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Calcareous nannofossil stratigraphy of the Upper Cretaceous–lower Paleocene sequence from the Dokan section, Sulaimani, Kurdistan- Iraq

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Abstract

The boundary of the Cretaceous/Tertiary in the Kurdistan region of Iraq is still under debate. Most previous studies consider the Danian sediments to be absent. This paper examines the boundary in the Dokan area northwest of the Sulaimani city of Kurdistan in northern Iraq. This research analyzes calcareous nannofossil assemblages and the biostratigraphy of the boundary. The sequence in the study section is characterized by alternations of olive green to greenish gray sandstone, siltstone, shale and marlstone of the Tanjero Formation of the late Campanian- Maastrichtian and the overlying Kolosh Formation of the early Paleocene. The upper part of the section includes thick sandstone beds and a reworked bioclastic conglomerate bed in addition to a dark- grey, silty calcareous shale. The study shows that deposition across the boundary is continuous. The boundary is biostratigraphically delineated by the last occurrence of Maastrichtian taxon and the first occurrences of *Biantholithus sparsus, Cruciplacolithus* spp. and *Coccolithus pelagicus* of biozone NP1, which indicate no hiatus. This succession highlights the occurrence of the early Danian sequence at the bottom of the Kolosh Formation.

Introduction

Many authors using planktonic foraminifera have long studied the Cretaceous/Tertiary boundary (K/T) in Northeastern Iraq. In the Dokan area, the boundary was considered unconformable based on planktonic foraminifera [1] and [4]. However, a more recent study by [12] using a planktonic foraminiferal zonation shows conformable relationship between the Maastrichtian and Danian sediments in the area. Also, [13] recognized the early Danian in the Dokan area, however they did not refer to the possible occurrence of sediments (P0 and Pα) at the boundary, and they did not find related foraminifera, although sedimentation appears to be continuous.

Our study examines the stratigraphic sequence across this boundary at one locality using calcareous nannofossils. This globally important boundary is characterized in our area by a sequence of flysch sediments of the foreland basin, which is developed over the Northeast Arabian Plate [3]. The flysch sediments are represented by the Maastrichtian Tanjero Formation and the overlying Paleogene Kolosh Formation. The Dokan section was selected for a case study to Sample and re-examine the age of the sequence. The sequence is 100 meters thick. The Dokan section lies inside the Dokan resort near Dokan Dam, close to Kalka Smaq Village (northeast limb of the Haibat Sultan anticline) near the Dokan-Kalka Smaq and Sulaimani- Khalakan main roads between coordinates 35°56'06"N and 44°45' 23"E as shown in

fig.1. There, 45 Samples were taken for the study of calcareous nannofossils and the construction of the biozonation chart.

Geological setting

The study area is located within the High Folded Zone of the Zagros orogenic belt, which is characterized by numerous folds and faults. To the northeast are the complicated, imbricate Zagros Suture Zones, where as to the southwest the folds become low in elevation with broader synclines in the Low Folded Zone [8]. The study section represents the flysch stage of the Zagros foreland basin that followed pelagic carbonate sedimentation on the passive Arabian margin [3]. The flysch sequence consists of alternating shale, siltstone, sandstone and conglomerate. The lithology includes the Tanjero Formation in the Maastrichtian and the Kolosh Formation (upper Paleocene).

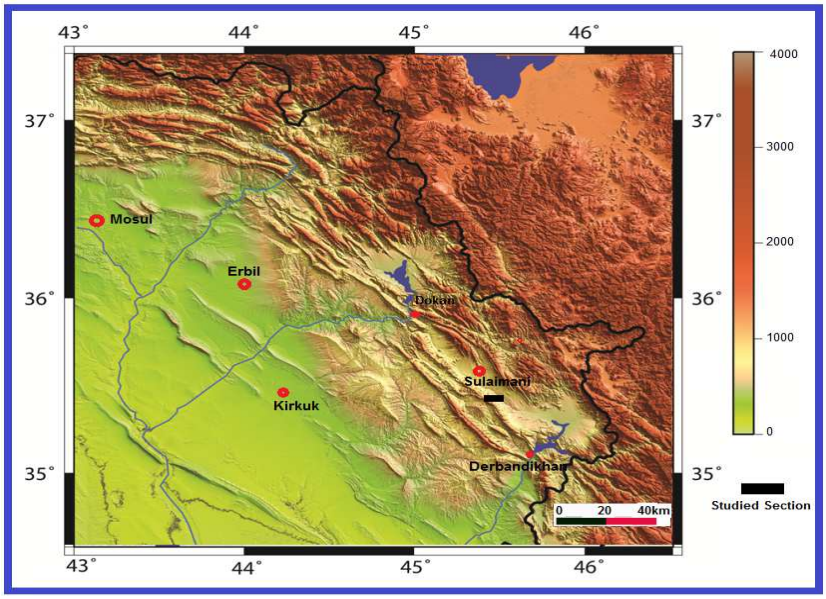

Fig.1.A**:** Relief map of northeast Iraq/Kurdistan shows the geographic location of the studied section**.**

Fig.**1.B**. Aerial photograph of the Dokan section (tilted image, Google earth). The yellow arrow denotes the extension of the sampled section

Lithostratigraphy of the Dokan section

The upper part of the Tanjero Formation in the Dokan section consists of 40 meters of dark grey shale and medium- bedded dark-grey marlstone and marly limestone with grey arenaceous limestone that contains ripple marks on the surface of the beds. They are underlain by creamy sandy limestone, pale to light grey marly limestone to marlstone and thin layers of argillaceous, sandy fossiliferous limestone and sandstone. The beds contain plant remains in dispersed patches. The sequence is about 15m thick, and it is considered to

be an equivalent of the Aqra Formation that is attributed to the late Maastrichtian (fig.2). This succession is overlain by a thick bed of dark brown marlstone that is considered here to be the base of the Kolosh Formation (Danian age). Previously this bed was regarded as the upper part of the Tanjero Formation, but after examination of the nannofossil contents of the unit, it is reassigned to the Danian (65 MY).

A thick bed of dark brown marlstone that is considered here to be the base of the Kolosh Formation overlies this succession. Previously this bed was regarded as the upper part of the Tanjero Formation, but after examination of the nannofossil contents of the unit, it is reassigned to the Danian.

A thick bed (4 meters) of light brown to yellow, friable limonitic and weathered calcareous sandstone rests on top of the first unit of marlstone of the Kolosh Formation (fig.3). It is followed by a thick bed of dark gray sandstone that has an exfoliated appearance. Thick beds of dark organic marlstone and shale succeed the sandstone bed. Occasionally this sandstone appears as a brown iron-bearing argillaceous marlstone. Sometimes, patches of limonite balls appear within the marlstone beds.

Fig.**2**. Stratigraphic succession of the Tanjero and Kolosh Formations, Dokan section.

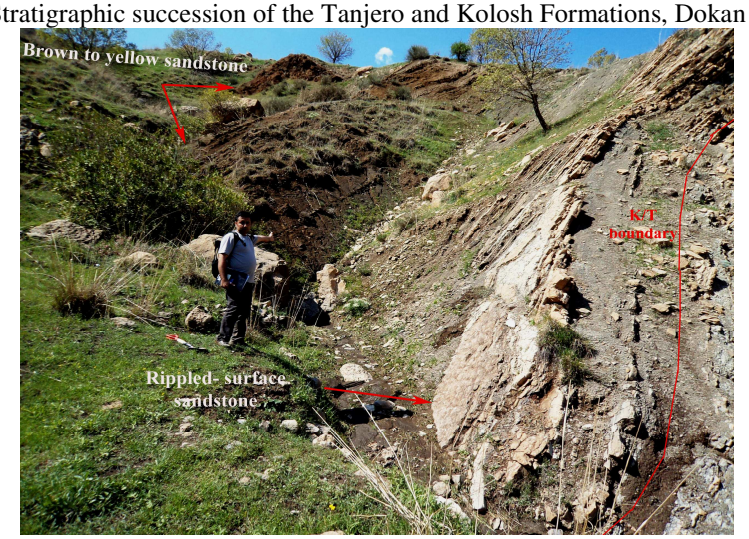

Fig.**3**. Alternation of shale, marlstone and rippled sandstone, which succeeded a thick bed of brown- yellow sandstone, lower part of the Kolosh Formation, Dokan section.

The sequence is succeeded by a bed of reworked conglomerate. It is a brownish bituminous, polygenetic fossiliferous conglomerate with thin beds of ferrous marly limestone overlain by a thinly bedded, brown pebbly claystone. The reworked materials consist of colonial corals, pelecypods and echinoderms with sponges (figs.4 A, B & C.). The shale-marl beds contain some medium beds of 20 centimeter thick bituminous sandstone; locally, medium beds of light-green marly limestone are also present (the marls contain pink nodules and concretions of clays precipitated between joints and fractures of these beds. Fig.(5) illustrates the lithostratigraphic column of the study section.

Fig.(**4**): **A**: Bryozoans fragment. **B**: Some pelecypod and gastropod shells. **C**: A coral colony, Reworked fossiliferous conglomerate, Kolosh Formation, Dokan section.

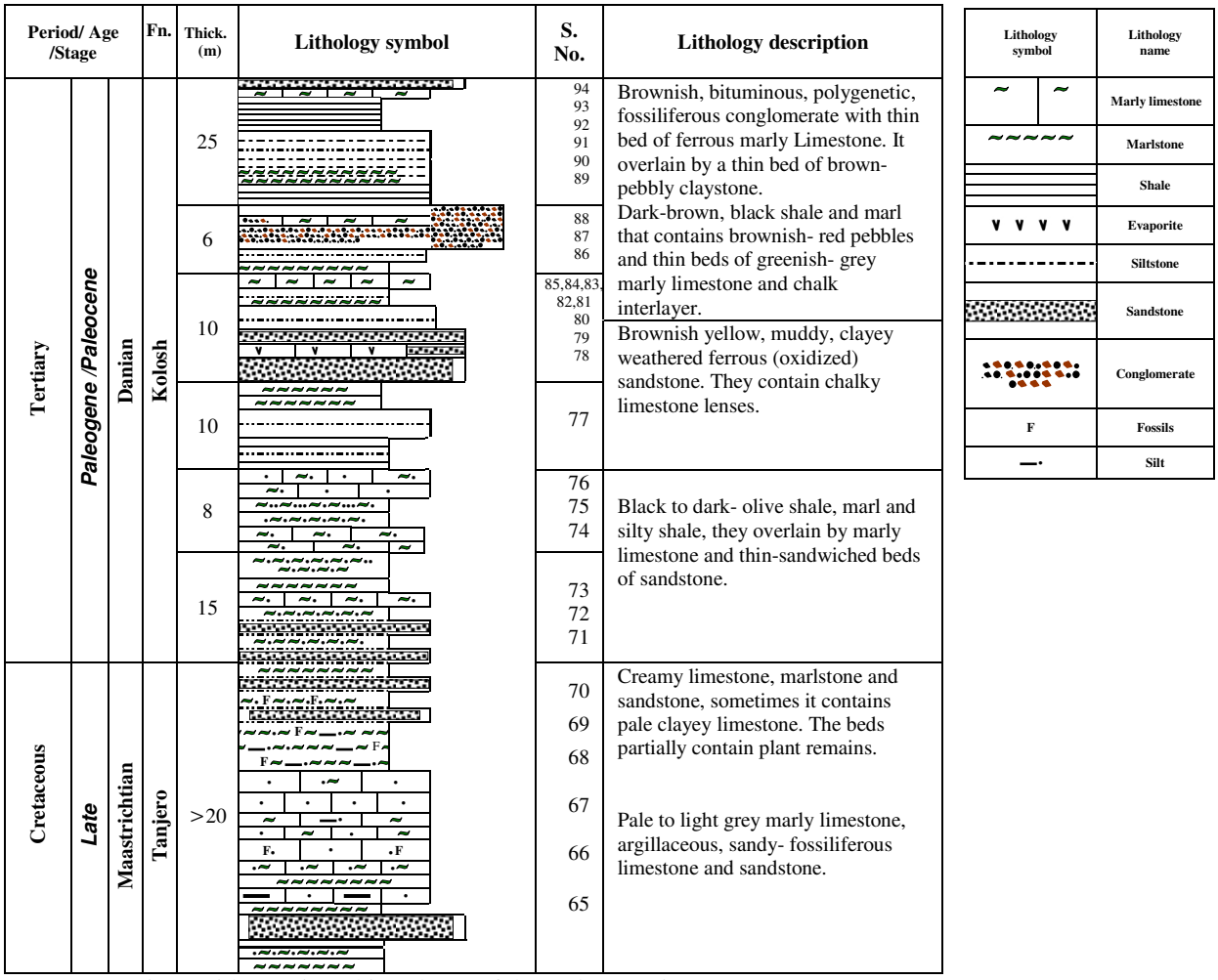

Fig.**5**: Lithostratigraphic column of the Dokan section.

Calcareous nannostratigraphy zonation

-Late Maastrichtian

Nephrolithus frequens Zone (CC26)

The nannofossils examined are moderately preserved. The overgrowth of calcite crystals is moderate and partially dolomitized so that they appear as ghosts. They are not widely distributed due to the sandy nature of the general lithology of that rock sequence. The biozonation scheme follows the standard calcareous nannofossil zonation chart of the International Nannoplankton Association (fig. 6). Figs. 7, 8, 9 & 10 show the position of the K/T boundary within the lithostratigraphic column of the Dokan section and explain the relative abundances of the selected individual species. They show the dominance of species *Micula murus* and *Watznaueria* spp. over all other species. Most of the Maastrichtian species are reworked into the Danian. The nannofossils of Zone CC26 are: *Micula premolisilvae, Micula swastica, Micula murus, Watznaueria*

barnesiae, *Watznaueria ovata, Watznaueria biporta, Eiffelithus eximius, Arkhangelskiella cymbiformis*, *Zygodiscus plectopons*, *Ceratolithoides quasiarcuatus, Ceratolithoides amplector, Cribrosphaerella santacruzensis*, *Uniplanarius gothicus, Microrhabdulus undosus* and *Rhagodiscus splendens*.. Some of these species are illustrated in fig.11 and figs 7, 8 & 9 provide the range chart of the Maastrichtian and early Danian and their boundary. The survivor species are *Cyclagelosphaera reinhardtii*. *Thoracosphaera* spp. are also present; *Thoracosphaera* is a calcareous dinoflagellate that bloomed after the K/T boundary.

-The K/T boundary and Early Danian

The early Danian assemblages in the Dokan section are poorly preserved. The calcite crystals are moderately overgrown and are less. *Biantholithus sparsus* that is considered the K/T boundary species [6] (fig.6) appears in Samples DKN 69A on the range chart. The early Danian taxa are: *Biantholithus sparsus*, *Thoracosphaera heimii, Thoracosphaera operculata*, *Coccolithus pelagicus*, *Cruciplacolithus intermedius, Cruciplacolithus tenuis-primus*, *Prinsius dimorphosus*, *Prinsius martinii, Praeprinsius tenuiculus, Chiasmolithus* sp. and *Futyania petalosa*. Fig.(11) shows some common early Danian species in the Dokan section.

Markalius inversus Zone (NP1)

Here the acme of the genus *Thoracosphaera* is after the first occurrence of *Biantholithus sparsus*. The first occurrence of *Biantholithus sparsus* identified at SampleDKN69A, which is considered the boundary between the Maastrichtian/early Danian. *Thoracosphaera* spp. bloomed 20 meters above the boundary. The marker species *Biantholithus sparsus* is then followed by *Cocolithus pelagicus*, *Praeprinsius* spp., *Prinsius martinii* and *Prinsius dimorphosus* at the beginning of NP1; they appeared between Samples DKN 69A to 73.

Cruciplacolithus tenuis Zone (NP2)

The *Cruciplacolithus* spp. are not well preserved within this sequence, but, a few species like *Cruciplacolithus primus/ tenuis* and *Cruciplacolithus intermedius* identified in Sample DKN73 and above that represents NP2.

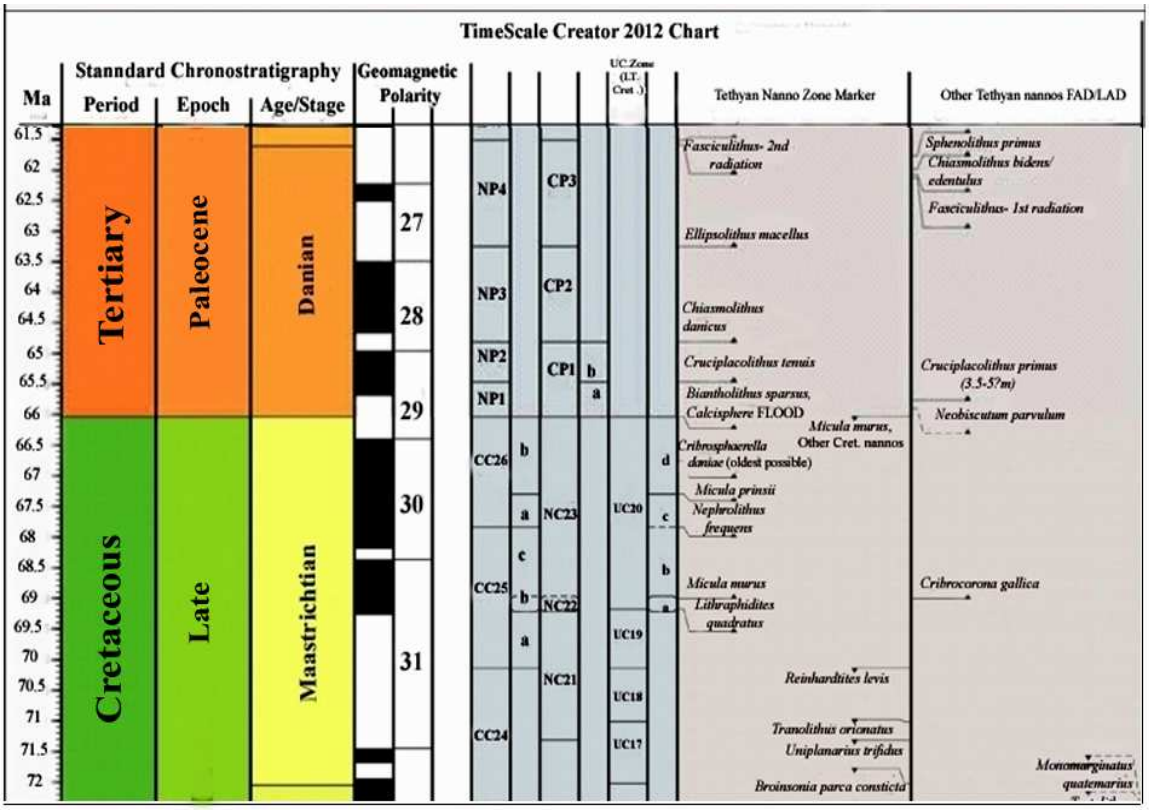

Fig.**6**: Standard calcareous nannofossil zonations through the Maastrichtian-Danian (from the International Nannoplankton Association (INA) website, [15].

Lithostra. column	Period/Age/ Stage	Bio. Zones	Formation	Thickness	Interval (m)	Sample No.	*Arkhangelskiella cymbiformis*	*Eiffellithus eximius*	*Lithraphidites quadratus*	*Watznaueria barnesae*	*Micula murus*	*Micula prinsii*	*Zygodiscus sigmoides*	*Cyclagelosphaera* spp.	*Thoracosphaera* spp.	*Biantholithus sparsus*	*Coccolithus pelagicus*	*Cruciplacolithus primus + tenuis*	*Futyania petalosa*	*Praeprinsius* spp.	*Prinsius martinii +dimorphosus*
	Tertiary/ Paleocene/ early Danian	NP2	Kolosh	37	1	87															
					0.5	86	0	0	0	0	1	0	0	4	9	0	0	3	0	0	0
					3	85	0	0	2	0	2	0	0	0	0	1	7	1	0	14	2
					1	84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
					0.2	83	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
					1	82	0	0	0	0	0	11	0	0	14	0	0	0	0	0	0
					1	81	0	0	0	2	1	13	0	2	11	0	0	0	0	1	0
					1	80	0	0	0	0	0	5	2	0	11	0	0	0	5	1	1
					1	79A	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
					1	79	0	0	0	0	0	10	0	0	0	0	0	0	0	3	0
					1	78A	5	0	0	15	15	0	0	2	15	0	2	0	3	1	9
					2	78	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0
					2	77A	15	1	0	15	15	2	1	0	0	0	0	3	15	0	2
					1	77	0	0	0	0	0	11	0	0	0	0	3	0	0	9	0
					1	76A	0	0	0	1	2	0	0	0	0	0	0	0	0	0	1
					1	76	0	0	0	0	1	14	0	0	0	0	1	0	0	0	1
					1	75A	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
					2	75	0	0	0	0	0	3	0	0	0	0	0	0	2	2	2
					1	74A	0	0	0	4	3	0	0	1	0	0	0	1	0	0	0
					2	74	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1
					1	73A	1	0	0	5	4	0	0	1	0	0	0	1	0	0	0
					2	73	0	0	4	0	4	3	0	0	0	1	2	0	0	8	2
					1	72A	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0
					0.5	72	0	0	8	0	2	0	0	0	0	1	2	0	0	8	0
					0.5	71A	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
					0.5	71	2	0	9	2	4	0	0	1	0	2	2	0	0	9	0
					0.5	70A	0	0	0	0	0	1	0	0	0	1	0	0	0	3	3
					2	70	0	0	8	3	1	0	0	0	0	1	1	0	0	0	0
					2	69B	1	0	0	1	1	0	0	0	1	0	8	0	0	0	0
					4	69A	0	0	0	1	0	1	0	0	0	1	1	0	0	0	0
	Cretaceous/Maastrichtian	CC26	Tanjero	26	4	69	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0
					3	68A	1	0	0	4	7	0	0	1	0	0	0	0	0	0	0
					3	68	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
					3	67A	1	0	0	15	15	1	0	0	1	0	0	0	0	0	0
					3	67	0	0	3	1	1	0	0	0	0	0	0	0	0	0	0
					2	66A	4	0	0	7	8	0	0	0	0	0	0	0	0	0	0
					3	66	3	0	1	3	3	0	0	0	0	0	0	0	0	0	0
					4	65A	10	0	0	8	15	0	0	0	0	0	0	0	0	0	0
					0	65	1	1	3	7	9	0	0	1	0	0	0	0	0	0	0

Fig.**7**: Calcareous nannofossil zonation chart of the Dokan section/numerical.

Lithostra. column	Period/Age/ Stage	Bio. Zones	Formation	Thickness	Interval (m)	Sample No.	*Arkhangelskiella cymbiformis*	*Eiffellithus eximius*	*Lithraphidites quadratus*	*Watznaueria barnesae*	*Micula murus*	*Micula prinsii*	*Zygodiscus sigmoides*	*Cyclagelosphaera* spp.	*Thoracosphaera* spp.	*Biantholithus sparsus*	*Coccolithus pelagicus*	*Cruciplacolithus primus + tenuis*	*Futyania petalosa*	*Praeprinsius* spp.	*Prinsius martinii i+ dimorphosus*
	Tertiary/ Paleocene/ early Danian	NP2	Kolosh	37	1	87															
					0.5	86	N	N	N	N	R	N	N	M	C	N	N	R	N	N	N
					3	85	N	N	R	N	R	N	N	N	N	R	M	R	N	F	R
					1	84	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
					0.2	83	N	N	N	N	N	R	N	N	N	N	N	N	N	N	N
					1	82	N	N	N	N	N	F	N	N	F	N	N	N	N	N	N
					1	81	N	R	R	R	R	F	N	R	F	N	N	R	N	R	N
					1	80	N	N	N	N	N	M	R	N	F	N	N	N	M	R	R
					1	79A	N	N	N	N	N	N	N	N	R	N	N	N	N	N	N
					1	79	N	N	N	N	N	F	N	N	N	N	N	N	N	R	N
					1	78A	M	N	N	F	F	N	N	R	F	N	R	N	R	R	C
					2	78	N	N	N	N	N	F	N	N	N	N	N	N	N	N	N
					2	77A	F	R	N	F	F	R	R	N	N	N	N	R	F	N	R
					1	77	N	N	N	N	N	F	N	N	N	N	R	N	N	C	N
					1	76A	N	N	N	R	R	N	N	N	N	N	N	N	N	N	R
					1	76	N	N	N	N	R	F	N	N	N	N	R	N	N	N	R
					1	75A	N	N	N	N	R	N	N	N	N	N	N	N	N	N	R
					2	75	N	N	N	N	N	R	N	N	N	N	N	N	R	R	R
					1	74A	N	N	N	M	R	N	N	R	N	N	N	R	N	N	N
					2	74	N	N	N	N	N	N	N	N	N	N	R	N	R	R	R
					1	73A	R	N	N	M	M	N	N	R	N	N	N	R	N	N	N
		NP1			2	73	N	N	M	N	M	R	N	N	N	R	R	N	N	C	R
					1	72A	N	N	N	R	R	N	N	N	N	N	N	N	N	N	N
					0.5	72	N	N	C	N	R	N	N	N	N	R	R	N	N	C	N
					0.5	71A	N	N	N	N	R	N	N	N	N	N	N	N	N	N	N
					0.5	71	R	N	C	R	M	N	N	R	N	R	R	N	N	C	N
					0.5	70A	N	N	N	N	N	R	N	N	N	R	N	N	N	R	R
					2	70	N	N	C	R	R	N	N	N	N	R	R	N	N	N	N
					2	69B	R	N	N	R	R	N	N	N	R	N	C	N	N	N	N
					4	69A	N	N	N	R	N	R	N	N	N	R	R	N	N	N	N
	Cretaceous/Maastrichtian	CC26	Tanjero	26	4	69	N	N	R	R	N	N	N	N	N	N	N	N	N	N	N
					3	68A	R	N	N	M	M	N	N	R	N	N	N	N	N	N	N
					3	68	N	N	N	R	N	N	N	N	N	N	N	N	N	N	N
					3	67A	R	N	N	F	M	R	N	N	R	N	N	N	N	N	N
					3	67	N	N	R	N	R	N	N	N	N	N	N	N	N	N	N
					2	66A	M	N	N	M	C	N	N	N	N	N	N	N	N	N	N
					3	66	R	N	R	R	R	N	N	N	N	N	N	N	N	N	N
					4	65A	C	N	N	C	F	N	N	N	N	N	N	N	N	N	N
					0	65	R	R	R	C	C	N	N	R	N	N	N	N	N	N	N

Fig.**8**: Calcareous nannofossil zonation chart of the Dokan section/numerical.

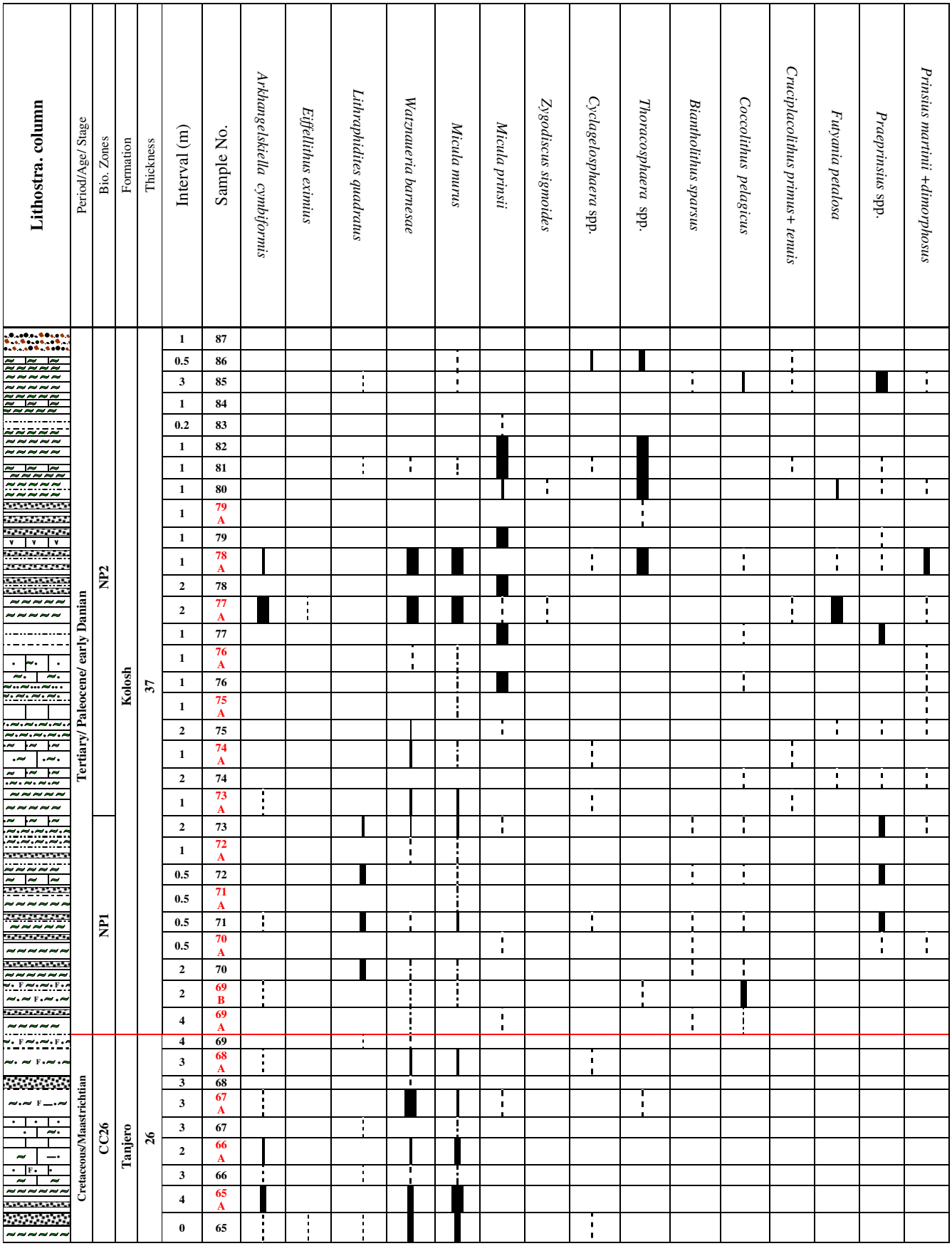

Fig.**9**: Calcareous nannofossil zonation chart of the Dokan section/graphical.

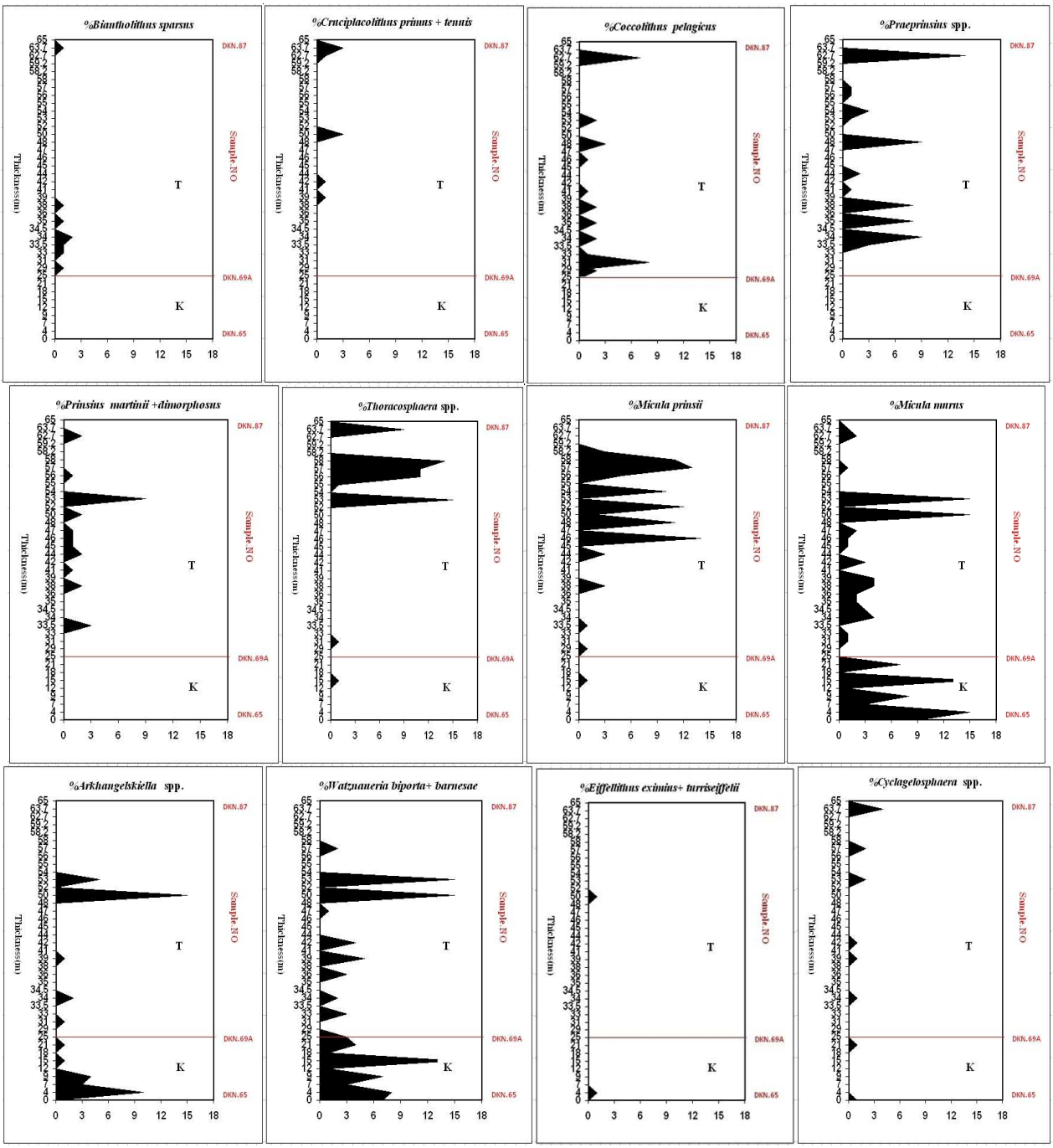

Fig.**10**: Percent abundance of selected individual nannofossil species across the Cretaceous/Tertiary boundary of the Dokan Section.

Discussion

The nannofossil marker species *Biantholithus sparsus, Cruciplacolithus tenuis/primus, Cruciplacolithus intermedius* and *Coccolithus pelagicus* are accompanied by *Praeprinsius* spp., *Prinsius martinii* and *Prinsius dimorphosus* with the acme of *Thoracosphaera operculata* at the beginning of the Tertiary (early Danian); they appear between Samples DKN69A-73. The assemblages are poorly preserved. The calcite crystals have moderate overgrowths but are not common.

The distribution of species like *Micula murus, Micula prinsii, Arkhangelskiella, Uniplanarius, Eiffellithus eximius, Lithraphidites quadratus, Watznaueria biporta, Watznaueria barnesae* and *Microrhabdulus* spp. that indicative of the latest Maastrichtian appear below SampleDKN69A. They appear in Sample numbers DKN69-65(figs.6, 7, 8 & 9). Hence the nannofossils are moderately preserved. The overgrowth of the calcite

crystals are moderate and partially dolomitized so that they appear as ghosts. The assemblages are not abundantly distributed due to the sandy nature of the lithology of the rock sequence.

The lithostratigraphy and calcareous nannofossil assemblages recognized in our study area show that deposition was continuous and the boundary between the Cretaceous and Tertiary is lithologically gradational. The result of this study does not support the previous idea, which stated there is a break between the boundary of the Cretaceous and Tertiary. Specifically [5]. stated that during the Tertiary/Cretaceous break, the environmental controls on facies distribution changed considerably, and it is unusual to find Maastrichtian rock units of any particular facies 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. [7] also described both formations and concluded that the lower contact of the Kolosh Formation is clearly unconformable and transgressive. In the type area, the Tanjero Formation underlies the Kolosh Formation; in other areas, the Shiranish Formation underlies it. Other studies such as [1] and [4] show that the K/T boundary at the Dokan section is unconformable. However, recent study of [12] also indicates a conformable K/T boundary at the Dokan area. The fauna and fossils fragments of the Cretaceous taxa/species reworked into the Paleocene sediments are considered to have been unconformably re-deposited by turbidity currents during the early Danian.

The results of our current study also do not match the study of [14], who had studied the Cretaceous to early Miocene calcareous nannofossils from Iraq oil wells. He states that this succession unconformably lay on the Upper Cretaceous and spans 3.7-6.1 million years (NP1 to NP3). He believed that the unconformity probably was resulted of the tectonic processes during the failed closure of the Tethys Ocean during the Late Cretaceous.

Conclusions

The biostratigraphic analysis of calcareous nannofossil assemblages across the K/T boundary at the Dokan area of Kurdistan region of NE Iraq, documents the presence of biozones CC26 of the Late Maastrichtian and NP1/NP2 of the early Danian. This supports deposition of the Danian sediment above the cretaceous with no gap, which was previously considered to be absent. It is confirmed by the changes in the nannofossil assemblages.

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Explanation of figure 11

1. *Chiasmolithus* sp., Kolosh Fn., early Danian, Slide No DKN 91, 400X.
2. *Thoracosphaera heimii,* Kolosh Fn., early Danian, Slide No. DKN 85, 400X.
3. *Thoracosphaera operculata,* Kolosh Fn., early Danian, Slide No. DKN 80, 400X.
4. *Futyania petalosa,* Kolosh Fn., early Danian, Slide No. DKN 80, 400X.
5. *Coccolithus pelagicus*, Kolosh Fn., early Danian, Slide No. DKN 85, 400X.
6. *Praeprinsius tenuiculus,* Kolosh Fn., early Danian, Slide No. DKN 80, 400X
7. *Cruciplacolithus intermedius,* Kolosh Fn., early Danian, Slide No DKN 74A, 400X.
8. *Prinsius dimorphosus*, Kolosh Fn., early Danian, Slide No DKN 74A, 400X.
9. *Prinsius martinii,* Kolosh Fn., early Danian, Slide No DKN 74A, 400X.
10. *Prinsius martinii*, Kolosh Fn., early Danian, Slide No. DKN 72A, 400X.
11. *Prinsius tenuiculus,* Kolosh Fn., early Danian, Slide No. DKN 77A, 400X.
12. *Biantholithus sparsus,* Kolosh Fn., early Danian, Slide No. DKN 72, 400.
13. *Biantholithus sparsus*, Kolosh Fn., early Danian, Slide No. DKN 69A, 400X.
14. *Watznaueria ovata,* Kolosh Fn., early Danian, Slide No. DKN 70, 400X.
15. *Micula staurophora*, Kolosh Fn., early Danian, Slide No. DKN 70, 400X.
16. *Coccolithus pelagicus,* Kolosh Fn., early Danian, Slide No. DKN 69A, 400X.
17. *Watznaueria biporta,* Tanjero Fn., latest Maastrichtian, sample No. DKN 69, 400X.
18. *Zygodiscus plectopons*, Tanjero Fn., latest Maastrichtian, sample No. DKN 69, 400X.
19. *Ceratolithoides quasiarcuatus,* Tanjero Fn., latest Maastrichtian, sample No. DKN 69, 400X.
20. *Micula murus,* Tanjero Fn., latest Maastrichtian, sample No. DKN 69, 400X.
21. *Cribrosphaerella santacruzensis*, Tanjero Fn., latest Maastrichtian, sample No. DKN 69, 400X.
22. *Uniplanarius gothicus,* Tanjero Fn., latest Maastrichtian, Slide No DKN 68, 400X.
23. *Microrhabdulus undosus,* Tanjero Fn., latest Maastrichtian, No. DKN 68A, 400X.
24. *Watznaueria barnesiae*, Tanjero Fn., latest Maastrichtian, Slide No. DKN 68, 400X.
25. *Rhagodiscus splendens*, Tanjero Fn., Latest Maastrichtian, sample No. DKN 68, 400X.
26. *Arkhangelskiella cymbiformis*, latest Maastrichtian, Slide No. DKN 66A, 400X.
27. *Ceratolithoides amplector,* Tanjero Fn., latest Maastrichtian, Slide No. DKN 66, 400X.
28. *Micula premolisilvae,* Tanjero Fn., latest Maastrichtian, Slide No. DKN 65, 400X.
29. *Micula swastica,* Tanjero Fn., latest Maastrichtian, Slide No. DKN 65, 400X.
30. *Eiffelithus eximius,* Tanjero Fn., Latest Maastrichtian, sample No. DKN 65, 400X.

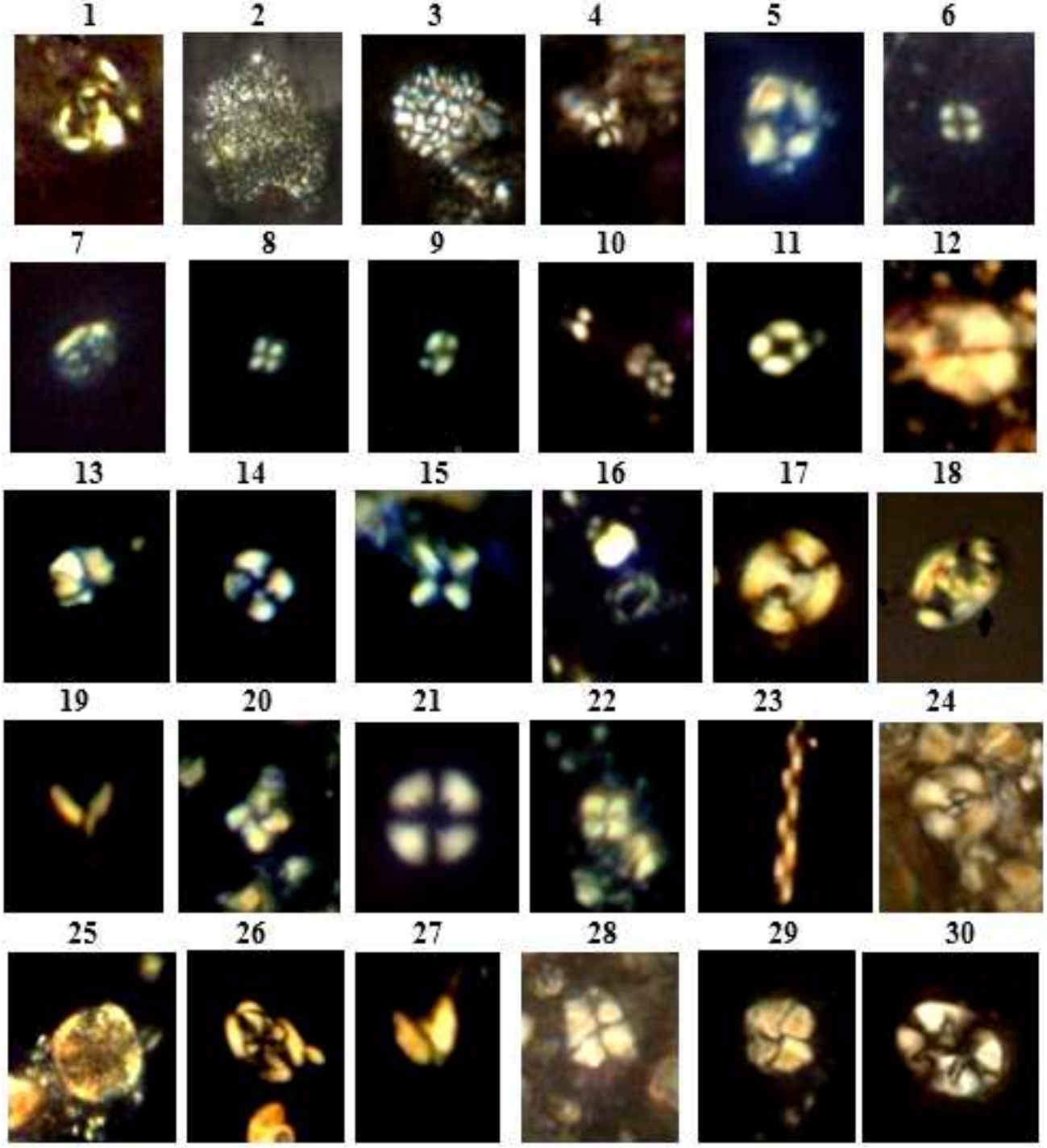

Fig.**11**. selected species from K/T boundary succession of the Dokan section.