Islamic Azad University
Mashhad Branch

Hadavi et al. / Iranian Journal of Earth Sciences 8 (2016) / 52-68

Biostratigraphy and paleoecology of Cretaceous rocks based on calcareous nannofossil in Sarayan section, East Iran

Fatemeh Hadavi[1], Marziyeh Notghi Moghaddam[2]*, Lida Khodadadi[3]

1. Professor, Department of Geology, Ferdowsi University of Mashhad, Mashhad, Iran
2. Assistant Professor, Department of Geology, Payame Noor University, Tehran, I.R of Iran
3. Department of Geology, Payame Noor University, Tehran, I.R of Iran

Received 1 June 2015; accepted 10 January 2016

Abstract

Calcareous nannofossil assemblages recovered from a long, continuous section have been described from the Sarayan region in Lut Block in east Iran. The marine Upper Cretaceous sediments of this section yield medium diverse and well-preserved calcareous nannofossil assemblages. A structural analysis of Upper Cretaceous calcareous nannofloras has revealed 30 nannofossil species. A revised zonation for the Cretaceous is used to subdivide the Cretaceous deposits in this section into five zones (CC21-CC25). Finally, the paleoecological applications of Upper Cretaceous nannofossils are considered in this section. Surface water temperature, productivity, and fertility are believed to have been the principal factors controlling species distribution. Warm water indicators such as Uniplanarius sissinghii, Uniplanarius trifidus, and Micula murus suggest warm surface water conditions in the studied thickness. In the Sarayan section, based on Lithraphidites carniolensis and Watznaueria barnesae, lower fertility conditions with low productivity at the Campanian to Maastrichtian were suggested for this region.

Keywords: *Biostratigraphy, Paleoecology, Cretaceous, Calcareous nannofossil, Sarayan, Iran*

1. Introduction

The Upper Cretaceous time-interval represents a particularly important period for calcareous nannofossils. During this time, coccolithophorid alge formed has become an increasingly important component of marine phytoplankton. This group of microfossils is very useful for biostratigraphy and paleoecology studies. Therefore, for the age determination and investigation of paleoecological conditions in Lut Block, a detailed study of calcareous nannofossils samples of the samples from Sarayan region was performed under an optical microscope. The Lut Block is under the title of 'Median Mass of East Iran'. This basin is a region characterized by the Jurassic-Cretaceous-Tertiary sequence (Stocklin and Nabavi 1973). The investigated sequence belongs to the marl and thin-bedded shale and cobblestone marl between the shale below and unsorted conglomerate above. These rocks represent a transect of 316 m that extents from the eastern margin of the Lut Block in Sarayan region, which was sampled (Figs. 1 and 2). The analysis of calcareous nannofossils was carried out on 68 samples.
The aim of this study is to identify the calcareous nannofossil species, to discuss the standard zonation, and to investigate the paleoecological conditions of this area through the Upper Cretaceous-especially during the Campanian to Maastrichtian.

2. Geological framework

The study area (Sarayan section) is located within the eastern Lut Block margin, east Iran (Fig. 1). Stocklin and Nabavi (1973) showed the Lut Block on their tectonic map of Iran as a separate structural zone and described it under the title of 'Median Mass of East Iran'. They stated that the 'Lacunar Jurassic-Cretaceous-Tertiary' sequence of similar facies are similar to that in central Iran, but sub-horizontal to gently warped and faulted, presumably resting on a rigid substratum consolidated in late Triassic and/or even earlier time. The investigated sedimentary interval spans from samples S_1-S_{89} and consists mostly of shale, marl, and thin bedded shale and cobblestone marl between the shale below and pink coloured unsorted conglomerate above (Fig. 2). The thickness of these sediments is 356m.

3. Material and methods

The material examined and described in this paper is taken from the released well section. Eighty-nine samples were collected from the Sarayan section, sampled at intervals from 4m. For the nannofossils, smear slides were prepared using the technique of Bown

----
*Corresponding author.
E-mail address (es): m.n.moghaddam@gmail.com

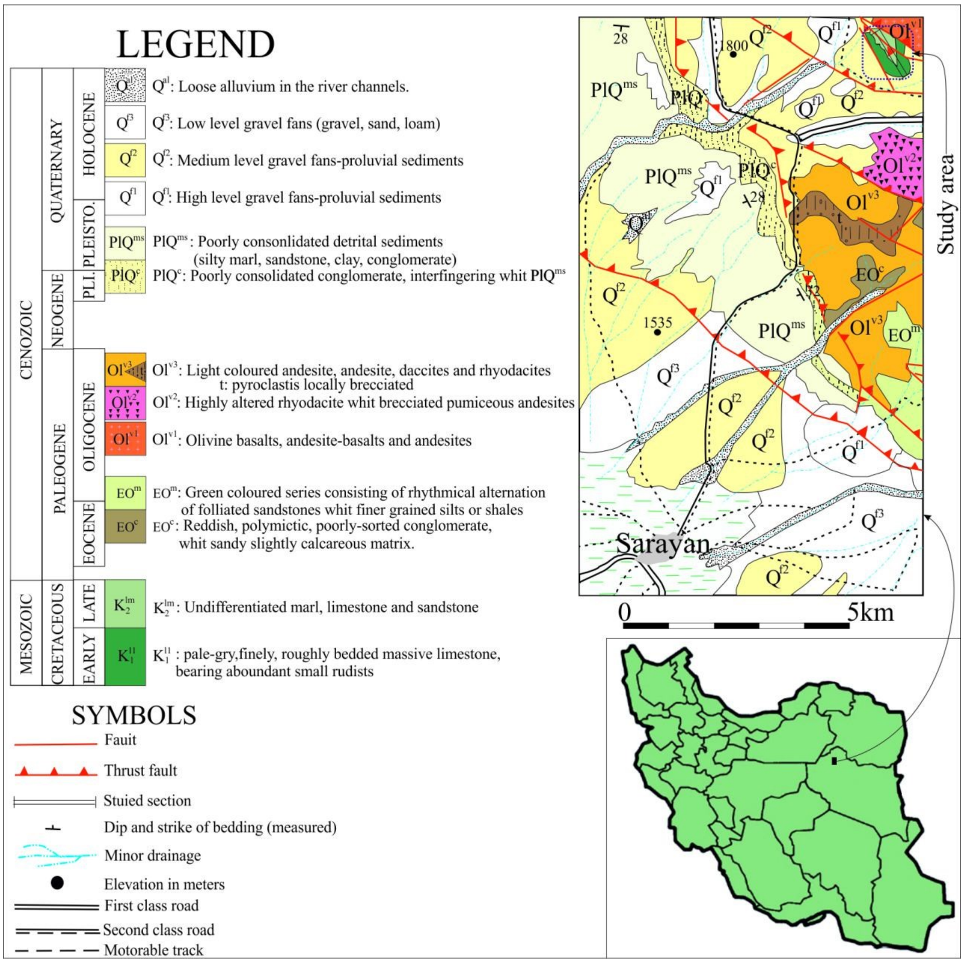


Fig. 1 Sample locality of Sarayan section. With changes of in the Grimonj map (1:100000) (after Amidi and Navai, 2005)

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) (Figures 3–7).

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 10 purviews. Next, the percentages of each species for drawing the diagrams were calculated (Table 1).

4. Previous investigation

The earliest paleontological studies of the Cretaceous deposits of the Lut Block focused on foraminifera (e.g., Babazadeh et al. (2010)). Some sedimentology investigations, magmatic evolution, and tectonic evolution**,** have also been conducted by Babazadeh et al. (2010), Saadat et al. (2010), Mazhari and Sharifiyan Attar (2012), and Asadi and Kolahdani (2014).

Previous nannofossil studies of Cretaceous deposits in Lut Block were by Hadavi et al. (2012) in the Gazak section (east Birjand).

In the present study, the nannofloras of the Sarayan region were discussed for the first time, and biostratigraphy and paleoenvironmental conditions across Campanian to Maastrichtian of this basin were deliberated.

5. Results

5.1. Nannofossils preservation

Dissolution and diagenesis can strongly alter the preservation of calcareous nannofossil assemblage. These factors can severely affect their application to paleoenvironmental reconstructions (Honjo, 1976; Steinmetz, 1994; Andruleit, 1997). The percentage of the dissolution of resistant nannofossil species and the percentage of the total calcareous nannofossil abundance were used to assess preservation (Williams and Bralower, 1995). In 89 samples from the Sarayan section, the nannofossils are not affected by etching; delicate structures are, however, still preserved but

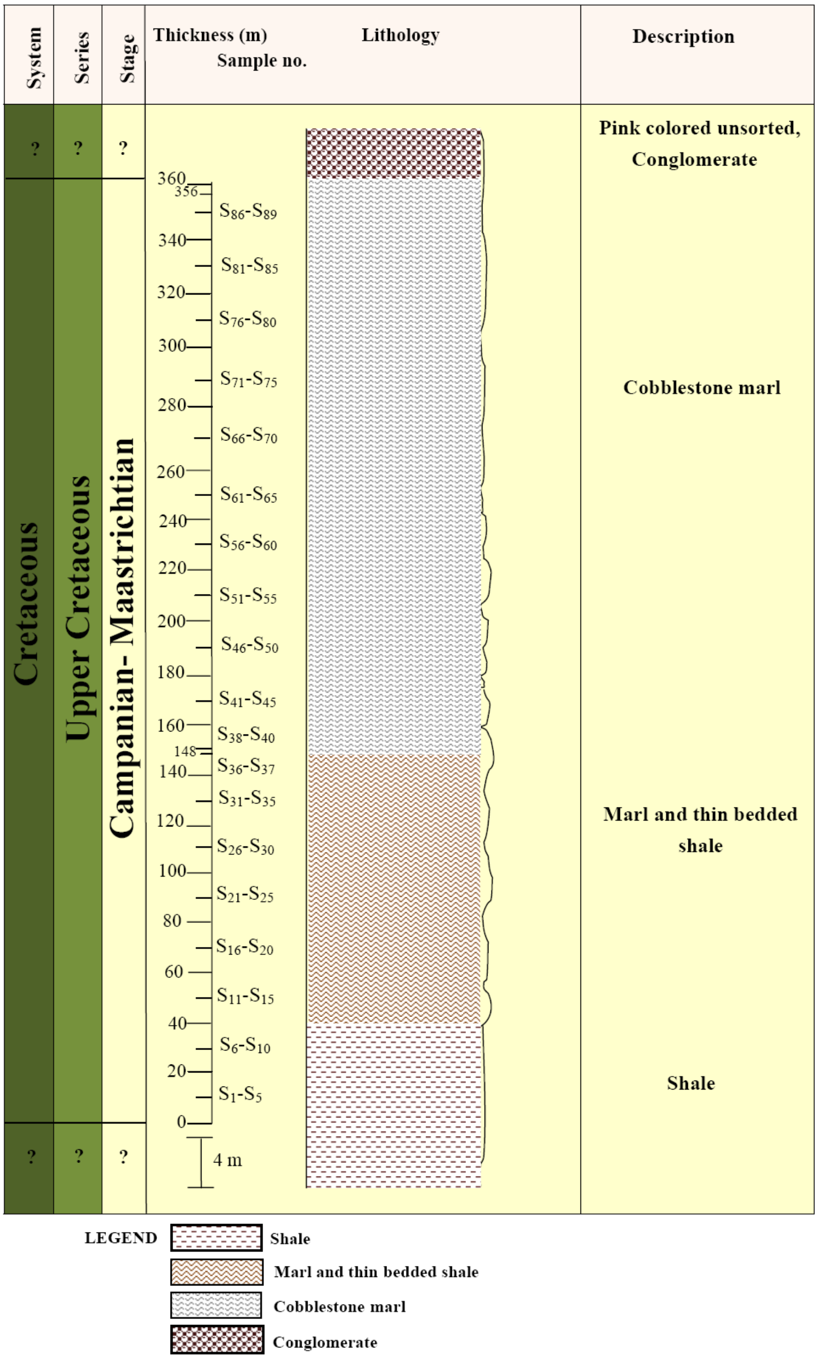


Fig. 2: Lithostratigraphic column of the Sarayan section.

significantly affected by secondary calcite overgrowth and some coccolith central structures sometimes tend to be lightly overgrown. Many authors use the percentage of the robust form of *W. barnesae*, which is less susceptible to dissolution, to assess the impact of the diagenesis. According to Roth and Krumbach (1986), assemblages containing less than 40% of *W. barnesae* are thought to be only slightly altered by diagenesis and can be used as primary signal. In this study, the abundance of *W. barnesae* varies in most cases from 10% to 64% in Table 1.

In conclusion, it is reasonable to think that the calcareous nannofossil assemblages of this section reflect a primary signal and can therefore be used as paleoenvironmental proxies to reconstruct the surface water conditions of the Lut Block basin.

Table 1: Abundance chart of the identified calcareous nannofossil species in the Sarayan section.

EARLY LATE CAMPANIAN																						PERIOD
SARAYAN SECTION																						SEDIMENTATION
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	SAMPLE No.
																						TAXA
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.67	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Acuturris scottus*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Arkhangelskiella cymbiformis*
0.00	0.00	0.00	0.00	0.67	1.00	0.00	0.00	0.00	1.00	0.67	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.33	0.33	*Aspidolithus parcus parcus*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Braarudosphaera bigelowii*
0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Bukryaster hayi*
5.00	4.33	6.33	6.00	6.67	7.00	5.00	4.33	4.00	0.00	0.00	0.00	0.00	0.00	4.33	6.00	4.00	4.00	4.00	6.00	5.00	6.00	*Calculites obscurus*
0.00	0.00	1.00	0.00	0.00	0.00	0.33	0.33	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	*Calculites ovalis*
0.00	0.00	0.00	0.00	0.00	1.67	1.00	0.67	1.00	1.33	1.00	0.33	0.33	0.33	0.67	1.33	1.67	1.00	1.00	1.33	0.00	0.00	*Ceratolithoides aculeus*
0.00	0.00	0.00	0.33	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Ceratolithoides arcuatus*
0.00	0.00	0.00	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	*Ceratolithoides sesquipedalis*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Cycloglosphaera deflandrei*
1.33	0.33	1.00	2.00	0.33	1.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	*Eiffellithus gorkae*
0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Eiffellithus turriseiffelii*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Gartnerago obliquum*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Lithraphidites sp.*
19.00	18.00	19.00	17.00	15.00	18.00	17.00	15.33	18.67	12.67	15.00	13.00	14.00	12.33	15.00	15.33	14.67	17.00	13.00	14.00	15.00	14.33	*Lucianorhabdus cayeuxii*
0.00	0.00	0.00	0.00	1.33	1.00	1.00	1.67	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.67	0.33	0.00	0.00	*Lucianorhabdus maleformis*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Marthastrites simplex*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Micula concava*
18.33	18.33	14.33	13.33	15.33	16.00	18.00	14.00	16.33	14.67	16.33	12.00	13.00	16.00	17.00	15.67	12.33	13.00	13.00	14.00	16.00	16.33	*Micula decussata*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***Micula murus***
0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	*Micula swastika*
0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Nannoconus* sp1
0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Nannoconus* sp2
1.00	0.33	0.67	1.33	1.33	1.33	2.00	2.00	1.67	1.33	1.00	2.00	1.67	0.67	0.33	0.33	0.33	0.33	0.67	0.33	0.67	0.33	*Quadrum gothicum*
39.67	36.67	31.00	38.66	34.33	33.00	40.00	45.00	40.00	49.33	39.00	45.00	44.67	46.00	40.00	38.33	37.00	40.00	44.00	39.33	39.67	39.00	***Quadrum Sissinghii***
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***Quadrum trifidum***
0.67	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.33	0.33	0.33	0.00	***Reinhardtites anthophorus***
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***Reinhardtites levis***
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.33	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***Tranolithus phacelosus***
10.00	15.00	18.33	15.00	17.67	12.00	11.33	11.00	11.67	12.00	19.00	20.33	18.00	16.33	12.33	15.00	20.00	16.33	17.00	17.67	17.33	18.00	*Watznaueria barnesae*
5.00	6.67	7.33	5.67	6.00	6.67	4.33	5.67	4.33	7.00	8.00	7.00	7.33	7.33	8.00	8.00	9.00	7.00	6.33	5.66	5.33	5.66	*Watznaueria biporta*
FO Quadrum Sissinghii																						NANNOFOSSIL EVENT
CC21																						NANNOFOSSIL ZONE Sissingh (1977)

Table 1: Continued.

LATEEST CAMPANIAN- EARLY MAASTRICHTIAN																								PERIOD
SARAYAN SECTION																								SEDIMENTATION
46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	SAMPLE No.
																								TAXA
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Acuturris scottus*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	*Arkhangelskiella cymbiformis*
0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Aspidolithus parcus parcus*
0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	*Brarudosphaera bigelowii*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Bukryaster hayi*
6.00	7.00	7.00	6.67	4.00	3.67	4.00	5.00	5.33	5.00	7.33	7.00	5.00	4.33	5.00	4.00	5.00	6.00	6.33	5.00	2.33	7.00	7.00	5.00	*Calculites obscurus*
0.00	0.33	0.67	1.00	1.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Calculites ovalis*
0.00	0.00	0.00	0.00	0.00	0.00	1.67	1.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Ceratolithoides aculeus*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	*Ceratolithoides arcuatus*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	*Ceratolithoides sesquipedalis*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Cycloglosphaera deflandrei*
1.00	1.67	1.33	1.00	0.33	0.33	1.67	1.00	0.67	1.00	0.33	2.00	0.00	1.33	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	*Eiffellithus gorkae*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	*Eiffellithus turriseiffelii*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Gartnerago obliquum*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Lithraphidites sp.*
15.00	13.00	11.00	12.00	11.00	13.67	12.33	12.33	11.00	12.33	12.00	14.67	15.00	16.33	12.00	14.00	14.67	12.67	11.67	12.00	15.00	16.00	13.67	12.33	*Lucianorhabdus cayeuxii*
0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.67	2.00	1.33	2.00	0.00	0.00	0.00	0.00	0.00	*Lucianorhabdus maleformis*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Marthastrites simplex*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Micula concava*
15.00	12.00	10.67	12.67	13.00	16.00	15.00	14.00	13.33	14.67	15.00	15.00	14.00	12.33	12.00	12.33	11.00	12.00	14.00	13.00	15.00	16.33	14.00	10.00	*Micula decussata*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***Micula murus***
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Micula swastika*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Nannoconus* sp1
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Nannoconus* sp2
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Quadrum gothicum*
28.33	29.00	30.00	29.33	32.00	33.00	30.00	29.33	32.00	30.67	34.00	26.33	29.00	36.33	36.67	30.00	32.00	33.00	31.00	30.67	30.67	29.00	30.67	32.00	***Quadrum Sissinghii***
14.00	16.33	19.00	17.00	19.00	12.00	16.33	18.00	18.00	17.00	11.33	16.00	19.33	13.00	16.33	19.00	17.00	15.00	16.67	17.67	17.00	10.00	12.00	15.33	***Quadrum trifidum***
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***Reinhardtites anthophorus***
0.33	0.33	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.33	0.33	0.00	0.00	0.00	0.00	0.33	0.33	***Reinhardtites levis***
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.33	0.67	0.33	***Tranolithus phacelosus***
15.67	15.00	14.00	14.00	15.00	15.00	12.00	12.00	11.33	12.33	12.67	12.00	13.33	13.00	13.00	14.00	14.00	14.33	14.33	17.00	14.00	15.67	16.00	19.00	*Watznaueria barnesae*
4.67	5.00	6.00	6.00	4.00	6.33	5.00	6.33	7.33	7.00	7.33	7.00	4.00	3.33	3.33	4.00	4.00	5.33	4.00	4.33	5.67	5.00	4.33	4.00	*Watznaueria biporta*
LO Reinhardtites anthophorus																								NANNOFOSSIL EVENT
CC23																								NANNOFOSSIL ZONE Sissingh (1977)

Table 1: Continued.

LATE LATE CAMPANIAN																							PERIOD
SARAYAN SECTION																							SEDIMENTATION
23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	SAMPLE No.
																							TAXA
0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.33	0.33	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	1.00	0.67	0.00	*Acuturris scottus*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Arkhangelskiella cymbiformis*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	1.33	1.33	1.00	0.33	0.00	0.00	0.00	0.33	0.67	0.33	0.00	*Aspidolithus parcus parcus*
0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.67	0.67	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Brarudosphaera bigelowii*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Bukryaster hayi*
6.67	6.67	6.67	8.00	8.00	7.00	7.00	7.00	7.67	8.00	8.00	7.67	4.33	3.67	4.00	6.00	5.00	5.00	4.33	6.00	6.33	5.00	5.00	*Calculites obscurus*
0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.33	0.67	1.00	0.00	0.00	0.00	0.00	*Calculites ovalis*
0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.67	1.00	0.33	0.33	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	*Ceratolithoides aculeus*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Ceratolithoides arcuatus*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Ceratolithoides sesquipedalis*
0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Cycloglosphaera deflandrei*
0.00	0.33	1.67	1.00	0.33	0.33	1.00	0.33	2.00	0.33	1.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.33	0.67	*Eiffellithus gorkae*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Eiffellithus turriseiffelii*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Gartnerago obliquum*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Lithraphidites sp.*
18.00	12.00	13.00	11.00	13.00	14.00	13.67	12.33	10.00	15.00	14.00	14.33	12.00	15.00	16.00	15.00	17.00	16.33	13.00	13.33	12.00	16.00	15.66	*Lucianorhabdus cayeuxii*
0.00	1.67	1.67	2.00	0.00	2.00	2.00	2.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.33	1.00	1.67	*Lucianorhabdus maleformis*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Marthastrites simplex*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Micula concava*
13.00	13.33	14.00	14.00	12.00	12.00	11.67	12.33	13.00	14.00	11.00	11.67	12.00	11.00	12.00	10.00	11.00	12.00	12.67	14.00	13.00	12.00	12.00	*Micula decussata*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***Micula murus***
0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Micula swastika*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Nannoconus* sp1
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Nannoconus* sp2
1.00	1.00	1.00	1.67	1.67	1.00	1.67	1.33	2.00	0.33	1.67	1.00	1.33	1.00	0.33	0.67	0.67	1.33	2.00	1.33	0.00	0.00	0.00	*Quadrum gothicum*
25.67	32.00	29.00	28.00	31.67	32.00	31.00	31.00	29.00	30.00	34.33	33.67	36.33	32.00	30.00	30.00	31.00	30.00	30.00	34.00	31.00	31.00	33.00	***Quadrum Sissinghii***
11.00	15.67	15.67	14.67	13.33	13.00	10.00	11.67	11.33	10.00	12.00	13.33	16.33	17.00	18.00	16.33	15.00	14.33	16.00	10.00	11.00	11.00	12.00	***Quadrum trifidum***
0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.33	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.33	0.33	0.33	***Reinhardtites anthophorus***
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	***Reinhardtites levis***
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.00	0.00	0.00	0.00	***Tranolithus phacelosus***
19.00	12.00	12.00	14.00	14.67	13.00	13.33	15.00	14.33	14.00	12.67	12.00	11.00	15.00	14.33	16.33	17.00	16.00	16.00	16.33	17.00	17.00	15.00	*Watznaueria barnesae*
5.33	5.00	4.00	5.00	5.00	5.67	6.00	5.00	6.33	6.33	4.00	4.33	4.00	4.00	4.00	3.33	3.00	4.00	4.00	4.00	5.00	5.00	4.33	*Watznaueria biporta*
FO Quadrum trifidum																							NANNOFOSSIL EVENT
CC22																							NANNOFOSSIL ZONE Sissingh (1977)

Table 1: Continued.

EARLY MAASTRICHTIAN - LATE MAASTRICHTIAN																				PERIOD
SARAYAN SECTION																				SEDIMENTATION
70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	SAMPLE No.
																				TAXA
0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Acuturris scottus*
0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	*Arkhangelskiella cymbiformis*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Aspidolithus parcus parcus*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.00	0.00	0.00	0.00	0.33	0.00	*Brarudosphaera bigelowii*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Bukryaster hayi*
10.67	10.33	7.67	7.00	11.33	11.00	12.00	11.33	13.00	8.00	6.00	11.00	11.00	10.33	9.00	5.67	11.00	10.33	8.00	8.00	*Calculites obscurus*
0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Calculites ovalis*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.33	0.33	0.33	0.00	0.00	0.00	0.00	*Ceratolithoides aculeus*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Ceratolithoides arcuatus*
0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Ceratolithoides sesquipedalis*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Cycloglosphaera deflandrei*
0.33	1.33	0.33	1.33	1.33	0.67	1.33	0.67	1.00	1.00	1.33	0.33	0.33	0.33	1.00	0.33	0.33	1.00	0.33	0.67	*Eiffellithus gorkae*
0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Eiffellithus turriseiffelii*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Gartnerago obliquum*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Lithraphidites sp.*
19.33	14.00	15.00	17.00	16.33	19.00	18.00	15.00	16.00	10.00	12.00	16.67	14.00	15.67	12.00	11.00	14.00	15.00	16.00	17.00	*Lucianorhabdus cayeuxii*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	1.00	1.67	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Lucianorhabdus maleformis*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Marthastrites simplex*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	*Micula concava*
8.67	7.00	10.33	8.00	7.67	7.33	6.00	7.00	8.00	8.33	7.67	8.00	7.00	7.00	6.67	6.00	8.33	8.00	8.33	9.00	*Micula decussata*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	1.00	0.67	1.00	1.33	***Micula murus***
0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Micula swastika*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Nannoconus* sp1
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Nannoconus* sp2
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*Quadrum gothicum*
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***Quadrum Sissinghii***
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***Quadrum trifidum***
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***Reinhardtites anthophorus***
0.33	0.33	0.33	0.33	0.00	0.00	0.00	0.33	0.67	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***Reinhardtites levis***
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***Tranolithus phacelosus***
55.00	58.33	56.00	56.00	53.00	52.00	56.00	55.33	51.00	59.00	59.00	48.67	58.00	61.00	63.00	64.33	59.67	56.00	56.33	56.67	*Watznaueria barnesae*
5.67	8.33	10.00	10.00	9.33	10.00	6.33	10.00	10.00	12.67	13.00	12.67	8.00	6.00	7.67	12.33	5.67	8.67	9.67	7.33	*Watznaueria biporta*
LO Tranolithus phacelosus										***LO Reinhardtites levis***										NANNOFOSSIL EVENT
CC24										CC25										NANNOFOSSIL ZONE Sissingh (1977)

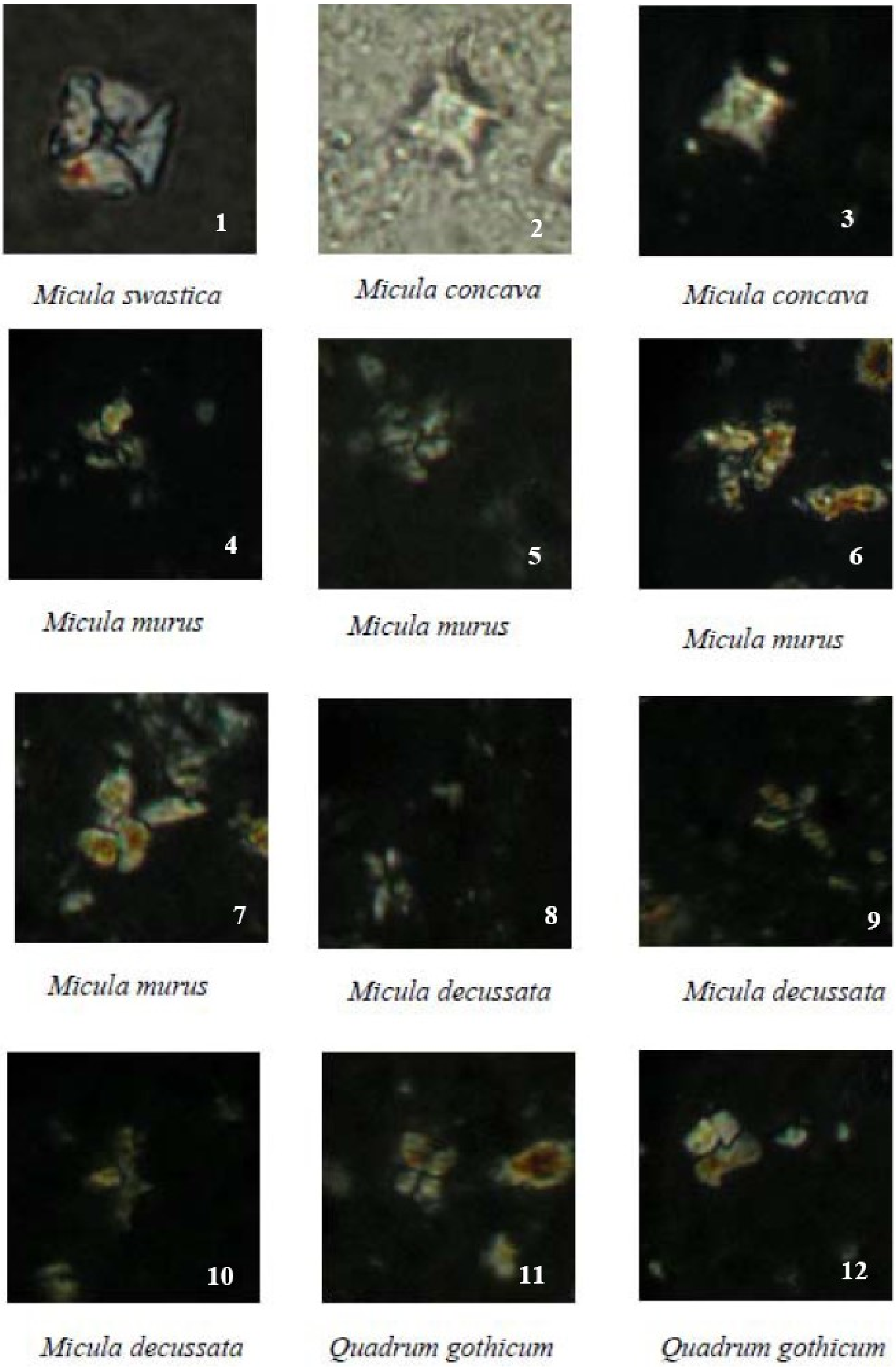


Figure 3**:** Nannofossil pictures of the studied sections (All figures light micrographs magnified X1000)

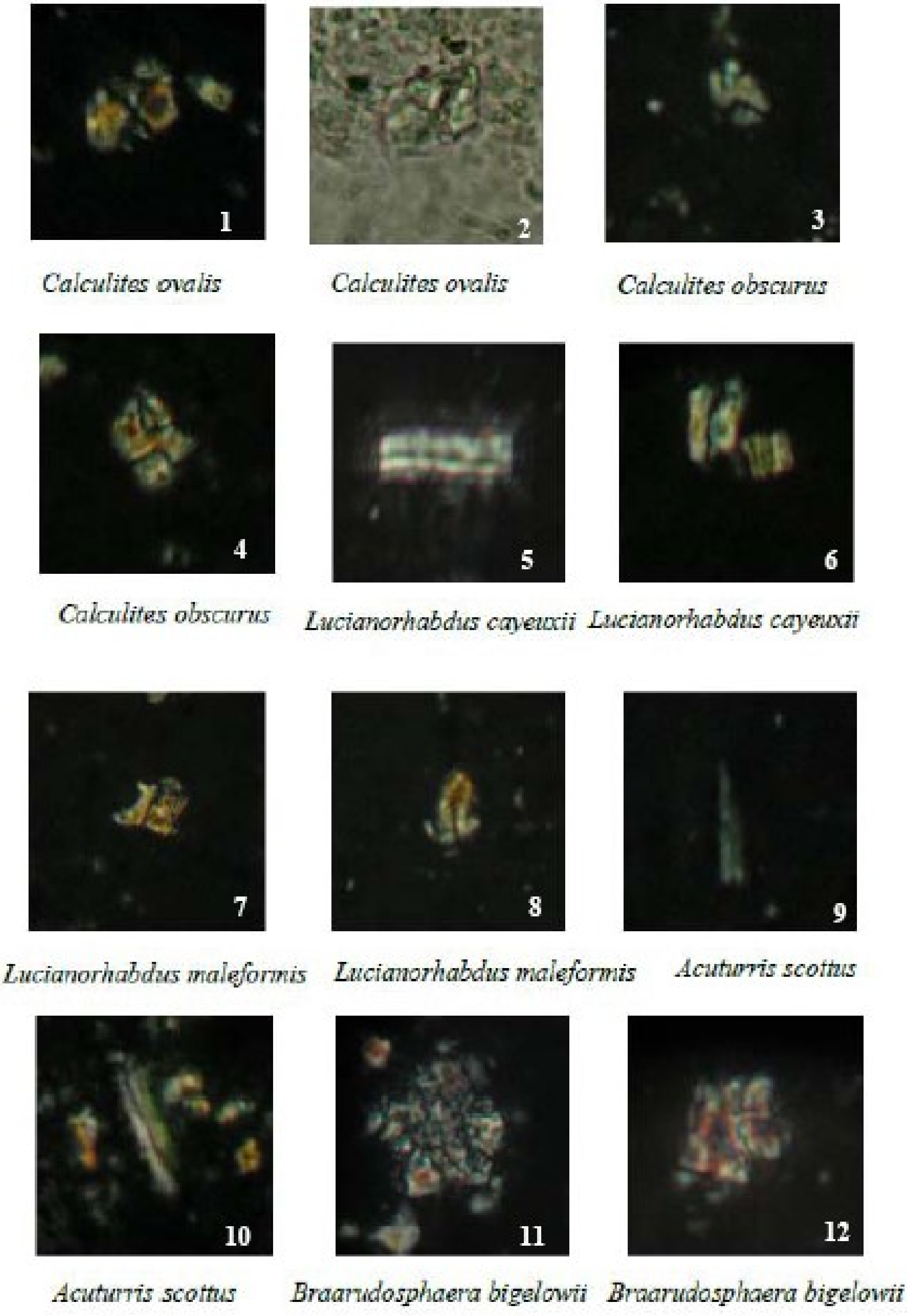


Figure 4: Nannofossil pictures of the studied sections (All figures light micrographs magnified X1000)

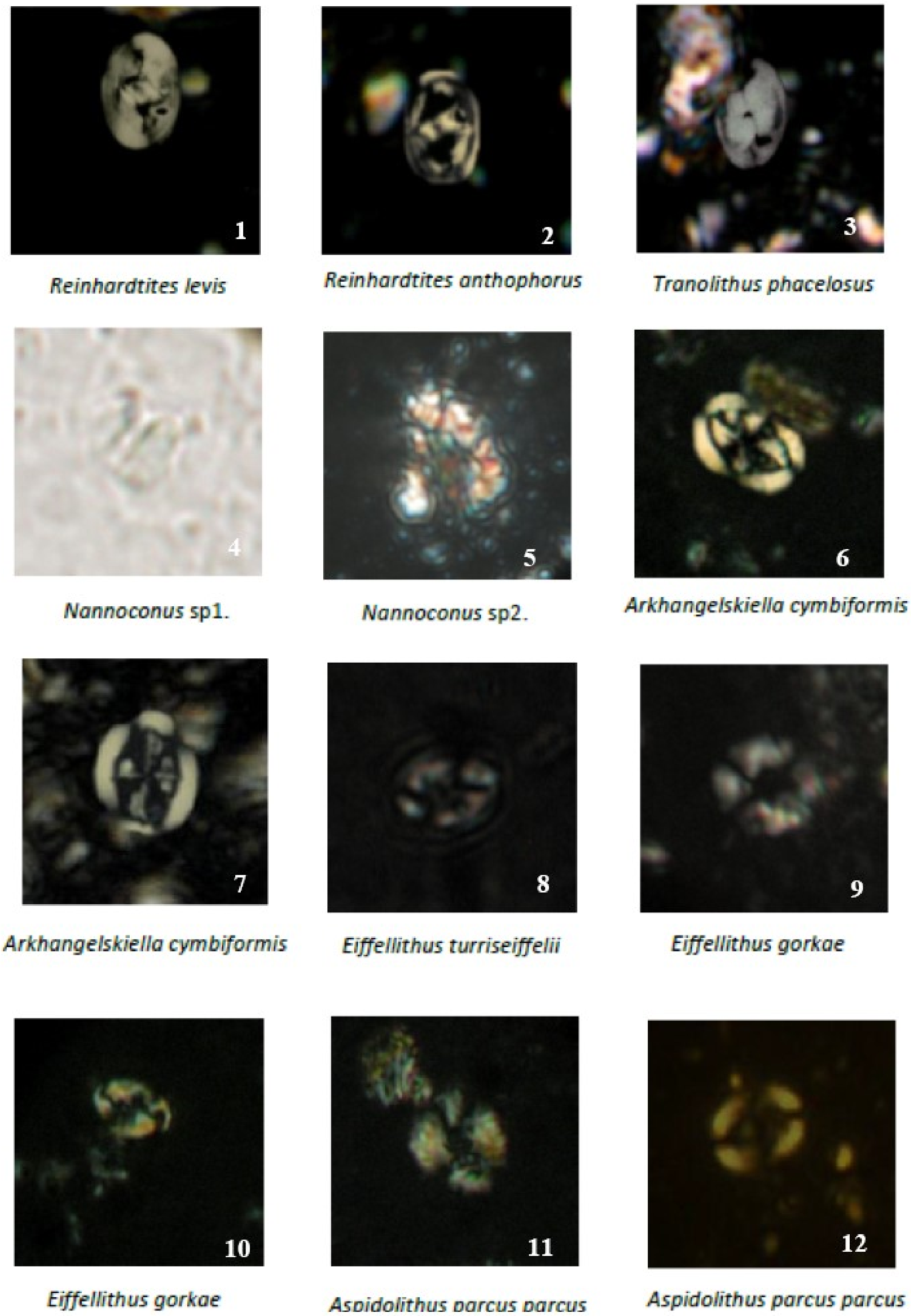


Figure 5**:** Nannofossil pictures of the studied sections (All figures light micrographs magnified X1000)

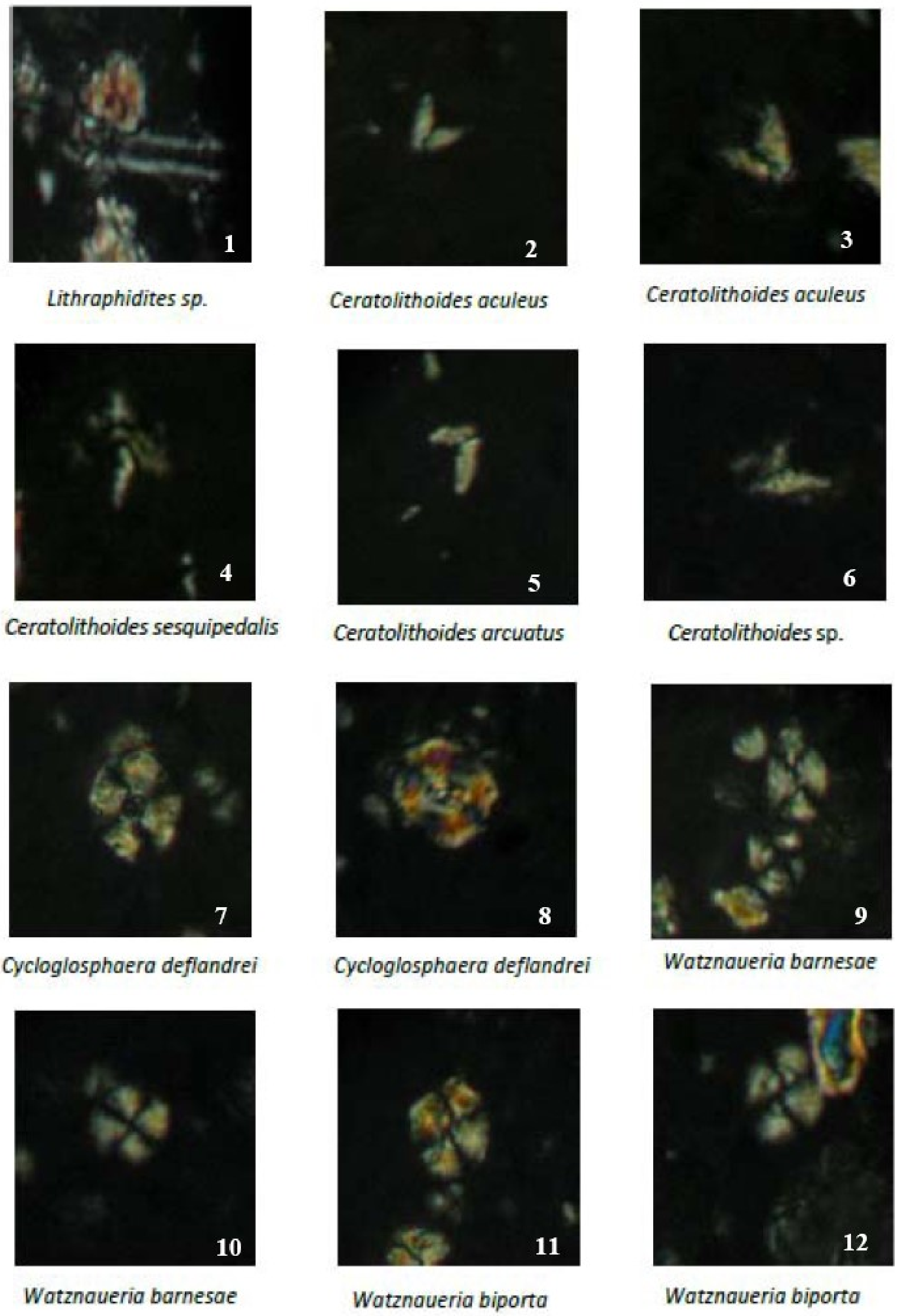


Figure 6: Nannofossil pictures of the studied sections (All figures light micrographs magnified X1000)

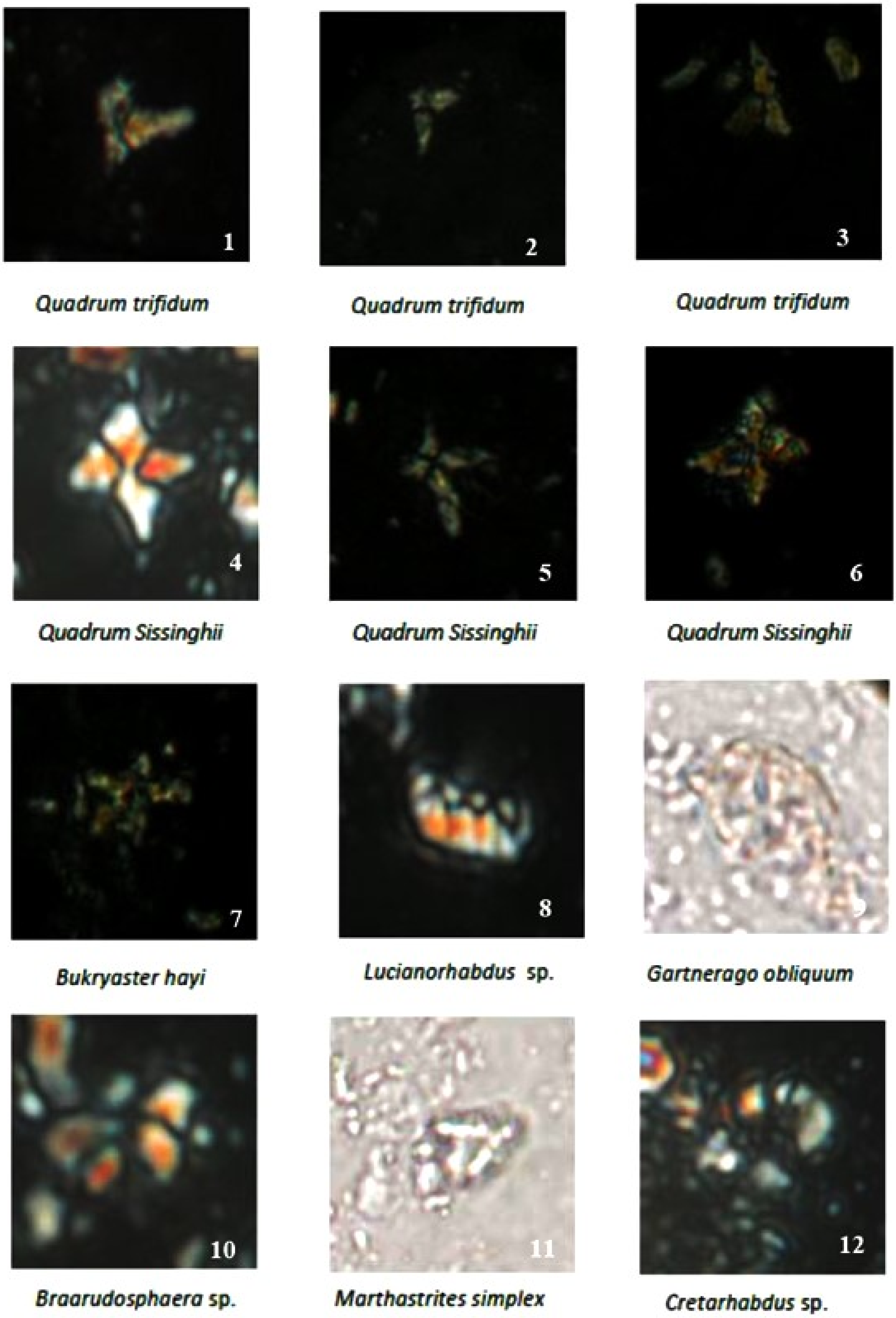


Figure 7: Nannofossil pictures of the studied sections (All Figures light micrographs magnified X1000)

5.2. Nannofossils diversity and abundance

In the present study, 30 species belonging to 21 genera of calcareous nannofossils in the Sarayan section were identified. These nannofossils are of well-to-moderate diversity and moderate-to-relatively high in abundance. The abundance of nannofossils in different samples does not follow a general pattern as some species tend to increase or decline from the base to top section—for example *W. barnesae* increases towards the top of these sections, while *Micula decussata* decreases along the same path (Table 1).

The most dominant species are *W. barnesae* with an average of 24.17%, *Q. sissinghii* with an average of 26.29%, *Q. trifidum* with an average of 7.76%, *Calculites obscurus* with an average of 6.22%, and *Lucianorhabdus cayeuxii* with an average of 14.41% in the Sarayan section.

Some Cretaceous nannofossil genera like *Marthastrites, Aspidolithus*, *Braarudosphaera*, and *Acuturris* are present in these samples, but occur only sporadically with relatively low percentages. Some species are rare, and they were identified only from the uppermost part of the studied sections such as *M. murus,* and *Arkhangelskiella cymbiformis* (Table 1).

5.3. Calcareous nannofossil zonation

Calcareous nannofossils are one of the primary fossil groups used in Mesozoic biostratigraphy because of their abundance, rapid rate of evolution, and planktonic nature that allows a wide dispersal throughout the world oceans (Bown, 1998). The calcareous nannofossil zonation of the Cretaceous (especially the Upper Cretaceous) is well advanced. The biostratigraphic zonation scheme used for the Upper Cretaceous sediments follows (Sissingh, 1977) as modified and illustrated in Perch-Nielsen (1985). For the Cretaceous, the first and last occurrence (FO; LO) of species are mainly used for subdivision and zonation.

Table 2 illustrates diagrammatically the most important Upper Cretaceous calcareous nannofossil zonations proposed in the Sarayan section. In this section, six bio-events are documented in the Sarayan section: the FO of *Uniplanarius sissinghii*, the FO of *Uniplanarius trifidus*, the LO of *Reinhardites anthophorus*, the LO of *Tranolithus phacelosus,* the LO of *Reinhardites levis,* and the FO of *M. murus* (Table 2). According to the FO and LO of marker species, five calcareous nannofossil biozones were recognized in Sarayan section—ranging in age from early Late Campanian to Late Maastrichtian. The proposed biozones arranged from base to top are *Uniplanarius sissinghii*, *Uniplanarius trifidus*, *Tranolithus phacelosus*, *Reinhardites levis*, and *Arkhangelskiella cymbiformis* zones.

Quadrum sissinghii zone (CC21)

The *Q. sissinghii* zone was proposed by Sissingh (1977). The age of this zone is early Late Campanian. The zone is explained as the interval from the FO of *Q. sissinghii* to the FO of *Q. trifidum* by Sissingh (1977). This is the oldest identified zone in the Sarayan section. The most dominant species in this zone are *Calculites obscurus, Eiffellithus gorkae, L. cayeuxii, W. barnesae, Watznaueria biporta*, and *R. anthophorus.* The thickness of this biozone is 88 m.

Quadrum trifidum zone (CC22)

The *Q. trifidum* zone (CC22) was proposed by Bukry and Bramlette (1970), emended by Sissingh (1977). The age of this zone is late Late Campanian. It is identified as the interval between the FO of *Q. trifidum* to the last occurrence (LO) of *R. anthophorus*. It is dominated, besides the marker species, by *C. obscurus*, *E. gorkae*, *L. cayeuxii*, *Lucianorhabdus maleformis*, *M. decussata*, *Q. gothicum*, R. *anthophorus, W. barnesae*, and *W. biporta.* The thickness of this zone is 92m.

Tranolithus phacelosus zone (CC23)

This zone, also named CC23, was described by Sissingh (1977); it includes the interval from the LO of *R. anthophorus* to LO of *T. phacelosus*. The age of this zone is latest Campanian to Early Maastrichtian. In this zone, the most dominant species, in addition to the marker species, are *C. obscurus*, *L. cayeuxii*, *M. decussata*, *Q. gartneri*, *W. barnesae,* and *W. biporta.* The thickness of this studied biozone is 96m.

Reinhardtites levis zone (CC24)

This zone (CC24) was proposed by Sissingh (1977) and is identified from LO of *T. phacelosus* to the LO of *R. levis*. Early Maastrichtian is the age of this zone. It is dominated, besides the marker species, by *C. obscurus*, *Calculites ovalis*, *E. gorkae, L. cayeuxii*, *M. decussata*, *W. barnesae*, and *W. biporta*.

The thickness of this biozone is 40m.

Arkhangelskiella cymbiformis zone (CC25)

The *A. cymbiformis* zone was proposed by Perch-Nielsen et al. (1982) and later emended by Sissingh (1977). The age of this zone is Late Maastrichtian. This zone is identified from the LO of *R. levis* to the FO of *Nephrolithus frequens*. In low latitudes, this zone is identified from the LO of *R. levis* to the FO of *M. murus* (Perch-Nielsen, 1972). In this section, *N. frequens* was not found and the FO of *M. murus* was used for the identification of the upper boundary of CC25. The most dominant species in this zone, besides the marker species, are *C. obscurus, Ceratolithoides aculeus, E. gorkae, L. cayeuxii, W. barnesae*, and *W. biporta.* The Thickness of *A. cymbiformis* zone is 40m.

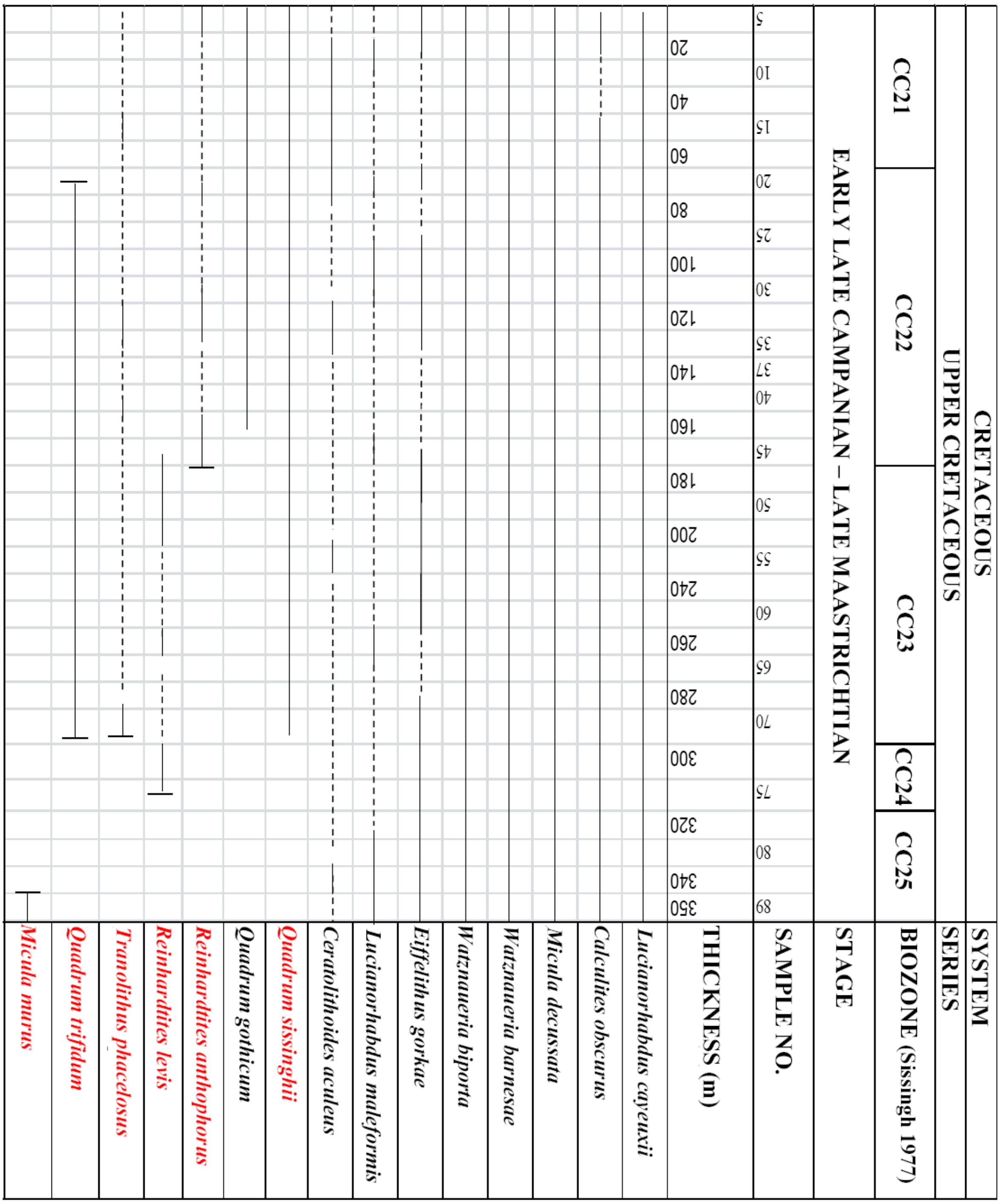
According to this study and also based on the calcareous nannofossil biostratigraphy, especially given the recognition of CC21-CC26 from the Sarayan section, the age of the sequence in the studied region was suggested early Late Campanian to Late Maastrichtian.

6. Discussion

6.1. Paleoecological features of the Sarayan section

Calcareous nannofossils include the coccoliths and coccospheres of haptophyte algae as well as the associated nannoliths that are of unknown provenance. Their calcareous skeletons are found in marine deposits

Table 2: Range chart showing the distribution of calcareous nannofossil species recorded in the Sarayan section.



often in vast numbers, sometimes making up the major component of a particular rock such as the chalk. The first recorded occurrences of calcareous nannofossils (nannoliths) are from the late Triassic (Carnian) (Bown and Young, 1998). Nannofossils are widespread in the present oceans, from coastal areas to open ocean settings, and constitute a large part of marine phytoplanktonic communities. Investigation of paleoecological conditions in Mesozoic, particularly Upper Cretaceous based on calcareous nannofossils, has been performed, by many authors (Sissingh 1977; Lees, 2002; Bornemann et al., 2003; Erba, 2004, 2006; Shamrock and Watkins, 2009). The distribution of calcareous nannoplankton in the current study is used to investigate the Paleoecological conditions in the studied region.

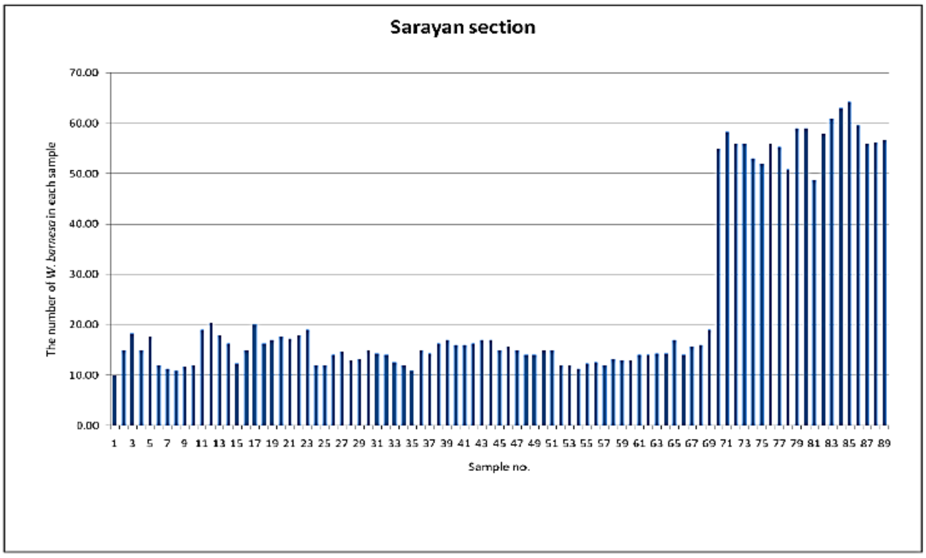


Figure 8: Abundance chart of *Watznaueria barnesae* in the Sarayan section

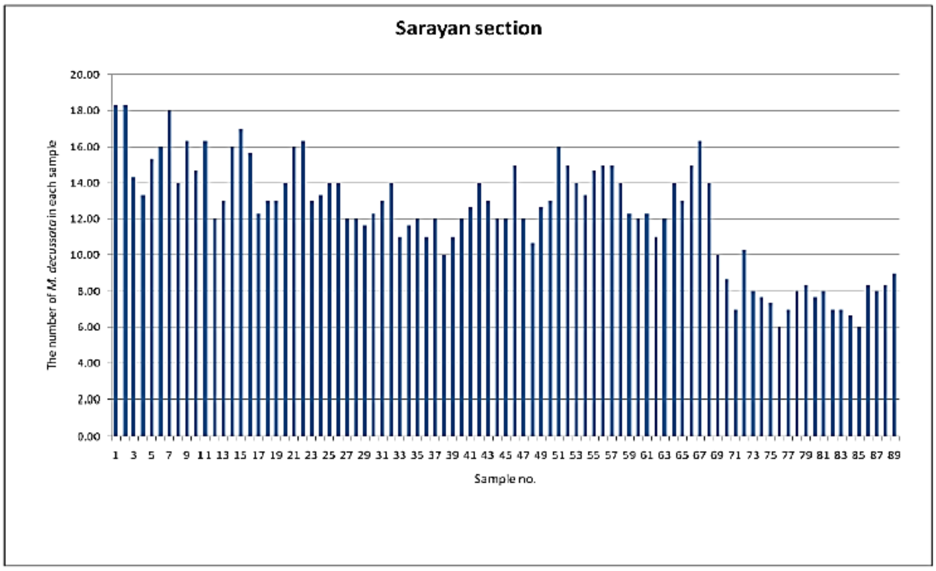


Figure 9: Abundance chart of *Micula decussata* in the Sarayan section

The common occurrences of the relatively eutrophic taxa *Zeugrhabdotus erectus* and *Biscutum constans* as well as of the cold-water species indicate high nutrient contents and cool surface water conditions during the deposition of the sequence. In the Cretaceous sediment, the species of *Eiffellithus* spp., *Prediscosphaera* spp. species (except *Prediscoshphaera stoveri*), *Lithraphidites* spp., *Microrhabdulus* spp., and *W. barnesae* are known as indicators of low productivity (Herrle et al., 2003; Friedrich et al., 2005). In the studied area, probably a low productivity level prevailed-this assumption is supported by the character of the nannofloral assemblages dominated by Tethyan taxa such as *Lithraphidites carniolensis* and *W. barnesae.*

In Upper Cretaceous, some taxa are more related to higher paleolatitudes with cold surface water, such as *Biscutum ellipticum, Kamptnerius magnificus, Gartnerago segmentatum,* and *Ahmuellerella regularis* (Erba et al., 1995; Svabenicka, 1999; Melinte and Lamolda, 2002; Aguado et al., 2005). In Upper Cretaceous, some nannofossils, such as *Ceratolithoides aculeus, Uniplanarius sissinghii, Uniplanarius trifidusrefer,* are used to warm surface water (Bukry, 1973; Wind and Wise, 1983; Watkins, 1992; Watkins, 1996; Watkins et al., 1996).

This is mirrored in the composition of the calcareous nannoplankton assemblages from the studied section, which contain low-to-middle latitude species such as *Ceratolithoides aculeus, Uniplanarius sissinghii, Uniplanarius trifidus*. The common occurrence within the Campanian to Maastrichtian of the studied region, of species belonging to the genus *Watznaueria* is indicative not only of a warm climate, but also of a low-latitude setting.
Some earlier researchers reported that *M. decussata* is becoming more abundant with an increasing depth, and W. barnesae is one of the most dominant species that shows a strong inverse correlation with depth (Thierstein, 1976; Thierstein, 1981). In the studied section, *W. barnesae* increases towards the top of this section and, conversely, *M. decussata* declines (Figures. 8 and 9). On the other hand, these observations indicate decreases in depth from the base to top of the Sarayan section. These results match well with lithological changes in the Lithostratigraphic column of this section.

7. Conclusions

In this study, 30 species and 21 genera were identified in the Sarayan section. The analysis of calcareous nannofossils revealed the presence of Campanian-Maastrichtian marine sediments in the eastern Lut Block margin. The nannofossil assemblages of the Sarayan section have relatively well-to-moderate preservation. The studied sediments in Sarayan region belong to Zones CC21-CC25 (Sissingh, 1977) on the basis of the first occurrence and last occurrence of *Q. sissinghii*, *Q. trifidum*, *R. anthophorus*, *T. phacelosus, R. levis,* and *M. murus,* respectively. The attribution of these biozones permits us to access an age of early Late Campanian to Late Maastrichtian for the studied section. Paying attention to the increased *W. barnesae* and decreased *M. decussate* from base to top as well as lithological changes (marl towards conglomerate) of the Sarayan section suggest a decline in depth towards the top of this section. Index calcareous nannofossil species at the studied sediments indicate low nutrients in relation to mesotrophic conditions and show that the basin of this sediments is in a low latitude with warm temperature.

References

Aguado R, Lamolda MA, Maurrasse FJ-MR (2005) Nanofósiles del límite Cretacico/ Terciário cerca de Beloc (Haití): bioestratigrafía, composición de las asociaciones e implicaciones paleoclimáticas. In: Lamolda MA, Maurrasse FJ-MR, Paul C (eds.), Bioevents: Their Stratigraphical Records, Patterns and Causes: *Special Issue of Journal of Iberian Geology* 311: 9–25.

Amindi SM, Navai I (2005) Geological Map of Grimonj 1:100000. Geological Survey of Iran, Tehran.

Andruleit H (1997) Coccolithophore fluxes in the Norwegian- Greenland Sea, seasonality and assemblage alterations. *Marine Micropaleontology* 31: 45- 64.

Asadi S, Kolahdani S (2014) Tectono-magmatic evolution of the Lut block, eastern Iran: A model for spatial localization of porphyry Cu mineralization. *Journal of Novel Applied Sciences* 3-9:1058-1069.

Babazadeh SA, Raeisosaddat SN, Ahrari F (2010) Biostratigraphy and investigation of Orbitolina evolution in sequence of the Cretaceous sedimentary series in the East margin of Lut Block, Southeast Qaen. *Sedimentary Facies* 3 (1): 1-10. (in Persian)

Bornemann A, Aschwer U, Mutterlose J (2003) The impact of calcareous nannofossils on the pelagic carbonate accumulation across the Jurassic - Cretaceous boundary. *Palaeo Journal* 199: 187- 228.

Bown PR, Young JR (1998) Techniques. In: Bown PR (ed) Calcareous nannofossil biostratigraphy. *Micropalaeontology Society Publication* pp: 16- 28.

Bown PR (1998) Calcareous nannofossil Biostratigraphy, Chapman and Hall, *Cambridge University Press* 316 p.

Bukry D (1973) Coccolith stratigraphy Eastern Equatorial Pacific. Leg 16 DSDP. *Initial Reports- Deep Sea Drilling Project* 16: 611-653.

Bukry D, Bramlette MN (1970) Coccolith age determination. Leg 3, Deep Sea Drilling Project. *Initial Reports- Deep Sea Drilling Project* 3: 589-611.

Burnett JA (1998) Upper Cretaceous In: Bown PR (ed), Calcareous Nannofossil Biostratigraphy. *Chapman& Hall/ Kluwer Academic Publishers* pp: 132-199.

Cepek P, Hay WW (1969) Calcareous nannoplankton and biostratigraphic subdivision of the Upper Cretaceous. Trans. *Gulf Coast Association geological Societies* 19: 323-336.

Erba E (2004) Calcareous nannofossils and Mesozoic oceanic anoxic events. *Marine micropaleontology Journal* 52: 85- 106.

Erba E (2006) The first 150 million years history of calcareous nannoplankton:Biosphere –geosphere interactions. *Palaeogeography, Palaeoclimatology, Palaeoecology Journal* 232: 237- 250.

Erba E, Premoli Silva I, Watkins DK (1995) Cretaceous calcareous plankton biostratigraphy of Sites 872 through 879. In: Haggerty JA, Premoli Silva I, Rack F, McNutt MK (eds.), Proceedings of ODP Results. Ocean *Drilling Program, College Station*, *TX* 144: 157–169.

Friedrich O, Herrle JO, Hemleben C (2005) Climatic changes in the Late Campanian – Early Maastrichtian: micropaleontological and stable isotopic evidence from an epicontinental sea. *Journal of Foraminiferal Research* 35: 228- 247.

Hadavi F, Khazaei AR, Rezaei F (2012) Nannostratigraphy of Gazak section in West Lahna-Mahroud (Southeast Birjand). *1st professional congress of sedimentology and stratigraphy* pp:61 (in Persian)

Herrle J, Pross J, Friedrich O, Kobler P, Hemleben C (2003) Forcing mechanisms for mid-Cretaceous black shale formation : evidence from the Upper Aptian and Lower Albian of the Vocontian Basin (SE France). *Palaeogeography, Palaeoclimatology, Palaeoecology Journal* 190: 399- 426.

Honjo S (1976) Coccoliths: production, transportation and sedimentation. *Marine Micropaleontology Journal1*: 65-79.

Lees JA (2002) Calcareous nannofossil biostratigraphy illustrates palaeoclimate changes in the Late Cretaceous Indian Ocean. *Cretaceous Research* 23: 537–634.

Mazhari SA, Sharifiyan Attar R (2012) Apatite Application to Investigate Magmatic Evolution of Zouzan Granites, NE Lut Block. *Iranian Journal of Earth Sciences* 4, 1:61-72.

Melinte MC, Lamolda MA (2002) Calcareous nannofossils around the Coniacian/ Santonian boundary in the Olazagutía section (N. Spain). In: Wagreich M (eds), Aspects of Cretaceous Stratigraphy and Palaeobiogeography: *Österreichische Akademie der Wissenschaften Schriftenreihe Erwissenschaftlichen Kommissionen*, 15: 351–364.

Perch- Nielsen K (1972) Remarks on Late cretaceous to Pleistocene coccoliths from the North Atlantic. *Initial Reports- Deep Sea Drilling Project* 12: 1003-1069.

Perch- Nielsen K (1985) Plankton Stratigraphy. In: Bolli Hm, Saunders JB, Perch- Nielsen K (eds). Cambridge University Press pp: 329- 426.

Perch- Nielsen K, Mckenzie JA, He Q (1982) Biostratigraphy and isotope stratigraphy and the catastrophic extinction of calcareous nannoplankton at the Cretaceous/ Tertiary boundary. *Special Paper, geological Society America* 190: 353-371.

Roth PH, Krumbach KR (1986) Middle Cretaceous calcareous nannofossil biogeography and preservation in the Atlantic and Indian oceans: implications for paleoceanography. *Marine Micropaleontology Journal* 10: 235- 266.

Saadat S, Karimpour MH, Stern CH (2010) Petrochemical Characteristics of Neogene and Quaternary Alkali Olivine Basalts from the Western Margin of the Lut Block, Eastern Iran. *Iranian Journal of Earth Sciences* 2:87-106.

Shamrock J L, Watkins DK (2009) Evolution of the Cretaceous calcareous nannofossil genus Eiffellithus and its biostratigraphic significance. *Cretaceous Research Journal* 30: 1083–1102.

Sissingh W (1977) Biostratigraphy of Cretaceous calcareous nannoplankton. *Geologie en Mijnbouw/ Netherlands Journal of Geosciences* 56: 37-65.

Steinmetz JC (1994) Stable isotopes in modern coccolithophores. In: Winter A and Siesser WG (eds) Coccolithophores. *Cambridge University Press* pp: 219- 229.

Stocklin J, Nabavi MH (1973) Tectonic map of Iran. *Geological Survey of Iran*.

Svabenicka L (1999) Penetration of high latitude nannoflora to the depositional area of the Outer Carpathians in the Turonian–Maastrichtian. *Geologica Carpathica* 50: 77–79.

Thierstein HR (1981) Late cretaceous nannoplankton and the change at the C/T boundary. Pp: 355-394.

Thierstein HR (1976) Mesozoic calcareous nannoplankton biostratigraphy of marine sediments. *Marine Micropaleontology Journal* 1: 325- 362.

Young JR (1999) Calcareous Nannofossil Biostratigraphy. London, *Kluwer Academic Publishers* p.315

Watkins DK (1992) Upper Cretaceous nannofossils from Leg 120, Kerguelen, Southern Ocean. *Procceding Ocean Drilling Program Scientific Research* 120: 343- 370.

Watkins DK (1996) Upper Cretaceous calcareous nannofossil biostratigraphy and paleoecology of the Southern Oceon. ln Moguilesvky A and Whatley R (eds.) Microfossils and Oceanic Environments. *Universityof Wales Aberystwyth Press* pp: 355-381.

Watkins DK, Wise SW, Pospichal JJ, Crux J (1996) Upper Cretaceous calcareous nannofossil biostratigraphy and paleoceanography of the Southern Ocean. In Moguilevsky A and Whatley R (eds), Microfossils and Oceanic Environments. *Universityof Wales Aberystwyth Press* pp: 355- 381.

Williams JR, Bralower TJ (1995) Nannofossil assemblages, fine fraction stable isotopes, and the paleoceanography of the Valanginian-Barremian (Early Cretaceous) North Sea Basin. *Paleoceanography Journal* 10: 815- 839.

Wind FH, Wise SW (1983) Correlation of upper campanian- lower maastrichtian calcareous nannofossils assemblages in drill and piston cores from the Falkland Plateau of the southwest Atlantic Ocean. pp: 551-563.