

Calcareous Nannofossils in Holocene Surface Sediments of the Persian Gulf

Pouresmaeil, Akram^{1*}; Hadavi, Fatemeh¹; Lak, Razieh²

1- Dept. of Geology, Faculty of Science, Ferdowsi University of Mashhad, Mashhad, IR Iran

2- Dept. of Marine Geology, Geological Survey of Iran, Tehran, IR Iran

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Abstract

The effect of the paleoclimatic and paleoenvironmental changes on the structure of the biotic communities are stronger and better recorded in the shelf area than in the open sea. The present study is devoted to impact of climatic events on some species of calcareous nannofossils. For this reason, 17 samples of surface sediments of the Persian Gulf were studied. Preservation of calcareous nannofossils in surface sediment samples was good and the dominant species were *Gephyrocapsa oceanica*, *Emiliana huxleyi*, *Helicosphaera carteri* and *Calcidiscus leptoporus*. The presence of these taxa indicated the Holocene sediments in the study area were deposited in the warm water and the Persian Gulf was a shallow and hyposaline basin in which productivity of calcareous nannofossils was high.

Keywords: *Calcareous nannofossils, Holocene, Persian Gulf*

1. Introduction

The Persian Gulf forms the northeast portion of the anticlock wise-moving Arabian plate. Perhaps arched type Holocene arid carbonate ramp, extending northeast across the gently sloping Arabian shield as water depth increases from largely emergent Sabkhas to depths in excess of 80 meters along the Zagros mountains for deep of Iran. The Persian Gulf, a marginal sea of the Indian Ocean, has a maximum depth 90 to 130 meters at its north-eastern side near the coast of Iran and Strait of Hurmuz but the average depth is 35 meters. The Persian Gulf is separated from the Gulf of Oman by the Strait of Hurmuz which is 56 km wide at its

narrowest point (Fig.1).

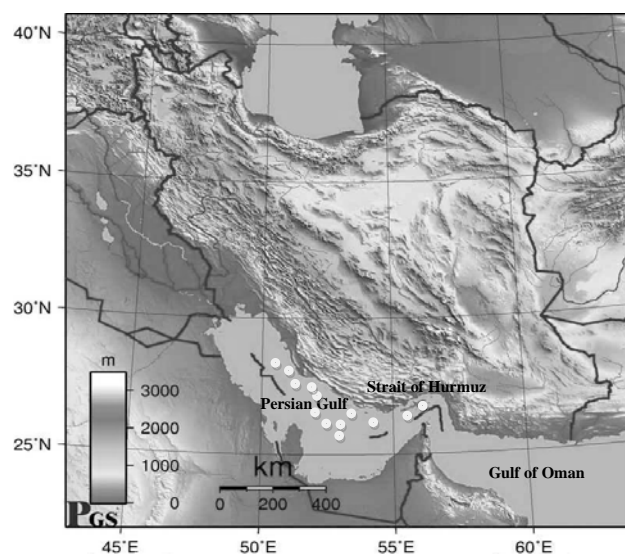


Fig. 1: Location of surface sediment samples in the Persian Gulf.

* Email: pouresmaeil517@gmail.com

The formation of the Persian Gulf could be seen in context of three events (1) movement of the Arabian plate into its present position; (2) influence of tectonic movement on the longitudinal morphological features on either side of the Persian Gulf and (3) formation of submarine platforms during the Holocene transgression. Nowadays, Persian Gulf, located between 24 -30 N. latitude and 48-56E. longitudes (Fig.1), is a shallow depression tectonically evolved during the late tertiary the steep slope on the Iranian side is related to the folding of the Zagros orogeny, whereas the low-dipping slope on the Arabian side is due to gentler tectonic movements.

The deepest facies in Persian Gulf are merely limestones. In the Persian Gulf basin floor or bed sediments have mostly microscopic assemblages that have the wide range of carbonate mud that are formed by calcareous algae such as abundant nannofossils. Basically, the recent sediments of the Persian Gulf to the depth are finer grain.

Calcareous nannofossils are fossil remains of golden-brown, single-celled algae that live only in the oceans. These algae make tiny calcite platelets inside their cells, and these platelets (the calcareous nannofossils) move to the surface of the cell. These calcite platelets are preserved in the rocks and are fossils that paleontologists study. Calcareous nannofossils are the most useful age indicator for marine sediments since the Jurassic to the recent because of their rapid rate of evolution and wide geographic distribution. They also could be used to help determining the temperature and current patterns of ancient oceans. For the lack of detailed paleontological studies in the Persian Gulf, the present investigation was undertaken. Few investigations have taken place in the Persian Gulf (Martini, 1971; Hartmann, 1971; kassler, 1973; Huq et al., 1978; Hubert et al., 1981, Al- sadi & Hadi, 1987, Konyuhov, A.I and Maleki, B. 2006), some of which explain calcareous nannofossils e.g. (Martini, 1971, Al- sadi and Hadi,1987, Hubert et al., 1981). In all these studies, only some species of phytoplankton were introduced.

Hadavi (2011) has studied 18 samples of surface sediments of the Persian Gulf and suggested the Persian Gulf was a high nutrient basin with high productivity of the calcareous nannofossils.

Thus knowledge of species level biodiversity and speciation is important for understanding marine ecology and biogeochemistry. Moreover, for geologists seeking to maximize biostratigraphic and paleoceanographic data retrieval from fossil assemblages reliable fine scale taxonomy is critical.

The calcareous nannofossils are well preserved specimens show low diversity and high abundance of taxa (23 species which belong to 15 genera, 7 families).

The nannofossils assemblages from the surface sediments of the Persian Gulf show abundant species which the most common species are: *Gephyrocapsa oceanica*, *E. huxleyi*, *Helicosphaera carteri*, *Calcidiscus leptoporus* and *Syracosphaera pulchra*. Other species, such as *Braarudosphaera bigelowii*, *Rhabdosphaera claviger*, *Umbilicosphaera sibogae*, *Calciosolenia murray*, *Florisphaera profunda* and *Coccolithus pelagicus*, are rare. The regular increase of reworked specimens in surface sediments of the Persian Gulf is a very common feature which was reported by Kassler (1971). Reworked nannofossils are *Reticulofenestra pseudumbilica*, *Cyclocargolithus floridanus*, *Reticulofenestra bisecta*, *Reticulofenestra dictyoda*, *Watznauria barnesa*, *Sphenolithus abies*, *Cribrosphaerella ehrenbergii*.

The relative abundance of selected species of nannofossils are shown in Table 1 and Fig. 2.

The average size of the calcareous nannoplankton is between 5-15 μm but, larger or smaller specimens are also common. A more restrictive definition (Tapan, 1980) considered the nannoplankton size of less than 2 μm and defined as ultramicroplankton those between 2 -20 micron.

The main objective of this study was to document and understand the role of calcareous nannoplankton as the main carbonate producer in relation to changes in global climate in the Holocene sediments in the Persian Gulf.

Table 1. Distribution of selected calcareous nannofossils in the study area.

Sample No.	Water depth (M)	<i>Braarudosphaera bigelowii</i>	<i>Calcidiscus leptoporus</i>	<i>Calciolenia murrayi</i>	<i>Calciolenia barsiliensis</i>	<i>Calciolenia corselli</i>	<i>Coccolithus pelagicus</i>	<i>Florisphaera profunda</i>	<i>Emiliania huxleyi</i>	<i>Gephyrocapsa muellera</i>	<i>Gephyrocapsa oceanica</i>	<i>Helicosphaera carteri</i>	<i>Syracosphaera pulchra</i>	<i>Umbilicosphaera foliosa</i>	<i>Umbilicosphaera sibogae</i>	<i>Umbellosphaera tenuis</i>
S-70	55	2.66	10.66	0.00	0.00	0.00	9.33	1.00	23.00	2.00	48.00	4.00	6.66	0.00	0.33	0.00
S-90	49	1.66	5.33	1.00	0.00	0.00	3.00	0.00	10.00	2.66	32.66	6.66	4.66	0.00	2.66	0.00
S-110	49	1.33	6.66	0.00	0.00	0.00	3.00	0.00	12.00	3.33	33.33	3.33	3.33	0.00	3.00	0.00
S-145	55	0.33	0.66	0.00	0.00	0.00	2.66	0.00	12.66	3.33	45.00	7.66	0.33	1.33	1.33	0.00
S-165	57	1.33	4.00	0.00	0.00	0.00	1.00	0.00	10.66	0.00	50.00	11.33	4.66	0.00	3.33	0.00
S-181	70	0.00	4.33	1.00	1.00	0.33	4.00	0.00	16.00	0.00	38.66	12.66	4.66	0.00	3.33	0.00
S-182	80	6.00	4.66	2.00	0.00	0.00	1.33	0.00	10.00	3.33	48.00	12.00	0.00	0.00	1.33	0.00
S-196	68	12.00	3.33	1.00	0.00	0.00	1.00	1.33	33.00	2.00	54.66	11.33	3.33	0.00	2.66	0.00
S-234	80	0.00	5.33	0.00	0.00	0.00	2.66	0.00	22.00	0.00	50.00	12.33	0.00	0.00	2.66	0.33
S-250	60	1.33	3.33	0.00	0.00	0.00	1.00	0.00	33.00	2.66	45.00	10.00	0.00	0.00	0.00	0.00
T-6-1	23	0.33	8.66	0.33	0.00	0.00	0.00	0.00	23.00	0.00	54.33	8.33	0.00	0.33	2.00	0.00
T-6-4	21	0.33	4.66	0.00	0.00	0.00	3.00	0.00	20.33	4.66	33.33	12.55	0.00	0.00	2.00	0.00
T-7-2	21	2.66	5.33	0.00	0.00	0.00	2.66	0.00	23.33	0.00	56.00	10.33	0.00	0.00	0.00	1.00
T-7-3	25	4.00	6.66	0.00	0.00	0.00	0.00	0.00	28.66	0.00	45.33	12.66	6.66	0.00	0.00	0.00
T-9-3	24	1.66	6.66	0.00	0.00	0.00	2.66	0.00	33.00	2.66	32.66	11.33	1.33	0.00	1.33	0.00
T-13-2	21	0.33	12.33	0.00	0.00	0.00	3.33	1.00	33.00	0.00	56.33	10.33	0.33	0.33	0.00	0.33
T-13-3	20	12.66	10.33	0.00	0.00	0.00	2.66	0.00	23.00	0.00	48.00	12.33	0.00	0.33	0.00	0.00

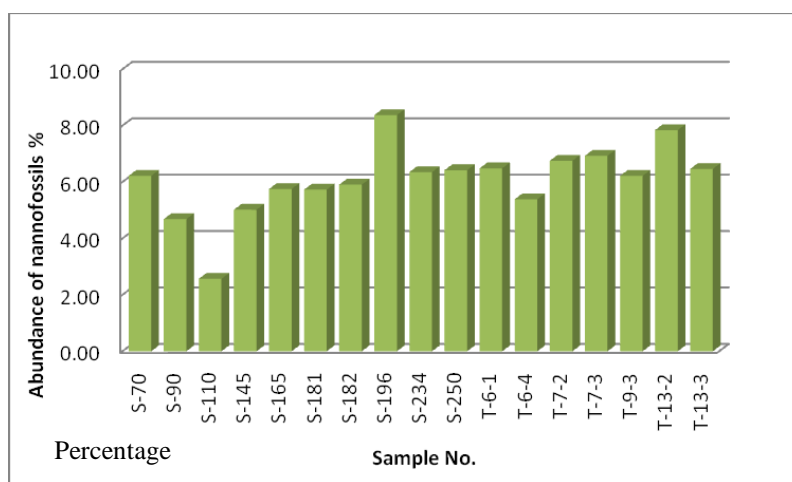


Fig. 2: Abundance of calcareous nannofossils in the study area.

We have also attempted to interpret changes in the temperatures of the sea surface water at the time of deposition (during the Holocene) based on the distribution and percentage of temperature-sensitive calcareous species.

2. Material and Methods

In this study, 17 samples of surface sediments

with different depth are collected from the Persian Gulf (Fig.1). For light microscopy, samples were prepared using Smear slide technique (Bown and Young, 1998). Nannofossil slides were examined by using a Sairan light microscope at a magnification of 1000x. From each slide, 300 specimens were counted. The samples photographed by a digital camera and sorted at the Department of Geology of Ferdowsi University of Mashhad.

The preparation of the sediment samples for the Scanning Electron Microscope (SEM) generally followed the combined dilution/filtering technique described by Andruleit (1996). The measurements of the placoliths were done following guidelines in Figure 4. Only distal view of the 30 flat lying placoliths specimens per sample was measured. The bridge angle was measured clockwise from the long axis of the central area.

3. Results and Discussion

3.1. Paleoecology

Coccolithophores form a substained component of the oceanic phytoplankton and their remains in sediments reflect the physical and chemical characteristics of overlying water masses (Roth, 1994). Coccoliths records have been utilized as proxy indicators to reconstruct paleoenvironmental conditions. Single species or the ratio between species groups have been applied to monitor variations in surface water productivity or nutria- and thermocline dynamics (e.g., Molfino and McIntyre, 1990; Jordan et al., 1996; Kinkel et al., 2000; Buamann and Freitag, 2004).

Our paleontological and paleoecological interpretations of the nannofossils are based on several species considered good paleoecological indicators for warm (e.g. *Gephyrocapsa oceanica*) marine water conditions or eutrophic and hyposaline environments (e.g. *Helicosphaera carteri*) and shallow environments (e.g. *Gephyrocapsa oceanic* and *Helicosphaera carteri*).

Bollmann (1997) conducted a global survey of Holocene *Gephyrocapsa coccoliths* and identified the following morphotypes which he interpreted as genotypically distinct taxa with variable ecological preferences. NB ba = bridge angle, measured from long axis of coccolith. SST = mean annual sea surface temperature (Figs. 3 and 4).

GL (larger); mean ba >56°; mean length >3.9 μm. Occurs in eutrophic temperate regions with

SST of 18-23°C.

GE (equatorial); mean ba >56°; mean length 3.1-3.9 μm. Occurs in equatorial regions, with SST of 25-30°C.

GO (oligotrophic); mean ba 27-56°; mean length >3.1 μm. Occurs in oligotrophic gyre regions with SSTs of 22-25°C.

GT (transitional); mean ba 27-56°; mean length 2.4-3.1 μm. Occurs in regions with SSTs of 19-20°C.

GC (cold); mean ba <27°; mean length >2.4-3.5 μm. Occurs in temperate to sub-arctic regions with SSTs of <21°C.

GM (minute); mean ba 20-50°; mean length <2.4 μm. Widespread, may include several species.

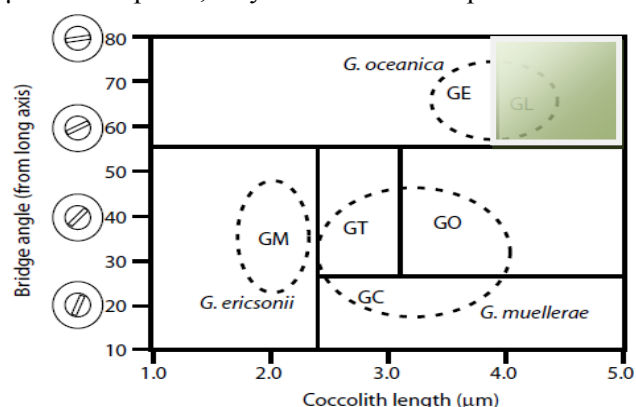


Fig. 3: Gephyrocapsa morphotypes in terms of size and bridge angle (Bollmann, 1997).

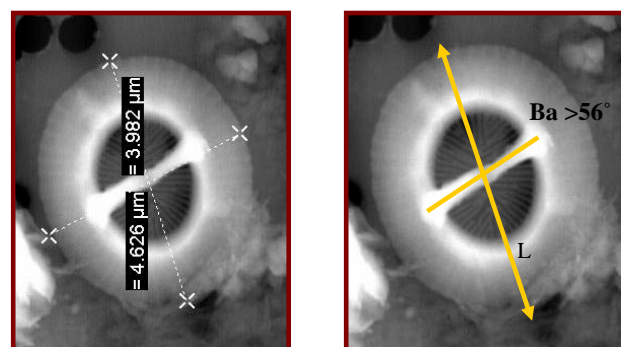


Fig. 4: measurements determined from digitized scanning electron microscope (SEM). Images of a single placolith: Ba, Bridge angle measured and L, Length of placolith

In many studies *G. oceanica* is reported to be abundant or dominate in plankton and sediment samples from marginal seas and neritic areas (Okada and Honjo, 1975; Giraudeau, 1992; Giraudeau et al., 1994) and from equatorial regions (Okada and Honjo, 1973; Geitzenauer et al., 1977; Kleijne et al., 1989).

A high salinity tolerance of *G. oceanica* was proposed by Okada and Honjo (1975).

In this study, the size of over 400 species of *Gephyrocapsa* measured were larger in size than 3.9 μm (Fig. 5). According to Bollmann (1977) all samples belonged to the type "GL" species which were found in the eutrophic regions and temperature range between 18 to 23° C. Also, the bridge angle of the majority of these samples were measured to be larger than 56°.

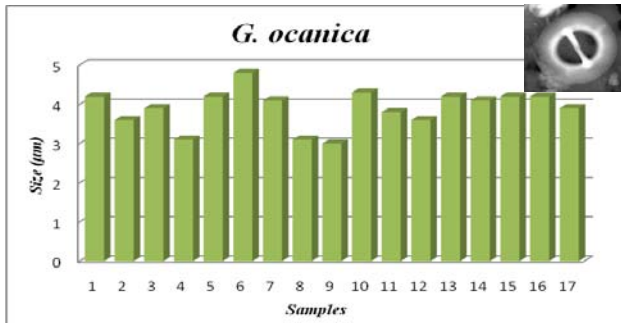


Fig. 5: Size frequency distributions of *Gephyrocapsa oceanica* in surface sediments.

Slits of *Emiliana huxleyi*, an ubiquitous species often forming blooms were between all distal shields and some proximal shield elements. This species showed strong variations in coccolith size and arrangement, number of shield elements and degree of calcification. Previous observations (McIntyre and Be, 1967; McIntyre et al., 1970) had defined a complete range of phenotypes, based on the degree of calcification and adaptation to different environmental temperature conditions.

The warm water species have an open proximal shield and central area covered by a grill of rod-like elements. This species had between 30-40 elements in shields. The cold water species have between 23-33 elements in shields and central area is closed (McIntyre and Be, 1967).

Young and Westbroek (1991) and Young (1994) distinguished three types based on heterococcolith morphology. Medlin et al., (1996) considered these types be regarded as separate varieties. A short description of the different varieties is given below:

Type A (*huxleyi*): liths medium sized (3-4 μm), distal shield elements robust, central area elements curved.

Type B (*pujosiae*): liths large (3.5-5 μm), distal shield elements delicate, central area elements irregular laths. Proximal shield often wider than distal shield.

Type C (*kleijneae*): liths small (2.5-3.5 μm), distal shield elements delicate, central area open or covered by thin plate.

In this study two different varieties were identified. *Emiliana* type A (*huxleyi*) and *Emiliana* type B (*pujosiae*) that both of them were found in warm waters and degree of calcification was good (Fig. 6).

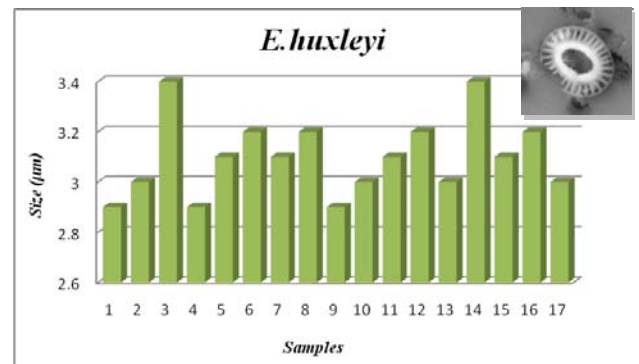


Fig. 6: Size frequency distributions of *Emiliana huxleyi* in surface sediments.

E. huxleyi and *G. oceanica* which were found in an average of 27% and 58% of assemblages, respectively, showed preference for shallow water depth and nearshore environments. These two taxa are also considered to be opportunistic species, increasing in abundance during upwelling conditions when surface productivity is high (e.g. Brand, 1994; Winter et al., 1994; Ziveri et al., 2000; Young et al., 2001). In the Persian Gulf, high nutrient areas were characterized by the dominance of *G. oceanica*. Increased productivity rather than high temperature is thought to be the cause of *G. oceanica* abundance in the South Atlantic (Baumann et al., 1999).

H. carteri has also been documented in eutrophic, hypersaline waters (Giraudeau, 1992) and estuarine environments (Cross, 2002; Cachao et al., 2002). The increase in the abundance of *H. carteri* here, and low nannofossil diversity may thus, represent a shift to a brackish, eutrophical shallow water environment. The relative abundance of common species of nannofossils in this study are shown in Figure 7.

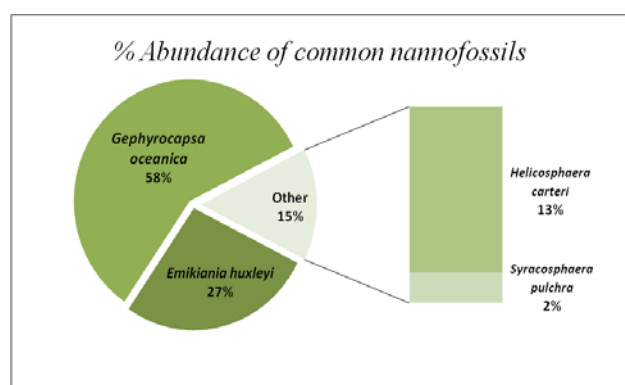


Fig. 7: Abundance of common species of nannofossils in the study area.

4. Conclusions

The following conclusions are drawn:

1) Generally calcareous nannofossils are well preserved in the entire samples. A total of 23 Calcareous nannofossil species were found in the study area (Appendix A; Plates 1-3).

2) From all identified taxa, *Gephyrocapsa oceanica*, *Emikiania huxleyi*, *Helicosphaera carteri* and *Calcidiscus leptoporus* were the most common species.

3) Considering the distribution of *G. oceanica*, *E. Huxleyi* and *H. carteri*, the Persian Gulf basin was a shallow, warm and hyposaline environment with high productivity and eutrophic conditions.

4.1. Appendix

Species list mentioned in the text and plates.

Family: Coccolithaceae Poche, 1913

Calcidiscus leptoporus (Murray and Blackman, 1898) Loeblich and Tappan, 1978

Coccolithus pelagicus (Wallich, 1877) Schiller, 1930

Oolithus fragilis (Lohmann, 1912) Martini and Müller, 1972

Umbilicosphaera sibogae (Weber-Van Bosse, 1901) Gaarder, 1970

Family: Helicosphaeraceae Black, 1971, emend. Jafar and Martini, 1975

Helicosphaera carteri (Wallich, 1877) Kamptner, 1954

Helicosphaera wallichii (Lohmann, 1902) Okada and McIntyre, 1977

Family: Noelaerhabdaceae Jerkovic, 1970

Emikiania huxleyi (Lohmann, 1902) Hay and Mohler, in Hay et al., 1967

Gephyrocapsa caribbeanica Boudreaux and Hay, in Hay et al., 1967

Gephyrocapsa oceanica Kamptner, 1943

Gephyrocapsa muelleri Brehe, 1978

Pseudoemiliana lacunosa (Kamptner, 1963) Gartner, 1969.

Reticulofenestra gelida (Geitzenauer, 1972) Backman, 1978

Reticulofenestra pseudoumbilicus (Gartner, 1967) Gartner, 1969

Reticulofenestra minutula (Gartner, 1967) Haq and Berggren, 1978

Family: Rhabdosphaeraceae Ostenfeld, 1899

Rhabdosphaera clavigera Murray and Blackman, 1898

Family: Syracosphaeraceae Lemmermann, 1908

Syracosphaera pulchra Lohmann, 1902

Family: Braarudosphaeraceae Deflandre, 1947

Braarudosphaera bigelowii (Gran and Braarud, 1935) Deflandre, 1947

Family: Calcisoleniaceae Kamptner, 1973

Calciosolenia brasiliensis (Lohmann, 1919) Young in Young et al., 2003

Calciosolenia corsellii Malinverno, 2004

Calciosolenia murrayi Gran, 1912

Genera: incertae sedis

Umbellosphaera tenuis (Kamptner, 1937) Paasche in Markali and Paasche, 1955

Florisphaera profunda Okada and Honjo, 1973 var. *profunda* Okada and McIntyre, 1977

Gladiolithus flabellatus (Halldal and Markali, 1985) Jordan and Chamberline, 1993b

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Plate 1

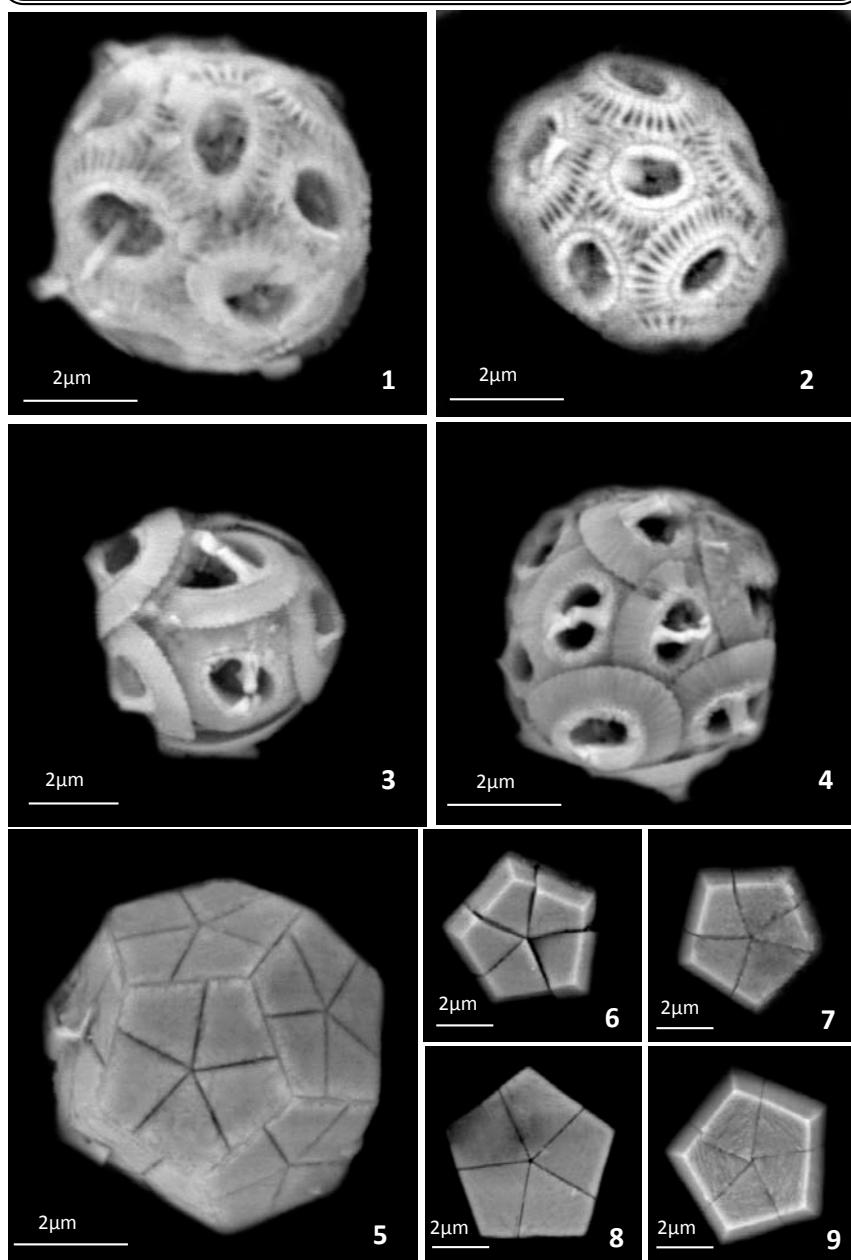


Plate 1:

Figs. 1-2: *Emiliana huxleyi* (Lohmann, 1902) Hay and Mohler, in Hay et al., 1967 (Coccosphere)

Figs. 3-4: *Gephyrocapsa oceanica* Kamptner, 1943 (Coccosphere)

Fig. 5: *Braarudosphaera bigelowii* (Gran and Braarud, 1935) Deflandre, 1947
Coccosphere

Figs. 6-9: *Braarudosphaera bigelowii* (Gran and Braarud, 1935) Deflandre, 1947

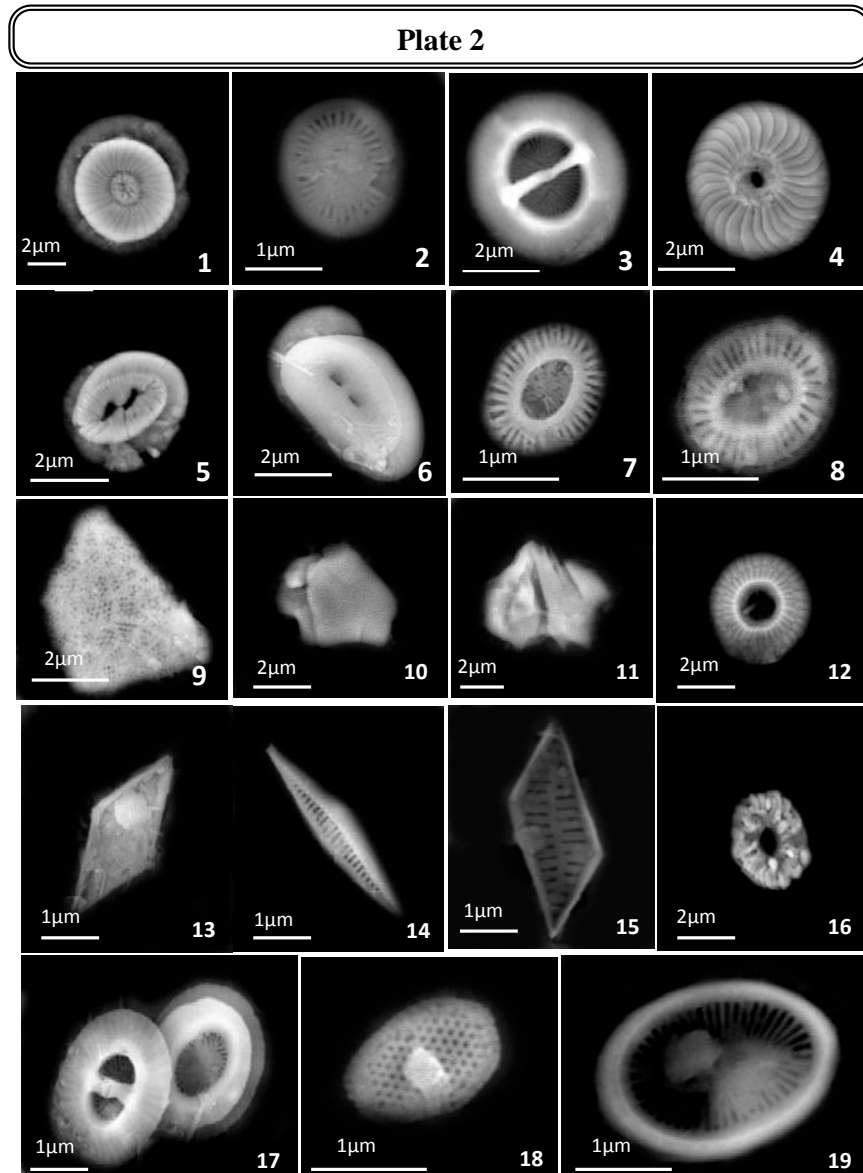


Plate 2:

- Fig. 1: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930
 Fig 2: *Cyrtosphaera aculeate* (Kamptner, 1941) Kleijne, 1992.
 Fig. 3: *Gephyrocapsa oceanica* Kamptner, 1943
 Fig. 4: *Calcidiscus leptoporus* (Murray and Blackman, 1898) Loeblich and Tappan, 1978
 Fig. 5: *Helicosphaera wallichii* (Lohmann, 1902) Okada and McIntyre, 1977
 Fig. 6: *Helicosphaera carteri* (Wallich, 1877) Kamptner, 1954
 Fig. 7: *Emiliana huxleyi* (Lohmann, 1902) Hay and Mohler, in Hay et al., 1967 Type A (huxleyi)
 Fig. 8: *Emiliana huxleyi* (Lohmann, 1902) Hay and Mohler, in Hay et al., 1967 Type B (pujosiae)
 Type B
 Fig. 9: *Sphaerocalyptra quaridentata* Young in Young et al., 2003
 Fig. 10: *Florisphaera profunda* Okada and Honjo, 1973 var. *profunda* Okada and McIntyre, 1977
 Fig. 11: *Gladiolithus flabellatus* (Halldal and Markali, 1985) Jordan and Chamberline, 1993b
 Fig. 12: *Umbilicosphaera sibogae* (Weber-Van Bosse, 1901) Gaarder, 1970

Fig. 13: *Calciosolenia murrayi* Gran, 1912

Fig. 14: *Calciosolenia brasiliensis* (Lphmann, 1919) Young in Young et al., 2003

Fig. 15: *Calciosolenia corsellii* Malinverno, 2004

Fig. 16: *Umbellosphaera tenuis* (Kamptner, 1937) Paasche in Markali and Paasche, 1955

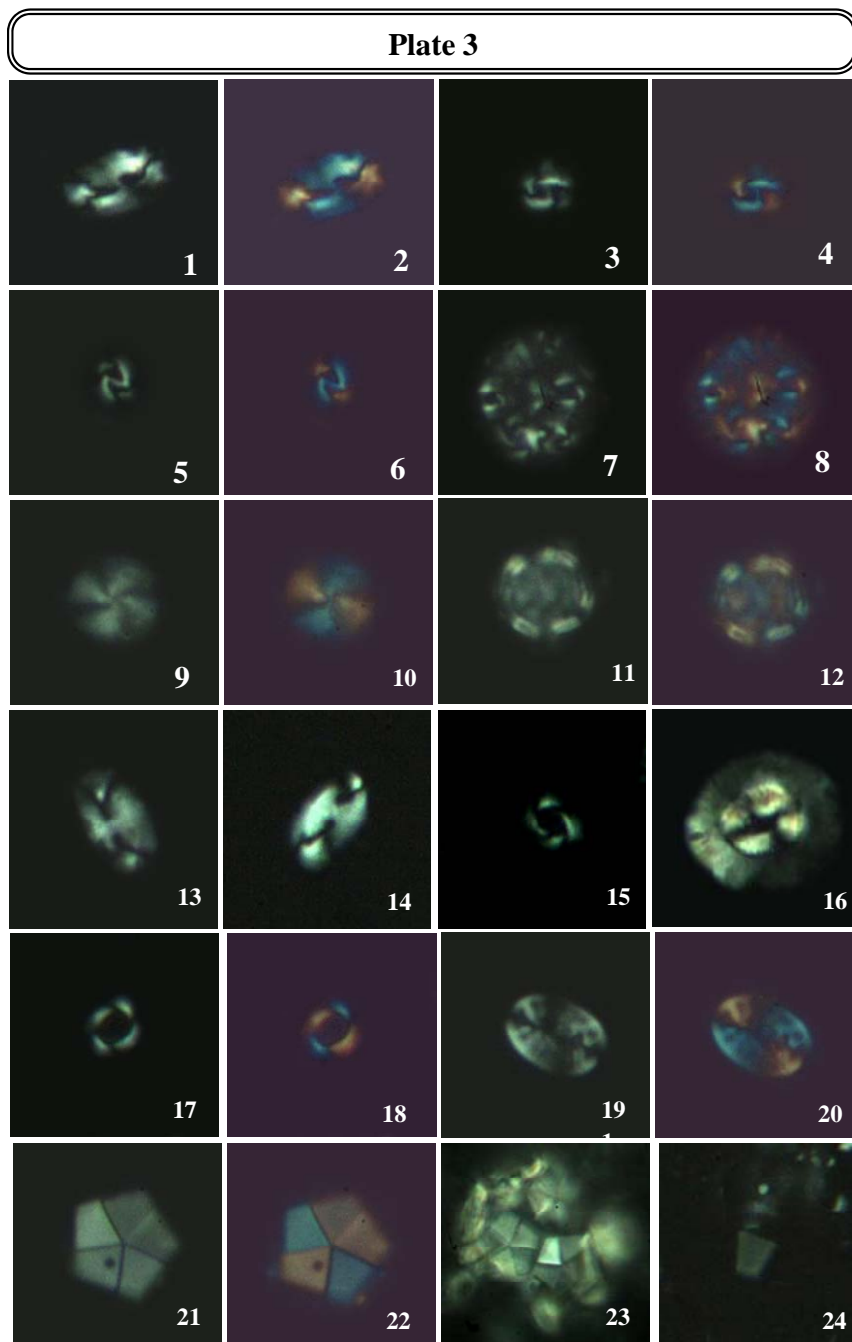
Fig. 17: *Gephyrocapsa oceanica* Kamptner, 1943

Fig. 18: *Helicosphaera carteri* (Wallich, 1877) Kamptner, 1954 (Holococcolith)

Fig. 19: *Syracosphaera pulchra* Lohmann, 1902

Light microscope of selected species at 1000 X magnification.

Plate 3:



- Figs. 1-2: *Helicosphaera wallichii* (Lohmann, 1902) Okada and McIntyre, 1977
Figs. 3-6: *Gephyrocapsa oceanica* Kamptner, 1943
Figs. 7-8: *Gephyrocapsa oceanica* Kamptner, 1943 (Coccosphere)
Figs. 9-10: *Calcidiscus leptoporus* (Murray and Blackman, 1898) Loeblich and Tappan, 1978
Figs. 11-12: *Emiliana huxleyi* (Lohmann, 1902) Hay and Mohler, in Hay et al., 1967 (Coccosphere)
Figs. 13-14: *Helicosphaera carteri* (Wallich, 1877) Kamptner, 1954 (Holococcolith)
Fig. 15: *Emiliana huxleyi* (Lohmann, 1902) Hay and Mohler, in Hay et al., 1967
Fig. 16: *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930
Figs. 17-18: *Pseudoemiliana lacunosa* (Kamptner, 1963) Gartner, 1969.
Figs. 19-20: *Pontosphaera discopora*
Figs. 21-22: *Braarudosphaera bigelowii* (Gran and Braarud, 1935) Deflandre, 1947
Fig. 23: *Braarudosphaera bigelowii* (Gran and Braarud, 1935) Deflandre, 1947 (Coccosphere)
Fig. 24: *Florisphaera profunda* Okada and Honjo, 1973 var. *profunda* Okada and McIntyre, 1977

