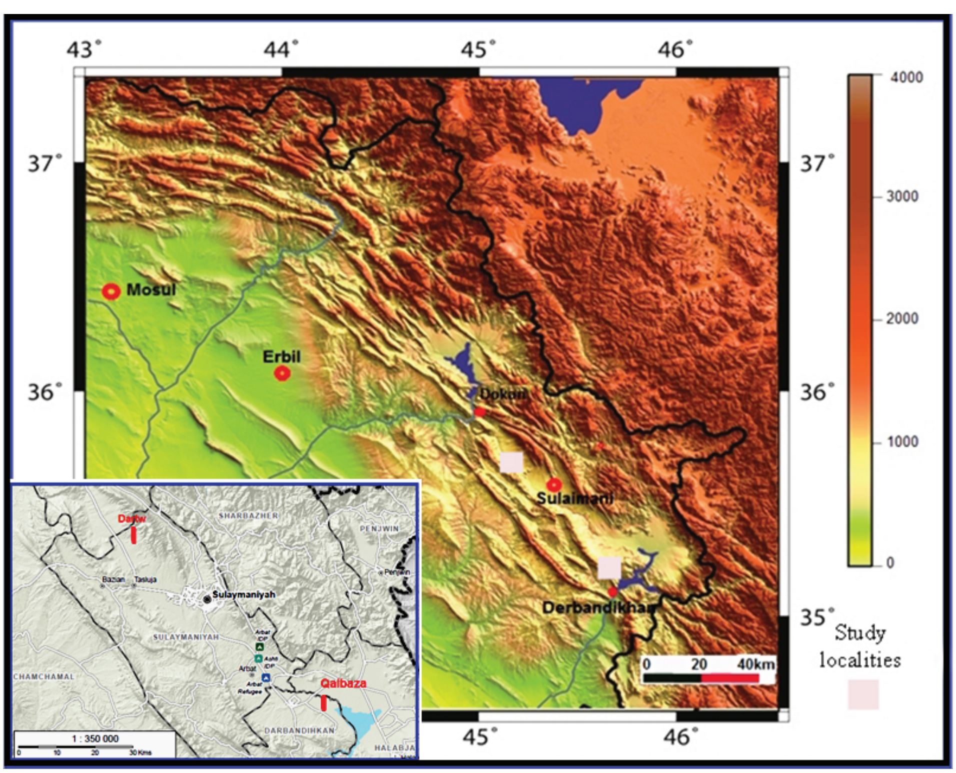


Fig. 1. Relief map of northeast Iraq/ Kurdistan shows the geographic location of the studied sections.

4. Results

4.1. Lithostratigraphy

A. Qalbaza locality

The stratigraphic units of the K\Pg boundary section at the Qalbaza locality is represented by the upper part of the Tanjero and the lower part of the Kolosh Formations which range from Maastrichtian to early Paleocene in age. The examined section is about 330 meters thick and strata gently dip at about 40-45^{o} towards southwest. The lithology of the succession consists of cyclic alternation of clastic sediments of mudstone, sandstone, siltstone and conglomerate. It can be divided into three units (A, B & C). The lower part of the section (Unit A) consists of 112 meters of cyclic alternations of olive to dark- green sandstone, siltstone, silty marlstone, organic shale and marlstone. These beds are overlain by yellow limonitic marlstone. At the top of the limonitic bed, there is a 0.5-meter dark brownish intraformational conglomerate bed. It is overlain by 30 centimeters of dark-grey pebbly bituminous sandstone. The cycle then changes to a coarse grain facies that is composed of 26 meters of dark-grey pebbly bituminous sandstone, which is followed by a coarsening upward of light-green marlstone, siltstone, sandstone and conglomerate.

The second unit (B) consists of 50 meters of alternations of medium beds of light-green to olive silty marl, marly limestone and organic shale with sandstones. In the middle part of this unit, the beds change to amalgamated fine-grained sandstone, then to organic shale and marlstone. Near the top, the sandstone beds become course- grained (Figure 2). The Unit (C) represents the sediments of the lower part of the Kolosh Formation, which consists of more than 41 meters of amalgamated sandstone (30-40cm thick), and thin siltstones, marlstone interlayers, and occasional pebbly sandstone. This unit is followed by light-gray to whitish marly limestone with two meters of a light- yellow to pale, friable polygenetic conglomerate (Figures 2 and 3).

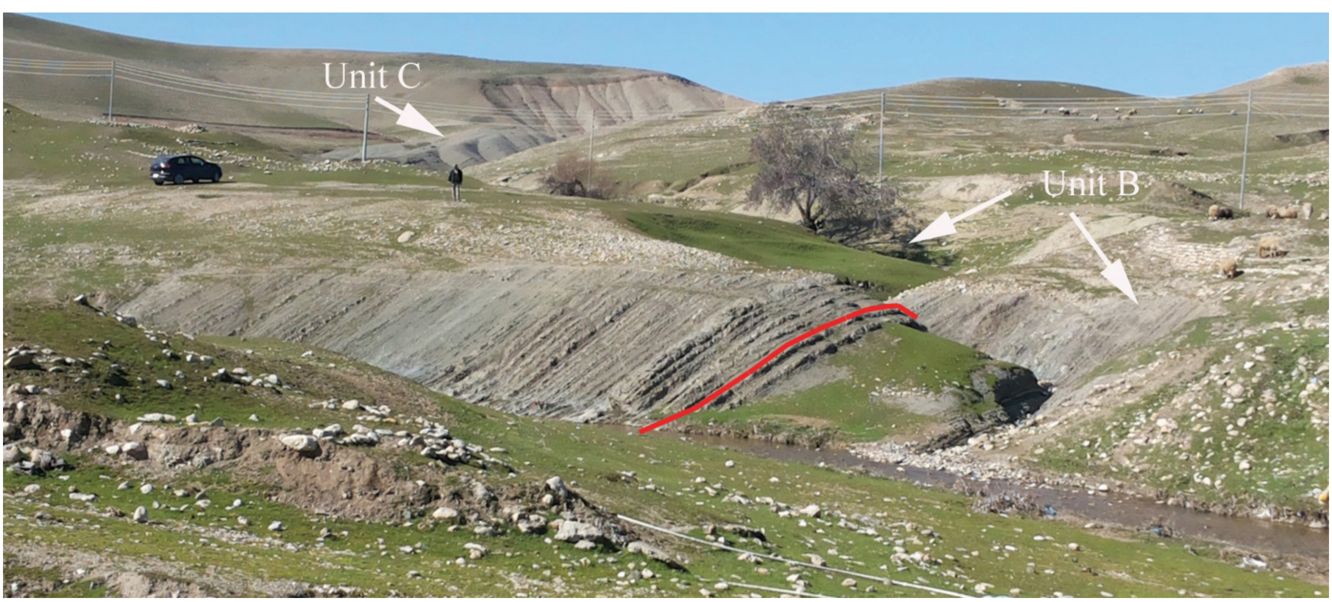


Fig. 2. Qalbaza section shows lithologic variation across the Cretaceous/Paleogene boundary.

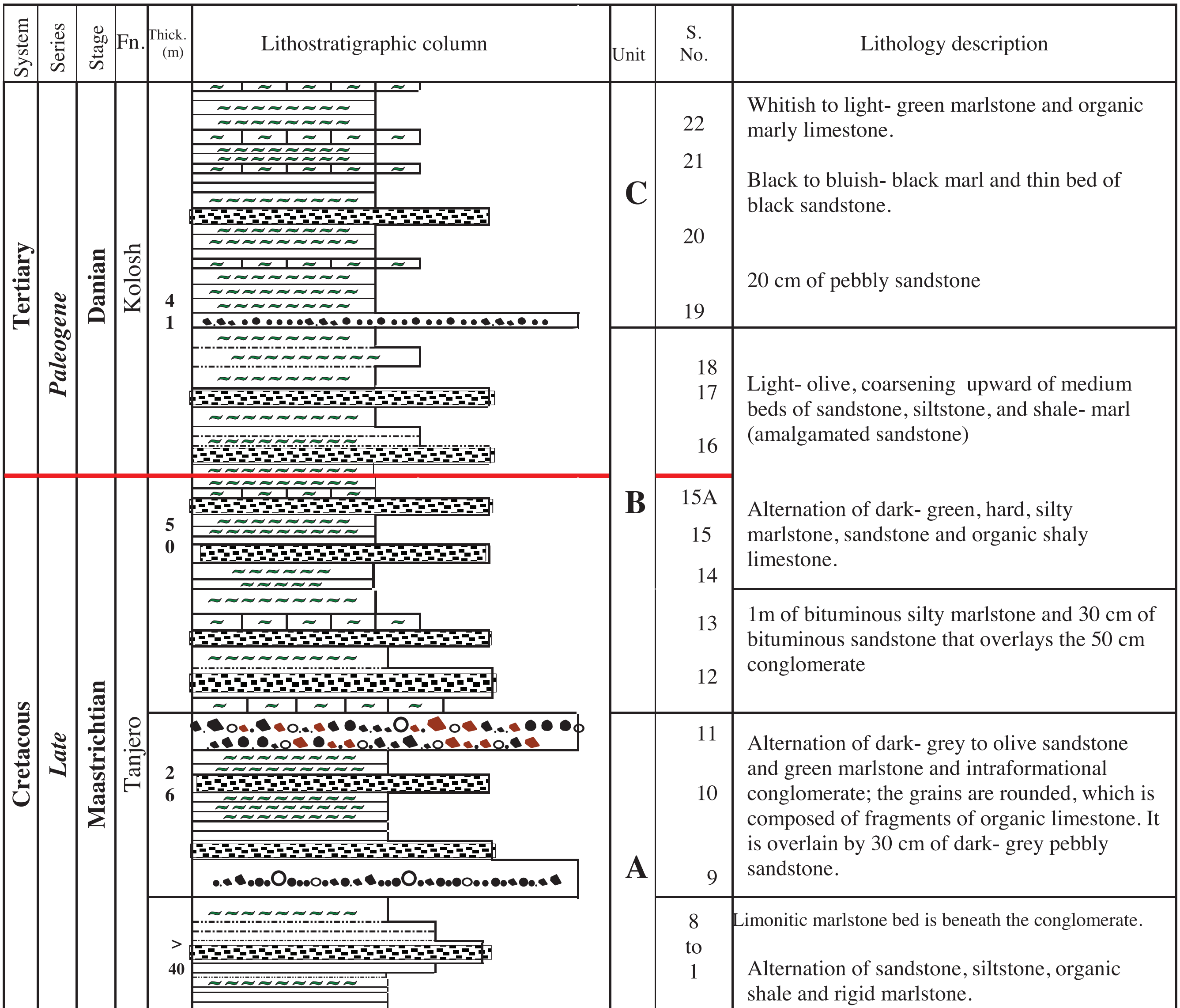
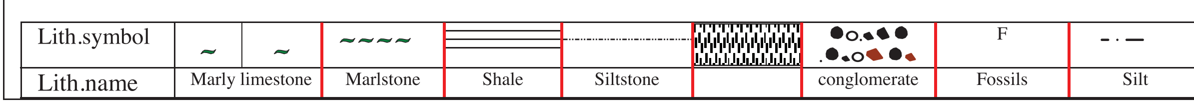


Fig. 3. Lithostratigraphic column of the Qalbaza section. The Red line indicates the K/Pg boundary.



B. Dartw locality

The Dartw section consists of cyclic alternations of marlstone, marly limestone and sandstone (Figure 4). The lithology of the lower Unit (A) is 28 meters thick, and it consists of repetition of light-yellow to pale, medium to thick beds, 30-60 centimeters of marly limestone, with thick dark-grey marlstone and thin beds of grayish-brown to brown, fine sandstone (Figure 5). The thin sandstone beds of the lower Unit (A) pass through the boundary succession. The lithology of the middle part Unit (B) shows no changes, excepting the thickness of the sandstone beds, which have become medium-bedded. These sandstone beds are laminated. They are 28 meters thick. The upper beds of Unit (C) consist of 29m- thick, argillaceous, dark, organic, rich, silty shale. The sandstone beds become thicker upwards. The lithology of the Dartw section shows the dominance of mudstones and marlstone (Figures 4 and 5).

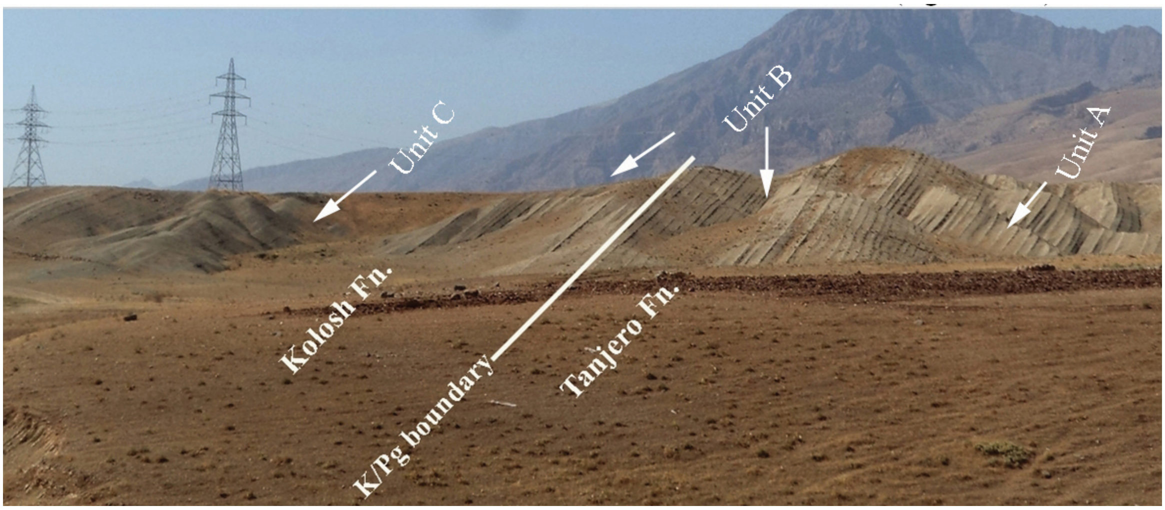


Fig. 4. study section across the Cretaceous/Paleogene boundary along the Dartw section.

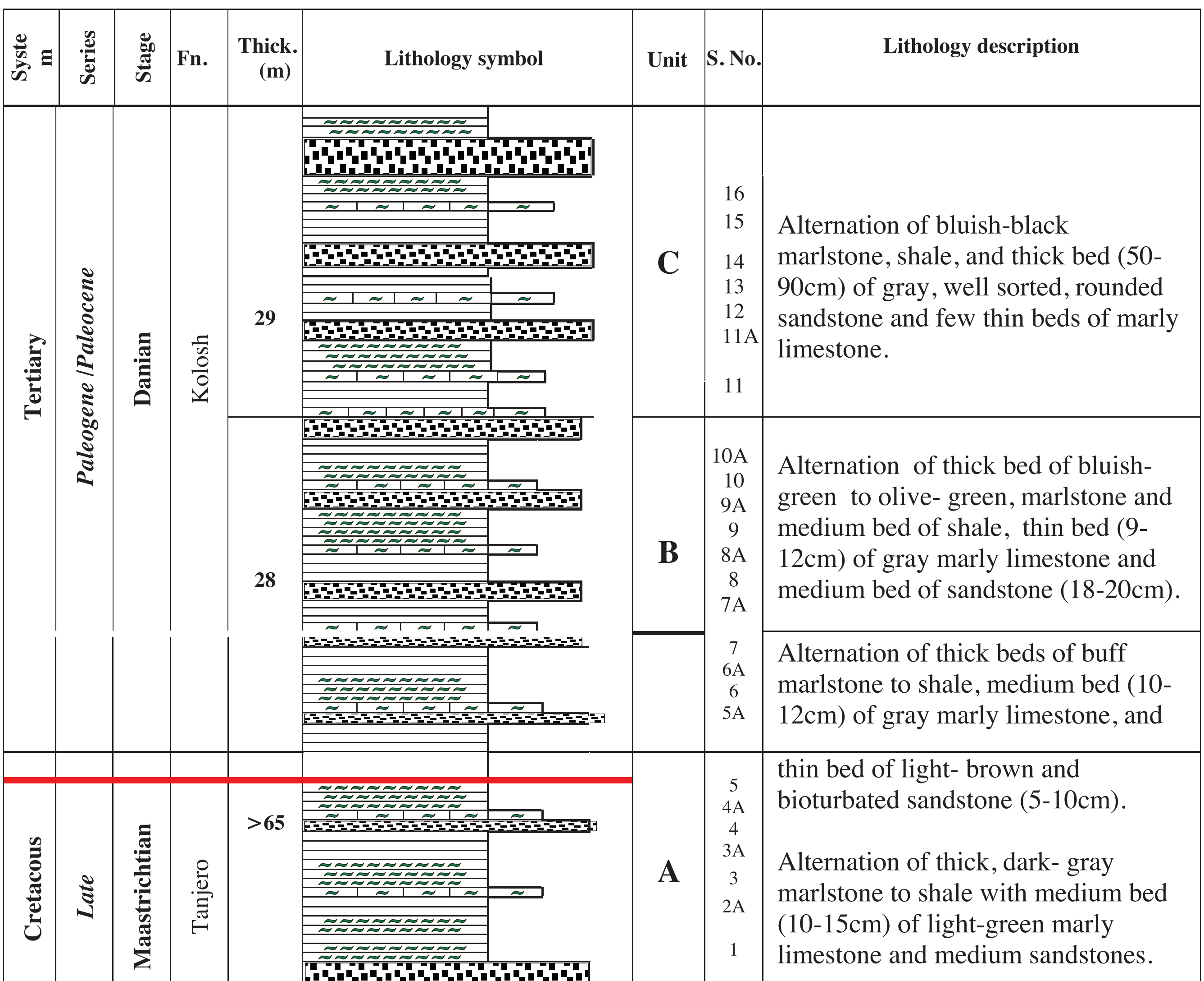


Fig. 5. Lithostratigraphic column of the Dartw section. The Red line indicates the K/Pg boundary.

4.2 Biostratigraphy

4.2.1 Qalbaza section

-Late Maastrichtian

Nephrolithus frequens Zone (CC26)

The nannofossils of the Late Maastrichtian at the Qalbaza section are moderately-to-well-preserved. The biocrystals of the nannofossils are moderately-to-highly- overgrown and widely distributed within the samples of the Tanjero Formation. Figure 6 shows the assemblages/ species of the late Maastrichtian, such as *Eiffelithus gorkae* **(6.15)**, *Zygodiscus sheldoniae* **(6.16)**, *Eiffelithus parallelus* **(6.17)**, *Microrhabdulus decoratus* **(6.18)**, *Eiffelithus eximius* **(6.19)**, *Micula staurophora* **(6.20)**, *Lithraphidites quadratus* **(6.21)**, *Micula swastica* **(6.22)**, *Cretarhabdus conicus* **(6.23)**, *Uniplanarius sissinghii* **(6.24)**, and *Watznaueria biporta,* **(6.25)**. Figure 8 represents the range chart of the Maastrichtian and early Danian with their boundary. It shows the dominance of *Watznaueria, Cyclagelosphaera* and *Arkhangelskiella species* over all other species.

Early Danian

The early Danian assemblages of the Qalbaza section are moderate-to-well- preserved. The biocrystals of the nannofossils are slightly overgrown and moderately distributed. The first occurrence of the genus *Biantholithus* is *Biantholithus hughesii;* it appeared in sample number 15A. This bed is considered a Late Maastrichtian/ early Danian boundary. Figure 6 shows some common early Danian species in the Qalbaza section, such as *Prinsius martinii* **(6.1)**, *Chiasmolithus* sp., **(6.2)**, *Coccolithus pelagicus* **(6.3 & 6.14)**, *Praeprinsius tenuiculus* **(6.4 & 6.8)**, *Thoracosphaera operculata* **(6.5)**, *Zygodiscus sigmoides* **(6.6)**, *Praeprinsius dimorphosus* **(6.7)**, *Cruciplacolithus intermedius* **(6.9)**, *Cruciplacolithus primus* **(6.10)**, *Micula prinsii* **(6.11)**, *Biantholithus sparsus* **(6.12)** and *Biantholithus sparsus/ hughesii* **(6.13)**.

Markalius inversus Zone (NP1)

At the Qalbaza section, the first acme of the genus *Thoracosphaera* spp. is before the boundary and the second bloom is after the boundary. *Thoracosphaera* spp. are accompanied by the first occurrence of *Biantholithus hughesii* at sample number 15A, which is considered to be the Maastrichtian/ early Danian boundary. The species *Biantholithus sparsus* appeared in sample 16. Other species are *Coccolithus pelagicus*, *Praeprinsius* spp., *Prinsius martinii* and *Prinsius dimorphosus* at the beginning of NP1 (early Danian).

Cruciplacolithus tenuis Zone (NP2)

The *Cruciplacolithus* spp. are not well preserved within this lithology. The first occurrence of *Cruciplacolithus* spp. like *Cruciplacolithus primus* and *Cruciplacolithus tenuis,* identified in samples 18 and above, is considered the beginning of NP2.

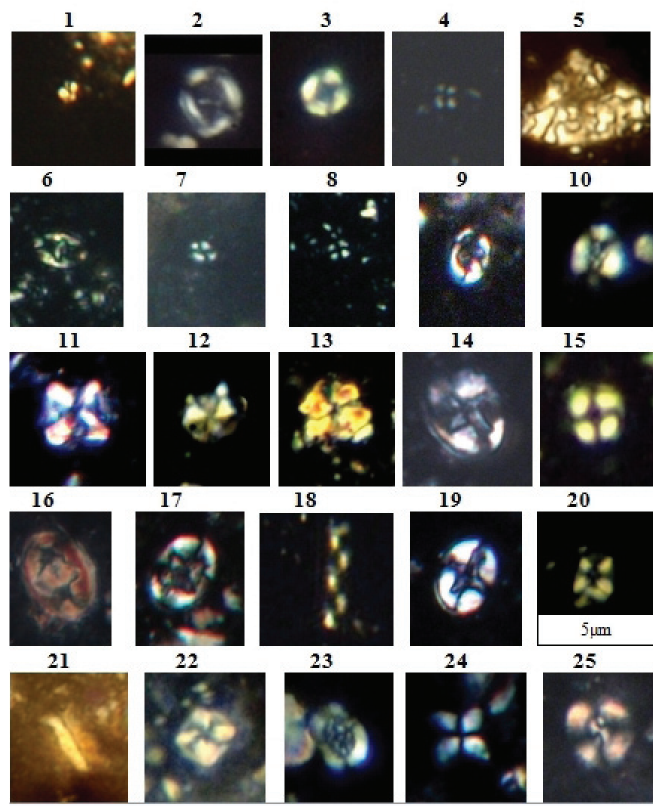


Fig. 6. 1. *Prinsius martinii,* Kolosh Fn., Early Danian, sample No. QLB22, 400X. **2.** *Chiasmolithus* sp., Kolosh Fn., Early Danian, sample No. QLB 21, 400X. **3.** *Coccolithus pelagicus,* Kolosh Fn., Early Danian, sample No. QLB 21, 400X. **4.** *Praeprinsius tenuiculus,* Kolosh Fn., Early Danian, sample No. QLB 20, 400X. **5.** *Thoracosphaera operculata,* Kolosh Fn., Early Danian, sample No. QLB 20, 400X. **6.** *Zygodiscus sigmoides,* Kolosh Fn., Early Danian, sample No. QLB 19, 400X. **7.** *Praeprinsius dimorphosus,* Kolosh Fn., Early Danian, sample No. QLB 19, 400X. **8.** *Praeprinsius tenuiculus,* Kolosh Fn., Early

Danian, sample No. QLB 19, 400X. **9.** *Cruciplacolithus intermedius,* Kolosh Fn., Early Danian, sample No. QLB 18, 400X. **10.** *Cruciplacolithus primus,* Kolosh Fn., Early Danian, sample No. QLB 18, 400X.. **11.** *Micula prinsii,* Kolosh Fn., Early Danian, sample No. QLB 18, 400X. **12.** *Biantholithus sparsus,* Kolosh Fn., Early Danian, sample No. QLB 16, 400X. **13.** *Biantholithus sparsus/ hughesii,* Kolosh Fn., Early Danian, sample No. QLB 15A, 400X. **14.** *Coccolithus pelagicus,* Kolosh Fn., Early Danian, sample No. QLB 16, 400X. **15.** *Eiffelithus gorkae,* Tanjero Fn., Latest Maastrichtian, sample No. QLB 15, 400X. **16.** *Zygodiscus sheldoniae,* Tanjero Fn., Latest Maastrichtian, sample No. QLB 15, 400X. **17.** *Eiffelithus parallelus,* Tanjero Fn., Latest Maastrichtian, sample No. QLB 15, 400X. **18.** *Microrhabdulus decoratus,* Tanjero Fn., Latest Maastrichtian, sample No. QLB 14, 400X. **19.** *Eiffelithus eximius,* Tanjero Fn., Latest Maastrichtian, sample No. QLB 14, 400X. **20.** *Micula staurophora,* Tanjero Fn., Latest Maastrichtian, sample No. QLB 13, 400X. **21.** *Lithraphidites quadratus,* Tanjero Fn., Latest Maastrichtian, sample No. QLB 12, 400X. **22.** *Micula swastica,* Tanjero Fn., Latest Maastrichtian, sample No. QLB 12, 400X. **23.** *Cretarhabdus conicus,* Tanjero Fn., Latest Maastrichtian, sample No. QLB 11, 400X. **24.** *Uniplanarius sissinghii,* Kolosh Fn., Early Danian, sample No. QLB 8, 400X. **25.** *Watznaueria biporta,* Tanjero Fn., Latest Maastrichtian, sample No. QLB 5, 400X.

4.2.2. Dartw section

-Late Maastrichtian

Nephrolithus frequens Zone (CC26)

The nannofossils of the Late Maastrichtian at the Dartw section are moderately preserved. The biocrystals of the nannofossils are low to moderately to highly overgrown and widely distributed in the samples of the Tanjero Formation. Figure 7 shows the recorded assemblages/ species of the late Maastrichtian, like *Broinsonia furtiva* **(7.15)**, *Watznaueria biporta* **(7.16)**, *Arkhangelskiella confusa* **(7.17)**, *Micula staurophora* **(7.18)**, *Microrhabdulus undosus* **(7.19)**, *Cretarhabdus conicus* **(7.20)**, *Broinsonia parca* **(7.21)**, *Watznaueria barnesiae* **(7.22)**, *Micula prinsii* **(7.23)**, *Eiffelithus gorkae* **(7.24)** and *Cribrosphaerella ehrenbergii* **(7.25)**. Figure 9 represents the range chart of the Maastrichtian and early Danian calcareous nannofossils. It shows the dominance of species *Micula murus, Cyclagelosphaera* spp. and *Watznaueria* spp. over all other species, besides *Thoracosphaera* spp.

-Early Danian

The assemblages of the early Danian in the Dartw section are poorly preserved. The biocrystals of the nannofossils have moderate overgrowth and the assemblages are thinly distributed. The species *Biantholithus sparsus* appears in Sample 5 of the early Danian assemblages identified here are shown in figure 7, such as *Cruciplacolithus* sp. **(7.1)**, *Placozygus spiralis,* **(7.2)**, *Cruciplacolithus tenuis* **(7.3)**, *Cruciplacolithus tenuis* **(7.4)**, *Cruciplacolithus intermedius* **(7.5)**, *Thoracosphaera operculata* **(7.6)**, *Micula prinsii* **(7.7)**, *Praeprinsius dimorphosus* **(7.8)**, *Zygodiscus sigmoides* **(7.9)**, *Zygodiscus sheldoniae* **(7.10)**, *Prinsius martinii* **(7.11)**, *Biantholithus sparsus* **(7.12)**, *Biantholithus sparsus* **(7.13)** and *Coccolithus pelagicus* **(7.14)**.

Markalius inversus Zone (NP1)

The acme of the genus *Thoracosphaera* spp. is noted in the NP1 Zone, before the first occurrence of *Biantholithus sparsus*. The first occurrence of *Biantholithus sparsus* at Sample 5 is considered as the Maastrichtian/ Early Danian boundary marker, and the *Thoracosphaera* spp. bloom is recorded at least 40 meters before the boundary. The *Biantholithus sparsus* is accompanied by *Coccolithus pelagicus*, *Cruciplacolithus* spp., *Praeprinsius* spp., *Prinsius martinii* and *Prinsius dimorphosus at* the beginning of the NP1 (Early Danian); they appeared between Sample 5 to 6A.

Cruciplacolithus tenuis Zone (NP2)

The *Cruciplacolithus* spp. are not well preserved within this sequence, but a few specimens of *Cruciplacolithus* spp. like *Cruciplacolithus primus* and *Cruciplacolithus tenuis* were identified in Samples 7 and above that represented NP2.

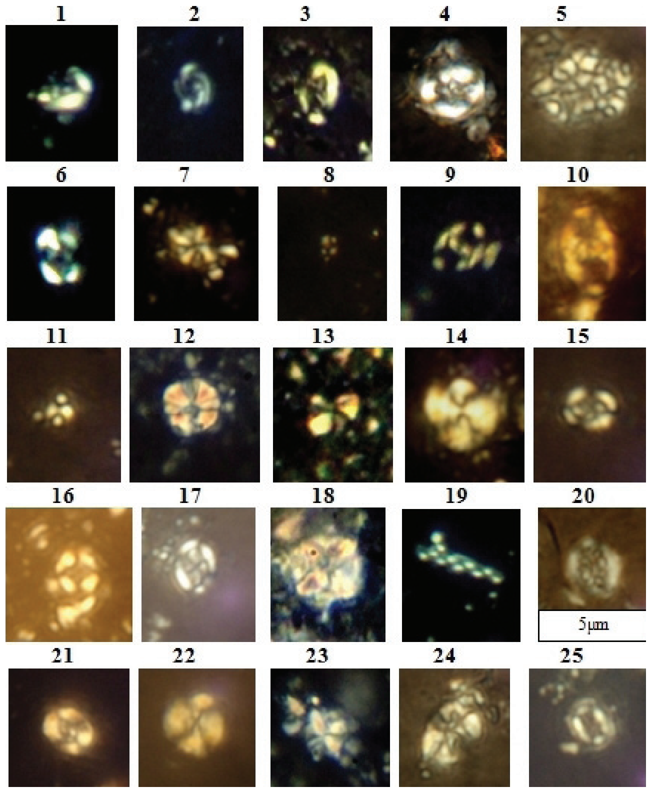


Fig. 7. 1. *Cruciplacolithus* sp., Kolosh Fn., early Danian, sample No. RTW 16, 400X. **2.** *Placozygus spiralis,* Kolosh Fn., Early Danian, sample No. RTW 16, 400X. **3.** *Cruciplacolithus tenuis*, Kolosh Fn., Early Danian, sample No. RTW 11, 400X. **4.** *Cruciplacolithus intermedius,* Kolosh Fn., Early Danian, sample No. RTW 15, 400X. **5.** *Thoracosphaera operculata*, Kolosh Fn., Early Danian, sample No. RTW 9, 400X. **6.** *Arkhangelskiella cymbiformis*, Kolosh Fn., Early Danian, sample No. RTW 8, 400X. **7.** *Micula prinsii,* Kolosh Fn., Early Danian, sample No. RTW 8, 400X. **8.** *Praeprinsius dimorphosus,* Kolosh Fn., Early Danian, sample No. RTW 8, 400X. **9.** *Zygodiscus sigmoides*, Kolosh Fn., Early Danian, sample No. RTW 7, 400X. **10.** *Zygodiscus sheldoniae,* Kolosh Fn., Early Danian, sample No. RTW 7, 400X. **11.** *Prinsius martinii,* Kolosh Fn., Early Danian, sample No. RTW 6, 400X. **12.** *Biantholithus sparsus*, Kolosh Fn., Early Danian, sample No. RTW 5, 400X. **13.** *Biantholithus sparsus*, Kolosh Fn., Early Danian, sample No. RTW 5, 400X. **14.** *Coccolithus pelagicus*, Kolosh Fn., Early Danian, sample No. RTW 5, 400X. **15.** *Broinsonia furtiva*, Tanjero Fn., Latest Maastrichtian, sample No. RTW4. **16.** *Watznaueria biporta*, Tanjero Fn., Latest Maastrichtian, sample No. RTW4. **17.** *Arkhangelskiella confusa,* Tanjero Fn., Latest Maastrichtian, sample No. RTW4. **18.** *Micula staurophora*, Tanjero Fn., Latest Maastrichtian, sample No. RTW4. **19.** *Microrhabdulus undosus*, Tanjero Fn., Latest Maastrichtian, sample No. RTW 3, 400X. **20.** *Cretarhabdus conicus*, Tanjero Fn., Latest Maastrichtian, sample No. RTW 2, 400X. **21.** *Broinsonia parca constricta,* Tanjero Fn., Latest Maastrichtian, sample No. RTW2, 400X. **22.** *Watznaueria barnesiae,* Tanjero Fn., Latest Maastrichtian, sample No. RTW 3, 400X. **23.** *Micula prinsii,* Tanjero Fn., Latest Maastrichtian, sample No. RTW2, 400X. **24.** *Eiffelithus gorkae*, Tanjero Fn., Latest Maastrichtian, sample No. RTW 2, 400X. **25.** *Cribrosphaerella ehrenbergii*, Tanjero Fn., Latest Maastrichtian, sample No. RTW1, 400X.

5. Discussion

The significant change in calcareous nannofossil assemblages at the Cretaceous/Paleogene boundary was first noted and illustrated by Bramlette & Martini (1964) and has since been globally described in detail (Perch-Nielsen, 1969, 1979a, b, 1981c; Percival and Fischer, 1977; Romein, 1977); *in* Perch-Nielsen, 1985a). The diverse Maastrichtian assemblage disappears suddenly, probably over a few thousand years after mass extinction at the K/Pg boundary (Figure 10). As Winter and Siesser (1994) stated, coccolithophores were quite abundant in both coastal and oceanic waters and in both polar and equatorial waters, but the vast majority of species in the diverse coccolithophore community became extinct at the end of the Cretaceous. Here we noted the bloom of *Thoracosphaera* sp. at Sample 15A in Qalbaza section, and it is noted at Sample 5 in the Dartw section accompanied by the first occurrence of *Biantholithus sparsus*; thus, the events are recorded very close to the boundary.

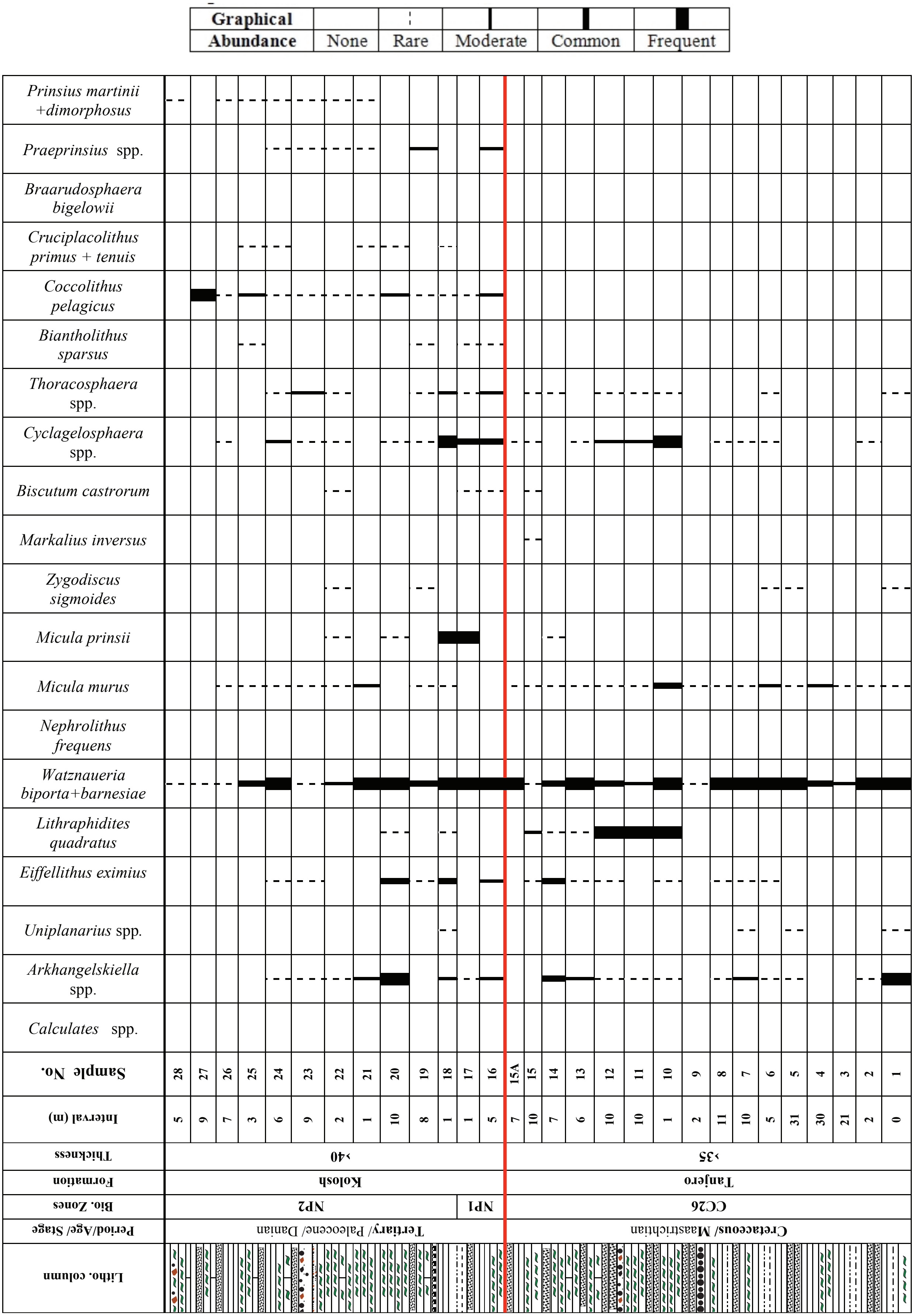


Fig. 8. Calcareous nannofossil biostratigraphic zonation chart of the Qalbaza section. The red line is indicative of the Tanjero/ Kolosh Formations (K/Pg) boundary.

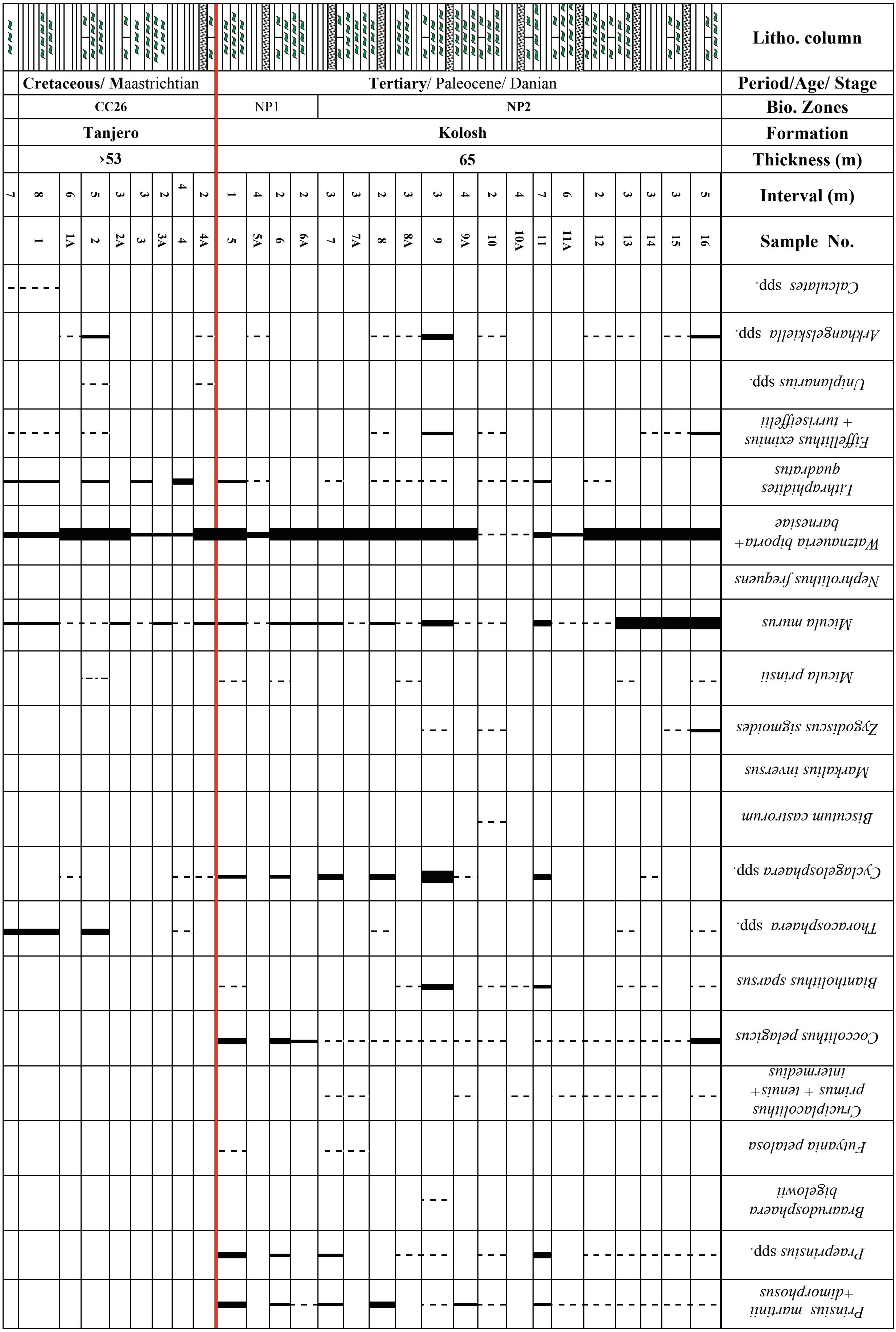


Fig. 9. Calcareous nannofossil biostratigraphic zonation chart of the Dartw section.

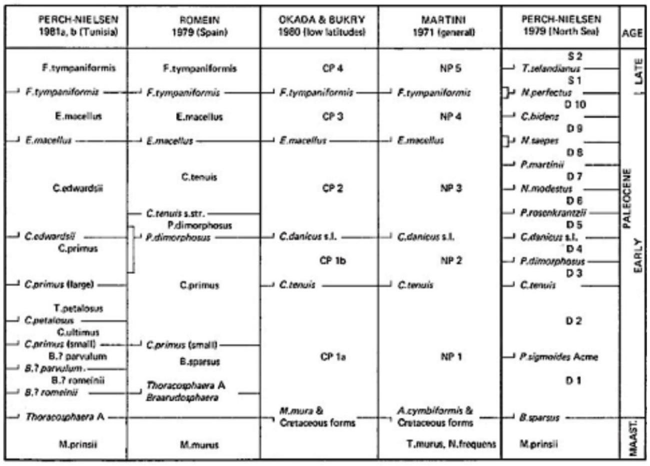


Fig. 10. Definition and correlation of zones and subzones in the early Paleocene (From Perch-Nielsen, 1985, p.435, Figure 6).

Figures 7-9 show nannofossil marker species like *Biantholithus sparsus, Cruciplacolithus tenuis,* and *Coccolithus pelagicus* which are accompanied by *Praeprinsius* spp., such as *Prinsius martinii* and *Prinsius dimorphosus* with the acme of *Thoracosphaera operculata* at the beginning of the early Danian (NP1). Taxa like *Micula murus, Micula prinsii, Arkhangelskiella* spp., *Uniplanarius* spp., *Eiffellithus eximius, Lithraphidites quadratus, Watznaueria barnesae* and *Microrhabdulus* spp. indicative of the latest Maastrichtian appear below the CC26 Zone. This zone is topped by the K/Pg boundary, as illustrated in figures 1-9 (The boundary is denoted by a red line). Also, the boundary is succeeded by Zone NP1.

The lithostratigraphy and calcareous nannofossil assemblages recognized in the studied area (Qalbaza and Dartw), clearly show that deposition was continuous across the K/Pg transition.

The result of this study does not match the previous idea, which stated that there is a gap between the Cretaceous and Paleogene. Specifically Bellen *et al.* (1959) stated that during the Cretaceous/Paleogene transition, the environmental controls on facies distribution changed considerably, and it is unusual to find Maastrichtian rock-units overlain by precisely similar rock units of Paleocene age; i.e., the Tanjero Formation underlies the Kolosh unconformably. The unconformity is marked by a total faunal change without transitional elements. Buday (1980) also described both formations, and he concluded that the lower contact of the Kolosh Formation is clearly unconformable. In the type area, the Tanjero Formation underlies the Kolosh Formation, whereas in other areas it is underlain by the Shiranish Formation. Fauna and fragments of the Cretaceous taxa/species reworked into the Paleocene sediments are considered to have been reworked by turbidity currents during the Early Danian.

The results of this study also do not match the results of Starkie (1994), who studied the Cretaceous to early Miocene calcareous nannofossils of Iraq oil wells. He stated that the Paleogene succession lays lies unconformably on the Upper Cretaceous with a gap which spans 3.7-6.1 Million years (NP1 to NP3 are missing). He believed that the unconformity probably was the result of the tectonic processes active during the final closure of the Tethys Ocean during the Late Cretaceous.

The presence of CC26 and NP1 Biozones is correlated with the surrounding areas. Senemari and Azizi (2012) determined the CC26-NP1 Biozones in Iran. In Jordan, Farouk *et al.* (2014) stated that the K/Pg boundary is marked by a major depositional hiatus that differs in magnitude from place to place.

In addition to so many studies which deny the occurrence of the Danian in the Kurdistan Region, others consider that a conglomerate bed within the flysch sequence represents the K/Pg unconformity. However, this study shows that the Danian sediments exist and the conglomerate bed is part of the Danian sediments of the Kolosh Formation. The lithological succession of the deep marine shale and sandstone across the boundary seems to be continuous with no marked changes supporting the biostratigraphic continuation. This succession is believed to represent an integral part of a submarine fan originated in the study area. It started developing during the late Maastrichtian and continued through the Danian. This fan is inferred from the facies type and the stratigraphic correlation with other neighboring areas. During the Maastrichtian, the study represents part of a mid-fan system prograded from the northeast towards the southwest, which intermixed with hemipelagic sediments. After passing through the K/Pg transition and during the middle to late Danian, different sediments were deposited in the studied area such as gravel, coarse sandstone, and siltstone, in addition to shale and marl. These facies represent an inner fan sediment with a relatively shallow marine setting that ranged from upper slope to shelf margin.

6. Conclusions

The biostratigraphic analysis of calcareous nannofossil assemblages across the K/Pg boundary at the Qalbaza and Dartw sections from Sulaimani area documents the presence of biozones CC26 of the Late Maastrichtian, and NP1and NP2 of the Early Danian. These zones indicate a transition in deposition across the K\Pg boundary with no break or hiatus. The changes across the boundary are marked however by changes in the assemblages where the Late Cretaceous calcareous nannofossils are topped by new taxa and species of the Danian. Continuous mid-fan deposits across the boundary succession support the conformable nature of the K/Pg boundary.

ACKNOWLEDGMENTS

We would like to thank Mr. Bashdar Jalil for his assistance during the field work. The Florida State University authorities are greatly acknowledged for providing some of the research facilities.

References

Abdel-Kareem, M.R., (1986). Planktonic foraminifera and stratigraphy of the Tanjero Formation (Maastrichtian), Northeastern Iraq. Journal of Micropaleontology, **32**(3): 215-231.

Al-Qayim B.A., Omar, A., & Koyi H., (2012). Tectonostratigraphy overview of the Zagros Suture Zone. Kurdistan Region. Northeast Iraq. Geoarabia/ Petrolink, Bahrain, **17**(4): 109-156.

Al-Shaibani, S., Al-Qayim, B.A., & Salman, L., (1986). Stratigraphic analysis of the Tertiary- Cretaceous contact, Dokan area, North Iraq. Journal of the Geological Society of Iraq, **19**(2): 101-110.

Bellen, R.C., Van Dunnington, H.V., Wetzel, R. & Morton, D., (1959). Lexique Stratigraphique International: Asie, Iraq, **3c** (10a): 333

Bown, P., (1998). Calcareous nannofossil biostratigraphy. 2nd edition, Chapman and Hill, Cambridge University Press, Cambridge, UK, p314.

Bramlette, M.N., & Martini, E., (1964). The great change in calcareous nannoplankton fossils between the Maestrichtian and Danian. Micropaleontology, **10**: 291–322.

Buday, T. (1980). In: Regional geology of Iraq, 1: Stratigraphy, I. I. M Kassab and S. Z. Jassim (eds) D. G. Geological Surveys and Mining Investigation Publications, Pp. 445.

Buday, T., & Jassim, S.Z., (1987). Regional geology of Iraq: tectonism, magmatism and metamorphism. State Establishment of Geological Surveys and Mining Investigation, Baghdad, Iraq, **2**: 352

Farouk, S, Marzouk, A.M., & Ahmad F., (2014). The Cretaceous/Paleogene boundary in Jordan. Journal of Asian Earth Sciences, Elsevier, **94**: 113-125.

Kassab, I.I.M., (1974). Biostratigraphy of Upper Cretaceous Lower Tertiary of North Iraq. Colloque Africain de Micropaleontology, Tunis, **1**: 277-325.

Martini, E., (1971). Standard Tertiary and Quaternary calcareous nannoplankton zonation. In: A. Farinacci (Ed.). Proceedings of the Second International Conference on Planktonic Micro-fossils, **2**: 739–785.

Okada, H. & Bukry, D., (1980). Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation (Bukry 1973, 1975). Marine Micropaleontology, **5**(3): 321-32.

Perch-Nielsen, K., (1985). Mesozoic calcareous nannofossils. In: Bolli, H. M., Saunders J. B., & Perch-Nielsen, K. (Eds.), Plankton Stratigraphy. Cambridge University Press, Cambridge, UK, Pp.329-426.

Perch-Nielsen, K., (1985). Cenozoic calcareous nannofossils. In: Bolli, H. M., Saunders, J. B., and Perch-Nielsen, K. (Eds.), Plankton Stratigraphy. Cambridge University Press, Cambridge, UK, Pp.427-554.

Senemari, S., & Azizi, M., (2012). Nanostratigraphy of Gurpi Formation (Cretaceous-Tertiary Boundary) in Zagros Basin, Southwestern Iran. Journal of World Applied Sciences, **17**(2): 205-210.

Sharbazheri, K.M.I., (2007). Biostratigraphy and paleoecology of Cretaceous/Tertiary boundary in the Sulaimani region, Kurdistan, NE Iraq. Unpublished Ph.D. thesis, University of Sulaimani, p. 121.

Sharbazheri, K.M.I., (2009). Biostratigraphy of the

Cretaceous/Tertiary boundary in the Sirwan Valley (Sulaimani Region, Kurdistan, NE Iraq). Geologica Carpathica, **60**(5): 381-39.

Starkie, S.P., (1994). Calcareous nannofossil biostratigraphy and depositional history of the Late Cretaceous to Early Miocene sequence of Iraq. Unpublished PHD thesis, Department of Geological Science/ Postgraduate Unit of Micropaleontology, University College of London/ London/UK, p. 325.

Winter, A., & Siesser, W.G., (1994). Coccolithophores. Cambridge University Press, Cambridge, UK, p. 242.

Submitted : 02/02/2019
Revised : 26/03/2019
Accepted : 09/04/2019