Biostratigraphy and paleoecology of Paleogen rocks based on calcareous nannofossil in Kafaz section, east Iran

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Abstract: In this study, the assemblage of calcareous nannofossils has been investigated in long and continuous deposits from a Kafaz section in Eastern Iran. A systematic study of calcareous nannofossils has indicated 39 nannofossils species. In order to the age determination of Kafaz's deposits, a revised zonation for the Eocene is used. Based on it, the Early-Middle Eocene deposits of Kafaz section is divided into 6 zones (NP11-NP16). Eventually, the Paleoecological applications of Eocene nannofossils are considered in this section. Three key factors which are mentioned as the main agents in controlling species distribution include surface water temperature, productivity and fertility. On the basis of three abundant species (*Zhgrhablithus bijugatus, Coccolithus plagicus and Sphenolithus moriformis*), Early-Middle Eocene sediments of Kafaz section were deposited in an environment with high temperature, lower productivity and lower depth..

Keywords: Biostratigraphy, Paleoecology, Eocene, Calcareous nannofossil, Kafaz, Iran.

1- Introduction

The studied area (Kafaz section) is located within the East-Flysch Zone. Ghorbani (2012) stated that Eastern Iran can be divided Lut Block and Flysch or colered mélange of Zabal-Baluch Zone parts. Unlike Lut Block, the Flysch Zone is highly deformed and tectonized and consist of thick deep sea sediments like argillaceous and silicic Shale, radiolarite and pelagic limestone and volcanic rocks such as basalt, spilitic basalt, diabase, andesite, dacite, rhyolite, and subordinate serpentinized ultramafic rocks. The basement is likely composed to an oceanic crust. Total thickness of this section is 1540 meters and consist of uniform sequence of grayish green shales with intercalations of thin layered sandstones.

After Upper cretaceous, Eocene is a most important time-interval for calcareous nannofossils because they have become one of the most important components of marine phytoplankton. So, in order to the investigation paleoecological conditions and the age determination, a detailed study of calcareous nannofossils samples from Kafaz section was performed under an optical microscope. Kafaz section is under the title of ((East-Flysh zone of Iran)). The studied area is situated in the south west of the geological map of Gazik (Figs 1 and 2). The analysis of calcareous nannofossils was carried out on 121 samples.

Before this study, the studied foraminifera, which conducted by Experts of Geological survey is the only paleontological study in this area. However, other studies such as tectonic evolution, Paleogeography and biostratigraphy investigations has also been carried out by Stocklin and Eftekharneghad(1972), Tirrul et al., (1983), Babazade (2003).

In conclusion, the present study is the first calcareous nannoplankton study in Gazik area and also it is the first biostratigraphy and paleoecology investigation in this region which conducted based on calcareous nannofossils. The exploration of calcareous nannofossils, the discussion of the standard zonation and the investigation of Paleoecological conditions of this area through the Early-Middle Eocene (Yepresian to Lutetian) are three goals of this study.

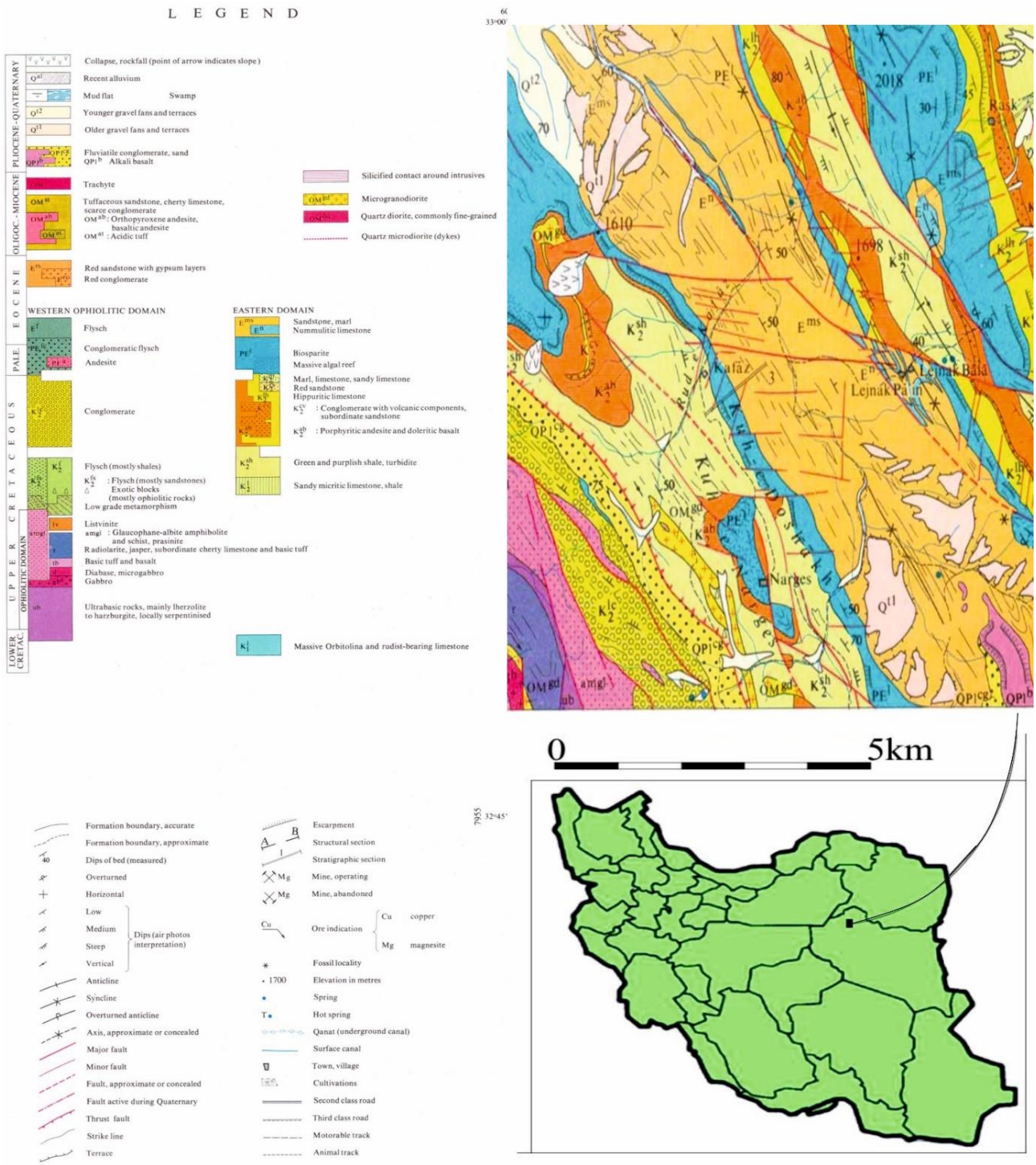

Figure 1) Sample locality of Kafaz section in Gazik map (1:100000).

2- Material and methods

The material examined and described in this paper is taken from the released well section. One hundred-twenty one samples were collected from Kafaz section. For the nannofossils, smear slides were prepared using the technique of

Bown and Young (1998) and examined under a light microscope at 1,000 magnification by both cross-polarized and phase-contrast methods. All calcareous nannofossil specimens encountered were identified following the taxonomic schemes of Cepek and Hay (1969), Thierstein (1976) Perch-Nielsen (1985), Burnett (1998), and Young (1999) (plates 1-7).

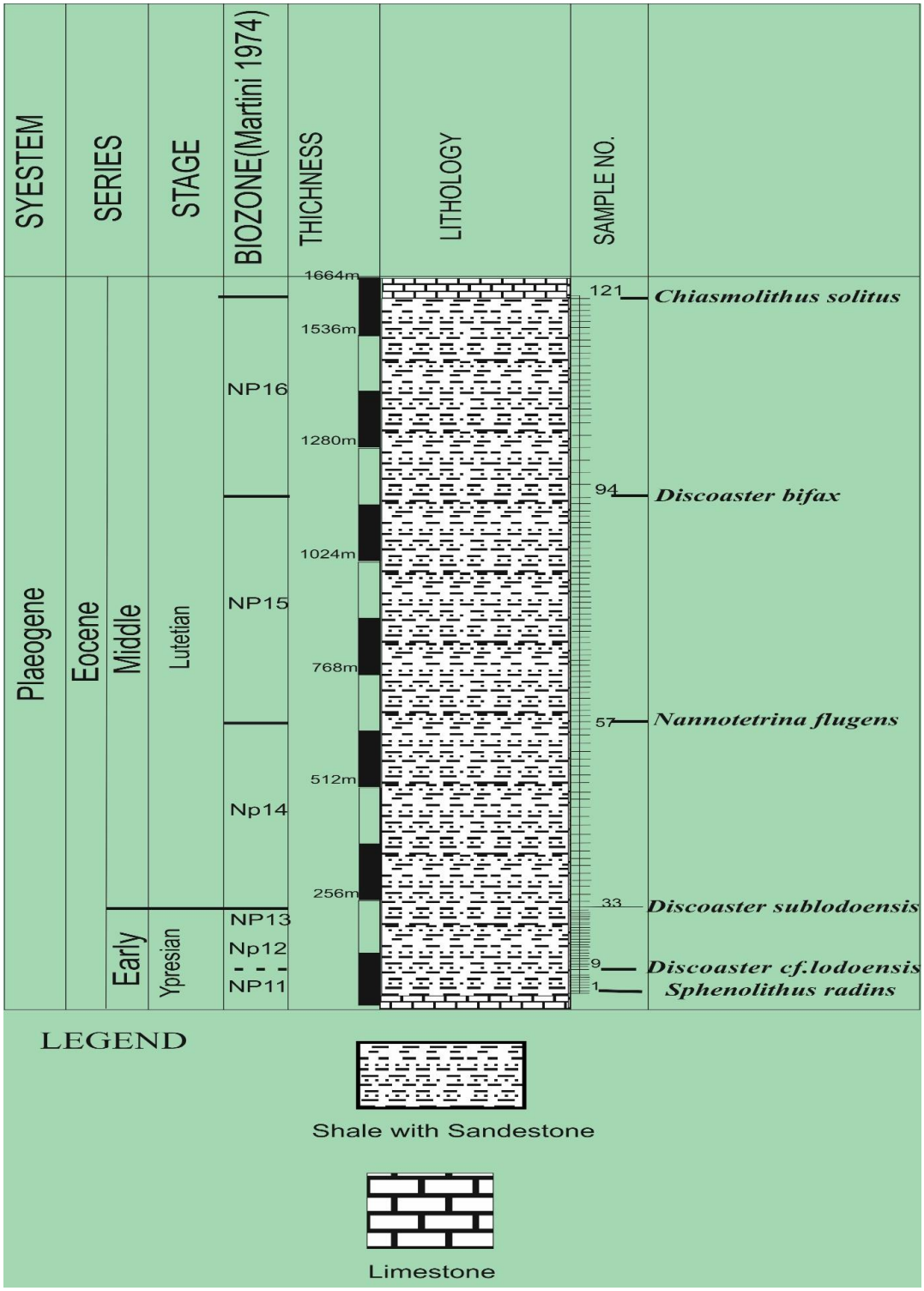

Figure 2) Lithostratigraphic column of Kafaz section.

The assemblages were qualitatively and semi-quantitatively characterized in terms of preservation and abundance.

The total abundance of Calcareous nannofossil was estimated as the number of specimens for the field of view. For the paleoecological studies and because of low abundance of

nannofossils in the studied samples, all nannofossil species were counted in 25 purviews. Next, the percentages of each species for drawing the diagrams were calculated (Table 1).

Table1: Abundance chart of the identified calcareous nannofossils in Kafaz section

period	Yeprisian																			
sedimentaion	Kafaz Section																			
Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Braarudosphaera bigelowii	5	5	2	2	1	2	0	2	1	0	0	0	0	0	0	0	0	0	0	0
Chiasmolithus solitus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clathrolithus ellipticus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccolithus crucis	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccolithus eopalagicus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccolithus formosus	1	5	4	5	4	5	5	5	1	0	5	5	5	5	5	0	0	0	0	0
Coccolithus pelagicus	10	20	24	18	25	15	25	30	25	15	25	15	15	20	15	20	35	20	25	15
Cruciplacolithus edwardsii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cruciplacolithus latipons	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cruciplacolithus primus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclicargarcolithus floridanus	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclagelosphaera reinhardtii	15	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster bifax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.deflandrei	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.lodoensis	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0
Discoaster sp	5	5	5	5	0	0	0	0	0	0	5	0	0	0	0	0	0	5	0	0
Dscoaster sublodoensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.nodiffer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.wemmelensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ericsonia robusta	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fasciculithus clinatus	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fasciculithus janii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Fasciculithus sp	3	2	0	5	5	5	7	15	20	25	15	30	20	21	30	35	25	20	15	30
Fasciculithus tympanyformis	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
Helicosphaera compacta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lanthernithus minutus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Markalius apertus	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrantholithus flos	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrantholithus mirabilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Micrantholithus sp	0	0	0	0	1	5	0	5	5	0	5	5	0	0	0	0	0	0	0	0
Nannotetrina flugens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reticulofenestra bisecta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reticulofenestra dictyoda	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reticulofenestra sp	45	20	30	25	25	20	25	20	20	5	10	5	10	9	5	5	5	10	5	0
Sphenolithus moriformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphenolithus radians	5	20	5	6	5	5	0	3	3	5	5	0	0	1	0	0	0	0	0	0
Sphenolithus sp	5	5	10	10	14	15	10	5	4	5	1	10	5	4	5	5	5	5	5	0
Toweius pertusus	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zygrhablithus bijugatus	10	10	15	14	20	15	25	15	20	45	29	30	45	40	40	35	30	33	50	50
Nannnofossils event	*Sphenolithus radians*									FO *Discoaster cf. Lodoensis*										
Nannofossil zone Martini(1971)	NP11									NP12-NP13										

Table 1) Continued

period	Yeprisian													Lutetian						
sedimentaion	Kafaz Section																			
Sample No.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Braarudosphaera bigelowii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chiasmolithus solitus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clathrolithus ellipticus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccolithus crucis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccolithus eopalagicus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccolithus formosus	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	14	0	0
Coccolithus pelagicus	20	35	25	35	20	15	20	38	0	34	0	33	33	0	50	50	61	38	20	40
Cruciplacolithus edwardsii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0
Cruciplacolithus latipons	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cruciplacolithus primus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclicargarcolithus floridanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclagelosphaera reinhardtii	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster bifax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.deflandrei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.lodoensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dscoaster sublodoensis	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0
Discoaster cf.nodiffer	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.wemmelensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ericsonia robusta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fasciculithus clinatus	0	2	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0
Fasciculithus janii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fasciculithus sp	50	28	50	25	20	70	50	0	50	0	75	33	0	33	25	33	0	18	40	15
Fasciculithus tympanyformis	0	0	0	0	20	0	0	0	16	0	0	0	0	0	0	0	0	0	20	0
Helicosphaera compacta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lanthernithus minutus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Markalius apertus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrantholithus flos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrantholithus mirabilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrantholithus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nannotetrina flugens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reticulofenestra bisecta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reticulofenestra dictyoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reticulofenestra sp	6.7	0	0	0	0	0	0	0	0	25	0	0	33	0	0	0	0	10	20	0
Sphenolithus moriformis	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphenolithus radians	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphenolithus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Toweius pertusus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zygrhablithus bijugatus	23	35	25	40	20	15	20	38	34	25	25	33	17	67	25	33	39	20	0	45
Nannnofossils event	FO *Discoaster sublodoensis*																			
Nannofossil zone Martini(1971)	NP12-NP13													NP14						

Table 1) Continued

period	Lutetian																			
sedimentaion	Kafaz Section																			
Sample No.	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Braarudosphaera bigelowii	0	0	0	0	0	0	0	17	6.3	0	0	0	0	0	0	0	0	0	0	0
Chiasmolithus solitus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clathrolithus ellipticus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccolithus crucis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccolithus eopalagicus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccolithus formosus	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.7	10	0	0
Coccolithus pelagicus	25	25	53	57	20	33	40	40	38	35	0	33	11	33	16	50	37	35	17	36
Cruciplacolithus edwardsii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cruciplacolithus latipons	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cruciplacolithus primus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclicargarcolithus floridanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclagelosphaera reinhardtii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster bifax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.deflandrei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.lodoensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster sp	0	0	0	0	0	0	0	0	0	0	43	0	0	0	0	0	7.4	0	17	7.1
Dscoaster sublodoensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.nodiffer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.wemmelensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ericsonia robusta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0
Fasciculithus clinatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fasciculithus janii	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fasciculithus sp	25	30	16	23	30	0	20	0	50	17	13	40	33	35	1	0	0	0	0	0
Fasciculithus tympanyformis	0	15	0	0	0	0	0	0	0	0	0	0	11	0	7.7	0	0	0	0	0
Helicosphaera compacta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lanthernithus minutus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0
Markalius apertus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrantholithus flos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrantholithus mirabilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrantholithus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nannotetrina flugens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.6	0	0	0
Reticulofenestra bisecta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reticulofenestra dictyoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reticulofenestra sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphenolithus moriformis	0	0	0	0	0	0	0	0	0	19	0	0	11	0	16	25	31	20	33	13
Sphenolithus radians	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.4	5	0	14
Sphenolithus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Toweius pertusus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zygrhablithus bijugatus	25	30	31	20	50	17	40	43	6.3	30	43	27	33	32	50	25	9.6	30	17	31
Nannofossils event	FO *Nannotetina flugens*																			
Nannofossil zone Martini(1971)	NP14																	NP15		

Table 1) Continued

period	Lutetian																			
sedimentaion	Kafaz Section																			
Sample No.	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Braarudosphaera bigelowii	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0
Chiasmolithus solitus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clathrolithus ellipticus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccolithus crucis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccolithus eopalagicus	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0
Coccolithus formosus	10	0	5.6	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	3.4	0
Coccolithus pelagicus	30	36	50	50	50	35	13	40	36	0	39	36	50	25	33	25	75	35	21	40
Cruciplacolithus edwardsii	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0
Cruciplacolithus latipons	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cruciplacolithus primus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclicargarcolithus floridanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclagelosphaera reinhardtii	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster bifax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.deflandrei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.lodoensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster sp	0	0	0	0	0	0	0	0	12	0	7.1	0	0	0	0	0	0	0	6.9	0
Dscoaster sublodoensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.nodiffer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.wemmelensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ericsonia robusta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fasciculithus clinatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fasciculithus janii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0
Fasciculithus sp	0	0	0	5.6	0	0	0	10	0	0	0	0	21	0	0	13	0	0	0	0
Fasciculithus tympanyformis	0	0	0	0	0	0	13	0	15	0	0	0	0	0	0	0	0	0	0	0
Helicosphaera compacta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lanthernithus minutus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Markalius apertus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrantholithus flos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrantholithus mirabilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0
Micrantholithus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.4	0
Nannotetrina flugens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reticulofenestra bisecta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reticulofenestra dictyoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reticulofenestra sp	0	0	0	5.6	0	13	0	20	0	0	0	15	0	0	0	13	0	0	0	7.5
Sphenolithus moriformis	20	29	12	0	39	20	13	0	15	46	21	0	0	25	50	0	0	0	17	13
Sphenolithus radians	20	0	0	0	0	0	0	0	0	33	0	13	0	0	0	0	0	0	6.9	0
Sphenolithus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Toweius pertusus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zygrhablithus bijugatus	20	36	32	39	11	13	50	40	22	21	33	0	29	50	17	25	25	40	41	40
Nannnofossils event	----------																			
Nannofossil zone Martini(1971)	NP15																			

Table 1) Continued

period	Lutetian																			
sedimentaion	Kafaz Section																			
Sample No.	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Braarudosphaera bigelowii	0	0	0	0	0	0	0	0	0	0	0	0	0	5.4	3.3	0	0	1	0	0
Chiasmolithus solitus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clathrolithus ellipticus	0	0	2.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccolithus crucis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccolithus eopalagicus	0	0	0	0	0	0	0	0	0	0	0	0	0	2.7	0	0	0	0	0	0
Coccolithus formosus	3.3	0	4.5	0	0	0	0	4.3	0	8	3.6	0	2.6	2.7	6.7	0	3.3	0	0	0
Coccolithus pelagicus	20	37	43	44	43	32	13	44	47	43	29	58	22	35	20	32	39	35	41	40
Cruciplacolithus edwardsii	0	0	0	0	0	0	0	0	0	0	0	2.3	0	0	0	0	0	0	0	0
Cruciplacolithus latipons	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cruciplacolithus primus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclicargarcolithus floridanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclagelosphaera reinhardtii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Discoaster bifax	0	0	0	0	0	0	0	0	0	0	0	0	0	2.7	0	0	0	0	0	0
Discoaster cf.deflandrei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.lodoensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster sp	0	0	2.3	0	0	0	6.3	0	0	0	3.6	0	0	5.4	0	4.3	0	0	0	0
Dscoaster sublodoensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.nodiffer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.wemmelensis	0	0	0	0	0	0	0	0	0	0	0	0	0	2.7	0	0	0	0	0	0
Ericsonia robusta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fasciculithus clinatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fasciculithus janii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fasciculithus sp	21	6.3	27	11	6.8	0	0	2.6	0	0	28	0	21	0	12	0	20	26	23	17
Fasciculithus tympanyformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6	0	0	0
Helicosphaera compacta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6	0	0	0
Lanthernithus minutus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Markalius apertus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrantholithus flos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrantholithus mirabilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrantholithus sp	0	0	0	0	0	0	0	0	0	0	3.6	0	0	2.7	0	0	0	0	0	0
Nannotetrina flugens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reticulofenestra bisecta	0	0	0	0	0	0	0	0	0	0	0	0	0	2.7	0	0	0	2.1	0	0
Reticulofenestra dictyoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reticulofenestra sp	0	2.3	0	0	2.6	0	0	0	0	3.6	1.6	4.1	0	0	0	0	0	0	0	0
Sphenolithus moriformis	20	17	9.1	0	0	2.6	53	1.3	5.6	12	3.6	8.3	21	14	3.3	31	0	2.1	2.3	3.1
Sphenolithus radians	3.3	0	0	0	0	0	0	0	3.6	0	1.3	0	3.3	4.3	0	5.3	0	0	0	0
Sphenolithus sp	0	0	12	0	0	21	0	0	0	0	3.6	0	0	0	17	0	0	2.1	0	0
Toweius pertusus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zygrhablithus bijugatus	33	38	0	44	57	45	28	48	44	33	23	27	30	20	38	28	34	30	34	40
Nannofossils event	FO *Discoaster bifex*																			
Nannofossil zone Martini(1971)	NP15														NP16					

Table 1) Continued

period	Lutetian																			
sedimentaion	Kafaz Section																			
Sample No.	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
Braarudosphaera bigelowii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.8	0	0
Chiasmolithus solitus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.3
Clathrolithus ellipticus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccolithus crucis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccolithus eopalagicus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccolithus formosus	0	0	0	0	5	0	5	0	0	0	0	0	0	0	0	0	0	0	10	0
Coccolithus pelagicus	49	29	39	37	45	40	25	20	10	25	40	25	15	45	15	35	25	20	30	35
Cruciplacolithus edwardsii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cruciplacolithus latipons	0	0	0	0	0	0	0	0	0	0	0	0	3.4	0	0	0	0	0	0	0
Cruciplacolithus primus	0	0	0	2.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclicargarcolithus floridanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclagelosphaera reinhardtii	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0
Discoaster bifax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.deflandrei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.lodoensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0
Dscoaster sublodoensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.nodiffer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Discoaster cf.wemmelensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ericsonia robusta	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Fasciculithus clinatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fasciculithus janii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fasciculithus sp	9.3	18	2.4	0	5	15	15	25	15	20	10	15	15	5	15	10	15	35	20	5
Fasciculithus tympanyformis	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Helicosphaera compacta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lanthernithus minutus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Markalius apertus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrantholithus flos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrantholithus mirabilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrantholithus sp	0	0	3.6	5	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0
Nannotetrina flugens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reticulofenestra bisecta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reticulofenestra dictyoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Reticulofenestra sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphenolithus moriformis	1.9	7.1	10	10	5	5	10	25	20	20	15	5	6.6	5	15	25	5	5	15	25
Sphenolithus radians	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphenolithus sp	15	11	0	0	5	0	15	0	10	0	0	0	0	0	0	0	0	0	0	0
Toweius pertusus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zygrhablithus bijugatus	25	40	43	45	45	35	25	30	30	35	35	55	60	45	55	30	25	35	25	29
Nannnofossils event	FO *Chiasmolithus solithus*																			
Nannofossil zone Martini(1971)	NP16																			

3- Results

3.1- Nannofossils preservation

Two important factors in nannofossils preservation are dissolution and diagenesis. These factors has a pivotal role in Paleoenvironmental reconstruction (Honjo, 1976; Steinmets, 1994; Andruleit, 1997). In order to assessing nannofossils preservation, the percentage of the dissolution of resistant nannofossils species and the percentage of the total calcareous nannofossils abundance were use (Williams and Bralower, 1995). In studied 121 samples of Kafaz section, calcareous nannofossils have a medium to low preservation. This rate of preservation may be related to the high rate of dissolution and the existence of relatively high levels of clastic particles in sediments. In addition, the structures of nannofossolis in Kafaz section are another reason to show that nannofossils of this section have a low preservation. As shown in the plates, many of nannofossils genera have a lot of deficiencies in their structures so that we cannot recognize of their species. For example, in samples of Kafaz section, there are a lot of Discoaster which identifying of its species are impossible because the number of their rays and arms is invisible.

3.2- Nannofossils diversity and abundance

In this study, 39 species belonging to 21 genera of calcareous nannofossils in Kafaz section were recognized. These nannofossils have well-to-moderate diversity and low abundance. The abundance of calcareous nannoplanktons in one sample is different from another sample and it doesn't follow a general pattern. For instance, *Braarudosphaera bigelowii* and *Sphenolithus moriformis* are abundance in the base and the top of the Kafaz section, respectively.

Coccolithus pelagicus with an average of 30.38%, *Zygrhablithus bijugatus* with an average of 31.26%, *Fasciculithus sp* with an average of 15.10% and *Sphenolithus moriformis* with an average of 7.99% are the dominant species in the base and top of the Kafaz section (Table 1).

Discoaster, Fasciculithus and Reticulofenestra are three genera which present in these samples even though they occur only sporadically with low percentage. Some species such as *Cruciplacolithus primus* and *Chiasmolithus solithus* are rare and also they were identify only from uppermost part of the studied section.

3.3- Calcareous nannofossils zonation

Calcareous nannofossils is one of the best fossil group for biostratigraphy studies in Cenozoic due to their abundance, rapid rate of evolution and plankton nature that make them to occur in a wide dispersal throughout the world oceans (Bown, 1998). Among periods of Cenozoic, Eocene has a well advance of calcareous nannofossil zonation. The global biostratigraphy zonations scheme used for the Early to Middle Eocene deposits follows (Martini, 1971) as modified and illustrated in Perch-Nielsen (1985). For the Paleogen, the first and last occurrence (FO;LO) of species are mainly used for subdivision and zonation.

The most important Early to Middle Eocene calcareous nannofossils provided in Kafaz asection showed in Table 3. In this section, there are five bio-event in the Kafaz section: FO of *Sphenolithus radians*, FO of *Discouaster lodoensis*, FO of *Discoaster sublodoensis*, FO of *Nannotetrina flugens* and FO of *Discoaster bifax* (Table 3). On the basis of FO and LO of marker species, six calcareous nannofossil biozones were indentified in the Kafaz section-ranging in age from Ypresian to Lutetian. The suggested biozones arranged from base to top are *Discoater binodosus, Tribrachiathus orthostylus, Discoaster lodoensis, Discoaster sublodoensis, Nannotetrina flugens* and *Discoaster tanii nodifer* zones.

***Discoaster binodosus* zone (NP11)**

This zone was defined by Mohler and Hay in Hay et al (1967). Early Eocene (Ypresian) is the age of this zone. This zone is an interval between LO of *Tribrachiatus contortus* and FO of *Discoaster lodoensis*. This the oldest identified zone in the Kafaz section. The most dominant species in this zone are *Discoaster distinctus, Sphenolithus editus, S.radians* and *S.conspicuus*. This biozone has 18 meter thickness.

***Tribrachiathus orthostylus* zone (NP12)**

This zone was defined by Bronnimam and Stradner (1960) and Bukry (1973). Early Eocene (Ypresian) is the age of this zone. This zone is an interval between FO of *Discoaster lodoensis* and LO of *Tribrachiathus orthastylus*. Beside marker species, *Discoaster kuepperi* and *Rhabdosphaera truncate* also are dominant species in this biozone. This biozone has 171 meter thickness. However, because the marker species of next biozone (NP13) was not identified in samples, this thickness, in fact, consist of the total thickness of two biozones (NP12+NP13).

***Discoaster lodoensis* zone (NP13)**

This zone was defined by Bronnimam and Stradner (1960) and Bukry (1973). Early Eocene (Ypresian) is the age of this zone. This zone is an interval between LO of *Tribrachiatus contortus* or FO of *Toweius? crassus* and FO of *Discoaster sublodoensis*. The most dominant species in this zone are *Discoaster nanaradiathus, Sphenolithus conspicuus, S.editus.*

***Discoaster sublodeonsis* zone (NP14)**

This zone was defined by Mohler and Hay (1964) and Bukry (1973). Middle Eocene (Lutetian) is the age of this zone. This zone is an interval between FO of *Discaoster sublodoensis* and FO of *Nannotetrina flugens*. The most dominant species in this zone are *Rhabdolithus inflata, Sphenolithus furcatolithoides* and *S.piniger*. This biozone has 503 meter thickness.

***Nannotetrina flugens* zone (NP15)**

This zone was defined by Hay in Hay et al (1967), emend. Martini (1970) and Bukry (1973). Middle Eocene (Lutetian) is the age of this zone. This zone is an interval between FO of *Nannotetrina flugens* and LO of *Rhabdolithus inflate* or FO of *Discoaster bifex. Rhabdosphaera gladius* and *Reticulofenestra umbilica* are other important species in this zone beside marker species. This biozone has 752 meter thickness.

***Discoaster tanii nodifer* zone (NP16)**

This zone was defined by Hay in Hay et al (1967), emend. Martini (1970) and Bukry (1973). Middle Eocene (Lutetian) is the age of this zone. This zone is an interval between FO of LO of *Rhabdolithus inflate* or FO of *Discoaster bifex* and LO of *Chiasmolithus solithus*. This is the youngest zone of the Kafaz section and its thickness is 96 meter.

In conclusion, as mentioned in the previous investigation section, Experts of Geological survey identified that the age of Kafaz sediments is Late Paleocene to Middle Eocene based on studied forminifera. However, the studied calcareous nannofossils revealed that the true age of Kafaz's deposits is Early-Middle (Yepresian-Lutetian) Eocene and as a result, they didn't sediment in Paleocene period.

4- Discussion

Paleoecological features of nannofossils in Kafaz section

Coccolithophores are one of the best fossil groups for paleoecological studies because not only are very abundance but also almost exist in all environment conditions. Coccolithophores are living in the photic zone and as a result, they the intensity of light has a strong influence on the nannofossil assemblages in their sequence strata arrangement (Okada and Hanjo, 1973). Also, calcification sensitivity and growth rate in

nannofossils is extremely depend on their nutrient conditions (Branl, 1994; Paashe, 1998).

Temperature, depth and the rate of nutrition are three major factors in the distribution of calcareous nannoplankton (Bralower, 2002).

Discoaster are considered as an indicator of high temperature water in that they have a low level of abundance in high latitude environments (Bukry, 1973).

Like Discoasters, *coccolithus formosus* is an indicator of warm water because it is absent in high latitude environment (Wei and Wise, 1990).

Coccolithus pelagicus is an important species because of its significant ecological role during the geological time of the earth. For example, Haq and Lohmann (1976) observed that *coccolithus pelagicus* occure in the low to middle latitude environment during Paleocene, while during Eocene, this species existed in middle latitude environment and during Oligocene, it occurred in high latitude environment.

Discoaster, Fasciculithus, Sphenolithus, Zygrhablithus and Ericsonia are genera which indicate the existence of high-temperature waters and oligotrophic conditions (Wei and Wise, 1990).

After studied 121 samples, it was found that *Coccolithus pealgicus, Zygrhablithus bijugatus* and *Sphenolithus moriformis* are the most dominant nannofossils in Kafaz section. Their abundance chart showed in Figure 3.

Regarding to above explantions, Tables 1 and 2 and the abundance chart of three most dominant species, it can be concluded that Kafaz's sediments have been deposited in environment that had a low depth, high-temperature and oligotrophic conditions during Early-Middle Eocene.

5- Conclusions

In this study, 39 species and 21 genera were identified in Kafaz section. The analysis of calcareous nannofossils indicated the presence of Ypresian-Lutetian marine sediments in the east wast of Gazik area. The nannofossil assemblages of Kafaz section have relatively moderate-to-low preservation. The studied sediments in Kafaz section region belong to the first and last occurrence of *Discoaster binodosus, Tribrachiathus orthostylus, Discoaster lodoensis. Discoaster sublodeonsis. Nannotetrina flugens* and *Discoaster tanii nodifer*, respectively. The attribution of these biozones permits us to access an age of late Ypresian to Early Lutetian for the studied section. Paying attention to three dominant species (*Coccolithus pealgicus*, *Zygrhablithus bijugatus* and *Sphenolithus moriformis*) and the existence of uniform lithology of Kafaz section suggest that these sediments have been deposited in a low depth environment. Index calcareous nannofossil species at the studied sediments indicate low nutrients in relation to oligotrophic conditions and show that the basin of this sediments is in a low latitude with warm temperature.

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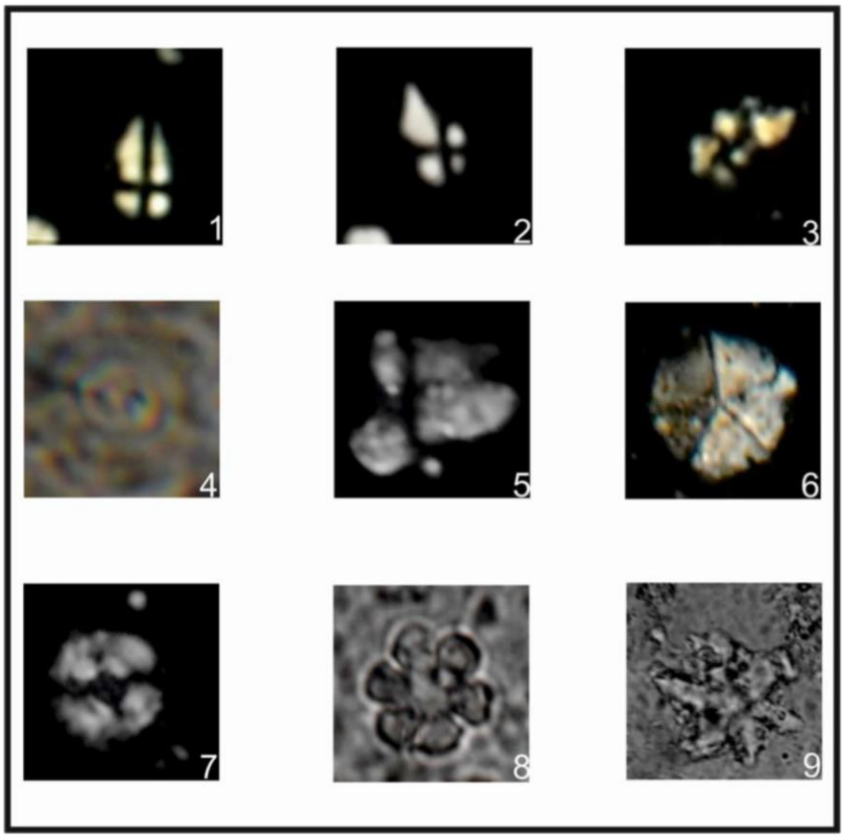

Plate 1: 1,2. Sphenolithus radians, 3,4.Toweius pertusus, 5.Fasciculithus janii, 6.Micrantholithus flos, 7.Coccolithus crusis, 8.Discoaster cf.deflandrei , 9.Discoaster cf. lodoensis (All figures light micrographs magnified x 1000).

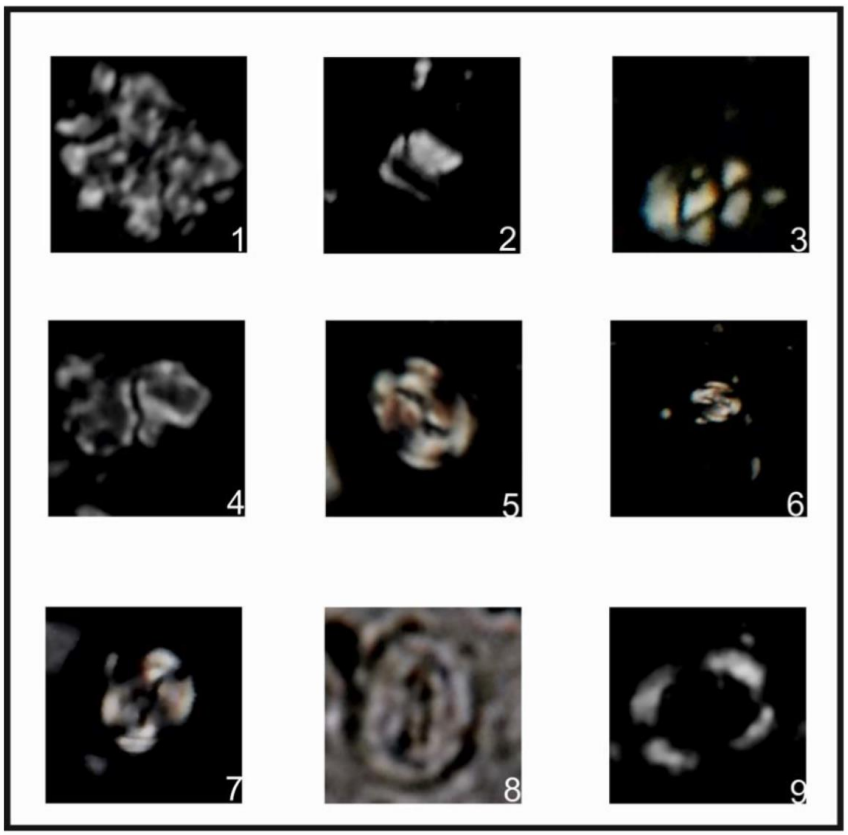

Plate 2: 1.Nannotetrina flugens, 2. Fasciculithus tympanyformis, 3. Coccolithus pelagicus, 4. Fasciculithus clinatus, 5 – 8. Reticulofenestra bisecta, 9. Chiasmolithus cf.solitus (All figures light micrographs magnified x 1000).

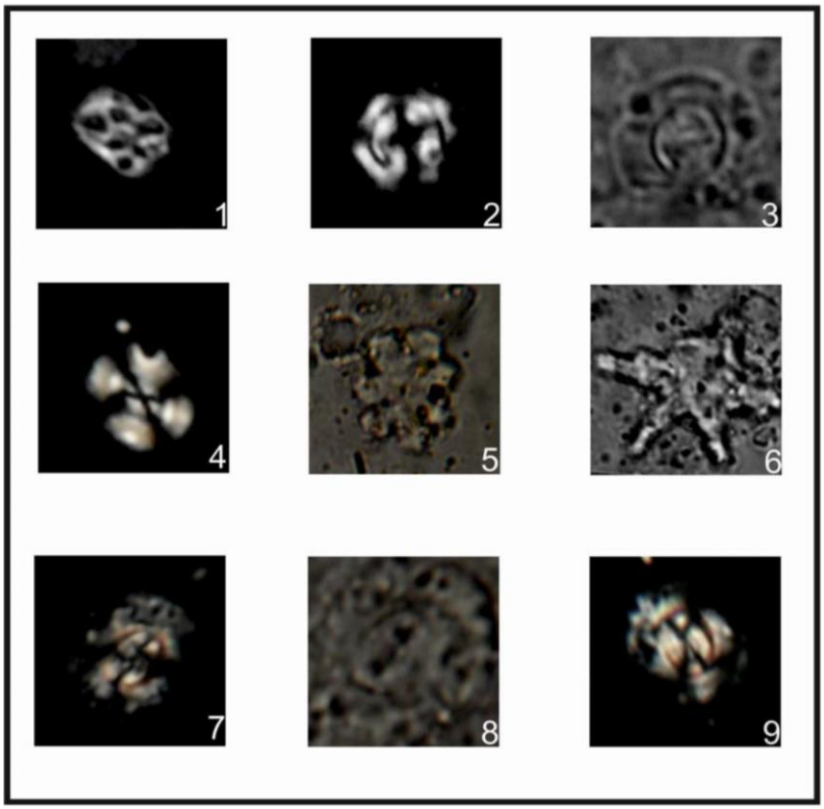

Plate 3: 1. *Clathrolithus ellipticus*, 2,3. *Coccolithus formosus*, 4. *Cyclagelosphaera renhardtii*, 5. *Discoaster cf.nodifer*, 6. *Discoaster sublodoensis*, 7-9. *Coccolithus pelagicus* (*All figures light micrographs magnified x 1000).*

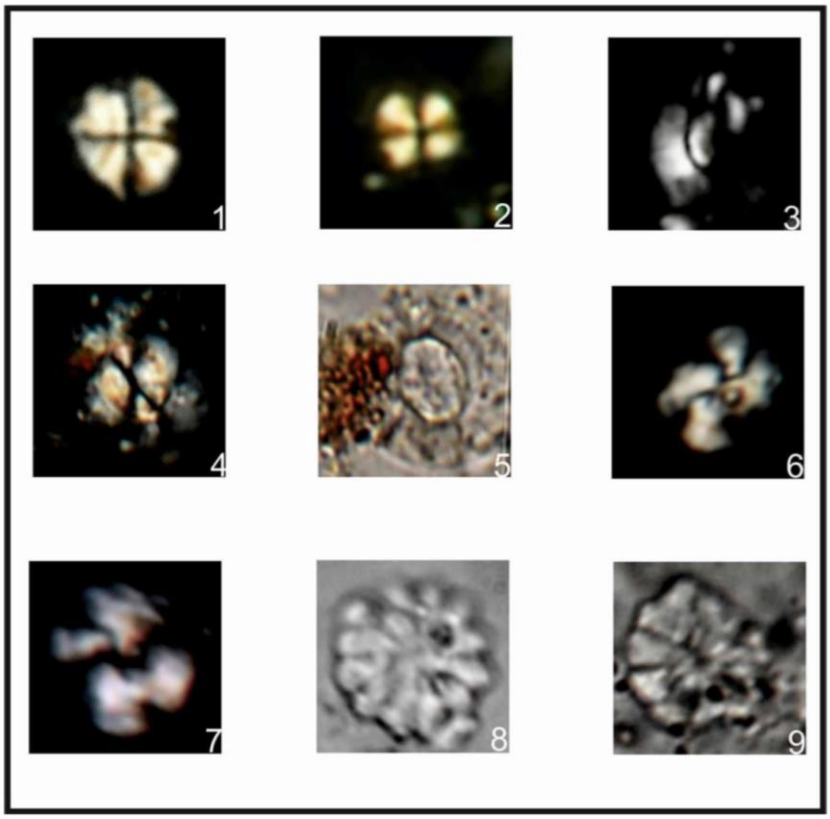

Plate 4: 1,2. Sphenolithus moriformis, 3. Helicosphaera cf. compacta, 4,5. Coccolithus eopelagicus, 6,7. Cyligarcolithus floridanus, 8. Discoaster bifax, 9. Discoaster cf.wemmelensis (All figures light micrographs magnified x 1000).

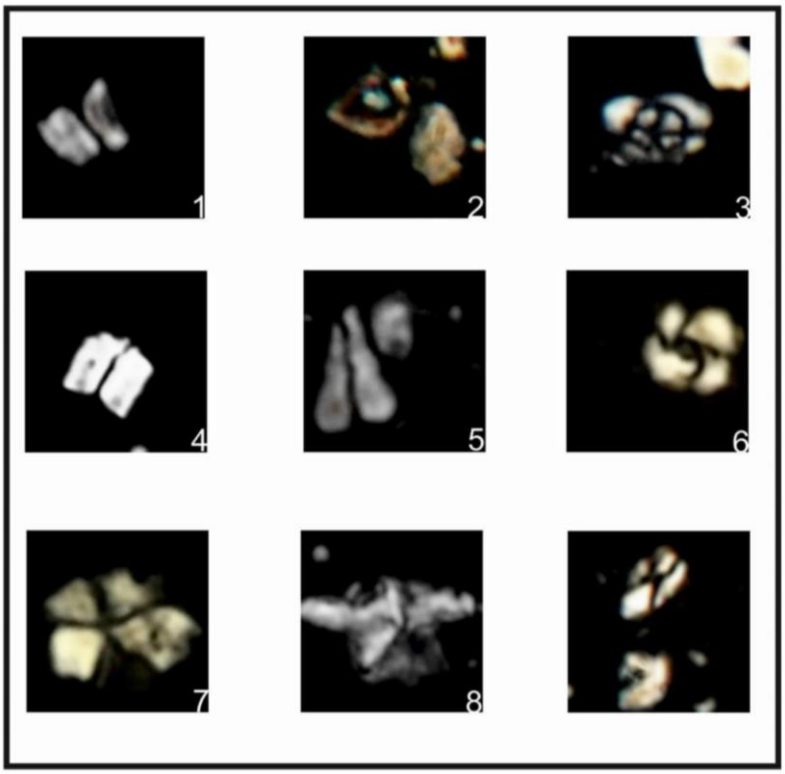

Plate 5: 1, 2. Fasciculithus sp, 3. Cruciplacolithus latipons, 4. Fasciculithus tympanyformis, 5. Zygrhablithus bijugatus, 6. Reticulofenestra dictyoda, 7. Braarudosphaera bigelowii, 8. Micrantholithus mirabilis, 9. Lanthernitus minutus (All figures light micrographs magnified x 1000).

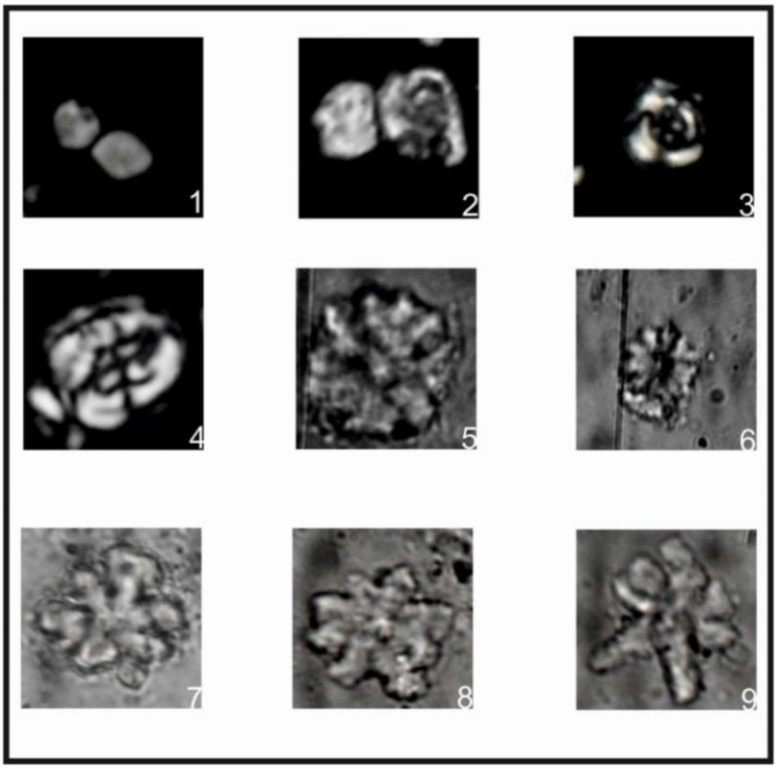

Plate 6: 1,2. Fasciculithus sp, 3. Cruciplacolithus primus, 4. Cruciplacolithus edwardsii, 5-9. Discoaster sp (All figures light micrographs magnified x 1000).

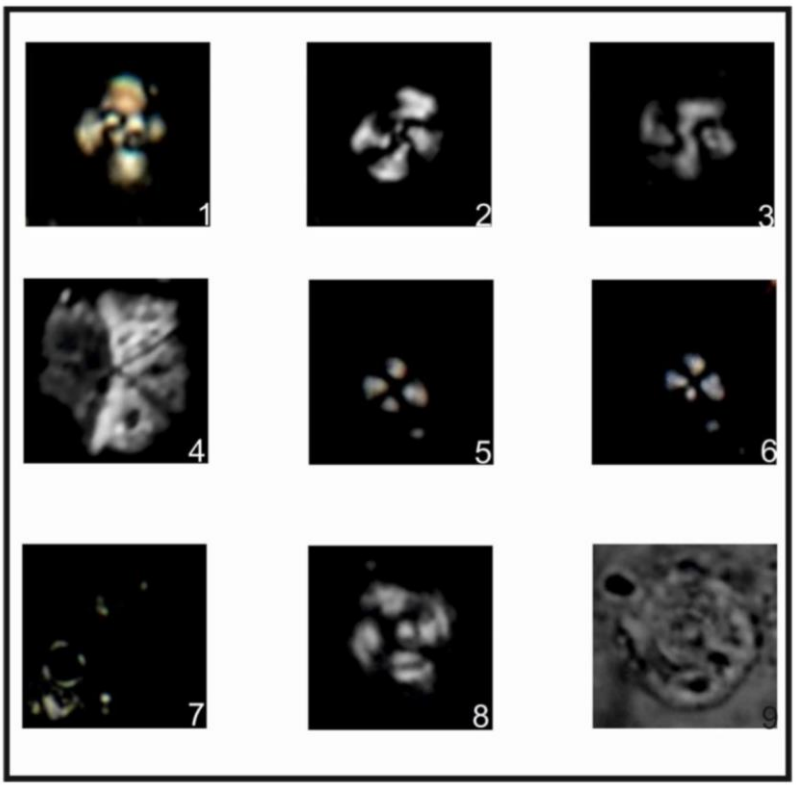

Plate 7: 1-3. Reticulofenestra sp, 4. Micrantholithus sp, 5,6. Sphenolithus sp, 7. Markalius apertus, 8,9. Ericsonia robusta (All figures light micrographs magnified x 1000).