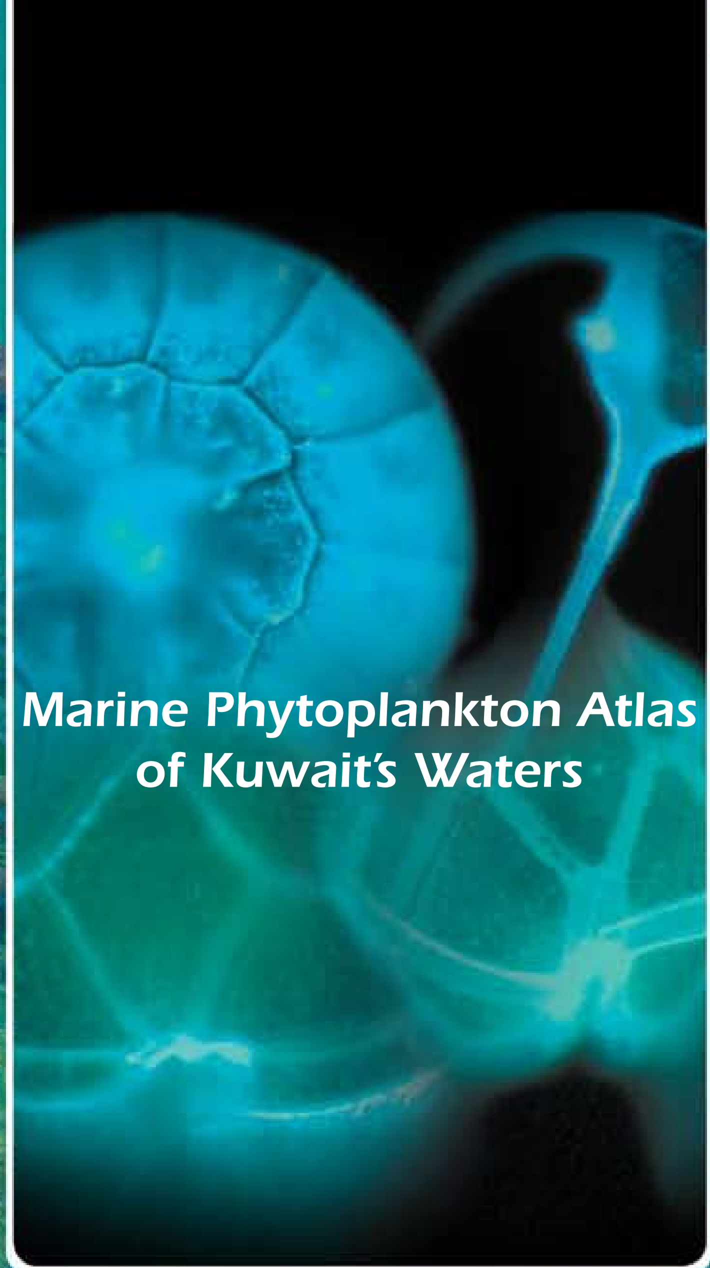

Marine Phytoplankton Atlas of Kuwait's Waters

Manal Al-Kandari
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Kuwait Institute for Scientific Research

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Published in Kuwait in 2009 by
Kuwait Institute for Scientific Research,
P.O.Box 24885, 13109 Safat, Kuwait

ISBN **99906-41-24-2**

Design by Melad M. Helani
Printed and bound by Lucky Printing Press, Kuwait

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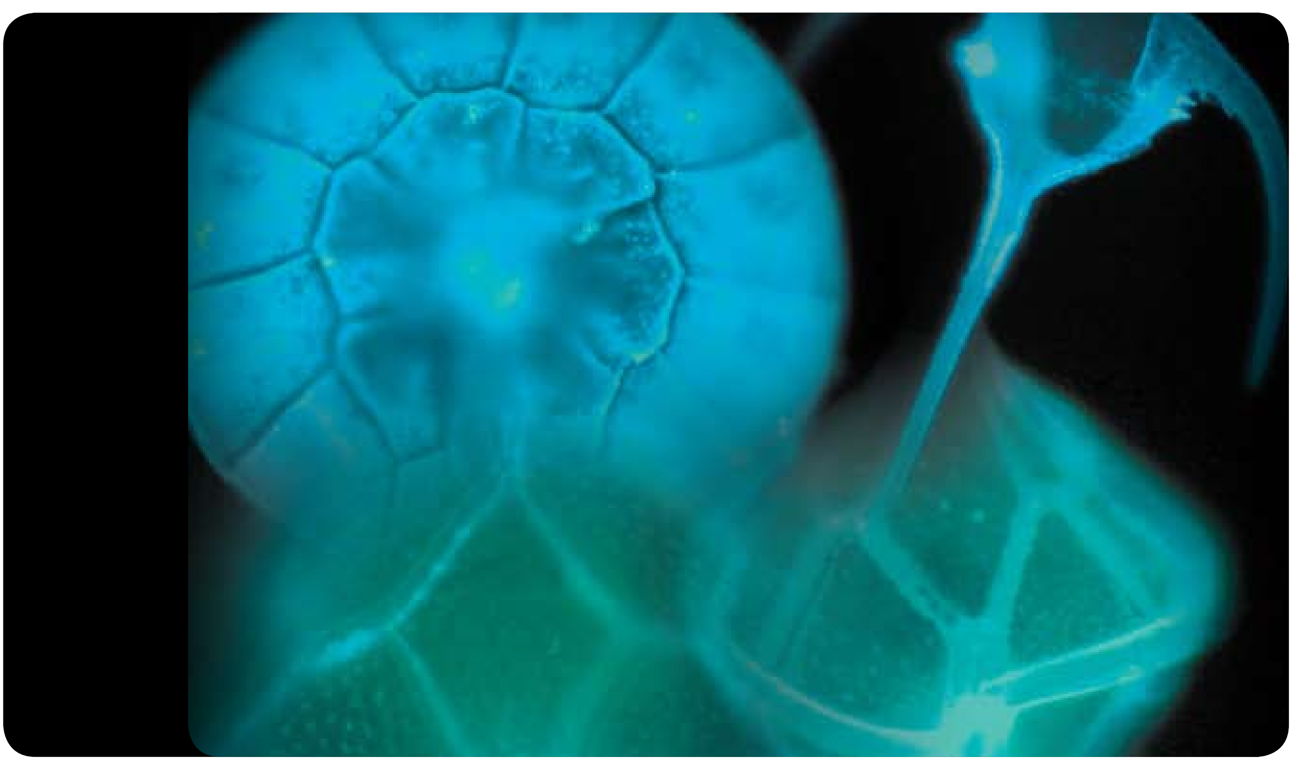

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CHAPTER 5

PLATES

OPENING REMARKS

"You can't cross the sea merely by standing and staring at the water."
Rabindranath Tagore

Phytoplankton are primary producers that form the base of the marine food web. They influence the concentration of dissolved oxygen and light penetration in our marine environment. Therefore, understanding the role they play and the factors that influence their growth form a critical step in learning how to manage our marine environment for sustainable healthy ecosystems.

The Oceanography Program at the Mariculture and Fisheries Department of the Kuwait Institute for Scientific Research conducts multidisciplinary research studies that include long-term measurements of key Oceanographic variables and plankton community structure as well as process-oriented research studies to help understand the complex ecological issues and to provide sound scientific evidence for managers who are in charge of making important environmental decisions.

Identifying phytoplankton can be a long and arduous duty. The “Phytoplankton Atlas of Kuwait’s Waters” is the first comprehensive reference of its kind for the Arabian Gulf region. The descriptions and photographs included in the Atlas are based on Kuwait’s phytoplankton specimens, which were collected during the period of 2003-2007.

The Atlas is intended to be a reference for marine scientists and college students interested in phytoplankton biodiversity and ecology.

THE AUTHORS

ACKNOWLEDGEMENTS

"Ideals are like stars: you will not succeed in touching them with your hands, but like the seafaring man on the ocean desert of waters, you choose them as your guides, and following them, you reach your destiny."

Carl Schurz

Special gratitude is expressed to Mr. Alan Lennox and to the Oceanography cruise staff of the Mariculture and Fisheries Department at the Kuwait Institute for Scientific Research for obtaining the phytoplankton samples, which were utilized to produce the Marine Phytoplankton Atlas for Kuwait's waters. Our thanks to Dr. Maria Saburova from the Institute of Biology of the Southern Seas (Sevastopol, Ukraine) for her time and guidance during the numerous scientific discussions concerning the identification of the different phytoplankton species. We are indebted to Dr. Jacob Larsen from the Botanical Institute/IOC Science and Communication Center on Harmful Algae (Copenhagen, Denmark) for his thorough review of the scientific and taxonomical information of the Atlas. We thank Mrs. Linda Fernandes for her great help in correcting and formatting the several drafts of this Atlas.

Chapter 1

MARINE PHYTOPLANKTON METHODOLOGY AND GENERAL RESULTS

INTRODUCTION

Marine phytoplankton are mostly microscopic and unicellular floating flora, which are the primary producers that support the pelagic food-chain. The two most prominent groups of phytoplankton are diatoms (Bacillariophyceae) and dinoflagellates (Dinophyceae). Phytoplankton also include numerous and diverse collection of extremely small, motile algae which are termed microflagellates (naked flagellates) as well as silicoflagellates and cyanophytes (blue-green algae). Many studies showed that the phytoplankton communities either in marine or in fresh water environment were dominated by diatoms rather than the dinoflagellates; which was also the case in Kuwait's waters (Enomoto, 1971; Al-Kaisi, 1976; Jacob et al., 1980; Dorgham et al., 1987; Dorgham and Moftah, 1989; Jacob and Al-Muzaini, 1990; Al-Yamani et al., 1997a; Al-Yamani et al., 1997b; Subba Rao and Al-Yamani, 1998; Thompson, 1998; Subba Rao and Al-Yamani 1999; Ismail et al., 1999; Al-Yamani et al., 2004). Dodge (1985) found that the number of dinoflagellate species and their abundance were much more in the sea than in freshwater lakes and ponds.

Phytoplankton community structures in the Arabian Gulf were characterized by a relatively high species diversity. Many studies were conducted on the phytoplankton species composition, biomass, and abundance (Hendey, 1970; Enomoto, 1971; Jacob et al., 1979; Jamal and Pavlov, 1979; Halim, 1984; Dorgham et al., 1987; Dorgham and Moftah, 1989; Jacob and Al-Muzaini, 1990; El-Gindy and Dorgham, 1992; Buo-Olayan and Subrahmanyam, 1996; Al-Yamani et al., 1997a; Al-Yamani et al., 1997b; Subba Rao and Al-Yamani, 1998; Subba

Rao and Al-Yamani, 1999; Ismail et al., 1999; Buo-Olayan et al., 2001). A total of 345 different taxa consisting mainly of diatoms and dinoflagellates were reported for the Arabian Gulf by Dorgham and Moftah (1989). A total of 888 diatoms, 211 dinoflagellates, 15 silicoflagellates, 15 coccolithophores, 81 cyanophytes, and other naked-flagellate species such as 82 of Chlorophyceae (Planktonic green algae), 7 of Euglenophyceae, 51 of Phaeophyta (Brown algae) and one species of cryptomonads have been reported in the region by Jacob and Al-Muzaini (1990). Most of the publications on the Arabian Gulf were of ecological nature and focused on identifying the phytoplankton community at a generic level whereas the species level identification with its description is very rare.

Kuwait's waters are characterized by being nutrient-rich, which contribute to the occurrence of a rich community of diatoms and dinoflagellates (Dorgham et al., 1987; Jacob and Al-Muzaini, 1990; Subba Rao and Al-Yamani, 1999; Buo-Olayan et al., 2001). Taxonomical descriptions of 205 diatom species were reported by Hendey (1970). However, Al-Kaisi (1976) recorded 135 diatoms and 13 dinoflagellates from the central region off Kuwait. Jacob et al. (1980) reported 19 genera of diatoms and 2 genera of dinoflagellates from Kuwait's surface waters in which they reported that *Chaetoceros* spp. and *Rhizosolenia* spp. were the dominant forms. Dorgham et al. (1987) documented 92 diatoms, 38 dinoflagellates and 1 silicoflagellate from Kuwait's waters. Ismail et al. (1999) reported about 26 dominant species of phytoplankton from different locations in Kuwait's waters including 21 diatoms and 5 dinoflagellates. Recently, Al-Yamani et al. (2004) provided a list of the most common phytoplankton species for Kuwait's waters, which includes 59 genera of diatoms (>140 species), 22 genera of dinoflagellates (>55 species), 1 silicoflagellate genus, 2 genera of coccolithophorids and 1 cyanophyte genus.

The present atlas includes the most commonly encountered genera and species of diatoms, dinoflagellates and other groups of marine phytoplankton such as silicoflagellates, naked flagellates and cyanophytes from Kuwait's waters, covering all seasons and all the territorial waters of Kuwait.

Fig. 1. Map of phytoplankton sampling stations in Kuwait's waters.

MATERIALS AND METHODS

Phytoplankton Collection and Preservation Methods

A total of 70 seawater samples and 80 oblique net samples were collected from different locations in Kuwait's waters for phytoplankton examination and identification. The different sampling stations, cover Kuwait's waters from north to south (Fig. 1 and Table 1). Water samples were collected using a 5-liter Niskin bottle and plankton samples were collected using a 20 µm plankton net. The samples were preserved in either a mixture of Paraformaldehyde and Gultraldehyde or in Lugol's iodine (see Throndsen, 1978 and Clesceri et al., 1989 for methods).

Sample Analysis

Light Microscope (LM) Observations. Preserved samples were shaken well before examination. Phytoplankton specimens were prepared as temporary and permanent slides. The collected samples were examined under the light microscope (LM) to determine the general community composition of phytoplankton and to identify the different species at the genus and species levels. Different LM magnifications (from 10x to 100x) were used according to the size of the phytoplankton. In addition, a bright field was used for interferential contrast.

Table 1. Location of Phytoplankton Sampling Stations in Kuwait's Waters.

Station	Latitudes° (N)	Longitude° (E)
Khor Al-Sabiya	29.59667	48.17748
North Failaka Island	29.48333	48.33381
Western end of Kuwait Bay	29.41667	47.83333
Mid-Kuwait Bay	29.45000	47.96667
Eastern end of Kuwait Bay	29.41619	48.09945
Off Ras Al-Ardh	29.33333	48.50000
Off Al-Fintas	29.17333	48.33333
Off Al-Ahmadi	29.06689	48.31167
Off Mina Abdulla	29.00000	48.33333
Off Ras Al-Qulaiah	28.93070	48.25010
Off Kuwait Naval Base	28.81667	48.50000
Off Mina Zor	28.78167	48.40000
Off Al-Khiran	28.66667	48.41635

Diatoms Slide Preparation. For accurate identification of diatoms (i.e., at least to the species level and, if possible, to the sub-species level, i.e., variety or forma), it is necessary to eliminate the organic matter which hides the fine siliceous structure of diatoms. Two methods were used to eliminate organic matter and to get more details on some diatom species, which are difficult to identify in preserved material: burning and hydrogen peroxide treatment.

- Burning. It is a simple method, which is used in identifying the weakly silicified diatoms. First, specimens were cleaned by taking approximately 20 ml from the preserved samples after concentrating and shaking them well in the test tubes which were labelled with station information. The frequency of cleaning with deionized or distilled water depends on the richness of each sample. After cleaning, the circular cover slips (18 mm) were deposited on a hot plate and a big drop was taken from each sample by a micropipette and was placed on each of the cover slips. The hot plate was set at low temperature at the beginning, then the temperature was increased to its maximum for burning the diatoms. During burning, the slides were prepared by inserting a drop of a mounting medium (Naphrax, a resin soluble in xylol and with a refractive index 1.71) on them. After burning of the slides, the cover slips were removed directly by the forceps and deposited on the slides in contact with the Naphrax. Then the slides were taken again to the hot plate and removed immediatley when the liquid evaporated. Finally, a little push was exerted on the cover slips to settle the diatoms down.

- Hydrogen peroxide (H_2O_2) treatment. This method, is used for the identification of strongly silicified diatoms. The preserved samples were shaken and a 20 ml volume was withdrawn for cleaning the diatom specimens. Thereafter, 1 ml of the cleaned specimens from each sample was taken by a micropipette and transferred into test tubes, which were labelled with station information (Fig. 2). A volume of 10 ml of 30% H_2O_2 was added to each test tube by a micropipette. The sand heater was turned on for 1 hour after inserting the tubes. Then the test tubes were removed and material was transferred into the centrifuge tubes. The specimens then were centrifuged for 5-6 times or more according to the clarity of the sample.

The cleaned specimens were deposited on the cover slips, which were placed on the hot plate until they became dry. Naphrax medium was added on the slides and the dried diatoms were placed in contact with Naphrax and was allowed to evaporate by putting the slides on a hot plate. The same mounting medium (Naphrax) was used after the materials were cleaned in both methods to make permanent slides and to allow for a better identification of silica-based diatoms.

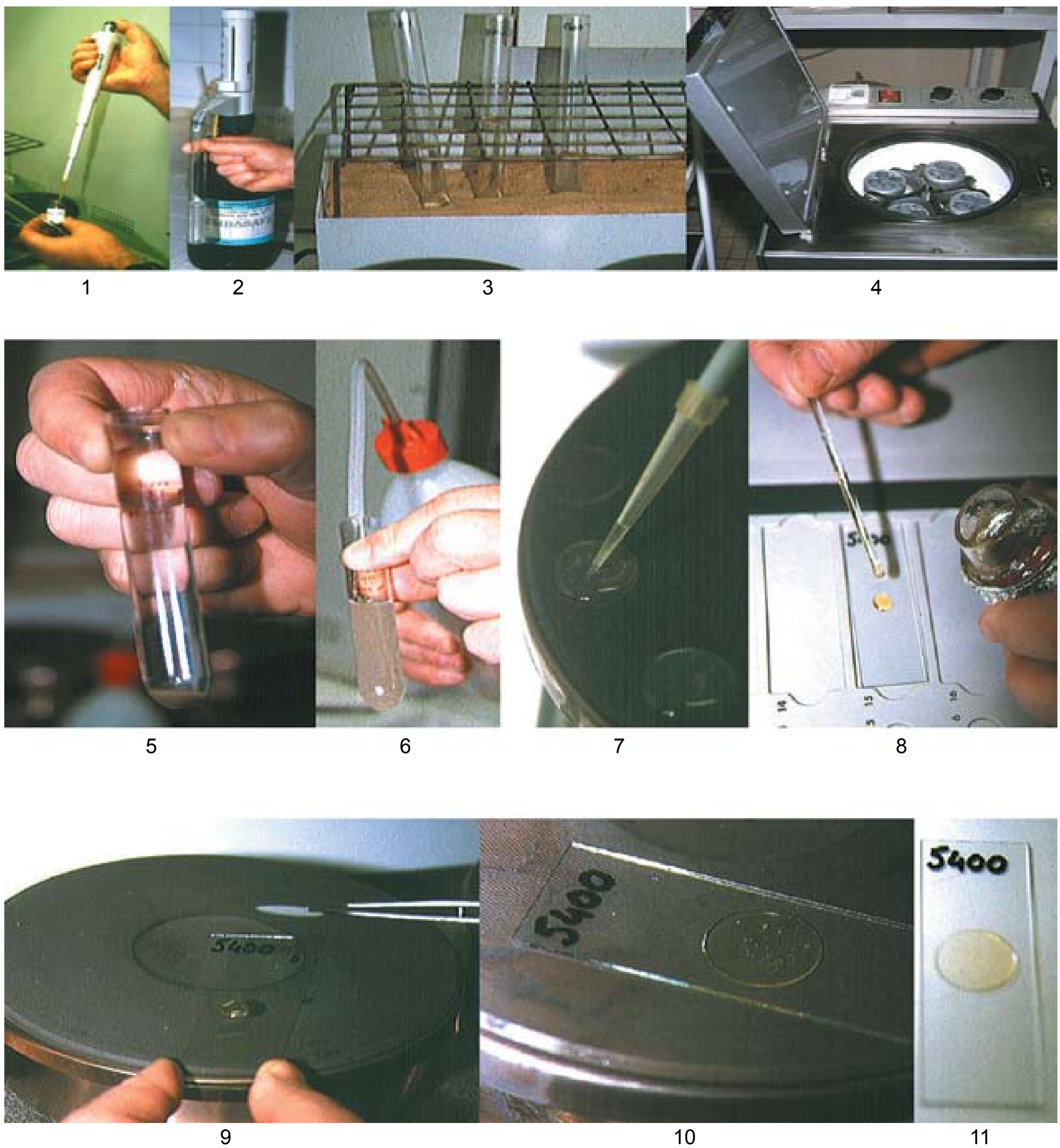


Fig. 2. Steps of pre-treatment (cleaning) and preparation of diatom slides: (1) take 1 ml from cleaned sample; (2) add 10 ml H_2O_2; (3) hot cleaning; (4) centrifugation; (5) remove supernatant; (6) rinsing; (7) deposit cleaned diatoms on cover slips, placed on a hot plate until drying; (8) add Naphrax mounting medium into slide; (9) put diatoms (on cover slip) in contact with Naphrax; (10) remove slide from hot plate when liquid evaporates; (11) final slide output.

Scanning Electron Microscope (SEM) Observations. Individual cells of diatoms were picked out of the samples (using a binocular microscope) by means of a Pasteur pipette. After isolation of the individual cells from the initial samples, they were cleaned with deionized water, and then with 30% H_2O_2 as with the previous method. The small studs with small circular filter papers were used here to dry the samples. The dried material was then coated with a gold-palladium in order to facilitate the examination. Then the prepared specimens were observed under the SEM in order to get three-dimensional (3-D) information on the diatom's general and fine structures to facilitate further identification of some diatoms.

Staining of the thecate dinoflagellate. It is necessary to stain the thecal plates of armoured dinoflagellates, particularly thin-walled species, like members of the genera *Protoperidinium*, *Gonyualax*, *Diplopsalis*, *Alexandrium*, etc. In this study, the CalcoFluor White method was used.

- CalcoFlour White. This method, first used on dinoflagellates by Fritz and Triemer (1985), requires an epifluoresence microscope equipped with a filter arrangement for 440 nm excitation and 500-520 nm emission. The advantage of this technique is that it primarily stains the cellulosic material, i.e., the thecal plates, and it is therefore not necessary to remove the protoplasm. The method is also very useful to visualize the pore-pattern in species of *Prorocentrum*. A stock solution of 10 mg/ml Calcofluor White 2MR or the equivalent Fluorescent Brightener 28 (Sigma) made up in distilled water is used to prepare a working solution of about 2-10 µg/ml. Staining works best in neutralized Lugol's or formalin solution (Hansen et al., 2001).

Phytoplankton Micrographs. Phytoplankton micrographs were taken with a Sony digital camera connected, upstream, to an Olympus LM and, downstream, to a G3 Apple computer fitted with a special acquisition card; and with an Olympus digital camera connected to the Olympus LM and Zeiss camera connected to the inverted Zeiss microscope. PhotoCapture, Camedia Master and Adope Photoshop programs were used for phytoplankton micrograph processing. Measurements of width, length, number of striae or punctae in 10 µm of the micrometer slide were generally recorded for each specimen encountered.

Phytoplankton Species Composition. Phytoplankton genera and species were identified using a variety of bibliographic references. MS Excel software was utilized for making a checklist of all the identified phytoplankton genera and species, with their geographical distribution.

GENERAL RESULTS

Phytoplankton Species Composition

Many samples from different locations in Kuwait's waters were examined for phytoplankton identification. From the collected samples, more than 323 phytoplankton species were identified based on their specific morphological characteristics, based on a variety of bibliographic sources. The phytoplankton were classified into two main groups: diatoms and dinoflagellates, which were the focus of this study. Other groups, such as the silicoflagellates, naked-flagellates and cyanobacteria (blue-green algae) were also classified and identified under the microscope.

Diatoms. Most of the observed phytoplankton specimens were diatoms, representing 75 genera belonging to 44 families. A total of 202 different species were identified, some were identified at the genus level and others at the species, variety, forma level. Specimens, which were identified only to the genus level (and not to the species level) were temporarily given a species number in order to differentiate them at a later time. The composition list of the different diatom species in Kuwait's waters with description of each species are included in Chapter 2.

Dinoflagellates. A total of 108 dinoflagellate species were identified, which represented 38 genera belonging to 17 families. The unidentified dinoflagellate species were numbered according to their different morphological characteristics. The list of the different dinoflagellate species composition in Kuwait's waters with description of each species are included in Chapter 3.

Other Marine Phytoplankton Groups. Three other phytoplankton groups were identified from the examined samples, namely, the Chromophyta, Chlorophyta and Cyanophyta. Five species belonging to four genera in Chromophyta, five species belonging to three genera in Chlorophyta and two species belonging to two genera in Cyanophyta were included in this Atlas. The species composition list and the description of these species are found in Chapter 4.

Harmful Algal Blooms. Examples of potentially harmful algal species of Kuwait's waters are included in Chapter 5.

REFERENCES

Al-Kaisi, K. A. 1976. On the phytoplankton of the Arabian Gulf, P 125. In the book of Abstracts of Papers Presented at joint Oceanographic Assembly, Edinburgh, UK, 13-24 September 1976. FAO, Rome.

Al-Yamani, F.Y., J. Bishop, K. Al-Rifaei, W. Ismail, A. Al-Yaqout, L. Al-Omran, A. Kwarteng, A. Al-Ghadban, and C. Sheppard. 1997a. Assessment of the effects of the Shatt Al-Arab's Altered Discharge Regimes on the Ecology of the Northern Arabian Gulf. **Final Report**. Kuwait Institute for Scientific Research, Report No. KISR 5174, Kuwait.

Al-Yamani, F.Y., J. Bishop, E. Ramadhan, M. Al-Husaini, and A.N. Al-Ghadban. 2004 Oceanographic Atlas of Kuwait's Waters. Kuwait Insitute for Scientific Research, Kuwait. 203p.

Al-Yamani, F.; R. Durvasula; W. Ismail; K. Al-Rifaie; T. Al-Saeed; A. Al-Yaqout; and L. Al-Omran. 1997b. Dynamic Oceanography of the Northwestern Waters of the Arabian Gulf: Ecological Significance of the Marine Food Web. **Final Report**. Kuwait Institute for Scientific Research, Report No. KISR 5173. Kuwait.

Buo-Olayan, A. H. and M. N. V. Subrahmanyam. 1996. Heavy metals in marine algae of the Kuwait Coast. Bull. Environ. Contam. Toxicol. **57:** 816-823.

Bu-Olayan, A. H., R. Al-Hassan, B. V. Thomas, and M. N. V. Subrahmanyam. 2001. Impact of trace metals and nutrients levels on phytoplankton from the Kuwait Coast. Environment International **26:** 199-203.

Clesceri, L. S., Greenberg, A.E. & Trusell, R R. [Eds] 1989. *Standerd Metn=ods for the Examination of water and Wastewater.* American Public Health Association. Washington DC, 1193 pp.

Dodge, J. D. 1985. *Atlas of Dinoflagellates: A Scanning Electron Microscope Survey*. London: Farrand Press.

Dorgham, M. M., A. Muftah and K. Z. El-Deeb. 1987. Plankton studies in the Arabian Gulf: II- The autumn phytoplankton in the northwestern area. Arab Gulf J. Scient. Res. Agric. Biol. Sci. B5 **(2):** 215-235.

Dorgham, M. M. and A. Muftah. 1989. Environmental conditions and phytoplankton stations in the Arabian Gulf and Gulf of Oman, September 1986. J. Mar. Biol. Assoc. India. **31:** 36-53.

El-Gindy, A. A. H. and M. M. Dorgham. 1992. Interrelations of phytoplankton, chlorophyll and physico-chemical factors in Arabian Gulf and Gulf of Oman during Summer. Indian Journal of Marine Sciences. **21:** 257-261.

Enomoto, Y. 1971. Oceanographic survey and biological study of shrimp stocks in the waters adjacent to the eastern coast of Kuwait. Bull. Tokai Reg. Fish. Res. Lab. **66:** 1-74.

Fritz, L., Triemer, R.E., 1985. A rapid simple technique utilizing Calcofluor White M2R for the visualization of dinoflagellate thecal plate. Journal of Phycology. 21: 662-664.

Halim, Y. 1984. Plankton of the Red Sea and the Arabian Gulf. Deep-Sea Res. **34A:** 969-982.

Hansen, G., Turquet, J., Quod, J. P., Ten-Hage, L., Lugomela, C., Kyewalyanga, M., Hurbungs, M., Wawiye, P., Ogongo, B., Tunje, S. and Rakot oarinjanahary, H. 2001. Potentially harmful microalgae of the Western Indian Ocean-a guide based on a preliminary survey. IOC Manuals and Guides No. 41. France: United Nations Educational, Scientific and Cultural Organization.

Hendey, N. I. 1970. Some littoral diatoms of Kuwait. Nova Hedwigia **31:** 101-167.

Ismail, W. A., F. Y. Al-Yamani and K. Al-Rifaie. 1999. Guide for the phytoplankton of the Arabian Gulf. Kuwait Institute of Scientific Research, Report No. KISR 5607, Kuwait.

Jacob P.G., M.A. Zarba., and V. Anderlini (1979). Hydrography, Chlorophyll and plankton of hte Kuwaiti coastel waters. Indian Journal of Marine sciences. **8**: 150-154.

Jacob, P. G., M. A. Zarba and V. Anderlini. 1980. Observations on the plankton and hydrography of the Kuwaiti waters. Mahasagar **13:** 325-334.

Jacob, P. G. and S. Al-Muzaini. 1990. Marine plants of the Arabian Gulf: A literature review. Kuwait Institute of Scientific Research, Report No. KISR 3426, Kuwait.

Jamal, A. H. H. and V. Pavlov. 1979. Introduction to phytoplankton study in the Arabian Gulf. Fisheries Research Administration, Ministry of Public Works, Kuwait (in Arabic), pp. 78.

Subba Rao, D. V. and F. Al-Yamani. 1998. Phytoplankton ecology in the waters between Shatt Al-Arab and Straits of Hormuz, Arabian Gulf: A review. Plankton Biol. Ecol. **45 (2):** 101-116.

Subba Rao, D. V. and F. Al-Yamani. 1999. Eolian dust affects phytoplankton in the waters off Kuwait, the Arabian Gulf. Naturwissenschaften **86:** 525-529.

Thompson, P. A. 1998. Spatial and temporal patterns of factors influencing phytoplankton in a Salt Wedge Estuary, the Swan River, Western Australia. Estuaries **21 (4B):** 801-817.

Throndsen, J. 1978. Preservation and storage. In *Phytoplankton manual*. Edited by A. Sournia. Paris: Unesco.

Chapter 2

DIATOMS

INTRODUCTION

Most of the phytoplankton studies conducted either in the Arabian Gulf or in the other waters of the world indicated that phytoplankton populations were dominated by diatoms (Dorgham et al., 1987; Dorgham and Moftah, 1989; Jacob and Al-Muzaini, 1990; Subba Rao and Al-Yamani, 1998; Thompson, 1998; Subba Rao and Al-Yamani, 1999; and Al-Yamani et al., 2004). The above results agree with the findings of this study, in which the phytoplankton species composition was clearly dominated by diatom species due to the abundance of silicate nutrient in Kuwait's waters. Indeed, Dorgham et al. (1987), Jacob and Al-Muzaini (1990), Subba Rao and Al-Yamani (1999), Buo-Olayan et al. (2001), and Al-Yamani et al. (2004) reported that the silicate compound was not a limiting factor for diatoms' growth in Kuwait's waters.

The Diatom Cell

All diatom species are unicellular or colonial coccoid algae that form the Class Bacillariophyceae. They are typically aquatic, although some can be found in damp terrestrial habitats. In the sea, diatoms live on the mud and sand of the sea bed, and on the surface of rocks and seaweeds, as well as floating freely in the water. Here they form an important part of the planktonic algal community which is usually called the phytoplankton. They carry out much of the marine primary production. They are pigmented and photosynthetic, although some at least can live heterophically in the dark if supplied with a suitable source of organic carbon (Hoek, 1995).

Each cell is encased by a unique type of cell wall, which is siliceous and takes the form of a box with an overlapping lid; this is termed the frustule. The chloroplasts are usually golden-brown, because the chlorophyll is masked by the accessory pigment fucoxanthin.

They are widespread in both marine and freshwater habitats. The Bacillariophyta contains two major groups, the centric diatoms and the pinnate diatoms, which are sometimes recognized by two orders (Centrales and Pennales) and are distinguished from each other on the basis of differences in cell wall structure (Sykes, 1981; Hoek, 1995).

The silica shell (frustule) of a pennate diatom is elongate and usually bilaterally symmetrical in face (valve) view, with a lanceolate or elliptical outline. The frustule (whole of the silica shell) consists of two halves: the hypotheca (the box in our box-and-lid analogy) and the epitheca (the overlapping lid). The epitheca consists in turn of two parts, viz. a flat upper part with down-turned edges, called the epivalve (epivalva), and a ring- or hoop-like side wall, the epicingulum (upper girdle). Similarly, the hypotheca consists of a hypovalve (hypovalva) and a hypocingulum (lower girdle). The epicingulum and epivalve are separated by a suture, as are the hypocingulum and hypovalve. The gross morphology of the frustule, types of girdle bands and sigments, and overlapping of bands are shown in Fig. 1.

When viewed with the light microscope, diatom shells can present two aspects. When the eipvalve or hypovalve is uppermost, the frustule is said to be 'in valve view'; if on the other hand the two parts of the girdle (epicingulum and hypocingulum) are uppermost, the frustule is said to be 'in girdle view'. The basic structure of the diatom cell is shown in Fig. 2. Descriptions of diatoms also often make use of a system of axes and planes. The valves are beautifully structured and ornamented, and the pattern of markings is to a large extent species-specific (Hoek, 1995).

In valve view, with a different pattern of surface sculpturing, based on a central line. The valve has a more-or-less narrow axial area with thickening in the center, the central nodule, and at each end, the polar nodules. Running between the nodules in many genera, e.g. *Navicula*, are two narrow slits, which form the raphe. The structure of generalized raphe-bearing pennate diatom is shown in Fig. 3. Most raphe-bearing diatoms live on the various solid surfaces of the sea bed and the shore, where the raphe is associated with a characteristic, jerky, cell movement. However, representatives of many such genera occur in the plankton, especially when stormy conditions have swept them into the surface waters. In other genera, which are more commonly planktonic e.g. *Asterionella*, there is no raphe. Many pennate diatoms typically have their cells united in various ways to form colonies e.g., *Bacillaria paxillifer, Asterionella glacialis* and *Thalassionema nitzschioides* (Sykes, 1981).

The structure of the valve of a centric diatom, and frequently its outline too, is basically radially symmetrical, the frustules often resembling a Petri dish. There are many exceptions, however, that depart from this simple idealized shape. As in pennate diatoms, the shells are ornamented with species-specific patterns and structures. In many centric diatoms the valves contain radical rows of small, more-or-less hexagonal chambers, called 'loculate areolae'. Each chamber (loculus) has an outer wall and an inner wall, and it is usual that one of these is perforated by a large round hole (foremen) while the other contains a delicate porous plate, sometimes called a 'sieve plate' (cribrum). No centric diatom ever has a raphe system (Hoek, 1995).

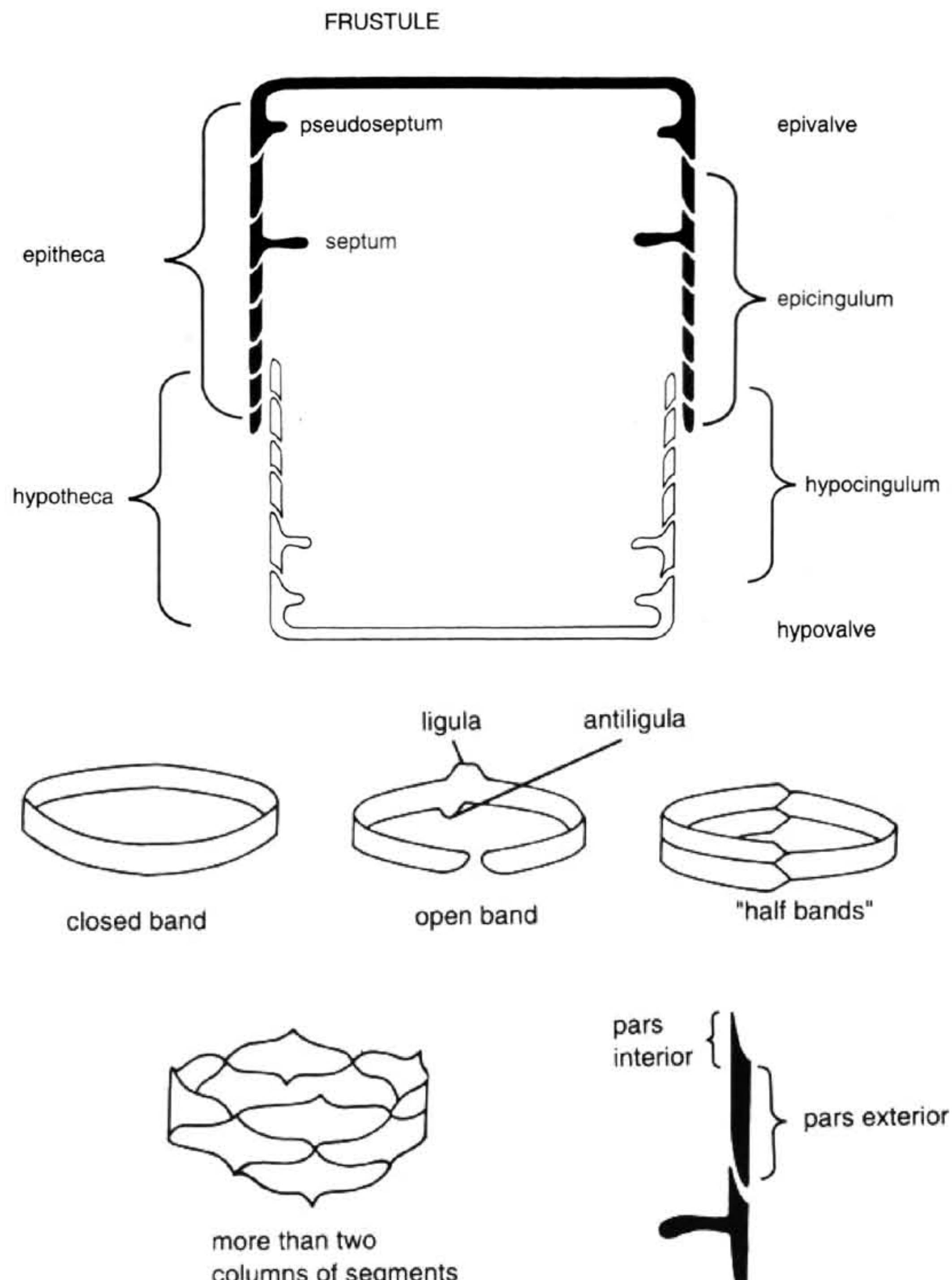


Fig. 1. Gross morphology of the frustule, types of girdle bands and sigments, and overlapping of bands in diatoms (after Hasle and Syvertsen, 1997).

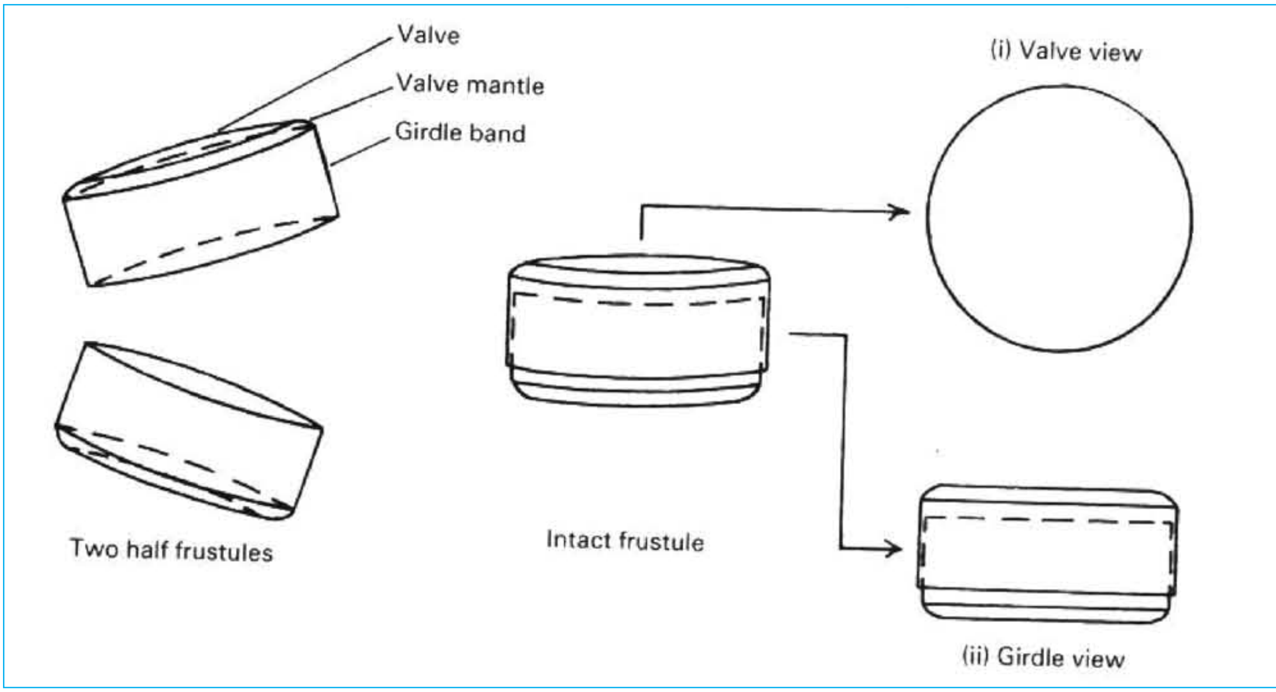


Fig. 2. The basic structure of a diatom cell (after Sykes, 1981).

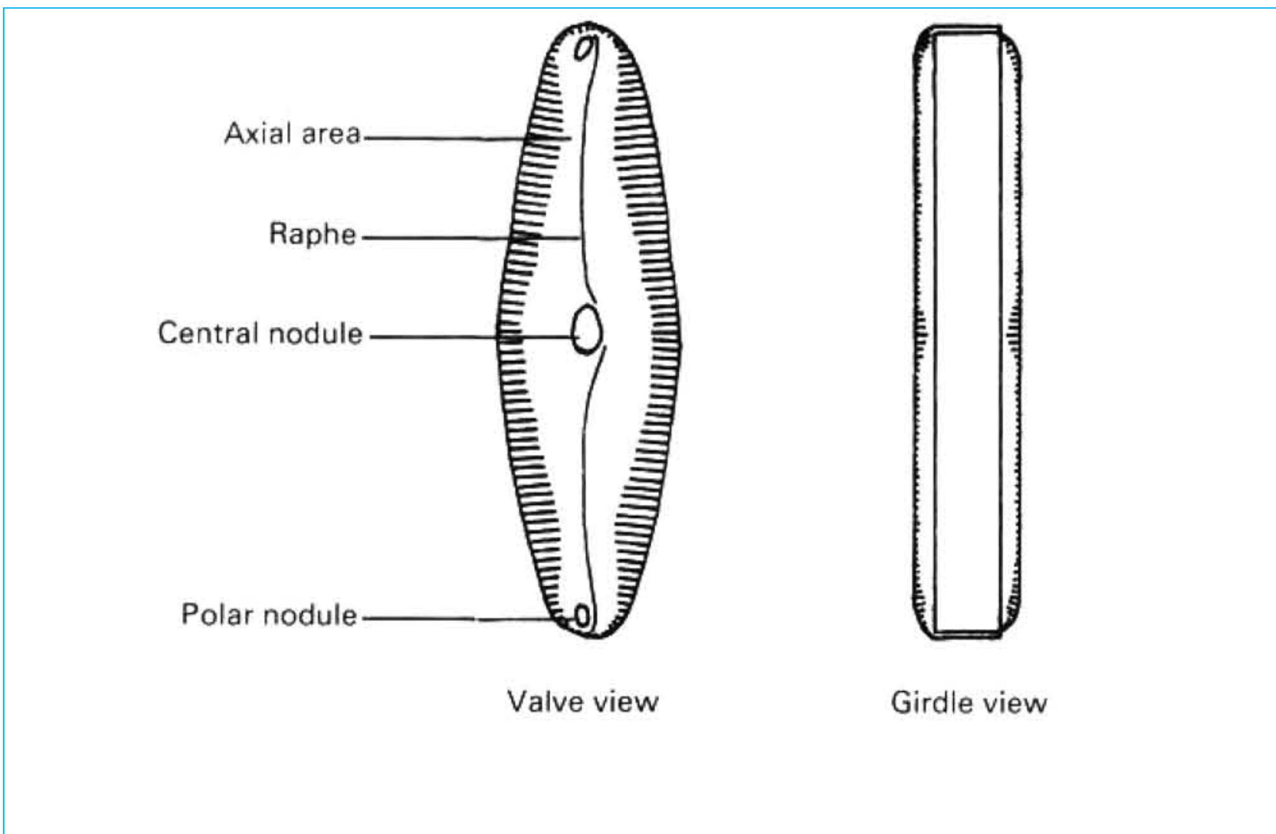


Fig. 3. The structure of a generalized raphe-bearing pennate diatom (after Sykes, 1981).

The valve view with the pattern of sculpturing is based on a central point as exemplified by *Coscinodiscus radiatus*. In other genera, however, this "pill box" shape is less apparent; e.g. *Rhizosolenia*, in which the valve is often conical and the girdle length may be up to fifty times the valve diameter, and *Chaetoceros*, in which long spines, called setae, arise from the valves. Many centric diatoms also form chains of cells, in which the cells are joined together by all, or part of, their valve surfaces. Three such genera are: *Chaetoceros, Lauderia* and *Eucampia*. In other genera, the cells are linked in chains by spines, e.g. *Skeletonema* or by mucilaginous threads arising from the valve surface, as in *Thalassiosira* (Sykes, 1981).

In addition to chloroplasts, a diatom cell also contain a nucleus, mitochondria, golgi apparatus, endoplasmic reticulum, ribosomes and vacuoles: all the organelles characteristic of eukaryote cells. The nucleus often lies in the center of the cell, in a bridge of cytoplasm, and is surrounded by a number of perinuclear golgi bodies (dictyosomes). These may play a part in the formation of the silica deposition vesicle following cell division. The nuclear envelope can be continuous with the chloroplast endoplasmic reticulum (Hoek, 1995).
A further important point results from the type of cell division shown by diatoms. During division, new valve and girdle bands are formed inside each half of the parent frustule. Thus, in each generation, one of the daughter cells is fractionally smaller than the parent. Over succeeding generations, this can result in a considerable difference in size between members of the same species. Therefore, valve diameter is not a sound character in the description of diatoms. Nevertheless, some species are typically much larger than others, and the usual size range of each form is given in the taxonomical key, but it is generally intended to be used as confirmatory rather than diagnostic evidence.

The progressive reduction in cell size, that results from repeated cell division, eventually reaches a critical point. The cell then stops dividing, the living contents enlarge, and typically become rounded, to form the auxospore. Eventually, a new frustule is formed and the cycle restarts. If conditions are unsuitable for further cell division, the auxospore may develop into a resting stage (Sykes, 1981).

TAXONOMIC LIST OF MARINE DIATOMS IN KUWAIT'S WATERS.

Kuwait's waters are rich with various centric and pennate diatom species. A total of 202 species were found representing 75 genera, 44 families, 27 orders, 9 sub-classes and 3 classes. All the genera and species dealt with in this Atlas are recorded in the list in Table 1. The classification of these taxa follows Round et al. (1990) in dividing the diatoms under the division Bacillariophyta into 3 classes including the centric diatoms (Coscinodiscophyceae), the pennate diatoms without a raphe (Fragilariophyceae) and the pennate diatoms with a raphe (Bacillariophyceae). The typefaces used for each classification are denoted thus: Phylum, Class, Subclass, Order, Family, Genus. A few species were classified in accordance with Hasle and Syvertsen (1997).

Table 1. A list of diatom species from Kuwait's waters

Phylum	Class	Sub-Class	Order	Family	Genus and Species
Bacillariophyta	Coscinodiscophyceae (Centric diatoms) Round and Crawford 1995	Thalassiosiraphycidae Round and Crawford 1995	Thalassiosirales Glezer and Makarova 1986	Thalassiosiraceae Lebour 1930	Genus: *Thalassiosira* Cleve 1873 *Thalassiosira eccentrica* (Ehrenberg) Cleve *Thalassiosira oestrupii* (Ostenfeld) Hasle *Thalassiosira oestrupii* var. *venrickae* Fryxell and Hasle *Thalassiosira* sp.1 Genus: *Planktoniella* Schütt 1892 *Planktoniella sol* (Wallich) Schütt
				Stephanodiscaceae Glezer and Makarova 1986	*Cyclotella* (Kützing 1833) Brébisson 1838 *Cyclotella striata* (Kützing) Grunow *Cyclotella stylorum* Brightwell
				Lauderiaceae (Schütt) Lemmermann 1899	Genus: *Lauderia* Cleve 1873 *Lauderia annulata* Cleve
				Skeletonemataceae Lebour 1930 emend. Round et al. 1990	Genus: *Detonula* Schütt ex De Toni 1894 *Detonula pumila* (Castracane) Gran *Skeletonema* Greville 1865 *Skeletonema costatum* (Greville) Cleve
		Coscinodiscophycidae Round and Crawford 1995	Melosirales Crawford 1995	Stephanopyxidaceae Nikolaev	Genus: *Stephanopyxis* (Ehrenberg) Ehrenberg 1845 *Stephanopyxis palmeriana* (Greville) Grunow
			Paraliales Crawford 1995	Paraliaceae Crawford 1995	Genus: *Paralia* Heiberg 1863 *Paralia sulcata* (Ehrenberg) Cleve
			Coscinodiscales Round and Crawford 1995	Coscinodiscaceae Kützing 1844	Genus: *Coscinodiscus* Ehrenberg 1838 *Coscinodiscus* cf. *asteromphalus* Ehrenberg *Coscinodiscus centralis* Ehrenberg *Coscinodiscus granii* Gough *Coscinodiscus jonesianus* (Greville) Ostenfeld *Coscinodiscus marginatus* Ehrenberg *Coscinodiscus oculus-iridis* Ehrenberg *Coscinodiscus oculus-iridis* var. *borealis* *Coscinodiscus radiatus* Ehrenberg *Coscinodiscus wailesii* Gran and Angst Genus: *Palmeria* Greville 1865 *Palmeria hardmaniana* Greville
				Hemidiscaceae Hendey 1937	Genus: *Actinocyclus* Ehrenberg 1837 *Actinocyclus octonarius* Ehrenberg *Actinocyclus octonarius* var. *crassus* (Wm. Smith) Hendey *Actinocyclus octonarius* var. *tenellus* (de Brébisson) Hendey Genus: *Hemidiscus* Wallich 1860 *Hemidiscus cuneiformis* Wallich
			Asterolamprales Round and Crawford 1995	Asterolampraceae H. L. Smith 1872	Genus: *Asteromphalus* Ehrenberg 1844 *Asteromphalus flabellatus* (Brébisson) Greville *Asteromphalus hookeri* Ehrenberg
		Biddulphiophycidae Round and Crawford 1995	Triceratiales Round and Crawford 1995	Triceratiaceae (Schütt) Lemmermann 1899	Genus: *Odontella* Agardh 1832 *Odontella aurita* (Lyngbye) C. A. Agardh *Odontella mobiliensis* (Bailey) Grunow *Odontella sinensis* (Greville) Grunow Genus: *Triceratium* Ehrenberg 1841 *Triceratium* cf. *broeckii* Leuduger-Fortmorel *Triceratium reticulum* Ehrenberg Genus: *Lampriscus* Schmidt 1882 *Lampriscus shadboltianum* (Greville) Simonsen
				Plagiogrammaceae De Toni 1890	*Dimeregramma* Ralfs 1861 *Dimeregramma minor* (Gregory) Ralfs
			Biddulphiales Krieger 1954	Biddulphiaceae Kützing 1844	Genus: *Biddulphia* Gray 1821 *Biddulphia pulchella* Gray
			Hemiaulales Round and Crawford 1995	Hemiaulaceae Heiberg 1863	Genus: *Cerataulina* Peragallo 1892 ex Schütt 1896 *Cerataulina bicornis* (Ehrenberg) Hasle *Cerataulina dentata* Hasle *Cerataulina pelagica* (Cleve) Hendey Genus: *Climacodium* Grunow 1868 *Climacodium frauenfeldianum* Grunow Genus: *Eucampia* Ehrenberg 1839 *Eucampia zodiacus* Ehrenberg Genus: *Hemiaulus* Heiberg 1863 *Hemiaulus membranaceus* Cleve *Hemiaulus sinensis* Greville

Phylum	Class	Sub-Class	Order	Family	Genus and Species
				Bellerocheaceae Crawford 1995	Genus: *Bellerochea* Van Heurck 1885 *Bellerochea horologicalis* Von Stosch *Bellerochea malleus* (Brightwell) Van Heurck
				Streptothecaceae Crawford 1995	Genus: *Helicotheca* Ricard 1987 *Helicotheca thamensis* (Shrubsole) Ricard
		Lithodesmiophycidae Round and Crawford 1995	Lithodesmiales Round and Crawford 1995	Lithodesmiaceae Round 1995	Genus: *Ditylum* Baily 1861 *Ditylum brightwelli* (West) Grunow
		Corethrophycidae Round and Crawford	Corethrales Round and Crawford 1995	Corethraceae Lebour 1930	Genus: *Corethron* Castracane 1886 *Corethron criophilum* Castracane
		Rhizosoleniophycidae Round and Crawford 1995	Rhizosoleniales Silva 1962	Rhizosoleniaceae De Toni 1890	Genus: *Rhizosolenia* Brightwell 1858 *Rhizosolenia bergonii* Péragallo *Rhizosolenia cochlea* Brun *Rhizosolenia imbricata* Brightwell *Rhizosolenia* cf. *pungens* Cleve-Euler *Rhizosolenia robusta* Norman *Rhizosolenia shrubsolei* Cleve *Rhizosolenia setigera* Brightwell *Rhizosolenia* sp. 1 Genus: *Proboscia* Sundström 1986 *Proboscia alata* (Brightwell) Sundström *Proboscia alata* f. *gracillima* (Cleve) Gran *Proboscia alata* f. *indica* (H. Péragallo) Ostenfeld Genus: *Pseudosolenia* Sundström 1986 *Pseudosolenia calcar-avis* (Schultze) Sundström Genus: *Guinardia* H. Peragallo 1892 *Guinardia flaccida* (Castracane 1886) H. Peragallo *Guinardia delicatula* (Cleve) Hasle *Guinardia striata* (Stolterfoth) Hasle *Guinardia* sp. 1 Genus: *Dactyliosolen* Castracane 1886 *Dactyliosolen fragilissimus* (P. Bergon) Hasle
		Chaetocerotophycidae Round and Crawford 1995	Chaetocerotales Round and Crawford 1995	Chaetocerotaceae Ralfs 1861/H. L. Smith 1872	Genus: *Bacteriastrum* Shadbolt 1854 *Bacteriastrum delicatulum* Cleve *Bacteriastrum* cf. *elegans* Pavillard *Bacteriastrum hyalinum* Lauder *Bacteriastrum varians* var. *hispida* (Castracane) Schröder Genus: *Chaetoceros* Ehrenberg 1844 *Chaetoceros affinis* Lauder *Chaetoceros atlanticus* Cleve *Chaetoceros coarctatus* Lauder *Chaetoceros compressus* Lauder *Chaetoceros costatus* Pavillard *Chaetoceros curvisetum* Cleve *Chaetoceros decipiens* Cleve *Chaetoceros denticulatus* Lauder *Chaetoceros didymus* Ehrenberg *Chaetoceros diversus* Cleve *Chaetoceros laciniosus* Schütt *Chaetoceros laevis* Leuduger-Fortmorel *Chaetoceros lorenzianus* Grunow *Chaetoceros peruvianus* Brightwell *Chaetoceros pseudocurvisetum* Mangin *Chaetoceros socialis* Lauder *Chaetoceros tortissimum* Gran
			Leptocylindrales Round and Crawford 1995	Leptocylindraceae Lebour 1930	Genus: *Leptocylindrus* Cleve 1889 *Leptocylindrus danicus* Cleve *Leptocylindrus minimus* Gran
	Fragilariophyceae Round 1995 (Araphid, pennate diatoms)	Fragilariophycidae Round 1995	Fragilariales Silva 1962	Fragilariaceae Greville 1833	Genus: *Asterionellopsis* Round 1990 *Asterionellopsis glacialis* (Castracane 1886) Round Genus: *Fragilaria* Lyngbye 1819 *Fragilaria* cf. *martyi* (Heribaud) Lange-Bertalot *Fragilaria* sp. 1 Genus: *Opephora* Petit 1888 *Opephora schwartzii* (Grunow) Petit *Opephora* sp. 1 Genus: *Synedra* Ehrenberg 1830 *Synedra* sp. 1 Genus: *Trachysphenia* P. Petit 1877 *Trachysphenia australis* Petit

Phylum	Class	Sub-Class	Order	Family	Genus and Species
			Licmophorales Round 1995	Licmophoraceae Kützing 1844	Genus: *Licmophora* Agardh 1827 *Licmophora* sp. 1
			Rhaphoneidales Round	Raphoneidaceae Forti 1912	Genus: *Diplomenora* Blazé 1984 *Diplomenora cocconeiformis* (Schmidt) Blazé
			Thalassionematales Round 1995	Thalassionemataceae Round 1995	Genus: *Thalassionema* Grunow 1902 *Thalassionema nitzschioides* (Grunow) Mereschkowsky *Thalassionema frauenfeldii* (Grunow) Hallegraeff Genus: *Thalassiothrix* Cleve and Grunow 1880 *Thalassiothrix* cf. *longissima* Cleve and Grunow
			Rhabdonematales Round and Crawford 1995	Rhabdonemataceae Round and Crawford 1995	Genus: *Rhabdonema* Kützing 1844 *Rhabdonema* sp. 1
			Striatellales Round 1995	Striatellaceae Kützing 1844	Genus: *Grammatophora* Ehrenberg 1839 *Grammatophora marina* (Lyngbye) Kützing *Grammatophora oceanica* Ehrenberg *Grammatophora* sp. 1 Genus: *Striatella* Agardh 1832 *Striatella unipunctata* (Lyngbye) Agardh
	Bacillariophyceae Haeckel 1878 emend Mann 1995 (Raphid, pennate diatoms)	Bacillariophycidae Mann 1995	Lyrellales Mann 1995	Lyrellaceae Mann 1995	Genus: *Lyrella* (Cleve) Karayeva 1978 *Lyrella* cf. *abrupta* (Gregory) Mann *Lyrella atlantica* (Schmidt) Mann *Lyrella clavata* (Gregory) Mann *Lyrella fogedii* Witkowski, Lange - Bertalot and Metzeltin *Lyrella* cf. *hennedyi* (Smith) Stickle & Mann *Lyrella spectabilis* (Gregory) Mann *Lyrella* sp. 1
			Mastogloiales Mann 1995	Mastogloiaceae Mereschkowsky 1903	Genus: *Mastogloia* Thwaites in Smith 1856 *Mastogloia arabica* Hendey *Mastogloia decussata* Grunow *Mastogloia erythraea* Grunow *Mastogloia linearis* Simonsen *Mastogloia Mac-Donaldii* Greville *Mastogloia* sp. 1 *Mastogloia* sp. 2 *Mastogloia* sp. 3
			Cymbellales Mann 1995	Cymbellaceae Greville 1833	Genus: *Cymbella* Agardh 1830 *Cymbella* sp. 1
				Gomphonemataceae Kützing 1844	Genus: *Gomphonema* Ehrenberg 1832 *Gomphonema* sp.1
			Achnanthales Silva 1962	Achnanthaceae Kützing 1844	Genus: *Achnanthes* Bory 1822 *Achnanthes brevipes* v. *intermedia* Agardh *Achnanthes* cf. *fimbriata* (Grunow) Ross *Achnanthes* sp. 1 Genus: *Planothidium* Round and Buktiyarova 1996 *Planothidium* sp.1
				Cocconeidaceae Kützing 1844	Genus: *Cocconeis* Ehrenberg 1837 *Cocconeis* cf. *guttata* Hustedt in ALeem and Hustedt *Cocconeis placentula* Ehrenberg
			Naviculales Bessey 1907		
			Sub-order: Neidiineae Mann 1995	Berkeleyaceae Mann 1995	Genus: *Berkeleya* Greville 1827 *Berkeleya scopulorum* cf. var. *perlonga* (Brun) Cox
			Sub-order: Sellaphorineae Mann 1995	Sellaphoraceae Mereschkowsky 1902	Genus: *Fallacia* Stickle and Mann 1995 *Fallacia* cf. *arenaria* Sabbe and Vyverman
				Pinnulariaceae Mann 1995	Genus: *Caloneis* Cleve 1894 *Caloneis* cf. *westii* (Smith 1853) Hendey Genus: *Oestrupia* Heiden 1935 *Oestrupia musca* (Gregory) Hustedt

Phylum	Class	Sub-Class	Order	Family	Genus and Species
			Sub-order: Diploneidineae Mann 1995	Diploneidaceae Mann 1995	Genus: *Diploneis* Ehrenberg 1844 *Diploneis chersonensis* (Grunow) Cleve *Diploneis didyma* (Ehrenberg) Cleve *Diploneis* aff. *gemmatula* (Grunow) Cleve *Diploneis interrupta* (Kützing) Cleve *Diploneis litoralis* (Donkin) Cleve *Diploneis smithii* (Brébisson in Smith) Cleve *Diploneis suborbicularis* (Gregory 1857) Cleve *Diploneis vacillans* var. *renitens* Schmidt *Diploneis weissflogii* (Schmidt) Cleve *Diploneis* sp. 1 *Diploneis* sp. 2
			Sub-order: Naviculineae Hendey 1937	Naviculaceae Kützing 1844	Genus: *Meuniera* Silva 1996 *Meuniera membranacea* (Cleve) Silva Genus: *Navicula* Bory 1824 *Navicula directa* var. *remota* Cleve *Navicula* cf. *erifuga* Lange-Bertalot *Navicula perrhombus* Hustedt *Navicula* sp. 1 *Navicula* sp. 2 *Navicula* sp. 3 Genus: *Trachyneis* Cleve 1894 *Trachyneis antillarum* Cleve *Trachyneis aspera* (Ehrenberg) Cleve Genus: *Haslea* Simonsen 1974 *Haslea* sp. cf. *balearica* in Witkowski et al., 2000 *Haslea* sp. 1 *Haslea* sp. 2
				Pleurosigmataceae Mereschkowsky 1903	Genus: *Donkinia* Ralfs 1861 *Donkinia* sp. 1 Genus: *Pleurosigma* Smith 1852 *Pleurosigma cuspidatum* Cleve *Pleurosigma diverse-striatum* Meister *Pleurosigma* cf. *elongatum* Smith *Pleurosigma formosum* Peragallo *Pleurosigma* cf. *strigosum* Smith Genus: *Gyrosigma* Hassall 1845 *Gyrosigma diminutum* Grunow
				Plagiotropidaceae Mann 1995	Genus: *Plagiotropis* Pfitzer 1871 *Plagiotropis lepidoptera* (Gregory) Cleve
			Thalassiophy-sales Mann 1995	Catenulaceae Mereschkowsky 1902	Genus: *Amphora* Ehrenberg 1840 *Amphora crassa* Gregory *Amphora decussata* Grunow *Amphora granulata* var. *biggibbosa* Ricard *Amphora obtusa* Gregory *Amphora ostrearia* Brébisson *Amphora proteus* Gregory *Amphora rhombica* Kitton ex Schmidt *Amphora spectabilis* Gregory *Amphora sulcata* *Amphora* cf. *turgida* Gregory *Amphora* sp. 1 *Amphora* sp. 2 *Amphora* sp. 3 *Amphora* sp. 4 *Amphora* sp. 5 *Amphora* sp. 6 *Amphora* sp. 7 *Amphora* sp. 8 *Amphora* sp. 9
			Bacillariales Hendey 1937	Bacillariaceae Ehren-berg 1831	Genus: *Bacillaria* J. F. Gmelin 1791 *Bacillaria paxillifera* (Müller) Hendey *Bacillaria socialis* (Gregory) Ralfs Genus: *Cylindrotheca* Rabenhorst 1859 *Cylindrotheca closterium* (Ehrenberg) Lewin and Reimann *Cylindrotheca* sp.1 Genus: *Hantzschia* Grunow 1877 *Hantzschia amphioxis* (Ehrenberg) Grunow Genus: *Nitzschia* Hassall 1845 *Nitzschia behrei* Hustedt

Phylum	Class	Sub-Class	Order	Family	Genus and Species
					Nitzschia coarctata Grunow *Nitzschia* cf. *fluminensis* Grunow *Nitzschia longissima* (Brébisson) Ralfs in Pritchard *Nitzschia lorenziana* Grunow *Nitzschia* cf. *sigma* (Kützing) Smith *Nitzschia* cf. *sigmoidea* *Nitzschia panduriformis* Gregory *Nitzschia* sp. 1 *Nitzschia* sp. 2 *Nitzschia* sp. 3 *Nitzschia* sp. 4 Genus: *Pseudo-nitzschia* Peragallo 1899 *Pseudo-nitzschia delicatissima* group *Pseudo-nitzschia seriata* group
			Surirellales Mann 1995	Entomoneidaceae Reimer in Patrick and Reimer 1975	Genus: *Entomoneis* Ehrenberg 1845 *Entomoneis sulcata* Müller
				Auriculaceae Hendey 1964	Genus: *Auricula* Castracane 1873 *Auricula* sp. 1
				Surirellaceae Kützing 1844	Genus: *Surirella* Turpin 1828 *Surirella fastuosa* Ehrenberg *Surirella* cf. *hybrida* Grunow *Surirella scalaris* Giffen *Surirella* sp. 1 Genus: *Plagiodiscus* Grunow and Eulenstein 1867 *Plagiodiscus nervatus* Grunow

Geographical Distribution of Marine Diatoms in Kuwait's Waters

The distribution of all the identified genera and species of diatoms that were obtained from the 13 sampled stations in Kuwait's waters are given in alphabetical order in Table 2.

Table 2. The geographical distribution of all the identified genera and species of diatoms from different localities in Kuwait's waters. A (+) sign indicates that the species is present at a particular locality.

Species composition	Khor Al-Sabiya	North Failaka Island	Western end of Kuwait Bay	Mid-Kuwait Bay	Eastern end of Kuwait Bay	Off Ras Al-Ardh	Off Al-Fintas	Off Al-Ahmadi	Off Mina Abdulla	Off Ras Al-Qulaiah	Off Mina Zor	Off Kuwait Naval Base	Off AL-Khiran
Achnanthes brevipes v. *intermedia*		+								+			
Achnanthes cf. *fimbriata*				+									
Achnanthes sp. 1				+									
Actinocyclus octonarius		+	+		+	+	+						
Actinocyclus octonarius var. *crassus*			+				+						
Actinocyclus octonarius var. *tenellus*		+											
Amphora crassa				+									
Amphora decussata				+									
Amphora granulata var. *biggibbosa*						+					+		
Amphora obtusa				+							+		
Amphora ostrearia				+			+				+		
Amphora proteus						+				+	+		
Amphora rhombica											+		
Amphora spectabilis							+						
Amphora sulcata				+							+		
Amphora cf. *turgida*		+											
Amphora sp. 1							+						
Amphora sp. 2											+		
Amphora sp. 3		+			+								
Amphora sp. 4					+		+				+		
Amphora sp. 5											+		
Amphora sp. 6											+		
Amphora sp. 7		+											
Amphora sp. 8									+				
Amphora sp. 9		+				+							
Asterionellopsis glacialis	+				+		+						
Asteromphalus flabellatus		+	+	+	+	+	+		+	+	+		
Asteromphalus hookeri			+										
Auricula sp. 1			+								+		
Bacillaria paxillifera			+	+			+		+		+		
Bacillaria socialis						+					+		
Bacteriastrum delicatulum					+	+					+		
Bacteriastrum cf. *elegans*					+								
Bacteriastrum hyalinum					+		+				+		
Bacteriastrum varians var. *hispida*					+	+							
Bellerochea horologicalis		+	+	+	+	+	+		+				
Bellerochea malleus		+			+								
Berkeleya scopulorum cf. var. *perlonga*				+									
Biddulphia pulchella								+	+				
Caloneis cf. *westii*											+		

Species composition	Khor Al-Sabiya	North Failaka Island	Western end of Kuwait Bay	Mid-Kuwait Bay	Eastern end of Kuwait Bay	Off Ras Al-Ardh	Off Al-Fintas	Off Al-Ahmadi	Off Mina Abdulla	Off Ras Al-Qulaiah	Off Mina Zor	Off Kuwait Naval Base	Off AL-Khiran
Cerataulina bicornis								+					
Cerataulina dentata			+				+					+	
Cerataulina pelagica	+		+	+	+	+	+		+			+	
Chaetoceros affinis								+					
Chaetoceros atlanticus			+		+	+	+	+	+			+	+
Chaetoceros coarctatus			+		+		+	+					
Chaetoceros compressus											+		+
Chaetoceros costatus							+	+					
Chaetoceros curvisetum			+		+	+	+		+				
Chaetoceros decipiens						+		+	+		+	+	+
Chaetoceros denticulatus							+		+			+	+
Chaetoceros didymus												+	
Chaetoceros diversus			+			+	+	+	+		+	+	+
Chaetoceros laciniosus						+			+		+	+	+
Chaetoceros laevis		+	+					+	+		+	+	+
Chaetoceros lorenzianus		+			+		+		+			+	+
Chaetoceros peruvianus		+	+					+	+	+	+		+
Chaetoceros pseudocurvisetum			+	+	+	+	+	+	+		+	+	+
Chaetoceros socialis			+					+					+
Chaetoceros tortissimum		+	+	+		+	+	+	+		+		
Climacodium frauenfeldianum		+	+	+		+	+						
Cocconeis cf. *guttata*			+										
Cocconeis placentula								+					
Corethron criophilum						+	+						
Coscinodiscus cf. *asteromphalus*							+				+		
Coscinodiscus centralis			+	+	+	+	+	+	+				+
Coscinodiscus granii		+			+	+	+	+					
Coscinodiscus jonesianus			+										
Coscinodiscus marginatus			+					+					
Coscinodiscus oculus-iridis	+					+	+	+	+			+	+
Coscinodiscus radiatus				+			+	+	+			+	
Coscinodiscus wailesii				+	+			+					
Cyclotella striata						+							
Cyclotella stylorum		+	+					+	+	+		+	+
Cylindrotheca closterium		+	+	+		+	+	+	+				+
Cylindrotheca sp. 1					+								
Cymbella sp. 1								+					
Dactyliosolen fragilissimus		+						+	+		+	+	+
Detonula pumila			+										
Dimeregramma minor						+							+
Diplomenora cocconeiformis			+										
Diploneis chersonensis									+				+
Diploneis didyma												+	
Diploneis aff. *gemmatula*									+				

Species composition	Khor Al-Sabiya	North Failaka Island	Western end of Kuwait Bay	Mid-Kuwait Bay	Eastern end of Kuwait Bay	Off Ras Al-Ardh	Off Al-Fintas	Off Al-Ahmadi	Off Mina Abdulla	Off Ras Al-Qulaiah	Off Mina Zor	Off Kuwait Naval Base	Off AL-Khiran
Diploneis interrupta				+									
Diploneis litoralis				+									
Diploneis smithii						+			+			+	+
Diploneis suborbicularis						+							+
Diploneis vacillans var. *renitens*						+							
Diploneis weissflogii						+		+					+
Diploneis sp. 1			+										+
Diploneis sp. 2			+					+					
Ditylum brightwellii			+	+		+	+						
Donkinia sp. 1			+			+							
Entomoneis sulcata		+	+	+	+	+	+	+	+			+	+
Eucampia zodiacus		+	+	+	+	+	+	+	+				
Fallacia cf. *arenaria*						+							
Fragilaria cf. *martyi*			+										
Fragilaria sp.1				+									
Gomphonema sp.1								+					
Grammatophora *marina*			+			+						+	
Grammatophora oceanica			+	+									
Grammatophora sp. 1			+										
Guinardia flaccida	+	+	+	+	+	+	+	+	+	+	+	+	+
Guinardia delicatula									+				+
Guinardia striata		+	+		+	+	+	+	+		+	+	+
Guinardia sp. 1			+										+
Gyrosigma diminutum												+	
Hantzschia amphioxis					+								
Haslea cf. *balearica*												+	+
Haslea sp. 1		+	+						+				
Haslea sp. 2						+	+				+		
Helicotheca thamensis		+	+	+	+		+		+				+
Hemiaulus membranaceus						+	+	+	+				
Hemiaulus sinensis		+	+	+	+	+	+	+	+	+	+	+	+
Hemidiscus cuneiformis			+	+		+							
Lauderia annulata		+	+	+	+	+	+	+	+	+	+		
Lampriscus shadboltianum			+	+					+		+	+	+
Leptocylindrus danicus			+	+	+	+	+	+	+		+		
Leptocylindrus minimus					+				+				
Licmophora sp. 1			+	+									
Lyrella cf. *abrupta*						+		+					
Lyrella atlantica									+				+
Lyrella clavata					+	+			+				+
Lyrella fogedii						+							+
Lyrella cf. *hennedyi*			+										+
Lyrella spectabilis						+							
Lyrella sp. 1						+							

Species composition	Khor Al-Sabiya	North Failaka Island	Western end of Kuwait Bay	Mid-Kuwait Bay	Eastern end of Kuwait Bay	Off Ras Al-Ardh	Off Al-Fintas	Off Al-Ahmadi	Off Mina Abdulla	Off Ras Al-Qulaiah	Off Mina Zor	Off Kuwait Naval Base	Off AL-Khiran
Mastogloia arabica						+							+
Mastogloia decussata													+
Mastogloia erythraea							+						
Mastogloia linearis						+							
Mastogloia MacDonaldii													+
Mastogloia sp. 1													+
Mastogloia sp. 2				+									+
Mastogloia sp. 3			+										+
Meuniera membranacea						+	+		+		+		
Navicula directa v. *remota*													+
Navicula cf. *erifuga*								+					
Navicula perrhombus				+		+							
Navicula sp. 1													+
Navicula sp. 2						+							
Navicula sp. 3												+	
Nitzschia behrei					+								
Nitzschia coarctata											+		+
Nitzschia cf. *fluminensis*								+					
Nitzschia longissima		+				+			+				+
Nitzschia lorenziana				+			+		+			+	+
Nitzschia cf. *sigma*													+
Nitzschia cf. *sigmoidea*							+				+		
Nitzschia panduriformis				+				+					
Nitzschia sp. 1													+
Nitzschia sp. 2			+										
Nitzschia sp. 3											+		
Nitzschia sp. 4				+									
Odontella aurita			+						+		+		
Odontella mobiliensis		+	+		+	+	+		+		+	+	
Odontella sinensis		+	+		+	+	+	+	+	+	+		
Oestrupia musca				+		+							+
Opephora schwartzii						+			+			+	+
Opephora sp. 1													+
Palmeria hardmaniana						+	+		+			+	
Paralia sulcata	+			+	+	+	+	+	+			+	+
Plagiodiscus nervatus												+	+
Plagiotropis lepidoptera			+										+
Planktoniella sol			+										
Planothidium sp.1			+										
Pleurosigma cuspidatum			+	+									
Pleurosigma diverse-striatum		+				+	+	+	+				+
Pleurosigma cf. *elongatum*			+				+						
Pleurosigma formosum													+
Pleurosigma cf. *strigosum*			+						+				

Species composition	Khor Al-Sabiya	North Failaka Island	Western end of Kuwait Bay	Mid-Kuwait Bay	Eastern end of Kuwait Bay	Off Ras Al-Ardh	Off Al-Fintas	Off Al-Ahmadi	Off Mina Abdulla	Off Ras Al-Qulaiah	Off Mina Zor	Off Kuwait Naval Base	Off AL-Khiran
Proboscia alata		+	+		+	+	+	+	+	+	+	+	+
Proboscia alata f. *gracillima*			+									+	
Proboscia alata f. *indica*			+			+	+						
Pseudonitzschia delicatissima group												+	+
Pseudonitzschia seriata group		+		+	+	+	+		+				
Pseudosolenia calcar-avis						+						+	+
Rhabdonema sp. 1													+
Rhizosolenia bergonii								+	+				+
Rhizosolenia cochlea		+	+	+	+	+	+	+	+		+	+	+
Rhizosolenia imbricata		+	+		+			+	+			+	+
Rhizosolenia cf. *pungens*												+	
Rhizosolenia robusta			+		+	+	+	+	+		+	+	
Rhizosolenia shrubsolei		+	+		+	+	+	+			+	+	+
Rhizosolenia setigera		+	+		+				+		+	+	+
Rhizosolenia sp. 1			+										
Skeletonema costatum			+				+						
Stephanopyxis palmeriana			+										
Striatella unipunctata			+										
Surirella fastuosa		+	+	+	+	+	+	+	+			+	+
Surirella cf. *hybrida*													+
Surirella scalaris				+		+							
Surirella sp. 1						+							
Synedra sp. 1			+										
Thalassionema nitzschioides		+	+	+	+	+	+	+	+	+	+	+	+
Thalassionema frauenfeldii					+		+		+	+		+	+
Thalassiothrix cf. *longissima*			+										
Thalassiosira eccentrica			+	+			+		+			+	
Thalassiosira oestrupii		+	+	+	+	+		+					+
Thalassiosira oestrupii var. *venrickae*				+									
Thalassiosira sp.1					+			+					
Trachyneis antillarum				+		+		+	+				+
Trachyneis aspera								+				+	+
Trachysphenia australis				+		+							
Triceratium cf. *broeckii*						+	+	+	+				
Triceratium reticulum			+										

Taxonomic Description Of Marine Diatoms In Kuwait's Waters

The taxonomical description for each taxon includes the previous names assigned to the taxon if a new name is subsequently given, the references according to which the identification is performed, the morphological and size characteristics and the distribution of the species. The illustrations for each species are given in the corresponding plates.

Phylum: Bacillariophyta (Diatoms)

Class: Coscinodiscophyceae (centric diatoms) Round and Carwford in Round et al. 1990

Sub-Class: Thalassiosiraphycidae Round and Carwford in Round et al. 1990

Order: Thalassiosirales Glezer and Makarova 1986

The order Thalassiorales was classified by Round et al. (1990) into four families: Thalassiosiraceae Lebour 1930, Stephanodiscaceae Glezer and Makarova 1986, Lauderiaceae (Schütt) Lemmermann 1899, and Skeletonemataceae Lebour 1930.

Family: Thalassiosiraceae Lebour 1930

The family is comprised of marine as well as freshwater planktonic diatoms, all having strutted processes as the main morphological, and taxonomic character (Hasle and Syvertsen, 1997).

Genus: *Thalassiosira* Cleve 1873

It has more than 100 species, and is the marine planktonic genus most thoroughly examined by modern methods (Hasle and Syvertsen, 1997). Cells are usually drum or disk-shaped, united in flexible chains by a cytoplasmic or gelatinous thread or living in formless gelatinous masses, or seldom solitary. One or more intercalary bands to each valve. Valves with areolae or delicate radial rows of punctuations. Marginal spinulae or little spines present, usually distinct, sometimes with mucilage threads extruding, which may be much longer than the cell itself. Valves rounded or flat, in a few species depressed in the center. Chromatophores numerous, small, platelike. It is a planktonic genus, principally neritic and arctic, occurs in cold and temperate seas. Some species not uncommon off Lower California and in Gulf of California (Cupp, 1943). Three species and one variety were obtained from Kuwait's waters. One species name is not finalized at this stage and is reported as species 1.

Thalassiosira eccentrica (Ehrenberg) Cleve (Plate 1A-I)

Basionym: *Coscinodiscus eccentricus* Ehrenberg 1841.

References: Hustedt, 1930; Cupp, 1943; Simonsen, 1974; Hasle, 1976; Pankow, 1990; Round et al., 1990; Hernández-Becerril and Tapia Peña, 1995; Hasle and Syvertsen, 1997; Throndsen et al., 2003.

Description: Cells solitary or forming chains linked by mucilage threads. Connecting thread about twice the cell diameter. Valves are disc-shaped and flat, mantle low and rounded. Areolae in curved tangential rows (eccentric structure), 8-11 areolae/10 µm, being slightly finer at the margins, 12-13 areolae/10 µm. Central strutted process adjacent to a central areola surrounded by a ring of seven areolae (strutted tubuli) (Hasle and Syvertsen, 1997). In addition to this central ring, there are generally more circules of tubuli which occur in numbers of 7 or its multiple. Simonsen (1974) mentioned that the tubuli in the valve plane cannot be considered as "scattered", i.e., of random distribution as documented by Hasle

and Syvertsen (1997). Two marginal rings of strutted processes with short external tubes; one ring of pointed spines further away from valve margin. The girdle view depending on cell diameter, pervalvar axis from one-sixth to longer than the length of the diameter (Hasle and Syvertsen, 1997). The areolation obtained in this survey was 9-10 areolae/10 µm.
Dimension: Valves diameter 25-69 µm (Hernández-Becerril and Tapia Peña, 1995); 44-49 µm valves diameter were obtained in the present survey, in Kuwait's waters.
Distribution: Cosmopolitan, coastal. Simonsen (1974) reported its presence, usually near the coast, in the Pacific, Atlantic, and Indian Oceans; Bergan, Norway; fairly common on the east and west coasts of the U.S., and also common in European waters. It is also reported as the most widely distributed species in the Gulf of California and Coasts off Baja California (Hernández-Becerril and Tapia Peña, 1995). It also occurs at different localities of Kuwait's waters.

Thalassiosira oestrupii **(Ostenfeld) Hasle (Plate 2A-F)**
Basionym: *Coscinosira oestrupii* Ostenfeld.
Synonym: *Coscinodiscus bulliens* A. Schmidt.
References: Hustedt, 1930; Hendey, 1964; Simonsen, 1974; Fryxell and Hasle, 1980; Hasle and Syvertsen, 1997.
Description: Pervalvar axis half to twice the diameter; valve face flat or slightly convex; mantle low and rounded. Cells in chains united by a thread from the central strutted process. Areolae usually larger in central part of valve than closer to the margin, sometimes in sublinear array. One nearly central strutted process; labiate process usually one or two areolae distant. It is distinguished from *T. oestrupii* var. *oestrupii* by a distinct eccentric areola pattern and by more widely separated marginal processes. The labiate as well as the strutted processes are discernible with LM (Hasle and Syvertsen, 1997).
Dimension: Diameter of valve 10-20 µm (Hendey, 1964). In the present materials from Kuwait's waters the valve diameter of the obtained cell was 13-16 µm.
Distribution: Present in the Indian Ocean (Simonsen, 1974). It was encountered in Kuwait's waters during this study.

Thalassiosira oestrupii **var.** ***venrickae*** **Fryxell and Hasle (Plate 2G-L)**
References: Fryxell and Hasle, 1980; Hernández-Becerril and Tapia Peña, 1995; Hasle and Syvertsen, 1997.
Description: Cells are solitary (also joined in chains). The valves are slightly convex or completely flat. Areolae are arranged in an eccentric pattern, slightly larger in the center (Hernández-Becerril and Tapia Peña, 1995).
Dimension: Valves diameter 8-27 µm (Hernández-Becerril and Tapia Peña, 1995).
Distribution: Tropical and subtropical, mainly coastal (Fryxell and Hasle, 1980). It was encountered in Kuwait's waters during this study.

Thalassiosira **sp. 1 (Plate 3A-B)**
Description: Cells in valve view, with two central processes.
Dimension: Valve diameter 34 µm.
Distribution: Found in Kuwait's waters.

Genus: *Planktoniella* Schütt 1892

Cells discoid. Organic extrusions from the girdle. Radial or tangential areolation. One central strutted process. One marginal ring of processes. One or two labiate processes (Hasle and Syvertsen, 1997). This marine genus is large and extremely diverse. Only one species is found in Kuwait's waters.

Planktoniella sol (Wallich) Schütt (Plate 3C)

Basionym: *Coscinodiscus sol* Wallich 1860.

References: Hustedt, 1930; Cupp, 1943; Hendey, 1964; Karsten, 1978; Round et al., 1990; Hasle and Syvertsen, 1997; Throndsen et al., 2003.

Description: Cells discoid, solitary, consisting of a central body surrounded by a wing-like expansion. Central or valvar portion small, valves convex covered with large polygonal areolation arranged in tangential curved lines (Hendey, 1964). Girdle with a continuous wing (Hasle and Syvertsen, 1997).

Dimensions: Diameter of the valve portion 30-180 µm, total diameter often as much as 360 µm (Hendey, 1964). The diameter of valve in this survey in Kuwait's waters is 60 µm.

Distribution: Warm water region, Atlantic waters in the Norwegian Sea and along the Norwegian west coast (Hasle and Syvertsen, 1997). An oceanic species, widely distributed but most common in tropical and sub-tropical seas (Cupp, 1943; Hendey, 1964; Round et al., 1990). It is also found in Kuwait's waters.

Family: Stephanodiscaceae Glezer and Makarova 1986

Genus: *Cyclotella* (Kützing 1833) Brébisson 1838

Cells usually solitary, but sometimes united in short chains. Frustules short, cylindrical, discoid, rectangular in girdle view. Valves circular, valve surface undulate, undulation more evident in the middle area. Middle area punctate, marginal area striate. Chromatophores, numerous rounded bodies scattered throughout the cell and often lying against the valves (Hendey, 1964). Previously, one species *Cyclotella stylorum* was reported in Mina Al-Ahmadi waters (Kuwait's waters) by Hendey (1970). However, in this survey two species were found at different localities of Kuwait's waters.

Cyclotella striata (Kützing) Grunow (Plate 3D-E)

Basionym: *Coscinodiscus striata* Kützing 1844.

References: Peragallo and Peragallo 1897-1908; Hustedt, 1930; Hendey, 1964; Simonsen, 1974; Foged, 1984; Ricard, 1987; Pankow, 1990; Hasle and Syvertsen, 1997; Bérard-Therriault et al., 1999.

Description: Cells discoid, somewhat rectangular in girdle view. Valves circular, strongly undulate, valve surface marked by a diametrical fold, very evident in the central area. Valve surface divided sharply into two areas, the center being somewhat coarsely punctate, puncta irregularly scattered, and the marginal area, from about half the radius, being radially striate, radial striae 8 in 10 µm (Hendey, 1964) and 7-10 in 10 µm (Bérard-Therriault et al., 1999).

Dimensions: Diameter of valve 20-60 µm (Hendey, 1964), or 7-10 µm (Bérard-Therriault et al., 1999). In this survey, the diameter of this species was 13-33 µm.

Distribution: A common marine and brackish-water species, often abundant in estuaries during the spring season. Frequent on all North Sea coasts, Thames, Tay and Clyde estuaries, and Bristol Channel (Hendey, 1964). Found along the Indian coast and in the northern part of the Arabian/Persian Gulf, rarely near the African coast. Its often observed near the coast, and it is of cosmopolitan distribution (Simonsen, 1974). It is also observed in Kuwait's waters.

Cyclotella stylorum Brightwell (Plate 3F-I)

References: Hustedt, 1930; Hendey, 1970; Simonsen, 1974.

Description: Cell small and the surface structure of the valve is very complex. The outer striated zone is slightly elevated at the margin and is depressed as it meets the central portion. This central portion is raised to the same level as the outer zone and its surface has an irregularly corrugated appearance (not distinctly punctae) and is crossed by an undulation which does not extend into the striate outer zone (Hendey, 1970). This species was recorded in Mina Al-Ahmadi waters (Kuwait's waters) by Hendey (1970). He mentioned that most of the published illustrations of this species failed to depict its true structure.

Dimension: Diameter 24-32 µm in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970), and at other localities in Kuwait's waters (this study). In this survey, it had a range from 18 to 30 µm.

Distribution: Found in the Indian Ocean but it is very rare, mainly distributed in warmer waters (Simonsen, 1974). Present frequently in Mina Al Ahmadi waters (Kuwait's waters) (Hendey, 1970), and also at other different localities of Kuwait's waters, as was found in this survey.

Family: Lauderiaceae (Schütt) Lemmermann 1899

Genus: *Lauderia* Cleve 1873

Cells cylindrical. Valves rounded. Cells united in straight chains by very fine gelatinous threads, cells either touching or separated. An unpaired, oblique, outwardly directed apiculus on each valve, and numerous very small spinulae or slime canals at the margin and over most of the surface. Center of valve slightly concave. Intercalary bands numerous, collarlike, more or less conspicuous. Chromatophores numerous small plates. Nucleus more or less central, in a cytoplasmic cord which binds the central parts of the valves together. Although the cell wall is thin, it has a distinct structure. The valve surface is radially striated, the mantle surface of the intercalary bands delicately areolated (Cupp, 1943).

It is a small genus of two recorded species: *Lauderia borealis* and *L. annulata* (Allen and Cupp, 1935; Ricard, 1974) but reduced to a single taxon as documented by Sournia (1968), Hasle (1974), Round et al. (1990) and Hasle and Syvertsen (1997). The present Atlas supports this view of placing *L. borealis* as a synonym of *L. annulata* because no significant morphological difference was visible between the various specimens of *Lauderia* species from different localities of Kuwait's waters. Many authors who described and demonstrated with drawings and photographs the *L. annulata* showed the same morphological structure as we found of our obtained species, especially the recent bibliographical references (Round et al. 1990; Hasle and Syvertsen 1997; Throndsen et al., 2003). This is the reason for reporting our species as *L. annulata*. Only one species occurs in Kuwait's waters.

Lauderia annulata Cleve (Plates 4A-E and 5A-B)

Synonym: *Lauderia borealis* Gran 1900.

References: Pavillard, 1925; Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964; Sournia, 1968; Hasle, 1973; Simonsen, 1974; Ricard, 1987; Round et al., 1990; Hasle and Syvertsen, 1997; Throndsen et al., 2003.

Description: Cells shortly cylindrical, joined to form straight filaments. In girdle view the well-rounded valves give a beaded appearance to the filament. Pervalvar axis slightly longer than diameter. Plastids numerous, discoid lobed. Valves very delicate, with fine radial costae radiating from a central annulus, fine pores penetrate the basal layer between the costae (Round et al., 1990). Prominent central annulus, sometimes with a few processes. A large marginal labiate process. Numerous strutted processes on valve face and margin. Long occluded processes in marginal zone (types of processes not differentiated with LM) (Hasle and Syvertsen, 1997).

Dimension: Diameter of valve 30-50 µm (Cupp, 1943; Hendey, 1964; Sykes, 1981). In the present specimens collected from Kuwait's waters, the diameter was 40-42 µm for the obtained species.

Distribution: *L. annulata* was recorded in Bengalen (Peragallo, 1897-1908), the Sea of Java (Allen and Cupp, 1935), Indian Ocean (Sournia, 1968, Simonsen, 1974). Common and widespread in the phytoplankton of the oceans (Round et al., 1990). *L. borealis (L. annulata)* was described from the Mediterranean Sea (Pavillard, 1925), Gulf of California to Scotch Cap, Alaska (Cupp, 1943), and North Sea (Hendey, 1964). It is also present in Kuwait's waters.

Family: Skeletonemataceae Lebour emend. Round et al. 1990

Genus: *Detonula* Schütt ex De Toni 1894

Cells usually united to form short curved chains, secured by means of a marginal circlet of spines. Cells cylindrical, pervalvar axis up to twice the diameter of the cell. Valves circular, marginal apicule absent. Girdle composed of numerous intercalary bands. Chromatophores: several, 8-16, rounded plate-like bodies. Nucleus attached to the margin of the cell (Hendey, 1964). The generic characteristics by Hasle and Syvertsen (1997) are: tight chains, valve surface with radial ribs and few well-developed areolae, one central strutted process, one marginal ring of strutted processes and one marginal labiate process. A fairly common marine planktonic genus sometimes forming blooms in coastal waters (Round et al., 1990). Only one species was found in Kuwait's waters.

Detonula pumila (Castracane) Gran (Plate 5C)

Basionym: *Lauderia pumila* Castracane 1886.

Synonyms: *Schroederella delicatula* (H. Péragallo) Pavillard; *Schroederella shroederi* (Bergon) Pavillard 1925; *Thalassiosira condensata* Cleve 1900.

References: Hustedt, 1930; Cupp, 1943; Hasle, 1973; Drebes, 1974; Round et al., 1990; Hasle and Syvertsen, 1997.

Description: Cells barrel-shaped, connected by short processes and mucilage threads into long filaments. Valves more or less convex, sometimes almost flat, always with a depression in the middle. Intercalary bands collarlike, varying greatly in number. Mantle surface of the cell delicately areolated, 18-20 areolae in 10 µm, sometimes very difficult to see, arranged in a two line system with the lines crossing each other (Cupp, 1943).

Dimension: Diameter 16-42 µm (Cupp, 1943). In the present study, in Kuwait's waters, the cells were 27.63 µm wide and 29.25 µm long.

Distribution: Neritic. Common off southern California and in the Gulf of Califrornia (Cupp, 1943). Probably cosmopolitan with a preference for warmer waters (Hasle and Syvertsen, 1997). It is also observed in Kuwait's waters.

Genus: *Skeletonema* Greville 1865

Cells in chains united by external tubes of strutted processes (complete or split longitudinally) arranged in one marginal ring. One labiate process inside the ring of strutted processes or close to valve center. Valve structure, radial areolation, central annulus more or less developed (Hasle and Syvertsen, 1997). One species was observed in Kuwait's waters.

Skeletonema costatum (Greville) Cleve (Plate 5D)

Synonyms: *Stephanopyxis costata* Hustedt 1956; *Skeletonema tropicum*; Cleve 1900; *Skeletonema cylindraceum* Makarova and Proshkina-Lavrenko 1964.

References: Cupp, 1943; Hendey, 1964; Simonsen, 1974; Ricard, 1987; Hasle and Syvertsen, 1997; Bérard-Therriault et al., 1999; Throndsen et al., 2003.

Description: Cells discoid, oblong or weakly spherical. Valves mostly convex, but sometimes almost flat. Cells united to form filaments by means of a marginal ring of long spines; spines straight, filaments straight, sometimes slightly spiral. Owing to the length of the spines the spaces between the individual cells are frequently larger than the cells themselves (Hendey, 1964). External tubes of marginal strutted processes trough shaped with a wide longitudinal slit facing the valve margin (Hasle and Syvertsen, 1997).

Dimensions: Diameter 8-15 µm (Hendey, 1964), 3-16 µm (Bérard-Therriault et al., 1999); 2-21 µm (Throndsen et al., 2003) and 9-11 µm in the present survey.

Distribution: Present in the Indian Ocean (Simonsen, 1974). Cosmopolitan (absent from the high Arctic and Antarctic) (Hasle and Syvertsen, 1997). It occurs in Kuwait's waters.

Sub-Class: Coscinodiscophycidae Round and Crawford in Round et al. 1990
Order: Melosirales Crawford in Round et al. 1990
Family: Stephanopyxidaceae Nikolaev
Genus: *Stephanopyxis* (Ehrenberg) Ehrenberg 1845

Valve mantle high, more or less curved. Valve wall with large hexagonal areolae with large external foramina (Hasle and Syvertsen, 1997). Only one species was found in Kuwait's waters.

Stephanopyxis palmeriana (Greville) Grunow (Plate 6A-B)

References: Cupp, 1943; Hasle and Syvertsen, 1997.

Description: Areolae larger on valve face than on valve mantle (Hasle and Syvertsen, 1997). Cells oblong. In shape much like *S. turris*, from which it is distinguished by the slight narrowing of the cylindrical part of the valve against the margin, and by the hexagonal areolations which are slightly smaller near the girdle line than on the Areolae; 1½-2½ at 10 µm at center of valve, 3½-4 on upper part of the mantle, and 5-5½ near girdle line. On the newly formed valves 2-2½ areolae in 10 µm on mantle. Cells united in chains by 10-22 hollow spines arranged in a circle at each end of cell. Chromatophores numerous, plateline. Nucleus central (Cupp, 1943).

Dimensions: Diameter of cells 27-71 µm (Cupp, 1943), and in the present study 42-45 µm.

Distribution: Neritic. Warmer-water species. Reported off southern California but more common in Gulf of California (Cupp, 1943). It is found in Kuwait's waters.

Order: Paraliales Crawford in Round et al. 1990
Family: Paraliaceae Crawford 1988
Genus: *Paralia* Heiberg 1863

Cells shortly cylindrical, united to form chains. Valves circular. Valve surface with faint radial lines merging into a wide, downward sloping valve margin and valve mantle that is strongly loculate and ornamented with a coarse network of sub-hexagonal cellulation. Chromatophores, usually numerous small rounded bodies (Hendey, 1964). One species occurs in Kuwait's waters. The same species was also found earlier in Mina Al-Ahmadi waters (Southern Kuwait's waters) (Hendey, 1970).

Paralia sulcata (Ehrenberg) Cleve (Plate 6C-I)

Basionym: *Gaillonella sulcata* Ehrenberg 1838.

Synonym: *Melosira sulcata* (Ehrenberg 1838) Kützing 1844, *Orthosira marina* Smith 1856, *Paralia marina* Heiberg 1863.

References: Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964; Hendey, 1970; Drebes, 1974; Simonsen, 1974; Sykes, 1981; Foged, 1984; Ricard, 1987; Pankow, 1990; Round et al., 1990; Hasle and Syvertsen, 1997; Bérard-Therriault et al., 1999.

Description: Cells discoid, small, short, thick-walled, with circular constrictions at each end. Fairly united valve to valve into short, straight chains. Valves concave. Areolate and punctuate. Margin of valve with a double row of cells, the outer row appearing as a crown of teeth. One girdle band usually covering the halves of two cells. Chromatophores consisting of numerous small plates (Cupp, 1943; Hendey, 1964). Cells in girdle view are more wide than long. Separation valves at ends of chains without marginal spines and reduced ridges (hetrovalvy) (Hasle and Syvertsen, 1997).

Dimensions: Diameter of valve 36-60 µm (Cupp, 1943; Hendey, 1964; Sykes, 1981), 8-130 µm (Hasle and Syvertsen, 1997), and 20-56 µm in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970). In the present survey, the diameter of valve ranged from 42-45 µm.

Distribution: A true bottom form, sometimes found in neritic plankton, particularly after winter gales. Very common along the south-eastern shores of the North Sea (Hendey, 1964). A common bottom form in Kuwait's waters (Mina Al-Ahmadi waters), frequently found in the plankton, particularly after heavy storms (Hendey, 1970). It is also found at other localities in Kuwait's waters (this study).

Order: Coscinodiscales Round and Crawford in Round et al. 1990
Family: Coscinodiscaceae Kützing 1844
Genus: *Coscinodiscus* Ehrenberg 1838

Cells disk or box-shaped, single or in twos immediately after cell division. Valves circular, without large knobs or processes, with hexagonal areolae arranged in various ways or fine round puncta. In the coarser areolated forms two membrane layers are usually clearly distinguishable. These are bound together by pervalvar-directed areolae walls. The outer layer is either smooth, at least apparently so, or more or less poroid. The inner layer has usually under each areola a larger or smaller opening toward the cell center (inside). Upon examination of the valve from the outside, these openings appear to be round "central spots" in the areolae. The areolae are usually in a closed mesh system but in a number of species they are more or less rounded and do not touch one another. The center of the disk is either smooth or sculptured, often with larger areolae forming a rosette. In some species the rosette may be present or the central area may be clear. In many species distinct but small meshes, interstitial meshes; are present at the beginning of short radial rows of areolae. These may be of systematic importance. Marginal spinulae present or absent, usually small and difficult to see. Apiculi, one (apiculus) or two, present or absent. If two present, apiculi, are located asymmetrically at an angle of more than 90º and less than 180º on the margin. Intercalary bands often present. Girdle zone formed of a single girdle band to each valve or of one or more collar-like intercalary bands. Chromatophores with numerous small plates. Nucleus usually at center of one valve, or suspended in center of cell by protoplasmic strands (Cupp, 1943).

Coscinodiscus is usually regarded as one of the largest marine planktonic diatom genera [400-500 validly described taxa (VanLandingham, 1968)]. A great number of the most frequently recorded *Coscinodiscus* species have been transferred to *Thalassiosira*, *Azpeitia*, and *Actinocyclus*, or to new genera as illustrated by the fact that of the approximately 20 *Coscinodiscus* species recorded in the Arctic literature between 1853 and 1911, only 4 are now regarded as belonging to the genus (Hasle and Syvertsen, 1997). Many species of *Coscinodiscus* occur in Kuwait's waters. Ten species of *Coscinodiscus* were reported in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970). Ismail et al. (1999) reported that there were several species of *Coscinodiscus* with different sizes observed in different locations of Kuwait's waters. They mentioned that the small size of these species showed the highest abundance (> 1000 Cells/L) and that they are one of the dominant species in Kuwait's waters. In this survey, it was found to be one of the most common genus at all the sampled stations of Kuwait's waters. Eight species of *Coscinodiscus* and one variety were found in this study.

Coscinodiscus asteromphalus Ehrenberg (Plate 7A-B)

Synonym: *Coscinodiscus asteromphalus* var. *conspicua* Grunow ex Van Heurck 1880-85**.**

References: Hustedt, 1930; Hendey, 1964, 1970; Hasle and Syvertsen, 1997.

Description: Cells discoid with slightly convex valves; valve center depressed and valve mantle gently sloping. Central rosette of somewhat larger areolae present, usually not prominent. Decussating arcs fairly distinct. No hyaline lines. Cribra just visible with LM. Ring of processes close to valve margin visible with LM. Interstitial meshes (probably smaller areolae) present at the points of origin of incomplete striae. Larger labiate processes comparatively small. In the girdle view numerous large rounded plate-like chloroplasts. Compared to *C. argus* and *C. centralis*, which are the most similar species, *C. asteromphalus* has the ring of processes closer to the margin (Hasle and Syvertsen, 1997); 3-4 striae in 10 µm of the present materials.

Dimensions: Diameter 230-360 µm, mostly 330 µm (Hendey, 1964), 180-280 µm in Mina Al-Ahmadi waters (Hendey, 1970) and 320 µm in the present specimens, taken from different localities in Kuwait's waters.

Distribution: A pelagic plankton species with a world-wide distribution. Found in North Atlantic and North Sea (Hendey, 1964). Present in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) and also at other localities of Kuwait's waters (this study).

Coscinodiscus centralis Ehrenberg (Plates 7C-F and 8A-F and 9A-C)

Synonyms: *Coscinodiscus asteromphalus* var. *centralis* Grunow 1884; *Coscinodiscus oculus-iridis* var. *tenuistriata* Grunow 1884.

References: Hustedt, 1930; Hendey, 1964, 1970; Hasle and Syvertsen, 1997; Throndsen et al., 2003.

Description: Cells discoid; valves gently convex, and numerous small plate-like chloroplasts in the girdle view. The valve has a distinct rosette of large areolae, sometimes with a small hyaline area in the middle. Areola rows grouped into narrow bundles bordered by hyaline lines. Decussating arcs in the central part of the valve. Hyaline lines associated with labiate processes at the valve margin. Interstitial meshes present, identical with the pentagonal arela at the point of incomplete stria or an adjacent larger areola. Cribra resolved with LM, consisting of one central pore and a marginal ring of pores. Marginal processes readily resolved with LM; the smaller processes are long necked and slightly curved, the two larger processes have two horns. Distinguished from *C. argus* and *C. asteromphalus* by the central areolae, and the cribra and processes readily resolved with LM (Hasle and Syvertsen, 1997), and by the decrease in size of the areolae from the semiradius to the valve margin with *C. asteromphalus* (Hendey, 1970) but similar in this character with *C. argus* (Hasle and Syvertsen, 1997). 4-5 striae in 10 μm were observed in the present specimens in Kuwait's waters.

Dimensions: Diameter 160-210 μm, mostly 200 μm (Hendey, 1964), 100-300 μm (Throndsen et al., 2003), 160-250 μm in Mina Al-Ahmadi waters (Hendey, 1970) and 175-286 μm in the present survey.

Distribution: A widely-spread oceanic plankton species. Common in the North Atlantic, and in the North Sea, found in the temperate zone in all oceans (Hendey, 1964). Present in Mina Al-Ahmadi waters (southern Kuwait's waters) (Hendey, 1970) and also at other localities of Kuwait's waters (present study).

Coscinodiscus granii Gough (Plates 9D and 10A-G)

References: Hustedt, 1930; Hasle and Syvertsen, 1997; Throndsen et al., 2003.

Description: Cells in girdle view are asymmetrical, one side much higher than the other. Valvocopula wedge shaped, widest opposite to the opening. Greatest convexity of the valve not in the center of the valve but nearest the widest part of the valvocopula. Chloroplasts discoid and smooth in outline. The valve with central rosette of larger areolae. Radial areolation, incomplete striae, and decussating arcs in the central part of the valve. Cribra barely dicernible with LM. One ring of marginal processes including two larger processes, readily seen with LM; the larger processes seen as deep indentations of the valve mantle. Hyaline lines from the marginal processes toward the valve center more or less distinct (Hasle and Syvertsen, 1997).

Dimensions: Diameter 100-120 μm; girdle, wide end 20 μm (Hendey, 1964), 40-200 μm, 8-11 areolae in 10 μm (Throndsen et al., 2003). In the present study, the diameter ranged from 65-116 μm.

Distribution: Neritic plankton species mainly confined to northwestern European coasts, North Sea, Norwegian and Danish Seas, Irish Sea, and English Channel (Hendey, 1964). It also occurs in Kuwait's waters.

Coscinodiscus jonesianus (Greville) Ostenfeld

Basionym: *Eupodiscus jonesianus* (Greville) Ostenfeld.

References: Hustedt, 1930; Hasle and Syvertsen, 1997.

Description: In girdle view cells about as high as wide. Valves convex, slightly concave in the center. In valve view central rosette of larger areolae more or less distinct. Areolae in radial and spiraling rows. Cribra visible with LM. At about half radius an irregular ring of intersatitial meshes (probably labiate processes). One marginal ring of processes, visible with LM, with hyaline lines bordered by one row of slightly larger areolae on either side toward the valve center. Inside the marginal ring two larger processes with prominent external areolated protuberances (Hasle and Syvertsen, 1997).

Dimensions: Diameter 140-250 µm (Hendey, 1964).

Distribution: Found in the English Channel, but common in sub-tropical waters. This species occurs in Kuwait's waters.

Coscinodiscus marginatus Ehrenberg (Plate 11A-B)

References: Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964, 1970; Round et al., 1990; Hasle and Syvertsen, 1997.

Description: Cells discoid, thick walled. Valves flat or nearly so with steeply sloping or straight mantle. Several small rounded chloroplasts. Valves covered with strong and large areolation, areolae polygonal, central hyaline area absent. No central rosette. Areolae arranged somewhat irregularly, radial, attaining their maximum size at about half radially striate. The areolae of the valve present a complex structure, showing an internal and lower membrane opening on the inside, surrounded by a ring of fine poroids and an outer sieve membrane (Hasle and Syvertsen, 1997). 5 striae in 10 µm was obtained in the present materials in Kuwait's waters.

Dimensions: Diameter of valve 44-80 µm (Hendey, 1964), 36-97 µm (Cupp, 1943); 50 µm in Mina Al-Ahmadi waters (Hendey, 1970) and 54-56 µm in the present survey.

Distribution: An oceanic species frequent in North Atlantic water, and North Sea (Hendey, 1964). It is also common in Mina Al-Ahmadi waters (Hendey, 1970) and also present at other localitis in Kuwait's waters (this study).

Coscinodiscus oculus-iridis Ehrenberg (Plate 11C-F and 12A-D)

References: Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964, 1970; Simonsen, 1974; Foged, 1984; Pankow, 1990; Semina, 2003.

Description: Cells discoid, solitary, large. Valves almost flat, or weakly convex. Valves covered with large polygonal areolation, arranged in radiating lines, the lines long and short. Central rosette often large, consisting usually of five areolae, but sometimes fewer. Areolae small at the center of the valve, increasing gradually in size as they proceed to the periphery. Periphery areolae usually much smaller. The areolae present secondary and tertiary structure, in the form of an inner chamber and associated poroids. The opening of the inner chamber provides that characteristic appearance known as the 'eye-spot'. Girdle minutely punctate. Chromatophores: numerous rounded bodies (Hendey, 1964). The distinctive features of this species are: the areolae form an irregular cluster at the center of the valve, much less pronounced than the other species, the radiating striae have small areolae at the center which increase in size for about ¾ of the distance toward the margin which is furnished with an apiculus (Hendey, 1970). 3-4 striae in 10 µm were observed in the present materials in Kuwait's waters.

Dimensions: Diameter 120-150 µm (Cupp, 1943), and 180-260 µm (Hendey, 1964, 1970). Diameter 180-200 µm in Mina Al-Ahmadi waters (Hendey, 1970) and 110-204 µm in this survey, from specimens encountered at different localities in Kuwait's waters.

Distribution: An oceanic, pelagic species found all over the world. Common in North Atlantic water. Frequent in the North Sea (Hendey, 1964) and in Mina Al-Ahmadi waters (Hendey, 1970) and also at other localities in Kuwait's waters (this study).

Coscinodiscus oculus-iridis var. *borealis* (Plate 12E-F)

Description: 3-4 striae in 10 µm.

Dimensions: Diameter 94-97 µm in the present specimens from Kuwait's waters.

Distribution: It is found in Kuwait's waters.

Coscinodiscus radiatus Ehrenberg (Plate 13A-D)

Synonym: *Coscinodiscus borealis* Ehrenberg 1862.

References: Pavillard, 1925; Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964, 1970; Drebes, 1974; Sykes, 1981; Foged, 1984; Pankow, 1990; Round et al., 1990; Hasle and Syvertsen, 1997; Bérard-Therriault et al., 1999; Throndsen et al., 2003.

Description: Cells discoid, solitary, small to medium, thin, coin shaped. Valves mostly flat covered with strong polygonal areolation. Indistinct central rosette of slightly larger areolae (Hendey, 1964; Hasle and Syvertsen, 1997). Areolae in radial rows, sometimes in indistinct decussating arcs, rows long and short; areolae usually of uniform size throughout the whole valve surface, except at the margin, where they are much smaller. Girdle simple, narrow, striate. Spinulae and apiculi absent. Chromatophores, numerous cocciform bodies, often in clusters (Hendey, 1964).

Dimensions: Diameter 35-60 µm (Cupp, 1943); 70-140 µm, mostly 100 µm (Hendey, 1964); 30-180 µm, 2-9 arelae in 10 µm (Throndsen et al., 2003); 107-130 µm in the present materials from Kuwait's waters.

Distribution: Oceanic and neritic (Cupp, 1943). Common in all North European coasts, North sea, and English channel (Hendey, 1964). It is also present in Kuwait's waters.

Coscinodiscus wailesii Gran and Angst (Plate13E-F and 14A-B)

References: Hustedt, 1930; Hasle and Syvertsen, 1997; Throndsen et al., 2003.

Description: Cells in girdle view are cylindrical, often as high as wide, and rectangular in outline at a certain focus. Valves flattened with a concentric depression near the steep high mantle. Numerous chloroplasts irregular in outline. Prominent central hyaline (unperforated) in the valve area; wide interstriae (hyaline lines) radiating from the central area. Irregular fasciculation formed, partly by wider interstriae, partly by distinct incomplete striae, originating near the valve center at a labiate process or a small hyaline area (area of solid silica). Cribra visible with LM. One ring of smaller processes in the junction zone between valve face and mantle, and one ring including two larger processes close to the valve margin. Processes in the first ring more densely spaced than those in the second ring. Hyaline lines more conspicuous and regular on valve mantle than on valve face, associated with processes (Hasle and Syvertsen, 1997).

Dimensions: Diameter 280-500 μm, 5-6 areolae in 10 μm (Throndsen et al., 2003). In the present study in Kuwait's waters, the diameter was 367-418 μm.
Distribution: Warm waters to temperate (recently introduced to North Atlantic waters) (Hasle and Syvertsen, 1997). It is also found in Kuwait's waters.

Genus: ***Palmeria*** Greville 1865

It is important to distinguish this hemi-discoid diatom from the genus *Hemidiscus*. *Palmeria* is clearly associated with *Coscinodiscus* on account of its wall structure and the type of rimoportulae whereas *Hemidiscus* has a pseudonodule and at present is allied to *Actinocyclus*. Simonsen (1972) reinstated *Palmeria* as a separate genus and, as with *Hemidiscus*, this can only be justified at present on the single criterion of cell shape (Round et al., 1990). One species occurs in Kuwait's waters.

Palmeria hardmaniana Greville (Plate 14C-F)

Synonyms: *Hemidiscus hardmanianus* (Greville) Mann 1907, *Coscinodiscus nobilis* var. *euodiaeformis* Tempère and Peragallo 1889-1895.
References: Allen and Cupp, 1935; Simonsen, 1974; Round et al., 1990; Hasle and Syvertsen, 1997.
Description: Cells in the form of a segment of a sphere. Valve semi-circular, with a flat valve face and an exstensive mantle on the convex side, which rises from the corners to the center of the semi-circle; there is almost no mantle along the straight edge. Areolae loculate (as in *Coscinodiscus*), externally with a cluster of central pores surrounded by a hexagonal outer series, internally with simple round, rimmed foramina. The areolae radiate from a plain area in the center of the valve face. Hyline run from near the center and terminate near the valve margin at rimoportulae. Macro- rimoportulae occur, replacing the smaller rimoportulae on each valve near the center of the convex, dorsal side. The other rimoportulae are relatively simple and tube-like internally (Round et al., 1990).
Dimensions: Diameter of 465-511 μm in the present study.
Distribution: Warm water regions. It is found in the Arabian Gulf where it is more frequent in the northern Arabian Gulf while very rare in the southern Arabian Gulf (Simonsen, 1974; Hasle and Syvertsen, 1997). It is also observed in Kuwait's waters.

Family: Hemidiscaceae Hendey 1937

Cells solitary, free, cuneate in the pervalvar axis. Valves semicircular, surface finely punctate, usually with a small ocellus in the middle of the ventral margin (Hendey, 1964). The pseudonodulus is the principle diagnostic feature of the Hemidiscaceae as emended by Simonsen (1975) and encompassing *Actinocyclus*, *Hemidiscus* and *Roperia*.

Genus: ***Actinocyclus*** Ehrenberg 1837

Valves circular or elliptical, surface convex, often flat in the center or with concentric zones of undulation. Central area small, circular or irregular, hyaline or sometimes occupied by a few scattered granules. Valve surface punctate or finely areolate, areolae in radiating lines, usually grouped in fascicules separated by short interfascicular spaces. The striae in each fascicule may be parallel to the middle one, in which case they become shorter upon each side, or the outer stria upon one side of the fascicule may be the longest, the others becoming shorter. The longest striae have the appearance of dividing the valve surface as clearly marked radii. Fascicules usually straight and radial, but sometimes may be curved.

Fascicules often clearly separated by hyaline radial interfascicular spaces. Marginal area of valve often clearly marked, either hyaline or finely striate. Marginal area usually plain, but may be furnished with fine apiculi and a marginal or sub-marginal ocellus or pseudo-nodule which takes the form of a lens-like thickening in the valve substance (Hendey, 1964). Hendey (1970) documented two species and one variety of *Actinocyclus* in Mina Al-Ahmadi waters (Kuwait's waters), while from our collected samples in Kuwait's waters we found only one species which is also similar of what was obtained in Mina Al-Ahmadi waters but in this present study it was found with two varieties.

Actinocyclus octonarius **var.** ***octonarius*** **Ehrenberg (Plate 15A)**

Synonym: *Actinocyclus ehrenbergii* Ralfs in Pritchard.

References: Hustedt, 1930; Hendey, 1964; Pankow, 1990; Round et al.,1990.

Description: Areolation distinctly fasciculated giving the impression of the valve face being divided into "compartments." Fascicles separated by pronounced complete striae running from the margin to a more or less well developed central annulus. Fasciculation accentuated by hyaline areas filling out spaces left open by shorter rows adjacent to the complete striae. A wide marginal zone with areolae smaller than those on the valve face. Processes positioned at the end of edge rows and a large pseudonodulus in the bend between valve face and mantle are readily seen with LM (Hasle and Syvertsen, 1997). Four varieties, in addition to the nominate variety dealt with by Hustedt (1930), differ in size and development of the central annulus, the amount of hyaline spaces and the width of the marginal zone. The central annulus was shown to be highly variable in cultured material of *A*. *octonarius* var. *tennelus*, whereas the valve areolation was stable (Villareal and Fryxell, 1983).

Dimensions: Diameter of valve 60-170 µm (Hendey, 1964). Diameter 80-120 µm in the specimens of Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970), and 84-90 µm was found in the present specimens from Kuwait's waters.

Distribution: cosmopolitan, common in the North Sea, Norwegian and Danish Seas, Baltic, English Channel and all Mediterranean, Atlantic and Pacific coasts, Arctic and Antarctic Oceans, in the neritic plankton (Hendey, 1964). It occurred in Mina Al-Ahmadi waters (Southern Kuwait's waters) (Hendey, 1970) and also at other localities in Kuwait's waters (present study).

Actinocyclus octonarius **var.** ***crassus*** **(Smith) Hendey (Plate 15B-C)**

Synonyms: *Eupodiscus crassus* Smith 1853; *Actinocyclus ehrenbergii* var. *crassa* (Smith) Hustedt 1927-30; *Actinocyclus crassus* (Smith) Ralfs in Pritchard 1861.

References: Hustedt, 1930; Hendey, 1964.

Description: Valves circular, less undulate than the type species. Central area large and filled with coarse puncta arranged in irregularly radiatining lines, or scattered. Marginal zone stronger and more clearly developed than in the type; often occupying up to 1/3rd radius. Pseudonodule small, but clearly seen, usually well removed from the valve margin to about 1/5th radius. Marginal rim strongly striae. Radial structure on the valve generally less evident (Hendey, 1964).

Dimensions: Diameter of valve 25-85 µm (Hendey, 1964); 41-45 µm in the present materials from Kuwait's waters.

Distribution: Common around all British coasts, in the neritic plankton (Hendey, 1964). It was found in Kuwait's waters.

***Actinocyclus octonarius* var. *tenellus* (de Brébisson) Hendey (Plate 15D-E)**

Synonyms: *Eupodiscus tenellus* de Brébisson 1854; *Actinocyclus tenellus* (de Brébisson) Grunow 1867; *Actinocyclus ehrenbergii* var. *tenella* (de Brébisson) Hustedt 1927-30.

References: Hustedt, 1930; Hendey, 1964, 1970.

Description: Cells solitary. Valves circular. Valve surface flat, divided into usually six sectors of loosely fasciculate striae. Puncta smaller as they approach the valve margin. Valve margin narrow, striae, apiculate; usually an apiculus is situated where the sectorial stria terminates on the valve margin (Hendey, 1964).

Dimensions: Diameter of valve 25-60 µm (Hendey, 1964). Diameter 60 µm in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) while, in the present survey, diameter ranged from 33-35 µm and the valve thickness was around 10 µm.

Distribution: In neritic plankton on all British coasts (Hendey, 1964). It is found in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970), and also at other localities in Kuwait's waters (this study).

Genus: *Hemidiscus* Wallich 1860

Cells solitary, free, shaped like a sector of a sphere, in girdle view wedge-shaped, narrowing from the dorsal toward the ventral side. Valve semicircular to asymmetrically elliptical. Valves flat with short valve mantles. Intercalary bands and septa absent, pervalvar axis not particularly elongated. Cells wall weakly or strongly siliceous, with regular and thick areolation, radial rows frequently in bundles. Marginal spinulae often present, also sometimes a pseudonodule (ocellus) near middle or ventral valve margin. With or without a central hyaline area. Chromatophores numerous, small rounded bodies (Cupp, 1943; Hendey, 1964). One species occurs in Kuwait's waters.

***Hemidiscus cuneiformis* Wallich**

Synonym: *Euodia cuneiformis* (Wallich) Schütt.

References: Pavillard, 1925; Cupp, 1943; Hendey, 1964; Simonsen, 1974; Ricard, 1987; Hasle and Syvertsen, 1997; Semina, 2003.

Description: Ventral margin regularly and gently convex, not drawn in (concave) near the ends. Dorsal margin strongly convex, in some individuals remarkably high-arched, without constrictions near the valve poles. Apical axis (along straight edge) 97 µm long; transapical axis 83 µm long. Sculpturing coarser or finer, near the center of the valve 9-12 areolae in 10 µm irregularly scattered; midway to margin 14-15 in 10 µm, in radial rows in more or less distinct bundles; near margin finer, 18-19 in 10 µm. Construction of bundles not so regular as in corresponding cases in *Coscinodiscus* species. In *Hemidiscus cuneriformis* the rows are shorter. In a circle about the valve there is a row of regularly spaced spinulae or pores that project toward the inner part of the cell papillary-like. The ventral papillae lie on the valve surface near the margin, the dorsal ones are deeper on the valve mantle and are therefore not visible in valve view in the type. They can be seen but are closer to the edge. Two papillae, one on each apical pole, are as a rule somewhat larger than the others. Near the middle of the ventral margin there is one larger eyelike spot (Cupp, 1943).

Dimensions: Length of valve 80-120 µm, breadth 10-70 µm (Hendey, 1964). Apical axis (along straight edge) 97 µm long; transapical axis 83 µm long (Cupp, 1943).

Distribution: An oceanic species, with a wide distribution in tropical and sub-tropical waters, but frequent in the North Sea and English Channel (Cupp, 1943; Hendey, 1964). It is also frequently observed in Kuwait's waters (this study).

Order: Asterolamprales Round and Crawford in Round et al. 1990

Family: Asterolampraceae Smith 1872

In the classification of Round et al. (1990) this family constitutes a separate order, Asterolamprales Round and Crawford, whereas Simonsen (1979) as well as Glezer et al. (1988) placed it in the order Centrales.

Genus: *Asteromphalus* Ehrenberg 1844

The genus encompasses 10 or more species commonly recorded from marine plankton (Hasle and Syvertsen, 1997). Cells solitary. Valves usually circular, flat or slightly convex. Valve surface finely areolate. Central space large, and extended into several radial areas that reach the valve margin, separating the areolate valve surface into sectors, one ray being narrower than the others. Central space traversed by a number of zigzag or branched lines, each of which terminates at the apex of one of the areolate sectors. Border narrow or absent (Hendey, 1964). Three different species of the genus *Asteromphalus* were found in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970). Two species were observed from Kuwait's waters during this study.

Asteromphalus flabellatus (Brébisson) Graville (Plates 15F and 16A-B)

References: Hustedt, 1930; Hendey, 1970; Simonsen, 1974.

Description: The valves are usually slightly oval with 9 rays.

Dimensions: Diameter (long axis) 50-60 μm in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970), while in the present materials from Kuwait's waters the cells were 38-48 μm long and 30 μm wide.

Distribution: Found in the middle of Arabian Sea and the Arabian/Persian Gulf (Simonsen, 1974). It occurred in Mina Al-Ahmadi waters (Southern Kuwait's waters) (Hendey, 1970) and also at other localities in Kuwait's waters (this study).

Asteromphalus hookeri Ehrenberg (Plate 16C)

Synonyms: *Asteromphalus buchii* Ehrenberg, 1844; *Asteromphalus humboldtii* Ehrenberg 1844.

References: Hendey, 1964.

Description: Cells solitary; valves circular, small; valve surface convex, sometimes slightly undulate. Central space hyaline, usually occupying about one half the diameter of the valve. Hyaline rays usually 5-7 extend from the central space towards the valve margin, dividing the valve into sectors. The rays are of equal length, but one is much narrower than the others. A system of branched zigzag lines traverses the central space radially, joining the apices of the peripheral sectors. Peripheral sectors areolate, areolae fine, arranged in trangential lines. Tops of the sectors flattened towards the central space. The hyaline rays terminate short of the valve margin, in a small apiculus (Hendey, 1964).

Dimensions: Diameter of valve 25-60 μm (Hendey, 1964).

Distribution: An oceanic plankton form common in north temperate waters; Atlantic Ocean and western coasts of British Isles (Hendey, 1964). It was also encountered in Kuwait's waters.

Sub-Class: Biddulphiophycidae Round and Crawford in Round et al. 1990
Order: Triceratiales Round and Crawford in Round et al. 1990
Family: Triceratiaceae (Schütt) Lemmermann 1899
Genus: *Odontella* Agardh 1832

Odontella is the only genus included in Eupodiscaceae Kützing 1849 *sensu* Simonsen, 1979 that has typically marine planktonic speices. Glezer et al. (1988) placed *Odontella* in Biddulphiaceae Kützing, order Biddulphiales. The species listed here as *Odontella* spp. were previously regarded as *Biddulphia* spp. Scanning Electron Microscopy examinations of genera of Biddulphiaceae showed, however, that they belong in *Odontella* partly because they have ocelli and labiate processes with long external tubes (Simonsen, 1974) whereas *Biddulphia* has pseudocelli. Which species really belong to *Odontella* is still disputed (Round et al., 1990); here we include those which are usually regarded as planktonic. Their valves are elliptical or lanceolate (bipolar). An elevation (horn) with an ocellus at each pole. Cells in straight (united by both elevations) or in zigzag chains (united by one elevation). Numerous small chloroplasts lying against valve wall. Characters showing differences between species: planktonic species with weakly, littoral with coarsely silcified cell wall, curvature of valve face, position of processes, direction of external tubes of processes, shape and direction of elevations, valve wall spinose or not and the presence or absence of resting spore formation (Hasle and Syvertsen, 1997). Three species occur in Kuwait's waters. One of them *Odontella mobiliensis* was also found by Hendey (1970) in Mina Al-Ahmadi waters (Kuwait's waters).

Odontella aurita (Lyngbye) Agardh (Plates 16D-I and 17A-B)

Basionym: *Diatoma auritum* Lyngbye 1819.

Synonym: *Denticella aurita* Ehrenberg; *Denticella gracilis* Ehrenberg; *Biddulphia pumila* Castracane; *Biddulphia aurita* (Lyngbye) Brébisson 1838; *Biddulphia sansibarica* A. Schmidt.

References: Hustedt 1930; Cupp, 1943; Hendey, 1964, 1970; Simonsen, 1974; Drebes, 1974; Ricard, 1987; Hasle and Syvertsen, 1997; Witkowski et al., 2000; Throndsen et al., 2003.

Description: Cells oblong in girdle view, with long spines and raised apical elevations. Often forming chains linked by the processes, with tubular spines crossing each other. Plastids many, small, discoid. Marine planktonic or epiphytic. Very abundant throughout the oceans. Valves elliptical or lanceolate, with no separation into face and mantle. Valve face plain or with fine granules, spinules or spines, sometimes with two ridges running on either side delimiting an elliptical area in the center. At each end there is an elevation, sometimes low and blunt, elsewhere horn-like. The spines which are very variable in length, are placed in the center of the valves or close to the bases of the elevations, diagonally opposite each other; they can have small apical spinules (Round et al, 1990). The valve coarsely areolated (8-11 areolae in 10 μm) (Witkowski et al., 2000).

Dimentions: Length of valve 20-54 μm (Hendey, 1964); 9-97 μm long (Witkowski et al., 2000). Apical length 20-32 μm, pricipal axis 29-64 μm. Apical length 40-68 μm, pricipal axis 32-60 μm in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) while in the present specimens from Kuwait's waters they were 38 μm long and 29-32 μm wide.

Distribution: A neritic and littoral species. Common in all parts of the North Sea, Baltic, and English Channel (Hendey, 1964). Widespread (cosmopolitan) inhabitant of the marine littoral, usually forming longer chains (Witkowski et al., 2000). It is also found in Mina Al-Ahmadi waters (Southern Kuwait's waters) (Hendey, 1970) and at other locations in Kuwait's waters (this study).

Odontella mobiliensis **(Bailey) Grunow (Plate 17C-E)**

Basionym: *Zygoceros mobiliensis* Bailey 1851.

Synonyms: *Biddulphia Baileyi* Smith 1856; *Biddulphia mobiliensis* (Bailey 1851) Grunow 1880-85.

References: Pavillard, 1925; Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964 and 1970; Drebes, 1974; Simonsen, 1974; Newell and Newell, 1977; Sykes, 1981; Foged, 1984; Pankow, 1990; Round et al., 1990; Hasle and Syvertsen, 1997; Semina, 2003.

Description: Cells solitary or united into short chains by long spines arising from the valve surface. Cells in girdle view roughly rectangular or sub-octagonal, with a wide girdle as a simple band. Valves elliptical or elliptic-lanceolate, convex, having the apices drawn out to from narrow tubular weakly capitate processes, that are directed outwards diagonally. The center of the valve is almost flat and is furnished with two slender straight spines directed outwards and almost parallel with the processes. The spines are set well apart and well removed from the processes. Valve surface faintly punctate, puncta arranged in decussating lines. The frustules are weakly siliceous and sometimes collapse when being mounted. Chromatophores, numerous granular plates (Hendey, 1964).

Dimensions: Length (apical axis) 60-200 µm (Hendey, 1964). Length 60-80 µm from Mina Al-Ahmadi waters (Southern Kuwait's waters) (Hendey, 1970) and in the present survey, from other localities in Kuwait's waters, the cells were 48-59 µm long.

Distribution: A common neritic plankton species from temperate waters. All parts of the North Sea, North Atlantic coasts, English Channel (Hendey, 1964) and in Mina Al-Ahmadi waters (Hendey, 1970) as well as at other locations in Kuwait's waters (this study).

Odontella sinensis **(Greville) Grunow (Plate 17F-K)**

Synonym: *Biddulphia sinensis* Greville 1866.

References: Pavillard, 1925; Cupp, 1943; Hendey, 1964; Drebes, 1974; Simonsen, 1974; Newell and Newell, 1977; Sykes, 1981; Pankow, 1990; Hasle and Syvertsen, 1997.

Description: Cells solitary or united by their spines to form loosely connected colonies. The frustule being about 2-2 $^1/_2$ times as long as it is broad. Weakly siliceous. Valves elliptical, having apices furnished with short processes. Valve surface slightly concave, bearing two spines which originate close to the base of the processes. Spines long, equal to or a little longer than the apical length of the valve (i.e., the width of the frustule when lying in girdle view). Chromatophores: numerous small irregular bodies scattered throughout the cell (Hendey, 1964).

Dimensions: Apical axis of valve 120-260 µm; transapical axis of valve 60-80 µm; length of cell, up to 300 µm (Hendey, 1964). In the present materials from Kuwait's waters they were 100-302 µm long and 144-205 µm wide.

Distribution: A truly planktonic species from eastern seas, but now fairly widely spread in temperate waters. It is common in the North Sea, English Channel, Danish waters and Irish Sea. This species appears to be able to withstand waters of salinities varying from 32 psu (practical salinity unit) to 36 psu (Hendey, 1964). It also occurs in Kuwait's waters, which has higher salinity.

Genus: *Triceratium* Ehrenberg 1841

Two species were observed in the present survey in Kuwait's waters, similar to what was reported by Hendey (1970).

Triceratium broeckii Leuduger-Fortmorel (Plate 17L and 18A-C)

Synonym: *Biddulphia broeckii* Mann.

References: Hustedt, 1930; Hendey, 1970; Simonsen, 1974; Stidolph, 1980.

Description: Valves triangular with convex sides and weakly convex valve surface. The angles of the valve are furnished with small horn-like processes. Valve surface covered with hexagonal areolae, smaller towards the margins. Areolae furnished with an inner poroid membrane that is finely punctate. When in girdle view the valve margin is seen to possess a palisade or a fimbriated extension of the valve surface as in *T. favus* (Hendey, 1970). This species has in the past been confused with *T. robertsianum*.

Dimensions: Length of valve 120-300 (Hustedt, 1930); 310 µm (Stidolph, 1980). Length of side 100-200 µm in Mina Al-Ahmadi waters (Kuwait's waters). In the present materials, the length of valve ranged from 85-89 µm.

Distribution: Found in New Zealand (Stidolph, 1980); and in Mina Al-Ahmadi waters (Hendey, 1970) and at other localities in Kuwait's waters (this study).

Triceratium reticulum Ehrenberg (Plate 18D)

Synonyms: *Triceratium sculptum* Shadboldt 1854; *Triceratium punctatum* Brightwell 1856; *Triceratium pardus* A. Schmidt; *Biddulphia sculpta* Van Heurck; *Triceratium debyi* Fortmorel; *Trigonium sculptum* Mann; *Trigonium punctatum* Peragallo.

References: Hendey, 1970; Foged, 1984; Witkowski et al., 2000.

Description: Concave margins. Middle part of the valve surface smoothly arched, apices separated by short furrows, indistinctly elevated above the valve face level. Valve face areolated, areolae in the middle circularly-rectangular; irregularly distributed, towards the margin forming radial rows, 5 in 10 µm, at apices areolae arranged in radial rows, 12-15 in 10 µm (Witkowski et al., 2000).

Dimensions: 25-80 µm long (Witkowski et al., 2000); 42-54 µm in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970), while in other localities of the present study they were 47 µm long (height) and 95 µm long (base).

Distribution: predominantly inhabiting marine littoral of warmer oceans, in Europe found from the Mediterranean to the Scandinavian coasts (Witkowski et al., 2000). Found in Smith's Bay, Portobello and Bruce's Rocks (New Zealand) (Wood, 1961). It is found as a quite common species in Mina Al-Ahmadi waters (Kuwait's waters) and showed considerable variation in puctuation (Hendey, 1970). It also occurred at other localities of Kuwait's waters (present study).

Genus: *Lampriscus* Schmidt 1882

The diatom included here was originally placed in *Triceratium*, removed to *Biddulphia*, and then to *Lampriscus*. In Hustedt (1927-66) and other texts the principal species is '*Triceratium shadboltianum*'. Mainly tropical; epiphytic or marine algae or attached to other submerged objects (Round et al., 1990). Only one species is found in Kuwait's waters.

Lampriscus shadboltianum (Greville) Simonsen (Plates 18E and 19A-B)

Synonym: ***Triceratium shadboltianum*** **Greville.**

References: Hustedt, 1930; Round et al., 1990.

Discription: Cells forming long, filamentous colonies. In girdle view rectangular with slight valve elevations, which link the cells. Valves with conspicuous pseudocelli which may superimpose a triangular pattern within the circular outline of the valve, or impose an overall angularity on the valve, making it triangular. Striae radiate from the center and continue without a break down of the deep valve mantle (Round et al., 1990).

Dimensions: In the present materials, length 47-53 µm and breadth 25-27 µm.

Distribution: Common and forms a bloom in the summer at some localities in Kuwait's waters (Kuwait Bay).

Family: Plagiogrammaceae De Toni 1890

Genus: *Dimeregramma* Ralfs 1861

Cells joined together in short fasciae, or free. Valves linear to linear-elliptic, with a small narrow pseudoraphe in the apical axis. Valve surface striate, striae transverse, punctate, apices usually a small smooth unstriated area. The genus is entirely marine, littoral and enjoys a world-wide distribution, though seldom found in great quantities (Hendey, 1964). Five species were observed in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970). One species occurred in our samples from Kuwait's waters.

Dimeregramma minor (Gregory) Ralfs (Plate 19C)

Basionym: *Denticula minor* Gregory 1857.

References: Hendey, 1964 and 1970; Foged, 1984; Pankow, 1990; Round et al., 1990.

Discription: Frustules quadrangular, slightly inflated at the angles. Valves small, oval-lanceolate in outline, with slightly produced apices. Valve surface punctate, radiate, with a clear linear-lanceolate median area. Puncta 8 to 9 in 10 µm (Hendey, 1964).

Dimensions: Length of valve 12-20 µm (Hendey, 1964), 14-22 µm in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970); in the present study, valve length was 19.4 µm.

Distribution: A widely spread littoral species, common on sandy beaches, and upon the larger algae. Found in English Channel (Hendey, 1964). It also occurred in Mina Al-Ahmadi waters (Hendey, 1970) and other locations in Kuwait's waters (this study).

Order: Biddulphiales Krieger 1954

Family: Biddulphiaceae Kützing 1844

Genus: *Biddulphia* Gray 1821

Cells box-shaped to cylindrical. Valves elliptical, with two poles or three or four sided (rarely five-sided). At the corners or at the ends of the apical axis more or less strongly developed processes or horns may be present, or with distinct corners, usually with transapical grooves so that valve surface is more or less strongly humped. Very fine pores usually present on end surfaces of processes or on corners of the valves, forming cushions which hold the cells together in straight or zigzag chains. In plankton forms, spines are usually present which hold the cells in chains or the cells may live singly. Girdle zone sharply differentiated from valve zone, cylindrical or prism-shaped, with numerous cross striations. Intercalary bands indistinct if present. Chromatophores numerous, small, lying against the cell wall.

Nucleus central. Cell wall, except in delicate plankton forms, strongly siliceous, usually with distinct areolae or granules. Auxospores formed. Flagellated microspores known in a few species. Usually coastal forms, often fixed. Certain species truly planktonic, but always neritic (Cupp, 1943). Five species were reported by Hendey (1970) in Mina Al-Ahmadi waters. Only one species was found in Kuwait's waters during this study.

Biddulphia pulchella Gray (Plate 19D)

References: Hendey, 1964; Simonsen, 1974; Foged, 1984; Ricard, 1987; Pankow, 1990; Round et al., 1990.

Cells colonial, often united by their angles to form short chains. Frustules quadrangular, angles slightly produced. Valves elliptical, with undulating margins, divided into three or more sections by strong costae. Costae usually transverse. Ends of the valve furnished with large globular or sub-conical processes covered with fine pores. Valve surface between the costae coarsely areolate, reticulate, areolae rounded, arranged in longitudinal or transverse rows towards the ends, but concentric or irregular in the center. Valve mantle deep. Girdle punctate, puncta in longitudinal lines. Chromatophores: a number of rounded or irregular bodies (Hendey, 1964).

Dimensions: Length of valve 60-90 µm; breadth 60-65 µm; pervalvar axis 160-260 µm (Hendey, 1964).

Distribution: A bottom form which attaches itself to any firm substratum. Often found in the neritic plankton of the English Channel and southern North Sea (Hendey, 1964). It occurs in Kuwait's waters.

Order: Hemiaulales Round and Crawford in Round et al. 1990

Family: Hemiaulaceae Heiberg 1863

The four recent planktonic genera, which are dealt with here were all placed in this family by Simonsen (1979) as well as by Round et al. (1990). In Round et al. (1990), Hemiaulaceae was placed in the new order Hemiaulales Round and Crawford. Glezer et al. (1988) placed *Eucampia* together with *Odontella* and *Biddulphia* in Biddulphiaceae Kützing.

Genus: *Cerataulina* H. Peragallo 1892 ex Schütt 1896

Cells cylindrical, usually in chains. Valves slightly arched, with two blunt projections or processes near their margin, attached to adjacent cell by means of a fine, small, curved, hairlike process which fits into the valve of the adjacent cell. Girdle composed of numerous intercalary bands. Chromatophores numerous, small. Nucleus against the cell wall. Cell wall soft and weakly siliceous, collapsing when dried. Sculpturing very delicate (Cupp, 1943; Hendey, 1964). Three species occur in Kuwait's waters.

Cerataulina bicornis (Ehrenberg) Hasle (Plate 19E-F)

References: Hasle and Syvertsen, 1997.

Description: Broad wing-like extensions of the elevations fitting into V-shaped deep furrows on mantle of adjacent valve, labiate process marginal, areola array irregular. Valve striae 18-30 in 10 µm (Hasle and Syvertsen, 1997).

Dimensions: Diameter 5-75 µm (Hasle and Syvertsen, 1997).

Distribution: Coastal warm water region (Hasle and Syvertsen, 1997). Found in Kuwait's waters (this study).

Cerataulina dentata Hasle (Plates 19G and 20A-E)

References: Ricard, 1987; Hasle and Syvertsen, 1997.

Description: Bands distinct, elevations and wings inconspicuous, valve margin dentate, labiate process submarginal, areola array fan shaped and oriented toward the process. Valve striae ca. 20 in 10 µm (Hasle and Syvertsen, 1997).

Dimensions: Diameter 5-12 µm (Hasle and Syvertsen, 1997).

Distribution: Found in coastal warm water region (Hasle and Syvertsen, 1997). It is also present in Kuwait's waters (this study).

Cerataulina pelagica (Cleve) Hendey (Plates 20F and 21A-C)

Basionym: *Cerataulina bergonii* H. Peragallo 1892.

Synonym: *Zygoceros pelagica* Cleve 1889.

References: Pavillard, 1925; Allen and Cupp, 1935; Hendey, 1964; Drebes, 1974; Simonsen, 1974; Sykes, 1981; Ricard, 1987; Pankow, 1990; Round et al., 1990; Hasle and Syvertsen, 1997; Bérard-Therriault et al., 2000.

Description: Cells cylindrical, pervalvar axis usually twice or three times the diameter. Cells united to form chains, often twisted. Valves slightly convex, furnished with two short, stout cylindrical processes. Processes opposite and terminated with a short spine. Valve mantle short. Valves with radial rows of puncta, 21-23 puncta in 10 µm. Girdle composed of numerous intercalary bands, collar-like, very indistinct, seen only with difficulty owing to the weakly siliceous nature of the cell. Chromatophores: numerous rounded bodies, nucleus small, often pressed to one side against the cell wall (Hendey, 1964).

Dimensions: Diameter of valve 36-56 µm; pervalvar axis 70-120 µm (Hendey, 1964), Diameter 7-56 µm (Hasle and Syvertsen, 1997).

Distribution: A neritic plankton species common in temperate waters; North Sea, Baltic, Norwegian and Danish Seas, and the English Channel (Cupp, 1943; Hendey, 1964). It was also found in our samples from Kuwait's waters.

Genus: *Climacodium* Grunow 1868

Cells straight but usually forming somewhat twisted chains. Valves elliptical. Apertures between cells in chains large (Hasle and Syvertsen, 1997). One species occurs in Kuwait's waters.

Climacodium frauenfeldianum Grunow (Plate 21D-F)

References: Cupp, 1943; Ricard, 1987; Hasle and Syvertsen, 1997.

Description: Valve surface between elevations flat, apertures right angled to oblong and larger in pervalvar direction than in the cell proper (Hasle and Syvertsen, 1997). Cells often united into long ribbon like chains. In girdle view with small, linear middle part with more or less long, thin processes on the poles of the apical axis (Cupp, 1943).

Dimensions: Length of apical axis 70-90 µm, pervalvar axis 12-15 µm (Cupp, 1943).

Distribution: Reported off lower California and central America (Cupp, 1943). It is present in Kuwait's waters (this study).

Genus: *Eucampia* Ehrenberg 1839

Cells usually united by means of valvar processes to form chains. Chains often spirally twisted. Large apertures between the cells. Cells somewhat quadrangular in girdle view, showing large intercellular foramina. Girdle composed of numerous intercalary bands seen only with difficulty. Valves narrowly elliptical with apices produced to form short truncate bosses. Valve surface finely areolate-punctate. Valves symmetrical on the apical and transapical axes, but in girdle view the cell is seen to be slightly cuneate; not only is the girdle itself cuneate, but the valve processes are more strongly developed at one end of the cell than at the other. This asymmetry accounts for the curving of the chain. Chromatophores, numerous small bodies (Hendey, 1964). One species occurs in Kuwait's waters.

Eucampia zodiacus **Ehrenberg (Plates 21G-H and 22A)**

References: Pavillard, 1925; Cupp, 1943; Drebes, 1974; Simonsen, 1974; Sykes, 1981; Ricard, 1987; Hasle and Syvertsen, 1997.

Description: Cells flattened, elliptical-linear in valve view, united in chains by two blunt processes. Chains spirally curved, with relatively narrow lanceolate or elliptical apertures. In girdle view the intercellular apertures appear large, varying in shape from narrowly lanceolate to broadly elliptical. Valve surface furnished with one small eccentric spine. Girdle composed of a number of narrow annular segments. Chromatophores: numerous rounded bodies (Hendey, 1964).

Dimensions: Length of polar axis 30-96 µm, pervalvar axis 40-50 µm (Hendey, 1964; Sykes, 1981).

Distribution: Neritic, temperate, widely distributed all around the world. All parts of the North Sea and English Channel (Cupp, 1943; Hendey, 1964). This species is found in Kuwait's water (Al-Yamani et al., 2004).

Genus: *Hemiaulus* Heiberg 1863

Cells single or united in chains. Valves elliptical in section, with two narrow, pointed, more or less long processes at the ends of the apical axis, parallel to pervalvar axis. One or more hyaline claws on the end of the processes. Intercalary bands indistinct or absent, without septa. Membrane strongly or weakly siliceous, finer or coarser areolated or punctated. Cells in girdle view rectangular, bipolar, with long horn-like processes tipped with apiculi. Chromatophores numerous (Cupp, 1943; Hendey, 1964). Two species occur in Kuwait's waters.

Hemiaulus membranaceus **Cleve (Plate 22B-C)**

References: Cupp, 1943; Hasle and Syvertsen, 1997.

Description: Chains twisted, horns short, with more or less sharp point, cell wall slightly silcified, areolation and labiate process indistinct (Hasle and Syvertsen, 1997).

Dimentions: Length of apical axis 30-97 µm (Cupp, 1943).

Distribution: Warm water region (Hasle and Syvertsen, 1997). It occurrs in Kuwait's waters (this study).

Hemiaulus sinensis **Greville (Plates 22D-E and 23A-E)**

References: Pavillard, 1925; Allen and Cupp, 1935; Cupp, 1943; Simonsen, 1974; Ricard, 1987; Round et al., 1990; Hasle and Syvertsen, 1997.

Description: Cells broadly elliptical in valve view. Chains straight or curved, more or less long. Pervalvar axis more or less elongated. Valves with slightly convex surface of elliptical outline. Valve mantle high, no groove at base. Processes on valves thin but strong, with a strong claw on the ends. Cell wall strongly siliceous areolated-punctated. Areolae in radial, on the mantle surface pervalvar, rows of characteristic excentric arrangement in that the center of the areolation does not coincide with the center of the valve, but lies on one of the mantle surfaces. Areolae in the center of the valve 7-9 in 10 μm, on the base of the mantle 11-13 in 10 μm. Intercalary bands visible with special preparation. Very fine punctuation present on bands in rows, 28-29 rows in 10 μm (Cupp, 1943).

Dimensions: Apical axis 15-36 μm long (Cupp, 1943); 20-40 μm (Hendey, 1970).

Distribution: Neritic, south temperate or subtropical species. Fairly common off southern California and southward but never abundant (Cupp, 1943). Frequent in Mina Al-Ahmadi waters (Hendey, 1970) and also at other localities in Kuwait's waters (this study).

Family: Bellerocheaceae Crawford in Round et al. 1990

Genus: *Bellerochea* Van Heurck 1885

Cells usually united to form chains so that the valves are more or less in contact over the whole surface, except for small foramina near the margins. Cells rectangular in broad girdle view, narrow. Valves bipolar, lanceolate, or triangular, with concave undulating sides. Valve apices slightly produced, valve surface very weakly siliceous, with a central projection and a circlet of fine spinule around the margin (Hendey, 1964). Short elevation at each corner of the valve; those of adjacent cells in ribbons abutting.Valves consisting of tracery of siliceous costae covering valve mantle, marginal ridge and most of valve face. Bilabiate process with long external tube. Chromatophores: numerous small spherical bodies scattered throughout the cell.

Characters showing difference between species: (1) type of ribbons (separate or inseperate), (2) shape of intercellular spaces and (3) location of bilabiate process (Hasle and Syvertsen, 1997). One species *Bellerochea malleus* forma *biangulata* Hustedt was found in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970). While in our samples two species were found from Kuwait's waters: *B. horologicalis* Von Stosch, and *B. malleus* (Brightwell) Van Heurck which is the same species reported by Hendey (1970).

Bellerochea horologicalis Von Stosch (Plate 23F-G)

References: Ricard, 1987; Round et al., 1990; Hasle and Syvertsen, 1997.

Description: Ribbons curved in transapical plane, or straight or nearly straight, cells biangular, intercellular spaces dumbbell shaped, costae partly continuous (Hasle and Syvertsen, 1997).

Dimensions: From our samples the valve length 40 μm and the width 62 μm.

Distribution: Reported from Florida (Gulf of Mexico) and Melville Bay, and Australia (Hasle and Syvertsen, 1997). It is also observed in Kuwait's waters.

Bellerochea malleus (Brightwell) Van Heurck (Plate 24A-E)

Basionym: *Triceratium malleus* Brightwell 1858

References: Hustedt, 1930; Hendey, 1964; Drebes, 1974; Hasle and Syvertsen, 1997.

Description: Ribbons usually straight. Cells biangular, triangular, or quadrangular, united to form chains or flat colonies. Intercellular spaces drop shaped, open only near elevations, costae interrupted in valve center (Hasle and Syvertsen, 1997). The poles of the cell are raised to produce flattened processes which adhere closely to the opposite processes of the adjacent cell at both (or all) poles. When seen in girdle view in chain formation the intercellular spaces are somewhat pear-shaped at each end of the cell. Valve surface slightly inflated in the middle and furnished with acirclet of puncta near the margin. The cell wall is weakly siliceous and no structure is visible under the light microscope. Chromatophores: numerous small plate-like bodies, scattered throughout the cell; nucleus central and usually distinct (Hendey, 1964).

Dimensions: Length of valve 110 µm, pervalvar axis 20 µm (Hendey, 1964). In the present study, the length of valve 33.23-49.08 µm and the width 28.58-48.42 µm.

Distribution: A neritic plankton species from tropical and sub-tropical waters. Known from the North Sea, the English Channel, the French and Portuguess Guinea, and Leigh, New Zealand (Hendey, 1964; Hasle and Syvertsen, 1997). It is also found in Kuwait's waters.

Family: Streptothecaceae Crawford in Round et al. 1990

Genus: *Helicotheca* Ricard 1987

Synonym: *Streptotheca* Shrubsole 1890

Cells flat, ribbon-like, united edge to edge to form short chains. Cells square in girdle view, girdle not evident. Valves linear, or very narrow linear-elliptic; cells joined valve to valve without any foramen, chains often twisted; very weakly siliceous, hyaline. Chromatophores: numerous small rounded or elliptical bodies in radiating lines from a centrally placed nucleus (Hendey, 1964). Only one species occurs in Kuwait's waters.

Helicotheca thamensis (Shrubsole) Ricard (Plates 24F-H and 25A-C)

Basionym: *Streptotheca thamensis* Shrubsole

References: Peragallo and Peragallo 1897-1908; Pavillard, 1925; Cupp, 1943; Hendey, 1964; Drebes, 1974; Hasle, 1975; Sykes, 1981; Ricard, 1987; Round et al., 1990; Hasle and Syvertsen, 1997.

Description: Cells rectangular, almost square, united to form long flat ribbon-like chains, twisted about the pervalvar axis. Adjacent valves adhering closely, leaving no aperture. Valve linear in outline, valve surface often showing a small prominence which fits into a corresponding depression upon the neighbouring cell. Chromatophores: numerous small rounded bodies, which are arranged in a number of lines radiating from the central nucleus. Cells very weakly siliceous, completely soluble in mineral acids and absorbing dyes readily (Hendey, 1964).

Dimensions: Polar axis of cell 80-100 µm; pervalvar axis 90-120 µm (Hendey, 1964; Sykes, 1981).

Distribution: Warm water region to temperate (Hasle and Syvertsen, 1997). Widely distributed in all parts of the North Sea and English Channel (Hendey, 1964). It was observed in our samples from Kuwait's waters.

Sub-Class: Lithodesmiophycidae Round and Crawford in Round et al. 1990

Order: Lithodesmiales Round and Crawford in Round et al. 1990

Family: Lithodesmiaceae Round in Round et al. 1990

Genus: *Ditylum* Baily 1861

Cells usually free, elongated, sub-cyclindrical, prismatic or quadrangular in girdle view, showing a well developed central spine and smaller spines at the corners. Girdle composed of numerous imbricate scales, which bear fine longitudinal striae. Valves triangular or quadrangular, with straight or usually undulating margins, furnished with a long central spine and smaller spines in the angles. The central spine is tubular and is often linked with that of the neighbouring cell to form short loose chains. Cells weakly siliceous. Valve surface finely areolate, punctate. Chromatophores: numerous small rounded bodies (Hendey, 1964). One species was encountered in Kuwait's waters.

Ditylum brightwelli (West) Grunow (Plate 25D-G)

References: Cupp, 1943, Hendey, 1964; Drebes, 1974; Round et al., 1990; Hasle and Syvertsen, 1997.

Synonyms: *Triceratium brightwellii* West, 1860; *Ditylum trigonum* Bailey, 1862; *Ditylum inaequale* Bailey, 1862.

Description: Cells triangular in space, somewhat like a prism, angles often rounded, giving a cylindrical appearance. Cells three to eight times longer than broad. Valves small, undulate, furnished with a corona of short but stout spines surrounding one large central spine. Central spine straight. Central area of valve often raised, hyaline. Girdle elongated. Lebour (1930) described the connecting zone as composed of scale-like intercalary bands. Chromatophores: numerous cocciform bodies, usually grouped towards the center of the cell. Cells very weakly siliceous (Hendey, 1964).

Dimensions: Diameter of valve 28- 46 µm; pervalvar axis 80-130 µm; length of spine 20-50 µm (Hendey, 1964).

Distribution: A neritic species, common around the coasts of the British Isles. Abundant in the North Sea and the English Channel (Hendey, 1964). A common form off southern California, in Gulf of California, and north to Scotch Cap, Alaska (Cupp, 1943). It is also encountered in Kuwait's waters.

Sub-Class: Corethrophycidae Round and Crawford in Round et al. 1990
Order: Corethrales Round and Crawford in Round et al. 1990
Family: Corethraceae Lebour 1930
Genus: *Corethron* Castracane 1886

Cells living singly. Cylindrical with rounded valves having a crown of long thin spines or setae at the margin directed outward at an angle. Numerous intercalary bands, scalelike, often very indistinct. Cell wall delicate, weakly siliceous. Chromatophores numerous, small (Cupp, 1943). One species occurs in Kuwait's waters.

Corethron criophilum Castracane (Plate 25H)

Synonym: *Corethron hystrix* Hensen 1887

References: Cupp, 1943, Hendey, 1964; Sykes, 1981; Round et al., 1990.

Description: Cells with cylindrical mantle and arched hemispherical valves. Circle of long slender setae at edge of valve. After cell division, while setae are enclosed within the girdle zone, they are parallel to the pervalvar axis. When free, on one valve all radiate out in same direction from center of cell; on other valve two types of setae are found, longer ones of uniform width and approximately parallel to those of the first valve, and shorter ones ending in an irregularly twisted knob. These shorter ones radiate forward. Intercalary bands not usually visible in water, collarlike. Chromatophores numerous round or slightly elongated plates (Cupp, 1943).

Dimension: Diameter 12-38 µm (Cupp, 1943), 20-60 µm, pervalvar axis 40-240 µm (Hendey, 1964).

Distribution: It is reported as an oceanic plankton form; observed in North Sea, English

Channel, North Atlantic, Norwegian and Danish Seas. Fairly common off California, in Gulf of California, and north to Scotch Cap, Alaska. It is considered as a temperate species (Cupp, 1943; Hendey, 1964). It was observed in Kuwait's waters during this study.

Sub-Class: Rhizosoleniophycidae Round and Crawford in Round et al. 1990
Order: Rhizosoleniales Silva 1962
Family: Rhizosoleniaceae Petit 1888

Dactyliosolen, *Guinardia*, and *Rhizosolenia* are the recent, marine, planktonic genera of this family as circumscribed by Simonsen (1979) and Glezer et al. (1988); Round et al. (1990) included the more recently described genera *Proboscia*, *Pseudosolenia*, and *Urosolenia*. In the latter classification Rhizosoleniaceae was placed in the order Rhizosoleniales P. Silva in the new subclass Rhizosoleniophycidae Round and Crawford. It is characterized by cylindrical cells which usually found separately or in chains. A single process with internal labiate, sometimes more tubular structure. Unipolar valve symmetry. Numerous small chloroplasts (Hasle and Syvertsen, 1997).

Genus: *Rhizosolenia* Brightwell 1858

Cells cylindrical with greatly elongated pervalvar axis, living singly or in compact or loose chains. Cells usually straight or more rarely curved, forming spirally twisted chains. Cross section elliptical or circular. Intercalary bands usually very numerous, but in some species difficult to see. Only a few species with ring-shaped intercalary bands; in most species they are rhombic, traperium-like, or scale-shaped. Their separation lines are called imbrication lines. The valves, called calyptrae in the genus *Rhizosolenia*, are in some species almost flat or symmetrically cone-shaped, usually, however, excentric sharp cone-shaped or hood-shaped. Likewise the valves have a usually excentric process, short or bristlelike elongated, blunt or sharp, solid or hollow. In a few species the process is completely absent and only the valve is more strongly drawn out and thinner to resemble a process. The cells are thin-walled throughout and usually collapse when dried. The membrane structure, frequently difficult to see, consists of puncta or little dots arranged in quineunx or definitely arranged lines. The chromatophores are usually small, numerous, distributed on the entire cell wall, but especially massed in the girdle zone about the nucleus. In some species larger platelike chromatophores are present (Cupp, 1943). Eight species are found in Kuwait's waters. One of the species name is not finalized at this stage and is reported as species 1.

Rhizosolenia bergonii H. Peragallo (Plates 25I and 26A-F)

References: Peragallo and Peragallo 1897-1908; Cupp, 1943; Hendey, 1964.

Description: Cells cylindrical, sometimes slightly flattened. Valves produced to form a long cone with slightly concave sides and terminating in a short spine which has a truncated apex. Girdle composed of numerous rows of imbricate scale-like plates with bow-shaped margins. Cell wall thick and having a finely striate surface (Hendey, 1964).

Dimensions: Diameter 22-70 µm; length up to 530 µm (Cupp, 1943). Diameter of valve up to 100 µm; length of cell up to 500 µm (Hendey, 1964).

Distribution: An oceanic species favouring warm waters but found occasionally in the English Channel (Hendey, 1964). Found off Lower California and in Gulf of California (Cupp, 1943). It also occurs in Kuwait's waters.

Rhizosolenia cochlea Brun (Plates 26G and 27A-E)

Synonym: *Rhizosolenia calcar-avis* var. *cochlea* Ostenfeld 1902.
References: Peragallo and Peragallo 1897-1908; Sournia, 1968; Simonsen, 1974; Karsten, 1978; Priddle and Fryxell, 1985; Sundström, 1986; Ricard, 1987.
Dimensions: In the present survey, length 135-495 µm and breadth 50-100 µm.
Distribution: A tropical species typical for the Indian Ocean and the westernmost part of the Pacific (Simonsen, 1974). Frequent in Kuwait's waters.

Rhizosolenia imbricata Brightwell (Plates 27F-I and 28A)

Synonyms: *Rhizosolenia shrubsolei* Cleve; *R. imbricata* var. *shrubsolei* (Cleve) Schröder.
References: Peragallo and Peragallo 1897-1908; Pavillard, 1925; Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964; Sournia, 1968; Hendey, 1970; Simonsen, 1974; Hasle, 1975; Priddle and Fryxell, 1985; Sundström, 1986; Ricard, 1987; Hasle and Syvertsen, 1997; Bérard-Therriault et al., 2000.
Description: Cells large, cylindrical, slightly flattened and furnished with depressed or flattened conical valves having a strongly oblique ventral margin. Valves furnished with a strong marginal spine which appears as a continuation of the dorsal side of the valve. Girdle composed of two lateral rows of intercalary scale-like markings. The segments have oblique ends and their edges form regular rings around the cell. Intercalary scales coarsely striate, striae oblique, converging upon a line or hyaline break which runs up the middle of the girdle. Markings finely areolate (Hendey, 1964).
Dimensions: Diameter of valve up to 80 µm; length of cell up to 400 µm (Cupp, 1943; Hendey, 1964).
Distribution: English Channel, west coast of Ireland (Hendey, 1964). Common in Mina Al-Ahmadi waters (Hendey, 1970) and at other localities in Kuwait's waters (this study).

Rhizosolenia cf. *pungens* Cleve-Euler (Plate 28B-C)

References: Drebes, 1974; Hasle and Syvertsen, 1997.
Description: Basal part of external process narrow, abruptly swollen for about half its length. Otherwise, same as *R. setigera* (Hasle and Syvertsen, 1997).
Dimensions: 8-14 µm in diameter (Hasle and Syvertsen, 1997).
Distribution: Mainly brakish water (Swedish and Danish coastal waters, Keil Bay, Brazil, Japan) (Hasle and Syvertsen, 1997). It is also found in Kuwait's waters.

Rhizosolenia robusta Norman (Plate 28D-F)

References: Peragallo and Peragallo 1897-1908; Pavillard, 1925; Cupp, 1943; Hendey, 1964; Drebes, 1974; Simonsen, 1974; Sundström, 1986; Ricard, 1987; Hasle and Syvertsen, 1997.
Description: Cells cylindrical with deeply convex or conical curved valves, Valvar plane elliptical. Cells either crescent-shaped or s-shaped. Usually living singly, or in short chains. Intercalary bands robust, numerous, typically collar-shaped. Calyptrae with distinct longitudinal lines (growth sectors) and excentric process with a fine, bristle-like point and suddenly dilated, hollow base. Cell wall thin, but more strongly siliceous than in most of the other species of this genus. Membrane delicately punctated, puncta in the three-line, self-crossing system (quincunx). Puncta on valve 19-20 in 10 µm; on intercalary bands 24-26 in 10 µm. Chromatophores numerous, lying along the wall. Nucleus near the wall (Cupp, 1943).

Dimensions: Diameter of valve 48-130 µm, up to $^{1}/_{2}$ mm or even 1 mm long (Cupp, 1943), 60-150 µm; length of cell up to 500 µm; length of conical valve up to 100 µm (Hendey, 1964).
Distribution: An oceanic form with a world-wide distribution. Common in all parts of the North Sea, English Channel, Irish Sea and the North Atlantic coasts. Frequently found off California but never common or abundant (Cupp, 1943; Hendey, 1964). It is also frequent in Kuwait's waters.

Rhizosolenia shrubsolei Cleve (Plates 28G and 29A-E)

Synonym: *Rhizosolenia imbricata* v. *shrubsolei* (Cleve) Schröder 1906.
References: Cupp, 1943; Hendey, 1964; Hasle and Syvertsen, 1997.
Description: Cells cylindrical, often flattened, narrow, solitary or united in chains. Valves conical, strongly eccentric, forming a continuous line with the girdle margin on one side, but oblique on the ventral side. Valves terminated by a short hollow spine which is furnished with an alate base. The small wings extend to about one-third the length of the spine but do not encroach upon the valve. Girdle composed of usually two rows of intercalary scale-like plates which present different patterns according to the position in which the cell is lying. When lying so that the spine on the valve appears to be central, the edges of the imbricate plates form a zigzag line; when the cell is lying so that the spine is eccentric, that is, lying along the dorsal margin, the edges of the plates form transverse rings around the cell. Intercalary plates striate. Chromatophores: numerous small rounded bodies radiating from a more or less centrally placed nucleus (Hendey, 1964).
Dimensions: Diameter of valve 6-20 µm; length of cell up to 300 µm (Hendey, 1964).
Distribution: A neritic species common in northern waters; North Sea, English Channel, North Atlantic coasts (Hendey, 1964). It occurs in Kuwait's waters.

Rhizosolenia setigera Brightwell (Plate 29F-G)

References: Peragallo and Peragallo 1897-1908; Pavillard, 1925; Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964; Sournia, 1968; Drebes, 1974; Simonsen, 1974; Sykes, 1981; Priddle and Fryxell, 1985; Sundström, 1986; Ricard, 1987; Pankow, 1990; Hasle and Syvertsen, 1997; Bérard-Therriault et al., 2000.
Description: Cells cylindrical, tubular, straight and usually solitary. Cell wall weakly silicified; structure not resolved with LM (Light Miscroscopy). Areolae poroid (SEM). Two dorsiventral columns of bands. Valves deeply conical and produced to form an elongated spine. Spines usually straight, frequently occupying two-thirds of the total length of the cell. No otaria. Labiate structure present. Girdle composed of two pervalvar lines of intercalary plates whose seams on the ventral margin point to the valve apex, and present the appearance of a zigzag line in the lateral aspect. Chromatophores: numerous small rounded bodies (Hendey, 1964; Hasle and Syvertsen).
Dimensions: Diameter of valve up to 8-25 µm; length of cell up to 300 µm (Cupp, 1943; Hendey, 1964; Sykes, 1981).
Distribution: A neritic species favouring colder waters. Common in North temperate Sea, Danish and Swedish Seas, North Atlantic, Arctic Seas (Cupp, 1943; Hendey, 1964) and in Kuwait's waters.

Rhizosolenia sp. 1 (Plate 29H)

Distribution: It was recorded in Kuwait's waters.

Genus: *Proboscia* Sundström 1986

Sundström (1986) wrote "*Proboscia* comprises the generic type *P. alata* and an undetermined number of species commonly referred to in the literature as *Rhizosolenia alata*, *Rh*. *arafurensis*, *Rh*. *indica*, *Rh*. *inermis*, *Rh*. *truncate*, etc. The valves subconical, terminating in a proboscis. No process. Claspers usually present (Hasle and Syvertsen, 1997). One species occurs in Kuwait's waters with 2 different varieties.

Proboscia alata (Brightwell) Sundström 1986

Basionym: *Rhizosolenia alata* Brightwell 1858 (Plate 30A-B)

References: Peragallo and Peragallo 1897-1908; Pavillard, 1925; Hustedt, 1930; Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964; Sournia, 1968; Drebes, 1974; Simonsen, 1974; Hasle, 1975; Karsten, 1978; Sykes, 1981; Priddle and Fryxell, 1985; Sundström, 1986; Ricard, 1987; Pankow, 1990; Round et al., 1990; Hasle and Syvertsen, 1997; Bérard-Therriault et al., 2000.

Description: Cells rod-shaped, cylindrical, straight; Valve shortly conical ending in tube-like. Depression at base of tube into which apex of adjoining cell fits. Intercalary bands scale-like, in two columns, numerous, rhomboidal, with pores (LM) scattered between loculate (SEM) areolae. Proboscis, tip, truncate, short longitudinal slit just below tip. Cell wall thin, weakly siliceous. Finely striated. On valve 21-23 puncta in 10 µm. None observed on intercalary bands. Chromatophores numerous, small (Cupp, 1943; Hasle and Syvertsen, 1997).

Dimensions: Diameter of valve 7-18 µm, up to 1 mm in length (Cupp, 1943), Diameter of valve 8-15 µm; length up to 600 µm (Hendey, 1964). In the present specimens, they were 42-49 µm wide at different localities of Kuwait's waters.

Distribution: An oceanic species, but frequently found in neritic plankton, having a wide distribution in temperate and sub-tropical seas. North Sea, English Channel, North Atlantic (Hendey, 1964). Common off California and north to Alaska. Sometimes abundant off southern California and common in the Gulf of California (Cupp, 1943). It is also recorded in the middle of the Arabian Sea and the Arabian/Persian Gulf (Simonsen, 1974). It is common in Kuwait's waters and bloomed in many localities mostly during summer in Kuwait Bay.

Proboscia alata f. *gracillima* (Cleve) Gran (Plate 29I-J)

Synonyms: *Rhizosolenia alata* forma *gracillima* (Cleve) Gran; *Rhizosolenia alata* var. *gracillima* (Cleve) Grunow; *Rhizosolenia gracillima* Cleve 1881

References: Hustedt, 1930; Cupp, 1943; Hendey, 1964.

Description: Cells similar to those of the type, but much thinner. The valve is somewhat less conical and usually more produced. Auxospore formation is common and cells of the post-auxospore generations are about the same size as the type forms (Hendey, 1964).

Dimensions: Diameter of valve 4-6 µm; pervalvar length up to 500 µm (Hendey, 1964). In the present materials, they were 6-7 µm wide and the process length was 4.19 µm.

Distribution: A neritic form abundant in the North Sea and English Channel during the summer months (Hendey, 1964). It is also found in Kuwait's waters.

Proboscia alata f. *indica* Peragallo (plate 30C-E)

Synonyms: *Rhizosolenia indica* H. Peragallo 1892; *Rhizosolenia alata* forma *indica* (Peragallo) Gran.

References: Hustedt, 1930; Cupp, 1943; Hendey, 1964.

Description: Cells similar to those of the type but much broader. Valves often identical with those of the type, but sometimes the apices are produced to form thin curved processes often somewhat obliquely set. It is not unusual to see cells having a forma alata apex at one end and a forma indica apex at the other (Hendey, 1964). This forma generally occurred together with the species.

Dimensions: Diameter of valve 20-60 µm (Hendey, 1964). In the present survey, they were 43-100 µm wide and 416 µm long in different localities of Kuwait's waters.

Distribution: Common in temperature and sub-tropical seas; frequent in the English Channel, often found mixed with the type form (Hendey, 1964). Found in the Arabian Sea, Arabian/Persian Gulf and the Mediterranean Sea (Simonsen, 1974). It is also encountered in Kuwait's waters but less frequent than the type form and mostly observed when *R. alata* blooms occurred.

Genus: *Pseudosolenia* Sundström 1986

The shape of the valve and the external as well as the internal parts of process and the poroid areolae distinguish the genus from *Rhizosolenia* (Hasle and Syvertsen, 1997). One species occurs in Kuwait's waters.

Pseudosolenia calcar-avis (Schultze) Sundström (Plate 31A-C)

Basionym: *Rhizosolenia calcar-avis* Schultze 1858

References: Peragallo and Peragallo 1897-1908; Pavillard, 1925; Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964, 1970; Sournia, 1968; Simonsen, 1974; Hasle, 1975; Karsten, 1978; Priddle and Fryxell, 1985; Sundström, 1986; Ricard, 1987; Pankow, 1990; Round et al., 1990; Hasle and Syvertsen, 1997.

Description: Cells rod-shaped cylindrical, like *R. styliformis*, but the valves not so oblique, more regularly conical, curved at the apex. Intercalary bands scale-like, rhombic, in small individuals in two dorsiventral rows, in the widest forms sometimes up to eight or more rows. Imbrication lines difficult to see. Process strong, gradually diminished in size from the base to the point, curved like a claw. No wings on process. Cell wall thin and weakly siliceous. Very delicately punctated. Puncta on valve 22-24 in 10 µm, on intercalary bands 20-23 in 10 µm. Chromatophores small, numerous (Cupp, 1943).

Dimensions: Cells 6-53 µm in diameter, up to nearly 1 mm in length (Cupp, 1943), breadth 35-70 µm (Hendey, 1964). In the present materials, they were 45-50 µm wide.

Distribution: An oceanic species from tropical and sub-tropical waters, frequently found in the southern North Sea and in the English Channel (Hendey, 1964). Common and even abundant at times off southern California. Moderately abundant in Gulf of California in 1937 (Cupp, 1943). It is found quite in the African side,middle of the Arabian Sea, Indian side, and very common (this study) in Mina Al-Ahmadi waters (Hendey, 1970) and other locations in Kuwait's waters.

Genus: *Guinardia* Peragallo 1892

Cells cylindrical, longer than broad, with a straight or slightly curved pervalvar axis, living singly or united in straight to twisted close-set chains. Intercalary bands numerous, collarlike or with wedge-shaped ends. Valves circular, surface flat, with an asymmetrical lateral rudimentary tooth at the valve margin. Chromatophores numerous, roundish, more or less lobed. Nucleus usually lying in a central plasma mass, suspended by cytoplasmic strands extending to the cell wall (Cupp, 1943). Four species occur in Kuwait's waters. One of the species names is not finalized at this stage and is reported as species 1.

Guinardia flaccida (Castracane) Peragallo (Plates 31D-I and 32A)

Basionym: *Rhizosolenia flaccida* Castracane 1886

Synonym: *Rhizosolenia castracanei* Cleve 1889

References: Peragallo and Peragallo 1897-1908; Pavillard, 1925; Cupp, 1943; Hendey, 1964; Drebes, 1974; Simonsen, 1974; Hasle, 1975; Sykes, 1981; Ricard, 1987; Pankow, 1990; Round et al., 1990; Hasle and Syvertsen, 1997; Semina, 2003.

Description: Cells typically cylindrical, one and a half to several times longer than broad, single or united in chains by whole valve surface. Valve nearly flat, very slightly concave, with an irregular tooth at the margin. Girdle composed of numerous intercalary bands; girdle hyaline, weakly siliceous, collapsing when dried, without visible sculpturing. Chromatophores lying near the wall, round to biscuit-shaped, more or less lobed or cleft plates in large numbers, with one pyrenoid. Nucleus more or less central (Cupp, 1943; Hendey, 1964; Hasle and Syvertsen, 1997).

Dimensions: Diameter of valve 36-80 µm; pervalvar axis of cell, up to 160 µm (Cupp, 1943; Hendey, 1964; Sykes, 1981).

Distribution: A neritic species from temperate seas. Common in all parts of the North Sea and English Channel. Never common off southern California. Present more commonly but never abundant in the Gulf of California (Cupp, 1943; Hendey, 1964). It is common in Kuwait's waters.

Guinardia delicatula Sykes, (Cleve) Hasle (Plate 32B-C)

Basionym: *Rhizosolenia delicatula* Cleve

References: Cupp, 1943; Hendey, 1964; Drebes, 1974; Sykes, 1981; Sundström, 1986; Pankow, 1990; Hasle and Syvertsen, 1997; Bérard-Therriault et al., 2000.

Description: Cells cylindrical, united to form short straight chains. Valves flat or only slightly convex and furnished with a short marginal spine, which fits into a small depression on the neighbouring cell. Girdle composed of annular segments seen only with difficulty. Chromatophores: several large plates (Hendey, 1964).

Dimensions: Diameter of valve 16-22 µm; pervalvar length up to 60 µm.

Distribution: A neritic species, common in temperate seas. English Channel, North Sea, Danish and Belgian coasts (Hendey, 1964). It is frequently encontered in Kuwait's waters.

Guinardia striata (Stolterfoth) Hasle (Plates 32D-F and 33A)

Basionym: *Eucampia striata* Stolterfoth

Synonym: *Rhizosolenia stolterfothii* H. Peragallo 1888 (Plate 56D)

References: Peragallo and Peragallo 1897-1908; Pavillard, 1925; Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964; Sournia, 1968; Drebes, 1974; Hasle, 1975; Karsten, 1978;

Sykes, 1981; Priddle and Fryxell, 1985; Sundström, 1986; Ricard, 1987; Pankow, 1990; Round et al., 1990; Hasle and Syvertsen, 1997.

Description: Cells cylindrical. Uniformly curved along pervalvar axis. United in curved chains, often spiral. Valves flat, rounded at the edges. Strong spine on valve margin, fits into depression on adjacent cell. Intercalary bands collar-like, numerous. Imbrication lines not always distinct, but very clear sometimes. Cell wall weakly siliceous, without detectable structure. Chromatophorea numerous, small, oval bodies scattered throughout the cell. Nucleus near wall (Cupp, 1943; Hendey, 1964).

Dimensions: Diameter of valve 6-30 µm (Cupp, 1943), 15-40 µm; length of cell up to 130 µm (Hendey, 1964).

Distribution: A neritic species widely spread in northern waters, common in North Sea, Danish and Swedish Seas, English Channel, and North Atlantic coasts (Hendey, 1964). It is common in Kuwait's waters.

Guinardia sp. 1 (Plate 33B-D)

Description: Cells thin, single or united in striaght chains by their whole valve surface.

Dimensions: Diameter of valve 22-25 µm.

Distribution: It is present in Kuwait's waters.

Genus: *Dactyliosolen* Castracane 1886

Valve structure composed of branching ribs radiating from the single process (often too delicate to be revealed with LM). Ends of half of the bands wedge shaped (Hasle and Syvertsen, 1997). One species occurs in Kuwait's waters.

Dactyliosolen fragilissimus (P. Bergon) Hasle (Plate 33E-H)

Basionym: *Rhizosolenia fragilissima* P. Bergon 1903.

References: Pavillard, 1925; Cupp, 1943; Hendey, 1964; Drebes, 1974; Hasle, 1975; Sundström, 1986; Pankow, 1990; Hasle and Syvertsen, 1997; Round et al., 1990; Bérard-Therriault et al., 2000.

Description: Cells shortly cylindrical, united to form short, loose chains. Valves weakly convex, furnished with a short spine placed almost in the center, which fits into a small depression on the valve of the neighbouring cell. Spines bent obliquely. Girdle composed of numerous annular segments, which because of the weakly siliceous nature of the cell, are somewhat difficult to see. Chromatophores: numerous small plates evenly distributed throughout the cell, or may be sometimes gathered in a cluster around the central nucleus (Hendey, 1964).

Dimensions: Diameter of valve 12-60 µm; pervalvar length 30-80 µm (Cupp, 1943; Hendey, 1964).

Distribution: A common neritic species in the North Sea and English Channel. Temperate, fairly common off California, abundant at times in Gulf of California (Cupp, 1943; Hendey, 1964). It is abundant in Kuwait's waters.

Sub-Class: Chaetocerotophycidae Round and Crawford in Round et al. 1990
Order: Chaetocerotales Round and Crawford in Round et al. 1990
Family: Chaetocerotaceae Ralfs 1861/ Smith 1872

Bacteriastrum and *Chaetoceros* belong in this family (Simonsen, 1979; Glezer et al., 1988; Round et al., 1990). *Bacteriastrum* used to belong to the family Bacteriastraceae, which is characterized by cylindrical cells, with flattened valves surrounded with a circlet of bristles; those of neighbouring cells fused together at first, then bifurcate. Cells colonial, united closely in chains without intercellular foramina. Frustules cylindrical, rectangular in girdle view. Valves circular with strong setae radiating from the margins. Setae variable. Terminal setae usually thicker and arranged in a single circlet, either straight or curved, intermediate setae bifurcate. Whereas, the Cheatoceraceae cells are colonial, united by long lateral bristles (setae) to form chains. Aperture-foramen-open space between adjacent (sibling) cells/valves in chains. Seta-hollow outgrowth of valve projecting outside the valve margin, with structure different from that of the valve. Inner intercalary setae occurring within the chain. Basal part-portion of a terminal seta closest to valve face, portion of an inner seta between its point of origin on valve face and its point of fusion or crossing with its sibling seta. Frustules weakly siliceous. Valves bipolar, symmetrical on the apical and transapical axes. Generally, the genus *Chaetoceros* has two setae per valve, one at each end of the apical axis while *Bacteriastrum* has more than two setae per valve, regularly arranged around its margin (Hendey, 1964; Hasle and Syvertsen, 1997).

Genus: *Bacteriastrum* Shadbolt 1854

Cells cylindrical, in cross section circular. Bound into loose chains by the fusion of the more or less numerous setae that are regularly arranged around the margin of the cells. Setae of two adjacent cells are fused for a certain distance beyond the base, farther out divided again. Terminal setae different from others, often curved, not fused and therefore not bifurcating. Intercalary bands absent as a rule. Apertures between cells of varying widths. Cell wall delicate and hyaline, without clearly visible structure. Chromatophores numerous, small, roundish, more or less lobed. All species are marine pelagic (Cupp, 1943). Only two species were reported and illustrated by Hendey (1970) in Mina AL-Ahmadi waters (Kuwait's waters). Four species were found in the present survey.

Bacteriastrum delicatulum Cleve (Plates 33A and 34A-D and 35A-B)

References: Pavillard, 1925; Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964; Hasle and Syvertsen, 1997.

Description: Cells cylindrical. Chains long, straight. Setae 6-12, with strong, long basal part. Apertures usually relatively large. The bifurcation plane of inner setae lies in the valvar plane, transverse to chain axis. Forked parts slightly curved, smooth or somewhat wavy. Terminal setae of both ends directed toward the inside of the chain and in front view of the valve similarly curved; stronger than inner setae and with fine spines arranged spirally. Chromatophores small, numerous, distributed along cell wall (Cupp, 1943).

Dimensions: Diameter of valve 6-15 μm (Cupp, 1943), 12-20 μm, pervalvar length 20-60 μm. Chains of up to 20 cells (Hendey, 1964).

Distribution: An oceanic form, common in temperate waters; Faroe-Shetland Channel, English Channel, North Atlantic coasts, Mediterranean. Fairly common in eastern Pacific (Cupp, 1943; Hendey, 1964). It occurs in Kuwait's waters.

***Bacteriastrum* cf. *elegans* Pavillard (Plate 35C)**

References: Pavillard, 1925

Distribution: It occurs in Kuwait's waters.

***Bacteriastrum hyalinum* Lauder (Plates 35D-E and 36A-C)**

References: Pavillard, 1925; Allen and Cupp, 1935; Hendey, 1964.

Description: Cells usually flat, wider than long. Basal part very short; bifurcation parallel to chain axis giving cells a hairy appearance. Terminal setae bent over chain axis and in toward it. Setae numerous, 24 to 33 (Allen and Cupp, 1935). 12-32 setae were repoted by Hendey (1964).

Dimensions: Diameter 24-36 µm (Allen and Cupp, 1935). 20-40 µm (Hendey, 1964).

Distribution: Fairly common in Java Sea (Allen and Cupp, 1935). It is found in Kuwait's waters.

***Bacteriastrum varians* var. *hispida* (Castracane) Schröder (Plates 36D-E and 37A)**

References: Allen and Cupp, 1935.

Description: Terminal setae, usually 8, with large spirally arranged spines on basal part, smaller spines beyond bend toward end. Entire frustule (Allen and Cupp, 1935).

Dimentions: Diameter of valve 16-20 µm, length of spines 56-66 µm (Hendey, 1970).

Distribution: Found in Java Sea (Allen and Cupp, 1935). It is also present in Kuwait's waters.

Genus: *Chaetoceros* Ehrenberg 1844

It is one of the largest, if not the largest genus of marine planktonic diatoms with approximately 400 species described (Hasle and Syvertsen, 1997).Cells with oval section to almost or rarely completely circular in valve view; in broad girdle view quadrangular with straight sides and concave, flat, or slightly convex ends. Valve with a more or less flat end surface or valve surface and a cylindrical part or valve mantle which are bound together without a seam. A long thick or thin seta, bristle or awn at each end of the long or apical axis of the valve on the corners. The opposite setae of neighboring cells touch one another near their origin, usually directly or sometimes by a bridge, and fuse firmly at a point near their base holding the cells in chains, usually with large or small apertures or foramina between the cells. Basal portion of the setae parallel to the pervalvar axis or directed diagonally outward with the outer portion frequently perpendicular to the axis to the chain. In most species the length of the chain is limited by the formation of special end cells, terminal setae usually shorter and thicker and more nearly parallel to the chain axis than the others. In relatively few species are cells solitary.

Cell wall formed of two valves and one or two girdle bands. Two frequently unequally developed girdle bands always present in most species. Intercalary bands present in some species usually difficult to see without special preparations. Chromatophores vary greatly in number, size, form, and position in different species; may be one to several, small or large, but are constant for a given species and consequently indispensable for species demarcation. In many species pyrenoids are distinctly visible. Great variations may be observed in chains of the same species from different localities and at different times of the year (Cupp, 1943). Many species of *Chaetoceros* spp. occur in Kuwait's waters.

Chaetoceros affinis Lauder (Plate 37B)

Synonyms: *Chaetoceros javanicum* Cleve 1873; *Chaetoceros ralfsii* Cleve 1873; *Chaetoceros schuettii* Cleve 1894; *Chaetoceros angulatum* Schütt 1895.

References: Pavillard, 1925; Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964; Drebes, 1974; Pankow, 1990; Round et al., 1990; Hasle and Syvertsen, 1997; Bérard-Therriault et al., 2000.

Description: Cells united to form short, straight chains, cylindrical, rectangular in girdle view. Valves elliptical, valve surface flat or weakly convex, with slightly produced apices leading to the thin and almost straight setae that emerge from the valve margin almost at right angles. Valve mantles deep, girdle narrow; setae of the lower valve of terminal cells strongly divergent and much thicker than the others. Chromatophore, a single body lying against the girdle with a large central pyrenoid and occupying the major part of the cell. Nucleus central. Foramina narrowly elliptical, with straight sides. Upper and lower surfaces almost equal and bearing numerous spines (Hendey, 1964).

Dimensions: Chains, 7-27 µm wide (Cupp, 1943), diameter of valve 10-25 µm (Hendey, 1964).

Distribution: A neritic species from temperate waters, common in all parts of the North Sea and the English Channel (Cupp, 1943; Hendey, 1964). It occurs in Kuwait's waters.

Chaetoceros atlanticus Cleve (Plate 37C-E)

References: Cupp, 1943; Simonsen, 1974; Ricard, 1987; Pankow, 1990; Round et al., 1990; Hasle and Syvertsen, 1997; Bérard-Therriault et al., 2000.

Description: Chains straight, flat, not twisted. Cells in broad girdle view oblong. Valves weakly convex, with a small spine in the center of each cell. Apertures between cells hexagonal, large, but smaller than cells. Valve mantle rather low, one-third the length of cell or less, making three zones nearly equal. Distinct constriction at suture between mantle and girdle. Setae arising slightly within valve margin, base narrow, then usually widened and later tapered. Terminal setae always shorter than others, at first diagonal, farther out bent in, so that points are about parallel to chain axis. Inner setae usually almost straight, approximately in apical plane. Setae armed with small spines. In some specimens all setae, particularly terminals, definitely clubbed (Cupp, 1943; Hendey, 1964).

Chromatophores: numerous small rounded bodies penetrating the setae.

Dimensions: Diameter (breadth = length along apical axis of valve) 10-26 µm broad (Cupp, 1943) 18-46 µm (Hendey, 1964).

Distribution: An oceanic plankton species favouring a high salinity. Common and wide-spread in the North Atlantic, Arctic Ocean, Norwegian Seas, North Sea (Cupp, 1943; Hendey, 1964). Observations from the southern cold water region are more complex (Hasle, 1969; Priddle and Fryxell, 1985). Present in Kuwait's waters.

Chaetoceros coarctatus Lauder (Plates 37F and 38A-D)

Synonym: *Chaetoceros rudis* Cleve 1901

References: Cupp, 1943; Hendey, 1964; Simonsen, 1974; Round et al., 1990; Hasle and Syvertsen, 1997.

Description: Cells cylindrical, united to form chains of usually twelve to sixteen cells. Chains long and robust in appearance, with two ends markedly different. Apertures almost absent. Valves elliptical to circular, strongly siliceous. Valve mantle is usually deep, often a little deeper than the girdle. Setae coarse, thickened, emanating from the margin of the valve. Setae proceed outwards in different planes, but usually obliquely, or almost at right angles to the axis of the chain for a distance equal to about a third of their length, then curve downwards, often sweeping across the chain axis. The setae are usually entire length. End setae on the lower valve of terminal cells very strong and convergent. Chromatophores: numerous small rounded bodies (Hendey, 1964).

Dimensions: Chains, 30-44 µm wide (Cupp, 1943), diameter of valve 30-40 µm (Hendey, 1964).

Distribution: Oceanic plankton species, preferring sub-tropical waters but sometimes found in the North Atlantic Ocean and the English Channel. Reported off Lower California (Cupp, 1943; Hendey, 1964). It is also observed in Kuwait's waters.

Chaetoceros compressus **Lauder (Plate 39A-D)**

References: Cupp, 1943; Drebes, 1974; Hasle and Syvertsen, 1997.

Description: Chains often very long and straight with cells more or less twisted about chain axis. Apertures variable in shape – four or six-sided to slit like. Setae arising well inside valve margin; basal part distinct; point of crossing near chain edge. Two types of inner setae: most are thin, some pairs are shorter, thickened, spirally undulate, covered with small spines, and strongly directed toward one end of chain. Resting spores smooth, parimary valve highly vaulted and secondary valve slightly vaulted (Hasle and Syvertsen, 1997).

Dimensions: 7-24 µm wide (Cupp, 1943).

Distribution: Neritic. Boreal to south temperate species. Found off California, lower California coasts and in Gulf of California (Cupp, 1943). It is also found in Kuwait's waters.

Chaetoceros* cf. *costatus **Pavillard (Plate 39E-F)**

Synonym: *Chaetoceros adhaerens* Mangin 1913

References: Cupp, 1943; Hendey, 1964; Drebes, 1974; Round et al., 1990; Hasle and Syvertsen, 1997.

Description: Cells united to form short straight chains, rectangular in girdle view. Chains even, more or less twisted. Valves elliptical, with concave central area and raised truncated apices, which are joined to those of the neighbouring cells by means of a pad of mucus. Setae arise from within the apices of the valves, short and divergent mostly at right angles to the chain axis, but some are bent towards one end of the chain. Valve mantles narrow with no distinguishing line separating the girdle. Foramina lanceolate, not reaching the valve apices. Chromatophore, a single plate lying on the girdle. Girdle composed of intercalary bands (Hendey, 1964).

Dimensions: Diameter of valve 18-28 µm (Hendey, 1964), apical axis 12-24 µm (Cupp, 1943).

Distribution: Neritic, warm water species, on the Atlantic coasts of West European countries, English Channel. Common off southern California, found in great abundance in Gulf of California (Cupp, 1943; Hendey, 1964). It also occurs in Kuwait's waters.

Chaetoceros curvisetum **Cleve (Plates 39G and 40A-E)**

References: Pavillard, 1925; Cupp, 1943; Hendey, 1964; Drebes, 1974; Simonsen, 1974; Pankow, 1990; Round et al., 1990; Hasle and Syvertsen, 1997.

Description: Cells united to form spirally twisted chains, without distinct terminal cells, rectangular in girdle view. Valves elliptical, with concave surfaces. Cells four-cornered in broad girdle view, adjacent cells connected by conspicuous corners. Valve mantle shallow, usually low, higher at corners of apical axis, very small notch at junction with girdle band. Apertures rhombic, oval, or circular. Setae arising from corners of cells, all bent toward same side of chain-toward outside of curved axis of spiral. Setae long and slender. Chromatophores one per cell with large central pyrenoid (Cupp, 1943; Hendey, 1964).
Dimensions: Chains, 7-30 µm wide (Cupp, 1943); apical axis 10-30 µm (Hendey, 1964).
Distribution: Neritic, south temperate species. Very abundant off California. Also common off Lower California and in the Gulf of California (Cupp, 1943). Common in all parts of the North Sea, Norwegian and Danish Seas, Baltic, North Atlantic, English Channel (Cupp, 1943; Hendey, 1964). It is abundant in Kuwait's waters.

Chaetoceros decipiens Cleve (Plate 40F-G)

References: Pavillard, 1925; Cupp, 1943; Hendey, 1964; Drebes, 1974; Simonsen, 1974; Pankow, 1990; Round et al., 1990; Hasle and Syvertsen, 1997.
Description: Cells united to form long, stiff and usually straight chains; cells rectangular in girdle view. Valves elliptical, flat or nearly so. Apertures varying in size and shape according to season of year; in winter small, linear to lanceolate; in summer and autumn larger, elliptical or circular. Apices of the valves slightly produced and bearing stiff setae. Setae emerge from the valve margin and immediately fuse with those of the adjacent cell and extend as one for a short distance at right angles to the pervalvar axis, after which they separate and diverge in straight lines. The setae of the lower valve of terminal cells are usually much stouter and shorter than the others; they emerge obliquely at first, then are bent towards the axis of the chain until they are almost parallel. Terminal setae bear minute spines and the electron microscope shows them to have thickened longitudinal ribs between which are rows of fine pores. Chromatophores 4-10 per cell. Foramina narrowly rectangular or sub-elliptical (Cupp, 1943; Hendey, 1964).
Dimensions: Cells 9-84 µm wide (Cupp, 1943), length of valve 30-80 µm (Hendey, 1964).
Distribution: An oceanic Arctic and Boreal species. Atlantic Ocean, Norwegian Seas. All parts of the North Sea, English Channel. It is also abundant off southern California (Cupp, 1943; Hendey, 1964). It is frequently encountered in Kuwait's waters.

Chaetoceros denticulatus Lauder (Plate 41A-B)

Synonym: *Chaetoceros denticulatus* f. *angusta* Hustedt; *C. denticulatus* f. *lata* Hustedt; *C. nanodenticulatus* Okamura 1907.
References: Allen and Cupp, 1935; Simonsen, 1974.
Description: Chains straight, cells cylindrical. Apertures small, vertically rhombic. Usually a small process or tooth on inner side of setae, possibly for articulation with adjoining cell. Setae spinous and striated. Small spine in center of valve (Allen and Cupp, 1935).
Dimensions: Breadth of cell, 24-30 µm (Allen and Cupp, 1935). Rang 24-30 µm long and 28-60 µm wide were recorded in our survey.
Distribution: A typical species in the tropical areas of the Indian Ocean and the westernmost parts of the Pacific. Found in the Arabian Sea, Arabian/Persian Gulf and Pakistan (Simonsen, 1974). It occurs in Kuwait's waters.

Chaetoceros didymus Ehrenberg (Plate 41C)

References: Simonsen, 1974; Hasle and Syvertsen, 1997.

Description: Chains straight. Apertures large and partly filled by the valve protuberance. Setae arising from corners of cells, crossing at their bases or farther out, sometimes far outside chain edge. Each choloroplast with a pyrenoid located in the protuberance (Hasle and Syvertsen, 1997).

Dimensions: Apical axis 10-40 µm (Hasle and Syvertsen, 1997).

Distribution: Warm water region to temperate (Hasle and Syvertsen, 1997). It occurs in Kuwait's waters.

Chaetoceros diversus Cleve (Plate 41D-E)

References: Peragallo and Peragallo 1897-1908; Pavillard, 1925; Cupp, 1943; Hendey, 1964; Simonsen, 1974; Round et al., 1990; Hasle and Syvertsen, 1997.

Description: Chains straight, not twisted, usually short. Cells with elliptical valve surface. Valves flat or slightly raised in the center, with high valve mantle, with small but distinct notch at junction with girdle. Girdle-band zone small in resting cells. Setae arising from the corners of the cell, without basal part. Apertures very narrow, slit-like. Setae within chains of two kinds: (1) thin setae more or less curved, often straight, and usually slightly turned toward the chain ends; and (2) heavy setae almost club-shaped increasing in thickness from the base out, then becoming thinner again near the ends. The first two-thirds of setae almost straight and at a sharp angle from the chain axis, then turning gradually and at obtuse angle toward one or the other end of the chain and running almost parallel to the chain axis in the outer part. The thicker setae are clearly angular and beset on the corners with fine, spirally arranged little teeth. Terminal setae always thin and differ from others in position-at first more or less U-shaped, in outer part nearly parallel to chain axis. Number of pairs of heavy setae in a chain various and seem to conform to no rule. Chromatophores one in each cell, on girdle side (Cupp, 1943).

Dimensions: Apical axis usually 8-12 µm long (Cupp, 1943; Hendey, 1964).

Distribution: A member of the neritic plankton frequently found in the North Sea. Tropical and subtropical species. Not common off California but numerous off Lower California (Cupp, 1943; Hendey, 1964). It is abundant in Kuwait's waters.

Chaetoceros laciniosus Schütt (Plates 41E and 42A-C)

References: Peragallo and Peragallo 1897-1908; Cupp, 1943; Hendey, 1964; Ricard, 1987; Hasle and Syvertsen, 1997; Round et al., 1990; Bérard-Therriault et al., 2000.

Description: Chains straight and loose. Cells in broad girdle view rectangular, with slightly projecting corners rounded at the outside. Valve surface slightly arched in the middle. Apertures large and broad, oblong, with rounded corners, slightly constricted in the middle. Setae thin; basal part parallel to chain axis and then perpendicular to chain axis; far outer part usually bent toward one chain end. Terminal setae different from the others-almost parallel in broad girdle view and more diverging in narrow girdle view; armed with small spines. Chromatophores two per cell, more or less lobed plates, situated against valve base, each with a central pyrenoid (Cupp, 1943; Hasle and Syvertsen, 1997).

Dimensions: Diameter of valve 10-48 µm (Cupp, 1943; Hendey, 1964).

Distribution: A neritic species widely distributed in temperate seas. Common in all parts of the North Sea, Norwegian Sea, Baltic, North Atlantic and the English Channel (Cupp, 1943; Hendey, 1964). It occurs in Kuwait's waters.

Chaetoceros laevis Leuduger-Fortmorel (Plate 42D)

References: Allen and Cupp, 1935; Cupp, 1943; Ricard, 1987.

Description: Chains straight, usually short, 3-4 cells. Cells in broad girdle view oblong, adjacent cells touching each other at corners or also by middle part. Apertures very narrow, appear to be lacking under low magnifications. One chromatophore, attached to girdle. Valve mantle high, distinct notch at suture between mantle and girdle. Setae various, terminals and some inner one thin, hairlike; part of inner ones heavier. Heavy setae fused for a short distance beyond base, then both heavy and terminal setae have same curvature, at first nearly perpendicular to chain axis, then turn abruptly off at right angles, run parallel to chain axis, and then converge slightly toward chain. Small inner setae leave cell at nearly right angles to chain axis and diverge more or less toward ends, may follow same course as heavy setae. Small spines present on heavy setae (Cupp, 1943).

Dimensions: Cells, 5-12 μm wide (Cupp, 1943).

Distribution: Neritic. Tropical species. Rare. Found only south of Lower California (Cupp, 1943). It is abundant in Kuwait's waters.

Chaetoceros lorenzianus Grunow (Plates 42E and 43A-B)

References: Peragallo and Peragallo 1897-1908; Pavillard, 1925; Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964; Simonsen, 1974; Round et al., 1990; Hasle and Syvertsen, 1997; Bérard-Therriault et al., 2000; Semina, 2003.

Description: Cells generally united to form short chains, but often solitary, rectangular in girdle view. Valves elliptical, central area flat or slightly convex. Valve mantle usually deep, with a narrow girdle. Apices of the valves produced to form long stiff setae that emerge immediately from the valve margin and fuse with those of the adjacent cell at the point of exit only. All setae are divergent and lie more or less in the same plane, but setae of upper and lower terminal cells are strong, divergent and thicker or wider in the more remote half of their length. All setae bear puncta in an alternate arrangement. Foramina elliptical or narrowly hexagonal (Hendey, 1964). Chromatophores large, platelike, 4-10 plates (Cupp, 1943) and 8-12 per cell (Hendey, 1964).

Dimensions: Cells 7-48 μm wide (Cupp, 1943), diameter of valve 26-60 μm (Hendey, 1964).

Distribution: Neritic, tropical and temperate. Common off Lower California and southern California (Cupp, 1943), English Channel, North Sea (Hendey, 1964). It is present in Kuwait's waters.

Chaetoceros peruvianus Brightwell (Plate 43C-G)

Synonym: *Chaetoceros chilensis* Krasske.

References: Peragallo and Peragallo 1897-1908; Pavillard, 1925; Allen and Cupp, 1935; Hendey, 1964; Simonsen, 1974; Karsten, 1978; Round et al., 1990; Hasle and Syvertsen, 1997.

Description: Cells usually solitary, seldom building short chains. Valves elliptical. Valves unlike, the upper rounded, lower flat, both with similarly constructed valve mantles which vary greatly from one-sixth to equal the length of the apical axis; on girdle-band margin with hollow channel-like groove of varying size, but always very distinct. Setae of upper valve arising from near center, turning sharply and running backward in more or less wide, outwardly convex curves after short basal region. At the end more or less divergent to convergent. Setae of lower valve springing from near margin, slightly convex toward outside, more nearly parallel to chain axis than those of upper valve. At end more or less divergent or even convergent. All setae strong, 3-5 µm thick, four-sided, with strong spines; striated, 20-22 striae in 10 µm (Cupp, 1943). Chromatophores: several rounded bodies (Hendey, 1964).

Dimensions: 16-32 µm broad (Cupp, 1943), diameter of valve 10-44 µm (Hendey, 1964).

Distribution: Oceanic, in south temperate to warmer seas (Cupp, 1943; Hasle and Syvertsen, 1997), an oceanic species from tropical seas, sometimes found in the North Atlantic and the English Channel (Hendey, 1964). It is frequent in Kuwait's waters.

Chaetoceros pseudocurvisetum Mangin (Plate 44A-C)

References: Peragallo and Peragallo 1897-1908; Pavillard, 1925; Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964; Simonsen, 1974; Ricard, 1987; Round et al., 1990; Hasle and Syvertsen, 1997.

Description: Cells compressed, united to form short chains, rectangular in girdle view. Apertures lenticular, slightly fused at insertion of setae. Four protuberances on each valve connected with similar knobs on adjacent cells. Valve face rectangular with bent angles. Setae joined at insertion. Valve mantle high, without definite notch at junction with girdle band. Girdle zone small in resting cells. One chromatophore per cell. In general appearance setae similar to those of *C. curvisetus* (Cupp, 1943; Hendey, 1964).

Dimentions: Cells 13-19 µm broad (Cupp, 1943), diameter of valve 15-40 µm (Hendey, 1964).

Distribution: A neritic species on the Atlantic coasts of Europe; English Channel. Tropical and subtropical species. Not common off southern California (Cupp, 1943; Hendey, 1964). It is common in Kuwait's waters.

Chaetoceros socialis Lauder (Plate 44D-F)

References: Cupp, 1943; Hendey, 1964; Hasle and Syvertsen, 1997; Bérard-Therriault et al., 2000.

Description: Chains short, curved, many united in large, slimy, circular colonies, held together by slime, or mucilaginous-like substance, and often by some very fine long setae which are felted together. Poles of adjacent valves not touching one another. Apertures rather long, slightly narrower in the center. Setae hair-like, arising from corners of the cell, short basal part. Three setae of two adjacent valves short, the fourth one straight, elongated, and serving in formation of the more or less spherical secondary colonies by being entwined in the colony center with the elongated setae of other chains. One chromatophore, on girdle side (Cupp, 1943; Hasle and Syvertsen, 1997).

Dimentions: Cells 6-12 µm wide (Cupp, 1943), Diameter of valve 8-12 µm (Hendey, 1964).

Distribution: A neritic species, of temperate seas. Widely distributed in North Atlantic area, Danish and Norwegian Seas, all parts of the North Sea, Baltic, English Channel. Common and often abundant off southern California (Cupp, 1943; Hendey, 1964). Probably cosmopolitan, very important in plankton close to the ice in the northern cold water region and, according to Cupp (1943), also one of the most prominent species in the Gulf of California (Hasle and Syvertsen, 1997). It occurs in Kuwait's waters.

Chaetoceros tortissimum Gran (Plates 44G and 45A)

References: Cupp, 1943; Hendey, 1964; Drebes, 1974; Round et al., 1990; Hasle and Syvertsen, 1997.

Description: Chains straight or slightly bent, loose, very strongly twisted about chain axis, without distinct terminal setae. Setae thin, arising somewhat inside the valve margin, perpendicular to chain axis but going in all directions. Apertures apparent only at corners; slightly convex valve surfaces of sibling cells touching in the middle. Cell wall weakly siliceous. Cells in broad girdle view rounded-rectangular. Valves with slightly convex valve surface, touching in the middle, not at corners, therefore apertures apparent only at corners. No notch at margin of girdle band. Chromatophores one, lying in girdle region (Cupp, 1943; Hasle and Syvertsen, 1997).

Dimentions: Cells 14-20 µm broad (Cupp, 1943), diameter of valve 12-16 µm (Hendey, 1964).

Distribution: It is considered neritic, north temperate species; not common (Cupp, 1943); cosmopolitan (Hasle and Syvertsen, 1997). It is abundant in Kuwait's waters.

Order: Leptocylindrales Round and Crawford in Round et al. 1990
Family: Leptocylindraceae Lebour 1930

Simonsen (1979) tentatively considered *Leptocylindrus* to belong to the family Melosiraceae, whereas Round et al. (1990) retained the family Leptocylindraceae and suggested a new order, Leptocylindrales, in the subclass Chaetocerotophycidae.

"Cells cylindrical, living singly or united in chains by the flat valve faces. Many collar-like intercalary bands." This diagnosis has to be emended, independent of whether Leptocylindraceae is regarded as monotypic, as done by Round et al. (1990), or as to encompass two genera as suggested in this chapter. The character to be added is: the presence of a marginal ring of spines, small, flap like, or triangular in *Leptocylindrus* and long and unique in shape in *Corethron* (Hasle and Syvertsen, 1997).

Genus: *Leptocylindrus* Cleve 1889

Cells long, cylindrical, united into chains by whole valve surface. Valves flat, without spines or processes. Intercalary bands present but very difficult to see. Cells thin walled, hyaline, without visible sculpturing. Chromatophores one or many roundish plates or granules (Cupp, 1943). Two species occur in Kuwait's waters.

Leptocylindrus danicus Cleve (Plate 45B-D)

References: Peragallo and Peragallo 1897-1908; Pavillard, 1925; Cupp, 1943; Hendey, 1964; Drebes, 1974; Hasle, 1975; Sykes, 1981; Ricard, 1987; Pankow, 1990; Hasle and Syvertsen, 1997; Round et al., 1990; Bérard-Therriault et al., 2000.

Description: Cells weakly siliceous, tubular, cylindrical, narrow, two to ten times as long. United in closed, long, straigth, stiff chains. Valves circular, flat or convex, occasionally concave, without visible sculpturing. Girdle elongated and composed of numerous pointed intercalary segments. Adjacent cells often with only one cell wall between two valves. Intercalary bands present but very difficult to see. Chromatophores few to numerous, not very small, oval plates, distributed throughout the cell (Cupp, 1943; Hendey, 1964).

Dimentions: Cells 7-10 µm (Cupp, 1943), 5-16 µm in diameter, pervalvar axis 30-50 µm (Hendey, 1964).
Distribution: Neritic, probably a north temperature species. English Channel, Scottish lochs, Davis Strait, North Sea, Norwegian and Danish Seas (Hendey, 1964). Fairly common off southern California. Reported at Scotch Cap, Alaska, and in Gulf of California where it may become even moderately abundant at times (Cupp, 1943). *L. danicus* in the subantarctic/ Antarctic was recorded as dominant species at 81°43'N; one of the dominant summer diatoms in Norwegian fjords (Hasle and Syvertsen, 1997). Common in Kuwait's waters.

Leptocylindrus minimus Gran (Plate 45E-G)

References: Hendey, 1964; Drebes, 1974; Hargraves, 1990; Hasle and Syvertsen, 1997.
Description: Cells tubular and in all respects similar to *L. danicus* Cleve, except that the diameter of the valves is much less and the chlorophyll consists of only two (seldom one) elongate plate-like bodies, often lying along the girdle. Girdle composed of numerous narrow intercalary bands having pointed or cuneate ends, which in *Leptocylindrus minimus* Gran terminate immediately above each other, the joints giving the appearance of a line parallel to the girdle edge (Hendey, 1964).
Dimensions: Diameter of valve 5-6 µm; pervalvar axis 40-50 µm (Hendey, 1964). The diameter 1.5-2.5 µm and 25 µm long were documented by Hargraves (1990). Similar diameter was also recorded for our obtained species in different localities of Kuwait's waters.
Distribution: Neritic, North Sea, English Channel (Hendey, 1964). It is also found in Kuwait's waters.

Class: Fragilariophyceae (Araphid, pennate diatoms) Round in Round et al. 1990
Sub-Class: Fragilariophycidae Round in Round et al. 1990
Order: Fragilariales Silva 1962
Family: Fragilariaceae Greville 1833
Genus: *Asterionellopsis* Round 1990

Synonym: *Asterionella* Hassall 1850

Cells linear with dissimilar ends and united into stellar or spiral colonies, or free. Valves linear, with inflated apices, one more so than the other. Cells united by adhesion at the larger ends. Valve surface finely striate, striae interrupted by a median pseudoraphe in the apical axis. Chromatophores: one or two small bodies, often folded, located at the broader end of the cell (Hendey, 1964). One species occurs in Kuwait's waters.

Asterionellopsis glacialis (Castracane) Round (Plate 46A-C)

Basionym: *Asterionella glacialis* Castracane 1886
Synonym: *Asterionella japonica* Cleve 1878
References: Pavillard, 1925; Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964; Drebes, 1974; Simonsen, 1974; Sykes, 1981; Foged, 1984; Round et al., 1990; Pankow, 1990; Hasle and Syvertsen, 1997; Bérard-Therriault et al., 2000.
Description: Cells united to form spiral star-shaped colonies, eight to twenty cells to a colony. Cells having one end inflated into a triangular head, while the other end is produced into a narrow rod-like outer portion. Valves shaped somewhat like a cricket bat with one broad

flattened end and a linear handle-like extension. Valve possessing a narrow pseudoraphe. Chromatophores: usually two, confined to the broad end of the cell (Hendey, 1964).

Dimensions: Length of valve 30-150 µm; length of enlarged region 10-23 µm; width of enlarged part 8-12 µm. Transapical striae very delicate, 28-34 in 10 µm (Cupp, 1943). Length of apical axis of cell 50-90 µm; inflated portion about one-quarter of the total length (Hendey, 1964).

Distribution: A neritic, south temperate species common and widespread in European waters. Often in great quantities in the North Sea. English Channel (Cupp, 1943; Hendey, 1964). It is also present in Kuwait's waters.

Genus: *Fragilaria* Lyngbye 1819

Cells colonial, valves united by the entire valve face to form flat ribbons. Valves linear, narrowly linear-lanceolate to lanceolate or elliptical. Valve surface flat, bilaterally symmetrical. Apical axis sometimes occupied by an elongated hyaline axial area which may be considered as a very rudimentary pseudoraphe. Valve surface with faint striae, either marginal or continuous across the face of the valve. Frustules rectangular in girdle view. Internal septa absent. Chromatophores: usually two plate-like bodies (Hendey, 1964). Two species found in Kuwait's waters.

Fragilaria cf. *martyi* (Heribaud) Lange-Bertalot (Plate 46D-E)

References: Witkowski et al., 2000

Distribution: It occurs in Kuwait's waters.

Fragilaria sp. 1 (Plate 46F-H)

Distribution: It occurrs in Kuwait's waters.

Genus: *Opephora* Petit 1888

Cells solitary. Frustules rectangular in girdle view. Valves symmetrical on the apical axis, asymmetrical on the transapical axis. Valves cuneiform, linear-elliptic. Valve surface furnished with coarse striae, striae transverse, separated by a hyaline space or pseudoraphe in the apical axis. Girdle without septa or intercalary bands (Hendey, 1964). Hendey (1970) reported three species of *Opephora* in Mina Al-Ahmadi waters (Kuwait's waters). Two species occur in Kuwait's waters.

Opephora schwartzii (Grunow) Petit (Plate 46I-J)

Synonym: *Fragilaria schwartzii* Grunow, 1863.

References: Hendey, 1964; Hendey, 1970.

Description: Frustules small, rectangular in girdle view. Valves linear, elongate, and slightly clavate, with a rounded upper apex, slightly convex margins and a smaller, narrower but rounded lower apex. Valve surface furnished with coarse areolae at right angles to the narrow pseudoraphe placed in the apical axis. Within each areola finer markings are sometimes visible. Areolae 3-4 in 10 µm (Hendey, 1964). The same number of areolae were also obtained in the present materials.

Dimensions: Length of valve 60-100 µm, breadth 10-12 µm (Hendey, 1964). Length was 60-85 µm in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) while, in the present study, length was 64 µm and breadth was 11 µm.

Distribution: Marine littoral, not common, but occurring on the west coasts of the British Isles (Hendey, 1964). It is also found in in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) and other localities of Kuwait's waters (this study).

Opephora sp. 1 (Plate 46K)

Genus: *Synedra* Ehrenberg 1830

Cells single or united into fanlike to clustered starlike colonies, seldom in short bands. In general with greatly elongated apical axis, rodlike, sometimes bent in the direction of the apical axis, very variable. Intercalary bands and septa absent, girdle band consequently narrow linear as a rule. Valve linear to very narrow lanceolate, sometimes with wavy edges, often widened in the middle or at the ends. Valve surface usually with transapical rows of delicate puncta and narrower pseudoraphe or wider lanceolate, hyaline central area sometimes with scattered puncta. In some species the cell wall is chambered on the inner side, the chambers entirely free toward the cell center or in some individual cells closed by a finely poroid, delicate membrance. The chambered forms have also more or less numerous, lateral-longitudinal ribs that are sometimes very close to the valve margin and very difficult to see. One valve end usually has a mucilage pore. Chromatophores numerous small granules or two larger plates (Cupp, 1943). One species is found in Kuwait's waters.

Synedra sp. 1 (Plate 46L)

Distribution: Present in Kuwait's waters.

Genus: *Trachysphenia* Petit 1877

Cells elongate, heteropolar in valve view, rectangular in girdle view. Plastids not observed. A marine genus epiphytic on algae (Hendey, 1964). One species is found in Kuwait's waters.

Trachysphenia australis Petit (Plate 47A-C)

References: Peragallo and Peragallo 1897-1908; Hendey 1964; Witkowski et al., 2000.

Description: Valves elliptic-lanceolate, with slightly produced ends and small rounded apices. Valve surface with longitudinal lines of large puncta. Pseudoraphe not obvious. Puncta 6 in 10µ (Hendey, 1964). While in the present materials the puncta were 9 in 10 µm which were the same with Witkowski et al. (2000).

Dimensions: 30-40 µm long, 5 µm broad (Witkowski et al., 2000). Length 35-50 µm in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) and 30-32 long and 6-7µm wide were obtained in the present survey from other localities of Kuwait's waters.

Distribution: Cosmopolitan marine species, widespread in littoral sandy sediments including the western Baltic Sea (Witkowski et al., 2000). Found on sandy beaches on the coasts of the British Isles (Hendey, 1964). It occurrs in Mina Al-Ahmadi waters (Kuwait's waters) and at other localities of Kuwait's waters.

Order: Licmophorales Round in Round et al. 1990
Family: Licmophoraceae Kützing 1844
Genus: *Licmophora* Agardh 1827

Cells colonial, mounted in fan-shaped fascicules upon mucous stipes. Frustules cuneate in girdle view; valves cuneate, clavate, surface punctate or striate and bearing usually a well-marked pseudoraphe in the apical axis. Septa often rudimentary. Chromatophores: numerous rounded bodies scattered throughout the cell or as several plate-like bodies arranged in two distinct bands.

Licmophora is a widely spread genus in marine habitats throughout the world. The cells are always sessile and attach themselves to larger algae, copepods or almost any solid substrate, providing the depth of water is not too great. It is most abundant during late spring and summer months (Hendey, 1964). One species occurs in Kuwait's waters.

Licmophora sp. 1 (Plate 47D-E)

Order: Rhaphoneidales Round in Round et al. 1990
Family: Raphoneidaceae Forti 1912
Genus: *Diplomenora* Blazé 1984

Cells circular in valve view. Plastids unknown. A marine genus, living on sand grains. All records so far are from the southern hemisphere or from the coasts of Mexico and California. This genus is fully discussed by Blazé (1984) (Round et al., 1990). Only one species occurred in Kuwait's waters.

Diplomenora cocconeiformis (Schmidt) Blazé (Plate 47F-H)

Basionym: *Coscinodiscus cocconeiformis* Schmidt

Synonyms: *Raphoneis superba (*Janisch) Grunow *sensu* Foged 1975; *Raphoneis discoides* Subrahmanyan 1946.

References: Hendey, 1958; Foged, 1984; Round et al., 1990; Witkowski et al., 2000.

Description: Valves circular to elliptical with an extremely shallow mantle. Valve face flat, costate, sternum narrow, hyaline. Areolae arranged in concentric arcs, 4-10 areolae in 10 µm. They reduce in size near the mantle. At both apices circular pore fields occur (Witkowski et al., 2000).

Dimensions: 18-50 µm in diameter (Witkowski et al., 2000). 20-36 µm in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970), whereas in the present materials, 24 µm long and 22-23 µm wide were found at other localities of Kuwait's waters.

Distribution: marine species predominantly distributed in warm waters, common on Indian ocean coasts and in the Mediterranean (Witkowski et al., 2000). It also occurs in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) and other localities of Kuwait's waters (present study).

Order: Thalassionematales Round in Round et al. 1990
Family: Thalassionemataceae Round in Round et al. 1990
Genus: *Thalassionema* Grunow 1902

Cells forming zigzag bands or star-shaped colonies, adjacent cells united to each other by small gelatinous cushions on one cell end. In girdle view linear. Intercalary bands and septa absent. Valves linear to narrow lancet-shaped. Valves with numerous tiny spines on the margin placed at regular intervals. Cell wall otherwise structureless. Chromatophores more or less numerous small granules. Pelagic, marine (Cupp, 1943). Only one species *Thalassionema nitzschioides* was recorded by Hendey (1970) in Mina Al-Ahmadi waters (Kuwait's waters). Two species occur in Kuwait's waters.

Thalassionema nitzschioides (Grunow) Mereschkowsky (Plate 48A-D)

Basionym: *Synedra nitzschioides* Grunow.

Synonym: *Thalassiothrix nitzschioides* Grunow.

References: Pavillard, 1925; Allen and Cupp, 1935; Cupp, 1943; Hasle and de Mendiola, 1967; Hendey, 1964, 1970; Drebes, 1974; Simonsen, 1974; Sykes, 1981; Ricard, 1987; Hasle and Syvertsen, 1997; Round et al., 1990; Bérard-Therriault et al., 2000; Semina, 2003.

Description: Cells united to form stellae or zigzag colonies. Cells in girdle view narrow linear, often slightly curved. Valves narrow linear with parallel sides and blunt-rounded ends. Valve surface structureless, but the margins are furnished with minute puncta. Marginal spines small, 10-12 in 10 µm. Chromatophores: numerous cocciform bodies (Cupp, 1943; Hendey, 1964).

Dimensions: Length 30-80 µm; width 2-3.5 µm (Cupp, 1943), length of cell 30-90 µm; breadth 2-5 µm (Hendey, 1964, 1970).

Distribution: A common and widespread neritic species, often in great numbers in the North Sea on all coasts, common in the North Atlantic and the English Channel. Very common and often abundant off southern California and Lower California, in the Gulf of California, and north to Scotch Cap, Alaska (Cupp, 1943; Hendey, 1964). It is also frequent in Mina Al-Ahmadi waters (Hendey, 1970) and common at other localities in Kuwait's waters (this study).

Thalassionema frauenfeldii (Grunow) Hallegraeff (Plate 48E-G)

Synonym: *Thalassiothrix frauenfeldii* Grunow 1880.

References: Pavillard, 1925; Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964; Hasle and de Mendiola, 1967; Simonsen, 1974; Ricard, 1987; Hasle and Syvertsen, 1997; Round et al., 1990; Semina, 2003.

Description: Cells united into star-shaped colonies or zigzag bands. In girdle view linear. Valves very narrow linear, ends distinct but only slightly unlike, one end blunt-rounded, near the other end usually widened then decreased to form a wedge-shaped point. Marginal spines small but regular, 6-9 in 10 µm. Valves otherwise structureless (Cupp, 1943).

Dimensions: Valves 90-120 µm long, 2-4 µm wide (Cupp, 1943), Length of valve 80-120 µm; breadth 3 µm (Hendey, 1964).

Distribution: An oceanic species favouring temperate waters. Widespread. Common on all North Sea and European coasts. Common in Gulf of California and north to Scotch Cap, Alaska (Cupp, 1943; Hendey, 1964). It is frequently observed in Kuwait's waters.

Genus: *Thalassiothrix* Cleve and Grunow 1880

Cells living singly or forming star-shaped colonies; zigzag bands, or bunches, united to one another by a gelatinous cushion on the end of the cell. In girdle view narrow linear. Intercalary bands and septa absent. In valve view linear or slightly lancet-shaped, ends unlike. Valve borders similar to those of proceding genus, often beset with small spines. Valve surface with short marginal striae or structureless. Chromatophores more or less numerous small granules. Pelagic marine forms. This genus contains the longest diatoms known at the present time. Often present in large masses in the plankton (Cupp, 1943). One species occurs in Kuwait's waters.

Thalassiothrix cf. *longissima* Cleve and Grunow (Plate 48H)

Synonym: *Synedra thalassiothrix* Cleve.

References: Pavillard, 1925; Cupp, 1943; Hendey, 1964; Hasle and de Mendiola, 1967; Simonsen, 1974; Hasle and Syvertsen, 1997; Bérard-Therriault et al., 2000; Semina, 2003.

Description: Cells usually free, but frequently matted together in dense masses. Cells very long, thread-like, usually slightly bent, rectangular, or prismatic in transapical section. Valves elongated, linear, with dissimilar ends. Valve surface hyaline, but the borders are furnished with minute striae, 12 in 10 µm (Hendey, 1964).

Dimensions: Width 3-6 µm, length of valve 1-4 mm (Cupp, 1943), up to 3-4 mm (Hendey, 1964).

Distribution: An oceanic pelagic species, often occurring in enormous masses in the North Atlantic, but neritic in the northern parts of the North Sea. Coasts of Scotland, Norway and in all Arctic Seas. It is reported from the Gulf of California and north to Scotch Cap, and in Alaska (Cupp, 1943; Hendey, 1964). It occurs also in Kuwait's waters.

Order: Rhabdonematales Round and Crawford in Round et al. 1990
Family: Rhabdonemataceae Round and Crawford in Round et al. 1990
Genus: *Rhabdonema* Kützing 1844

Cells united to form flat ribbon-like colonies. Cells in valve view elliptical to linear-lanceolate, in girdle view quadrangular with rounded corners. Valve surface punctate, striate, with a faint pseudoraphe in the apical axis. Girdle composed of numerous segments bearing septate partitions. Septa with one or more foramina. Girdle punctate, costate. Chromatophores, numerous, arranged in clusters or rosettes (Hendey, 1964). One species occurs in Kuwait's waters.

Rhabdonema sp. 1 (Plate 49A)

Distribution: It was observed in Kuwait's waters.

Order: Striatellales Round in Round et al. 1990
Family: Striatellaceae Kützing 1844
Genus: *Grammatophora* Ehrenberg 1839

Cells in girdle view rectangular with rounded corners, usually united into zigzag chains. Resting cells with two intercalary bands, one in each cell half. Intercalary bands with two polar, flat or more or less undulating septa that run far toward the cell center and leave only a central window in the intercalary bands. Valve mantle with short pseudosepta near ends. Valve surface as a rule linear with parallel or more or less transapically constricted sides. Membrane with transapical rows of puncta, puncta in more or less transapically constricted sides. Membrane with transapical rows of puncta, puncta in more or less regular longitudinal rows or in a self-crossing oblique line system. Valve ends usually with irregularly sculptured polar fields. Pseudoraphe narrow. Mucilage pores present on the poles. Chromatophores one to several, large, more or less lobed plates. All species are littoral marine (Cupp, 1943). The two species *Grammatophora oceanica* Ehrenberg and *Grammatophora macilenta* Wm. Smith were documented by Hendey (1970) in Mina Al-Ahmadi waters (Kuwait's waters). Three species occur in Kuwait's waters (this study).

Grammatophora marina (Lyngbye) Kützing (Plate 49B-E)

Basionym: *Diatoma marinum* Lyngbye 1819

References: Peragallo and Peragallo 1897-1908; Cupp, 1943; Hendey, 1964; Simonsen, 1974; Foged, 1984; Ricard, 1987; Pankow, 1990; Round et al., 1990.

Description: Cells with septa having only a single and slight undulation close to the base or nearly flat. With short rows of striae only at the poles on the dividing line between valve mantles and intercalary bands. Pseudosepta of the valve mantles short. Valves relatively broad, linear, in the middle usually more or less transapically widened, on the ends broadly rounded. Cells in girdle view oblong, uniting by their opposite and alternate, or more rarely, by their adjacent angles to form a zigzag chain. Transapical striae delicate but distinct, 20-22 in 10 µm, distinctly punctated areolated, puncta in quineunx. Pseudoraphe very narrow. Hyaline polar field usually small. Chromatophores: several small rounded bodies (Cupp, 1943; Hendey, 1964).

Dimensions: Length of apical axis 30-82 µm; of transapical axis 5-10 µm (Cupp, 1943). Length of valve 60-76 µm; breadth 10-12 µm (Hendey, 1964).

Distribution: A common littoral species found around all British coasts (Cupp, 1943); all North Sea and North Atlantic coasts; widespread (Hendey, 1964). It is present in Kuwait's waters.

Grammatophora oceanica Ehrenberg var. *oceanica* (Plate 49F-I)

References: Hendey, 1964.

Synonym: *Grammatophora marina* var. *communis* Grunow ex Van Heurck 1880-85.

Description: Cells rectangular in girdle view, with rounded corners. Valves linear or narrowly linear-lanceolate with very slightly produced, rounded ends. Valve surface striate, striae 20-24 in 10 µm, finely punctate, puncta arranged in quincunx. Pseudoraphe straight and very narrow and terminated by small hyaline polar areas. Internal septa moderately straight, except for an undulation near the girdle (Hendey, 1964).

Dimensions: Length of valve 20-100 µm, breadth 4-8 µm (Hendey, 1964).

Distribution: Common on all North Sea coasts (Hendey, 1964). It occurs in Kuwait's waters.

Gramatophora sp.1 (Plate 49J-K)

Distribution: Present in Kuwait's waters.

Genus: *Striatella* Agardh 1932

Cells in girdle view nearly rectangular, tabular. United into closed bands or zigzag chains. Intercalary bands numerous, open on one end, on the other with shorter or longer shallow septa thickened slightly near the margin, the thickenings alternating in adjacent intercalary bands. Valves linear-lanceolate, with a narrow pseudoraphe and delicate transapical rows of punctuated striae. Intercalary bands likewise striated in pervalvar direction. Cell wall weakly siliceous. Chromatophores numerous small granules, radiate. All marine species, predominantly littoral, but often found in the plankton (Cupp, 1943). One species occurs in Kuwait's waters.

Striatella unipunctata (Lyngbye) Agardh (Plate 50A)

References: Pavillard, 1925; Cupp, 1943; Hendey, 1964; Round et al., 1990.

Description: Cells colonial, united by their corners by small mucous pads, to form zigzag chains, tabular in girdle view with slightly rounded corners. Intercalary bands numerous, 6-10 in 10 µm, with short septa, 3-5 in 10 µm. Valves linear to elliptical-lanceolate with moderately blunt-rounded ends. Valve surface delicately areolated-punctated. Puncta in a three self-crossing line system, 18-25 oblique lines in 10 µm. Valve ends with small hyaline region. Pseudoraphe very narrow but sharply marked. Mantle surface of the intercalary bands with delicate pervalvar striae, 29-30 in 10 µm. Chromatophores granular to oblong, arranged radially about the nucleus, often connected in the middle and then with a central pyrenoid or separate with a pyrenoid in the middle of each plate (Cupp, 1943).

Dimensions: Length of apical axis 50-78 µm; of transapical axis 6-10 µm (Cupp, 1943), Apical length of valve 60-130 µm, breadth 20-36 µm (Hendey, 1964).

Distribution: Very common in the littoral zone. Occurs in the plankton accidentally. Temperate species (Cupp, 1943). Common on coasts in English Channel (Hendey, 1964). It occurs in Kuwait's waters.

Class: Bacillariophyceae (Raphid, pennate diatoms) Haeckel 1979 emend. Mann in Round et al. 1990

Sub-class: Bacillariophycidae Mann in Round et al. 1990

Order: Lyrellales Mann in Round et al. 1990

Family: Lyrellaceae Mann in Round et al. 1990

Genus: *Lyrella* (Cleve) Karayeva 1978

Lyre-shaped 'hyaline' areas appear to have arisen independently in several raphid groups, including *Lyrella*, *Cocconeis* and *Mastogloia*. *Lyrella* is undoubtedly closely related to *Petroneis* but the plain lyre-shaped area (sternum) and details of areola structure serve to separate them. The smaller lyrate naviculoids allied to '*Navicula*' *pygmaea* do not belong here, differing in valve, areola, plastid, and raphe structure; these are separated into *Fallacia*. *Lyrella* species are known from sediments dating back to the Eocene and are probably preserved well because of their heavy silicification. The genus was established for the type *L. lyra*, by Karayeva (1978), but few other combinations appear to have been made until now (Round et al., 1990). Seven different species occur in Kuwait's waters. One of the species names is not finalized at this stage and is reported as species 1.

Lyrella cf. *abrupta* (Gregory) Mann (Plate 50B)

Basionym: *Navicula abrupta* (Gregory) Donkin

Synonym: *Navicula lyra* var. *abrupta* Gregory 1857

References: Hendey, 1964, 1970; Round et al., 1990; Witkowski et al., 2000.

Description: Valves linear-elliptic to elliptic-lanceolate with cuneate broadly to obtusely rounded apice. Raphe straight, external central endings expanded, distant axial area moderately broad, towards central nodule narrowed, central area transversely rectangular connected to lateral areas. Lateral areas variable in length, fairly narrow more narrowed towards apices, in the middle constricted, terminating below apices. Transapical striae in the marginal zone radiate, 12 in 10 µm, finely punctuate, 22-30 poroids in 10 µm (Witkowski et al., 2000). The marginal zone radiate in the present specimen, in Kuwait's waters, 12-14 µm in 10 µm.

Dimensions: Length of valve 38-60 μm, breadth 16-28 μm (Hendey, 1964). 45-148 μm long, 22-46 μm broad (Witkowski et al., 2000). Length 42-54 μm, breadth 17-22 μm were recorded in Mina al Ahmadi waters (Kuwait's waters) (Hendey, 1970) and 30 μm long, 15 μm wide in the present materials at other localities in Kuwait's waters.
Distribution: Littoral on all North Sea coasts, English Channel and Irish Sea coasts; common (Hendey, 1964). Widespread (cosmopolitan) marine species, entering also the western Baltic Sea (Witkowski et al., 2000). Frequent in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) and also found at other localities in Kuwait's waters (this study).

Lyrella atlantica (A. Schmidt) Mann (Plate 50C-D)

Basionym: *Navicula lyra* var. *atlantica* Schmidt.
References: Hendey, 1964, 1970; Round et al. 1990; Witkowski et al., 2000.
Description: Valves linear with parallel to slightly concave margins. Raphe straight, external central endings relatively approximate, axial area narrowly linear, central area small, transversely rectangular connected to lateral area. Lateral areas narrow, in the middle weakly constricted, narrowed towards apices, terminating below apices. Transapical striae punctuate, in the middle parallel towards apices becoming radiate, 10 in 10 μm (Witkowski et al., 2000). Whereas, in the present specimen, in Kuwait's waters, 7-9 striae in 10 μm. Very similar to *L. abrupta* but differing from it in that the axial area is narrow (Hendey, 1970).
Dimensions: 55-100 μm long, 25-32 μm broad (Witkowski et al., 2000). Length 54-64 μm in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) while in the present specimen at other localities in Kuwait's waters 28 μm long and 17 μm wide was obtained.
Distribution: marine species, more frequent in the northern hemisphere (Witkowski et al., 2000). Littoral on North Sea coasts, English Channel, coasts of Wales and Scotland (Hendey, 1964). It occurred in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) and at other localities in Kuwait's waters.

Lyrella clavata (Gregory) Mann (Plate 50E-G)

Basionym: *Navicula clavata* Gregory.
References: Hendey, 1964, 1970; Round et al. 1990; Witkowski et al., 2000.
Description: Valve elliptic with short rostrate, obtusely rounded apices. Raphe straight, external central endings expanded, relatively approximate, axial area narrow, linear, central area small connected to large lateral areas. Lateral areas hyaline, broadly lanceolate, terminating at the valve margin. Transapical striae slightly radiate, 10-14 in 10 μm (Witkowski et al., 2000). In the present material, 11-14 striae in 10 μm is recorded.
Dimensions: 30-110 μm long, 20-60 μm broad (Witkowski et al., 2000). Length 54-64 μm in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) while in the present specimens at other localities in Kuwait's waters 28-33 μm long and 17-21 μm wide were obtained.
Distribution: marine species widespread in Europe from the Mediterranean up to the Norwegian coasts (Witkowski et al., 2000). It is also found in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) and at other localities in Kuwait's waters (this study).

Lyrella fogedii Witkowski, Lange-Bertalot and Metzeltin (Plate 51A)

Synonym: *Navicula aestimata* Hustedt sensu Foged 1975

References: Witkowski et al., 2000.

Description: Valves circular-elliptic to elliptic with broadly rounded apices. Raphe straight, external central endings large, triangular, axial area narrow, central area transversely rectangular connected to lateral areas. Lateral areas lanceolate bearing transverse markings. Transapical striae punctuate in the middle parallel towards apices becoming radiate, 17-19 in 10 µm (Witkowski et al., 2000). While in the present survey, 18-19 striae in 10 µm is obtained.

Dimensions: 23-30 µm long, 16-18 µm broad (Witkowski et al., 2000). Wheraes, in the present specimen 35.4 µm long and 20.4 µm wide are recorded.

Distribution: It is found in Kuwait's waters.

Lyrella cf. *hennedyi* (W. Smith) Stickle and Mann (Plate 51B-C)

Basionym: *Navicula hennedyi* W. Smith.

References: Hendey, 1964, 1970; Round et al. 1990; Witkowski et al., 2000.

Description: Valves broadly elliptic with cuneate, broadly to obtusely rounded apices. Raphe straight, external central endings expanded, distant, axial area narrow linear, close to central area lanceolately widened, central area transversely rectangular connected to lateral areas. Lateral areas relatively large semi-elliptic to semi-lanceolate, encompassing ⅓ to more than ½ of the valve width, marked by obscure, granulate prolongations of transapical striae. Transapical striae developed in the marginal part of the valve, slightly radiate, 9-11 in 10 µm, poroids, 9-20 in 10 µm (Witkowski et al., 2000). In the present survey, they have 11-12 striae in 10 µm.

Dimensions: 25-140 µm long, 15-65 µm broad (Witkowski et al., 2000). Length 56-60 µm, breadth 30-32 µm in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) and in the present materials at other localities in Kuwait's waters, 44-46 µm long, 29-32 µm wide were obtained.

Distribution: Marine species widespread (cosmopolitan) in the coastal areas, entering also the western Baltic Sea (Witkowski et al., 2000). It also ocurred in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) and at other localities in Kuwait's waters (this study).

Lyrella spectabilis (Gregory) Mann (Plate 51D)

Basionym: *Navicula spectabilis* Gregory

References: Hendey, 1964, 1970; Round et al. 1990; Witkowski et al., 2000.

Description: Valves elliptic to rhombic-elliptic with cuneate broadly to obtusely rounded apices. Raphe straight, external central endings distant, axial area narrow, central area transversely rectangular connected to lateral areas. Lateral areas relatively broad, hyaline, narrowed towards apices, encompassing ¼ to more than ½ of the valve width. Transapical striae developed in the marginal zone radiate, 7-14 in 10 µm (Witkowski et al., 2000). In the present specimen it has 10-11 striae in 10 µm.

Dimensions: 46-166 µm long, 23-90 µm broad (Witkowski et al., 2000). Length 60-80 µm, breadth 30-50 µm in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) and in the present survey at other localities in Kuwait's waters it was 59 µm long and 30 µm broad.

Distribution: Widespread (cosmopolitan) marine species, in Europe known from the Arctic and the Mediterranean (Witkowski et al., 2000). It also ocurred in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) and at other localities in Kuwait's wters.

Lyrella sp. 1 (Plate 51E)

Description: Valves small and elliptic with straight raphe. Transapical striae developed in the marginal zone radiate, 15-16 in 10 µm.
Dimensions: 17.5 µm long and 12 µm broad.
Distribution: Present in Kuwait's waters.

Order: Mastogloiales Mann in Round et al. 1990
Family: Mastogloiaceae Mereschkowsky 1903
Genus: *Mastogloia* Thwaites in Wm. Smith 1856

Cells usually embedded in mucus, attached to larger algae, or sometimes free. Valves linear, linear-lanceolate, elliptical or lanceolate-rhombic, with obtuse, rounded or produced rostrate apices. Axial area narrow or indistinct, polar nodules small, central area small, often dilated transversely. Raphe straight, or undulate. Valve surface punctate, or finely areolate, areolate arranged in striae that are weakly radiate, often decussate, or in longitudinal undulating lines. Within the valve is fitted a marginal septum which is usually divided into a number of compartments. This septum is clearly seen through the valve surface, when it appears as a number of loculi around the valve margin and, when in girdle view, as a plate between the edge of the valve and the beginning of the girdle. Girdle simple. Chromatophores: two folded bodies, one at each end of the cell, with a cleft in each, arranged so that their ends are towards the central nodule. The septa of *Mastogloia* are of several types, but mainly they are loculate, with openings into the cell. They are easily detachable, and in acid-cleaned material valves are frequently found with their septa removed, in which case they look very like *Navicula* spp. (Hendey, 1964). As many as 18 species of the genus *Mastogloia* were reported in Mina Al-Ahmadi waters (Kuwait's waters) by Hendey (1970). Eight species are also observed at other localities in Kuwait's waters (this study). Three of the species names are not finalized at this stage and are reported as species 1, 2 and 3.

Mastogloia arabica Hendey (Plate 51F-G)

References: Hendey, 1970.
Description: Valve elliptic-lanceolate, with subrostrate apices. Marginal loculi not reaching the apices, with interior margins weakly convex. Raphe straight, small central area only a little punctuate. Transapical striae weakly radiate towards the apices, punctuate, and interrupted by a line more or less parallel to the margin (Hendey, 1970).
Dimensions: Length 60-72 µm and breadth 22-25 µm (Hendey, 1970).
Distribution: Found in Mina Al-Ahmadi (Kuwait's waters) (Hendey, 1970) and at other localities in Kuwait's waters (this study).

Mastogloia decussata Grunow (Plate 51H)

Synonym: *Mastogloia trivolva* Brun
References: Hustedt, 1930; Hendey, 1970; Witkowski et al., 2000.
Description: Valves lanceolate with slightly protracted broadly rounded apices. Raphe

slightly undulating, axial area very narrow, central area small ovoid or slightly transapically widened. Transapical striae parallel, 26-30 in 10 µm, composed of three areola rows crossing each other. Terminate at some distance below apices, partecta uniform shape, transapically elongated, rectangular with inner margin straight, 9-10 in 10 µm (Witkowski et al., 2000). The loculi 8-9 in 10 µm are rectangular, equal in size, and form a complete band around the valve margin. In the middle of the locular band, i.e. opposite the small transversely diluted central nodule, the loculi are complicated by two lines placed at angles of about 150° whose apex is directed towards the central nodule (Hendey, 1970). In the present specimen, in Kuwait's waters, the loculi 10-11 in 10 µm.

Dimensions: 70-130 µm long, 22-27 µm braod (Witkowski et al., 2000). Length 100-120 µm, breadth 20-30 µm in Mina Al-Ahmadi (Kuwait's waters) (Hendey, 1970), while, in the present material, in Kuwait's waters, it is 74 µm long and 24 µm wide.

Distribution: Commonly found on the tropical coasts of the Indian and Pacific Oceans New Caledonia (Witkowski et al., 2000). The commonest *Mastogloia* in Mina Al-Ahmadi (Kuwait's waters) (Hendey, 1970). It also occurs at other localities in Kuwait's waters (this study).

Mastogloia erythraea Grunow (Plate 52A)

Synonyms: *Mastogloia interrupta* Hantzsch in Rabenhorst; *Mastogloia bullata* A. Schmidt

References: Peragallo and Peragallo 1897-1908; Hustedt 1931-1959; Hendey, 1970; Foged, 1984; Witkowski et al., 2000.

Description: The valves are lanceolate or slightly lanceolate rhombic with acuminate apices. A flexuose raphe occupies a very narrow axial area, which expands to form a unilateral elongated central area. The undulating lines, giving rise to puncta that are elongated transversely; striae 18-23 in 10 µm (Hendey, 1970). Transapical striae in the middle parallel becoming slightly radiate towards apices and finally slightly convergent at the apices, 21-25 in 10 µm, crossed by slightly wavy longitudinal ribs, 16-20 in 10 µm. Partectal ring close to the valve margin or slightly displaced towards the raphe, continues almost to the apices, partecta of variable size, the largest positioned in the middle between the apices and the valve middle part, 2-3 µm broad, narrowed at the valve margin or rectangular, 3-7 in 10 µm, smaller partecta 1-1.75 µm broad, rectangular to square, 9-15 in 10 µm, inner margin of large partecta convex, of the smaller ones flat. The number of large partecta varies from 1 to 9 in each quarterband (Witkowski et al., 2000).

Dimensions: 23-80 µm long, 6-18 µm broad (Witkowski et al., 2000). Length 65-90 µm, breadth 15-26 µm in Mina Al-Ahmadi (Kuwait's waters) (Hendey, 1970), whereas, in the present specimen, in Kuwait's waters, it is 62 µm long and 16 µm wide.

Distribution: Widespread on the warmer climate ocean coasts, in Europe on the Mediterranean coasts (Witkowski et al., 2000). Common in Mina Al-Ahmadi (Kuwait's waters) (Hendey, 1970) and at other localities in Kuwait's waters (this study).

Mastogloia linearis Simonsen (52B)

References: Witkowski et al., 2000.

Description: Valves linear with parallel to slightly convex margins, protracted to capitate apices. Raphe straight, external central endings distinct, slightly expar appropriate, axial

area narrowly linear, central area very small. Transapical striae: middle parallel towards apices becoming slightly radiate, 22-24 in 10 µm, crossed by irregularly spaced longitudinal ribs. Partectal ring 0.75-1 µm wide terminating close to the apices, partecta uniform in shape and size, apicaly elongated with inner margin convex, 4-5 in 10 µm (Witkowski et al., 2000).
Dimensions: 10-2 µm long, 4-4.5 µm broad (Witkowski et al., 2000).
Distribution: Described by Simonsen from the western Baltic Sea, recorded also from the Mediterranean (Witkowski et al., 2000). It occurs in Kuwait's waters.

Mastogloia Mac-Donaldii **Greville (Plate 52C)**

References: Peragallo and Peragallo 1897-1908; Hustedt 1931-1959; Hendey, 1970; Withkowski et al., 2000.
Description: Valves elliptic to rhombic-lanceolate with more or less protracted apices. Raphe straight, axial area very narrow, central area distinct in form of a transapically widened fascia to about ⅓-½ of the valve width. Transapical striae radiate, 22-25 in 10 µm, crossed by slightly wavy longitudinal ribs, 22-25 in 10 µm. At both sides of the raphe, semi-lanceolate lateral areas occur. Partectal ring 2 µm wide, uniform in shape terminating shortly below apices, partecta rectangular to square with inner margin convex, 3-5 in 10 µm (Witkowski et al., 2000).
Dimensions: 35-45 µm long, 13-45 µm broad (Witkowski et al., 2000). Length 49-76 µm, breadth 17-30 µm, striae 15-22 in 10 µm (Hendey, 1970).
Distribution: widely distributed on the coasts of tropic and subtropic oceans and on southern coasts of Europe (Witkowski et al., 2000). Found in Mina Al-Ahmadi (Kuwait's waters) (Hendey, 1970) and at other localities in Kuwait's waters (this study).

Other *Mastogloia* spp.: Three of the unidentified *Mastogloia* species occur in Kuwait's waters.

Mastogloia **sp. 1 (Plate 52D)**

Distribution: This species was encountered in Kuwait's waters.

Mastogloia **sp. 2 (Plate 52E)**

Distribution: This species was observed in Kuwait's waters.

Mastogloia **sp. 3 (Plate 52F-H)**

Distribution: This species was observed in Kuwait's waters.

Order: Achnanthales Silva 1962

Family: Achnanthaceae Kützing 1844

The *Achnanthaceae* are characterised by having dissimilar valves. The lower valve carries a true raphe, which is, with one or two exceptions, borne in the apical axis. The upper valve does not possess a raphe, but the valve structure is arranged about an apical hyaline space, usually referred to as the pseudoraphe (Hendey, 1964).

Genus: *Achnanthes* Bory 1822

Cells single or united into ribbon-like bands, with or without a gelatinous stalk to hold the chains to the substrate. They are seldom pelagic. Valves usually linear-lanceolate, seldom elliptical; in girdle view in general rectangular, but more or less strongly broken along the transapical axis. One valve is with a true raphe, the other with a more or less wide pseudoraphe. Membrane with more or less distinctly punctated transapical rows, sometimes double rows of puncta, seldom with the space between the rows of puncta thickened into strong ribs, or with the entire cell wall areolated. Chromatophores one lying along the valve without a raphe, two or four plates lying along the girdle, or in one species (*A. longipes*) numerous small platelets. Chiefly llittoral species (Cupp, 1943).

Hendey (1970) reported 6 species of *Achnanthes* in Mina Al-Ahmadi waters (Kuwait's waters). One of them is regarded as *Achnanthes kuwaitensis* as Hendey refered to the place where he obtained it from. Three species are found in Kuwait's waters. One of the species names is not finalized at this stage and is reported as species 1.

Achnanthes brevipes v. *intermedia* Agardh (Plate 53A-F)

References: Hendey, 1964; Hendey, 1970.

Description: Cells united in filaments and supported by a short mucous stipe. Valves linear to linear-elliptical, usually slightly constricted in the middle, with broad cuneate or obtuse apices. Frustules in girdle view genuflexed on the transapical axis. Valve structure punctuate, puncta 7 or 8 in 10 μm, coarse, somewhat rectangular and not in alternate arrangement. Valve surface without costae. Valves dissimilar, the upper bearing an eccentric pseudoraphe, the lower bearing a strongly marked raphe enclosed in a stout rib, which at the central area is dilated to produce a transverse stauros reaching the margins of the valve. Girdle structure composed of annular segments, punctuate. Chromatophores, usually four irregular or elliptical bodies arranged around the girdle in pairs (Hendey, 1964).

Dimensions: Length of valve 60-90 μm, breadth 30-40 μm (Hendey, 1964). Length 60 μm and breadth 24 μm in Mina Al-Ahmadi (Kuwait's waters) (Hendey, 1970).

Distribution: a sessile littoral species common in estuaries and harbours where less than fully saline conditions occur. Common on the south and east coasts of Britain (Hendey, 1964). Found in Mina Al-Ahmadi (Kuwait's waters) (Hendey, 1970) and at other localities in Kuwait's waters (this study).

Achnanthes cf. *fimbriata* (Grunow) Ross (Plate 54A-E)

Basionym: *Schizostauron fimbriatum* Grunow

Synonym: *Achnanthes manifera* Brun; *Achnanthes stroemii* Hustedt

References: Hustedt, 1930; Simonsen, 1987; Witkowski et al., 2000.

Description: Valves lanceolate with acutely rounded apices. RLV (rapheless valve): sternum very narrow, linear, transapical striae robust, radiate throughout, 15-16 in 10 μm crossed by delicate longitudinal ribs. RV (raphe valve): raphe straight, axial area narrow, slightly widened towards the middle, central area forming a narrow transverse fascia, transapical striae radiate throughout, 19 in 10 μm (Witkowski et al., 2000).

Dimensions: 28-38 μm long, 10-13 μm broad (Witkowski et al., 2000).

Distribution: not frequent, but widespread in the marine littoral sediments from subarctic Island) to the tropics (Witkowski et al., 2000). It occurred in Kuwait's waters.

Achnanthes sp. 1 (Plate 54F)

Distribution: Present in Kuwait's waters.

Genus: *Planothidium* Round and Buktiyarova 1996

One species occurs in Kuwait's waters and the name is not finalized at this stage and is reported as species 1.

Planothidium sp.1 (Plate 54G-H)

Distribution: Present in Kuwait's waters.

Family: Cocconeidaceae Kützing 1844

Genus: *Cocconeis* Ehrenberg 1837

Cells usually solitary, sessile, valves elliptical, dissimilar. Lower valve bearing polar nodules, central nodule and a well-formed raphe. Upper valve bearing in the apical axis a narrow hyaline space or pseudoraphe and no nodules. Valve surface punctate or loculate or with a loculate band around the margin, sometimes costate. Valves usually slightly bent on the longitudinal axis. Chromatophores, one or two plates.The genus is very widespread and is well represented in marine and freshwater habitats. All species are sessile and are common epiphytes on the larger algae. Several species, are only to be found on the skin of whales, where it is presumed they live, in part at least, saprophytically (Hendey, 1964). Six *Cocconeis* spp. were recorded in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970). Two species occur in Kuwait's waters (this study).

Cocconeis cf. *guttata* Hustedt in ALeem and Hustedt (Plate 54I-K)

References: Hendey, 1964; Simonsen, 1987; Witkowski et al., 2000.

Description: Valves elliptic. RLV: sternum narrow, somewhat irregular, transapical striae coarsely punctuate, slightly radiate, 8-9 in 10 µm. RV: raphe straight, axial area narrow, central area very small, circular, transapical striae finely punctuate, distinctly radiate, 22 in 10 µm (Witkowski et al., 2000).

Dimensions: 15 µm long, 9 µm broad (Witkowski et al., 2000).

Distribution: Common in Ireland and rare from the French Atlantic coast (Witkowski et al., 2000). It occurs in Kuwait's waters.

Cocconeis placentula Ehrenberg (Plate 54L)

References: Peragallo and Peragallo 1897-1908; Simonsen, 1974; Hustedt, 1976; Stidolph, 1980; Foged, 1984; Ricard, 1987; Pankow, 1990.

Description: It has 18-19 striae in 10 µm in the present materials.

Dimensions: Length of valve 24 µm (Stidolph, 1980). In the present materials, length 18-24 µm, breadth 11-12 µm.

Distribution: Found in the Arabian/Persian Gulf **(**Simonsen, 1974). It also occurs in Kuwait's waters.

Order: Cymbellales Mann in Round et al. 1990
Family: Cymbellaceae Greville 1833
Genus: *Cymbella* C. Agardh 1830

Cells slightly to strongly dorsiventral, colonial and forming branched mucilage stalks or solitary. Valves almost naviculoid to strongly arcuate; poles rounded, rostrate or capitate. Mantles more-or-less equal in naviculoid forms but progressively more unequal with increasing asymmetry of valve outline; valve face planar, rarely ridged near dorsal mantle. Striae uniseriate, containing poroids. Raphe system lying along or near the midline of the valve, curved in strongly dorsiventral forms. It is a large and diverse genus (Round et al., 1990). Only one species occurs in Kuwait's waters and its name is not finalized at this stage and is reported as species 1.

Cymbella sp.1 (Plate M)

Family: Gomphonemataceae Kützing 1844

In Gomphonemaceae the cells possess true raphes on both valves. The valves are symmetrical on the apical axis, having straight raphes, and asymmetrical on the transapical axis, having dissimilar ends. The valve outline is clavate, though a constriction that frequently occurs above the central nodule near the broader end tends to give the valve what can only be described as an anthropomorphic appearance (Hendey, 1964).

Gomphonemaceae, together with Cymbellaceae, are frequently included in the Naviculaceae, but the separation was made (Hendey, 1937) on account of the symmetry of the valves. Naviculaceae is reserved for cells having a true raphe on both valves and bilateral symmetry on both apical and transapical axes (Hendey, 1964).

Genus: *Gomphonema* Ehrenberg 1832

Cells usually in fan-shaped colonies, attached to dichotomously branched mucous stipes, sometimes free. Valves symmetrical on the apical axis, asymmetrical on the transapical axis. Girdle cuneate, simple. Valves cuneate, clavate. Apical nodules small, axial area narrow, central area usually small, rounded. Raphe distinct, straight. Valve surface striate, striae punctate, transverse or slightly radiate. Chromatophore, a single body (Hendey, 1964). One species occurs in Kuwait's waters and its identification is not finalized at this stage and is reported as species 1.

Gomphonema sp.1 (Plate 54N)

Order: Naviculales Bessey 1907
Sub-order: Neidiineae Mann in Round et al. 1990
Family: Berkeleyaceae Mann in Round et al. 1990
Genus: *Berkeleya* R. K. Greville 1827

Only one species occurs in Kuwait's waters.

***Berkeleya scopulorum* cf. var. *perlonga* (Brun) Cox (Plate 55A)**

Synonym: *Navicula scopulorum* var. *perlonga* Brun

References: Peragallo and Peragallo 1897-1908.

Description: The present species is more likely the species variety *Navicula scopulorum* var. *perlonga* that was described by Peragallo and Peragallo (1897-1908). Similar to the type species but with more elongate valve and less rounded at the apices, 17 striae/10 µm.

Dimension: The present specimen length 178 µm, in the middle 8.21 µm broad, in the sides 5-6 µm broad.

Distribution: It occurs in Kuwait's waters.

Sub-order: Sellaphorineae Mann in Round et al. 1990
Family: Sellaphoraceae Mereschkowsky 1902
Genus: *Fallacia* Stickle and Mann in Round et al. 1990

One species occurs in Kuwait's waters.

***Fallacia* cf. *arenaria* Sabbe and Vyverman (Plate 55B)**

References: Witkowski et al., 2000.

Description: Valves elliptical. Raphe slightly arched, external central endings approximate, axial area very narrow, central area variable, rectangular to circular, separated from lateral areas by a row of puncta. Lateral areas indistinct almost linear, very slightly constricted in the middle. Transapical striae in the middle parallel, towards apices becoming radiate, 26.5-27.5 in 10 µm (Witkowski et al., 2000).

Dimensions: 6.4-9.8 µm long, 3.9-5 µm broad (Witkowski et al., 2000). While, in the present specimen of Kuwait's waters 5.88 µm long and 3.82 µm broad.

Distribution: Marine to brackish-water species described from the North Sea coasts, common in the Mississippi Delta (Witkowski et al., 2000). It also occurs in Kuwait's waters (this study).

Family: Pinnulariaceae Mann in Round et al. 1990
Genus: *Caloneis* Cleve 1894

Cells solitary free, valves linear, linear-lanceolate to lanceolate-rhombic, more or less convex, valve surface striate, striae crossed by one or more longitudinal lines. Chromatophores: usually two. Electron microscope studies have shown that the genus is closely related to *Pinnularia*, in that the valve structure is composed of elongated chambers or alveoli arranged upon either side of the raphe. The surfaces of the alveoli are covered by sieve membranes, and in most species the lower or inner wall possesses a cover pore (see Hendey, 1959). The genus is well represented in marine, brackish and fresh waters all over the world. The marine species, however, are seldom found in great quantities (Hendey, 1964). The two species *Caloneis elongata* (Grunow) Boyer and *Caloneis liber* (Wm. Smith) Cleve were recorded in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970). Only one species occurred in the present materials.

Caloneis cf. *westii* (Smith 1853) Hendey (Plate 55C)

Basionym: *Navicula westii* Smith 1853.

Synonym: *Caloneis formosa* (Gregory 1856) Cleve 1894; *Navicula formosa* Gregory 1856.

References: Peragallo and Peragallo, 1897-1908; Hendey, 1964; Foged, 1984; Ricard, 1987; Pankow, 1990; Round et al., 1990.

Description: Cells solitary, valves lanceolate, with obtuse or sub-cuneate apices. Axial area linear or narrowly lanceolate, often slightly irregular, somewhat unilateral and often slightly dilated at the center of the valve. Valve surface striate, striae 12-14 in 10 µm, slightly radiate (Hendey, 1964).

Dimensions: Length of valve 60-13 µm; breadth 20-28 µm (Hendey, 1964).

Distribution: A brackish-water form frequently found in the littoral zone; common on all coasts of the North Sea, English Channel (Hendey, 1964). It is present in Kuwait's waters.

Genus: *Oestrupia* Heiden 1935

Cells solitary, free. Valves linear, lanceolate to elliptic-lanceolate, often with a moderate median constriction. Apical nodules small, axial area narrow or wide, linear or lanceolate. Raphe straight, with small approximate central pores. Valve surface coarsely alveolate, alveoli weakly radial and interrupted by a hyaline longitudinal line each side of the raphe, parallel to the valve margin (Hendey, 1964). Three species of *Oestrupia* were reported in Mina Al-Ahmadi waters (Kuwait's waters) by Hendey (1970). Only one species was obtained from Kuwait's waters during this present study.

Oestrupia musca (Gregory) Hustedt (Plate 55D)

Synonyms: *Navicula musca* Gregory, 1857; *Caloneis musca* (Gregory) Cleve.

References: Hustedt, 1930; Hendey, 1964 and 1970.

Description: Valves elliptical to elliptic-lanceolate with a median constriction, with broad cuneate apices. Raphe straight, polar nodules small, central pores small, approximate. Axial area lanceolate, sometimes very slightly constricted in the middle. Valve surface coarsely striate, alveolate. Alveoli finely punctuate around the margins, indistinct (Hendey, 1964). With 6-7 striae/10 µm in Mina Al-Ahmadi waters in Kuwait's waters and the same number in the present materials at other localities in Kuwait's waters.

Dimensions: Length of valve 40-60 µm (Hendey, 1964). Length 42-70 µm, breadth 18-20 µm (Hendey, 1970) while in the present materials, they were 99 µm long and 28 µm wide.

Distribution: On clean sandy shores on the north and west coasts of the British Isles; Scottish and N. Wales coasts (Hendey, 1964). It also occurred in Mina Al-Ahmadi waters (Hendey, 1970) and at other localities in Kuwait's waters (present study).

Sub-Order: Diploneidaceae
Family: Diploneidaceae Mann in Round et al. 1990
Genus: *Diploneis* Ehrenberg 1844

Cells solitary, free. Valves elliptical or linear-elliptic, with or without a median constriction. Apices rounded or broadly cuneate. Central nodule prominent, often large, quadrate and strongly formed. Central area small, reduced, and produced to form longitudinal extensions usually described as "horns", which lie upon either side of the raphe and enclose it as solid ribs. Beyond the "horns" are thinner, usually narrow, depressed areas, usually referred to as the "furrows". These may be hyaline and structureless, or may contain a row of large puncta, or may be crossed by faintly transverse costae. Beyond the furrows on each side of the raphe there is, in some species, a more or less lunate area in each segment (that is, above and below the transapical axis) which is usually referred to as the "lunula". This may be crossed by costae or alveoli which may or may not bear a single or double row of puncta. These are frequently more strongly developed close to the valve margin. In some species transverse costae may be absent. Chromatophores: usually two deeply crenulate bodies that lie along the girdle. The cell wall of *Diploneis* Ehrenberg has been investigated by Hustedt, 1930, who has shown the complicated areolate structure to be composed of chambers in the wall which may or may not have openings on the inner side. The genus is mainly littoral, but is frequently found in the plankton. It enjoys a world-wide distribution (Hendey, 1964). Fifteen species of *Diploneis* were reported in Mina Al-Ahmadi waters (Kuwait's waters) by Hendey (1970). Eleven species were recorded in Kuwait's waters during this present study. Two of the species names are not finalized at this stage and are reported as species 1 and 2.

Diploneis chersonensis (Grunow) Cleve (Plate 55E)

Synonym: *Navicula chersonensis* Grunow; *Navicula apis* A. Schmidt; *Diploneis apis* Heiden.

References: Peragallo and Peragallo, 1897-1908; Hustedt, 1930; Hendey, 1964, 1970; Foged, 1984; Ricard, 1987; Round et al., 1990; Witkowski et al., 2000.

Description: Valves linear-elliptic, with a deep transapical constriction opposite the central nodule to produce a panduriform outline, with two tongue-shaped segments having rounded apices. Central nodule small, quadrate, short. Horns narrow, strong, linear, parallel, and flanked by narrow linear furrows which usually bear a longitudinal line of puncta. Those opposite the central nodule are more clearly defined. Valve surface covered with transverse striae that are only very slightly radiate. Costae 8-13 in 10 µm. Striae crossed by several (2-5) longitudinal lines or ribs. These lines are usually parallel and straight and do not interrupt the costae opposite the central nodule. *D. chersonensis* is very closely allied to *D. splendida*, and intermediate forms exist that make identification difficult (Hendey, 1964).

Dimensions: Length of valve 65-120 µm; breadth 22-44 µm (Hendey, 1964), 35-150 µm long, 14-60 µm broad (10-30 µm broad in the middle) (Witkowski et al., 2000). Length 100-120 µm in Mina Al-Ahmadi waters in (Kuwait's waters) (Hendey, 1970) while in the present survey, they were 75 µm long and 26 µm wide.

Distribution: Common on sandy beaches of North Sea countries; west coasts of England and Wales (Hendey, 1964). Marine (cosmopolitan) species, found on all oceanic coast (Witkowski et al., 2000). It also occurred in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) and at other localities in Kuwait's waters (present study).

Diploneis didyma (Ehrenberg) Cleve (Plate 55F)

Synonym: *Navicula (Pinnularia) didymus* Ehrenberg 1840.

References: Hendey, 1964; Witkowski et al., 2000.

Description: Valves panduriform, slightly constricted in the middle, dividing the valve surface into two tongue-shaped segments. The central nodule is sub-quadrate or sometimes almost circular, and produced to form two horns, one on either side of the raphe or median line. Valve surface constate, transverse in the middle, but is slightly curving, radiating lines towards the apices and crossed by numerous undulating longitudinal lines (Hendey, 1964). Transapical striae robust, radiate throughout, 8-10 in 10 µm (Witkowski et al., 2000). In the present specimen, it has 9 striae in 10 µm.

Dimensions: Length of valve 50-90 µm, breadth 17-36 µm (Hendey, 1964); 30-90 µm long, 15-36 µm broad (Witkowski et al., 2000). In the present materials, they were 57.5 µm long and 27.5 µm broad.

Distribution: Common and widespread on all British coasts and on all coasts of North Sea countries. It is also found in Kuwait's waters.

Diploneis aff. *gemmatula* (Grunow) Cleve (Plate 55G)

References: Hustedt, 1930; Witkowski et al., 2000.

Synonym: *Navicula gemmatula* Grunow.

Description: Valves linear-elliptic, usually with slightly constricted margins and widge-shaped apices. Raphe straight, central nodule relatively small circular or quadratic raphe sternum furrows robust, parallel, becoming convergent at the apices, longitudinal canals broad. Transapical striae robust, slightly radiate, 5.5-7 in 10 µm (Witkowski et al., 2000). In the present material, its 6.5 striae in 10 µm.

Dimensions: 50-160 µm long, 26-45 µm broad (Witkowski et al., 2000). In the present Kuwaiti specimens, length 75 µm, breadth 33 µm.

Distribution: Marine species primarily occurring in warmer water of the oceans (Witkowski et al., 2000). It also occurs in Kuwait's waters.

Diploneis interrupta (Kützing) Cleve (Plate 55H)

Synonym: *Navicula interrupta* Kützing

References: Hustedt, 1930; Witkowski et al., 2000.

Description: Valves linear-elliptic with distinctly constricted valves and broadly rounded apices. Central nodule circular to square, raphe sternum furrows broad, associated with two apically elongated ribs, which become narrower towards apices, longitudinal canals moderately broad, parallel becoming narrower at the apices. Transapical striae robust, 8-12 in 10 µm (Witkowski et al., 2000).

Dimensions: 29-72 µm long, 12-27 µm broad (Witkowski et al., 2000).

Distribution: Cosmopolitan brackish-water form, especially frequent on salt marshes of the Baltic Sea embayments (Witkowski et al., 2000). It also occurs in Kuwait's waters.

Diploneis litoralis (Donkin) Cleve (Plate 55I)

Synonym: *Navicula littoralis* Donkin.

References: Hustedt, 1930; Hendey, 1964, 1970; Foged, 1984.

Description: Valves elliptical, central nodule small, rounded or subrectangular, produced to form two horns about the raphe. Furrows very narrow, close to the horns. Valve surface costate. Small areolae between the coatae in double rows. With fine costae 10-14/10 µm in Mina Al-Ahmadi waters in (Kuwait's waters) (Hendey, 1970) and in the present specimens from other localities in Kuwait's waters, 11 striae in 10 µm.

Dimensions: 25-70 µm long, 15-33 µm broad (Witkowski et al., 2000). Length 30-50 µm with fine costae 10-14/10 µm in Mina Al-Ahmadi waters in (Kuwait's waters) (Hendey, 1970) while in the present survey, they were 57 µm long and 31 µm wide.

Distribution: Widespread along the Atlantic (e.g. Europe, Canary Islands) and Indian Oceans (Oman, Southern African coasts). It is also found in Mina Al-Ahmadi waters (Hendey, 1970) and at other localities in Kuwait's waters (present study).

Diploneis smithii (Brébisson) Cleve (Plate 55J-O)

Basionym: *Navicula smithii* Brébisson.

References: Peragallo and Peragallo 1897-1908; Hendey, 1964, 1970; Simonsen, 1974; Foged, 1984; Ricard, 1987; Pankow, 1990; Round et al., 1990; Droop et al., 2000.

Description: Valves elliptical, central nodule small, often rounded, produced to two horns, enclosing the raphe. Furrows narrow, punctate, close to the horns. Area of the furrows narrowly elliptical, often inflated in the middle around the central nodule. Valve surface costate, alternating with double rows of areolae (Hendey, 1964). Transapical striae biseriate in the middle slightly towards apices becoming strongly radiate, 5-15 in 10 µm (Witkowski et al., 2000).

Dimensions: Length of valve 30-80 µm; breadth 16-30 µm (Hendey, 1964). 25-200 µm long, 14-75 µm broad (Witkowski et al., 2000). Length 50-70 µm, breadth 26-32 µm in Mina Al-Ahmadi waters in (Kuwait's waters) (Hendey, 1970) while in the present materials, they were 38 µm long and 20-34 µm wide.

Distribution: A widely-spread species, common in brackish and marine conditions (Hendey, 1964). Frequent in Mina Al-Ahmadi (Kuwait's waters) (Hendey, 1970). It is present at other locations in Kuwait's waters (present study).

Diploneis suborbicularis (Gregory) Cleve (Plate 56A-C)

Basionym: *Navicula smithii* var. *suborbicularis* Gregory 1857.

Synonym: *Navicula suborbicularis* Donkin.

References: Peragallo and Peragallo, 1897-1908; Hustedt 1931-1959; Hendey, 1964, 1970; Foged, 1984; Ricard, 1987; Pankow, 1990; Witkowski et al., 2000.

Description: Valves broadly elliptical or oblong-elliptical, with rounded apices and almost parallel sides. Central nodule large, quadrate, produced into two curved horns. Furrows linear, close to the horns, crossed by a faint continuation of the strong costae that ornament the valve surface; costae transverse in the middle, but radiate towards the apices. Costae 6 to 8 in 10 µm (Hendey, 1964). In the present materials, with 8-9 striae in 10 µm.

Dimensions: Length of valve 40-46 µm; breadth 20-23 µm (Hendey, 1964). 44-55µm long, 24-32 µm broad (Witkowski et al., 2000). Length 42-50 µm in Mina Al-Ahmadi waters (in Kuwait's waters) (Hendey, 1970), while in other localities of the present survey they were found to be 50 µm long and 25 µm wide.
Distribution: Frequent on all North Sea and English Channel coasts, coasts of Scotland (Hendey, 1964). Inhabiting mainly warm marine waters e.g. the Caribbean, in Europe in the Mediterranean and along Atlantic coasts (Witkowski et al., 2000). It is also found in Mina Al-Ahmadi waters (Hendey, 1970) and at other localities in Kuwait's waters (present study).

Diploneis vacillans var. renitens Schmidt (Plate 56D)

Synonyms: *Diploneis vacillans* f. A Cleve; *Diploneis vacillans* var. *corsicana* Grunow; *Navicula vacillans* var. A. Schmidt; *Navicula pfitzeriana* O'Meara; *Navicula vacillans* var. *minuta* Grunow
References: Hustedt, 1930; Hendey, 1970; Witkowski et al., 2000.
Description: Differs from the nominate variety by having constricted valve margins, the extent of the constriction varies from slight to moderate (Witkowski et al., 2000).
Dimensions: Length 56 in Mina Al-Ahmadi waters (in Kuwait's waters) (Hendey, 1970), while in other localities, from the present materials they were 48 µm long and 18 µm wide, with 11 striae in 10 µm.
Distribution: Marine form reported from the Caribbean, and New Caledonia (Witkowski et al., 2000). It is also recorded in Mina Al-Ahmadi waters (Hendey, 1970) and at other localities in Kuwait's waters (present study).

Diploneis weissflogi (Schmidt) Cleve (Plate 56E-G)

Synonyms: *Navicula diversa* Greville; *Navicula weissflogi* Schmidt.
References: Peragallo and Peragallo, 1897-1908; Allen and Cupp, 1935; Hendey, 1964; Hendey, 1970; Foged, 1984; Ricard, 1987.
Description: Valves linear-elliptic in outline with relatively deeply constricted valve margins and broadly rounded apices. Central nodule small, apically elongated, raphe sternum furrows close together and parallel, longitudinal canals linear, slightly convex towards the valve margins. Transapical striae robust, slightly radiate, 7-8 in 10 µm, crossed by straight or slightly wavy longitudinal ribs (Witkowski et al., 2000).
Dimensions: 27-110 µm long, 11-35 µm broad (7-25 µm broad in the middle) (Witkowski et al., 2000). Length 36 µm (Hendey, 1970) in Mina Al-Ahmadi waters (in Kuwait's waters) while in the present survey, they were found to be 47-49 µm long and 15-19 µm wide, with 9-10 striae in 10 µm.
Distribution: Widespread along the warm water coasts of the oceans, e.g. Indian Ocean (Western Australia), Pacific (Borneo), Atlantic (Caribbean, Gulf of Mexico) (Witkowski et al., 2000). It is also found in Mina Al-Ahmadi waters (Hendey, 1970) and at other locations in Kuwait's waters (present study).

Other *Diploneis* spp.: Two of the *Diploneis* unnamed species are observed in Kuwait's waters.

Diploneis sp. 1 (Plate 56H-I)

Distribution: This species was observed in Kuwait's waters.

Diploneis sp. 2 (Plate 56J)

Distribution: This species was observed in Kuwait's waters.

Family: Naviculaceae Kützing 1844

Valves symmetrical on the transapical axis, asymmetrical on the apical axis, dorsiventral. Valves auricular or reniform, with the dorsal margin raised in the form of a ridge carrying the raphe (Hendey, 1964).

Sub-Order: Naviculineae
Family: Naviculineae Kützing
Genus: *Meuniera* Silva 1996

One species was encountered in Kuwait's waters.

Meuniera membranacea (Cleve) Silva (Plates 56K-L and 57A-B)

Basionym: *Navicula* (*Stauroneis*) Cleve.
Synonyms: *Stauropsis membranacea* (Cleve) Meunier; *Navicula membranacea* Cleve 1897; *Stauroneis membranacea* (Cleve 1897) Hustedt 1959.
References: Pavillard, 1925; Cupp, 1943; Hendey, 1964; Drebes, 1974; Simonsen, 1974; Sykes, 1981; Pankow, 1990; Round et al., 1990; Hasle and Syvertsen, 1997; Round et al., 1990.
Description: Cells delicate, thin-walled. United to form short, thick, straight chains. Valves flat or slightly concave in the center, with a thickening in the middle at right angles to the raphe. In valve view cells are narrow, linear, with weak median inflation; ends pointed. Connective zone or girdle deep, giving the cell a rectangular girdle view; finely striate, striae difficult to see. Chromatophores: two undulating ribbon-like bodies arranged in the apical axis of the cell. Several pyrenoids present (Cupp, 1943; Hendey, 1964).
Dimensions: Cells 30-50 µm wide (Cupp, 1943), Apical axis of cell 60-84 µm; pervalvar axis 30-40 µm (Hendey, 1964; Sykes, 1981).
Distribution: Neritic, truly planktonic. Temperate species. Found occasionally off southern California and in Gulf of California (Cupp, 1943). Common in the North Sea and English Channel (Hendey, 1964). It is abundant in Kuwait's waters.

Genus: *Navicula* Bory 1824

Cells usually free, solitary, but in some species united in frondose mucous colonies often several centimeters long. Frustules linear, lanceolate, elliptical, elliptic-oblong or some combination of these shapes. Apices acute, rounded, rostrate, or capitate. Axial area narrow or wide, usually clearly defined. Raphe and polar nodules distinct. Valve surface punctate, puncta either scattered irregularly over the surface, or in striae, which may be straight, curved, radiate, convergent, or transverse. Puncta usually simple, but may be lineate, or minutely loculate. Girdles usually simple, but sometimes finely punctate, or compound and composed of numerous folds. Chromatophores: various, usually two flattened band-like bodies, lobed or crenulate, usually lying along the girdle, one upon either side of the raphe, but may be a large single body lying along the girdle. In some species the single chromatophore breaks up to form four or eight smaller bodies. Pyrenoids usually absent. Oil globules often present as two, four, or more highly refractile bodies, usually located towards the ends of the cell (Hendey, 1964). As many as 29 species of the genus *Navicula* were identified in Mina Al-Ahmadi waters (Kuwait's waters) by Hendey (1970). He discovered a new species in which he regarded it as *Navicula kuwaitana* related to the place where he obtained it from. Some of the species are transferred now into other genera which are more related to the family Naviculaceae. Six species of *Navicula* occured in other locations in Kuwait's waters (present study). Three of the species names are not finalized at this stage and are reported as species 1, 2 and 3.

Navicula directa **var.** ***remota*** **Cleve (Plate 57C)**

Synonyms: *Navicula directa* var. *remota* Grunow, 1880 ; *Navicula (Pinnularia) longa* Gregory in Schmidt; *Navicula longa* Gregory var. in Schmidt

References: Peragallo and Peragallo, 1897-1908; Hendey, 1964; Simonsen, 1974; Ricard, 1987; Round et al., 1990.

Description: Valves long, slender, rhombic-lanceolate, with sub-acute apices. Axial area narrow, polar and central nodules small. Central area moderately large, sub-rectangular, equal to half the valve width. Valve surface striate, striae well-shaped, coarsely lineate, very weakly radiate at the center, transverse throughout the remainder of the valve. Striae 5 in 10 μm (Hendey, 1964).

Dimensions: Length of valve 150-180 μm; breadth 15-17 μm (Hendey, 1964).

Distribution: North Sea, coasts of Britain and Norway, not common in the English Channel. *Navicula directa* and its varieties enjoy a world-wide distribution, but are particularly numerous in sub-arctic waters, where a good deal of interspecific variation makes accurate identification very difficult (Hendey, 1964). It occurs in Kuwait's waters.

Navicula **cf.** ***erifuga*** **Lange-Bertalot (Plate 57D)**

Synonyms: *Navicula leptocephala* Brébisson; *Navicula cincta* var. *leptocephala* (Brébisson) Van Heurck; *Navicula cinctaeformis* Hustedt.

References: Witkowski et al., 2000.

Description: Valves langeolate with obtusely to acutely rounded, rarely weakly produced apices. Raphe straight, external central endings approximate slightly bent in one side, axial area narrow, central area small, more or less rectangular at the side of the central endings and lanceolate at the opposite side. Transapical striae slightly radiate at apices convergent, 12-14 in 10 μm, lineolae 30-35 in 10 μm (Witkowski et al., 2000).

Dimensions: 25-35 μm long, 5-7 μm broad (Witkowski et al., 2000).

Distribution: cosmopolitan, found in brackish-waters and freshwater with high ion content in both hemispheres, common on European coasts (Witkowski et al., 2000). It is found in Kuwait's waters.

Navicula perrhombus Hustedt (Plate 57E)

References: Simonsen, 1987; Witkowski et al., 2000.

Description: Valves rhombic. Raphe straight, external central endings expanded, slightly bent in one side, apical endings strongly hooked to one side, axial area at apices narrow towards central broadening, central area moderately large, rhombic. Transapical striae coarse in the middle radiate, at apices parallel, 10-12 in 10 μm (Witkowski et al., 2000).

Dimensions: 16-25 μm long, 7-8 μm broad (Witkowski et al., 2000).

Distribution: marine species known from warm waters, rarely recorded (Witkowski et al., 2000). It was observed in Kuwait's waters.

Other *Navicula* spp.: Three unnamed species of *Navicula* were observed in Kuwait's waters during this study.

Navicula sp. 1 (Plate 57F)

Distribution: This species was observed in Kuwait's waters.

Navicula sp. 2 (Plate 57G)

Distribution: This species was observed in Kuwait's waters.

Navicula sp. 3 (Plate 57H-I)

Distribution: This species was observed in Kuwait's waters.

Genus: *Trachyneis* Cleve 1894

Cells solitary, free. Valves lanceolate, elliptic-lanceolate to elliptical. Axial area narrow, raphe straight, central area dialted to form an expanding stauros which may or may not reach the valve margin. Valve surface alveolate, complex, with an outer lamina bearing fine perforations superimposed upon an inner loculate layer. Alveoli oblique, radiate. Girdle composed of a plain unstriated band. Chromatophores: two elongated plates, lying along the girdle (Hendey, 1964). Five species of *Trachyneis* were described by Hendey (1970) in Mina Al-Ahmadi waters. Two species occur in Kuwait's waters (present study).

Trachyneis antillarum Cleve (Plate 58A-E)

References: Hustedt, 1930; Hendey, 1970; Simonsen, 1974.

Synonym: *Allioneis antillarum* Cleve and Grunow.

Description: Valve linear-lanceolate with obtuse apices. Raphe eccentric, axial area broad, irregularly linear and unilateral. Central area rounded, unilateral, developed as a rounded area on the narrow side opposite the central nodule. Valve surface coarsely aveolate. Aveoli in longitudinal flexuose or irregularly oblique rows (Hendey, 1970).

Dimensions: Length 100-120 μm, breadth 29 μm in Mina Al-Ahmadi waters (in Kuwait's waters) (Hendey, 1970) while in the present materials, they were 87 μm long and 21 μm wide.

Distribution: It is a benthic tropical species, found in the African side, Indian profiles, at near coast stations off Pakistan and very common in the Arabian/Persian Gulf (Simonsen, 1974). It also frequently occurred in Mina Al-Ahmadi waters (Hendey, 1970) and at other localities in Kuwait's waters (present study).

Trachyneis aspera (Ehrenberg) Cleve var. *aspera* (Plate 58F-H)

Basionym: *Navicula aspera* Ehrenberg 1840.

Synonyms: *Stauroneis pulchella* W. Smith; *Stauroneis pulchella* Wm. Smith, 1853; *Trachyneis aspera* var. *pulchella* (Wm. Smith) Cleve, 1894.

References: Hendey, 1964 and 1970; Simonsen, 1974; Witkowski et al., 2000.

Description: Frustules rectangular with rounded corners. Valves elliptic to linear-elliptic with obtusely or broadly rounded apices. Raphe straight, external central endings approximate, axial area very narrow unilateral, central area expanded into a transverse fascia broadened towards margins, terminating before reaching the margins. Transapical striae composed of rectangular alveoli, arranged in transverse rows, radiate throughout, 6-8 in 10 µm (Witkowski et al., 2000).

Dimensions: Length of valve 80-200 µm, breadth 20-36 µm (Hendey, 1964). 60-300 µm long, 24-50 µm broad (Witkowski et al., 2000). Length 90-120 µm, breadth 11-17 µm in Mina Al-Ahmadi waters (in Kuwait's waters) (Hendey, 1970) while in the present materials, they were 148 µm long and 33 µm wide.

Distribution: cosmopolitan marine species, common on European coasts including the western Baltic Sea (Witkowski et al., 2000). Very scattered occurrences in the coastal station of the African side and Indian profiles; in the Arabian/Persian Gulf only in the north (Simonsen, 1974). It was reported from Mina Al-Ahmadi waters (Hendey, 1970) and at other localities in Kuwait's waters (present study).

Genus: *Haslea* Simonsen 1974

Cells solitary (or in mucilage tubes = benthic forms). Cell wall weakly silicified. Cells generally fusiform in girdle and valve views. Valves narrow and linear to lanceolate, valve ends pointed. Transverse and longitudinal striae crossed at right angles. Raphe central pores small and approximate. Chloroplasts, two plate like (*H. ostrearia*) (Hasle and Syvertsen, 1997). Three species are obtained from Kuwait's waters. Two of the species names are not finalized at this stage and are reported as species 1 and 2.

Haslea spec. cf. *balearica* in Witkowski et al., 2000 (Plate 58I-K)

References: Witkowski et al., 2000.

Distribution: This species occurs in Kuwait's waters.

Other *Haslea* spp.: Two species of *Haslea* were observed in Kuwait's waters.

Haslea sp. 1 (Plate 59A)

Distribution: This species was observed in Kuwait's waters.

Haslea sp. 2 (Plate 59B)

Distribution: This species was observed in Kuwait's waters.

Genus: *Donkinia* Ralfs 1861

Cells solitary, free. Valves linear or linear-lanceolate, not truly sigmoid, or only slightly so towards the ends. Ends unilaterally oblique. Central area small, rounded. Raphe very strongly sigmoid and raised as a ridge, particularly as it becomes coincident with the valve margin from about the middle distance to the apices. Valve surface striate, striae punctuate, striae arranged in longitudinal and transverse lines as in *Gyrosigma* Hassall or in oblique and transverse lines as in *Pleurosigma* Wm. Smith. When seen in girdle view the frustules appear to be constricted in the middle, due to the raised ridge bearing the raphe. Girdle simple, plain (Hendey, 1964). One species is found in Kuwait's waters and the name is not finalized at this stage and is reported as species 1.

Donkinia sp.1 (Plate 59C-D)

Distribution: This species occurs in Kuwait's waters.

Family: Pleurosigmataceae Mereschkowsky 1903

Genus: *Pleurosigma* Smith 1852

Valves linear to lanceolate, usually sigmoid. Raphe usually sigmoid, central or excentric. Striae finely punctate in oblique and transverse lines. Central nodule usually small and rounded. Cells narrow in girdle view, with narrow connective zone, sometimes twisted or arcuate, or constricted in the middle. Chromatophores usually two bands, one on each valve. Each band is lobed or indented and sometimes differs in opposite valves. Numerous pyrenoids present in most forms (Cupp, 1943). Five *Pleurosigma* spp. were obtained from Kuwait's waters during the present study. Hendy (1970) identified 8 species of *Pleurosigma* from Mina Al-Ahmadi waters.

Pleurosigma cuspidatum Cleve (Plate 59E-H)

References: Hendey, 1964.

Description: Valves lanceolate, not sigmoid, with produced rostrate apices. Raphe straight, or only very slightly undulate, central. Ends of raphe curved in opposite directions. Valve surface striate, striae punctuate. Oblique striae 22-24 in 10 µm, transverse striae 20 in 10 µm (Hendey, 1964).

Dimensions: Length of valve 75-100 µm, breadth 22-25 µm (Hendey, 1964).

Distribution: Not common, occasionally in the English Channel, coasts of Scotland and N. Wales (Hendey, 1964). It is also found in Kuwait's waters (this study).

Pleurosigma diverse-striatum Meister (Plates 59I-J and 60A-F)

References: Peragallo and Peragallo, 1897-1908; Hendey, 1970; Ricard, 1987.

Dimensions: Length 80-160 µm, breadth 15-20 µm, striae 12-15 in 10 µm at center; 18-20 in 10 µm at ends (Hendey, 1970).

Distribution: It occurred in Mina Al-Ahmadi waters (Hendey, 1970) and at other localities in Kuwait's waters (present study).

Pleurosigma cf. *elongatum* Smith (Plate 61A-E)

References: Hendey, 1964.

Description: Valves elongate, linear-lanceolate, gently tapering from about the middle to acute apices. Valves gently sigmoid, raphe central, central and polar nodules small. Valve surface striate, striae punctuate, transverse and oblique, the latter 16-20 in 10 µm, crossing each other at an angle of about 60°-70° (Hendey, 1964).

Dimensions: Length of valve 130-380 µm, breadth 24-30 µm (Hendey, 1964).

Distribution: A marine and brackish species common on North Sea coasts and in the English Channel. Sometimes found in the plankton. Reported also from Spitzbergen, coasts of Norway, Baltic Sea (Hendey, 1964) and Kuwait's waters (this study).

Pleurosigma formosum Peragallo (Plate 61F-H)

References: Peragallo and Peragallo, 1897-1908; Cupp, 1943; Hendey, 1964; Ricard, 1987; Round et al., 1990.

Description: Valves elongated, linear to linear-lanceolate, sigmoid, with sub-acute apices. Raphe strongly sigmoid and towards the ends eccentric, sweeping across the valve at about middle distance and becoming almost coincident with the convex margin as it approaches the apices. Polar and central nodules small, axial area absent. Valve surface striate, striae punctate, and arranged in oblique lines, 10-14 in 10 µm, and in transverse lines, 14-16 in 10 µm. Oblique striae crossing each other at an angle of about 90^0 (Hendey, 1964).

Dimensions: Length of valve 360-500 µm, breadth 34-46 µm (Hendey, 1964).

Distribution: Widely spread around all British coasts and on the coasts of all North Sea countries. Frequent on coasts all over the world. A fully marine species favouring water of high salinity (Hendey, 1964). It is present in Kuwait's waters.

Pleurosigma cf. *strigosum* Wm. Smith (Plate 62A-C)

Synonym: *Pleurosigma angulatum* var. *strigosa* Van Heurck 1880-1985

References: Hendey, 1964.

Description: Valves lanceolate, slightly sigmoid, with sub-obtuse apices. Raphe sigmoid, somewhat eccentric towards the ends; central area small, sub-circular. Valve surface striate, striae oblique and transverse, oblique striae crossing each other at an angle of about 60°. Striae equidistant, 18-22 in 10 µm. Chromatophores, two large plates lying against the valves (Hendey, 1964).

Dimensions: Length of valve 164-300 µm, breadth 32-36 µm (Hendey, 1964).

Distribution: Marine, common on muddy shores and estuaries of the North Sea countries and English Channel, sometimes very abundant (Hendey, 1964).

Genus: *Gyrosigma* Hassall 1845

Cells solitary. Valves elongate linear or lanceolate. Usually sigmoid. Axial area very narrow. Central area small. Striae punctate, in transverse and longitudinal rows. Chromatophores two, in long and narrow bands, one on each valve, the margins serrated in marine forms. Pyrenoids present in all species (Cupp, 1943). One species occurs in Kuwait's waters.

Gyrosigma diminutum Grunow (Plate 62D)

References: Peragallo and Peragallo 1897-1908; Hendey, 1964; Ricard, 1987.
Distribution: Present in Kuwait's waters.

Family: Plagiotropidaceae Mann in Round et al. 1990
Genus: *Plagiotropis* Pfitzer 1871

One species occurs in Kuwait's waters.

Plagiotropis lepidoptera (Gregory) Cleve (Plate 62E-I)

Synonyms: *Tropidoneis lepidoptera* (Gregory) var. *lepidoptera*; *Amphiprora lepidoptera* Gregory, 1857; *Tropidoneis lepidoptera* var*. mediterranea* Peragallo, 1897.
References: Peragallo and Peragallo, 1897-1908; Hendey, 1964; Ricard, 1987; Round et al., 1990.
Description: Frustules rectangular, linear-oblong, somewhat constricted in the middle. Wings distinct, projecting equally above and below the central nodule. Valve linear-lanceolate to lanceolate, with acute, apiculate apices. Central area often indistinct, small, and often transversely lanceolate or elliptical. Keel unilateral, projecting above the median line, seldom seen in a median position as the valve tends to lie somewhat tilted over. Chromatophores, two or four irregular bodies (Hendey, 1964).
Dimensions: Length of valve 240 µm -280 µm, breadth 32-36 µm (Hendey, 1964).
Distribution: Common and widespread on the coasts of Britain; North Sea, English Channel, coasts of N. Wales (Hendey, 1964). It is present in Kuwait's waters (present study).

Order: Thalassiophysales Mann in Round et al. 1990
Family: Catenulaceae Mereschkowsky 1902
Genus: *Amphora* Ehrenberg 1840

Cells solitary, generally free-floating or in a tough mucous film adhering to a substratum; in girdle view elliptical with truncated flattened ends. Frustules asymmetric, shaped like a third of an orange. Valves not parallel with each other but with surfaces in planes at an angle one with another. Valves curved or sub-lunate, and in the complete frustule the ventral margins lie parallel and close to each other, with the raphes of the two valves in the same focal plane, while the dorsal margins are separated by a very deep development of the girdle. Raphe usually eccentric, lying closer to the ventral margin. Valve surface striate, usually punctate. Ventral side narrower, and often without structure or with less structure than on the arcuate dorsal side. Girdle usually complex, composed of numerous bands that may or may not bear puncta. Chromatophores: very variable, and may be from one to four irregularly shaped plates, or as numerous granules (Hendey 1964). Several species of *Amphora* occurred in Kuwait's waters. As many as 19 *Amphora* spp. were recorded in Mina Al-Ahmadi waters (Hendey, 1970). Nine of the species names have not been finalized at this stage and are reported as species 1 to 9.

Amphora crassa Gregory (Plate 63A-C)

References: Hendey, 1964, 1970; Witkowski et al., 2000.
Description: Frustules oblong-elliptic with slightly inflated sides and rounded corners, valves linear with rounded apices, ventral margin almost straight, slightly inflated at apices and

in the middle, dorsal margin almost straight. Raphe slightly biarcuate, close to the ventral margin, external central endings distant, axial area absent, central area on the ventral side, semi-elliptic. Transapical striae coarsely punctate, 5-8 in 10 µm (Witkowski et al., 2000).
Dimensions: 50-100 µm long, 20-30 µm broad (Witkowski et al., 2000). Length 66 µm in Mina al Ahmadi waters (Kuwait's waters) (Hendey, 1970).
Distribution: Marine species widespread (cosmopolitan), found from the Arctic to the tropics, common on European coasts including western Baltic Sea and the Mediterranean (Witkowski et al., 2000). It is found in Mina Al-Ahmadi waters (Hendey, 1970) and at other localities in Kuwait's waters (this study).

Amphora decussata Grunow (Plate 63D-E)

References: Foged, 1984; Hendey, 1964.
Description: Cells elliptical, often with truncate ends. Valves flat, lunate, with straight ventral margin and arcuate dorsal margin, with somewhat flattened sides from the sub-acute apieces to the mid-point on the dorsal side, giving the valve the appearance of an equilateral triangle rounded at the apex. Raphe along the ventral margin. Central nodule dilated to form a narrow stauros. Valve surface striate, striae punctuate and arranged in decussating oblique rows. Striae 16-18 in 10 µm (Hendey, 1964).
Dimensions: Length of valve 70-110 µm (Hendey, 1964).
Distribution: Not common, but occasionally in the English Channel (Hendey, 1964). It is also found in Kuwait's waters.

Amphora granulata var. *biggibbosa* Ricard (Plate 63F)

References: Simonsen, 1974; Ricard, 1977.
Description: The type *Amphora granulata* is characterized by linear-elliptic frustules. Valves semi-elliptic with short sub-capitate apices, bent in ventral side. Raphe slightly arcuate, external central endings approximate, bent towards dorsal side, axial area narrowly linear, central area small, semicircular developed on the ventral side (Witkowski et al., 2000).
Dimensions: 46.5-57 µm long, 15-26 µm broad (Witkowski et al., 2000).
Distribution: Widespread in the marine littoral (Witkowski et al., 2000). It is present in Kuwait's waters.

Amphora obtusa Gregory 1857 (Plates 63G-H and 64A)

References: Peragallo and Peragallo, 1897-1908; Hendey, 1964; Foged, 1984; Ricard, 1987; Round et al., 1990.
Description: Cells elliptical to oblong-elliptic, with rounded or slightly produced truncate ends. Valves broadly linear, with weakly arcuate dorsal margin flattened in the middle and rounded at the ends, and a straight or nearly straight ventral margin. Raphe biarcuate, axial area absent, central area is very small and confined to the dorsal side. Valve surface striate, striae 10-12 in 10 µm. Girdle composed of several striate longitudinal segments (Hendey, 1964).
Dimensions: Length of valve 160 -250 µm (Hendey, 1964).
Distribution: Frequent on the Atlantic coasts of the British Isles (Hendey, 1964). It is also observed in Kuwait's waters.

Amphora ostrearia Brébisson (Plate 64B-C)

References: Peragallo and Peragallo, 1897-1908; Hendey, 1964; Foged, 1984; Ricard, 1987; Witkowski et al., 2000.

Description: Frustules sub-rectangular to elliptic-oblong with rounded apices. Girdle composed of numerous punctuate bands, 20-22 in 10 µm. Valves with arcuate dorsal margin, straight ventral margin and acutely rounded apices, 9-16 µm broad. Rephe biarcuate, axial area very narrow, central area on the dorsal side extended into a narrow, transverse fascia. Transapical striae punctuate, parallel throughout, on the dorsal side 12-14 in 10 µm, on the ventral side 13-14 in 10 µm (Witkowski et al., 2000).

Dimensions: Length of valve 56-66 µm (Hendey, 1964). 56-94 µm long, 30 µm broad (Witkowski et al., 2000).

Distribution: Widely distributed on all North Sea coasts; particularly associated with sandy shores (Hendey, 1964). Widespread marine species (Witkowski et al., 2000). This species was observed in Kuwait's waters.

Amphora proteus Gregory (Plates 64D-F and 65A)

References: Peragallo and Peragallo 1897-1908; Witkowski et al., 2000.

Description: Frustules elliptic to circular-elliptic (smaller specimens). Valves semi-elliptic with convex dorsal margin, slightly concave ventral margin and obtusely rounded apices. Raphe strongly curved distant from the ventral margin, axial area narrow along the dorsal side, distinct but somewhat irregular on the ventral side, central area on the ventral side large. Transapical striae on the dorsal side radiate throughout, crossed by undulating longitudinal ribs, 9-11 in 10 µm in the middle, 10-13 in 10 µm at the apices, at the ventral side, 8-12 in 10 µm (Witkowski et al., 2000).

Dimensions: 56-113 µm long, 27-53 µm broad (Witkowski et al., 2000).

Distribution: Widespread (cosmopolitan) species of the marine littoral (Witkowski et al., 2000). It also occurred in Kuwait's waters.

Amphora rhombmica Kitton ex A. Schmidt (Plate 65B)

References: Peragallo and Peragallo, 1897-1908; Witkowski et al., 2000.

Description: Valves semi-rhomboidal with dorsal margin convex and ventral margin almost straight. Raphe slightly biarcuate, axial area narrow, central area small, circular. Transapical striae on the dorsal side composed of elongate areolae arranged in radiate rows, indicated are 10-12 in 10 µm (in our measurements 16 in 10 µm), on the ventral side transverse, 11-13 in 10 µm (in our measurements 27 in 10 µm) (Witkowski et al., 2000).

Dimensions: 100-260 µm long, 21-50 µm broad (Witkowski et al., 2000).

Distribution: Marine species widespread on marine coasts (Witkowski et al., 2000). It is also found in Kuwait's waters.

Amphora spectabilis Gregory (Plate 65C)

References: Peragallo and Peragallo, 1897-1908; Hendey, 1964, 1970; Witkowski et al., 2000.

Description: Frustules elliptic to oblong-elliptic with broadly rounded apices. Valves broadly linear with arcuate in the middle flattened dorsal margin, undulating ventral margin and obtusely rounded apices, 20 μm broad. Raphe biarcuate, external central endings approximate, closer to the ventral margin, axial area narrow, central area on the dorsal side semi-elliptic. Transapical striae on the ventral margin parallel, finely punctuate, 8-9 in 10 μm, on the dorsal side punctuate, bifurcating, 5-6 in 10 μm (Witkowski et al., 2000). It is clearly identifiable by the strongly marked valve showing coarse and more distant striae on the dorsal side, clearly bifurcate near the raphe and the finer, often slightly curved striae on the ventral side of the valve, usually showing less bifurcation (Hendey, 1970).

Dimensions: 70-140 μm long, 50 μm broad (Witkowski et al., 2000). Length 70-75 μm, breadth 14 μm in Mina Al-Ahmadi waters (in Kuwait's waters) (Hendey, 1970).

Distribution: Marine species widespread on European coasts up to the Arctic, entering also the western Baltic Sea (Witkowski et al., 2000). It is also obtained frequently in Mina Al-Ahmadi waters (Hendey, 1970) and at other localities in Kuwait's waters (present study).

Amphora sulcata **(Plate 65D)**

Distribution: This species occurs in Kuwait's waters.

Amphora **cf.** ***turgida*** **Gregory var.** ***turgida*** **(Plate 65E-G)**

References: Hendey 1964; Witkowski et al., 2000.

Description: Frustules broadly elliptic to orbicular with rostrate ends. Valves semi-lanceolate with straight ventral margin, broad, arcuate dorsal margin and slightly produced apices, 7-9 μm broad. Raphe straight, close to ventral margin, axial and central area absent. Transapical striae in the middle parallel, towards apices becoming radiate, 13 in 10 μm (Witkowski et al., 2000).

Dimensions: 17-36 μm long, 15-20 μm broad (Witkowski et al., 2000).

Distribution: marine species of world wide-distribution, found from the Arctic to the tropics, inhabiting marine littoral (Witkowski et al., 2000). It is also found in Kuwait's waters

Other *Amphora* spp.: Several species of *Amphora* are found in Kuwait's waters (present study).

Amphora **sp. 1 (Plate 65H)**

Dimensions: Length 65 μm and breadth 17 μm.

Distribution: This species is present in Kuwait's waters.

Amphora **sp. 2 (Plate 66A)**

Description: With 14-15 striae in 10 μm.

Dimensions: Length 34 μm and breadth 5.14 μm.

Distribution: This species is present in Kuwait's waters.

Amphora **sp. 3 (Plate 66B)**

Distribution: This species is present in Kuwait's waters.

Amphora sp. 4 (Plate 66C-H)

Description: With 7-8 striae in 10 µm.
Dimensions: Length 95 µm and breadth 27.5 µm in valve view, 71.18-95 µm and breadth 37.5-39 µm in girdle view.
Distribution: This species occurs in Kuwait's waters.

Amphora sp. 5 (Plate 66I-L)

Dimensions: Length 77.5 µm and breadth 17.5 µm.
Distribution: This species occurs in Kuwait's waters.

Amphora sp. 6 (Plate 66M)

Distribution: This species occurs in Kuwait's waters.

Amphora sp. 7 (Plate 67A-B)

Distribution: This species occurs in Kuwait's waters.

Amphora sp. 8 (Plate 67C)

Distribution: This species occurs in Kuwait's waters.

Amphora sp. 9 (Plate 67D)

Distribution: This species occurs in Kuwait's waters.

Order: Bacillariales Hendey 1937

Family: Bacillariaceae Ehrenberg 1831

Cells usually solitary, sometimes in packet-like colonies, or joined tip to tip in long ribbons, or enclosed in mucus. Cells linear, often slightly sigmoid, with raphe enclosed in a keel, usually marginal, isopolar (Hendey, 1964).

Genus: *Bacillaria* Gmelin 1791

Cells colonial, united valve to valve to form rectangular blocks. Cells narrowly rectangular in girdle view. Valves linear with produced, sub-acute apices. Raphe carried in a ridge or keel as in *Nitzschia* Hassall. Keel central, keel puncta equal in size. Valve surface finely striate, striae transverse. The cells of *Bacillaria* Gmelin possess a very peculiar form of motility in that one cell slides along the surface of the neighbouring cell, for the full length of the raphe (or less), but does not part company from it. Each cell in the colony may so move and so elongate the colony to a filament of cells joined only at their apices. The filament then reverses the movement until the block-like or packet colony is re-formed. Sometimes some cells are seen to move in one direction, while others move in the opposite direction- the distance of travel being limited by the length of the raphe (Hendey, 1964). Two species occur in Kuwait's waters.

Bacillaria paxillifera (O. F. Müller) Hendey (Plate 68A-E)

Basionym: *Vibrio paxillifer* O. F. Müller 1786.
Synonyms: *Bacillaria paxillifer* (O. F. Müller) Nitzsch 1817, *Bacillaria paradoxa* J. F. Gmelin 1791; *Nitzschia paradoxa* (J. F. Gmelin 1791) Grunow 1880; *Nitzschia paxillifer* (O. F. Müller 1786) Heiberg 1863.

References: Pavillard, 1925; Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964; Drebes, 1974; Simonsen, 1974; Prescott, 1978; Sykes, 1981; Foged, 1984; Ricard, 1987; Pankow, 1990; Hasle and Syvertsen, 1997.

Description: Cells free, or united to form a colony. Valves linear-lanceolate to lanceolate, with produced apices. Keel occupying a central position on the valve. Keel puncta stron, 7-9 in 10 µm. Striae 20-21 in 10 µm. Valve surface striate; striae transverse. Chromatophores: several small, rounded or irregular bodies. Nucleus central. This species is remarkable for the characteristic method of cell movement. The cells at one moment appear to form a filament or short ribbon with adnate frustules, then with a gliding movement (very like extending a slide-rule) the cells slide forward, adhering one to another only by their ends, to form an elongated chain (Cupp, 1943; Hendey, 1964).

Dimensions: Length of valves 80-115 µm; width 5-6 µm (Cupp, 1943), length of valve 70-100 µm (Hendey, 1964).

Distribution: Littoral, marine and brackish water species, strongly euryhaline. Common on all coasts bordering the North Sea and English Channel (Cupp, 1943; Hendey, 1964). It is abundant in Kuwait's waters.

Bacillaria socialis (Gregory) Ralfs (Plates 68F and 69A-D)

Synonym: *Nitzschia socialis* Grunow.

References: Peragallo and Peragallo, 1897-1908; Hendey, 1964; Simonsen, 1974; Foged, 1984; Ricard, 1987; Pankow, 1990.

Description: Cells united in groups from 6 to 20. valves narrow, lanceolate, tapering from the middle to produced, sub-acute apices. Keel central, with 6-7 keel puncta in 10 µm. Valve surface finely striate, striae 14-15 in 10 µm, transverse (Hendey, 1964).

Dimensions: Length of valve 80-120 µm; breadth 7-8 µm (Hendey, 1964).

Distribution: A boreal species; North European coasts (Hendey, 1964). It is present in Kuwait's waters.

Genus: *Cylindrotheca* Rabenhorst 1859

Cells solitary. Frustules cylindrical, fusiform, raphe borne upon a helically twisted keel. Weakly siliceous (Hendey, 1964). Two species occur in Kuwait's waters. One species name is not finalized at this stage and is reported as species 1.

Cylindrotheca closterium (Ehrenberg) Lewin and Reimann (Plate 69E)

Basionym: *Ceratoneis closterium* Ehrenberg 1840.

Synonym: *Nitzschia closterium* (Ehrenberg 1840) W. Smith 1853.

References: Allen and Cupp, 1935; Cupp, 1943; Hendey, 1964; Simonsen, 1974; Sykes, 1981; Pankow, 1990; Hasle and Syvertsen, 1997; Bérard-Therriault et al., 2000.

Description: Cells solitary, but usually found matted together in dense masses. Central part of valve weakly oblong, with tapering apices forming hair-like awns or spines. Sometimes the apices are reduced to form short crescentic or fusiform valves. The produced apices may be curved in the same or in opposite directions. Valve surface very faintly striate, striae 20-30 in 10 µm, indistinct. Chromatophores: two small flattened bodies (Hendey, 1964).

Dimensions: Length of valve 50-80 µm (Hendey, 1964).

Distribution: Common in neritic plankton all around the British Isles (Hendey, 1964). It is also abundant in Kuwait's waters.

Cylindrotheca sp. 1 (Plate 59F)

Distribution: This species occurs in Kuwait's waters.

Genus: *Hantzschia* A. Grunow 1877

One species was found in Kuwait's waters.

Hantzschia amphioxis (Ehrenberg) Grunow (Plate 70A-B)

References: Round et al., 1990.

Description: Cells solitary, straight or sigmoid, usually lying in girdle view, markedly dorsiventral. Two (rarely 4) plastids. lying one on either side of the median transapical plane. The valves are asymmetrical with respect to the apical plane, or sigmoid. The raphe is eccentrically placed on the valve and both raphes are on the same, usually less convex, ventral side of the cell, i.e. the frustule is mirror-symmetrical about the valvar plane ('hantzschioid symmetry'). Valve face quite distinct in some but in others grading imperceptibly into the mantles. Raphe continuous from pole to pole or interrupted centrally, often biarcuate (closer to the ventral side centrally than, nearer the poles). aphe subtended internally by fibulae which are massive, or slender and rib-like. Girdle complex, containing open or closed bands, of which at least some bear two or more rows of poroids (Round et al., 1990).

Dimensions: In the present survey, length 57 µm, breadth 8.13 µm.

Distribution: Widely distributed in the marine and freshwater epipelon, especially in intertidal sand, but extending into subaerial habitats (Round et al., 1990). This species occurs in Kuwait's waters.

Genus: *Nitzschia* Hassall 1845

Cells spindle-shaped, single or united into mucous colonies, filaments or fronds. Valves usually linear, having marginal keels situated diagonally on the frustule, keels usually eccentric but sometimes central. The keel including a concealed raphe, usually diagonally opposite, either central or excentric. Keel puncta short or prolonged. Striae transverse, punctate. No central nodule. Chromatophores two bands placed transversely upon one zone. In certain forms the number of plates may vary from four to six. A pyrenoid sometimes found in center of a chromatophore (Cupp, 1943, Hendey, 1964). Six different species were recorded in Mina Al-Ahmadi waters (Kuwait's waters) by Hendey (1970). As many as 12 species of *Nitzschia* are observed in Kuwait's waters. Four of the species names are not finalized at this stage and are reported as species 1 to 4.

Nitzschia behrei Hustedt (Plate 70C-D)

References: Hustedt 1959; Simonson 1987; Witkowski et al., 2000.

Description: Frustules in girdle view narrowly lanceolate, sigmoid. Valves in keel position very narrowly langeolate, straight with long rostrate, produced, capitate apices. Raphe slightly eccentric, fibulae broad, in the middle 6 in 10 µm at apices up to 15 in 10 µm, in the middle equally spaced, connected with numerous striae. Transapical striae by oblique illumination well discernible, 40-42 in 10 µm (Witkowski et al., 2000).

Dimensions: 220-250 µm long, 5-6.5 µm broad (Witkowski et al., 2000). In the present material, the breadth is 7 µm.

Distribution: Described from the plankton of the River Weser Estuary (Witkowski et al., 2000). It is found in Kuwait's waters.

Nitzschia coarctata Grunow (Plates 70E-F and 71A)

References: Foged, 1984; Witkowski et al., 2000.

Synonyms: *N. punctata* var. *coarctata* (Grunow) Hustedt; *Tryblionella coarctata* (Grunow) Mann in Round et al. 1990.

Description: Valves linear panduriform with broadly cuneate, short rostrate or sub-apiculate apices. Raphe strongly eccentric, fibulae as many as striae in 10 µm. transapical striae punctuate, 8-10 in 10 µm, puncta arranged in transverse rows, interrupted by a longitudinal fold (Witkowski et al., 2000).

Dimensions: 25-140 µm long, 11-22 µm broad (Witkowski et al., 2000). From the present survey, length 18-37 µm, breadth 7-13 µm.

Distribution: marine to brackish-water species complex, widespread (cosmopolitan). This complex is heterogenous and contains very likely some independent biological species (Witkowski et al., 2000). It is found in Kuwait's waters.

Nitzschia cf. *fluminensis* Grunow (Plates 71B-F and 72A-B)

Synonym: *Nitzschia neogena* Grunow.

References: Peragallo and Peragallo, 1897-1908; Hustedt, 1976; Ricard, 1987; Witkowski et al., 2000.

Description: Valves lanceolate with produced apices. Raphe central, fibulae 4-6 in 10 µm, partly prolonged into transapical ribs. Transapical striae punctate, 14-16 in 10 um (Witkowski et al., 2000).

Dimensions: 130-160 µm long, 13-15 µm broad (Witkowski et al., 2000).

Distribution: Marine species inhabiting warmer waters sea coasts, in Europe it is found in the Mediterranean (Witkowski et al., 2000). Present in Kuwait's waters.

Nitzschia longissima (Brébisson) Ralfs in Pritchard (Plates 72C-F and 73A-B)

Basionym: *Ceratoneis longissima* Brébisson 1849

References: Peragallo and Peragallo, 1897-1908; Pavillard, 1925; Allen and Cupp, 1935; Cupp, 1943; Hendey,1964, 1970; Simonsen, 1974; Foged, 1984; Ricard, 1987; Pankow, 1990; Hasle and Syvertsen, 1997.

Description: Valves linear-lanceolate tapering to very long apical extremities. Valves usually straight over the whole length, extremities not curved as in *Cylindrotheca closterium*. Keel puncta 8-14 in 10 µm. Chromatophores as in *N. closterium* (Cupp, 1943; Hendey, 1964). Raphe with fibulae and central larger interspace can be distinct in mounted cleaned material, while the transverse striae and interstriae hardly visible with LM (Hasle and Syvertsen, 1997).

Dimensions: Length of valve 125-250 µm (Cupp, 1943); 200-450 µm (Hendey, 1964); apical axis, 125-450 µm; transapical axis (Hasle and Syvertsen, 1997). Length 300-400 µm in Mina Al-Ahmadi waters in Kuwait's waters (Hendey, 1970) while in this survey**,** length 401.71 µm and width 9.08 µm.

Distribution: Littoral species, common in the plankton of the North Sea and English Channel (Cupp, 1943; Hendey, 1964). It occurred in fairly large quantities; particularly during the summer months in Mina Al-Ahmadi waters (Hendey, 1970) and also at other localities in Kuwait's waters (present study).

Nitzschia lorenziana **Grunow (Plate 73C-I)**

References: Peragallo and Peragallo, 1897-1908; Pavillard, 1925; Allen and Cupp, 1935; Hendey, 1970; Simonsen, 1974; Ricard, 1987; Witkowski et al., 2000.

Description: Frustules in girdle view sigmoid. Valves sigmoid narrowly lanceolate with long rostrate acutely rounded apices. Raphe eccentric, fibulae evenly spaced, 6-10 in 10 µm, but the median two ones distant, central nodule present, transapical striae 13-19 in 10 µm (Witkowski et al., 2000).

Dimensions: (37) 50-190 µm long, (3) 4-7 µm broad (Witkowski et al., 2000). Length 180-200 µm in Mina Al-Ahmadi waters (in Kuwait's waters) (Hendey, 1970)**.**

Distribution: brackish-water species found on marine coasts, rarely also in electrolyte rich inland waters (Witkowski et al., 2000). Found in Mina Al-Ahmadi waters (Hendey, 1970) and at other localities in Kuwait's waters (present study).

Nitzschia **cf. *sigma*** **(Kützing) Smith (Plate 74A-B)**

Basionym: *Synedra sigma* Kützing.

References: Witkowski et al., 2000.

Description: Frustules in girdle view strongly sigmoid. Valves depending on the position more or less sigmoid or in the middle part linear to linear-lanceolate with long cuneate to opposite sides curved apices. Raphe strongly eccentric, fibulae (3)7-12 in 10 µm, equidistantly spaced, transapical striae (15)19-38 in 10 µm, punctuate (Witkowski et al., 2000).

Dimensions: 35-ca. 1000 µm long, 4-25(26) µm broad (Witkowski et al., 2000).

Distribution: cosmopolitan taxon inhabiting marine coasts and estuaries, rarely also in electrolyte rich freshwaters. The extremely wide range of dimensions and structures density points to a heterogenous complex of different species under the name of this taxon. A general taxonomic revision is needed (Witkowski et al., 2000). It is also found in Kuwait's waters.

Nitzschia **cf. *sigmoidea*** **(Ehrenberg) Smith (Plate 74C-E)**

References: Hustedt, 1930.

Description: Cells more or less bent into "S"-shape in girdle view, otherwise linear with parallel margins and rounded corners. Valves long canoe-shaped, narrow-lanceolate in somewhat rotated position with narrowed, wedge-shaped ends, Keel slightly eccentric, keel puncta 5-7 in 10 µm. Striae distinct, 23-26 in 10 µm (Hustedt, 1930).

Dimensions: 160-500 µm long, 8-14 µm wide (Hustedt, 1930).

Distribution: Widely distributed and common (Hustedt, 1930). It occurs in Kuwait's waters.

Nitzschia panduriformis* **Gregory 1857 (Plate 74F-G)**

References: Allen and Cupp, 1935; Hendey, 1964, 1970; Simonsen, 1974; Simonsen, 1974; Foged, 1984; Pankow, 1990.

Description: Cells solitary, narrowly rectangular in girdle view. Valves linear-elliptic, with concave or slightly constricted sides, dividing the valve into two tongue-shaped segments.

Apices broadly cuneate, sometimes sub-acuminate. Margin with strongly marked keel, keel puncta 6 in 10 µm. Valve surface with a distinct longitudinal fold more or less in the apical axis, but usually displaced slightly towards the keel margin. Valve surface striate, striae arranged in transverse and oblique lines, 14-19 in 10 µm. Sometimes the striae cross the apical fold, or the fold may appear to be hyaline (Hendey, 1964).
Dimensions: Length of valve 60-120 µm; breadth 12-30 µm (Hendey, 1964). Length 80-100 µm, breadth 18-22 µm in Mina Al-Ahmadi waters in Kuwait's waters (Hendey, 1970) while in the present specimens, they were 72 µm long and 19 µm wide with 17-20 striae in 10 µm.
Distribution: Reported on all North European coasts. Frequent along the English Channel (Hendey, 1964). A common and widely distributed species on sandy shores all around the world (Hendey, 1964, 1970). It is also observed in Mina Al-Ahmadi waters (Hendey, 1970) and at other localities in Kuwait's waters (present study).
***Remarks:** This species is classified under the new genus *Psammodictyon* D.G. Mann; type species is *P. panduriforme* (Gregory) Mann in Round et al. (1990).

Other *Nitzschia* spp.: Many species of *Nitzschia* are observed in Kuwait's waters.

Nitzschia sp. 1 (Plates 74H and 75A)
Distribution: This species occurs in Kuwait's waters.

Nitzschia sp. 2 (Plates 75B-E)
Distribution: This species occurs in Kuwait's waters.

Nitzschia sp. 3 (Plate 76A)
Distribution: This species occurs in Kuwait's waters.

Nitzschia sp. 4 (Plate 76B-E)
Distribution: This species occurs in Kuwait's waters.

Nitzschia sp. 5 (Plate 76F)
Distribution: This species occurs in Kuwait's waters.

Genus: *Pseudo-nitzschia* Peragallo 1899
It is a geographically, and a widely distributed genus, which is restricted to marine plankton. The identification of this genus will be difficult without the scanning electron microscopy work. According to this it will be only divided as genus into two groups depending on the width of the frustule in valve view:

1. *Pseudo-nitzschia seriata* group (Plates 76G-J and 77A-B)

The frustule width > 3 µm in valve view.

2. *Pseudo-nitzschia delicatssima* group (Plate 77C)

The frustule width ≤ 3 µm in valve view.

Order: Surirellales Mann in Round et al. 1990

Family: Entomoneidaceae Reimer in Patrick and Reimer 1975

Genus: *Entomoneis* Ehrenberg 1845

Cells single or in ribbonlike chains. Cells constricted in the middle. Valves lanceolate, convex, with raphe, central nodule, and a sigmoid keel. One-half of keel lies on each side of the chain axis. Terminal nodules present. Striae transverse, punctate. Girdle or connective zone complex, with numerous longitudinal rows of transverse striae. Chromatophores usually single, along the girdle (Cupp, 1943). One species occurs in Kuwait's waters

Entomoneis sulcata Müller (Plates 77D-F and 78A-B)

Synonyms: *Amphiprora gigantea* var. *sulcata* (O'Meara) Cleve; *Amphiprora sulcata*, O'Meara 1894

References: Peragallo and Peragallo, 1897-1908; Allen and Cupp, 1943; Simonsen, 1974; Hustedt, 1976.

Description: Cells strongly constricted. Keel with a hyaline margin, broader toward the ends. Junction line curved like a bow. Keel with puncta forming obliquely decussating rows, 14-16 in 10 µm. Striae of the valve curved, divergent from the central nodule, 12-14 in 10 µm, not decussating. Median line strongly sigmold. Connecting zone with numerous longitudinal divisions. Striae on connective zone transverse, 21-24 per 10 µm. (Cupp, 1943).

Dimensions: Length of valves 95-120 µm (Cupp, 1943). From the present survey, length 87-155 µm, Breadth 35-60 µm.

Distribution: Found in Southern California (Cupp, 1943). It is present in Kuwait's waters.

Family: Auriculaceae Hendey 1964

Valves symmetrical on the transapical axis, asymmetrical on the apical axis, dorsiventral. Valves auricular or reniform, with the dorsal margin raised in the form of a ridge carrying the raphe (Hendey 1964*).*

Genus: *Auricula* Castracane 1873

Cells solitary, free. Frustules rectangular, with rounded corners, or broadly elliptical to globular with truncate ends, often weakly siliceous, membranaceous. Girdle complex, composed of numerous intercalary bands. Valves auricular, reniform, sometimes elongated to become almost cymbiform, with rounded ends and possessing along the dorsal margin a strongly-formed ridge or keel. The keel is strong and not separated from the valve by a line of juncture, but developes as a continuous structure from the substance of the valve. Raphe carried on the margin of the keel, which is slightly depressed at the central nodule, thereby giving the keel margin a biarcuate appearance, sometimes deeply so. Valve structure striate, striae sometimes finely punctate, striae arranged in curved, radiating or irregular lines. A wide degree of variation is encountered in the shape of the valves in each species, and the keel in this, as in other genera possessing it, tends to make the valve lie in positions that present different aspects and give different degrees of arcuity to the dorsal margin. Chromatophore, a large single body lying along the ventral side of the girdle (Hendey, 1964). One species occurs in Kuwait's waters and its name is not finalized at this stage and is reported as species 1 (plate not included).

Family: Surirellaceae Kützing 1844

The *Surirellaceae* comprises four genera, of which only *Surirella* Turpin and *Campylodiscus* Ehrenberg are represented in the marine flora. The diagnostic character of the family is that the raphe is carried on a wing-like projection around the valve margin (Hendey, 1964).

Genus: *Surirella* Turpin 1828

Cells single. In girdle view linear or wedge-shaped. Valves linear, elliptical or oval, sometimes constricted. Costae long or short, extending toward the center but not quite to it, with intermediate striae more or less evident. Central space linear or lanceolate, often obscure. Valves with a longitudinal central pseudoraphe and marginal, more or less elevated, undulated keel produced into winglike expansions containing the raphe on each side. Pseudoraphes of the two valves parallel. Raphe difficult to see. Distinct canal pores usually visible. Valve surface nearly flat, rarely spirally twisted. Bottom and littoral forms found occasionally in the plankton (Cupp, 1943). Hendey (1970) reported 8 different *Surirella* spp. in Mina Al-Ahmadi waters (Kuwait's waters). Four species were encountered from our samples in Kuwait's waters. One of the species names is not finalized at this stage and is reported as species 1.

Surirella fastuosa Ehrenberg (Plate 79A-I)

References: Peragallo and Peragallo, 1897-1908; Allen and Cupp, 1935; Hendey, 1964; Simonsen, 1974; Foged, 1984; Ricard, 1987; Pankow, 1990; Witkowski et al., 2000.

Description: Cell solitary, cuneate, with rounded angles. Valves broadly ovate, marginal alae small. Costae few, 1-2 in 10 µm, dilated towards the margin, and becoming narrow as they proceed towards the broadly lanceolate central area. Valve surface striate, striae evident at the margin, and in a narrow band about half-way between the margin and the center of the valve. This narrow striate zone is almost parallel with the valve margin (Hendey, 1964).

Dimensions: Length of valve 60-130 µm. Length/breadth ratio about 1.5 : 1 (Hendey, 1964). In the present material (Kuwait's waters), length 38-71 µm and breadth 20-45 µm.

Distribution: A common marine species frequent in harbours and estuaries in all North Sea countries (Hendey, 1964). It is common in Kuwait's waters.

Surirella cf. *hybrida* Grunow (Plate 80A-B)

References: Hendey, 1970; Witkowski et al., 2000.

Dimensions: Length 90-100 µm, breadth 36-40 µm in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) while in the present survey (Kuwait's waters), length 83 µm and breadth 31 µm.

Distribution: Found in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) and at other localities in Kuwait's waters (present study).

Surirella scalaris Giffen (Plate 80C-D)

References: Witkowski et al., 2000.

Description: Valves heteropolar, elliptic to ovate with broadly rounded apices. Marginal structure narrow, fibulae, 25-30 in 100 µm, sternum more or less linear, structured with a row of distinct striae, 15-18 in 10 µm; the surface of the valve striated with 20-23 striae in 10 µm (Witkowski et al., 2000).

Dimensions: 18-32 µm long, 13-24 µm broad (Witkowski et al., 2000). From the present survey (Kuwait's waters), length 16-17 µm and breadth 13-15 µm.

Distribution: Described from South Africa in the material studied it occurred in sample from Kenia (Witkowski et al., 2000). It is also found in Kuwait's waters.

Surirella sp.1 (Plate 80E-F)

Dimensions: In the present material (Kuwait's waters) length 77.5 µm and breadth 32.5 µm.

Distribution: Found in Kuwait's waters.

Genus: *Plagiodiscus* Grunow and Eulenstein 1867

Cells solitary, disc-like, reniform in valve view. Plastids unknown. A marine, coastal genus containing a few species, which have sometimes been classified in *Surirella* (Round et al., 1990). One species occurs in Kuwait's waters.

Plagiodiscus nervatus Grunow (Plate 80G-H)

Synonym: *Surirella reniformis* Peragallo and Peragallo 1897-1908.

References: Hendey, 1970; Foged, 1984; Ricard, 1987; Round et al., 1990.

Description: Valves broad, with a central indentation on one side. Valve face flat or slightly undulate, slightly ribbed externally near the raphe system, often with granules externally. Valve face separated from mantles by the slightly keeled raphe system, which runs around the whole perimeter of the valve as in *Surirella.* Mantle shallow on the ventral (indented) side, but rising along the dorsal side from either end towards the centre. Striae bi- to multiseriate, containing small round poroids.Valve interior with conspicuous ribs, which cross beneath the raphe system and there thicken to form angle irons; they also function as fibulae. The ribs thin towards the center or fuse with a curved rib along the midline of the valve (Round et al., 1990).

Dimensions: Length 52-64 µm, breadth 27-28 µm in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) and in the present survey, obtained other localities in Kuwait's waters, Length 62.5 µm and breadth 35 µm.

Distribution: Widely distributed in the Pacific, being found in the Philippine and Hawaiian Islands. Recorded from tropical or subtropical waters (Round et al., 1990). It is also observed in Mina Al-Ahmadi waters (Kuwait's waters) (Hendey, 1970) and at other localities in Kuwait's waters (present study).

REFERENCES

Allen, W. E., and E.E. Cupp. 1935. Plankton diatoms of the Java Sea. Annales Du Jardin Botanique, De Buitenzorg, **44 (2):** 101-174.

Al-Yamani, F.Y., J. Bishop, E. Ramadhan, M. Al-Husaini, and A.N. Al-Ghadban. 2004 Oceanographic Atlas of Kuwait's Waters. Kuwait Institute for Scientific Research, Kuwait. 203p.

Bérard-Therriault, L., M. Poulin, L. Bossé. 1999. *Guide d'identification du phytoplankton marin de l'Estuaire et du Golfe du Saint-Laurent*. Ottawa: Les presses scientifiques du CNRC.

Blaze, K.L. (1984). Morphology and taxonomy of Diplomenora gen:nov. (Bacillariophyta). Br. Phycol. Journal. **19:** 217-225.

Bu-Olayan, A. H., R. Al-Hassan, B. V. Thomas, and M.N.V. Subrahmanyam. 2001. Impact of trace metals and nutrients levels on phytoplankton from the Kuwait Coast. Environment International **26:** 199-203.

Cupp, E.E. 1943. Marine plankton diatoms of the west coast of North America, Vol. 5, No. 1. Berkeley and Los Angeles, University of California Press, pp. 1-238.

Dorgham, M. M., A. Muftah and K. Z. El-Deeb. 1987. Plankton studies in the Arabian Gulf: II- The autumn phytoplankton in the northwestern area. Arab Gulf J. Scient. Res. Agric. Biol. Sci. B5 **(2):** 215-235.

Dorgham, M. M. and A. Muftah. 1989. Environmental conditions and phytoplankton Stations in the Arabian Gulf of Oman, September 1986. Journal of Marine Biological Association of India, **31:** 36-53.

Drebes, G. 1974. *Marines Phytoplankton: Eine Auswahl der Helgolander Planktonalgen (Diatomeen, Peridineen)*. Stuttgart, Germany: Georg Thieme Verlag.

Droop, S. J. M., Mann, D. G. and Lokhorst, G. M. 2000. Spatial and temporal stability of demes in *Diploneis smithii*/*D. fusca* (Bacillariophyta) supports a narrow species concept **39**: 527-546.

Foged, N. 1984. *Freshwater and Littoral Diatoms from Cuba*, Band 5. Vaduz: J. Cramer.

Fryxell, G. A., and Hasle, G. R. 1980. The marine diatom *Thalassiosira oestrupii*: structure, taxonomy and distribution. American Journal of Botany **67**: 804-814.

Glezer, S. I., Makarova, I. V. (editor-in-cheif), Moisseeva, A. I., and Nikolaev, V. A. 1988. The Diatoms of the USSR, Fossil and Recent 2(1): Pyxidieulaceae, Thalassiosiropsidaceae, Triceratiaceae, Thalassiosiraceae. Nauka publisher, Leningrad. 116 PP. 61 plates (In Russian).

Hargraves, P. E. 1990. Studies on marine plankton diatoms: V. Morphology and distribution on *Leptocylindrus minimus* Gran. Beiheft zur Nova Hedwigia **100**: 47-60.

Hasle, G.R. 1969. An analysis of the phytoplankton of the Pacific Southern Ocean: Abundance, composition and distribution during the "Brategg" Expedition, 1947-1948. Hvalrad. Skr. **52:** 1-168.

Hasle, G. R. 1973. Some marine plankton genera of the diatom family Thalassiosiraceae. Beiheft zur Nova Hedwigia **45**: 1-49.

Hasle, G. R. 1974Validation of the names of some marine planktonic species of *Nitzschia* (Bacillariophyceae). TAXON **23:** 425-428.

Hasle, G. R. 1975. Some living marine species of the diatom family Rhizosoleniaceae. Beiheft zur Nova Hedwigia **53**: 99-140.

Hasle, G. R. 1976. The biogeography of some marine planktonic diatoms. Deep-Sea Research **23:** 319-338.

Hasle, G. R., and de Mendiola, B. R. E. 1967. The fine structure of some *Thalassionema* and *Thalassiothrix* species. Phycologia **6**:107-125.

Hasle, G. R., and E. E. Syvertsen. 1997. Marine diatoms. In *Identifying Marine Phytoplankton*. Edited by C.R. Tomas. London : Academic Press.

Hendey, N.I. 1958. Marine diatoms from Weat African Ports. Journal of Royal Microscopic Society, **77:** 28-88.

Hendey, N.I. 1973. The plankton diatoms of the Southern Seas. Discovery Reports, **16:** 151-364. Plates. I-XIII.

Hendey, N.I. 1959. The structure of the diatoms cell wall as revealed by the electron microscope. J. Quekett Microscopial Club, **5:** 147-175.

Hendey, N. I. 1970. Some littoral diatoms of Kuwait. Nova Hedwigia **31:** 101-167.

Hernández-Becerril, D. U., and M. I. Tapia Peña. 1995. Planktonic diatoms from the Gulf of California and Coasts off Baja California: species of the genus *Thalassiosira*. Botanica Marina **38:** 543-555.

Hoek, C. V. D. 1995. Algae: An introductory to phycology. Cambridge University Press: Cambridge.

Hustedt, F., 1930. Die Kieselalgen Deutschlands, Österreichs und der Schweiz. Dr. L. Rabenhorsts Kryptogamen-Flora von Deutschland, Österreich und der Schweiz **7(1):** 1-920.

Hustedt, F., 1927-1966. Die Kieselalgen Deutschlands, Österreichs und der Schweiz, mit Berüchsichtigung der übrigen Lünder Europas sowie der angrenzenden Meeresgebiete. *In* Rabenhorst, L. (Ed.), Kryptogamen Flora von Deutschland, Österreich und der Schweiz: Leipzig (Akademische Verlagsgesellschaft), Teil **I**, Sect. 1-4, pp. 1-920, 1927-1930; Teil **II**, Sect. 1-5, pp. 1-845, 1931-1959; Teil **III**, Sect. 1-3, pp. 1-816, 1961-1966.

Hustedt, F. 1931-1959. Die Kieselalgen Deutschlands, Österreichs und der Schweiz. In Kryptogamen-Flora 7 ((Rabenhorts, L.,ed.), Leipzig, part 2, 1-176 (1931); 177-320 (1932); 321-432 (1933); 433-576 (1933); 577-736 (1937); 737-845 (1959).

Hustedt, F. 1959. Die Diatomeenflora des Neusiedler Sees in osterreichischen Burgenland. Osterreichischen Botanischen Zeitschrift, 106:390-430, See: Diatomaceae 9(11).

Hustedt, F. 1976. *Heft 10. Bacillariophyta (Diatomeae). Zweite Auflage*. Koenigstein, West Germany: Otto Koeltz Science Publishers.

Ismail, W. A., F. Y. Al-Yamani and K. Al-Rifaie. 1999. Guide for the phytoplankton of the Arabian Gulf. Kuwait Institute of Scientific Research, Report No. KISR 5607, Kuwait.

Jacob, P. G. and S. Al-Muzaini. 1990. Marine plants of the Arabian Gulf: A literature review. Kuwait Institute of Scientific Research, Report No. KISR 3426, Kuwait.

Karayeva, N.I. (1978). Novyi podporyadok diatomovykh vodoroslej (A new suborder of diatoms). *Bot*. *Zh*., **93:** 1747-1750.

Karsten, G. 1978. Das indische Phytoplankton. Nach dem Material der Deutschen Tiefsee-Expedition 1898-1899. Germany: Otto Koeltz Science Publishers.

Newell, G.E., and R.C. Newell. 1977. *Marine Plankton*. 5th ed. London: Hutchinson and Co. (Publishers) Ltd.

Pankow, H. 1990. Ostsee-Algenflora. Gustav Fischer Verlag Jena.

Pavillard, J. 1925. Bacillariales. Report on the Danish Oceanographical Expeditions of 1908-10 to the Mediterranean and Adjacent Seas, Volume II. Biology.

Peragallo, H. and M. Peragallo. 1897-1908. *Diatomées Marines de France*. Germany: Koeltz Scientific Books.

Prescott, G. W. 1978. How to know the freshwater algae. Third edition. Dubuque: Wm. C. Brown Company Publishers.

Priddle, J., and G. Fryxell. 1985. Handbook of the Common Plankton Diatoms of the Southern Ocean: Centrales Except the Genus. *Thalassiosira*. Cambridge: British Antarctic Survey.

Ricard, M. 1977. Les peuplements de diatomées des lagons de l'archipel de la société (Polynésie française). Floristique, écologie, structure des peuplements et contribution à la production primaire. Revue Algologique **12** (3/4): 141-336 - Volume7.

Ricard, M. 1987. *Atlas du Phytoplankton Marin*, Vol. 2: *Diatomophycées*. Paris : Editions du CNRS.

Round, F.E., R.M. Crawford and D.G. Mann. 1990. *The Diatoms: Biology and Morphology of the Genera*. New York: Cambridge University Press.

Semina, H. J. 2003. SEM-Studied Diatoms of Different Regions of the World Oceans. Rugell: A. R. G. Gantner Verlag Kommanditgesellschaft.

Simonsen, R. 1972. Ideas for a more natural system of the centric diatoms. Nova Hedwigia, Beih. **39:** 37-54.

Simonsen, R. 1974. The diatom plankton of the Indian Ocean Expedition of RV "Meteor" 1964-1965. "Meteor" Forschungsergebnisse Reihe D **19:**1-107.

Simonsen, R. 1975. Om the pseudonodulus of the centric diatoms, or Hemidiscaceae reconsidered. Beheft zur Nova Hedwigia **53:** 83-94.

Simonsen, R. 1979., The diatoms system: ideas on phylogeny. Bacillaria, **2:** 9-71.

Sournia, A. 1986.Diatomees planctoniques du Canal de Mozambique et de l'ile Maurice. Memoire O.R.S.T.O. M. **31:** 1-120. Paris.

Stidolph, S. R. 1980. A record of some coastal marine diatoms from Porirua Harbour, North Island, New Zealand. New Zealand Journal of Botany **18:** 379-403.

Subba Rao, D. V. and F. Al-Yamani. 1998. Phytoplankton ecology in the waters between Shatt Al-Arab and Straits of Hormuz, Arabian Gulf: A review. Plankton Biol. Ecol. **45 (2):** 101-116.

Subba Rao, D. V. and F. Al-Yamani. 1999. Eolian dust affects phytoplankton in the waters off Kuwait, the Arabian Gulf. Naturwissenschaften **86:** 525-529.

Sundström, B. G. 1986. *The Marine Diatom Genus* Rhizosolenia: *A New Approach to the Taxonomy*. Sweden: Lund.

Sykes, J. B. 1981. An illustrated guide to the diatoms of British coastal plankton. Field Studies **5:** 425-468.

Thompson, P. A. 1998. Spatial and temporal patterns of factors influencing phytoplankton in a Salt Wedge Estuary, the Swan River, Western Australia. Estuaries **21 (4B):** 801-817.

Throndsen, J., Hasle, G.R., and Tangen, K. 2003. Norsk Kystplankton Flora. Almater Forlag AS, 341 PP. (in Norwegian).

Villareal, T.A., Fryxell, G.A., 1983. The Genus Actinocyclus (Bacillariophyceae): frustule morphology of A. sagittulus sp. nov. and two related species. Journal of Phycoloy **19:** 452-466.

Witkowski, A., Lange-Bertalot, H., and Metzeltin, D. 2000. Diatom flora of marine coasts I. In *Iconographia Diatomologica Annotated Diatom Micrographs*. Edited by Horst Lange-Bertalot. Ruggel: A. R. G. Gantner Verlag Kommanditgesellschaft.

Wood, E. J. F. 1961. Studies on Australian and New Zealand Diatoms V. The Rawson Collection of Recent Diatoms. Transaction of the Royal Society if New Zealand. **88** (4): 699-712.

LIST OF PLATES

Note: MC in plate legend means "Magnified Cell"

Chapter 3

DINOFLAGELLATES

INTRODUCTION

The vast majority of Dinoflagellates are small (usually less than 100 µm) unicellular flagellates which swim freely in water and only a few are coccoid or filamentous. In addition, there are some curious and highly specialized heterotrophic forms. The name ‘dino’ comes from a Greek word meaning ‘whirling’ as this type of movement is characteristic of these organisms. Most of the dinoflagellates (about 90% of the species) are marine or brackish water, while the remainder are fresh water species. Species may be planktonic, benthic or epiphytic, some live as symbionts, for example the zooxanthella of corals and other invertebrates, and some are obligate parasites.

Dinoflagellates are characterized by the presence of two dissimilar flagella, one is ribbon-shaped and encircles the cell in a semi-helical fashion, the transverse flagellum, the second is whip-like and trails behind the cell, the longitudinal flagellum. In most species flagella are situated in furrows on the cell body, the transverse furrow, cingulum, and the longitudinal furrow, sulcus (dinokont cell type). The side of the cell from which the flagella originate is by convention termed the ventral side, with left and right sides (Fig. 1). In a few groups, like the prorocentroids, the flagella arise anteriorly and the cingulum and sulcus are absent (desmokont cell type) (Taylor, 1987; Hansen et al., 2001). The transverse flagellum provides propulsion and the longitudinal flagellum provides direction (Steidinger and Tangen, 1997). The schematic desmokont and the dinoflagellate cell type are shown in figure 1 and the dinokont cell type in figures 1 and 2.

Most dinoflagellates have a distinct nucleus, and the condensed chromosomes are usually visible as either discrete “points” or short rods under the light microscope. The chloroplasts, where present, are surrounded by three membranes, none of which is connected to the

endoplasmic reticulum. A few dinophytes have aberrant chloroplasts, which represent eukaryotic endosymbionts, reduced to a greater or lesser extent. Many dinophytes are heterotrophic and lack chloroplasts. The most important chlorophyll is chlorophyll *a*, with chlorophyll C_2 also present. Again, there are some interesting exceptions to this among the species with endosymbionts; chlorophyll *b* is absent. The chloroplasts are usually brown, since the green chlorophylls are masked by yellow and brown accessory pigments (ß-carotene and several xanthophylls, of which the most important is peridinin). Certain species with endosymbiotic algae possess other accessory pigments. Pyrenoids of various kinds occur in dinophyte chloroplasts. For instance, they can be stalked or embedded within the chloroplast. They may be partly penetrated by thylakoids (Hoek, 1995).

Dinoflagellates may be divided into armoured and unarmoured (naked) species based on the presence or absence of thecal plates. Like the diatoms, most Dinophyta are covered with a species-specific ‘armour’, which is often strange and beautiful in its shape and ornamentation. The resemblance to the diatoms is only superficial, however, since the armour of the two groups differs in both structure and chemical composition. The dinophyte armour is divided into an upper (epicone or epitheca) and a lower (hypocone or hypotheca) half, and consists of polygonal plates, which fit tightly against each other. The important constituent of the armour is a polysaccharide, apparently cellulose, whereas in the diatoms the wall elements are made of silica (Hoek, 1995). The taxonomy of armoured dinoflagellates is primarily based on the arrangement and number of the thecal plates, whereas the taxonomy of the unarmoured species has primarily been based on cell shape and cingular and sulcal arrangement (Hansen et al., 2001).

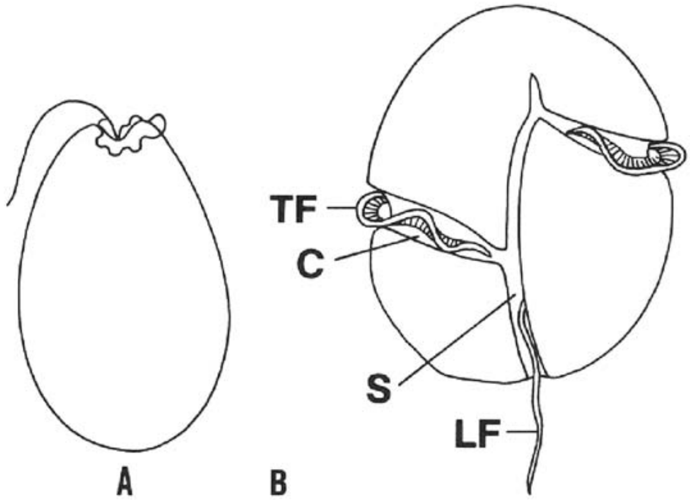


Figure 1. (A) Lateral view of a desmokont cell illustrating anterior location of two dissimilar flagella. (B) Ventral view of dinokont cell type illustrating location of two dissimilar flagella, both housed in furrows. Longitudinal flagellum (LF), transverse flagellum (TF), cingulum (C); sulcus (S), (Steidinger and Tangen, 1997).

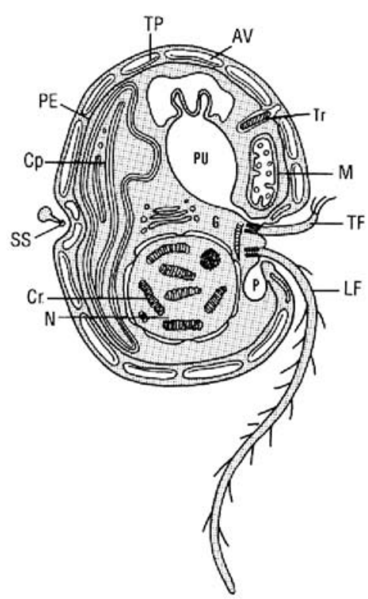
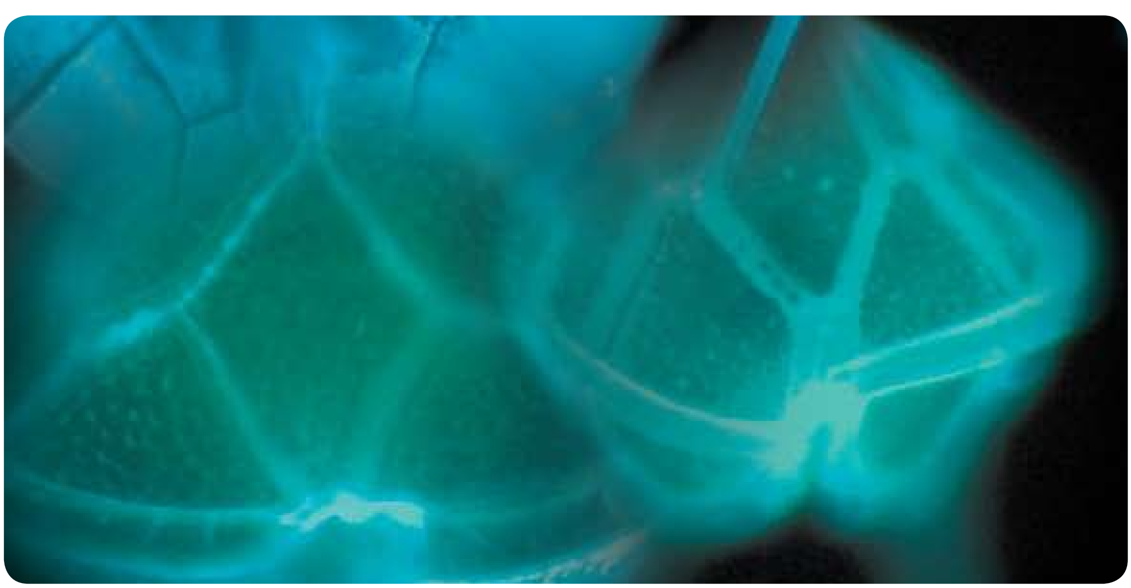


Figure 2. Lateral view of dinokont cell illustrating insection of flagella and typical dinophycean organelles. Thecal vesicle (AV) with thecal plate material (TP), chloroplast (CP), chromosome (Cr), Golgi apparatus (G), longitudinal flagellum (LF), mitrochondria (M), nucleus (N), pellicle layer (PE), pusule (PU), striated strand (SS) of tranverse flagellum (TF), trichocyst (Tr). Redrawn from Taylor (1980).

The armored or thecate dinoflagellates comprise the Prorocentroid, the Dinophysoid, the Gonyaulacoid and Peridiniod species (Figure 3). They differ in the number and arrangement of their plates which is known as tabulation. The basic system, as worked out by Kofoid, consists of a number of series of plates: apicals, precingulars, cingulars, sulcals, postcingular and antapicals; designated ’,’’, c, s,’’’,’’’’, respectively. Intercalary plates may also be present (Dodge, 1982).
The unarmored or naked flagellates comprise the Gymnodiniod species (600-700). A combination of characters is used to identify the unarmored dinoflagellates to genera and species: 1) size, shape and proportions of the cells, 2) cingular position and displacement, 3) sulcal placement and intrusion on the epicone, 4) presence/absence of an apical groove and its shape, and 5) presence and location of organelles e.g. nucleus, nuclear capsule, chloroplasts, pyrenoid, nematocysts, stigma or ocelloid. In order to observe any of these characters it is usually necessary to observe live cells, as most unarmored dinoflagellates are very delicate and will not withstand normal fixations like Lugol’s solution or formalin.

Cingular position and displacement have been used as a main character at the generic level (Figure 4). For example the genera *Gymnodinium* and *Gyrodinium* have been separated only on the degree of cingular displacement, which in *Gymnodinium* must not exceed 20% of the body length, whereas in *Gyrodinium* it is more than 20% (Kofoid & Swezy 1921). Recent progress in ultrastructual and molecular sequence analysis has shown that *Gymnodinium/ Gyrodinium*, as presently defined, are polyphyletic, and *Gymonodinium* has been split into several new genera (see Daugbjerg et al. 2000). *Gymnodinium* sensu stricto is now characterized by (1) the presense of a horseshoe-shaped apical groove (Figure 5), which runs in an anticlockwise direction around the apex of the cell, (2) distinct chambers in the nuclear envelope, and (3) a nuclear fibrous connective, which interlinks the nucleus and the flagellar apparatus. The important neurotoxic and/or fish kiling species *Gymnodinium breve* and G. *mikimotoi* have been transferred to a new genus *Karenia*, which is characterized by the presence of a straight apical groove (Figure 5), absence of nuclear chambers and absence of a nuclear fibrous connective (Daugbjerg et al., 2001).



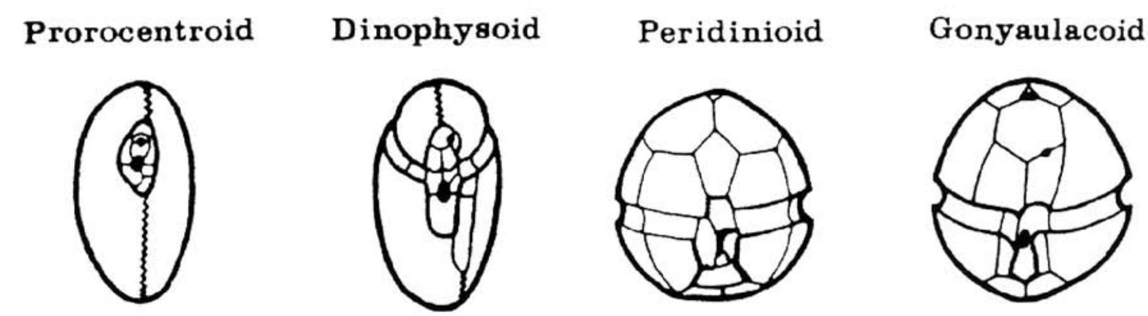


Figure 3. Armored dinoflagellates classified according to the number and arrangement of their plates.

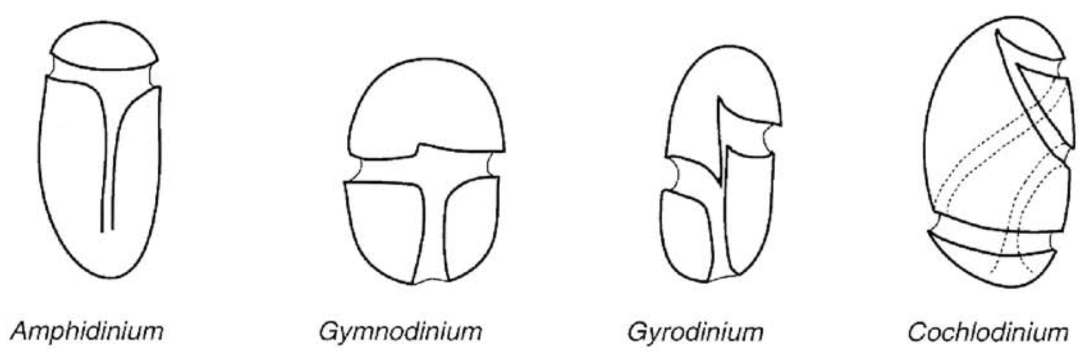


Figure 4. Unarmoured dinoflagellates classified according to cingular displacement (Hansen et al., 2001).

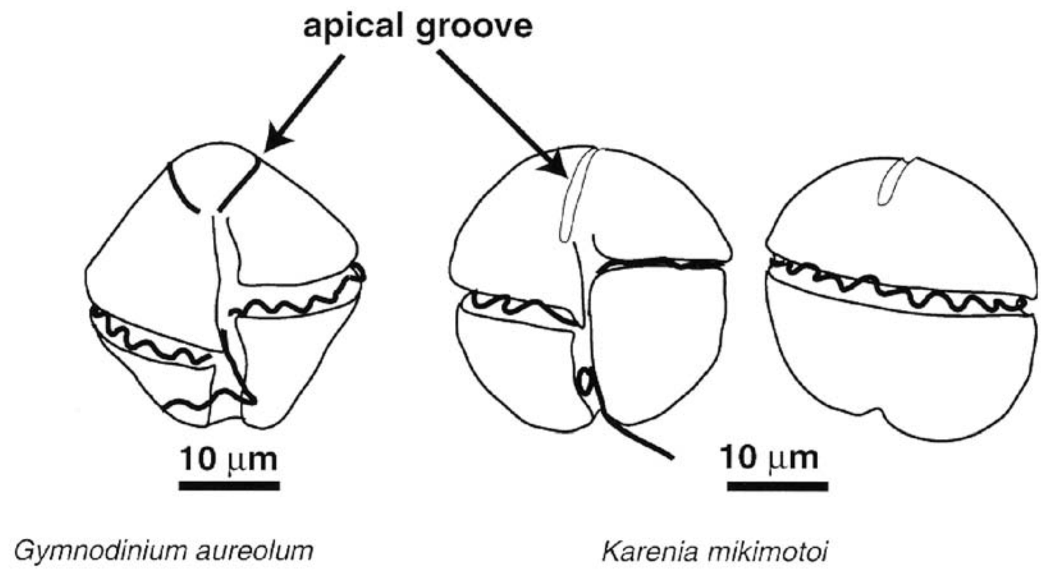


Figure 5. Unarmored dinoflagellates classified according to type of apical groove (from Daugbjerg et al., 2000).

TAXONOMIC LIST OF MARINE DINOFLAGELLATES IN KUWAIT'S WATERS

Many dinoflagellate species were identified from Kuwait's waters reaching a total of 105 species representing 37 genera belonging to 5 orders and 17 families. All the genera and species dealt with in this atlas are recorded in the list in Table 1. They are classified in accordance with Fensome et al., (1993) and Steidinger and Tangen (1997) under the division Pyrrophyta (or Dinophyta) in which they are categorized into two classes, Dinophyceae and Desmophyceae, and five orders, Prorocentrales Lemmermann 1910, Dinophysiales Lindemann 1928, Noctilucales Haeckel 1894, Gonyaulacales F. J. R. Taylor 1980 and Peridiniales Haeckel 1894. The typefaces used for each classification are denoted thus: Phylum, Class, Order, Family, Genus. Many old and recent literature were used in the identification of dinoflagllates such as Schiller (1937), Dodge (1982), Taylor (1987), Steidinger and Tangen (1997) and Larsen and Nguyen et al. (2004).

Table 1. Taxonomic list of marine dionflagellates in Kuwait's waters.

Phylum	Class	Sub-Class	Order	Family	Genus and Species
Pyrrophyta (or Dinophyta)	Dinophyceae West and Fritch 1927		Prorocentrales Lemmermann 1910	Prorocentraceae Stein 1883	*Prorocentrum* Ehrenberg 1833 *Prorocentrum balticum* (Lohmann) Loeblich III 1970 *Prorocentrum compressum* (Baily) Abé ex Dodge 1975 *Prorocentrum gracile* Schütt 1895 *Prorocentrum lima* (Ehrenberg) stein 1878 *Prorocentrum micans* Ehrenberg 1833 *Prorocentrum rhathymum* Loeblich III, Sherley and Schmidt 1979 *Prorocentrum triestinum* Schiller 1918 *Prorocentrum* sp.1
	Desmophyceae Smith		Dinophysiales Lindemann 1928	Dinophysiaceae Stein 1883	*Dinophysis* Ehrenberg 1839 *Dinophysis acuta* Ehrenberg 1841 *Dinophysis caudata* Saville-Kent 1881 *Dinophysis miles* Cleve *Dinophysis mitra* (Schutt) Abé 1967 *Dinophysis norvegica* Claparède and Lachmann 1859 *Dinophysis rotundata* Claparède and Lachmann 1859 *Histioneis* Stein 1883 *Histioneis costata* Kofoid and Michener 1911 *Ornithocercus* Stein 1883 *Ornithocercus magnificus* Stein 1883 *Pseudophalacroma* Jörgensen 1923 *Pseudophalacroma nasutum* Kofoid and Skogberg 1928
			Gymnodinialis Lemmermann 1910	Gymnodiniaceae Lankester 1885	*Amphidinium* Claparède and Lachmann 1859 *Amphidinium* sp. 1 *Cochlodinium* Schütt 1896 *Cochlodinium* sp. 1 *Akashiwo* Hansen et Moestrup 2000 *Akashiwo sanguinea* (Hirasaka) G. Hansen et Moestrup 2000 *Gymnodinium* Stein 1878 *Gymnodinium* spp. cf. aff. *gracilentum* *Gyrodinium* Kofoid and Swezy 1921 *Gyrodinium* sp. 1 *Gyrodinium* sp. 2 *Gyrodinium* sp. 3 *Katodinium* Fott 1957 *Katodinium glaucum* (Lebour) Loeblich III 1965 *Torodinium* Kofoid and Swezy 1921 *Torodinium robustum* Kofoid and Swezy 1921
				Kareniaceae Bergholtz, Daugbjerg, Moestrup and Ferna'ndez-Tejedor 2005	*Karenia* G. Hansen and Moestrup 2000 *Karenia selliformis* Haywood, Steidinger and Mackenzie 2004 *Karenia* cf. *brevis* (Davis) G. Hansen and Moestrup 2000
				Polykrikaceae Kofoid and Swezy 1921	*Polykrikos* Bütschli 1873 *Polykrikos schwartzii* Bütschli 1873
			Noctilucales Haeckel 1894	Noctilucaceae Kent 1881	*Noctiluca* Suriray 1836 *Noctiluca scintillans* (Macartney 1836) Kofoid and Swezy 1921 *Pronoctiluca* Fabre-Domergue 1889 *Pronoctiluca pelagica* Fabre-Domergue 1889
			Gonyaulacales F. J. R. Taylor 1980	Ceratiaceae Lindemann 1928	*Ceratium* Schrank 1793 *Ceratium breve* (Ostenfeld and Schmidt) Schröder 1906 *Ceratium furca* (Ehrenberg 1836) Claparéde and Lachmann 1859 *Ceratium fusus* (Ehrenberg 1834) Dujardin 1841 *Ceratium lineatum* (Ehrenberg) Cleve 1899 *Ceratium massiliense* (Gourret) Jörgensen 1911 *Ceratium trichoceros* (Ehrenberg) Kofoid 1908 *Ceratium tripos* (O. F. Müller 1781) Nitzsch 1817 *Ceratium* sp. 1
				Cladopyxidaceae Stein 1883	*Cladopyxis* Stein 1883 *Cladopyxis hemibrachiata* Balech 1964
				Goniodomataceae Lindemann 1928	*Alexandrium* Halim 1960 *Alexandrium insuetum* Balech 1985 *Alexandrium leei* Balech 1985 *Alexandrium minutun* Halim 1960 *Alexandrium tamarense* (Lebour) Balech 1985 *Alexandrium* sp. 1 *Goniodoma* Stein 1883 *Goniodoma polyedricum* (Pouchet) Jörgensen 1899 *Pyrodinium* Plate 1906 *Pyrodinium bahamense* var. *compressum* (Böhm) Steidenger, Tester, and Taylor 1980

Phylum	Class	Sub-Class	Order	Family	Genus and Species
				Gonyaulacaceae Lindemann 1928	*Gonyaulax* Diesing 1866
					Gonyaulax polygramma Stein 1883
					Gonyaulax sp.1
					Lingulodinium (Wall) Dodge 1989
					Lingulodinium polyedrum (Stein) Dodge 1989
					Protoceratium Bergh 1881
					Protoceratium reticulatum (Claparéde and Lachmann) Bütschli 1885
					Protoceratium sp. 1
				Oxytoxaceae Lindemann 1925	*Corythodinium* Loeblich Jr. & Loeblich III 1966
					Corythodinium tesselatum (Stein) Loeblich Jr. & Loeblich III 1966
					Oxytoxum Stein 1883
					Oxytoxum gracile Schiller 1937
					Oxytoxum sceptrum (Stein) Schröder 1906
					Oxytoxum sp. 1
				Pyrocystaceae (Schütt) Lemmerman 1899	*Pyrocystis* Murray *ex* Haeckel 1890
					Pyrocystis obtusa Pavillard 1931
					Pyrocystis fusiformis Wyville-Thomson in Murray 1885
				Pyrophacaceae Lindemann 1928	*Pyrophacus* Stein 1883
					Pyrophacus horologicum Stein 1883
					Pyrophacus steinii (Schiller) Wall & Date 1971
				Calciodinellaceae F. J. R. Taylor 1987	*Scrippsiella* Balech 1959
					Scrippsiella trochoidea (Stein) Loeblich III 1976
			Peridiniales Haeckel 1894	Kolkwitziellaceae Lindemann 1928	*Diplopsalis* Bergh 1881
					Diplopsalis lenticula Bergh 1881
					Diplopsalopsis Meunier 1910
					Diplopsalopsis orbicularis (Paulsen) Meunier 1910
					Diplopelta Stein ex Jörgensen
					Diplopelta parva (Abé) Matsuoka 1988
					Oblea Balech 1964
					Oblea rotunda (Lebour) Sournia 1973
					Preperidinium Mangin 1913
					Preperidinium meunieri (Pavillard) Elbrächter 1993
				Peridiniaceae Ehrenberg 1828	*Heterocapsa* Stein 1883
					Heterocapsa sp.1
				Protoperidiniaceae F. J. R. Taylor	*Protoperidinium* Bergh 1881
					Protoperidinium biconicum (Dangeard) Balech
					Protoperidinium bipes (Paulsen 1904) Balech 1974
					Protoperidinium cerasus (Paulsen 1904) Balech 1974
					Protoperidinium claudicans (Paulsen) Balech 1974
					Protoperidinium conicum (Gran) Balech 1974
					Protoperidinium crassipes (Kofoid) Balech 1974
					Protoperidinium curtipes (Jörgensen) Balech 1974
					*Protoperidinium depressum (*Bailey 1855) Balech
					Protoperidinium divergens (Ehrenberg) Balech 1974
					Protoperidinium elegans (Cleve) Balech 1974
					Protoperidinium grande Kofoid 1907
					Protoperidinium leonis (Pavillard) Balech 1974
					Protoperidinium marie-lebourae (Paulsen) Balech 1974
					Protoperidinium minutum (Kofoid) Leoblich III 1970
					Protoperidinium murrayi Kofoid 1907
					Protoperidinium ovatum Pouchet 1833
					Protoperidinium pellucidum (Bergh) Balech 1974
					Protoperidinium pentagonum Gran 1902
					Protoperidinium punctulatum (Paulsen 1907) Balech
					Protoperidinium spiniferum (Schiller) Balech 1974
					Protoperidinium steinii (Jorgensen) Balech 1974
					Protoperidinium subinerme (Paulsen) Leoblich III 1970
					Protoperidinium thorianum (Paulsen) Balech 1974
					Protoperidinium ventricum (Abé) Balech 1974
					Protoperidinium sp. 1
					Protoperidinium sp. 2
					Protoperidinium sp. 3
					Protoperidinium sp. 4
					Protoperidinium sp. 5
					Protoperidinium sp. 6
					Protoperidinium sp. 7
					Protoperidinium sp. 8
					Protoperidinium sp. 9
					Protoperidinium sp. 10
					Protoperidinium sp. 11
					Protoperidinium sp. 12
					Protoperidinium sp. 13

Phylum	Class	Sub-Class	Order	Family	Genus and Species
				Podolampaceae Lindemann 1928	*Blepharocysta* Ehrenberg 1873 *Blepharocysta splendormaris* Ehrenberg 1859 *Podolampas* Stein 1883 *Podolampas palmipes* Stein 1883 *Podolampas bipes* Stein 1883

Geographical Distribution of Marine Dinoflagellates in Kuwait's Waters

The distribution of all the identified genera and species of dinoflagellates that were obtained from 13 different stations of Kuwait's waters are given in alphabetical order in Table 2.

Table 2. Geographical distribution of dinoflagellate species composition at different localities in Kuwait's waters.

Species composition	Khor Al-Sabiya	North Failaka Island	Western end of Kuwait Bay	Mid-Kuwait Bay	Eastern end of Kuwait Bay	Off Ras Al-Ardh	Off Al-Fintas	Off Al-Ahmadi	Off Mina Abdulla	Off Ras Al-Qulaiah	Off Mina Zor	Off Kuwait Naval Base	Off AL-Khiran
Akashiwo sanguinea		+	+					+		+	+	+	+
Alexandrium insetum		+											
Alexandrium leei	+												
Alexandrium minutum	+												
Alexandrium tamarense			+										
Alexandrium sp.1			+	+									
Amphidinium sp. 1			+		+	+	+	+	+			+	+
Blepharocysta splendormaris												+	
Ceratium brevis			+	+		+	+	+	+		+	+	+
Ceratium furca	+	+	+	+	+	+	+	+	+	+	+	+	+
Ceratium fusus			+	+	+	+	+	+	+	+	+	+	+
Ceratium lineatum			+	+	+	+	+		+			+	
Ceratium massiliense			+	+		+	+	+	+			+	+
Ceratium trichoceros			+		+	+	+	+	+			+	+
Ceratium tripos						+			+				
Ceratium sp. 1			+										
Cladopyxis hemibrachiata			+		+	+						+	
Cochlodinium sp.1					+	+	+						
Corythodinium tesselatum	+		+					+					
Dinophysis acuta		+											
Dinophysis caudata			+	+	+	+	+	+	+		+	+	+
Dinophysis miles			+	+	+	+	+	+	+			+	
Dinophysis mitra							+	+	+			+	+
Dinophysis norvegica			+										
Dinophysis rotundata			+				+	+	+		+	+	
Diplopelta parva	+		+				+						
Diplopsalis lenticula							+						+
Diplopsalopsis orbicularis	+		+						+				
Goniodoma polyedricum						+			+				+
Gonyaulax polygramma			+		+		+	+	+			+	+
Gonyaulax sp.1													+
Gymnodinium cf. aff. *G. gracilentum*			+	+	+	+	+	+	+	+	+	+	+
Gyrodinium sp. 1		+	+	+	+	+	+	+	+	+	+	+	+
Gyrodinium sp. 2	+												
Gyrodinium sp. 3		+							+				
Heterocapsa sp. 1			+										
Histioneis costata					+		+	+	+		+	+	+
Karenia selliformis													
Karenia cf. *brevis*		+	+	+	+	+	+						
Katodinium glaucum			+				+						
Lingulodinium polyedrum													+
Noctiluca scintillans		+	+			+	+	+	+				

Species composition	Khor Al-Sabiya	North Failaka Island	Western end of Kuwait Bay	Mid-Kuwait Bay	Eastern end of Kuwait Bay	Off Ras Al-Ardh	Off Al-Fintas	Off Al-Ahmadi	Off Mina Abdulla	Off Ras Al-Qulaiah	Off Mina Zor	Off Kuwait Naval Base	Off AL-Khiran
Oblea rotunda	+								+				
Ornithocercus magnificus			+						+			+	+
Oxytoxum gracile			+				+	+	+	+			+
Oxytoxum sceptrum												+	
Oxytoxum sp. 1			+					+	+	+	+	+	+
Podolampas palmipes							+	+	+	+	+	+	+
Podolampas bipes									+				
Polykrikos schwartzii				+			+						
Preperidinium meunieri		+											
Pronoctiluca pelagica								+					
Prorocentrum balticum			+		+		+						
Prorocentrum compressum			+		+	+	+		+			+	
Prorocentrum gracile		+	+	+	+	+	+	+	+		+	+	+
Prorocentrum lima			+			+							
Prorocentrum micans		+	+	+	+	+	+	+	+		+	+	+
Prorocentrum rhathymum			+										
Prorocentrum triestinum			+										
Prorocentrum sp. 1													
Protoceratium reticulatum								+	+				+
Protoceratium sp.1													+
Protoperidinium biconicum				+									
Protoperidinium bipes			+										
Protoperidinium cerasus			+					+	+				
Protoperidinium claudicans	+		+										
Protoperidinium conicum			+		+		+	+				+	
Protoperidinium crassipes			+				+						
Protoperidinium curtipes			+		+	+	+		+			+	+
Protoperidinium depressum			+			+	+	+	+	+		+	
Protoperidinium divergens									+				+
Protoperidinium elegans			+						+				+
Protoperidinium grande							+						
Protoperidinium leonis							+						
Protoperidinium marie-lebourae			+										
Protoperidinium minutum	+												
Protoperidinium murrayi			+				+		+			+	+
Protoperidinium ovatum													+
Protoperidinium pellucidum							+						+
Protoperidinium pentagonum			+				+	+				+	
Protoperidinium punctulatum			+										
Protoperidinium spiniferum													+
Protoperidinium steinii			+				+						+
Protoperidinium subinerme	+		+				+						+
Protoperidinium thorianum									+				
Protoperidinium ventricum									+				
Protoperidinium sp. 1									+			+	
Protoperidinium sp. 2							+		+			+	
Protoperidinium sp. 3			+			+			+				+
Protoperidinium sp. 4			+					+	+				

Species composition	Khor Al-Sabiya	North Failaka Island	Western end of Kuwait Bay	Mid-Kuwait Bay	Eastern end of Kuwait Bay	Off Ras Al-Ardh	Off Al-Fintas	Off Al-Ahmadi	Off Mina Abdulla	Off Ras Al-Qulaiah	Off Mina Zor	Off Kuwait Naval Base	Off AL-Khiran
Protoperidinium sp. 5													+
Protoperidinium sp. 6									+				
Protoperidinium sp. 7											+		
Protoperidinium sp. 8													+
Protoperidinium sp. 9													+
Protoperidinium sp. 10									+				
Protoperidinium sp. 11			+	+									
Protoperidinium sp. 12			+										
Protoperidinium sp. 13			+										
Pseudophalacroma nasutum			+										
Pyrocystis obtusa			+						+			+	
Pyrocystis fusiformis												+	+
Pyrodinium bahamense var. *compressum*												+	+
Pyrophacus horologicum			+				+	+	+		+	+	+
Pyrophacus steinii										+		+	
Scrippsiella trochoidea			+				+		+				
Torodinium robustum		+	+	+		+	+	+	+	+	+	+	+

Taxonomic Description of Marine Dinoflagellates in Kuwait's Waters

The taxonomical description for each taxa includes the previous names of the taxa if it was given a new name, the literatures according to which the identification is performed, the morphological and size characteristics and their distribution. The illustrations of the dinoflagellate species are represented in 40 plates.

Phylum: Pyrrophyta (or Dinophyta)

Class: Dinophyceae West and Fritch 1927

This class, considered by most authors to contain the most primitive representatives of the dinoflagellates, was created for those few genera in which the flagella arise in an apical position. Both nonthecate and thecate genera are included within it. While the anterior insersion of the flagella is undoubtly (Taylor, 1976).

Order: Prorocentrales Lemmermann 1910

Armored, bivalvate cells with desmokont flagellar insertion. Anterior periflagellar area; no cingulum nor sulcus (Steidinger and Tangen, 1997).

Family: Prorocentraceae Stein 1883

Genus: *Prorocentrum* Ehrenberg 1833

Synonyms: *Cercaria* Michaelis 1830, *Exuviaella* Cienkowski 1881, *Postprorocentrum* Gourret 1883.

Cell elongate-oval; anterior end bluntly pointed with spinous projection at pole; posterior end usually acute, covered mainly by two thecal plates or valves which fit together at their edges. One valve designated the right valve, has a small apical indentation, where 5-14 (usually 8) small periflagellar platelets are located forming the flagellar and auxiliary pores (Figure 6). Fagellar pore complex, anterior, consisting of a number of small plates which may also bear an anterior spine or projection; flagella two, each emerging from its own pore, one normal and the other helical. Nucleus single, in posterior half of cell, containing permanently condensed chromosomes; chloroplasts two, reticulate, one situated under each main thecal plate; pyrenoid(s) sometimes present; sack pustules situated in anterior end of cell, opening into flagellar canal; trichocysts sometimes present, with associated pores through thecal plates. Size range from 6-100 µm. Almost all species occur in marine habitats, world-wide distribution (Wood, 1968; Dodge, 1982). Characters used for species identification are: cell shape and size, morphology and ornamentation of the apical area, presence/absence of an apical spine, surface ornamentation, number and distribution of valve pores and/or areolae, and details of the intercalary band (Hansen et al., 2001). During this survey we have observed 8 species in Kuwait's waters.

Prorocentrum balticum (Lohmann) Loeblich III 1970 (Plate 1A)

Synonyms: *Exuviaella baltica* Lohmann 1908; *Prorocentrum pomoideum* Bursa 1959; *Exuviaella aequatorialis* Hasle 1960.

References: Lebour, 1925; Schiller, 1933, 1937; Wood, 1968; Taylor, 1976; Dodge, 1982; Balech, 1988; Pankow, 1990; Steidinger and Tangen, 1997; Throndsen et al., 2003.

Description: Small, round to slightly ovate in valve view, round and scarcely compressed in side view. Periflagellar area bordered by two minute apical projections. Valves covered with many interconnected spines; pores appear rimmed and scattered; nucleus sub-spherical and posterior in position (Dodge, 1982; Steidinger and Tangen, 1997).

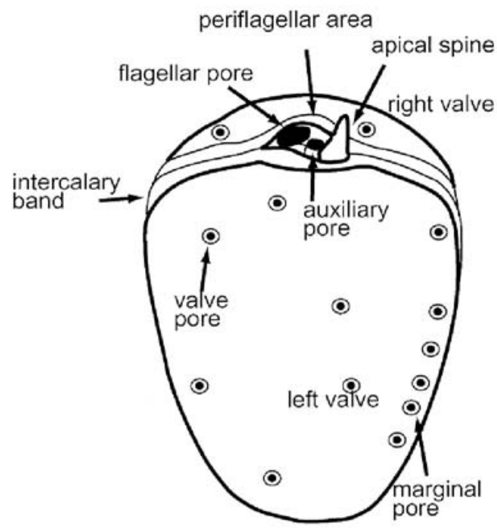


Figure 6. Schematic diagram of *Prorocentrum* (redrawn from Faust et al., 1999).

Dimension: Length 9-10 µm (Lebour, 1925), 6-12 µm (Throndsen et al., 2003), <20 µm (Steidinger and Tangen, 1997).

Distribution: Neritic; worldwide distribution (Steidinger and Tangen, 1997). Off western Scotland in the Gulf Stream area (Dodge, 1982). It also occurs in Kuwait's waters.

Prorocentrum compressum **(Baily) Abé ex Dodge 1975 (Plate 1B-E)**

Synonyms: *Exuviaella compressa* (Baily) Ostenfeld 1903, *Pyxidicta compressa* Baily.

References: Lebour, 1925; Schiller, 1933, 1937; Wood, 1968; Drebes, 1974; Taylor, 1976; Dodge, 1982, 1985; Balech, 1988; Pankow, 1990; Steidinger and Tangen, 1997.

Description: Small to medium-sized, broadly ovate cell in valve view, compressed in side view. Two opposed minute spines (apical projections) bordering the periflagellar area. Valves covered with pores and shallow depressions. Ornamentation more developed centrally. Nucleus sub-spherical and posterior in position (Dodge, 1982; Steidinger and Tangen, 1997).

Dimensions: Length 34-46 µm (Lebour, 1925), 25-45 µm long and 20-35 µm wide (Throndsen et al., 2003).

Distribution: Neritic, oceanic; cosmopolitan in cold temperate to tropical waters (Steidinger and Tangen, 1997). Off western Scotland in the Gulf Stream area (Dodge, 1982). It is also observed in Kuwait's waters.

Prorocentrum gracile Schütt 1895 (Plate 1F-J)

Synonyms: *Prorocentrum macrurus* Athanassopoulos 1931, *Prorocentrum hentschelii* Schiller 1933, *Prorocentrum sigmoides* Bohm 1933, *Prorocentrum diamantinae* Wood 1963.

References: Schiller, 1933, 1937; Wood, 1968; Taylor, 1976; Dodge, 1982; Sournia, 1986; Balech, 1988; Steidinger and Tangen, 1997; Bérard-Therriault et al., 1999.

Description: Small to medium-sized, elongate *P. micans*-like cell that is more than twice as long as broad, lanceolate, rounded anteriorly, widest about one-third of the distance from apex, posteriorly tapering; sides slightly concave with a long, sharp, slightly sigmoid process. Narrow in plate view, thecal plates with surface perforated by trichocyst pores and patterned with surface depressions. Long, winged anterior spine adjacent to periflagellar area (Wood, 1968; Dodge, 1982; Steidinger and Tangen, 1997).

Dimension: Length 50-60 µm (Wood, 1968); 40-60 µm (Dodge, 1882).

Distribution: Principally neritic and estuarine; cosmopolitan in cold temperate to tropical waters (Steidinger and Tangen, 1997). Atlantic Ocean: Coral Sea. Sargasso Sea (Hulburt, 1963); Brazil (north coast). Pacific, Mediterranean (Wood, 1968; Dodge, 1882). Present in Kuwait's waters.

Prorocentrum lima (Ehrenberg) Dodge 1975 (Plate 1K-O)

References: Steidinger and Tangen, 1997; Larsen and Nguyen, 2004.

Synonyms: *Cryptomonas lima* Ehrenberg 1859, *Exuviaella marina* Cienkowski 1881, *Dinopyxis laevis* Stein 1883, *Exuviaella lima* (Ehrenberg) Butschii 1885, *E. laevis* (Stein) Schroder 1900, *E. cincta* Schiller 1933, *E. ostenfeldii* Schiller 1933, *E. caspica* Kiselev 1940, *Prorocentrum marinum* Dodge and Bibby 1973.

Description: The cell is pear-shaped in valve view and narrowly oval in lateral view. A conspicuous central pyrenoid is present in each chloroplast. The nucleus is located posteriorly. The valve surface is smooth and has few scattered pores except in the central area, marginal pores are present (Larsen and Nguyen, 2004). In the present survey, *P. lima* is identified by the conspicuous central pyrenoids, the distribution of the valve pores, particularly the marginal pores and the size characteristics.

Dimensions: 35-45 µm long, 25-30 µm wide (Larsen and Nguyen, 2004).

Distribution: Neritic and estuarine. Benthic/epiphytic; can be tychoplanktonic. Worldwide distribution (Steidinger and Tangen, 1997). It occurs in Kuwait's waters.

Prorocentrum micans Ehrenberg 1833 (Plate 2A-D)

Synonyms: *Cercaria* sp. Michaelis 1830, Prorocentrum *schilleri* Bohm in Schiller 1933, *P. levantinoides* Bursa 1959, *P. pacificum* Wood 1963.

References: Lebour, 1925; Schiller, 1933, 1937; Wood, 1968; Drebes, 1974; Taylor, 1976; Dodge, 1982, 1985; Sournia, 1986; Balech, 1988; Pankow, 1990; Steidinger and Tangen, 1997; Bérard-Therriault et al., 1999; Throndsen et al., 2003.

Description: Medium-sized, pyriform to heart-shaped cell with a rounded anterior end and pointed posterior end, broadest around the middle or towards the anterior, usually less than twice as long as broad. Prominent anterior spine with wings. Thecal plates perforated by numerous tubular trichocyst pores, mainly arranged in radial rows, and surface of plates covered by regularly arranged depressions. Chloroplasts containing large internal pyrenoids. Nucleus large, V-shaped and situated in the posterior end of the cell. This species is one of the most common and variant species in the genus tolerating salinities above 90 ‰ in salt lagoons in Caribbean islands (Dodge, 1982; Steidinger and Tangen, 1997).
Dimensions: Length 35-50 μm (Wood, 1968); 35-70 μm long, 20-50 μm wide (Dodge, 1982).
Distribution: Cosmopolitan, neritic species reported from practically all parts of the world. West Channel, Santaren Channel, Straits of Florida; Benguela Current; Bermuda (Hulburt, 1963); Gulf Stream (Hulburt, 1963); Brazil (north coast); Caribbean Sea (Wood, 1968; Dodge, 1882). It also occurs in Kuwait's waters.

Prorocentrum rhathymum Loeblich, Sherley and Schmidt 1979 (Plate 2E-I)

Synonyms: *Prorocentrum maximum* Schiller 1937; *Prorocentrum mexicanum* Tafall 1942.
References: Steidinger and Tangen, 1997; Larsen and Nguyen, 2004.
Description: The cell shape is asymmetrical, almond-shaped in valve view with a small apical spine. The right valve has a small indentation, which may be lined by pores. Pyronoids are absent. The nucleus is located in the poster part of the cell. The valve pores form fine, radial lines perpendicular to the cell periphery; marginal pores absent. Smaller pores also occur, but can be observed only by SEM (Larsen and Nguyen, 2004).
Dimensions: 25-30 μm long and 20-22 μm wide (Larsen and Nguyen, 2004).
Distribution: Neritic and estuarine. Benthic; can be tychoplanktonic. Tropical and subtropical waters (Steidinger and Tangen, 1997). It is also observed as a bloom in Kuwait's waters.

Prorocentrum triestinum Schiller 1918 (Plate 2J)

Synonym: *Prorocentrum redfeldii* Bursa 1959.
References: Schiller, 1933, 1937; Taylor, 1976; Dodge, 1982, 1985; Steidinger and Tangen, 1997.
Description: Small posteriorly pointed cell resembling a thin, narrow *P. micans*. Depressions few and mainly peripherally located. Cell with a thin anterior spine (Steidinger and Tangen, 1997).
Dimensions: <30 μm in length (Steidinger and Tangen, 1997).
Distribution: Oceanic and neritic; worldwide distribution (Steidinger and Tangen, 1997). It also occurs in Kuwait's waters.

Prorocentrum sp.1 (Plate 2K-M and 3A)

Distribution: Present in Kuwait's waters.

Class: Desmophyceae Smith

Dinoflagellates in which the flagella are inserted laterally (Taylor, 1976).

Order: Dinophysiales Lindemann 1928

Family: Dinophysiaceae Stein 1883

Genus: *Dinophysis* Ehrenberg 1839

Synonyms: *Phalacroma* Jörgensen 1923; *Prodinophysis* Balech 1944.

Cells more or less compressed laterally, more or less; epitheca small or almost rudimentary with obliquely set girdle lists, the upper list being almost funnel-shaped, projecting beyond epitheca and often strengthened by radial ribs; left sulcal list often strongly developed and porulate; hypotheca may have spines or protuberances (Wood, 1968). Typically possesses 18 thecal plates: 4 epithecal, 4 hypothecal, 4 cingular, 4 sulcal and two platelets surrounding the apical pore. Two of the hypothecal plates are very large while all other plates are small. The plate pattern or tabulation is remarkably constant within the dinophysoid lineage and is normally not used in species identification. Important characters for species identification are: shape and size of the cell seen in lateral view, the morphology of the left sulcal list and the ribs supporting it, the shape and size of the cingular lists, the size of the epicone, presence/absence of chloroplasts, and presence/absence of an antapical spine or horn (s) (Figure 7) (Hansen et al., 2001). Six species are found in Kuwait's waters.

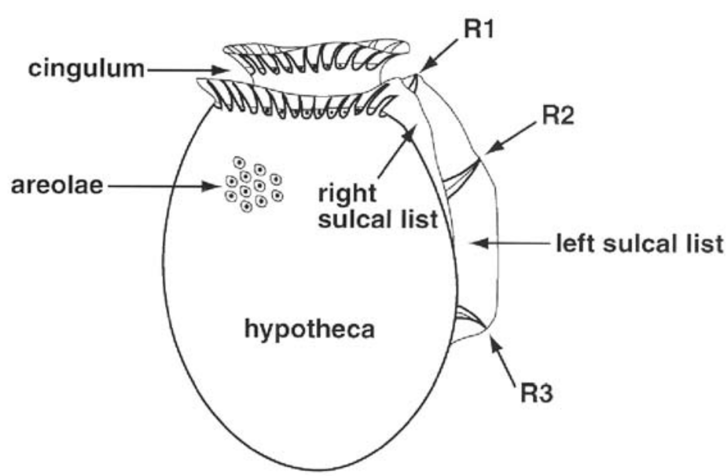


Figure 7. *Dinophysis* (redrawn from Steidenger and Tangen, 1996).

Dinophysis acuta Ehrenberg 1839 (Plate 3B-D)

References: Taylor, 1976; Dodge, 1982; Steidinger and Tangen, 1997.

Description: Large, robust cell with a rounded dorsal curvature and a posterior broad V-shaped lateral profile. The left sulcal list extends about two-thirds of the body length and ends at or above the the deepest portion of the cell below the midpoint. The R3 is at or above this point. Surface with areolations. This species can be easily confused with *D. norvegica*. The distinction between the two species can be made by determining whether the deepest portion of the cell is two-thirds the cell length or one-half and determining the length of the left sulcal list in relation to the cell length. Toxic species (Steidinger and Tangen, 1997).

Dimension: 54-94 µm long (Dodge, 1982).

Distribution: Oceanic and neritic; cold temperate, worldwide distribution (Steidinger and Tangen, 1997). It is also observed in Kuwait's waters.

Dinophysis caudata Saville-Kent 1881 (Plate 3E-H)

References: Lebour, 1925; Schiller, 1933, 1937; Wood, 1968; Taylor, 1976; Dodge, 1982; Sournia, 1986; Balech, 1988; Steidinger and Tangen, 1997; Throndsen et al., 2003.

Synonyms: *Dinophysis caudata* var. *tripos* (Gourret) Gail 1950, *D. tripos* Gourret 1883.

Description: Medium-sized species that has a characteristic posterior finger-like process; cells often occur in pairs, dorsally attached (Steidinger and Tangen, 1997). Body very variable; epitheca low; hypotheca long, widest at or near the middle (Wood, 1968). The epitheca is obscured by a deep funnel formed by the anterior cingular list and supported by ribs. At the distal margin the funnel flattens out. The posterior cingular list is narrow dorsally, becoming wider on the left ventral side where it meets the left sulcal list. The expansion in width is less marked on the right ventral side where it joins the right sulcal list. The posterior cingular list is projected anteriorly and is supported by ribs. Viewed laterally, the hypotheca is narrow at the girdle; the ventral margin is usually straight or sigmoid to the base of the left sulcal list from where it bends sharply towards the centre before again sharply bending towards the posterior; the dorsal margin is straight or concave near the girdle, becoming straight or convex towards the posterior. The hypotheca has its widest point usually at the position of the base of the left sulcal list. The dorsal side of the hypotheca may curve sharply towards the centre where it turns to continue down the drawn-out posterior part of the hypotheca or may itself be projected to form a hallow point. The transition between the anterior and posterior portions of the hypotheca may be sudden or gradual. The epithecal and hypothecal plates are covered with areoles each containing a pore or, at the plate margins, one or two pores. The left sulcal list is wide and supported by three ribs spaced equally apart, which are straight or slightly curved. R1 projects anteriorly, R2 ventrally and R3 posteriorly. The right sulcal list is widest at its anterior end, becoming very narrow between the position R2 and R3 where it ends. The lists may be reticulated. Twinned forms occur frequently, joined together on the dorsal surface at the widest part of the hypotheca (Dodge, 1982).

Dimensions: Length about 100 µm (Lebour, 1925; Wood, 1968), 70-170 µm (Dodge, 1982).

Distribution: Neritic and estuarine in warm temperate to tropical waters, worldwide; rarely found in cold water (Steidinger and Tangen, 1997). Found off SW England and North of Scotland (Wood, 1968; Dodge, 1882). It is also present in Kuwait's waters.

Dinophysis miles Cleve (Plate 3I-L)

References: Schiller, 1933, 1937; Taylor, 1976; Sournia, 1986.

Description: This species represents one of the most extreme body modifications of the genus , and can be looked upon as an extension of a developmental series from *D. caudata* Saville-Kent, through *D. tripos* Gourret to this species in which the dorsal process achieves maximum development.

Dimensions: 150 μm long, 60 μm wide (Taylor, 1976).

Distribution: Indo-West Pacificregion, Mediterranean, Red Sea and the Arabian Gulf (Böhm, 1931, 1935). It is also present in Kuwait's waters.

Dinophysis mitra (Schutt) Abé 1967 (Plate 4A-G)

Synonym: *Phalacroma mitra* Schutt 1895.

References: Taylor, 1976; Balech, 1988; Steidinger and Tangen, 1997; Larsen and Nguyen, 2004.

Description: The cells are broad wedge-shaped. The dorsal side smoothly convex, the ventral side is more or less straight in the sulcal region, and from the end of the left sulcal list to the antapex. The epitheca is flat or slightly convex, broad ellipsoidal in apical view. The hypotheeca is widest between the second and third ribs of left sulcal list. The thecal plates are thick and coarsely reticulated (Larsen and Nguyen, 2004).

Dimensions: 55-65 μm wide (Larsen and Nguyen, 2004).

Distribution: Warm temperate to tropical oceanic and neritic waters; worldwide distribution (Steidinger and Tangen, 1997; Larsen and Nguyen, 2004). It also occurs in Kuwait's waters

Dinophysis norvegica Claparède and Lachmann 1859 (Plate 4H)

Synonyms: D. *debilior* Paulsen 1949; *D. norvegica* var *debilior* Pauls 1907.

References: Lebour, 1925; Schiller, 1937; Wood, 1968; Dodge, 1982; Steidinger and Tangen, 1997; Throndsen et al., 2003.

Description: Variable in appearance but generally with low concealed epitheca and hypotheca with straight to concave sides at posterior end forming a central point when seen in lateral view. The anterior cingular list is wider than the posterior list, its being projected anteriorly. Its may be sculptured with fine or coarse irregular sinuous lines or reticulations. The hypotheca may be smooth in outline or coarse irregular bumps at the posterior end may be present and less frequently all round the hypothecal margin. The dorsal margin of the hypotheca is convex becoming concave to straight at the antapical end. The ventral margin is straight or convex becoming concave at the antapex. The left sulcal list is generally narrower than in *D. acuta* and curved to the right between R2 and R3. R1 and R2 are closer together than R2 and R3 and projected towards the anterior; R3 is curved or straight and projects towards the posterior. The right sulcal list is short, ending between R2 and R3. The sulcal lists may be smooth but usually are covered with conspicuous areoli each containing a pore. The main hypothecal plates are covered with conspicuous areoles each containing a pore. The epithecal plates bear a sinuous sculpture. Toxic species (Dodge, 1982).

Dimension: Length 56-64 μm (Lebour, 1925), 48-67 μm long (Dodge, 1982).

Distribution: Neritic; cold water species (Steidinger and Tangen, 1997). Widely distributed. Occurs in the North of Britain, most abundantly in the North Sea (Lebour, 1925; Dodge, 1982). It is also found in Kuwait's waters.

Dinophysis rotundata Claparède and Lachmann 1859 (Plate 4I)

Synonyms: *Phalacroma rotundatum* (Claparède and Lachmann 1889) Kofoid and Michener 1911, *Prodinophysis rotundatum* (Claparède and Lachmann) Balech 1944, *Dinophysis whittingae* Balech 1971.

References: Lebour, 1925; Schiller, 1933, 1937; Wood, 1968; Drebes, 1974; Taylor, 1976; Dodge, 1982; Sournia, 1986; Balech, 1988; Pankow, 1990; Steidinger and Tangen, 1997; Bérard-Therriault et al., 1999; Throndsen et al., 2003.

Description: In lateral view almost circular with low rounded epitheca which may be flattened at apex. In ventral view cell seen to be compressed but with convex sides. Both cingular lists are inclined anteriorly but the anterior one does not mask the epitheca entirely. The left sulcal list is of moderate width, widening posteriorly with three conspicuous ribs; R1 and R2 are closer together than R2 and R3. This list extends over half the length of the hypotheca. The right sulcal list is narrower than the left and is long, ending either at R3 or to the posterior of R3; it is sigmoid in outline with a concavity at the corresponding position of R2. The thecal surface is covered with poroids and scattered pores. Cell contents colorless or pinkish. Chromatophores absent (Dodge, 1982).

Dimension: 36-56 µm long (Dodge, 1982).

Distribution: Occurs all around British Isles, a widely distributed species. Recorded from the North Sea, Pacific, Atlantic and Indian Oceans. Off Norway, Greenland, Nova Scotia, from the Baltic, Mediterranean, Black Sea, Gulf of Siam, Barents Sea, Inland Sea of Japan and Arabian Sea (Lebour, 1925; Dodge, 1982). It also occurs in Kuwait’s waters.

Genus: *Histioneis* Stein 1883

Synonym: *Parahistioneis* Kofoid and Skogsberg 1928

Body rotund, gourd-shaped, porulate, usually slightly longer than wide; epitheca small; girdle wider dorsally than ventrally; anterior girdle list flared and strongly ribbed; posterior list forming a cylindrical collar with less than six radial ribs and without submarginal cross-rib; left sulcal list large with single posterior lobe and one complete rib behind fission rib (Wood, 1968). One species occurs in Kuwait’s waters.

Histioneis costata Kofoid and Michener 1911 (Plate 5A-B)

References: Schiller, 1937.

Distribution: Occurs in Kuwait’s waters.

Genus: *Ornithocercus* Stein 1883

Body subcircular to subovate, compressed laterally; epitheca low and disk-like; girdle usually wide, oblique; girdle lists large and funnel-shaped, extending forward of body, usually ribbed or reticulate; left sulcal list large and sail-like, often extending dorsally of antapex, often ribbed or reticulate (Wood, 1968). Species of this genus can be differentiated by size and shape (Steidinger and Tangen, 1997). One species occurs in Kuwait’s waters.

Ornithocercus magnificus Stein 1883 (Plate 5C)

References: Schiller, 1933, 1937; Wood, 1968; Taylor, 1976; Sournia, 1986; Balech, 1988; Steidinger and Tangen, 1997.

Description: Small to medium-sized circular full body in lateral view with extensive sulcal and cingular list and rib systems that characterize the species. Ribs and lists are formed at the extremities of plates, near sutures. Body surface markings of pores, poroids, or areolae. Lacks chloroplasts, but can have photosynthetic symbionts in cingular chamber (Steidinger and Tangen, 1997).

Dimension: Length 40-120 µm (Wood, 1968).

Distribution: Oceanic; cosmopolitan in warm temperate to tropical waters (Steidinger and Tangen, 1997). West channel, Strait of Florida; Benguela Current; Brazil (north coast); Caribbean Sea (Wood, 1968). It is also found in Kuwait's waters.

Genus: *Pseudophalacroma* Jörgensen 1923

Epitheca conspicuous. Sulcus prolonged on to epitheca up to about two-thirds the distance from girdle to apex, showing a dilated rounded end. Left longitudinal list very slightly developed and presumably destitute of ribs or spines (Lebour, 1925). One species occurs in Kuwait's waters.

Pseudophalacroma nasutum Kofoid and Skogberg 1928 (Plate 5D)

References: Lebour, 1925; Schiller, 1937.

Description: Body in side view oval or roundish. Epitheca low and small. Narrow girdle lists and inspicuous longitudinal list. In ventral view elliptical with rounded ends. Theca with coarse poroids all over.

Dimension: Length 45-49 µm (Lebour, 1925).

Distribution: Mediterranean, Adriatic, Tortugas between Iceland and Nova Scotia, Norwegian coast near Bergen (Lebour, 1925). Present in Kuwait's waters.

Order: Gymnodinialis Lemmermann 1910

Family: Gymnodiniaceae Lankester 1885

Genus: *Amphidinium* Claparède and Lachmann 1859

Synonym: *Trochodinium* Conrad 1926.

A genus of naked dinoflagellates distinguished by having a much reduced epicone and the girdle situated near the anterior end of the cell. The sulcus is usually only found on the hypocone but may run from apex to antapex. The cell is typically dorso-ventrally flattened but a few species have rounded cells. (The laterally flattened species in Lebour (1925) and other early works are now placed in other genera). The flagella are generally inserted a short distance apart, often there is a 'bridge' between the two pores. Chloroplasts may be present and then there is usually (but not in *A. britannicum*) a single large pyrenoid. Species without chloroplasts may contain coloured granules. Nutrition is autotropic or heterophic and at least one species is phagotrophic. The nucleus is usually situated in the posterior end of the cell and varies from sphaerical to U-shaped. One or more pusules may be present, associated with the flagellar canals. The cell is covered by a delicate membranous theca and consequently the cells usually distort or change shape on fixation (Dodge, 1982).

The majority of species found around the British Isles are littoral organisms living in rock pools, salt marshes, and among the sand grains on beaches. In the latter case the *Amphidinium* may be present in sufficient numbers to colour the beach green or brown at low tide and the organisms migrate from the surface down into the sand when the tide comes in. The main species are probably distributed all around the British Isles. Some species are very robust and will grow readily in rough cultures made from shore collections. Many are extremely tolerant of salinity variations and some supposedly freshwater species can be found on the shores (Dodge, 1982). One species was observed in Kuwait's waters.

Amphidinium sp. 1 (Plate 5E-I)

Distribution: This species was observed in Kuwait's waters.

Genus: *Cochlodinium* Schütt 1896

Synonym: *Gymnodinium* Stein partim.

Naked dinoflagellates in which the body is twisted at least 1.5 turns. The girdle forms a descending left-handed spiral of 1.5 turns or more and has a considerable displacement of the two ends. The sulcus is also twisted around the cell by 0.5 turns or more. The fairly large nucleus is situated in a central or posterior position and the cell may be colourless or contain pigmentation. A few species contain chloroplasts. Pusules are found associated with the flagellar pores. Some species tend towards a colonial habit (Dodge, 1982). One species was observed in Kuwait's waters.

Cochlodinium sp. 1 (Plate 6A)

Distribution: This species was observed in Kuwait's waters.

Cochlodinium polykrikoides was reported from the waters of the United Arab Emirates, Iran and Oman.

Genus: *Akashiwo* Hansen and Moestrup 2000

The apical groove running clockwise around the apex of the cell and the nuclear envelope chambers and fibrous connective are absent. It has a peridinin which is the major carotenoid pigment (Daugbjerg et al, 2000).

Akashiwo sanguinea (Hirasaka) Hansen and Moestrup 2000 (Plate 6B-D)

Basionym: *Gymnodinium sanguineum* Hirasaka 1922.

Synonyms: *Gymnodinium splendens* Lebour 1925, *Gymnodinium nelsonii* Martin 1929.

References: Drebes, 1974; Dodge, 1982; Sournia, 1986; Balech, 1988; Steidinger and Tangen, 1997; Throndsen et al., 2003.

Description: Cell ovoid, flattened dorso-ventrally with convex dorsal surface and concave ventrally. Epicone and hypocone nearly equal. In ventral view the epicone is in the shape of a blunt, rounded cone and the hypocone is deeply indented by the sulcus. The girdle is impressed, left-handed displaced one to two girdle widths. The sulcus expands posteriorly. The nucleus is slightly anterior of the midline. Numerous yellow-brown chromatophores radiate from outside the centre to the periphery. Longitudinal flagellum is about one and a quarter times the body length (Dodge, 1982).

Dimension: 40-80 μm long (Dodge, 1982; Steidinger and Tangen, 1997; Throndsen et al., 2003).

Distribution: Temperate to tropical estuarine and coastal waters; cosmopolitan (Steidinger and Tangen, 1997). Found off South and North west coast of England and N.W. of Scotland. Also recorded from California, Florida, Gulf of Mexico and East coast of U.S.A (Dodge, 1982). It is also present in Kuwait's waters.

Genus: *Gymnodinium* Stein 1878

Body variable in shape, round to subconical, depressed, lack a thickened theca. Although some species with such a feature have been included erroneously in the genus; they have a more or less centrally positioned girdle which is not displaced more than one fifth total body length. They may or may not have chloroplasts. The sulcus may extend from the apex to the antapex or may be restricted to the hypocone; it is usually without torsion. The nucleus is usually centrally positioned. The cell surface may be striate, smooth, or punctate. Cyst formation occurs and the cyst generally consists of a thin, hyaline membrane. This genus, can form toxic blooms if they are present in large numbers (Dodge, 1982). Several unidentified *Gymnodinium* species were observed in Kuwait's waters and need to be studied in more details.

Gymnodinium spp. Campbell 1973 (Plate 6E-I)

Several species of *Gymnodinium* were observed in Kuwait's waters. The one species that was the most abundant was photographed and identified as cf. *gracilentum*.

Genus: *Gyrodinium* Kofoid and Swezy 1921

Synonyms: *Gymnodinium* Schutt 1895, *Spirodinium* Schutt 1896

Theca absent; cell rounded or ovate; sulcus more or less. Girdle characteristically descending in a left spiral displaced more than 0.2 of the total body length. Sulcus longitudinal, or with torsion of less than half a transdiameter in the intercingular region, extending from girdle or epiconeto hypocone or antapex. The nucleus is usually situated near the centre. Pusules may be present. Chromatophores rarely present. Surface smooth o with longitudinal striations. Cell shape variable but frequently ovoid or fusi form with girdle centrally positioned although epicone and hypocone can be subequal. Cells vary in length from 11 µm to 200 µm. They occur in marine brackish or fresh water and are pelagic, neritic, or littoral (living in sand) (Wood, 1968; Dodge, 1982). Three species of *Gyrodinium* are found in Kuwait's waters.

Gyrodinium sp. 1 (Plate 6J)

Distribution: This species was found in Kuwait's waters.

Gyrodinium sp. 2 (Plate 6K)

Distribution: This species was found in Kuwait's waters.

Gyrodinium sp. 3 (Plate 6L)

Distribution: This species was found in Kuwait's waters.

Genus: *Katodinium* Fott 1957

Synonym: *Massartia* Conrad 1926.

One species was found in Kuwait's Waters.

Katodinium glaucum (Lebour) Loeblich III 1965 (Plate 8B).

Synonym: *Spirodinium glaucum* Lebour 1917.

References: Dodge, 1982; Steidinger and Tangen, 1997.

Description: Small fusiform cell theca thick, with about 20 longitudinal ribs on epitheca and 2 or 3 on hypotheca; epitheca has circular apical groove. Cingulum displaced 4 or 5 X cingulum width and about one-fifth of body. Epitheca exceeds hypotheca in both length and width. Chloroplasts absent; food vacuoles present. Nucleus round and in epitheca. This is an easily recognizable species (Steidinger and Tangen, 1997).

Dimension: 40-56 µm long (Dodge, 1982).

Distribution: Common estuarine species; temperate to tropical waters. Cosmopolitan (Steidinger and Tangen, 1997). It is also found in Kuwait's waters.

Genus: *Torodinium* Kofoid and Swezy 1921

Synonym: *Gymnodinium* Pouchet 1885, partim.

Body elongate, about 4 times as long as broad, epicone several times longer than the hypocone. Girdle forming a slightly displaced left-handed spiral. Sulcus is curved and runs along most of the epicone, not observed on the hypocone. Nucleus said to be elongated. Long pigmented bodies (chloroplasts or rhabdosomes) in the epicone, along the sides and collected in a mass at the apex. A long narrow pusule is associated with the flagellar pore of the longitudinal flagellum (Dodge, 1982). One species occurs in Kuwait's waters.

Torodinium robustum Kofoid and Swezy 1921 (Plate 8C).

Synonyms: *Gymnodinium teredo* Schutt 1895, *G. teredo* Paulsen 1908.
References: Lebour, 1925; Drebes, 1974; Dodge, 1982; Sournia, 1986; Throndsen et al., 2003.
Description: Body elongated fusiform, around 3 times as long as broad. Epicone very long, four-fifths of total length, hypocone reduced to a conical structure. Girdle forming a left-handed spiral. Sulcus commencing near cell apex with a loop nearly completely around the cell then curves to meet the girdle. It has not been observed on the hypocone. The flagella arise from the junction of girdle and sulcus and the longitudinal flagellum is very short. The nucleus is elongated and situated along the centre of the cell. Also there is an elongated pusule which extends anteriorly from the flagellar pores, this appears pink in live cells. The cell contains numerous refractile granules and a number of elongated yellow bodies of unknown function with more aggregated into a stellate cluster at the anterior end. The cytoplasm has a greenish coloration.
Dimensions: 36-75 µm long; 21-25 µm wide (Lebour, 1925; Dodge, 1982).
Distribution: A planktonic species which has been found at Burnham (Essex) and Plymouth. Also reported from the North Sea and the Pacific (Dodge, 1982). It also occurs in Kuwait's waters.

Family: Kareniaceae Bergholtz, Daugbjerg, Moestrup and Fernández - Tejedor 2005
Genus: *Karenia* G. Hansen and Moestrup 2000

The classification was based on the cell's fucoxanthin-derived pigments (19'-hexanoyl-oxyfucoxanthin and/or 19'-butanoyl-oxyfucoxanthin), a straight apical groove. A groove located at the anterior part of the cell extending posteriorly on both the ventral and dorsal sides. On the ventral side, it does not go any further than the sulcus. The chloroplast is present. Cingulum with longitudinal ridges.It has a longitudinal flagellum, the whiplike tail protruding from the sulcus. This tail acts like a rudder and steers the cell. The sulcus which is the longitudinal area on the ventral surface of the cell that forms a somewhat pronounced furrow or depression that houses the longitudinal flagellum. Theca consist of multiple membrane layers that encompass the whole cell; contains vesicles, which are small, bladderlike cavities sometimes filled with material. It has also transverse flagellum, the ribbonlike tail encircling the cell within the cingulum. When beating, this propels the cell. Two species are found in Kuwait's waters.

Karenia selliformis Haywood, Steidinger and MacKenzie 2004 (Plate 7A-D)

Synonym: Referred to as *Gymnodinium* sp. in Mac-Kenzie et al. (1996).
References: Glibert et al., 2002 ; Heil et al., 2001; Haywood et al., 2004.
Description: Thin oval in longitudinal section. The epitheca is a flattened hemisphere or slightly conical and is generally smaller than the hypotheca. The apical groove extends vertically to at least one third of both the ventral and dorsal epitheca and has prominent rolled

margins. The hypotheca is bilobed and centrally excavated. The cingulum is descending and premedian and typically displaced by twice its width. An intercingular tubular structure with an anterior projection arises from the region of flagella insertion and traverses the center of the cell form the right to the left ends of the cingulum. The right margin of the sulcus almost joins the apical groove in the middle center epitheca, and the left sulcal margin is open but narrows onto the epitheca, and the left sulcal margin is open but narrows onto the epitheca, reaching almost to the cell's apex in some cells. Both sulcal margins have prominent rolled ridges. The nucleus is centrally located in the hypotheca and is oval to elliptical to elongated reniform in the horizontal plane. The left hypotheca has a single dorsolateral pore. There are several chloroplasts, which are, peripheral, and yellow-green to green in color (Haywood et al., 2004).
Dimensions: Cells 20-30 µm long, 16-30 µm wide, and 5-10 µm in thickness (Haywood et al., 2004).
Distribution: Found in Foveaux Strait, New Zealand (Haywood et al., 2004). It was also reported in the waters of Kuwait Bay and the northern waters outside the Bay as one of the toxic species that caused the massive fish kill in 1999 (Al-Yamani et al., 2002; Glibert et al., 2002; Heil et al., 2001), and was found at other locations in Kuwait's waters.

***Karenia* cf. *brevis* (Davis) Hansen and Moestrup 2000 (Plate 8A).**
Synonym: *Gymnodinium breve* Davis.
Description: Dorsal and ventral views showing bulbous apical carina, ventral extent of straight apical groove, and short apical groove intrusion onto dorsal epitheca. Ventral view with refractive bodies, peripheral chloroplasts, the nucleus in left hypotheca and the open ended sulcus onto epitheca, adjacent to the straight apical grove (Haywood et al., 2004).
Dimensions: 19 µm wide (Haywood et al., 2004).
Distribution: Found in John's Pass/Florida, USA (Haywood et al., 2004). It is also present in Kuwait's waters.

Family: Polykrikaceae Kofoid and Swezy 1921
Genus: *Polykrikos* Butschli 1873
Synonym: *Pheopolykrikos* Chatton 1933.
Organisms with a permanent colonial or coenocytic organisation consisting of 2-8 gymnodinioid individuals (zooids) joined in a chain and each having longitudinal and transverse flagella. The number of nuclei is often half that of the number of zooids. Girdles in each zooid slightly offset to the right side of the cell, sulci straight. Cells may be colourless and heterotrophic or may contain yellow-brown chloroplasts. Nematocysts may be present (Dodge, 1982). One species occurs in Kuwait's waters.

***Polykrikos schwartzii* Bütschli 1873 (Plate 8D)**
References: Lebour, 1925; Dodge, 1982; Sournia, 1986; Steidinger and Tangen, 1997; Throndsen et al., 2003.
Description: Colony composed of 2-8 units with half the respective number of nuclei. Shape an elongated ovoid with flattened anterior end and slightly depressed posterior end. Girdles of the zooids distinct and displaced by their own width, sulci appear to connect together to run the entire length of the colony. Lines of demarcation between zooids not very conspicuous. Cell contents pinkish (no chloroplasts) containing nematocysts and refractile granules. Nutrition heterotrophic (Dodge, 1982).

Dimension: Length 100-150 µm (Lebour, 1925; Dodge, 1982).
Distribution: La Jolla, California; Arctic near Iceland, Skaggerak, Cattegat, Norway, Baltic, North Sea, Mediterranean, English Channel (Lebour, 1925). A neritic species found all around the British Isles (Dodge, 1982). It also occurs in Kuwait's waters.

Order: Noctilucales Haeckel 1894
Family: Noctilucaceae Kent 1881
Genus: *Noctiluca* Suriray 1836

Body very large, almost macroscopic, inflated, reniform to sphaeroidal, largely vacuolated; sulcus very deep, forming an apical trough; longitudinal flagellum short, transverse flagellum reduced to a projecting mobile tooth; large tentacle at posterior end of sulcus; spores multiple, gymnodinioid. Non-thecate form which is globular and possesses a hydrostatic system so that its density may be regulated enabling it to occur over wide depths, usually the upper 50 meters, or may be buoyant and occur at the surface. Not differentiated in vegetative stage into epitheca and hypotheca; girdle not discernible but sulcus well developed as an oral groove. Cell with striated tentacle (Wood, 1968; Dodge, 1982). One species occurs in Kuwait's waters.

Noctiluca scintillans (Macartney 1836) Kofoid and Swezy 1921 (Plate 8E)

Synonym: *Noctiluca miliaris* Suriray (Lamarck) 1816.
References: Lebour, 1925; Wood, 1968; Drebes, 1974; Taylor, 1976; Newell and Newell, 1977; Balech, 1988; Steidinger and Tangen, 1997; Throndsen et al., 2003.
Description: Body inflated, somewhat reniform; no distinction between epicone and hypocone; sulcus very deep, mouth region extended anteriorly as an apical trough; longitudinal flagellum short, transverse flagellum as a mobile tooth; tentacle at posterior end of sulcus; zoospores gymnodinioid (Wood, 1968). Well known for its large size and luminescent qualities (Lebour, 1925).
Dimension: Diameter 1,000 µm (Wood, 1968).
Distribution: Cosmopolitan in warm water, neritic. Straits of Florida; off French Guiana (Lebour, 1925; Wood, 1968). It is also found in Kuwait's waters; sometimes occurred in large numbers causing a bloom at different localities in Kuwait's waters.

Genus: *Pronoctiluca* Fabre-Domergue 1889

Synonym: *Protodinifer* Kofoid and Swezy 1921.
Non-photosynthetic organism with short apical tentacle and two anteriorly placed long flagella. Flexible cell wall present with delicate cyst walls produced on the exterior (Dodge, 1982). One species occurs in Kuwait's waters.

Pronoctiluca pelagica Fabre-Domergue 1889 (Plate 8F-G)

References: Dodge, 1982; Sournia 1986; Taylor, 1976; Steidinger and Tangen, 1997.
Description: Small to medium-sized fusiform cell with premedian indistinct cingulum and anterior tentacle. Tentacle flexible and without cytoplasm. Sulcus exists on epitheca only. Anterior nucleus reported with condensed chromosomes. Chloroplasts absent (Steidinger and Tangen, 1997).
Dimension: Length 12-45 µm (Dodge, 1982).
Distribution: Found at Port Erin, Isle of Man. Also known from the coast of Brittany, Gulf of Lions, Bay of Kiel, Indian Ocean (Dodge, 1982). It is also found in Kuwait's waters.

Order: Gonyaulacales F. J. R. Taylor 1980
Family: Ceratiaceae Lindemann 1928
Genus: *Ceratium* Schrank 1793

Theca usually flattened dorsoventrally, drawn out into a number (2-4) of hollow horns which may have open or pointed (closed) tips. Epitheca rarely swollen and rounded but generally drawn out into a single apical horn with apical and ventral. Hypotheca drawn out into 2-3 horns, usually with pointed tips. Sulcus very wide, almost circular; modified into an invagination from which the flagella arise. Cell covered with relatively thick thecal plates having numerous trichocyst pores. Basic plate pattern 4', 5", 4c, 5'", 2"" plus ventral plates and reduced sulcal plates. Cells usually contain numerous discoid chloroplasts of yellow-brown colour and may have phagotrophic vacuoles, starch grains and lipid globules. A large nucleus is situated near the center of the cell (Wood, 1968; Dodge, 1982). Eight species occur in Kuwait's waters.

Ceratium breve (Ostenfeld and Schmidt) Schröder 1906 (Plate 8H-I)

References: Wood, 1968; Taylor, 1976; Dodge, 1982; Sournia, 1986.
Description: Robust species; epitheca more than half as long as broad, left contour steep, right strongly and broadly convex; hypotheca as long as or longer than epitheca, base contour even or swollen in middle, horns strong, antapicals evenly curved forward; theca porulate, ridged (Wood, 1968).
Dimension: Length 100-200 μm (Wood, 1968).
Distribution: Brazil (north coast); Caribbean Sea (Wood, 1968). It is also present in Kuwait's waters.

Ceratium furca (Ehrenberg 1836) Claparéde and Lachmann 1859 (Plate 9A).

References: Lebour, 1925; Wood, 1968; Drebes, 1974; Taylor, 1976; Dodge, 1982, 1985; Sournia, 1986; Balech, 1988; Pankow, 1990; Steidinger and Tangen, 1997; Throndsen et al., 2003.
Description: Body straight; epitheca tapering gradually into apical horn; hypotheca varying from parallel-sided to tapering from girdle; antapicals strong, unequal, usually straight, parallel to subparallel, may be toothed (Wood, 1968).
Dimension: Length 70-100 μm (Wood, 1968).
Distribution: Cosmopolitan, except in Antarctic waters. Gulf Stream (Hulburt, 1963); Gulf of Mexico (Curl, 1959); Santaren Channel, Straits of Florida; Benguela Current; Brazil (north coast); Florida Everglades; Caribbean Sea (Wood, 1968). It is also common in Kuwait's waters.

Ceratium fusus (Ehrenberg 1834) Dujardin 1841 (Plate 9B).

Synonym: *Peridinium fusus* Ehrenberg 1834.
References: Lebour, 1925; Wood, 1968; Drebes, 1974; Taylor, 1976; Dodge, 1982; Sournia, 1986; Balech, 1988; Pankow, 1990; Steidinger and Tangen, 1997; Throndsen et al., 2003.
Description: An elongated needle-shaped species. Medium to small species. Widest point adjacent to the girdle from which the epitheca long, gradually tapering to a cylindrical or gently tapering apical horn, usually slightly bent dorsally or straight; hypotheca tapering; left antapical long, slightly curved, rarely straight; right antapical rudimentary or absent (Wood, 1968; Dodge, 1982).
Dimensions: Length 200-300 μm, 15-30 μm wide (Wood, 1968; Dodge, 1982).
Distribution: Cosmopolitan except in Antarctic and sub-Antarctic waters. Found all around

the British Isles (Dodge, 1982). Sargasso Sea and Gulf Stream (Hulburt, 1963); Gulf of Mexico (Curl, 1959); Benguela Current; Pigeon Key; Santaren Channel, West Channel, Straits of Florida; Brazil (north coast); Caribbean Sea (Wood, 1968; Dodge, 1982). It is also common in Kuwait's waters.

Ceratium lineatum (Ehrenberg) Cleve 1899 (Plate 9C)

References: Lebour, 1925; Sournia, 1967; Wood, 1968; Drebes, 1974; Taylor, 1976; Dodge, 1982; Balech, 1988; Steidinger and Tangen, 1997; Throndsen et al., 2003.
Synonym: *Peridinum lineatum* Ehrenberg 1854.
Description: A rather small and delicate member of the genus. Epitheca forming a more or less equilateral triangle with a sharp transition into a fairly long apical horn; hypotheca rather rectangular extended at the lower corners into two unequal antapical horns which are straight but diverge slightly. Thecal plates rather thin and not strongly ornamented but usually have longitudinal ridges. Chloroplasts lightly pigmented, yellowish-brown (Dodge, 1982).
Dimension: length 30-60 µm; 25-45 µm wide (Wood, 1968; Dodge, 1982).
Distribution: A cool and temperate water species. Found all around the British Isles (Dodge, 1982). Recorded by Hulburt (1963) from the Gulf Stream. It also occurs in Kuwait's waters.

Ceratium massiliense (Gourret) Jrögensen (Plate 9D-F)

References: Wood, 1968; Taylor, 1976; Dodge, 1982; Sournia, 1986; Balech, 1988; Steidinger and Tangen, 1997.
Description: Large, long-horned, very variable; epitheca oblique; base contour straight or slightly concave; apical long, straight; antapicals arising almost at right angles to each other, then bending sharply through a right angle and becoming straight or evenly curved with wavy or incurved ends (Wood, 1968).
Dimension: length 50-80 µm; total length variable (Wood, 1968).
Distribution: Warm-water species, interoceanic. Straights of Florida; Benguela Current; Gulf of Mexico (Curl, 1959); Gulf Stream (Hulburt, 1962); Brazil (north coast); Caribbean Sea. (Wood, 1968). It also occurs in Kuwait's waters.

Ceratium trichoceros (Ehrenberg) Kofoid 1908 (Plate 10A)

References: Lebour, 1925; Wood, 1968; Taylor, 1976; Dodge, 1982; Sournia, 1986; Balech, 1988; Steidinger and Tangen, 1997.
Description: Body small; epitheca rounded; horns thin and long; antapicals beginning almost parallel to girdle, then curved until they are parallel with apical horn and almost the same length forming a flat-bottomed U (Wood, 1968).
Dimension: Length 300-500 µm (Wood, 1968).
Distribution: Tropical and subtropical species, oceanic-neritic. Straits of Florida; Benguela Current; Gulf of Mexico (Curl, 1959); Sargasso Sea and Gulf Stream (Hulburt, 1963); Brazil (north coast); Caribbean Sea. (Wood, 1968). It is also present in Kuwait's waters.

Ceratium tripos (O. F. Müller 1781) Nitzsch 1817 (Plate 10B-C)

Synonym: *Cercaria tripos* O.F. Muller 1781.
References: Lebour, 1925; Wood, 1968; Drebes, 1974; Taylor, 1976; Karsten, 1978; Dodge, 1982; Sournia, 1986; Balech, 1988; Pankow, 1990; Steidinger and Tangen, 1997; Throndsen et al., 2003.

Description: Body of cell stout, about as broad as it is long. Epitheca triangular leading sharply into a fairly long straight horn, plates usually apparent. Antapicals more or less continuous with slightly flattened base, then sharply curved forward, parallel to or making an acute angle with apical horn. Hypotheca slightly flattened at the posterior end (Wood, 1968; Dodge, 1982).
Dimension: length 75-90 μm (Wood, 1968; Dodge, 1982).
Distribution: Cosmopolitan. Straits of Florida; Benguela Current; Gulf of Mexico (Curl, 1959); Caribbean Sea; very common around the British Isles (Wood, 1968). It also occurs in Kuwait's waters.

Ceratium sp. 1 (Plate 10D)
Distribution: It occurs in Kuwait's waters.

Family: Cladopyxidaceae Stein 1883
Genus: *Cladopyxis* Stein 1883
Body ovate to spherical; epitheca smaller that hypotheca and with apical pore; girdle deep, anterior; from the middle of the four epithecal and six hypothecal plates arise spines or processes which may be straight or branched; plate formula 4', 0a, 8'', 6''', 2'''' (Wood, 1968). One species occurs in Kuwait's waters.

Cladopyxis hemibrachiata Balech 1964 (Plate 10E)
References: Lebour, 1925.
Distribution: It occurs in Kuwait's waters.

Family: Goniodomataceae Lindemann 1928
Genus: *Alexandrium* Halim 1960
Synonyms: *Gonyaulax* Diesing 1866; *Pyrodinium* Plate 1906; *Gessnerium* Halim 1967 ex Halim 1969; *Protogonyaulax* Taylor 1979.
This genus has extensive synonymy due to continual scrutiny of toxic species causing public health, economic, and ecological problems. Cells are armoured, typically spherical to hemispherical to oval to slightly biconical, but without horns or spines. Plate formula: Po, cp, 4', 0a, 6", 6c, 9 or 10s, 5' ", and 2"". Schematic *Alexandrium* are shown in Figure 8. Descending median cingulum without overhang or contortion, displaced 1-1.5 girdle widths. Surface markings include pores, reticulae, and vermiculae. Thecae can be thin and delicate to rugose. Cytoplasm includes elongate to C-shaped nucleus and all species contain chloroplasts. In this subgenus, the Po touches the 1', but the connection is sometimes obscured in older cells with plate overlap growth of 2' and 4'. Also, in some species of the genus, the ventral-dorsal positioning of the APC and the age of the theca can produce an apical protuberance (Steidinger and Tangen, 1997).
Species of this genus are differentiated by the following characters: shape and position of the Po plate, shape and position of pores (foramen) in the Po and sp plates, shape of sa, the presence and size of the ventral pore, displacement of 1' plate, shape and size of the ssa, chain formation, shape and size of 6", shape of cell, and cell dimensions (Steidinger and Tangen, 1997). Five species are found in Kuwait's waters.

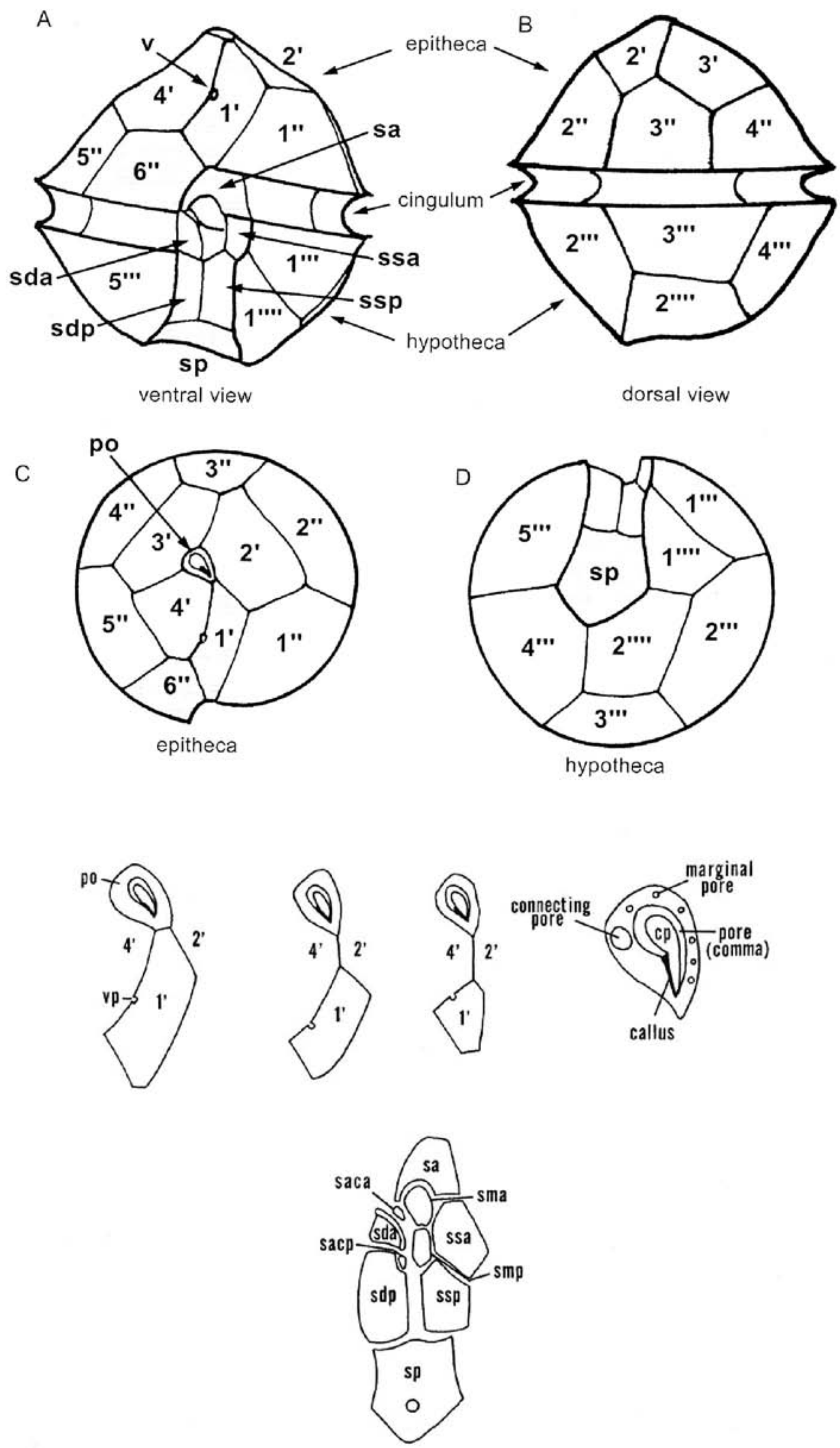


Figure 8. Schematic plate tabulation of *Alexandrium* (Steidinger and Tangen, 1997; Hansen et al., 2001).

Alexandrium insuetum Balech 1985 (Plates 10F-J and 11A-F)

References: Steidinger and Tangen, 1997; Larsen and Nguyen, 2004.

Description: Cells with a regularly oval or ovate shape. The epitheca is a little longer than the hypotheca. The girdle is descening, displaced about one girdle width. The thecal plates carry a pronounced reticulation, which is clearly visible in LM. The pre- and post-cingular series of plates have lines of pores laying adjacent to the cingulum; scattered pores occur on all plates. The nucleus is located in the epitheca. The first apical plate (1') is dislocated from the APC, with a small ventral pore at the middle of the right margin adjoining the 4' plate. The APC is without a connecting pore, but with large marginal pores. The s.a. plate has no pre-cingular part, the s.p. plate is without connecting pore (Larsen and Nguyen, 2004).

Dimensions: 25-28 μm long, about 25 μm wide (Larsen and Nguyen, 2004).

Distribution: Coastal, Korea and Japan (Steidinger and Tangen, 1997), and Vietnam (Larsen and Nguyen, 2004). It also occurs in Kuwait's waters.

Alexandrium leei Balech 1985 (Plates 11G-I and 12A-B)

Synonym: *Protogonyaulax leei* (Balech) Fukuyo.

References: Steidinger and Tangen, 1996; Hansen et al., 2001; Larsen and Nguyen, 2004.

Description: Cells are solitary. The epitheca is broadly conical; the hypotheca is slightly longer than the epitheca, and sometimes appears asymmetrical with the left lobe being larger than the right one. Trichocyst pores are clearly visible on dried cells in LM. The cingulum is descending, displaced about one girdle width. The 1' plate connects directly to the APC; the ventral pore is usually clearly visible and not associated with the left plate margin, but located a short distance inside the plate. The APC has a rather long, comma-shaped pore sometimes with marginal pores, no connecting pore; the apical pore plate has an indentation at its right side. The s.a. plate is flat anteriorly with no pre-cingular part; the s.p. plate has no connecting pore (Larsen and Nguyen, 2004).

Dimensions: 37-40 μm long, 38-40 μm wide (Larsen and Nguyen, 2004).

Distribution: Has been recorded from Korea, Japan, Thailand, the Philippines and Vietnam (Steidinger and Tangen, 1997). Found in the Western Indian Ocean (Hansen et al., 2001). It is also present in Kuwait's waters.

Alexandrium minutum Halim 1960 (Plate 12C-F)

Synonym: *Alexandrium ibericum* Balech 1985.

References: Steidinger and Tangen, 1997; Throndsen et al., 2003.

Description: The cells are small, regularly oval in shape, sometimes a little wider than long. The epitheca and hypotheca are similar in size. The 1'-plate is connected directly to the APC, and has a ventral pore at the margin adjoining the 4' plate, some cells with intercalary bands between the 1' and the s.a. plate. The 6" plate is longer than wide. The s.p. plate is wider than long, the anterior margin is irregular and the posterior margin is convex, a posterior attachment pore is present in the upper right part of the plate and connected to the anterior margin by a groove. The APC has no attachment pore. Toxic species (Larsen and Nguyen, 2004).

Dimensions: 25-27 μm long, 24-26 μm wide (Larsen and Nguyen, 2004).

Distribution: Coastal; Alexandria Harbor, Egypt; Bay of Naples, Italy; Bay of Izmirl Turkey; Greece; Spain; Portugal; France; south of England; New York state, United States; and south of Australia (Steidinger and Tangen, 1997). It also occurs in Kuwait's waters.

Alexandrium tamarense (Lebour) Balech (Plates 12G-I and 13A-C)

References: Throndsen et al., 2003; Larsen and Nguyen, 2004.

Basionym: *Gonyaulax tamarensis* Lebour 1925.

Synonyms: *Gonyaulax tamarensis* var. *excavate* Braarud 1945, *Gonyaulax excavate* (Braarud) Balech 1971, *Gessnerium tamarensis* (Lebour) Loeblich et Loeblich 1979, *Protogonyaulax tamarensis* (Lebour) Taylor 1979, *Alexandrium excavatum* (Braarud) Balech et Tangen 1985.

Description: The cells are slightly asymmetrical with the left side longer than right side. This species often forms chains up to 4 cells. The cells located inside the chain usually have a shoulder. Epitheca is convex-conical in shape and nearly equal to hypotheca. There are many trichocyst pores on the theca. The 1' plate connects directly to the APC and has a small ventral pore near the middle of the right margin. The APC has an attachment pore in some cells, while it is absent in others. The s.p plate is longer than wide, anteriorly with small projections at the corner, rounded posteriorly, in some cells with an attachment pore. It is a variable species which is best identified by the presence of a ventral pore, the shape of the s.p. plate, and the APC which usually does not have connecting pores (Larsen and Nguyen, 2004).

Dimension: 38-42 µm in diameter (Larsen and Nguyen, 2004).

Distribution: It has been recorded from all sampling areas along the Vietnamese coast. It is widespread, and presumably a cosmopolitan species (Larsen and Nguyen, 2004). It is also observed in Kuwait's waters.

Alexandrium sp. 1 (Plate 13D)

References: Wood, 1968; Steidinger and Tangen, 1997.

Distribution: Occurs in Kuwait's waters.

Genus: *Goniodoma* Stein 1883

Synonyms: *Heteraulacus* Diesing 1850; *Triadinium* Dodge 1981.

Cell polygonal or rounded; girdle equatorial, not displaced, with strong lists supported by spines; apical pore present but not apical or antapical horns; plate formula 3 or 4', 7", 5'", 3"" (Wood, 1968). One species occurs in Kuwait's waters.

Goniodoma polyedricum (Pouchet 1883) Jörgensen 1899 (Plate 13E)

Basionym: *Peridinium polyedricum* Pouchet 1883.

Synonyms: *Heteraulacus polyedricus* (Pouchet) Drugg et Loeblich; *Triadinium polyedricum* (Pouchet) Dodge 1981.

References: Lebour, 1925; Wood, 1968; Ricard, 1974; Taylor, 1976; Dodge 1982; Sournia, 1986; Balech, 1988; Pankow, 1990; Steidinger and Tangen, 1997.

Description: Species with very characteristic polyhedral, heptagonal shape, deep set areolae, and cingular list. Cingulum descending less than two widths. Epitheca with three corners, hypotheca with two; apical pore elongate, directed to one side; transverse section nearly circular; girdle equatorial, left-handed, ribbed girdle lists; theca strongly pored; sutures well marked (Wood, 1968; Steidinger and Tangen, 1997).

Dimension: Length 30-60 µm (Wood, 1968).

Distribution: Oceanic; cosmopolitan in subtropical to tropical waters; worldwide distribution (Steidinger and Tangen, 1997). Red Sea, Indian Seas, English Channel (Lebour, 1925); Bahama Banks, West Channel, Santaren Channel, Straits of Florida; Benguela Current, Bermuda and Sargasso Sea (Hulburt, 1962); Brazil (north coast), Caribbean Sea (Wood, 1968). It also occurs in Kuwait's waters.

Genus: *Pyrodinium* Plate 1906

Armored, monotypic genus with two varieties. Cells medium-sized with distinct apical and antapical spines and lists even when cells are in chains. One variety can form long chains in nature. Plate formula: Po, cp, 4-5', 6'', 6c, 6s, 6''', and 2''''. Plate sutures with crests. Chloroplasts present (Steidinger and Tangen, 1997). One species occurs in Kuwait's waters.

Pyrodinium bahamense var. *compressum* (Böhm) Steidenger, Tester, and Taylor 1980 (Plates 13F-K and 14A-D)

References: Steidinger and Tangen, 1997.

Description: Variety with prominent apical protuberance or horn and an apical spine with a list. Cells typically in chains and slightly anterioposteriorly compressed with associated reductions. Pores larger than in other variety. Toxic. This variety, so far, has only been identified from the Pacific and Indian Oceans, not the Atlantic (Steidinger and Tangen, 1997).

Distribution: Warm water species; Pacific (Steidinger and Tangen, 1997). It also occurs in Kuwait's waters.

Family: Gonyaulacaceae Lindemann 1928

Genus: *Gonyaulax* Diesing 1866

Theca variable in shape from spheroidal to polygonal but epitheca and hypotheca subequal. Girdle left-handed, displaced from one-half to seven times its width. Sulcus occupies the whole ventral area; first apical plate narrow and even, extending from girdle to apex (Figure 9). The plate formula 3-5', 0-2a, 6", 6''', 1p, 1'''' (Wood, 1968; Dodge, 1982). Two species occur in Kuwait's waters.

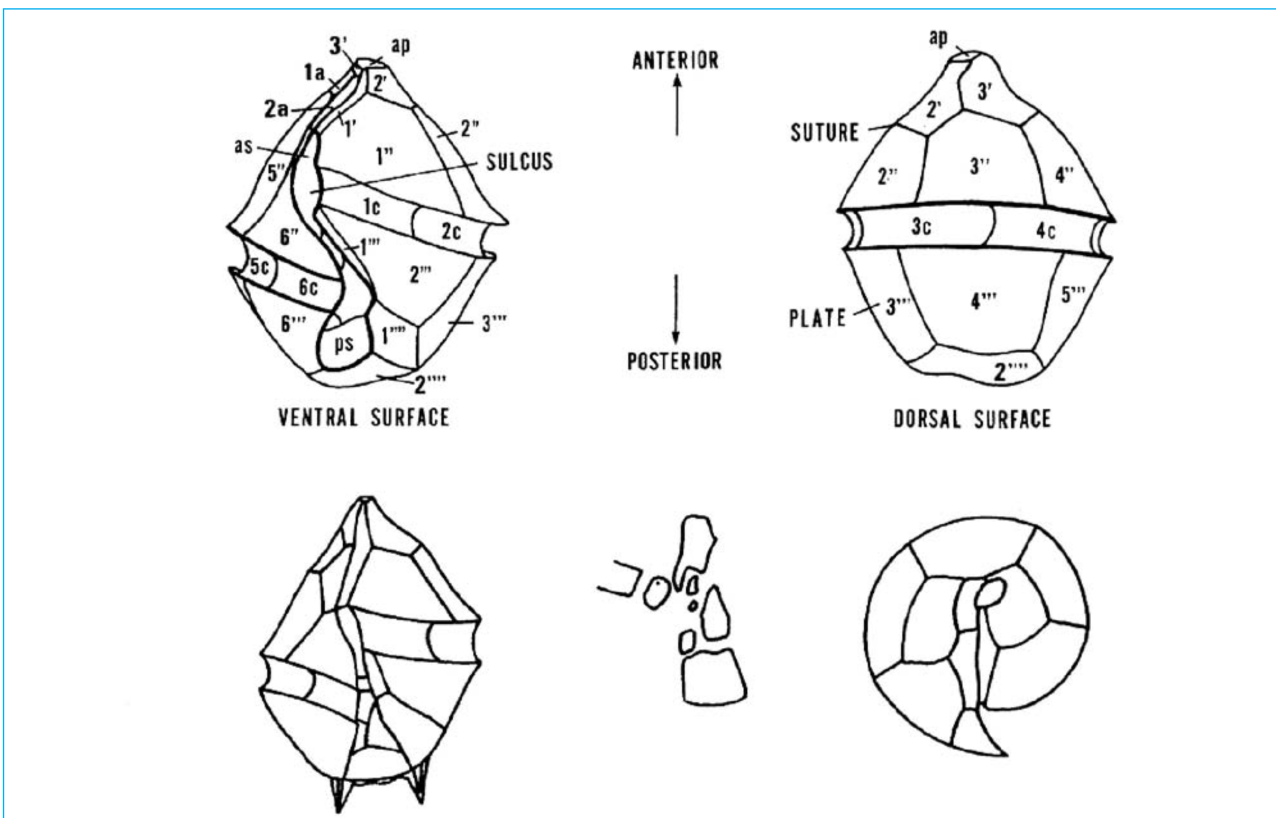


Figure 9. Schematic plate tabulation of *Gonyuaulax* (Steidinger and Tangen, 1997).

Gonyaulax polygramma Stein 1883 (Plate 14E-I)

Synonyms: *Gonyaulax schuetti* Lemmermann 1899; *Protoperidinium pyrophyrum* Pouchet 1883.

References: Lebour, 1925; Wood, 1968; Dodge, 1982; Balech, 1988; Steidinger and Tangen, 1997; Throndsen et al., 2003.

Description: Cell elongated with epitheca exceeding hypotheca; girdle descending, displaced about 1.5 widths. Epitheca convex to angular, tapering to the apical horn; hypotheca symmetrical, rounded or truncate, may have a variable number of short antapical spines. Sulcus slightly excavated, widening to the posterior, and to the anterior running onto the epitheca. Plates ornamented with longitudinal ridges which may be very thick and spinulose on old cells; reticulations between the ridges; plate formula 3' (4'), (1a), 6", 6c, 7s, 6"", 1p, 1"". Chloroplasts present; nucleus large, avoid, located in the posterior part of the cell (Dodge, 1982).

Dimensions: Length 29-66 µm; width 26-54 µm (Wood, 1968; Dodge, 1982).

Distribution: Mainly around Scotland, occasionally found in the south west. Also reported from Florida and South Africa (Dodge, 1982). Cosmopolitan, Bahama Banks, Santaren Channel, Straits of Florida, Brazil (north coast) and Caribbean Sea (Wood, 1968). It also occurs in Kuwait's waters.

Gonyaulax sp.1 (Plate 14J-L)

Distribution: This species occurs in Kuwait's waters.

Genus: *Lingulodinium* (Wall) Dodge 1989

Synonym: *Gonyaulax polyedra* Stein 1883.

One species was found in Kuwait's waters.

Lingulodinium polyedrum (Stein) Dodge 1989 (Plate 14M-O and 15A-C)

Synonym: *Gonyaulax polyedra* Stein 1883.

References: Dodge, 1989; Steidinger and Tangen, 1997; Throndsen et al., 2003.

Description: Cell polyhedral shaped, without antapical spines and apical horn. Descending cingulum without overhang. Theca is reticulate to areolate with pores in the depressions. Plate formula: Po, 3', 3a, 6", 6c, 7s, 6'", and 2"". The APC is characteristic of *Gonyaulax*, e.g., *G. verior* and *G. digitale.* The raised inner elliptical rim of the Po can be closely appressed and appears as a lattice or protuberances. Forms distinctive cysts. Toxic species (Steidinger and Tangen, 1997).

Distribution: Neritic; warm temperate to tropical waters (Steidinger and Tangen, 1997). It occurs in Kuwait's waters.

Genus: *Protoceratium* Bergh 1881

Synonym: *Gonyaulax* Diesing 1866

Cell a somewhat angular oval or sphere. Girdle equatorial or slightly in front of the center. Theca strongly reticulated so as to obscure the plates, sometimes with spines at the intersection of the meshes. Intercalary bands sometimes very broad. There is no apparent apical pore (Lebour, 1925). Two species are found in Kuwait's waters.

Protoceratium reticulatum (Claparéde and Lachmann) Bütschli 1885 (Plate 15D-I)

References: Lebour, 1925.

Description: Epitheca and hypotheca sub-equal or hypotheca slightly the longer. Rounded angular. Girdle left-handed, displaced about a girdle width, with narrow lists supported by spines. Ventral area reaching not quite to the antapex. Theca strongly reticulated and often with spicules. First apical very narrow, the second polygonal and occupying the anterior end. Six large precingulars. Girdle apparently not divided. Hypotheca with 6 postcingulars, the first shorter, with a small posterior intercalary plate behind it. Two long plates occupying most of the ventral area and these regarded as antapicals (Lebour, 1925).

Dimensions: 28-56 µm (Lebour, 1925).

Distribution: Neritic. Very common Northern species, Bosphorus, Adriatic. Abundant at Plymouth (Lebour, 1925). It is also present in Kuwait's waters.

Protoceratium sp. 1 (Plate 16A-D)

Distribution: This species is present in Kuwait's waters.

Family: Oxytoxaceae Lindemann 1925

All members of this family share a tendency towards left-handed displacement of the girdle with accompanying torsion effects. Torsion and displacement is least in *Oxytoxum* and strongest, effecting both the epi- and hypotheca, in *Corythodinium.* In these both genera, which are observed in this survey, the sulcus notches the hypotheca strongly. Details are given below (Figure 10) under each genus (Taylor, 1976).

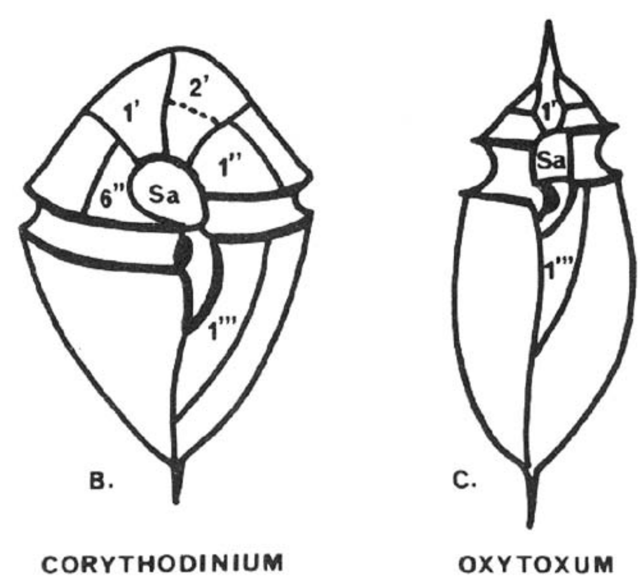


Figure 10. Ventral views of the two principal genera of Oxytoxaceae are recognized here (Taylor, 1976). Note the differences in the form of the ventral area (not all plates are shown) and the anterior sulcal plate (sa).

Genus: *Corythodinium* Loeblich Jr. & Loeblich III 1966

Relatively robust species, rounded or broadly elongated, lacking "affixed" apical spines (although the epitheca may rise to a pointed cone) but usually possessing an antapical spine. The epitheca often shows signs of dextrial torsion, with the plates displaced accordingly. In a few species the epitheca may be laterally flattened and raised into a crest. The girdle is strongly developed, lacking lists, with right-handed (descending) displacement of one or more girdle widths. The proximal ends of the girdle may overlap slightly. Both the epitheca and the hypotheca are strongly notched by the sulcus. The anterior sulcal plate is unusually large and usually obovate (sometimes pentangular) with the narrower end and closer to the flagellar pore(s). The thecal plates are usually strongly reticulated and poroid, and intercalary bands may develop. The plate formula of the type species is 3', 2a, 6'', 5c, ?s, 5''',1'''' (Taylor, 1976). One species occurs in Kuwait's waters.

Corythodinium tesselatum (Stein) Loeblich Jr. & Loeblich III 1966 (Plate 16E-I)

Synonym: *Oxytoxum tesselatum* (Stein) Schütt.
References: Schiller, 1937; Taylor, 1976, Balech, 1988; Steidinger and Tangen, 1997.
Description: Medium-sized cell. Cingulum premedian; hypotheca exceeds epitheca and ends in a thick antapical spine. Epitheca with reticulate markings and broad hypotheca with characteristic longitudinal striae connecting evenly spaced, offset horizontal striae. Horizontal striae with linear field of pores on inside margin (Steidinger and Tangen, 1997).
Dimensions: Length 58 µm (Schiller, 1937).
Distribution: Warm temperate to tropical waters; most records from the Atlantic Ocean (Steidinger and Tangen, 1997). It is present in Kuwait's waters.

Genus: *Oxytoxum* Stein 1883

Cell elongated with pointed apices, clavate to fusiform. Girdle deep and broad, median or anterior to the centre, circular or with slight displacement. Epitheca small, compared with larger epitheca in *Corythodinium.* The anterior sulcal plate slightly indents the epitheca in contrast with *Corythodinium* where it is almost wholy situated in the epitheca. The sulcus itself is short. Plates may have longitudinal sculpturing or poroids. Typically a warm water genus (Dodge, 1982). Three species of *Oxytoxum* occur in Kuwait's waters.

Oxytoxum gracile Schiller 1937 (Plate 16J)

References: Schiller, 1937; Wood, 1968; Throndsen et al., 2003.
Description: Epitheca conical, pointed with concave margins; girdle narrow, varying in depth. Hypotheca with wide shoulders tapering to antapical spine; sulcus short (Wood, 1968).
Dimension: Length 25-30 µm (Wood, 1968).
Distribution: Adriatic Sea; southwest Pacific Ocean. Brazil (north coast); Caribbean Sea (Wood, 1968). It is also present in Kuwait's waters.

Oxytoxum sceptrum (Stein) Schröder (Plate 16K)

Distribution: It also occurs in Kuwait's waters.

Oxytoxum sp. 1 (Plate 16L-M)

Distribution: It is an abundant species in Kuwait's waters.

Family: Pyrocystaceae (Schütt) Lemmerman 1899

Genus: *Pyrocystis* Murray *ex* Haeckel 1890

Synonyms: *Gymnodinium* Stein, 1978, *Murracystis* Haeckel, 1891, *Diplodinium* Klebs, 1912, *Dissodinium* Klebs in Pascher, 1916.

Marine dinophytes with a dominant coccoid stage which is fusiform, lunate or spherical Cell naked, very large and hyaline; cytoplasm parietal or clustered around the nucleus; chloroplasts numerous held in protoplasmic threads radiating from nucleus to cell wall; spores multiple, gymnodinioid. Normally bioluminescent (Wood, 1968; Dodge, 1982). Two species are present in Kuwait's waters.

Pyrocystis obtusa Pavillard 1931 (Plate 17A-B)

References: Wood, 1968; Taylor, 1976.

Description: Body lunate with blunt ends directed toward each other (Wood, 1968).

Dimension: Length 150-250 µm (Wood, 1968).

Distribution: East Indian Ocean. Sargasso Sea (Hulburt, 1963). It also occurs in Kuwait's waters.

Pyrocystis fusiformis Wyville-Thomson ex Blackmann (Plate 17C-D)

References: Taylor, 1976; Wood, 1968; Sournia, 1986; Balech, 1988.

Description: Vegetative cells large, thin and fusiform or wider and shorter with rounded ends; protoplasmic strands marginal; spores gymnodinium-like (Wood, 1968).

Dimension: Length to 600 µm (Wood, 1968).

Distribution: Interoceanic warm-water species. Straits of Florida; Benguela Current; Gulf Stream (Hulburt, 1963). It also occurs in Kuwait's waters.

Family: Pyrophacaceae Lindemann 1928

Genus: *Pyrophacus* Stein 1883

Cell low, lenticular; epitheca and hypotheca equal, obliquely conical; girdle even; sulcus with a few small plates; plate formula 5', 9", 9"', 3"" (Wood, 1968). Cell anterior-posteriorly flattened having a bi-convex lens shape when seen from the side. Rather thin thecal plates with a variable plate formula 5-9', 0-8a, 7-15", 9-16c, 8-17'", 0-9p, 3-7"". Cell contents tend to round up, pushing apart the epitheca and hypotheca (Dodge, 1982). Two species are found in Kuwait's waters.

Pyrophacus horologicum Stein 1883 (Plate 18A-D)

References: Wood, 1968; Drebes, 1974; Taylor, 1976; Dodge, 1982; Sournia, 1986; Balech, 1988; Pankow, 1990; Steidinger and Tangen, 1997; Throndsen et al., 2003.

Description: Cell low, biconvex; lens-shaped test with epitheca and hypotheca equal, much wider than high; plates well marked with linear markings in the middle; sulcus with a few small plates. Most conservative species with little variation in plate formula. Typically the epitheca has 5', 0a, and 9", intercalary bands narrow to very broad. Cytoplasm with a strong tendency to round up, containing numerous chloroplasts (Wood, 1968; Dodge, 1982; Steidinger and Tangen, 1997).

Dimension: Length 40 µm (Wood, 1968); width 35-136 µm, height 32-125 µm (Dodge, 1982).

Distribution: Warm oceans. Brazil, only in Amazon delta (Wood, 1968). Found all around the British Isles but most commonly near to land and in the North Sea (Dodge, 1982). Oceanic, neritic, estuarine. Cosmopolitan in cold temperate to tropical waters (Steidinger and Tangen, 1997). It is also present in Kuwait's waters.

Pyrophacus steinii (Schiller) Wall & Date 1971 (Plate 19A-F)

References: Balech, 1988; Steidinger and Tangen, 1997.

Description: Flattened, lenticular cell with attenuated epitheca. Typically, the epitheca has 7', 0a, and 12" (Steidinger and Tangen, 1997).

Distribution: Restricted to warm temperate to tropical waters of all oceans (Steidinger and Tangen, 1997). It is also found in Kuwait's waters.

Order: Peridiniales Haeckel 1894
Family: Calciodinellaceae F. J. R. Taylor 1987
Genus: *Scrippsiella* Balech 1959

Small dinoflagellates with a conical epitheca and rounded hypotheca separated by a median excavated girdle. Chloroplasts present, nucleus ovoid, centrally placed. Thecal plates relatively thin and unsculptured. Plate formula: 4', 3a, 7", 5-6c, 5'", 2"", 4s (Dodge, 1982). Species of this genus can have variant plate formulae in cultured specimens; they can produce additional plates in known series. Currently, species are differentiated based on the following characters: size and shape, shape of 1' and 2a, number of precingular plates, surface ornamentation, the presence of stigma, and habitat (Steidinger and Tangen, 1997). One species occurs in Kuwait's waters.

Scrippsiella trochoidea (Stein) Loeblich III 1976 (Plate 20A-B)

References: Dodge, 1982; Steidinger and Tangen, 1997; Throndsen et al., 2003.

Description: Small pyriforme cell with conical epithea. The girdle is wide, excavated, composed of six plates and surrounded by narrow lists. The epitheca has orthohexa tabulation. There are no antapical projections and the wide excavated sulcus does not indent the antapex. The theca has scattered poroids. Several yellow-brown chromatophores are present and the nucleus is central. Plate formula: 4', 3a, 7", 6c, 5'", 2"" (Dodge, 1982). This species is differentiated by its pear shape, narrow 1', and apical process (Steidinger and Tangen, 1997).

Dimensions: 16-36 µm long; 20-23 µm broad (Dodge, 1982).

Distribution: Cosmopolitan neritic and estuarine species (Steidinger and Tangen, 1997). Occurs all round coast of Britain. Elsewhere from Atlantic, West Indies (Dodge, 1982) and also found in different locations of Kuwait's waters.

Family: Kolkwitziellaceae Lindemann 1928

This is a confused group of distinctive species. The confusion arises from interpretation and assignment of plates to a series and the extensive synonymy involved in tracking a single species (Steidinger and Tangen, 1997). The schematics redrawn from Dodge and Hermes (1981) of the genera of this group are shown in Figure 11 and the summary of the tabulation patterns in these genera are shown in Table 3. They follow Balech (1976) in dividing the group into two on the basis of the number of antapical plates: cells with one antapical plate (Sub-group I) (Figure 11D) such as *Diplosalis* Bergh, *Zygabikodinium* Loeblich and Loeblich and *Boreadinium* Dodge and Hermes and two antapical plates (Sub-group II) (Figure 11H) such as *Diplopelta* Stein (*Dissodium* Abé), *Diplosalopsis* Meunier and *Oblea* Balech. In the Kuwaiti materials, several species often occurred in the same sample. Three genera were observed in Kuwait's waters.

Table 3. Summary of the tabulation patterns in the six genera of the Diplosalis group.

	Tabulation						
	′	a	″	c	s	‴	⁗
Sub-group I							
Diplosalis	3	1	6	3	P5	5	1
Zygabikodinium	3	2	6	3	P5	5	1
Boreadinium	4	1	7	3	P5	5	1
Sub-group II							
Diplopelta (Dissodium)	3	2	6	3	P5	5	2
Diplosalopsis	3	2	6	3	P5	5	2
Oblea	3	1	6	3	P5	5	2

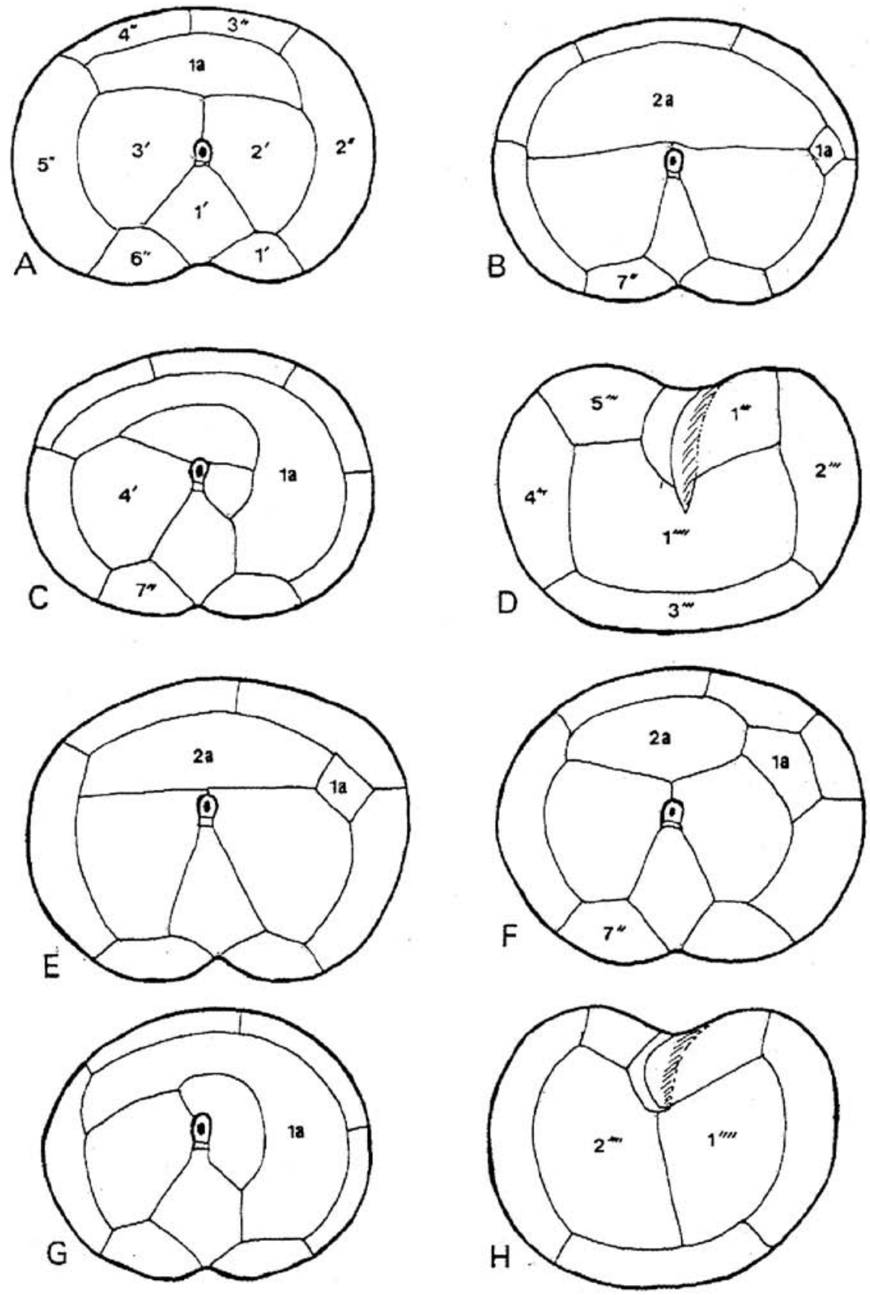


Figure 11. Drawings to show the thecal tabulation in the six recognized genera of the Diplosalis group. A-C and E-G show epitheca, D and H show hypotheca. A. *Diplosalis*; B. *Zygabikodinium*; C. *Boreadinium* D. Hypotheca type of sub-group I; E. *Diplopelta;* F. *Diplosalopsis*; G. *Oblea*; H. Hypothaca type of sub-group II. The thecal code is given in full for one epitheca (Fig 11A) and one hypotheca (Fig 11D) but otherwise only where there are variations.

Genus: *Diplopsalis* Bergh 1881

Synonyms: *Dissodinium* Abé 1941 in part; *Glenodinium* Ehrenberg 1836 in part.
Cells lenticular with wide sulcal list reaching to center of hypotehca. Characteristically with a single antapical plate distinguishing this genus from *Dissodium* which has two (Dodge, 1982). Three apical plates present and one, dorsally situated, anterior intercalary plate (Figure 11A). The first apical (1') is broad, symmetrical and four-sided (ortho). There are six pre-cingular plates (Dodge and Hermes, 1981). One species occurs in Kuwait's waters.

Diplopsalis lenticula Bergh 1881 (Plate 20C-L)

Synonym: *Glenodinium lenticula* Pouchet 1883; *Dissodium lenticulum* (Bergh) Loeblich III 1970.
References: Lebour, 1925; Schiller, 1937; Dodge and Hermes, 1981; Dodge, 1982; Dodge and Toriumi, 1993; Steidinger and Tangen, 1997; Throndsen et al., 2003.
Description: Armored. Medium-sized subsperical to lenticular cell in shape with APC and prominent left sulcal list typical of diplopsalids. Surface with scattered pores. Chloroplasts absent. Produces cysts (Steidinger and Tangen, 1997). Three apical plates present and one, dorsally situated, anterior intercalary plate. The 1'-plate is ortho and the hypotheca with one antapical plate.
Dimensions: Diameter 23-48 μm (Dodge, 1982); 40-50 μm (Dodge and Toriumi, 1993).
Distribution: Estuarine to oceanic; cosmopolitan in cold temperate to tropical waters (Steidinger and Tangen, 1997). Elsewhere recorded from the Baltic, Mediterranean, Red Sea, Australia, Gulf of Aden, Indian Ocean, Caribbean, Antarctic, China Sea (Dodge, 1982), North Sea and Pacific Ocean (Dodge and Toriumi, 1993). It is also present in Kuwait's waters.

Genus: *Diplopsalopsis* Meunier 1910

Three apical plates and two anterior intercalaries of which one is large and dorsal whilst the second is small and situated on the left side (Figure 11F). 1' is ortho and rather narrow and there are seven pre-cingular plates as in *Zygabikodinium* Loeblich and Loeblich. Two antapical plates present (Dodge and Hermes, 1981). One species occurs in Kuwait's waters.

Diplopsalopsis orbicularis (Paulsen) Meunier 1910 (Plate 20M-O and 21A-E)

Synonyms: *Peridinium orbiculare* Paulsen 1908; *Diplopsalis orbicularis* (Paulsen) Paulsen 1930.
References: Lebour, 1925; Dodge and Toriumi, 1993; Steidinger and Tangen, 1997; Throndsen et al., 2003.
Description: Armored. Small to medium-sized subsperical cell with APC and prominent left sulcal list of diplopsalids. Surface with scattered pores. Chloroplasts absent. Produces cysts (Steidinger and Tangen, 1997). Three apical plates present and one, dorsally situated, anterior intercalary plate. The 1' plate is ortho and the hypotheca with one antapical plate.
Dimensions: Diameter 40-46 μm (Lebour, 1925); 47-55 μm (Dodge and Toriumi, 1993).
Distribution: Pacific Ocean, North Sea, Japan Sea, Danish waters, Iceland, English Channel and Plymouth (Lebour, 1925; Dodge and Toriumi, 1993; Steidinger and Tangen, 1997). It is also found in Kuwait's waters.

Genus: *Diplopelta* Stein ex Jörgensen 1912

Synonym: *Dissodium* Abé 1941.

There are three apical plates and two anterior intercalaries. One large and one small (Figure 11E) (Dodge and Hermes, 1981). One species occurs in Kuwait's waters.

Diplopelta parva (Abé) Matsuoka 1988 (Plate 21F-K)

Basionym: *Dissodium parvum* Abé 1941.

Synonyms: *Diplopsalis parva* (Abé) Abé 1981; *Diplopelta parva* (Abé) Matsuoka 1988

References: Dodge and Toriumi, 1993; Steidinger and Tangen, 1997.

Description: Cells are almost globular in shape. An apical pore and canal plate are present and the apical pore is enclosed by a pore plate. The apical series consist of three plates with the apical plate 1' of the ortho-type. The anterior intercalary and antapical series each consist of two plates and the1a plate is of the diamond-shaped. The precingular series consists of six plates. The posterior sulcal plate is of the caspica-type (Dodge and Toriumi, 1993).

Dimensions: Diameter 40-41 µm (Dodge and Toriumi, 1993).

Distribution: Coastal; temperate (Steidinger and Tangen, 1997). Found in the Pacific Ocean (Dodge and Toriumi, 1993) and also in Kuwait's waters.

Genus: *Oblea* Balech 1964

There are three asymmetrical apical plates of which 1' is meta and one large curved intercalary plate (Figure 11G). There are only six pre-cingular plates (Dodge and Hermes, 1981). One species occurs in Kuwait's waters.

Oblea rotunda (Lebour) Balech ex Sournia 1973 (Plate 21L-P)

Synonyms: *Diplopsalis rotundta* (Lebour) Wood 1954; *Glenodinium rotundum* (Lebour) Schiller 1937; *Peridiniopsis rotunda* Lebour 1922.

References: Dodge, 1982; Dodge and Toriumi, 1993; Throndsen et al., 2003.

Description: The cells are almost globular in shape. An apical pore and canal plates are present and the apical pore is enclosed by a pore plate. The apical series consist of three apical plates with the apical plate 1' of the meta-type. One anterior intercalary plate and two antapical plates are present. The precingular series consists of six plates.

Dimension: 22-34 µm in diameter (Dodge, 1982), 22-28 µm in diameter (Dodge and Toriumi, 1993).

Distribution: Found all round coast of Britian and also from Australia, Antarctic, Straits of Florida and Gulf of Mexico (Dodge, 1982). It is recorded in the North Sea, Pacific Ocean and Atlantic Ocean (Dodge and Toriumi, 1993). It is also present in Kuwait's waters.

Genus: *Preperidinium* Mangin 1913

Synonyms: *Diplopeltopsis* Pavillard 1913; *Zygabikodinium* Leoblich Jr. and Leoblich III 1970. The schematic drawing of this genus is shown in figure 11B. One species occurs in Kuwait's waters.

Preperidinium meunieri (Pavillard) Elbrächter 1993 (Plate 22A-H)

Synonyms: *Peridinium paulsenii* Mangin 1911; *P. lenticulatum* Mangin 1911, *Diplopeltopsis minor* (Paulsen) Pavillard 1913, *Diplopsalis lenticula* f. *minor* Paulsen 1907, *Diplopsalis minor* (Paulsen) Lindemann 1927; *Zygabikodinium lenticulatum* Leoblich Jr. and Leoblich III 1970.

References: Dodge, 1982; Steidinger and Tangen, 1997.

Description: Armored. Small to medium-sized sublenticular to subglobular cell with prominent left sulcal list and APC. Cingulum median and circular with prominent rib-supported lists. Surface with scattered pores. Chloroplasts absent (Steidinger and Tangen, 1997).

Dimension: Diameter 28-56 μm, usually over 40 μm (Dodge, 1982).

Distribution: Recorded from all around the British coast. Also from the Baltic, Australia, Brazil and Caribbean Sea (Dodge, 1982). It is also found in Kuwait's waters.

Family: Peridiniaceae Ehrenberg 1828

Genus: *Heterocapsa* Stein 1883

Synonym: *Cachoninna* Loeblich III 1968.

Armored. Small (<20 μm) peridinioid that appears unarmored at the light microscope level of resolution. Epitheca rounded to conical; hypotheca rounded to attenuated. Cingulum slightly displaced and descending. Thinly thecate with characteristic body scales. Chloroplasts present. Most typical plate formula: Po, cp, X, 6', 3a, 7", 6c, 5s, 5"', 0 or 1p, 2"". The 1' is displaced from the Po and lies above the sa. The sa plate is small. The X plate is at the anterior left margin of the 6' and in contact with the Po. Species can be bloom formers (Steidinger and Tangen, 1997). One species occurs in Kuwait's waters.

Heterocapsa sp. 1

Distribution: Occurs in Kuwait's waters.

Family: *Protoperidiniaceae* F. J. R. Taylor 1987

Genus: *Protoperidinium* Bergh 1881

Synonym: *Peridinium* Ehrenberg 1831 partim.

Body polygonal to rotund, often flattened to curved laterally; epitheca and hypotheca more or less equal; girdle may be depressed or not, with or without lists; sulcus usually with lists which may extend beyond antapex; apical horn may be "affixed" or tapering, long or rudimentary; antapical spines may be present or antapex may extend into two antapical processes; plate formula variable. Chromatophores and chloroplasts are usually absent (Wood, 1968; Dodge, 1982). The schematic *Protoperidinium* species tabulation are shown in Figure 12. Many *Protoperidinium* spp. are found in Kuwait's waters. Thirteen of the species names are not finalized at this stage and are reported as species 1 to 13.

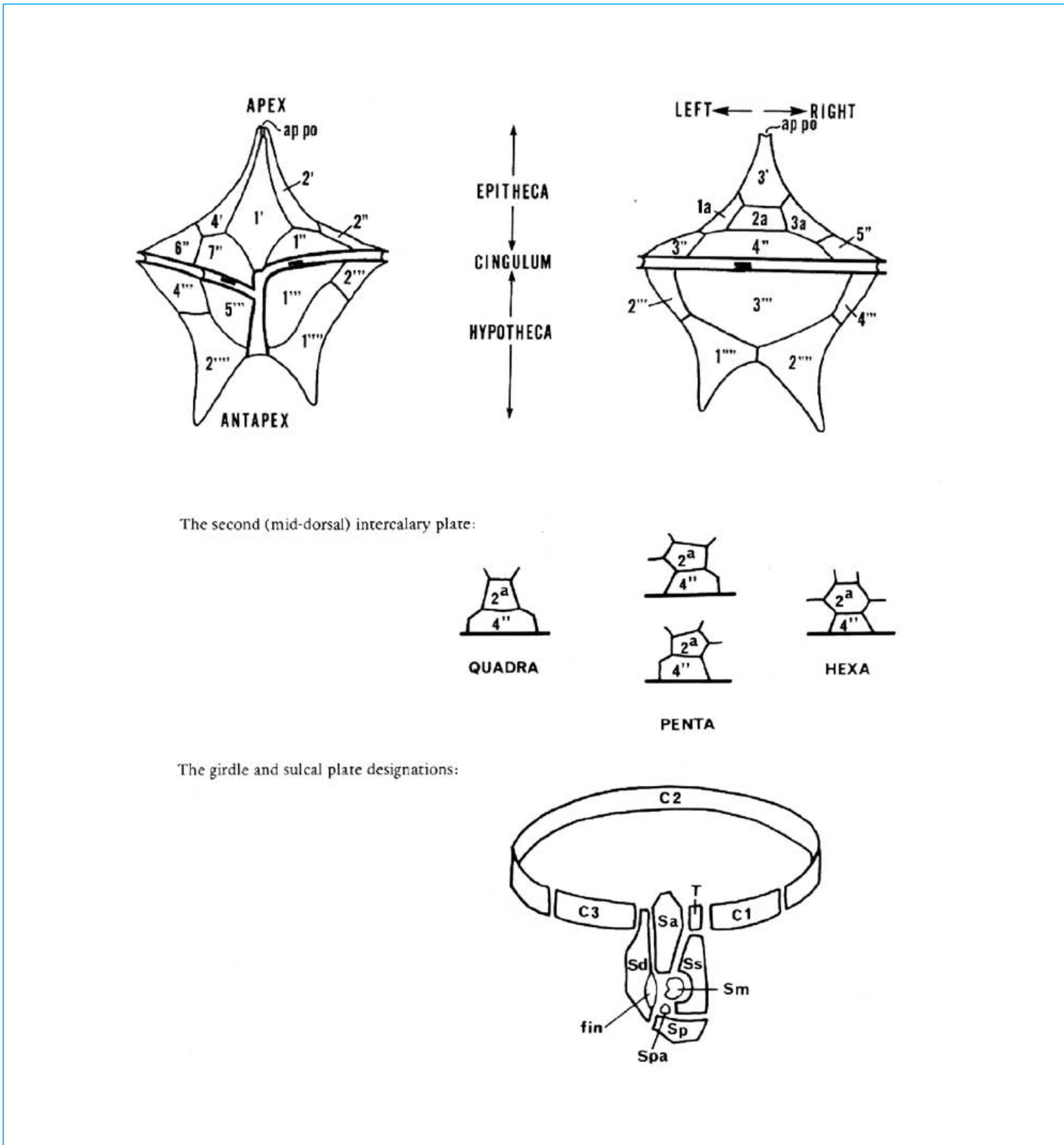


Figure 12. The schematic plate tabulation diagram of *Protoperidinium* species (Steidinger and Tangen, 1997).

Protoperidinium biconicum **(Dangeard) Balech (Plates 22I-K and 23A)**

Basionym: *Peridinium biconicum* Dangeard 1927

References: Schiller, 1937; Taylor, 1976.

Description: the cells are biconical in shape and slightly dorso-ventrally flattened. The theca is lightly reticulated. The 1' plate is ortho and the 2a plate is hexa (Taylor, 1976).

Dimensions: 60-70 µm long, 70-80 µm wide (Taylor, 1976).

Distribution: It has been recorded in the Arabian/Persian Gulf (Schiller, 1937) and Indian Ocean (Taylor, 1976). It is also present in Kuwait's waters.

Protoperidinium bipes **(Paulsen 1904) Balech 1974 (Plate 23B)**

Basionym: *Glenodinium bipes* Paulsen 1904.

Synonym: *Peridinium minusculum* Pavillard 1905; *Minuscula bipes* (Paulsen 1904) Lebour 1925.

References: Dodge, 1982; Balech, 1988; Pankow, 1990; Bérard-Therriault et al., 1999.

Description: Belonging to Balech's (1974) subgenus *Minisculum* this species has six precingular plates. Cell flattened dorsoventrally with triangular epitheca ending in a long apical horn and a shorter hypotheca ending in two fine, solid, antapical horns. The thecal plates are delicate. The first apical is of meta type and 2a is penta. In ventral view, the slides of the epitheca may be straight or concave and the hypotheca straight-sided with the posterior end flattened. The antapical spines are situated at the angle between the flattened antapex and the sides of the hypotheca and diverge outwards. The girdle is slightly right-handed, excavated and bordered by lists. The sulcus wides posteriorly. The cell contents are colorless which, together with the relatively small size, may cause it to be overlooked. Plate pattern: 4', 3a, 6", 5"", 2"" (Dodge, 1982).

Dimensions: 20-35 µm long; 17-19 µm wide (Dodge, 1982).

Distribution: Neritic; found all around Britain Greenland, Iceland, Baltic, Bosporus and Mediterranean (Dodge, 1982). It is also found in Kuwait's waters.

Protoperidinium cerasus **(Paulsen 1907) Balech 1973 (Plate 23C-H)**

Synonym: *Peridinium cerasus* Paulsen 1907.

References: Schiller, 1937; Wood, 1968; Subrahmanyan, 1971; Drebes, 1974; Taylor, 1976; Dodge, 1982, 1985; Balech, 1988; Steidinger and Tangen, 1997.

Description: The cells are oval-pyriform with a short apical horn. Cell body more or less globular in shape, which makes it difficult to observe this species in straight ventral or dorsal views. The cingulum is ascending, displaced about one girdle width. The sulcus is lined by lists and left left sulcal list continues in a conspicuous spine with wings oriented perpendicularly to the ventral plane of the cell. The thecal plates seems smooth in light microscope. The shape of the 1' plate is meta and the 2a plate is quadra.

Dimensions: 50-60 µm long, 40-50 µm wide. Length 46 µm; breadth 30-40 µm. (Balech's *P. cerasus* is generally larger 53-80 µm + 6-9 µm for spines) (Dodge, 1982).

Distribution: It is presumably a cosmopolitan species (Schiller, 1937). Found all around British Isles. Also in the Caribbean and off S. America (Dodge, 1982). This species is common in Kuwait's waters.

Protoperidinium claudicans (Paulsen) Balech 1974 (Plate 23I-L)

Synonym: *Peridinium claudicans* Paulsen 1907.

References: Schiller, 1937; Taylor, 1976; Dodge, 1982; Balech, 1988; Pankow, 1990; Steidinger and Tangen, 1997; Throndsen et al., 2003.

Description: Thinly thecate medium-sized cell; broadly pyriform with antapical horns. Dorsoventrally compressed. Epitheca attenuated into short apical horn. Plates ortho, quadra or penta. Cingulum descending 1-1.5X. Sulcus slightly invades epitheca (Steidinger and Tangen, 1997). Hypotheca bears two unequal hollow antapical horns (the right side longer than the left). The girdle is left-handed, excavated and bordered by lists supported by ribs. Theca finely reticulated. Said to be luminescent. Cell contents pale yellow (Dodge, 1982).

Dimensions: 50-105 µm long; 48-76 µm wide (Dodge, 1982).

Distribution: It has previously been reported from the Indian Ocean (Schiller 1937). Principally coastal and open water, but found in estuarine environments. Temperate to tropical species; cosmopolitan (Steidinger and Tangen, 1997). Neritic; found all around coast of Britain. Also found in coastal waters of Europe, N. America and Indian Ocean (Dodge, 1982). It is also found in Kuwait's waters.

Protoperidinium conicum (Gran) Balech 1974 (Plate 24A-G)

Basionym: *Peridinium conicum* Gran 1902.

References: Lebour, 1925; Schiller, 1937; Wood, 1968; Subrahmanyan, 1971; Drebes, 1974; Taylor, 1976; Dodge, 1982, 1985; Balech, 1988; Pankow, 1990; Steidinger and Tangen, 1997.

Description: Medium-sized to large pentagonal cell with short antapical horns. Ventral epitheca concave. Dorsoventrally compressed. Ortho, hexa. Cingulum circular. Surface reticulated. Anterior sutures of 1', right sulture of 1", and left suture of 7" are excentuated and form a thick inverted V suture line from the X plate. Broad 1' and triangular 1" and 7". APC of A' type (Steidinger and Tangen, 1997). The deep sulcus divides the posterior end of the hypotheca into two hollow horns. Girdle excavated, bordered by narrow lists supported by spines. Cell contents pink (Dodge, 1982). The plates appeared smooth in the present material.

Dimensions: Length 70-85 µm; breadth 60 µm (Dodge, 1982).

Distribution: It has been reported previously from the Indian Ocean (Tayor 1976). Coastal and oceanic. Cosmopolitan in temperature to tropical waters (Steidinger and Tangen, 1997). Neritic. Found all around coast of Britain. Also from Mediterranean, Baltic, English Channel, Atlantic and Amazon Estuary (Lebour, 1925; Dodge, 1982). It is a common species in Kuwait's waters.

Protoperidinium crassipes (Kofoid 1907) Balech 1974 (Plate 24H-K)

Basionym: *Peridinium crassipes* Kofoid 1907.

References: Schiller, 1937; Steidinger and Williams, 1970; Pankow, 1990; Steidinger and Tangen, 1997.

Description: Large cell with apical and antapical horns; right antapical horn wider and longer than left horn. Cell almost circular in cross section. Ventral area slightly excavated. Surface reticulate. Meta, quadra. Cingulum descending 1 or 2x. APC probably of B' type. Not as angular as *P. depressum* or *P. divergens.* Phaetotrophic (Steidinger and Tangen, 1997). The antapicals were observed without claws in the present material while they were strongly developed in *Protoperidinium curtipes.*

Distribution: Coastal; even forms blooms in warm water estuaries.Temperature to tropical waters; cosmopolitan (Steidinger and Tangen, 1997). It also occurs in Kuwait's waters.

Protoperidinium curtipes (Jörgensen) Balech 1974 (Plate 24L-O)

Basionym: *Peridinium curtipes* Jörgensen 1912.

Synonym: *P. crassipes* Paulsen 1907.

References: Lebour, 1925; Wood, 1968; Schiller, 1937; 1968; Subrahmanyan, 1971; Balech, 1974; Drebes, 1974; Taylor, 1976; Dodge, 1982, 1985; Steidinger and Tangen, 1997; Throndsen et al., 2003.

Description: Cell of slightly greater breadth than length, not dorsoventrally flattened. Walls of epitheca and hypotheca markedly concave. Thecal plates meta-quadra and strongly reticulated with spines at the junction of the reticulations. Broad intercalary striae frequent, Hypotheca ending in two hollow horns which characteristically bear projections inside, whicha re continuations of sulcal lists and end in spines. Girdle not displaced, deeply excavated and bordered by lists supported by spines. Cell contents yellow (Dodge, 1982).

Dimensions: Length 80-100 µm; breadth 67-100 µm (Lebour, 1925; Dodge, 1982).

Distribution: Oceanic; found all around coast of Britain (Dodge, 1982). It is a widespread species (Taylor, 1976; Throndsen et al., 2003). It is a common species in Kuwait's waters.

Protoperidinium depressum (Bailey 1855) Balech (Plate 25A-J)

Synonym: *Peridinium depressum* Bailey 1855.

References: Wood, 1968; Subrahmanyan, 1971; Drebes, 1974; Taylor, 1976; Dodge, 1982, 1985; Balech, 1988; Pankow, 1990; Steidinger and Tangen, 1997.

Description: Cell broad, obliquely flattened dorsoventrally; axis very oblique. Epitheca tapering into large apical horn, whrease hypotheca with two long, tapering antapicals, each with a spinelet continuous with the sulcal list. The sulcus is deeply excavated. Girdle left-handed, unexcavated, bordered by wide lists supported by spines. Intercalary striae when present may be broad. Sides of the theca concave towards apex and antapex and convex near the girdle. Cell contents pink. A luminescent species (Wood, 1968; Dodge, 1982).

Dimensions: Length 100-200 µm (Wood, 1968); 116-200 µm long; 116-144 µm wide (Dodge, 1982).

Distribution: Euryhaline and eurythermal, found from Antarctic to Arctic waters. Straits of Florida; Benguela Current; Gulf Stream (Hulburt, 1963); west coast of Florida (Curl, 1959); Brazil (north coast); Caribbean Sea (Wood, 1968). Occurs all around the British Isles (Dodge, 1982). It is a common species of Kuwait's waters.

Protoperidinium divergens (Ehrenberg) Balech 1974 (Plate 26A-J)

Synonym: *Peridinium divergens* Ehrenberg 1840.

References: Lebour, 1925; Schiller, 1937; Taylor, 1976; Dodge, 1982; Pankow, 1990; Steidinger and Tangen, 1997.

Description: Cell longer than broad with concave sides to both epitheca and hypotheca. Prominent apical horn and two diverging hollow antapical horns. Meta-quadra plate arrangement. Sulcus widening slightly, posteriorly, bordered by lists which project antapically appearing as spines on the inside of the antapical horns. Girdle excavated with lists supported by spines, not offset. Theca strongly reticulated with spines at the junctions of the reticulations. Intercalary straie broad. Cell contents pink (Dodge, 1982). It is distinguished from other members of the divergentia-group by the more slender form and by the lack of antapical spines

Dimensions: Length 80-84 µm; breadth 56 µm (Lebour, 1925; Dodge, 1982).

Distribution: Neritic; found in Danish and Norwegian Seas, English Channel, Adriatic, Golden Horn, Bosphorus, California (Lebour, 1925), North Sea and off S.W. coast of England (Dodge, 1982). It is a cosmopolitan species (Steidinger and Tangen, 1997). It also occurs in Kuwait's waters.

Protopheridinium elegans (Cleve) Balech 1974 (Plate 27A-C)

References: Steidinger and Williams, 1970; Steidinger and Tangen, 1997.

Description: Large cell with long apical and antapical horns. Cell greatly compressed between base of apical and antapical horns and proximal end of antapicals which arise from antapical plates; this central area almost flat. Apical horn centrally located. Antapical horns almost straight, slightly divergent with corrugated ends. Right horn in front of left. Surface reticulated. Meta, quadra. Cingular circular or slightly displaced. APC probably of B' type (Steidinger and Tangen, 1997).

Distribution: Coastal and oceanic; tropical waters; worldwide (Steidinger and Tangen, 1997). Found in Kuwait's waters.

Protoperidinium grande Kofoid 1907

References: Wood, 1968; Subrahmanyan, 1971; Drebes, 1974; Ricard, 1974; Taylor, 1976; Karsten, 1978; Dodge, 1982, 1985; Steidinger and Tangen, 1997.

Description: A very large species of the divergens group, with flaring girdle and long horns; girdle median, narrow, slightly left-handed, depressed, ribbed; sides of theca deeply concave; antapicals slightly unequal, divergent, conical, acute; sulcus with membranous list extending beyond base (Wood, 1968).

Dimension: Length 150-200 µm (Wood, 1968).

Distribution: Tropical, interoceanic. Straits of Florida; Benguela Current; Caribbean Sea (Wood, 1968). It also occurs in Kuwait's waters.

Protoperidinium leonis (Pavillard) Balech 1974 (Plate 28A-F)

Synonym: *Peridinium leonis* Pavillard 1916.

References: Schiller, 1937; Taylor, 1976; Dodge, 1882; Pankow, 1990; Steidinger and Tangen, 1997.

Description: Medium-sized pentagonal or rhombic-shaped species. Cell slightly flattened dorsoventrally. Cell as long as wide or slightly longer. Epitheca and hypotheca more or less straight-sided or slightly concave. Ortho-hexa plate arrangement, rarely a fourth intercalary plate may be present bur normally there are only three. Differs from *P. conicum* in having zigzag sultures from apex to girdle. Hypotheca ends in two hollow horns each bearing a single solid spine. Sulcus deeply excavated, with small lists. Girdle excavated with lists supported by spines, circular or slightly left-handed. Theca with scattered pores, reticulated with fine spines at junctions of reticulations or may bear longitudinal ridges (Dodge, 1982). Its distinguished from other species belonging in the oceanica-group by the lined pattern of the thecal reticulation (Steidinger and Tangen, 1997).
Dimensions: Length 53-95 µm; breadth 53-95 µm (Dodge, 1982).
Distribution: Occurs all around Britain. Also from Atlantic, Pacific and Indian Oceans, the Mediterranean and Caribbean (Dodge, 1982). Temperate to tropical waters; worldwide distribution (Steidinger and Tangen, 1997). It is present in Kuwait's waters.

Protoperidinium marie-lebourae (Paulsen) Balech 1974 (Plates 28G-I and 29A-D)
Synonym: *Peridinium obtusum* Lebour 1925.
References: Lebour, 1925; Schiller, 1937; Balech, 1974; Throndsen et al., 2003.
Description: Cell rhombic with two hollow horns at antapex. The cell is flattened dorsoventrally. The epitheca has straight to weakly-convex sides. It has a regular ortho first apical plate and quadra 2a. On the dorsal surface the intercalary bands between the plates and the girdle are in a straight line; 2a which is trapezoid therefore touches 1a, 4" and 3a. At the end of the hollow horns there are small spines. The girdle is excavated and bordered by lists supported by ribs. The sulcus does not widen posteriorly. The cell surface is covered with small spines although rarely these are not present and fine reticulation or punctuation occurs (Dodge, 1982).
Dimensions: Length 48-75 µm, breadth 45-70 µm (Dodge, 1982).
Distribution: Found all around the coast of Britain except the NW of Scotland. Also recorded as common in the North Sea (Dodge, 1982). It occurs in Kuwait's waters.

Protoperidinium minutum (Kofoid) Leoblich III 1970 (Plate 29E-I)
Synonym: *Peridinium minutum* Kofoid 1907; *Peridinium monospinum* Paulsen 1907.
References: Schiller, 1937; Taylor, 1976; Dodge, 1982; Steidinger and Tangen, 1997.
Description: Small globular cell with short apical horn. Sulcus expands posteriorly and has prominent, short left sulcal list. Surface with papillae or short spines. Ortho, hexa. Cingulum circular. Only two anterior intercalaries (Steidinger and Tangen, 1997).
Dimensions: 23-43 µm long; 23-56 µm wide (Dodge, 1982).
Distribution: Coastal and open water. Cold temperate to warm waters; cosmopolitan (Steidinger and Tangen, 1997). Found all around the British Isles, also in the Pacific and Atlantic (Dodge, 1982). It also occurs in Kuwait's waters.

Protoperidinium murrayi Kofoid (Plates 29J-K and 30A-B)

Basionym: *Peridinium murrayi* Kofoid.

Synonym: *Peridinium oceanicum* (VanHöffen) Balech 1974.

References: Wood, 1968; Taylor, 1976; Dodge, 1982, 1985; Steidinger and Tangen, 1997.

Description: The thecal plates are smooth; the 1'-plate is ortho, and the 2a-plate is quadra. This large species most closely resembles *Protoperidinium oceanicum,* being distinguished from it chiefly by its more elongate apical horn which arises more abruptly from the epitheca than in the latter species. The antapical horns can be more divergent than in *P. oceanicum.* The girdle is clearly at the widest point of the cell, whereas in *P. oceanicum* the sides of the epitheca are as wider or wider (Taylor, 1976).

Dimensions: Length about 200 µm, width about 100 µm (Taylor, 1976).

Distribution: It is found in the Andaman Sea, Arabian Sea, central and southern Indian Ocean and at the southern end of Mozambique Channel (Taylor, 1976). It is also present in Kuwait's waters.

Protoperidinium ovatum Pouchet 1883 (Plate 30C-G)

Synonym: *Peridinium ovatum* (Pouchet) Shutt 1895; *Peridinium globulus* var*. ovatum* Schiller 1937.

References: Schiller, 1937; Taylor, 1976; Dodge, 1982; Throndsen et al., 2003.

Description: Cell lenticular, slightly flattened anterio-posteriorly, hypotheca ending with two solid spines. Meta-quadra (or sometimes penta) plates on the epitheca. There is a small apical horn. The girdle is offset; may or maynot be excavated, with lists supported by spines. The hypotheca is rounded antapically and bears two slightly diverging spines either side of the sulcus each with wings. The sulcus is shallow. The thecal plates (and some of the sulcal plates) are sculptured with poroids or areolae and reticulations (Dodge, 1982).

Dimensions: Length 54-68 µm; breadth 57-88 µm (Dodge, 1982).

Distribution: Occurs commonly all around coast of Britian. Also found in the Mediterranean, Indian Ocean, Atlantic (Dodge, 1982). It is also found in Kuwait's waters.

Protoperidinium pellucidum (Bergh 1881) Balech 1974 (Plates 30H-K and 31A)

Synonym: *Peridinium pellucidum* (Bergh 1882) Schütt 1895.

References: Schiller, 1937; Taylor, 1976; Pankow, 1990 Steidenger, 1997.

Description: Small to medium-sized broadly pyriform cell with short apical horn, two winged antapical spines, and one prominent curved, antapical winged spine that originates from a left sulcal list. Circular in cross section. Surface reticulated. Para, hexa. Cingulum slightly ascending, 0.5X. APC of B' type. Although this species can be confused with *P. pallidum,* it is smaller, circular in cross section, and has a prominent sulcal list that ends in a curved antapical spine (Steidinger and Tangen, 1997).

Dimensions: Length 30-68 µm; bredth 36-70 µm (Pankow, 1990).

Distribution: Mainly coastal and cosmopolitan in temperate to tropical waters (Steidinger and Tangen, 1997). It is present in Kuwait's waters.

Protoperidinium pentagonum (Gran) Balech 1974 (Plates 31B-I and 32A)

Basionym: *Peridinium pentagonum* Gran 1902.

References: Lebour, 1925; Schiller, 1937; Wood, 1968; Subrahmanyan, 1971; Drebes, 1974; Taylor, 1976; Dodge, 1982, 1985; Balech, 1988; Pankow, 1990; Steidinger and Tangen, 1997.

Description: Medium-sized to large, broadly pentagonal cell with truncate posterior margin with short antapical winged spines. Sulcus broad posteriorly, not extending to antapex. Cell in cross section reniform (Steidinger and Tangen, 1997). Epitheca conical; hypotheca trapezoidal, margins straight or concave, base almost straight or concave. This species is characterised by the flattened antapex, the slightly displaced girdle, the short sulcus and the distinct ridges situated between the apex and the girdle, bordering plates 1', 2', 4', and 1", 2", 6" and 7". (The latter is a feature shared with *P. conicum*). The first apical plate is of ortho type; the second anterior intercalary plate is hexa, touching 3", 4" and 5". There are two solid spines antapically. Usually the girdle diameter is greater than the length of the cell. The girdle is excavated, bordered by lists and is left-handed. The nucleus is central and in the living cell the contents are pink. Plate formula: 4', 3a, 7", 3c, 5'", 2"" (Wood, 1986; Dodge, 1982).

Dimensions: Length 75-100 µm, breadth 75-100 µm (Lebour, 1925; Wood, 1986; Dodge, 1982).

Distribution: Estuarine-neritic form, widely distributed in all oceans. Trinidad and from the Straits of Florida. Found all around the British Isles, Northern Seas and English Channel (Lebour, 1925; Wood, 1986; Dodge, 1982). Principally coastal, but found in estuarine environments. Cosmopolitan in temperature to tropical waters (Steidinger and Tangen, 1997). Occurs in Kuwait's waters.

Protoperidinium punctulatum (Paulsen 1907) Balech (Plate 32B-I)

Basionym: *Peridinium punctulatum* Paulsen 1907, *P. subinerme* Paulsen var. *punctulatum* (Paulsen) Schiller, 1937.

References: Schiller, 1937; Balech, 1974; Dodge, 1982.

Description: Shape of cell similar to *P. subinerme* but the surface is punctuate or spiny without reticulations and there are no antapical spines at the sides of the sulcus. The cell has a straight or slightly convex-sided epitheca, when seen in dorsoventral view, forming a cone. The hypotheca has concave or straight sides with a flattened antapex. The girdle is equatorial, excavated, and has lists supported by spines. The sulcus is narrow (usually narrower than in *P. subinerme*) and reaches the centre of the hypotheca. The first apical is ortho and the species was through by Lebour (1925) to belong to the section tabulate (i.e., 2a touches 4" and 5" or 3" and 4"). Plate formula: 4', 3a, 7", 3c, 5'", 2"".

Dimension: Length 40-72 µm (Dodge, 1982)

Distribution: Oceanic and neritic. Found frequently in the southern North Sea but does occur all around British Isles (Dodge, 1982).   It is observed in Kuwait's waters.

Protoperidinium spiniferum **(Schiller) Balech 1974 (Plate 33A-F)**

Basionym: *Peridinium spiniferum* Schiller.

References: Schiller, 1937; Taylor, 1976.

Description: This is a medium-sized species, most readily distinguished by the strong short spines protruding from the outer corners of the short antapical horn. The first apical plate is meta and the second intercalary plate is hexa (Taylor, 1976).

Dimension: Length 70 to 120 µm (Taylor, 1976).

Distribution: It was widespread in the Bay of Bengal/Andaman Sea following the N.E. Monsoon and was also present in the west coast of India. The species is an inter-oceanic tropical to temperate species (Taylor, 1976). It occurs in Kuwait's waters.

Protoperidinium steinii **(Jörgensen) Balech 1974 (Plates 33G-I and 34A-G)**

Synonyms: *Peridinium steinii* Jörgensen var. *mediterraneaum* Kofoid 1909; *P. steinii* Jörgensen, 1889; *P. michaelis* Stein, 1883.

References: Schiller, 1937; Dodge, 1982.

Description: Cell pyriform with elongated apical horn and rounded hypotheca bearing two long three-winged spines; round in polar view. Epitheca with meta-penta plate arrangement. Girdle right-handed, not excavated, with prominent lists supported by spines. Chromatophores absent, cell contents colourless or pale pink or yellow. Intercalary striae usually broad (Dodge, 1982).

Dimensions: Length including spines 39-60 µm, breadth 22-44 µm, length of spines 9-14 µm (Dodge, 1982).

Distribution: Found all around the coast of Britain. Probably oceanic and neritic. Recorded from Atlantic, Pacific and Indian Oceans and Baltic and Caribbean Seas (Dodge, 1982). It also occurs in Kuwait's waters.

Protoperidinium subinerme **(Paulsen) Leoblich III 1970 (Plates 34H-I and 35A-F)**

Basionym: *Peridinium subinerme* Paulsen.

References: Schiller, 1937; Taylor, 1976; Dodge, 1982; Steidenger and Tangen, 1997.

Description: Medium-sized pentagonal cell with indented posterior margin. Cell almost circular in cross section. Sulcus broader posteriorly, sometimes L shaped because of the wide sp plate. Ortho, hexa. Cingulum circular. Surface reticulate with short spines at junctures of network. Anterior sutures of 1' shorter than posterior and straight or concave in outline. Posterior sutures of 1' can be slightly convex in outline making posterior half of 1' wider. APC of A' type. Its Can be confused with *Peridinium punctulatum* (Paulsen) Balech which was once considered a variety of this species. *Peridinium punctulatum* is more broadly pentagonal with a rounded, truncate antapex; surface markings are papillae or broad-based short spines; ventral area is more excavated; 2a typically penta but can be hexa; sulcus extends to antapex and is not expanded posteriorly (Steidenger and Tangen, 1997).

Dimensions: Length 50-75 µm; breadth 50-60 µm (Dodge, 1982).

Distribution: Coastal and open water. Temperature to tropical waters. Cosmopolitan (Steidenger and Tangen, 1997). Occurs all around the coast of Britain, also in waters off Iceland, Greenland, and in the Barents and Kara Seas (Dodge, 1982). It is found in Kuwait's waters.

Protoperidinium thorianum (Paulsen) Balech 1974 (Plate 35G)

Basionym: *Peridinium thorianum* Paulsen 1905.

Synonym: *Properidinium thorianum* Meunier 1919.

References: Dodge, 1982; Steidinger and Tangen, 1997.

Description: Medium-sized cell; almost broadly biconical with slightly indented posterior margin. Circular in cross section. Hypotheca exceeds epitheca in length. Sulcus deeply excavated, widening and extending to posterior margin. Surface rugose with pits with raised edges; sometimes reported as papillae. Ortho, hexa. Only two anterior intercalaries; approximately the same size and shape. Cingulum descending about 1X. Produces cysts (Steidinger and Tangen, 1997).

Distribution: Coastal and open water. Cold temperate to warm water; cosmopolitan (Steidinger and Tangen, 1997). Occurs sporadically all around coast of Britain. Also recorded from Iceland, Faroes, Skagerak, coast of Norway, Canada, California, Okhotsk Sea and coast of Hokkaido, and Indian Ocean (Dodge, 1982). It also occurs in Kuwait's waters.

Protoperidinium ventricum (Abé) Balech 1974 (Plates 35H-I and 36A-C)

References: Schiller, 1935; Taylor, 1976.

Description: It has the short epitheca in comparison with the hypotheca, exhibit the curious, slit-like apical plate found also in some other members of the subgsenus. The right posterior part of the hypotheca usually protrudes beyond the left part (Taylor, 1976).

Dimension: Length 51-54 µm (Taylor, 1976).

Distribution: It has been recorded in the Indian Ocean (Taylor, 1976). It is present in Kuwait's waters.

Other *Protoperidinium* spp.: Several unidentified species of *Protoperidinium* are found in Kuwait's waters.

Protoperidinium sp. 1 (Plate 36D-I)

Description: The cells are more or less round in shape. The antapical spines are present. The first apical plate 1' is para.

Distribution: It occurs in Kuwait's waters.

Protoperidinium sp. 2 (Plate 37A-F)

Description: The cells are oval in shape. The two antapicals with their spines are present. It has the meta 1'-plate and the hexa 2a-plate.

Distribution: It occurs in Kuwait's waters.

Protoperidinium sp. 3 (Plate 37G-N)

Description: The cells have an elongated apical horn and an elongated antapicals. It has the meta 1'-apical plate. The cingulum has a conspicuous ribs on it.

Distribution: It occurs in Kuwait's waters.

Protoperidinium sp. 4 (Plate 37O-P and 28A-D)

Description: Cells are oval in shape. The two antapicals spines are present. It has the meta 1'-plate and the hexa 2a-plate.
Distribution: It occurs in Kuwait's waters.

Protoperidinium sp. 5 (Plate 38E-J)

Description: Cells are broad pyriform in shape. The two antapicals spines are present. It has the meta 1'-plate.
Distribution: It occurs in Kuwait's waters.

Protoperidinium sp. 6 (Plate 38K-N)

Distribution: It occurs in Kuwait's waters.

Protoperidinium sp. 7 (Plate 38O)

Distribution: It occurs in Kuwait's waters.

Protoperidinium sp. 8 (Plate 38P)

Distribution: It occurs in Kuwait's waters.

Protoperidinium sp. 9 (Plate 39A-D)

Description: Appears similar to *Protoperidinium oblongum* (VanHöffen) Balech 1974, which has the dorsal quadra 2a intercalary plate while, the present material has the dorsal penta 2a intercalary plate.
Distribution: It occurs in Kuwait's waters.

Protoperidinium sp. 10 (Plate 39E)

Distribution: It occurs in Kuwait's waters.

Protoperidinium sp. 11 (Plate 39F)

Distribution: It occurs in Kuwait's waters.

Protoperidinium sp. 12 (Plate 39G-K)

Distribution: It occurs in Kuwait's waters.

Protoperidinium sp. 13 (Plate 39L-N)

Distribution: It occurs in Kuwait's waters.

Family: *Podolampaceae* Lindemann 1928

References: Nie, 1939, 1942; Schiller, 1937; Balech, 1963; F.J.R. Taylor, 1976; Dodge, 1982; Sournia, 1986.

Genus: *Blepharocysta* Ehrenberg 1873

Synonym: *Peridinium* Ehrenberg, 1859.

Cell spherical to ovoid, girdle apparently absent and sulcus reduced to a narrow groove which may be extended to the apical pore. Cells covered with smooth plates which have a similar tabulation to that of Podolampas although there is considerable disagreement over the details of this (see Balech, 1963). The apical and antapical plates are very small and the ranks of larger plates in between probably represent precingulars and cingulars. A genus of warmer waters only occasionally found to the south-west of the British Isles. One species occurs in Kuwait's waters.

Blepharocysta splendor-maris (Ehrenberg) Ehrenberg 1873 (Plate 39O)

References: Lebour, 1925; Steidinger and Tangen, 1997.

Description: Armored. Medium-sized cell, spherical or subspherical to oval without apical attenuation. Homologous cingular area not excavated and cell without cingular lists but with sulcal lists. Plate formula: Po, cp, X, 3', 1a, 5", 3c, 4 or 5s, 4 or 5"', and 1"". Postcingular plates without prominent double pore tract as in Podolampas. Plate pore patterns may help in differentiating species. At least four species can be distinguished by general shape and shape and position of sulcal lists in lateral view. Chloroplasts present (Steidinger and Tangen, 1997).

Genus: *Podolampas* Stein 1883

Synonym: *Parrocelia* Gourret 1883.

Cells pyriform, tapering to an apical horn often with a spine; girdle not apparent, probably fused with precingular plates; flagellar pore in ventral area; one to two strong antapical spines, one with wing fused to left sulcal list. Members of this genus are found in warmer waters (Wood, 1968). Two species occur in Kuwait's waters.

Podolampas palmipes Stein 1883 (Plate 39P-Q)

References: Lebour, 1925; Wood, 1968; Ricard, 1974; Dodge, 1982; Sournia, 1986; Balech, 1988; Steidinger and Tangen, 1997.

Description: Cell pyriform, longate pear-shaped, narrow in front. The epitheca is drawn out into a long, slender neck. The intercalary plate is more or less pentagonal. The precingular plates bear elongated pores roughly arranged in a transverse row. There are three cingular plates. The cingulars are notably wide being nearly half the length of the body. The hypotheca is greatly reduced in depth being less than one tenth of body length. The post cingular plates have on them two transverse rows of pores. The first antapical plate (1"") has a large spine which is slightly sinuous and bordered by wings. The plate itself is small and has a few pores. 2"" is small, has pores at the top. 3"" has a short spine bordered by wings. The right hand spine is therefore much shorter than the left antapical spine. The nucleus is elongated and situated in the right half of the cell in the cingulum region (Wood, 1968; Dodge, 1982).

Dimensions: Length 70-110 μm length of body, 20-37 μm wide. Length of left spine 24-28 μm; length of right spine 14-23 μm (Wood, 1968; Dodge, 1982).
Distribution: Tropical interoceanic species. Santaren Channel, Straits of Florida; Benguela Current; Sargasso Sea (Hulburt, 1963); Brazil (north coast); Caribbean Sea (Wood, 1968). Occasionally found in Gulf Stream waters. Ocean Weather Station India in the North Atlantic. Elsewhere recorded as common in warm waters of the Atlantic and Pacific Oceans (Wood, 1968; Dodge, 1982). It is also found in Kuwait's waters.

Podolampas bipes **Stein 1883 (Plate 39R)**
References: Lebour, 1925; Wood, 1968; Taylor, 1976; Dodge, 1982, 1985; Sournia, 1986; Balech, 1988; Steidinger and Tangen, 1997; Throndsen et al., 2003.
Description: There is no obvious girdle and the surface of the cell is smooth apart from the very well developed antapical horns. Cell broadly pear-shaped, narrowing to apical horn; girdle not apparent, probably fused with adjacent precingular plates; flagellar pore in ventral area; two strong, equal, antipical spines supporting transverse wings, the left being a continuation of the ventral area; theca porulate, wings more or less reticulate; plate formula 2', 1a, 6", 3", 4"" (Wood, 1968; Dodge, 1982).
Dimensions: Length 80-100 μm (Wood, 1968; Dodge, 1985).
Distribution: Tropical, interoceanic species. Found in West Channel, Straits of Florida; Benguela Current; Brazil (north coast); Caribbean Sea (Wood, 1968). It is also present in Kuwait's waters.

Unidentified Armored and Unarmoured Dinoflagellate spp.
Several Unidentified species of unarmored (Plate 40A-G) and armored (Plate 40H-K) dinoflagellates were encountered at different stations of Kuwait's waters.

REFERENCES

Al- Yamani, F., W. Ismail, K. Al-Rifaie, A. M'Harzi, D.V.S. Rao, A. Lennox, T. Saeed, A.N. Al-Ghadban, K. AlMatrouk, M. Bahlol and Al-Khabaz, 2002. Oceanographic and Environmental Assessment of Kuwait Bay in relevance to toxic algal blooms. Final Report, restricted, FM028K. Kuwait Institute for Scientific Research, Report No. KISR 6558, July 2002.

Balech, E. 1988. Los Dinoflagelados del Atlantico Sudoccidental. In Publicaciones Especiales del Institutto Espanol de Oceanografia, No. 1, pp. 310. Madrid, Spain.

Bérard, E. 1963. Dos dinoflagagelades de una laguna Salobre de la Argentina., Notas del Museo de la Plate. **20:** 111-123.

Bérard, E. 1974. E1 genero "Protopridinium" Bergh, 1881 ("Pridinium" Ehrenberg, 1831, partim). Revta Mus. Argent. Cienc. nat. "B. Rivadavia. Hidrobiologia **4:** 1-79.

Bérard, E. 1976. Clave illustrada de Dinoflagelados Antarticos. Pub1. Inst.Antart. Argent. **11:** 1-99.

Bérard, E. 1988. Los Dinoflagagelades del Atlantico Sudoccidental. In Publicaciones Especiales del Institutto Espanol de Oceanografia, No. 1, pp. 310 Madrid, Spain.

Bérard-Therriault, L., M. Poulin, L. Bossé. 1999. Guide d'identification du phytoplankton marin de l'Estuaire et du Golfe du Saint-Laurent. Ottawa: Les presses scientifiques CNRC.

Böhm, A. 1931. Peridineen aus dem Persischen Golf und dem Gulf von Oman. Arch. Protistenk. **74:** 188-197.

Böhm, A. 1935. Zum Variationaproblem der Peridineen. Öst. Bot. Z. **84:** 271-281.

Curl, H., JR. 1959. The phytoplankton of Apalacheen. Bay and the northeastern Gulf of Mexico. Pub1. Inst. Marine Sci. Univ. Texas, **6:** 277-320.

Daugbjerg, N., Hansen, G., Larsen, J. & Moestrup, O. 2000. Phylogeny of some major genera of dinoflagellates based on ultrastructure and partial LSU rDNA sequence data, including the erection of 3 new genera of unarmoured dinoflagellates. Phycologia **39:** 302-317.

Dodge, J. D. 1981. Three new generic names in the Dinophyceae: *Herdmania, Sclerodinium*, and *Triadinium* to replace *Heteraulacus* and *Goniodoma*. British Phycological Journal **16:** 273-280.

Dodge, J. D. 1982. Marine Dinoflagellates of the British Isles. London: Crown Copyright.

Dodge, J. D. 1985. Atlas of Dinoflagellates: A Scanning Electron Microscope Survey. London: Farrand Press.

Dodge J. D. and Hermes H. 1981. A revision of the *Diplopsalis* group of dinoflagellates (Dinophyceae) based on material from the British Isles. Botanical Journal of the Linnean Society **83:** 15-26.d1-1

Dodge J. D. and Toriumi S. 1993. A taxonomic revision of the *Diplopsalis* group (Dinophyceae). Botanica Marina **36:** 137-147.d1-3

Drebes, G. 1974. Marines Phytoplankton: Eine Auswahl der Helgolander Planktonalgen (Diatomeen, Peridineen). Stuttgart, Germany: Georg Thieme Verlag.

Fensome, R.A., Taylor, F.J.R., G., Sarjeant, W.A.S., Wharton, D.I. and Williams, G.L. 1993. A classification of fossil and living dinoflaellates. Micropaleontology Press Special Paper, no.7, 351 p.

Gilbert, P.M., Landsberg, J.H., Evans, J.J., Al-Sarawi, M.A., Faraj, M., Al-Jarallah, M.A., Haywood, A., Ibrahem, S., Klesius, P., Powell, C., and Shoemaker, C. 2002. A Fish Kill of Massive Proportion in Kuwait Bay, Arabian Gulf, 2001: The Roles of Bacterial Disease, Harmful Algae, and Eutrophication. Harmful Algae **1:** 215-231.

Hansen, G., Turquet, J., Quod, J.P., Ten-Hage, L., Lugomela, C., Kyewalyanga, M., Hurbungs, M., Wawiye, P., Ogongo, B., Tunje, S. and Rakotoarinjanahary, H. 2001. Potentially survey. IOC Manuals and Guides No. 41. France: United Nations Educational, Scientific and Cultural Organization.

Haywood, A. J., Steidinger, K. A. and Truby, E. W. 2004. Comparative morphology and molecular phylogenetic analysis of three new species of the genus *Karenia* (Dinophyceae) from New Zealand. J. Phycol. **40:** 165-179.

Heil, C.A., Glibert, P.M., Al-Sarawi, M.A., Faraj, M., Behbehani, M., Husain, M., 2001. First record of a fish-killing *Gymnodinium* sp. bloom in Kuwait Bay, Arabian Sea: chronology and potential causes. Mar. Ecol. Prog. Ser. **214:** 15-23.

Hoek, C. V. D. 1995. Algae: An introductory to phycology. Cambridge University Press: Cambridge.

Hulbert, E.M. 1962. Phytoplankton in the southwestern Sargasso Sea and north equatorial current, February 1961. Limnol. Oceanogr. **7:** 307-315.

Hulbert, E. M. 1963. The diversity of phytoplankton populations in oceanic, coastal, and estuarine regions. J. Mar. Res., **21:** 81-93.

Karsten, G. 1978. Das indische Phytoplankton. Nach dem Material der Deutschen Tiefsee-Expedition 1898-1899. Germany: Otto Koeltz Science Publishers.

Kofoid, C.A. and Sweezy, O. 1921. The Free-living unarmored Dinoflagellata. Mem. Univ. Calif. **5:** 1-562.

Konovalova G.V. 1998. Dinoflagellate (Dinophyta) of the far Eastern Seas of Russia and adjusent waters of the Pacific Ocean. Dalnauka: Vladivostok. (In Russian).

Larsen, J and Nguyen-Ngoc, L. (eds). 2004. Potentially Toxic Microalgae of Vietnamese Waters. - Opera Botanica **140:** 1-216.

Lebour, M.V. 1925. The dinoflagellates of northern seas. The Marine Biological Ass. U.K.

Newell, G.E., and R.C. Newell. 1977. Marine Plankton. 5th ed. London: Hutchinson and Co. (Publishers) Ltd.

Nie, D. 1939. Dinoflagellata of the Hainan region. II. On the thecal morphology of *Blepharocysta*, with a description of a new species. Contributions of the biological laboratory of the Science Society of China. Zoological Series **13 (3):** 23-42.

Nie, D. 1942. Dinoflagellata of the Hainan region. IV. On the thecal morphology of *Podolampas*, with descriotion of species. Sinensia, Shanghai **13 (1-6):** 53-60.

Pankow, H. 1990. Ostsee-Algenflora. Gustav Fischer Verlag Jena. Leipzig, Germany, pp. 648.

Ricard, M. 1974. Quelques dinoflagellatés planctoniques marins de Tahiti étudiés en microscopie a balayage. Protistologica **1:** 125-135.

Schiller, J. 1933. Dinoflagellatae (Peridineae), 617 p. In Kryptogamen Flora von Deutschland, Osterreich und der Schweiz. L. Rabenhorst. (ed.). Part I. Akademische s Gesellschaft. Geet y Portig K.-G. Leipzig.

Schiller, J. 1937. Dinoflagellatae (Peridineae). In: Rabenhorst, L. (ed). Kryptogamen Flora von Deutschland, Österreich und der Schweiz 10(3). II Teil. Akademische Verlagsgesellschaft. Leipzig.

Sournia, A. 1986. Atlas du Phytoplancton Marin. Vol. 1: Cyanophycées, Dictyochophycées, Dinophycées and Raphidophycées. Paris: Editions du CNRS.

Steidinger, K. A. and Tangen, K. 1997. Dinoflagellates. In Identifying Marine Phytoplankton. Edited by C.R. Tomas. London: Academic Press.

Steidinger, K.A. and Williams, J. 1970. Dinoflagellates. Memoris of the Hourglass Cruises, Vol. 2, Florida Department of Natural Resourses Marine Research Laboratory, St. Petersburg, Florida. **2:** 251 pp.

Subrahmanyan, R. 1971. The Dinophyceae of the Indian Seas. Part 2: Family Peridiniaceae. Marine Biological Association of India, Memoir II , Cochin, India.

Taylor, F.J.R. 1976. Dinoflagellates from the International Indian Ocean Expedition. A report of material collected by the R.V. "Anton Bruun" 1963-64. – Bibliotheca Botanica, Stuttgart.

Taylor, F.J.R.. 1980 On dinoflagellate evolution. BioSystems. **13:** 65-108.

Taylor, F.J.R. (ed.). 1987. The Biology of Dinoflagellates. Bot. Monogr. 21. Blackwell & Univ. Calif. Press. 786 pp.

Throndsen, J., Hasle, G.R., and Tangen, K. 2003. Norsk Kystplankton Flora. Almater Forlag AS, 341 PP. (in Norwegian).

Wood, E. J. F. 1968. Dinoflagellates of the Caribbean Sea and Adjacent Areas. Coral Gables, Florida: University of Miami Press.

LIST OF PLATES

Note: MC in plate legend means “Magnified Cell”

Chapter 4

OTHER MARINE PHYTOPLANKTON GROUPS

INTRODUCTION

Marine plankton mostly consists of unicellular, nonmotile cells from many classes of algae and bacteria, motile flagellates, and ciliates. These cells range from less than 1 µm to greater than 1 mm and can attain population abundances exceeding a million cells per liter during bloom periods (Throndsen, 1997).

Less is known of the relative importance of planktonic “naked” flagellates, primarily due to the absolute requirement of examining living material and of having a familiarity with the characteristics spanning a number of classes and orders. A hint at the global importance of the planktonic flagellates is evident from the many phytoplankton counts of preserved material that consistently report a large component of “unidentified flagellates”. Some indication of their abundance and impact on the marine ecosystem is also evident when flagellates form toxic blooms (Throndsen, 1997). The presence or absence of chloroplasts is the most obvious criterion for distinguishing between phototrophic and heterotrophic flagellates. Fine structural evidence is presently redefining the criteria for modern flagellate systematics and questions the validity of chloroplast presence or absence in defining related species. Based on this evidence, many colorless (heterotrophic) flagellates appear to be related in evolutionary schemes to taxa (classes, orders) that also contain phototrophic species classified as algae (Throndsen, 1997). Flagellates are found scattered throughout the algal system, and therefore any treatise on them as a group must include a number of taxa of higher ranks including classes, orders, and families, which often contain one or a few genera at the lower levels. Some genera are monospecific, whereas others such as *Cyrysochromulina* and *Pyramimonas* may contain 50 or more species (Throndsen, 1997). The surface of flagellate cells may either be smooth, covered with scalelike structures composed wholly of organic material (Prymnesiophyceae, Prasinophyceae), calcified as in coccolithophorids, or silicified (Chrysophyceae). Silica skeletons are either found externally, as in the Dictyochophyceae, or internally, as in the Ebriidae (Throndsen, 1997).

Organic scales may cover the cell surface and/or the flagella in many species, especially in the Prasinophyceae and Prymnesiophyceae. These scales often show a pattern typical for the taxon, some typical for higher taxa such as class, order, family, or genus, and others characteristic for the single species. The scales are usually very difficult to observe in the light microscope, but some exceptions exist. Scales of Apedinella, for instance, are visible in bright field after cellulose staining, and *Chrysochromulina polylepis* scales may be seen in fluorescence microscopes using acridine orange (Throndsen, 1997).

Flagellates are also characterized by the presence of one or more flagella, with one, two, or four as the most common number, and eight and 16 occasionally found in some *Pyramimonas* species (Prasinophyceae). The general flagellar anatomy is a fairly conservative feature, though details (e.g., of the transitional region) give important information on evolutionary trends. Variation in flagellar roots external flagellar structures (scales and hairs) reflects the polyphyletic evolutionary affiliations of the flagellates (Throndsen, 1997). The microanatomy of the flagellate cell varies with its evolutionary background and hence is a valuable clue in modern taxonomy and classification. Important organelles in this context are mitochonodria, which may have tubular or flat cristae, and chloroplasts, which may have two or four enveloping membranes. The photosynthetic apparatus of the chloroplasts, the thylakoids and photosynthetic pigments, show systematic variations within the algae and phytoflagellates as well. The accumulation products in these flagellates, as in other algae, vary from fats and oils, which are both generally present, to specific carbohydrates like starch (Crypto-, Dino-, Prasino-, and Chlorophycease), chrysolaminaran (Chryso- and Prymnesiophyceae), and paramylon (Euglenophyceae) (Throndsen, 1997). Flagellates are found in all marine biotopes from the oligotrophic open oceans to eutrophic inshore waters, mud flats, and marshland ditches. Similar biotopes in geographically distant areas are often inhabited by the same morphological species.

The ecological importance of flagellates appears to be quite comprehensive and varies with the trophic roles they play in different ecosystems. As grazers of bacteria they are vital components of the microbial loop but also serve as food for ciliates.

Most “naked” flagellates cannot be identified from preserved material in the light microscope, hence most of the taxonomic information on this group comes from observing live cells almost exclusively from studies of coastal areas including brackish water localities.

The general problem related to working with “naked” flagellates is the lack of adequate fixing agents, requiring the study of living material for a reliable indentification in the light microscope. The proper identification of many species relies upon submicroscopic details revealed only by the electron microscope. When dominant species require electron microscopy for proper identification, materials may be prepared as described in advanced techniques. Future identification of some flagellates may be completely dependent on EM analysis of specific morphological structures/features or be replaced by DNA-based identification of genomes (Throndsen, 1997).

Table 1 includes examples of three marine phytoplankton groups: the chromophytes, the chlorophytes and the cyanophytes.

Table 1. A list of other marine phytoplankton groups.

Phylum	Class	Order	Family	Genus and Species
Chromophyta	Cryptophyceae Fritsch 1927	Cryptononadales Engler 1903	Cryptononadaceae Ehrenberg 1831, Pascher 1913	*Plagioselmis* Butcher 1967 cf. *Plagioselmis* sp. 1
	Raphidophyceae Chadefaud ex Silva 1980		Chattonellaceae Trondsen 1993	*Heterosigma* Hada 1968 *Heterosigma akashiwo* (Hada) Hara et Chihara 1987
	Dictyochophyceae Silva 1980	Dictyochalis Haeckel 1894	Dictyochaceae Lemmermann 1901	*Dictyocha* Ehrenberg 1837 *Dictyocha fibula* Ehrenberg 1839 *Dictyocha speculum* Ehrenberg 1839
	Prymnesiophyceae Hibberd 1976	Prymnesiales Papenfuss 1955	Phaeocystaceae Lagerheim 1896	*Phaeocystis* Lagerheim 1893 *Phaeocystis* sp. 1
Chlorophyta	Euglenophyceae Schoenichen 1925	Euglenales Engler 1898	Eutreptiaceae	*Eutreptiella* de Cunha 1914 *Eutreptiella* sp. 1 *Eutreptiella* sp. 2
	Prasinophyceae Moestrup & Throndsen 1988	Chlorodendrales Fritsch 1917	Halosphaeraceae Haeckel 1894	*Pterosperma* Pouchet 1893 *Pterosperma undulatum* Ostenfeld in Ostenfeld et Schmidt 1902 *Pyramimonas* Schmarda 1850 *Pyramimonas* sp. 1
	Chlorophyceae Christensen 1962	Volvocales Oltmanns 1904	Dunaliellaceae Christensen 1967	*Dunaliella* Teodoresco 1905 *Dunaliella salina* (Dunal) Teodoresco 1905
Cyanophyta (Blue-green algae)	Cyanophyceaea Schaffner 1909	Oscillatoriales Elenkin 1934	Phormidiaceae Anagnostidis et Koma'rek 1988 **Subfamily**: Phormidioideae Anagnostidis et Koma'rek 1988	*Trichodesmium* Ehrenberg ex Gomont 1892 *Trichodesmium erythraeum* Ehrenberg 1830
			Subfamily: Spirulinoideaea Forti 1907	*Spirulina* Turpin ex Gomont 1892 *Spirulina* sp. 1

Geographical Distribution of Other Marine Phytoplankton Species in Kuwait's Waters

The distribution of all the identified genera and species of other marine phytoplankton species that were obtained from 13 different stations in Kuwait's waters are given in alphabetical order in Table 2.

Table 2. Geographical distribution of the "Other Marine Phytoplankton" species at different locations in Kuwait's waters.

Species composition	Khor Al-Sabiya	North Failaka Island	Western end of Kuwait Bay	Mid-Kuwait Bay	Eastern end of Kuwait Bay	Off RasAl-Ardh	Off Al-Fintas	Off Al-Ahmadi	Off Mina Abdulla	Off Ras Al-Qulaiah	Off Mina Zor	Off Kuwait Naval Base	Off AL-Khiran
Dunaliella salina		+								+			
Dictyocha fibula				+									
Dictyocha speculum				+									
Eutreptiella sp. 1		+	+		+	+	+						
Eutreptiella sp. 2			+				+						
Heterosigma akashiwo		+											
Phaeocystis sp. 1				+									
cf. *Plagioselmis* sp. 1				+									
Pterosperma undulatum						+					+		
Pyramimonas sp. 1				+							+		
Spirulina sp. 1				+			+				+		
Trichodesmium erythraeum								+					

Taxonomic Description of Other Marine Phytoplankton Species in Kuwait's Waters.

Phylum: Chromophyta

This division has chlorophyll a, not b, yellowish-green, golden, blue, or red chloroplasts with lamellae; mitochondria with tubular cristae (Throndsen, 1997).

Class: Cryptophyceae Fritsch 1927

Cell shape asymmetrical with furrow or depression. Gullet or furrow lined with two or more rows of ejectosomes. Two flagella, originating at the end of the furrow/gullet, with two and one row of fine tubular hairs (EM). Mode of swimming is heterodynamic. Its color brown, green, red, or blue. One or two chloroplasts, with double thylakoids, girdle lamella lacking (EM). Pyrenoids often with starch shield, which is contained inside chloroplast ER-membrane (EM). Phototrophic and heterotrophic species. (Throndsen, 1997).

Order: Cryptononadales Engler 1903

Family: Cryptononadaceae Ehrenberg 1831, Pascher 1913.

Cells with longitudinal groove-gullet system, with ejectosomes (Throndsen, 1997).

Genus: *Plagioselmis* Butcher 1967

Small, 6-10 μm, lacrymuloid cells with a longitudinal furrow; single chloroplast pink, red, orange, or yellow; single pyrenoid; heterodynamic flagella; *P. prolonga* Butcher, *P. punctata* Butcher (Throndsen, 1997). One species occurs in Kuwait's waters.

cf. *Plagioselmis* sp. 1 (Plate 1A)

Distribution: It occurs in Kuwait's waters.

Class: Raphidophyceae Chadefaud ex Silva 1980

Many chloroplasts, anterior and posterior flagellum. Cell shape ovoid to pyriform, asymmetric, more or less flattened. A more or less pronounced flagellar groove may be present *(Olisthodiscus, Heterosigma)*. Cell surface apparently smooth, has two flagella, one flimmer flagellum, pointing forward, the other also with hairs, often in shallow ventral groove, pointing backward. Their colour yellow to yellowish brown (with fucoxanthin), they have many discoid chloroplasts, with thylakoids in triplets and +/- girdle lamellae (Throndsen, 1997).

Distribution: Coastal and shallow marine or brackish waters, may cause toxic discolored water (Throndsen, 1997).

Family: Chattonellaceae Trondsen 1993

Genus: *Heterosigma* Hada 1968

Cells moderately compressed, with mucus bodies (Throndsen, 1997). One species was observed in Kuwait's waters.

Heterosigma akashiwo (Hada) Hara et Chihara 1987 (Plate 1B-W)

Basionym: *Entomosigma akashiwo* Hada 1967.

Synonyms: *Chattonella akashiwo* (Hada) Leoblich II; *Heterosigma akashiwo* (Hada) 1968; *Heterosigma carterae* (Hulburt) Taylor 1992; *Heterosigma inlandica* Hada 1968.

References: Throndsen, 1997; Larsen and Nguyen, 2004.

Description: Cells are small, irregular in shape, but usually slightly dorso-ventrally compressed. The cell shape of this species varies considerably, and has been referred to as 'potato' shaped. The flagella emerge from a sub-apical, oblique grove. There are many disc-shaped yellow-brown chloroplasts each with a pyrenoid. The nucleus is located centrally and tear-drop shaped (Larsen and Nguyen, 2004).
Dimensions: Length 12-18 µm (Throndsen, 1997), 8-25 µm (Larsen and Nguyen, 2004).
Distribution: Coastal, brackish; Pacific, Atlantic. Found in the Red Sea waters (Throndsen, 1997). It also blooms at different localities in Kuwait's waters.

Class: Dictyochophyceae Silva 1980

"Flimmer"/winged flagellum, +/- radial symmetry, +/- external skeleton (Throndsen, 1997).

Order: Dictyochalis Haeckel 1894

External silica skeleton, one family (Throndsen, 1997).

Family: Dictyochaceae Lemmermann 1901

Cell shape-often round or pyriform. Cell covering-naked or covered by cellulose scales, which may be silicified, cellulose or chitin lorica present in some species. Flagella-winged flagellum with paraxial rod and flimmer hairs, second flagellum present as basal body only. Flagellar action-planar sinus waves. Mode of swimming-the flagellum is pulling the cell. Color-yellow to yellowish brown. Chloroplasts-many, six, three, or lacking; if present with triple thylakoids and girdle lamella (EM). Silicified cysts-produced endogenously. Planktonic species found in coastal and oceanic areas but mostly confined to inshore waters, especially brackish sheltered areas (Throndsen, 1997).

Genus: *Dictyocha* Ehrenberg 1837

Skeleton with a basal ring, and a convex portion which joins the centers of the sectors of this basal ring, which may be elliptical, or triangular, or more or less diamond-shaped. The convex portion may therefore be a curved strip, or have three or four rays. There are usually but not always spines extending outward from the corners (Wood, 1968). Two species occur in Kuwait's waters.

Dictyocha fibula Ehrenberg 1839 (Plate 2A-E)

References: Wood, 1968; Sournia, 1986; Pankow, 1990; Throndsen, 1997; Bérard-Therriault et al., 1999.
Description: Skeleton box-shaped; basal ring quadrate, rhombic or rhomboid with spines at corners , four "windows"and spinules or teeth along the limbs of the skeleton. Many, yellow-brown chloroplasts (Wood, 1968; Throndsen, 1997).
Dimensions: Length 50-70 µm (Wood, 1968), skeleton size: 10-45 µm (Throndsen, 1997).
Distribution: Cosmopolitan, living or fossil. Gulf Stream only by examination of fresh phytoplankton (Wood, 1968). Oceanic; Baltic, North Sea, Atlantic, Mediterranean (Throndsen, 1997). It is also present in Kuwait's waters.

Dictyocha speculum Ehrenberg 1839 (Plate 2F)

Synonym: *Distephanus speculum* (Ehrenberg) Haeckel 1887.

References: Throndsen, 1997.

Description: Regular, usually hexagonal skeleton, with many yellow-brown chloroplasts (Throndsen, 1997).

Dimensions: Skeleton size 19-34 µm + spines (Throndsen, 1997).

Distribution: Coastal, oceanic; cosmopolitan in cold and temperate waters (Throndsen, 1997). It occurs in Kuwait's waters.

Class: Prymnesiophyceae Hibberd 1976-Haptophyceae Christensen 1962 (Exclusive of Coccolithophorids)

Systematic position: Class **Haptophyceae** Christensen 1962, renamed **Prymnesiophyceae** Hibberd 1976.

Cell spherical, round or flattened, elongated or saddle-shaped, with two flagella. Cell body surface covers with organic scales are usually not seen in the light microscope; large spiny scales may be observed in the fluorescence microscope after staining. It has the haptonema, short or long thread-like organelle (sometimes used for anchoring the cell), may be protruding in the swimming direction. Long haptonema coil when relaxed. They are yellow-brown to golden-brown, may be pale in their colour. Contain one or two chloroplasts (Throndsen, 1997).

Distribution: Planktonic: many unicellular species, single or in colonies recorded in neritic and oceanic waters; heterotrophic species not common. Benthic species: insufficiently known, but many are recorded from shallow areas (Throndsen, 1997).

Order: Prymnesialis Papenfuss 1955

Cells covered by organic scales only (Throndsen, 1997).

Family: Phaeocystaceae Lagerheim 1896

Cells with short haptonema (Throndsen, 1997).

Genus: *Phaeocystis* Lagerheim 1893

Nonmotile cells embedded in round or lobed jelly colonies, motile stage *Prymnesium* like; *P. pouchetii* (Hariot) Lagerheim, *P. globosa* Scherffel, *P. antarctica* Karsten, *P. brucei* Mangin, *P. giraudyi* (Derbés and Solier) Hamel, *P. scrobiculata* Moestrup.

Phaeocystis sp. 1. (Plates 2G-I and 3A)

Distribution: It occurs in Kuwait's waters.

Phylum: Chlorophyta

It has chlorophyll *a* and *b*, green chloroplast with lamellae or grana structure; mitochondria with flattened cristae (Throndsen, 1997).

Class: Euglenophyceae Schoenichen 1925

Pellicula, flagellar canal with one or two emerging flagella, containing paramylon (Throndsen, 1997).

Order: Euglenales Engler 1898

Synonym: Euglenida Bütschli 1884.

Cell covering-pellicula, subsurface system of proteinacious interlocking bands running usually in spiral, giving the cells a striped pattern. Body metaboly-euglenoid movements (a swelling of the cell body running from posterior end of the cell) and more irregular changes in the cell shape. Flagella-one, two, or four emergent, running from their bases in the reservoir through the canal. Nonemergent flagellum to the level of the eyespot. Mode of swimming-homo- or heterodynamic. Color-bright green in phototrophic forms. Chloroplasts-one or many, reticulated, ribbon or disc shaped. Pyrenoids-often with paramylon shields or clusters of paramylon granules. Eyespot-orange or red, usually conspicuous, situated near the canal plasmalemma, separate from the chloroplasts. Nucleus-large, with condensed chromosomes, often prominent, in the middle of posterior part or the cell. Canal-apically or subapically, leading from the anterior cell surface to the reservoir. Reservoir-an interior dilatation into which the contractile vacuole empties. A contractile vacuole is lacking in true marine species. Storage products-typically paramylon (solid ß-1, 3-glucan), occasionally chrysolaminaran (liquid ß-1, 3-glucan).

Distribution: Planktonic, only a few marine species reported, mainly of *Eutreptiella*. Benthic: sand and muddy shores with *Euglena*; salt marshes with *Eutreptia* and *Euglena* (Throndsen, 1997).

Family: Eutreptiaceae

Cells with two flagella emerging from the canal (Throndsen, 1997).

Genus: *Eutreptiella* de Cunha 1914

Two subequal heterodynamic flagella (Throndsen, 1997). Two species occur in Kuwait's waters.

Eutreptiella sp. 1 (Plate 3B-C)

Distribution: It occurs in Kuwait's waters.

Eutreptiella sp. 2 (Plate 168 3D)

Distribution: It occurs in Kuwait's waters.

Class: Prasinophyceae Moestrup and Throndsen 1988

Cell shape-quadrangular or bilaterally compressed, often with a depression where the flagella originate. Cell covering-organic scales cover cell body and flagella, which may assemble to form a theca (e.g., *Tetraselmis*). Naked species also occur. Flagella-one, two, four, eight (or 16) covered with minute scales and simple hairs, appear rather stiff and "thick". Mode of swimming-hetero- or homodynamic, flagella pushing the cell. Color-slightly olive-green. Chloroplasts-one (or two) simple or lobed campanulate, or many disc-shaped (phycoma stages). Storage product-starch in shield around pyrenoid, and as stroma starch in the chloroplast (Throndsen, 1997).

Order: Chlorodendrales Fritsch 1917

Flagella and cell body covered by an underlayer of square or diamond-shaped scales (Throndsen, 1997).

Family: Halosphaeraceae Haeckel 1894

The underlayer scales on the flagella are covered by meshwork scales in nine longitudinal rows (Throndsen, 1997).

Genus: *Pterosperma* Pouchet 1893

Motile cells bilaterally symmetrical with four long flagella, nonmotile stage walled, with wings (alae), and many discoid greenish yellow to golden brown chloroplasts (Throndsen, 1997). One species occurs in Kuwait's waters.

Pterosperma undulatum Ostenfeld in Ostenfeld et Schmidt 1902 (Plate 3E-G)

References: Throndsen, 1997; Bérard-Therriault et al., 2000.
Distribution: It occurs in Kuwait's waters.

Genus: *Pyramimonas* Schmarda 1850

Quadrilateral symmetry and pyramidoidal cells with four flagella. It comprises approximately 50 species. The identification of most species has to be confirmed by EM (Throndsen, 1997).

Pyramimonas sp. 1 (Plate 3H)

Distribution: It occurs in Kuwait's waters.

Class: Chlorophyceae Christensen 1962 (green algae)

Cell is rounded or ovoid, may be lobed, naked or with cellulose wall. Have one, two, four (or eight) flagella. Its colour bright green. One chloroplast, parietal or campanulate, lobed or reticulated with starch shield. Found in coastal waters near and on shore, rock pools (Throndsen, 1997).

Order: Volvocales Oltmanns 1904
Family: Dunaliellaceae Christensen 1967 (cells naked)
Genus: *Dunaliella* Teodoresco 1905 (two flagella)

Have two flagella (Throndsen, 1997). They are widespread in saline habitats. One species occurs in Kuwait's waters.

Dunaliella salina (Dunal) Teodoresco 1905 (Plates 3I-J and 4A-B)

Synonym: *Haematococcus salinus* Dunal 1838.
References: Al-Hasan and Sallal, 1985; Jones, 1986; Al-Hasan and Jones, 1989; Throndsen, 1997.
Description: Free-swimming, unicellular, naked biflagellate of microscopic size, ellipsoidal or ovoid in shape with cup-shaped green chloroplast at the posterior end of the cell and two flagella. A girdle of refractive granules, which may be have a reddish tinge (Jones, 1986; Throndsen, 1997).

Dimensions: Cell length 16-24 μm (Throndsen, 1997).
Distribution: Tropical and subtropical high saline areas. Found in Mediterranean and Atlantic (Throndsen, 1997). It is also found in salt marshes in Al-Khiran (Al-Hasan and Sallal, 1985), Bubiyan Island and other locations of Kuwait's waters because it is characteristic of high shore pools and salt lakes where it produces 'blooms', turning the water brownish red due to carotene production by the algae (Jones, 1986; Al-Hasan and Jones, 1989). This species was encounterd during the present study.

Other naked flagellates spp.: (Plate 4 C-O)
Many unidentified species of naked flagellates are observed in Kuwait's waters.

Phylum: Cyanophyta (Cyanobacteria or Blue-green algae)

Cyanobacteria have an algal-like morphology and unlike other bacteria are able to perform oxygenic photosynthesis. They are therefore classified under the Botanical Code of Nomenclature as the class Cyanophysceae or the blue-green algae (Hansen et al., 2001). However, they are purplish red, cellular plants; cells usually small. They lack cell organelles such as a nucleus, mitochondria and the chloroplasts and thus plastids are absent and color is diffused throughout cell contents. Individual plants vary from microscopic colonies of cells to elaborate filaments and are extremely common, especially on tropical shores (Jones, 1986).

Class: Cyanophyceaea Schaffner 1909
Order: Oscillatoriales Elenkin 1934
Family: Phormidiaceae Anagnostidis et Komarek 1988
Subfamily: Phormidioideae Anagnostidis et Komarek 1988
Genus: *Trichodesmium* Ehrenberg ex Gomont 1892

Planktonic organisms mostly forming assemblages with parallel or radially arranged fascicles joined by mucilage. Trichomes are without sheath more or less straight or curved, 6-22 μm with cylindrical or tapering ends. Blue-green or reddish in colour. Apical cells straight, rounded or slightly capitate. This genus comprises about 10 species, which have their main distribution in warm temperate and tropical seas (Cronberg and Annadotter, 2006).

Trichodesmium erythraeum Ehrenberg 1830 (Plates 4P-Q, 5A-C and 6A)

Synonym: *Oscillatoria erythrea.*
References: Hallegraeff, 1991; Janson et al., 1995; Hansen et al., 2001.
Description: Colonies consist of straight trichomes with a parallel orientation. The ends of the trichomes may have a cap or calyptra. The central part of the cells has a granular appearance. Cells longer or shorter than wide (Janson et al., 1995).
Dimension: 7-12 μm wide, 60-750 μm long (Hallegraeff, 1991).
Distribution: Widely distributed in tropical and subtropical waters (Hansen et al., 1995). It occurs in Kuwait's waters.

Subfamily: Spirulinoideaea Forti 1907
Genus: *Spirulina* Turpin ex Gomont

Spirulina sp. 1 (Plate 6B-D).

Distribution: It occurs in Kuwait's waters.

REFERENCES

Al-Hasan, R. H. and Sallal, A-K. J. 1985. Preliminary studies on a halotolerant alga: *Dunaliella* sp. from Kuwait salt marshes. Journal of University of Kuwait **12:** 205-214.

Al-Hasan, R. H. and Jones, W. E. 1989. Marine algal flora and sea grasses of the coast of Kuwait. Journal of University of Kuwait **16:** 289-340.

Bérard-Therriault, L., M. Poulin, L. Bossé. 1999. Guide d'identification du phytoplankton *marin de l'Estuaire et du Golfe du Saint-Laurent*. Ottawa: Les presses scientifiques du CNRC.

Cronberg, G. and Annadotter, H. 2006. Manual on aquatic cyanobacteria: A photo quide and a synopsis of their toxicology. Denmark: International Society for the Study of Harmful Algae.

Daugbjerg, N., Hansen, G., Larsen, J.& Moestrup, O. 2000. Phylogeny of some major genera of dinoflagellates based on ultrastructure and partial LSU rDNA sequence data, including the erection of 3 new genera of unarmoured dinoflagellates. Phycologia, **39:** 302-317.

Hallegraeff, G. M. 1991. Aquaculturists' Guide to Harmful Australian Microalgae. Australia: CSIRO Division of Fisheries.

Hansen, G., Turquet, J., Quod, J. P., Ten-Hage, L., Lugomela, C., Kyewalyanga, M., Hurbungs, M., Wawiye, P., Ogongo, B., Tunje, S. and Rakotoarinjanahary, H. 2001. Potentially harmful microalgae of the Western Indian Ocean: a guide based on a preliminary survey. IOC Manuals and Guides No. 41. France: United Nations Educational, Scientific and Cultural Organization.

Jones, D. A. 1986. A field guide to the sea shores of Kuwait and the Arabian Gulf. University of Kuwait, 192 pp.

Larsen, J. and Nguyen-Ngoc, L. (eds). 2004. Potentially Toxic Microalgae of Vietnamese Waters. - Opera Botanica **140:** 1-216.

Pankow, H. 1990. Ostsee-Algenflora. Gustav Fischer Verlag Jena.

Sournia, A. 1986. *Atlas du Phytoplancton Marin. Vol. 1:* Cyanophycées, Dictyochophycées*, Dinophycées and Raphidophycées*. Paris: Editions du CNRS.

Throndsen, J. 1997. The Planktonic Marine Flagellates. In Identifying Marine Phytoplankton. Edited by C.R. Tomas. London : Academic Press.

Wood, E. J. F. 1968. *Dinoflagellates of the* Caribbean Sea and Adjacent Areas. Coral Gables, Florida: University of Miami Press.

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Chapter 5

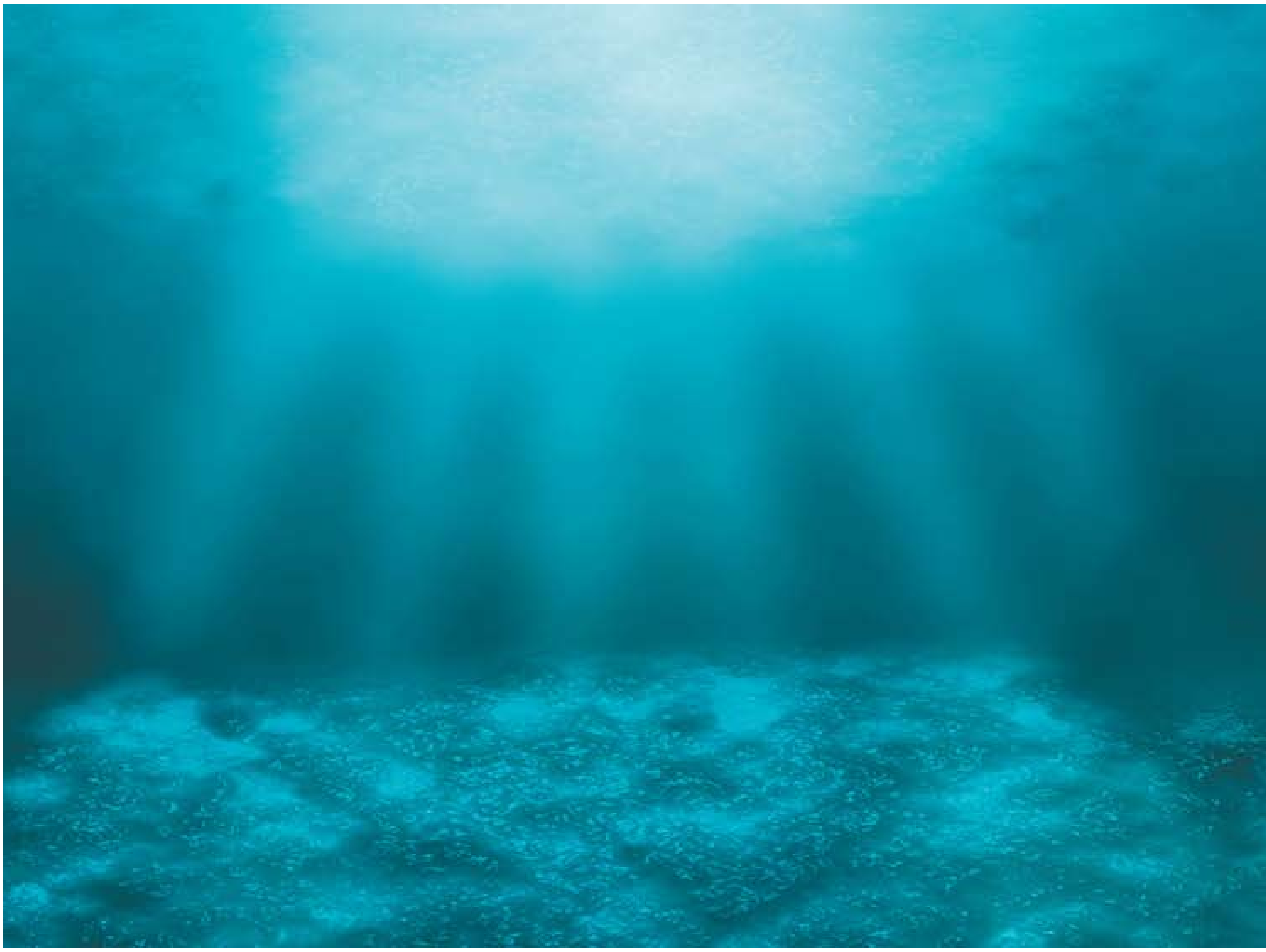
ALGAL BLOOMS IN KUWAIT'S WATERS

EXAMPLES OF ALGAL BLOOMS IN KUWAIT'S WATERS

Although algal blooms, including those considered toxic or harmful, can be natural phenomena, the nature of the global problem of harmful algal blooms (HABS) has expended both in extent and its public perception over the last several decades. In certain times of the year, phytoplankton blooms occur in Kuwait's waters (Figs 1-7). Most of the blooms are benign (not harmful) in nature. Planktonic species, which often bloom in Kuwait's waters, are the following species: *Chaetoceros peruvianus* and other *Chaetoceros* spp., *Cylindrotheca closterium*, *Dunaliella salina*, *Myrionecta rubra*, *Nitzschia* spp., *Noctiluca scintillans*, *Phaeocystis* sp., *Rhizosolenia* spp. (including *R. alata*).

Potentially Harmful Algae in Kuwait's waters

Examples of toxic microalgal species that bloomed in Kuwait's waters include the dinoflagellates *Karenia selliformis*, *Prorocentrum rhathymum* (*P. mexicanum*), *Pyrodinium bahamense* var. *compressum*, as well as, the diatom *Pseudo-nitzschia* spp., the marine filamentous cyanobacteria *Trichodesmium erythraeum* and the raphidophyte *Heterosigma akashiwo*. Furthermore, there are other common toxic species that were found also during certain months of the year (mostly in summer in Kuwait Bay and around) such as *Alexandrium* spp. (*A. minutum* and *A. tamarense*), *Dinophysis caudata*, *D. miles*, *D. mitra*, *D. norvigica* and *D. rotundata*, *Gonyaulax polygramma*, and *Lingulodinium polyedrum*. Other toxic species occur in Kuwait's waters but with low abundance.



The Arabian Gulf and the northen Gulf of Oman have experienced several harmful algal blooms (HABs) during August 2008 - May 2009, caused mainly by the *Cochlodinium polykrikoides* species with accompanying massive fish kills. The first known toxic algal blooms in Kuwait's waters were of *Karenia selliformis* as well as *of Prorocentrum rathymum,* which occurred in Kuwait Bay and were implicated with the massive mortality of wild mullets during September-October 1999 (Glibert and Heil, 1999; Heil et al., 2001; Al-Yamani et al., 2002; Glibert et al., 2002). Many other toxic species were also recorded at that time, but they did not reach the bloom conditions. The results of the above red tide and fish kill phenomena serve as a warning sign that more HAB outbreaks could occur in the future. Table 1 shows the potentially harmful species that were found in Kuwait's waters.

Table 1. Potentially harmful algae which were observed in Kuwait's waters. Some species have been recorded as potentially harmful and others as potentially toxic species. (* indicates that it is a toxic species).

Species	References
Cyanophytes	
Oscillatoria spp.	Hansen et al., 2001; Cronberg et al., 2004, Hallegraeff, 1991;
*Trichodesmium erythraeum**	Hansen et al., 2001; Nguyen et al., 2004; Cronberg et al., 2004
Diatoms	
Cerataulina pelagica	Fryxell and Hasle, 2004
Chaetoceros atlanticus	Fryxell and Hasle, 2004
C. peruvianus	Hansen et al., 2001; Fryxell and Hasle, 2004
C. socialis	Fryxell and Hasle, 2004
Coscinodiscus centralis	Fryxell and Hasle, 2004
C. wailesii	Fryxell and Hasle, 2004
Cylindrotheca closterium	Fryxell and Hasle, 2004
Guinardia delicatula	Fryxell and Hasle, 2004
*Pseudo-nitzschia multiseries**	Fryxell and Hasle, 2004
Pseudo-nitzschia. spp.*	Hansen et al., 2001; Fryxell and Hasle, 2004; Skov et al., 2004
Skeletonema costatum	Fryxell and Hasle, 2004
Dinoflagellates	
Alexandrium insuetum	Nguyen and Larsen, 2004
A. leei	Hansen et al., 2001;Fukuyo et al., 2003; Nguyen and Larsen, 2004; Taylor et al., 2004
*A. minutum**	Fukuyo et al., 2003; IOC Reference List of Toxic Algae, 2004; Nguyen and Larsen, 2004; Taylor et al., 2004
*A. tamarense**	Hansen et al., 2001; Fukuyo et al., 2003; IOC Reference List of Toxic Algae, 2004; Nguyen and Larsen, 2004; Taylor et al., 2004
*Amphidinium carterae**	Hulburt 1957

Species	References
Ceratium furca	Zingone and Enevoldsen, 2000; Glebert et al. 2001; Fukuyo et al., 2003
C. fusus	Fukuyo et al., 2003; Taylor et al., 2004
C. trichoceros	Fukuyo et al., 2003
*Dinophysis acuta**	Fukuyo et al., 2003; IOC Reference List of Toxic Algae, 2004; Taylor et al., 2004
*D. caudata**	Hansen et al., 2001; Fukuyo et al., 2003; IOC Reference List of Toxic Algae, 2004; Larsen and Nguyen, 2004; Taylor et al., 2004
*D. miles**	Fukuyo et al., 2003; IOC Reference List of Toxic Algae, 2004; Larsen and Nguyen, 2004; Taylor et al., 2004
*D. mitra**	Fukuyo et al., 2003; IOC Reference List of Toxic Algae, 2004; Larsen and Nguyen, 2004; Taylor et al., 2004
*D. norvigica**	Fukuyo et al., 2003; IOC Reference List of Toxic Algae, 2004; Taylor et al., 2004
*D. rotundata**	Hansen et al., 2001; Fukuyo et al., 2003; IOC Reference List of Toxic Algae, 2004; Taylor et al., 2004
Gonyaulax polygramma	Fukuyo et al., 2003; Taylor et al., 2004
G. spinifera	Fukuyo et al., 2003
*Gymnodinium catenatum**	Glibert et al. 2002; IOC list of February 2003
Gyrodinium impudicum	Glibert et al. 2002
*Karenia selliformis**	Glibert et al., 2002 ; Heil et al., 2001 ; Haywood et al., 2004
*K. brevis**	Zingone and Enevoldsen, 2000; Fukuyo et al., 2003; IOC Reference List of Toxic Algae, 2004; Taylor et al., 2004
Lingulodinium polyedrum	Hansen et al., 2001; Fukuyo et al., 2003; Taylor et al., 2004
Noctiluca scintillans	Zingone and Enevoldsen, 2000; Fukuyo et al., 2003; Larsen and Nguyen, 2004; Taylor et al., 2004
Prorocentrum balticum	Fukuyo et al., 2003; Nguyen and Larsen, 2004

Species	References
Dinoflagellates	
P. compressum	Fukuyo et al., 2003
*P. emarginatum**	Fukuyo 1981
P. gracile	Fukuyo et al., 2003
*P. lima**	Hansen et al., 2001; Fukuyo et al., 2003; IOC Reference List of Toxic Algae, 2004; Nguyen and Larsen, 2004; Taylor et al., 2004
P. micans	Zingone and Enevoldsen, 2000; Hansen et al., 2001; Fukuyo et al., 2003
*P. rhathymum**	Hansen et al., 2001; Fukuyo et al., 2003; IOC Reference List of Toxic Algae, 2004; Taylor et al., 2004
P. triestinum	Fukuyo et al., 2003
Polykrikos schwartzii	Fukuyo et al., 2003
*Protoceratium reticulatum**	Hansen et al., 2001; Fukuyo et al., 2003; Taylor et al., 2004
*Protoperidinium crassipes**	IOC Reference List of Toxic Algae, 2004
Pyrodinium bahamense var. *compressum**	Glebert et al. 2002; IOC Reference List of Toxic Algae, 2004; Nguyen and Larsen, 2004; Taylor et al., 2004
Pyrophacus steinii	Fukuyo et al., 2003
Scrippsiella trochoidea	Fukuyo et al., 2003
Haptophytes	
Phaeocystis spp.*	Moestrup and Thomsen, 2004
Raphidophytes	
*Heterosigma akashiwo**	IOC Reference List of Toxic Algae, 2004
Silicoflagellates	
Dictyocha fibula	Hansen et al., 2001
Dictyocha speculum	Hallegraeff, 1991; Hansen et al., 2001

• There are many unidentified *Gymnodinium* and *Gyrodinium* spp. in Kuwait's waters which could be potentially toxic species.

REFERENCES

Al-Yamani, F., W. Ismail, K. Al-Rifaie, A. M'Harzi, D.V.S. Rao, A. Lennox, T. Saeed, Al-Gadban, K. AlMatrouk, M. Bahlol and Al-Khabaz, 2002. Oceanographic and Environmental Assessment of Kuwait Bay in relevance to toxic algal blooms. Final Report, restricted, FM028K. Kuwait Institute for Scientific Research, Report No. KISR 6558, July 2002.

Cronberg, G. C., Carpenter, E. J. and Carmichael, W. W. 2004. In *Manual on harmful marine microalgae*, Monographs on oceanographic methodology 11. Edited by Hallegraeff, G.M., Anderson, A.D. and Cambella, A. D. Paris: United Nations Educational, Scientific and Cultural Organization, pp. 523-562.

Fryxell, G.A. and Hasle, G.R. 2004. Taxonomy of harmful diatoms. In *Manual on harmful marine microalgae*, Monographs on oceanographic methodology 11. Edited by Hallegraeff, G.M., Anderson, A.D. and Cambella, A. D. Paris: United Nations Educational, Scientific and Cultural Organization, pp. 389-432.

Fukuyo, Y., Sako, Y., Matsuoka, K., Imai, I., Takahashi, M. and Watanabe, M. 2003. Biological Character of red–tide organisms. In *Red tides*. Edited by Tomotoshi Okaichi. Tokyo: Terra Scientific Publishing Company/ Kluwer Academic Publishers.

Glibert, P.M. and C.A. Heil. 1999. The Red Tide Event in Kuwait Bay, October 1999. Final Report to the Kuwait Environment Public Authority, 31 pp + appendices.

Glibert, P.M., J. Landsberg, J. Evans, M.A. Al-Sarawi, M. Faraj, M.A. Al-Jarallah, A. Haywood, S. Ibrahem, P. Klesius, C. Powell, and C. Shoemaker. 2002. A fish kill of massive proportion in Kuwait Bay, Arabian Gulf, 2001: The roles of infectious bacteria, harmful algae, and eutrophication. Harmful Algae. **12:** 1-17

Hallegraeff, G. M. 1991. Aquaculturists' Guide to Harmful Australian Microalgae. Australia: CSIRO Division of Fisheries.

Hansen, G., Turquet, J., Quod, J. P., Ten-Hage, L., Lugomela, C., Kyewalyanga, M., Hurbungs, M., Wawiye, P., Ogongo, B., Tunje, S. and Rakotoarinjanahary, H. 2001. Potentially harmful microalgae of the Western Indian Ocean: a guide based on a preliminary survey.

Heil, C.A., P.M., Glibert, M.A. Al-Sarawi, M. Faraj, M. Behbehani and M. Husain. 2001. First record of fish killing *Gymnodinium* sp. bloom in Kuwait Bay, Arabian Sea: Chronology and Potenial causes. *Marine Ecology Progress Series* **214:**15-23.

IOC Reference List of Toxic Algae. 2004. Moestrup, Q. (Ed.): Intergovernmental Oceanographic Commission of UNESCO; ioc.unesco.org./hab/data.htm.

Larsen, J and Nguyen-Ngoc, L. (eds). 2004. Potentially Toxic Microalgae of Vietnamese Waters. Opera Botanica **140:** 1-216.

Moestrup, Ø and Thomsen, H.A. 2004. Taxonomy of toxic haptophytes (prymnesiophytes). In *Manual on harmful marine microalgae*, Monographs on oceanographic methodology 11. Edited by Hallegraeff, G.M., Anderson, A.D. and Cambella, A. D. Paris: United Nations Educational, Scientific and Cultural Organization, pp. 389-432.

Taylor, F.J.R., Fukuyo, Y., Larsen, J. & Hallegraeff, G.M. 2004. Taxonomy of harmful dinoflagellates. In *Manual on harmful marine microalgae*, Monographs on oceanographic methodology 11. Edited by Hallegraeff, G.M., Anderson, A.D. and Cambella, A. D. Paris: United Nations Educational, Scientific and Cultural Organization, pp. 389-432.

Zingone, A. and Enevoldsen, H.O. 2000. The diversity of harmful algal blooms: a challenge for science and management. Ocean and Coastal Management **43:** 725-748.

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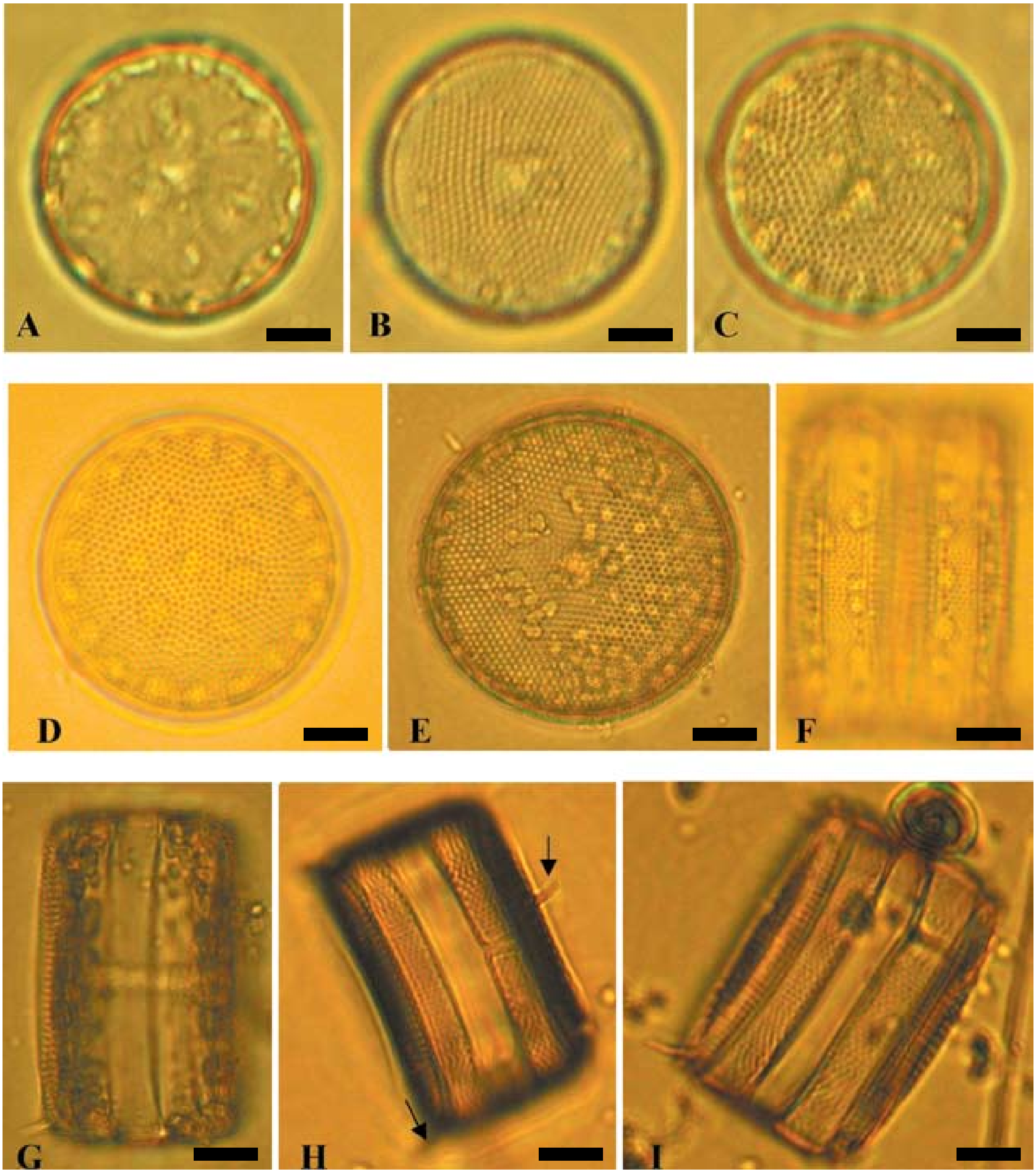

Plate 1. Light micrographs of A-I. *Thalassiosira eccentrica*: A-E. valve view in different magnification showing the areolation pattern: A-C. the same cell in different focus; D-E. different cell, F-I. Cells in girdle view with two marginal processes which both of them clearly visible on H (arrows). (Photos E and G-I by Dr. M. Saburova).
(Scale Bars, A=7.22 μm; B=6.11 μm; C=5.98 μm; D=8.78 μm; E=8.60 μm; F=9.41 μm; G=7.74μm; H=8.37 μm; I=7.88 μm).

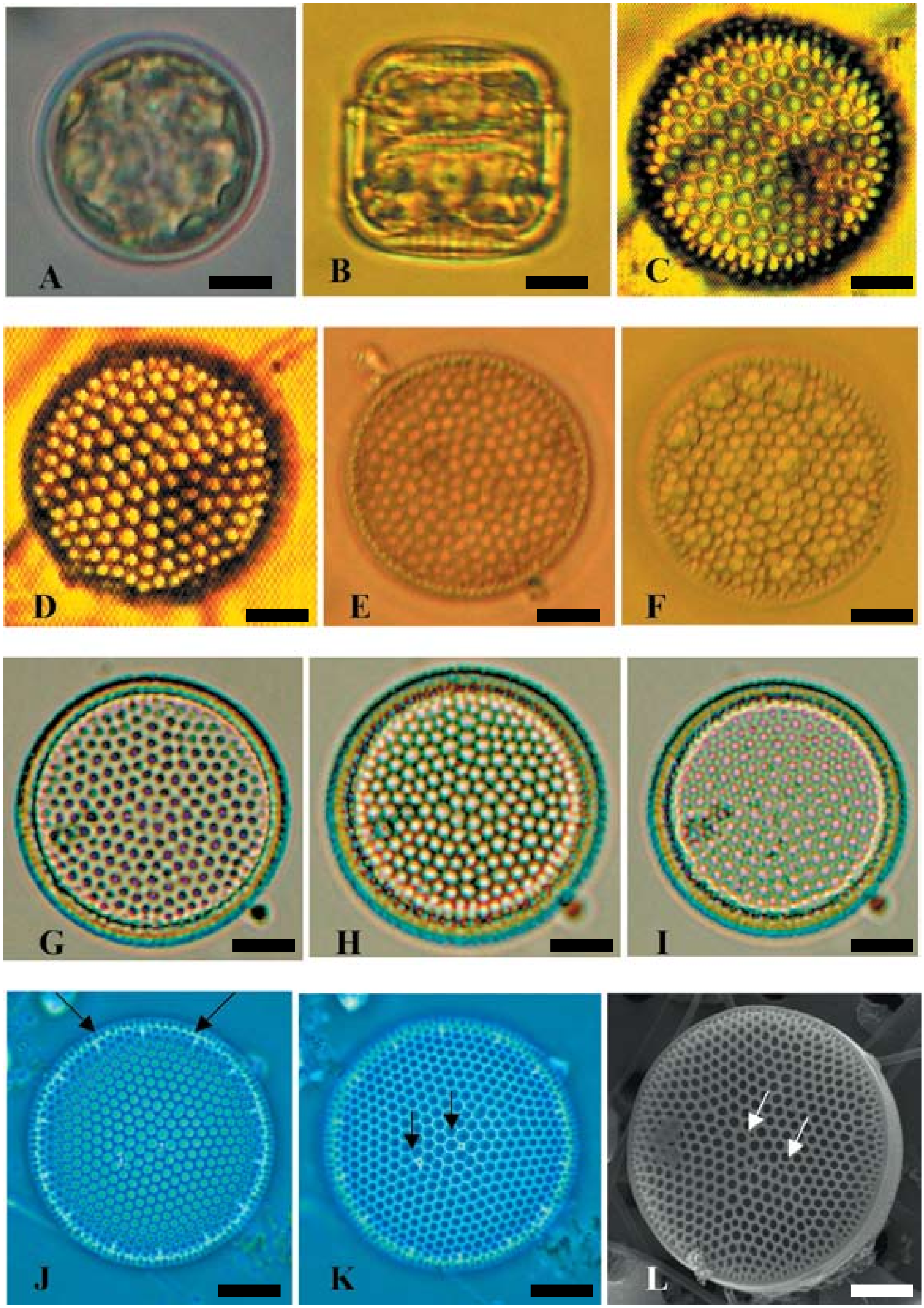

Plate 2. Light micrographs of A-F. *Thalassiosira oestrupii*: A. live cell of valve view with scattered chloroplasts, B. live cell in girdle view, striated at the marginal, C-F. different cells in valve view with different focus showing the areolation pattern; G-L. *T. oestrupii* var. *venrickae*: in valve view; G-I. the same cell in different focus; J-K. other cell showing the widely separated marginal processes (arrows in K) and the two processes near the center (arrows in K and L). L. Scanning electron micrographs of the same species variety. (Photos J-K by Dr. M. Saburova).

(Scale Bars, A=9.17 µm; B=9.17 µm; C=8.07 µm; D=5.95 µm; E=8.97 µm; F=8.75 µm;G=7.56 µm; H=7.22 µm; I=7.93 µm; J=6.75 µm; K=6.75 µm; L=6.90 µm).

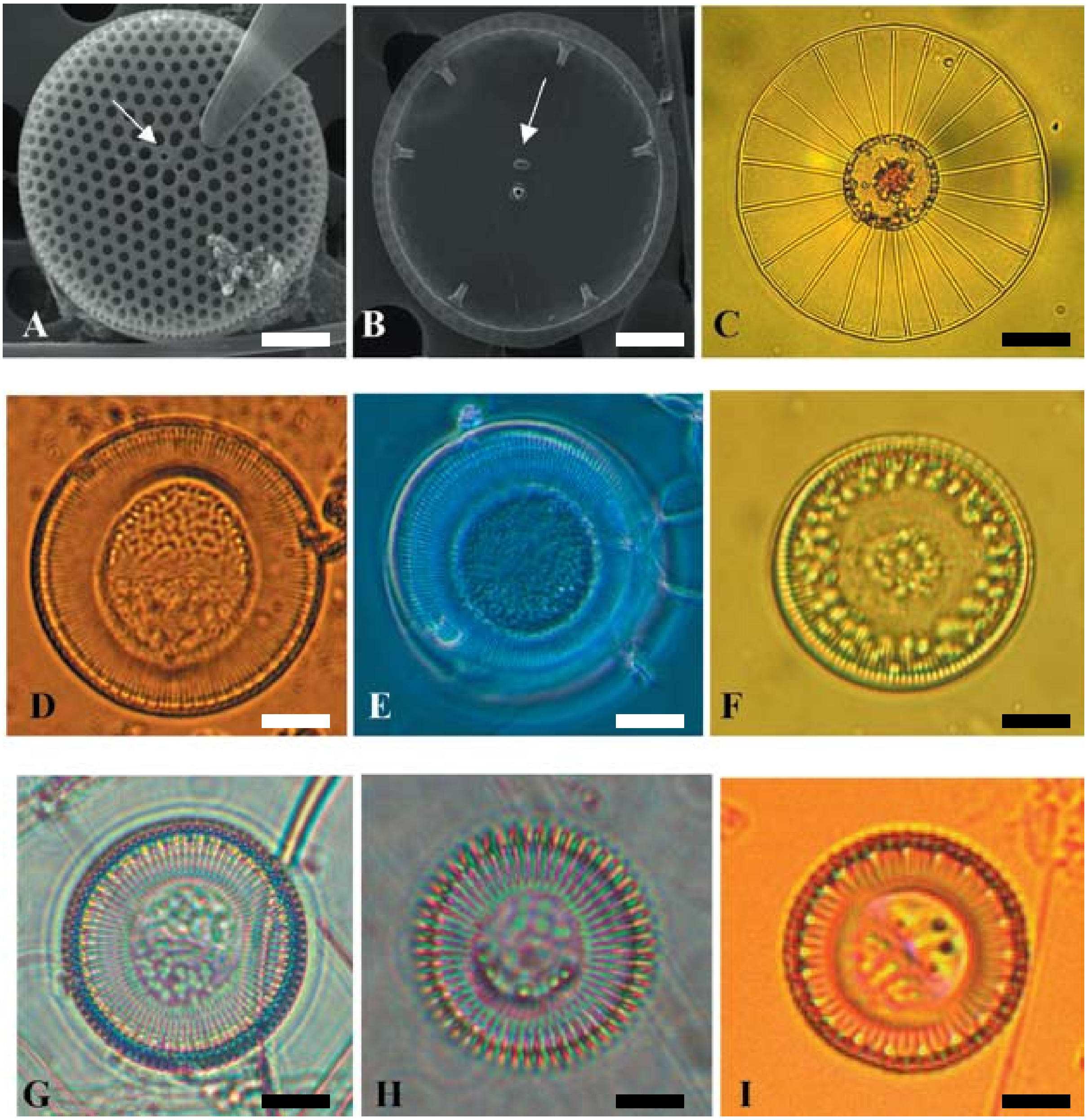

Plate 3. Scanning electron micrographs of A-B. *Thalassiosira* sp.1: valve with process pattern, two process clearly near the center (arrows). Light micrographs of C. *Planktoniella sol*: in valve view with a central small body surrounded by a wing like expansion; D-E. *Cyclotella striata*: different cells in different filter; F-I. *Cyclotella stylorum*: different cells in different focus.
(Scale Bars, A&B=7.56 µm; C=10.76 µm; D=7.67 µm; E=8.13 µm; F=6.97 µm; G=7.36 µm; H=5.00 µm; I=5.44 µm)

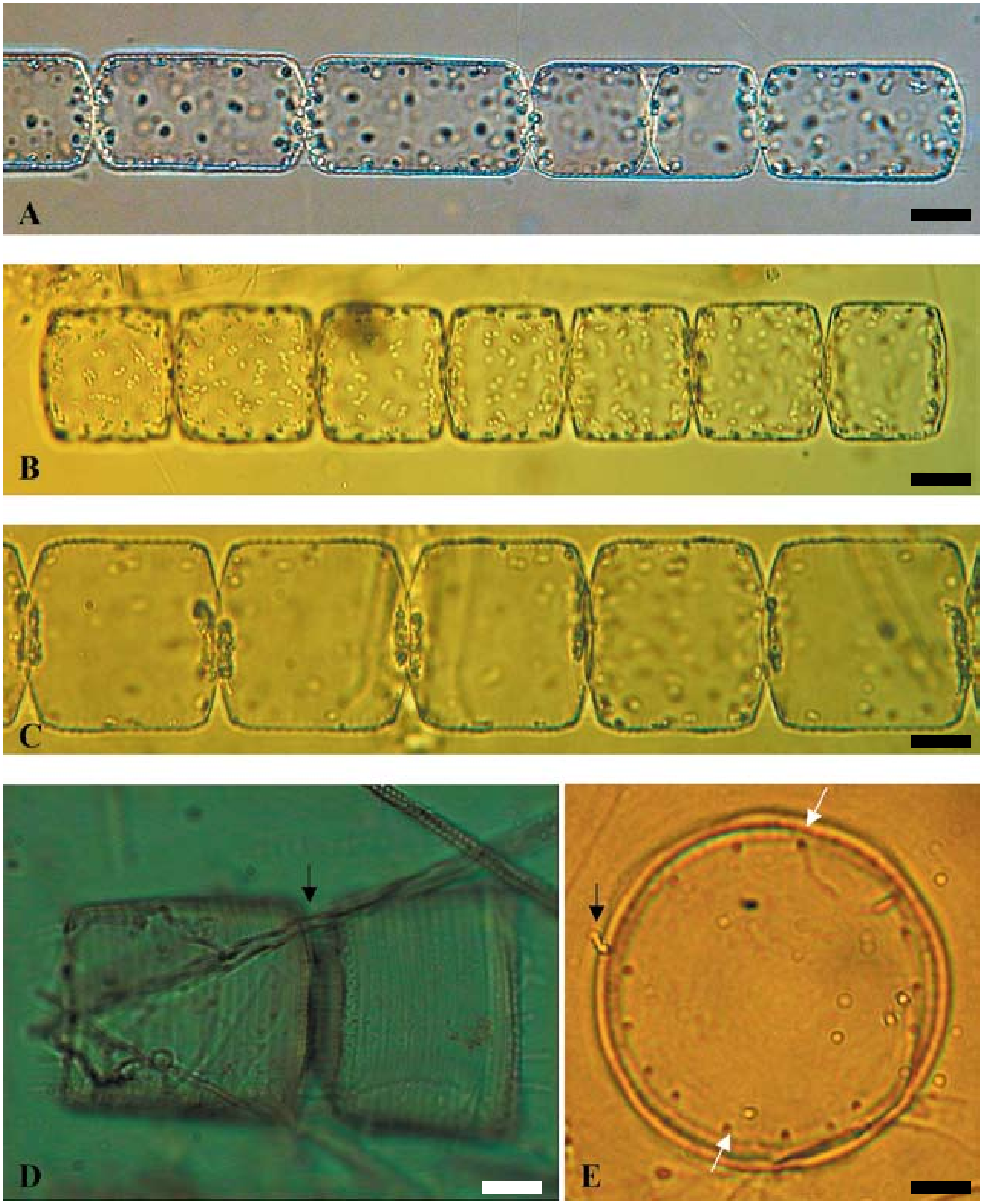

Plate 4. Light micrographs of A-E. *Lauderia annulata*: A-C. different cells in different views and magnifications, in girdle view, they fairly joined in straight chains; D. the cells in chain separated by occluded processes (hair-like processes) on marginal part of the valve (arrow); E. cell in valve view, shows the surface with single large marginal labiate process (black arrow) and many strutted processes on valve margin (white arrows).
(Scale Bars, A=20.95 μm; B=18.22 μm; C=13.23 μm; D=10.86 μm; E=6.95 μm).

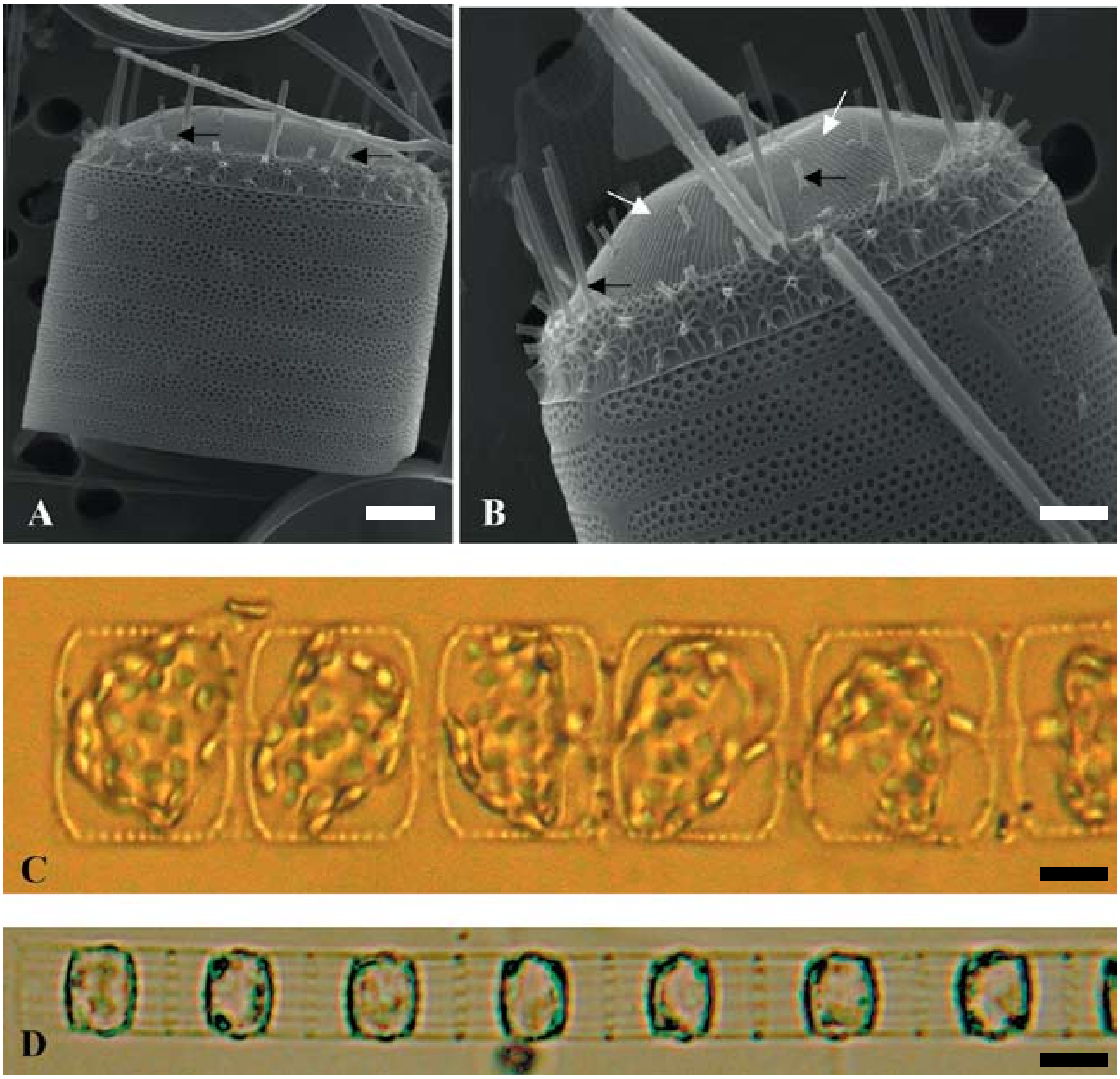

Plate 5. Scanning electron micrographs of A-B. *Lauderia annulata*: the same cell in different magnifications, cell surface with its intercalary bands which has rows of pores in between them; scattered unequal strutted processes were more in the marginal than the central zone (black arrows); fine radial costae radiating from a central annulus were clearly visible in B (white arrows). Light micrographs of: C. *Detonula pumila*: chain with conspicuous connecting thread in between cells; D. *Skeletonema costatum*: cells in straight chain united by external tubes of strutted processes which arranged in one marginal ring. (Photo C by Dr. M. Saburova).
(Scale Bars, A=7.25 μm; B=4.92 μm; C=8.91 μm; D=8.33 μm).

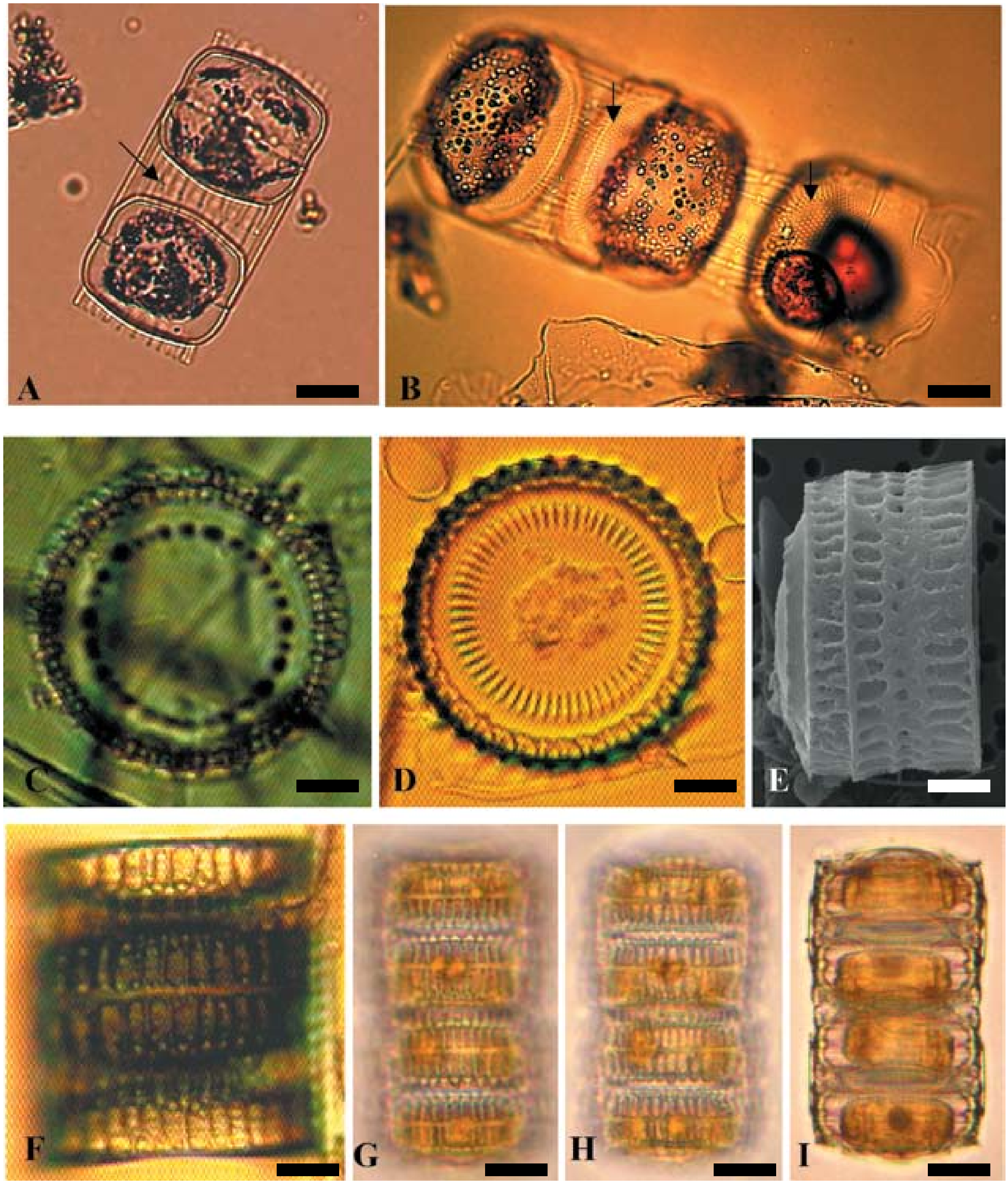

Plate 6: Light micrographs of: A-B. *Stephanopyxis palmeriana*: A. shows clearly the external structures of labiate processes joined midway between cells (arrow); B. the valves wall cover with areolae (arrows), C-I. *Paralia sulcata*: C-D. valve view; E. Scanning electron micrographs of the same species in girdle view; F-I. Light micrographs of same species: different cells in connecting view (Photos A and B by Dr. M. Saburova).
(Scale Bars, A=18.00 µm; B=15.00 µm; C=8.08 µm; D=8.52 µm; E=8.86 µm; F=10.00 µm; G=17.58 µm; H=16.88 µm; I=15.63 µm).

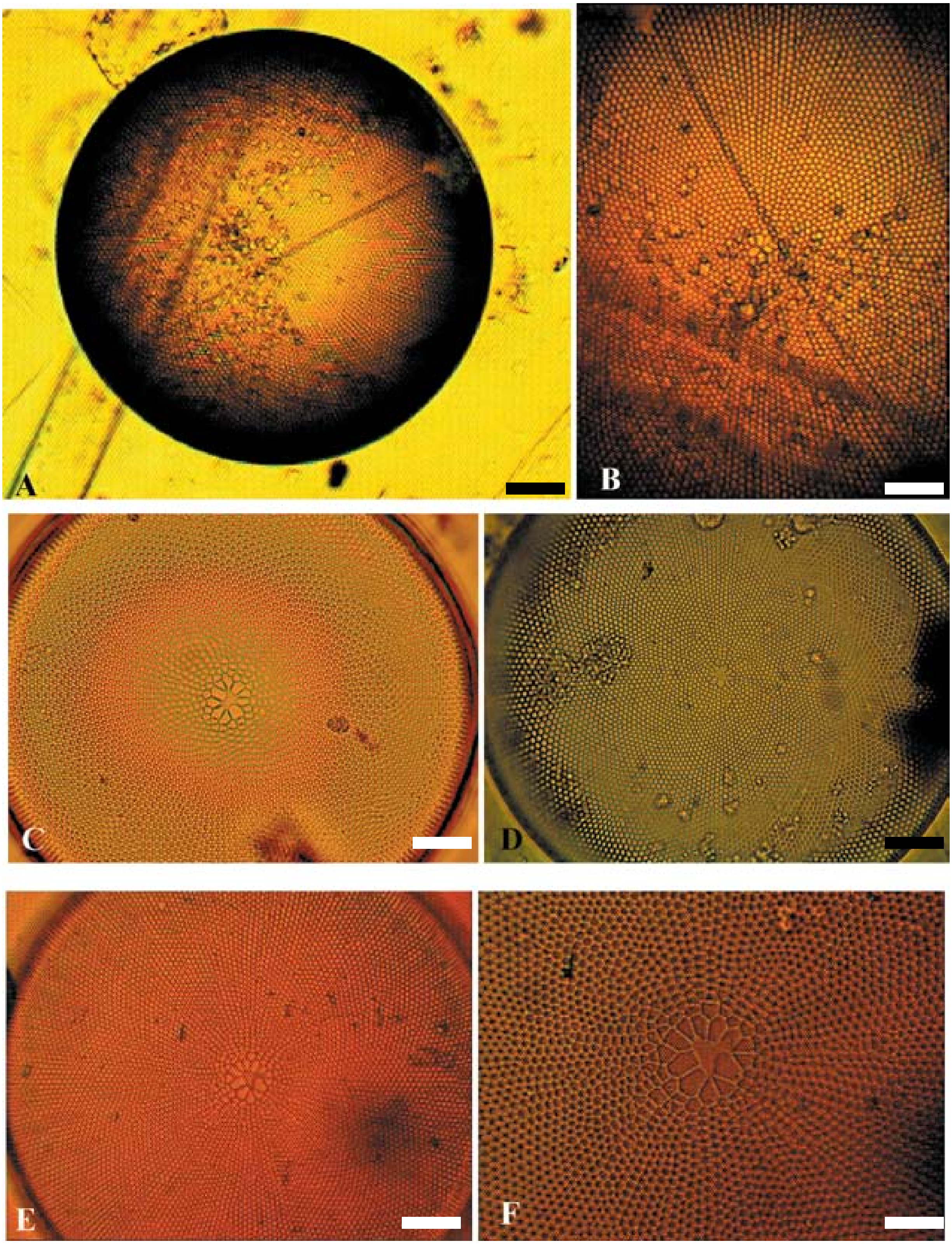

Plate 7. Light micrographs of A-B. *Coscinodiscus asteromphalus*: A. entire view; B. middle region magnified, C-F. *Coscinodiscus centralis*: C-E. different cells entire views (scale bar = 40.39 µm); F. middle region magnified of the cell in E.
(Scale Bars, A=43.24 µm; B&F =MC; C=32.89 µm; D=35.30 µm; E=33.13 µm).

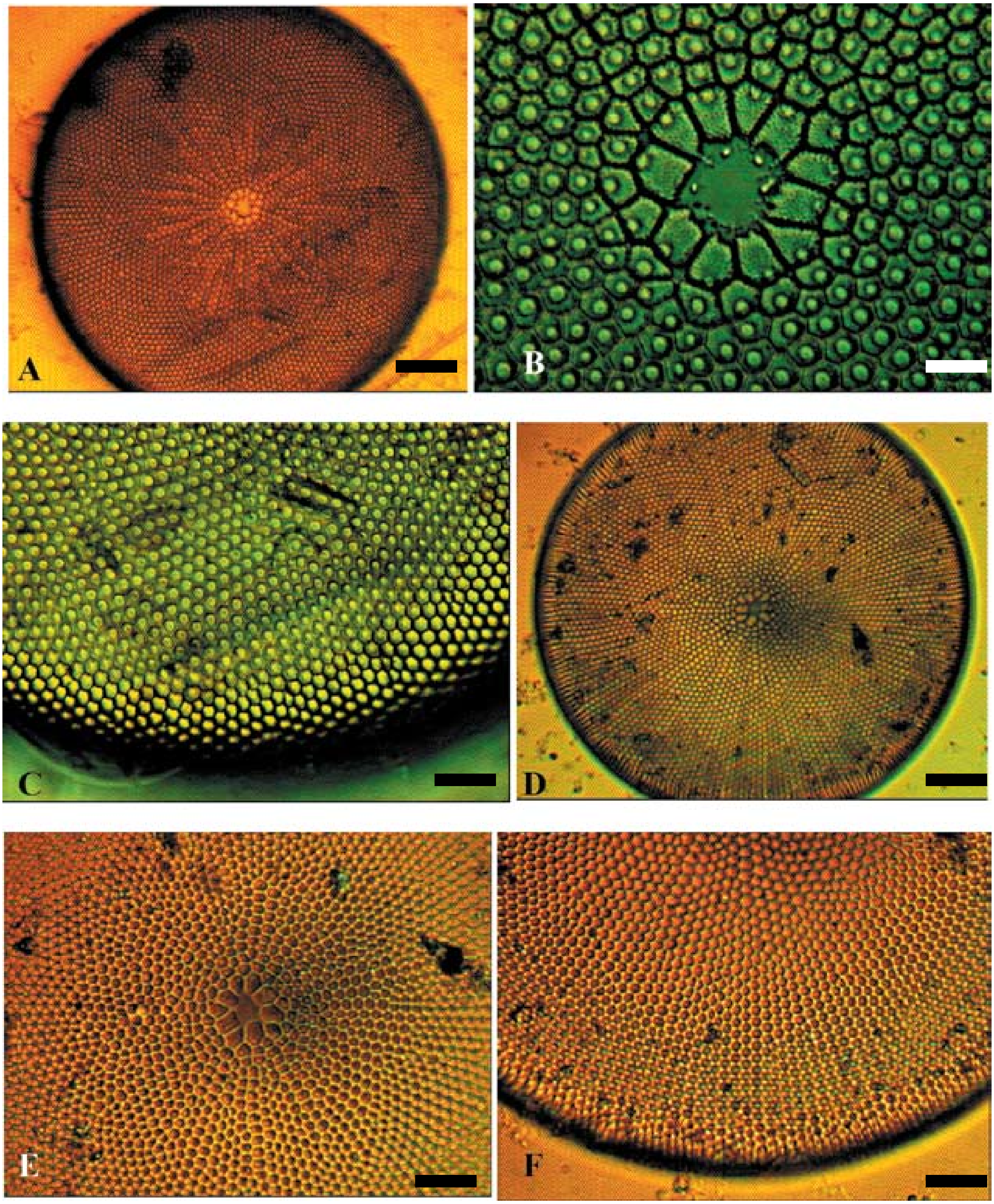

Plate 8. Light micrographs of A-F. *Coscinodiscus centralis*: A-C. the same cell: A. entire view; B. middle region further magnified shows the largest areolae in the center surrounded by the much smaller areolae; C. peripheral region magnified; D-F. another cell: D. entire view; E. middle region magnified; F. peripheral region magnified.
(Scale Bars, A=30.88 µm; B&C=MC; D=29.86 µm; E&F=MC)

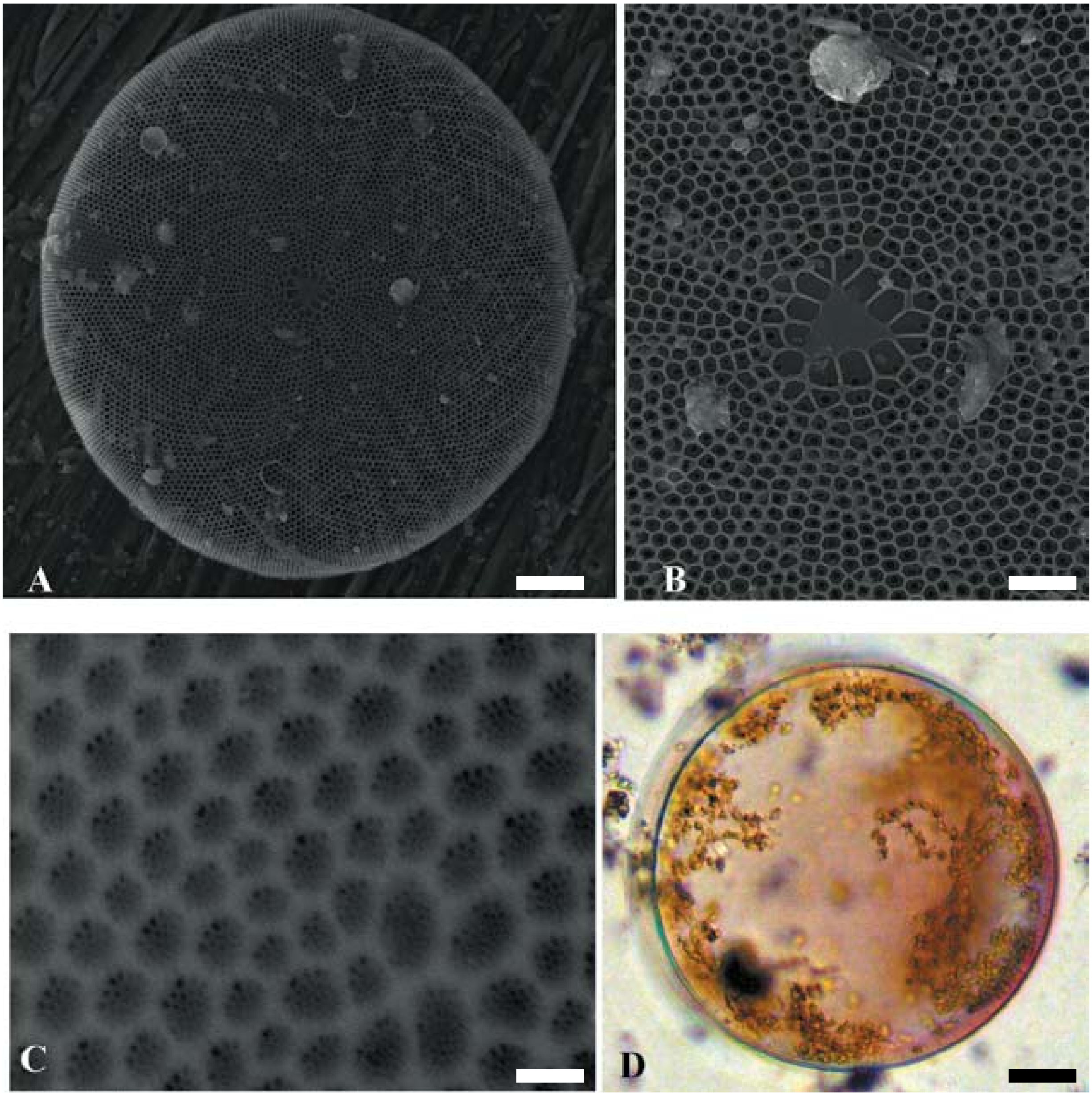

Plate 9. Scanning electron micrographs of A-C. *Coscinodiscus centralis*: A. entire view; B. middle region magnified; C. striae magnified. Light micrographs of D. *Coscinodiscus granii*: live entire view.
(Scale Bars, A=41.08 μm; B&C = MC; D=10.83 μm)

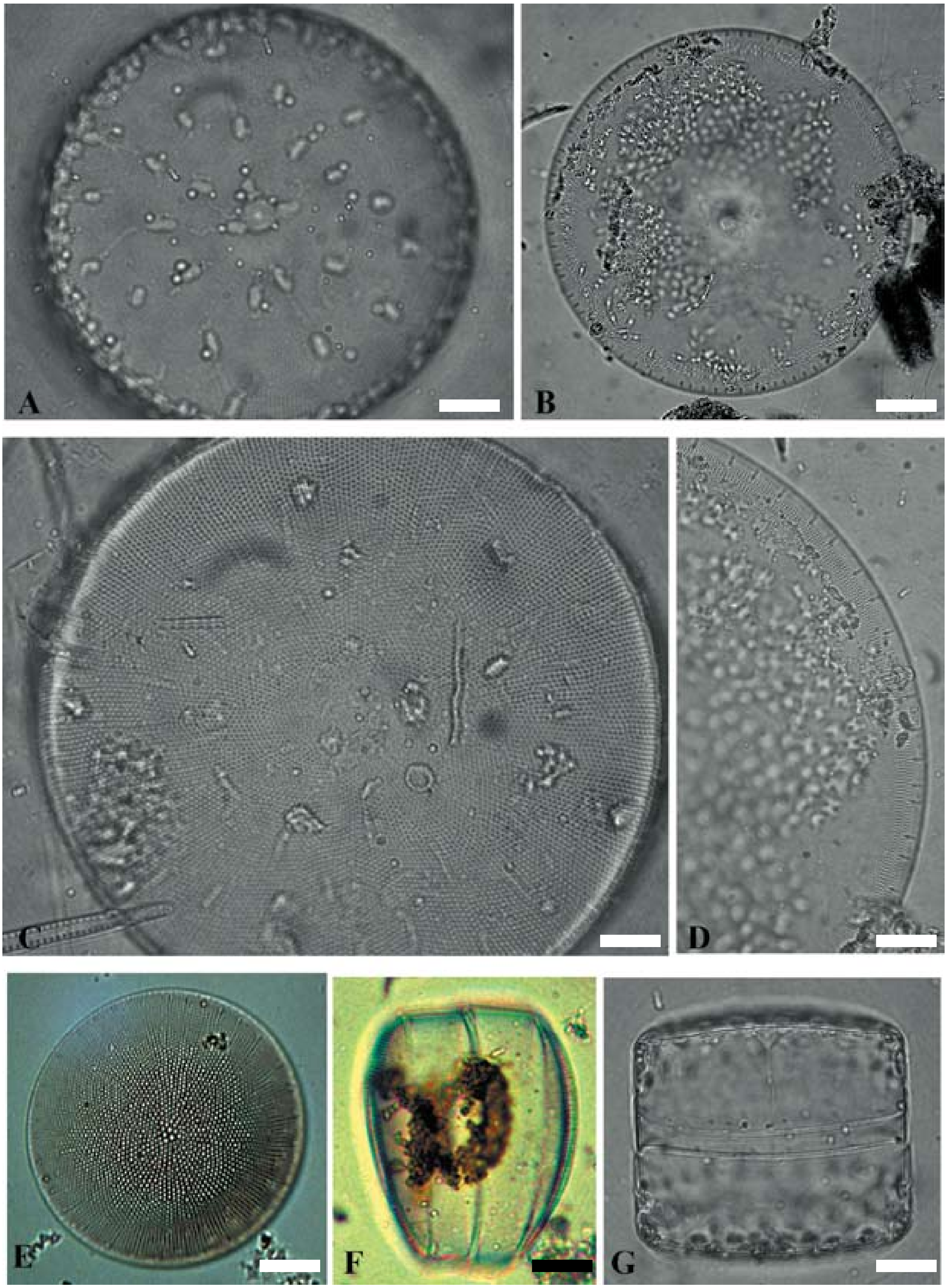

Plate 10. Light micrographs of A-G. *Coscinodiscus granii*: A-B. entire view with chloroplasts; C. further magnification of the valve showing the radial areolation; D. marginal processes magnified; E. another cell showing the valve with central rosette of larger areolae; F-G. girdle views. (Photos A-G by Dr. M. Saburova).

(Scale Bars, A=16.43 µm; B=18.03 µm; C=10.68 µm; D=MC; E=21.74 µm; F=23.26 µm; G=25.00 µm).

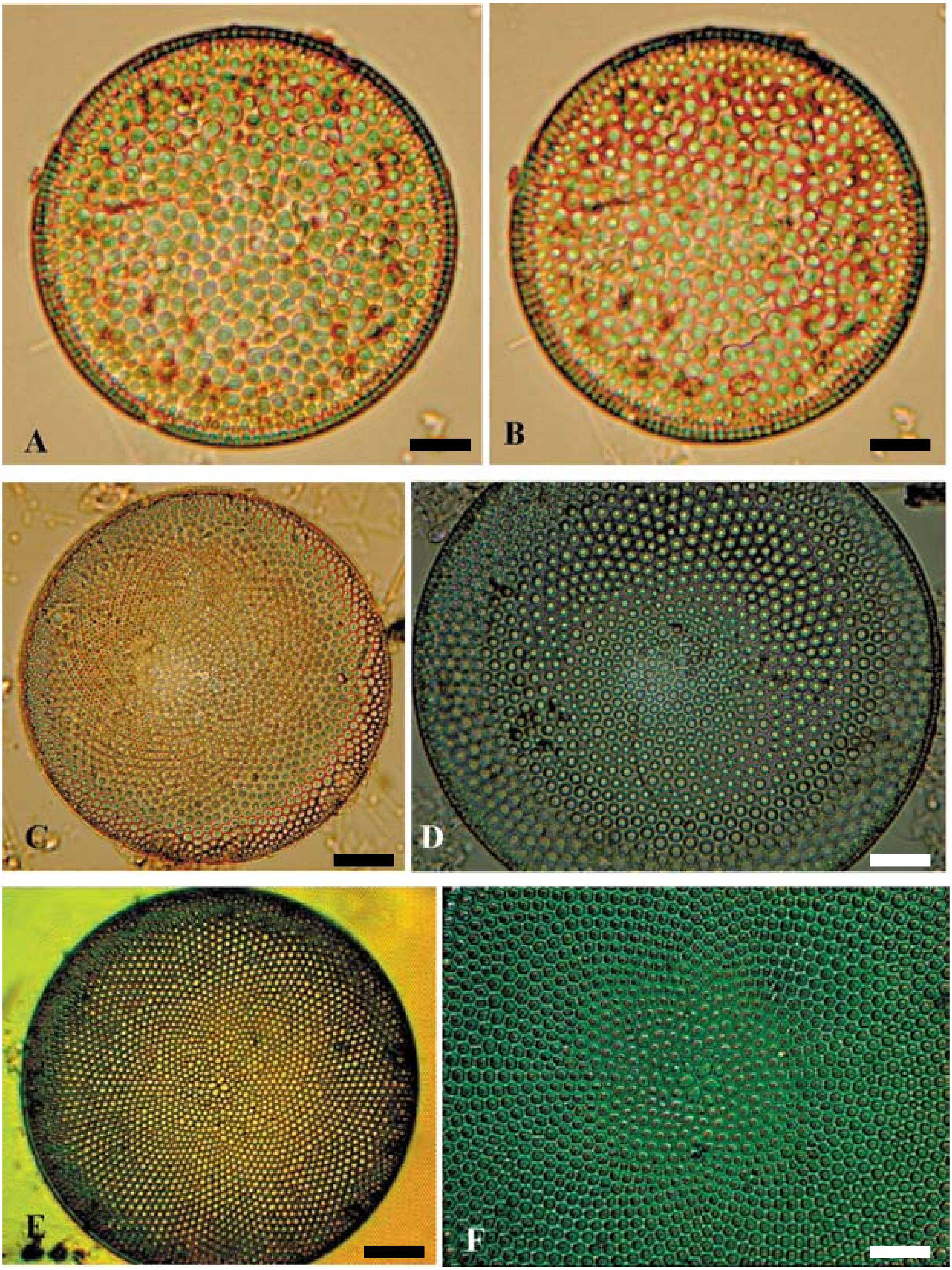

Plate 11. Light micrographs of A-B. *Coscinodiscus marginatus*: in different focus showing the valve with largely areolae arranged irregularly and coarsely striated border; C-F.*Coscinodiscus oculus-iridis*: the valve view shows the increasing of areolae from the center till reach to the periphery in which they are much smaller; C-E. different cells; F. middle region magnified of E.
(Scale Bars, A=7.86 µm; B=7.97 µm; C=18.47 µm; D=22.73 µm; E=29.70 µm; F= MC).

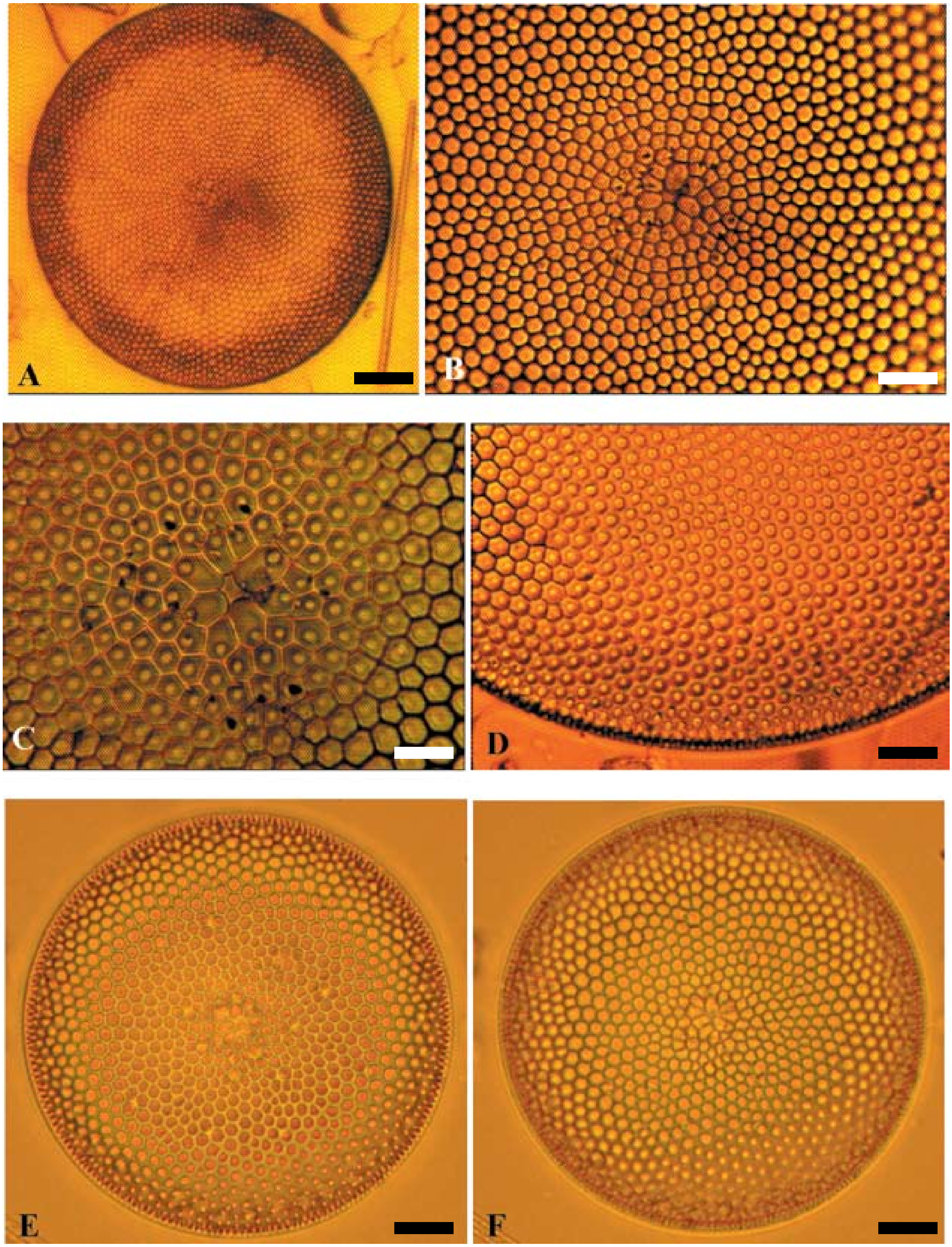

Plate 12. Light micrographs of *Coscinodiscus oculus-irridis*: A. entire view; B. middle region magnified; C. middle region further magnified; D. peripheral region magnified; E-F.*Coscinodiscus oculus-iridis* var. *borealis*: the same cell in different focus.
(Scale Bars, A=28.71 µm; B-D = MC; E=13.13 µm; F=13.13 µm).

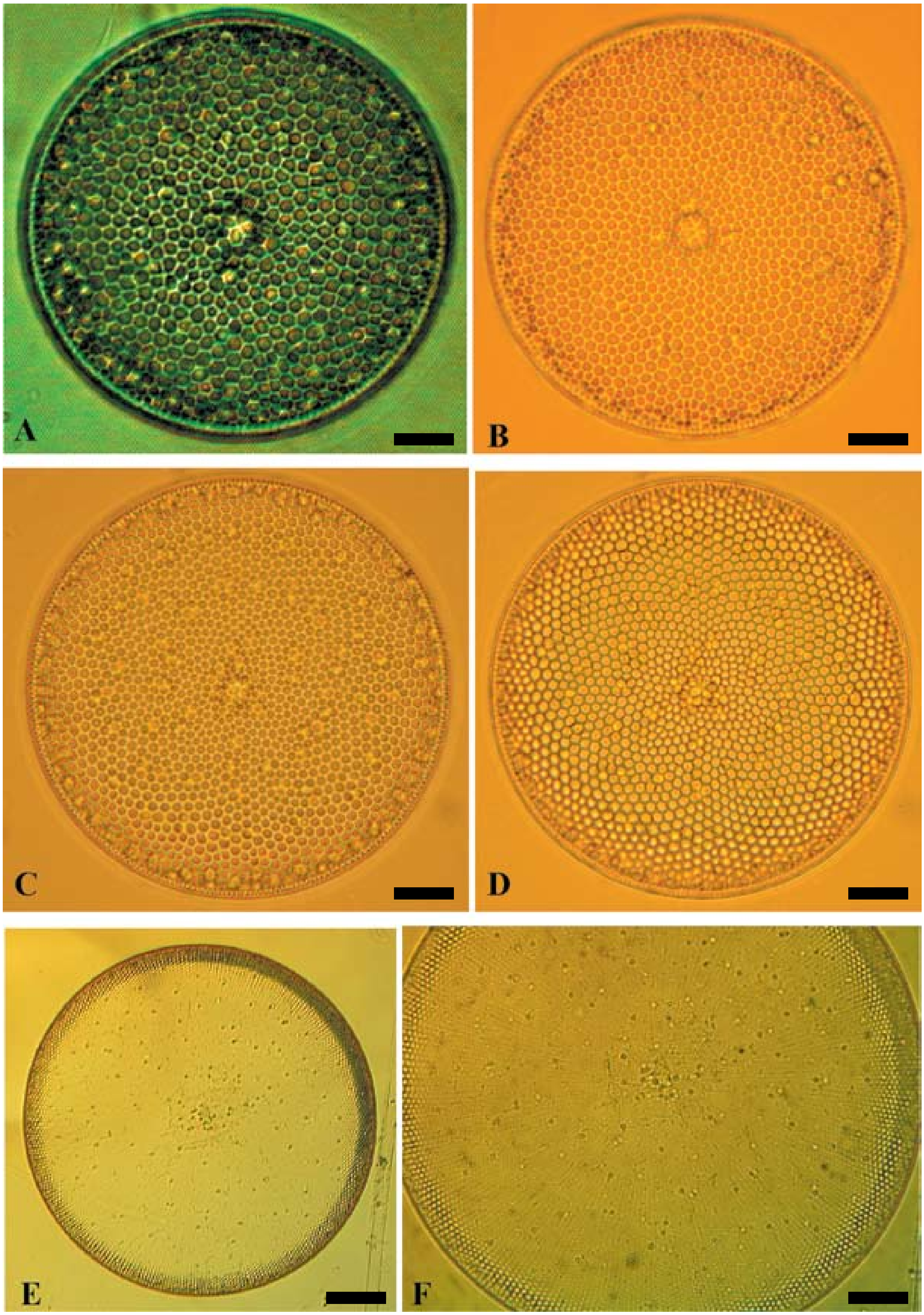

Plate 13. Light micrographs of: A-D. *Coscinodiscus radiatus*: A-B. entire view of the same cell in different focus; C-D. entire view of another cell; E-F. *Coscinodiscus wailesii*: E. the entire view of the cell valve, F. the same cell in more magnification.
(Scale Bars, A=13.01 μm; B=13.38 μm; C=18.44 μm; D=18.31 μm; E=89.66 μm; F=58.13 μm).

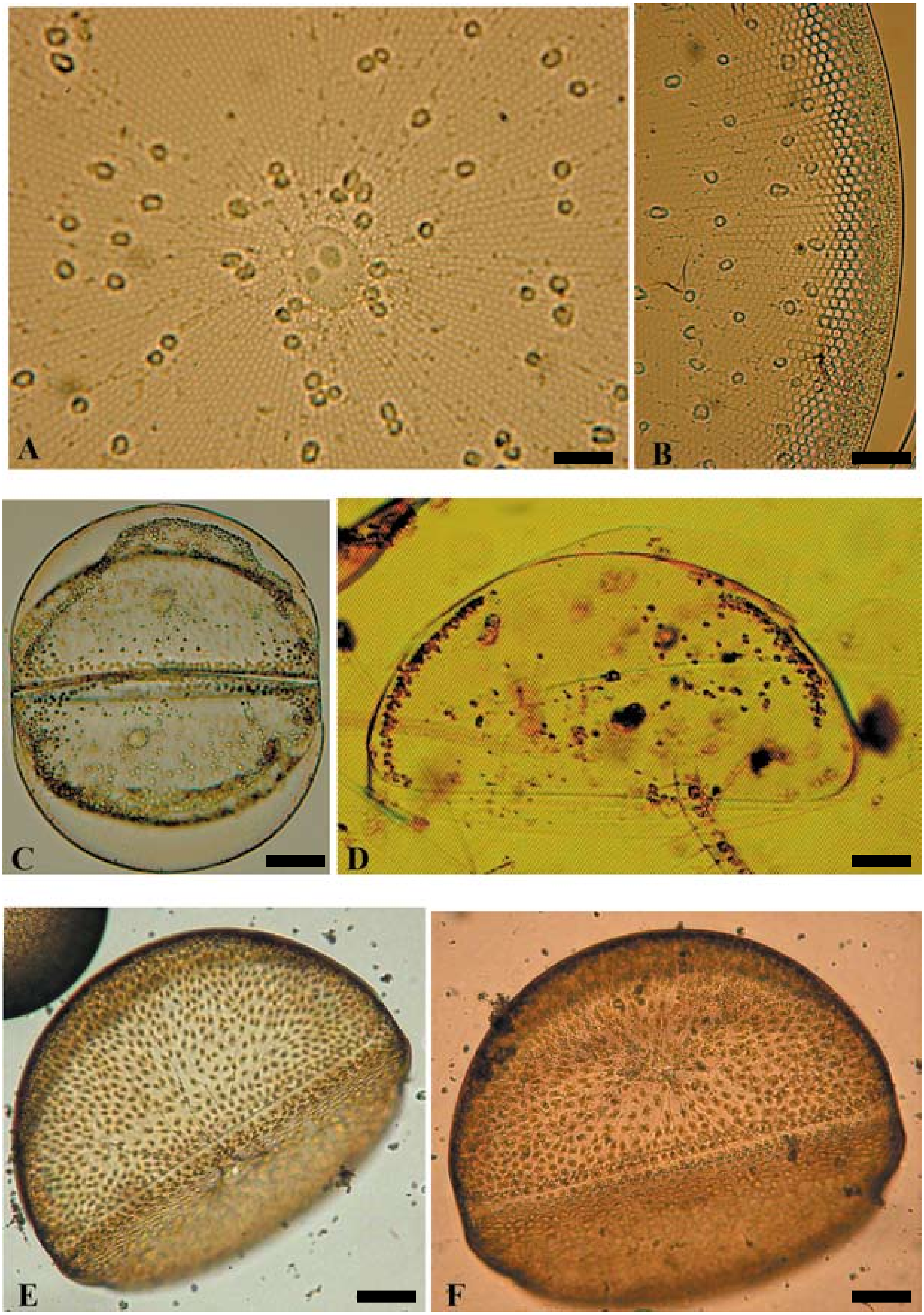

Plate 14. Light micrographs of: A-B. *Coscinodiscus wailesii*: A. middle region magnified; B. peripheral region magnified; C-F. *Palmeria hardmaniana*: Different cells in different views. (Photo E, F by Dr. M. Saburova).
(Scale Bars, A&B= MC of E-F in plate 13; C=89.81 μm; D=63.69 μm; E=71.97 μm; F=66.36 μm).

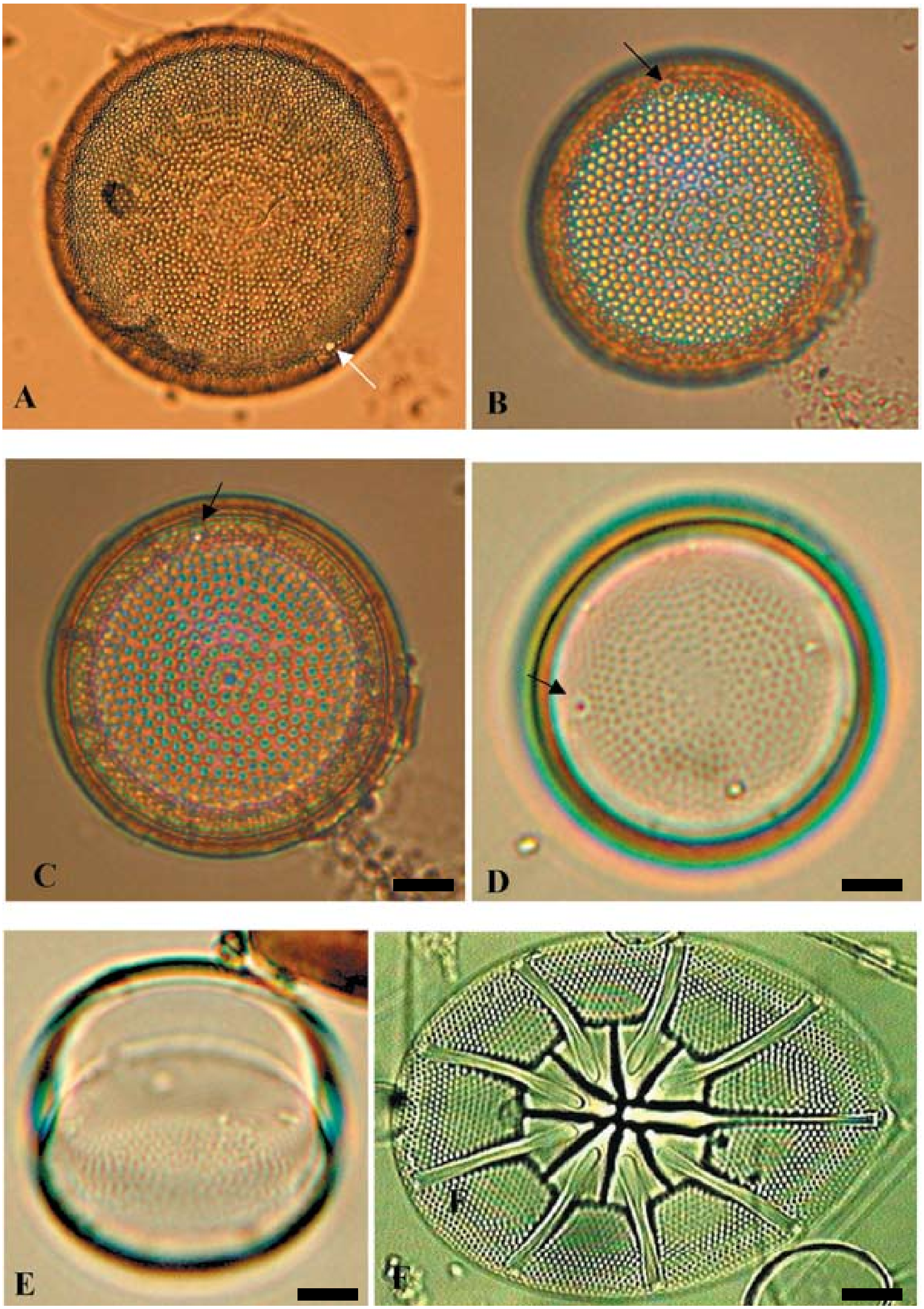

Plate 15. Light micrographs of A-E. *Actinocyclus octonarius*: A. *Actinocyclus octonarius* var. *octonarius*; B-C. *Actinocyclus octonarius* var. *crassus*; D-E. *Actinocyclus*. *octonarius* var. *tenellus*; (arrows indicated the presence of oculus); F. *Asteromphalus flabellatus*: oval valve view with 9 rays, the narrow somewhat longer than the others, the surface areolation is clearly visible.
(Scale Bars, A=14.92 μm; B=7.32 μm; C=6.67 μm; D=6.14 μm; E=7.29 μm; F=6.52 μm).

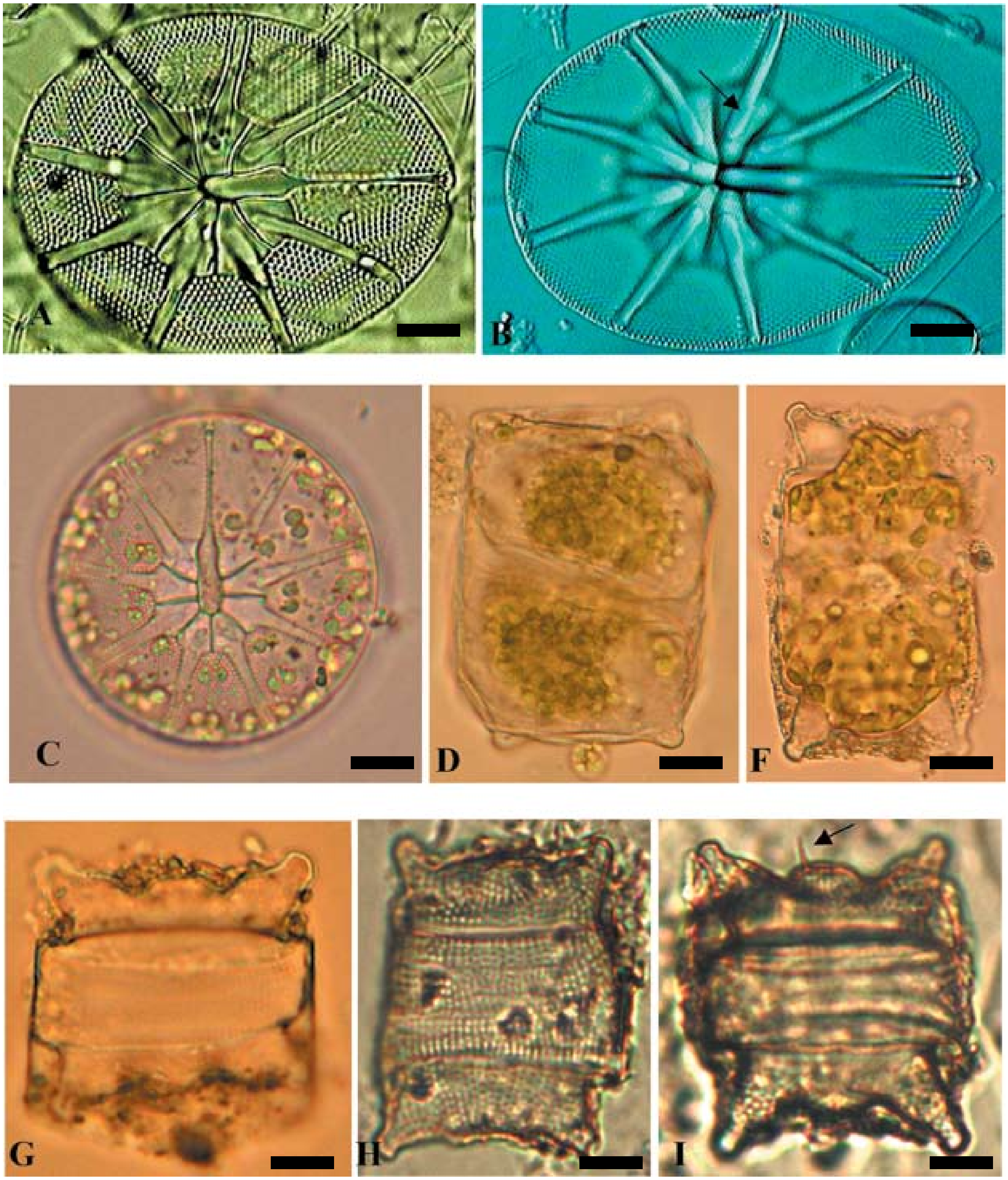

Plate 16. Light micrographs of A-B. *Asteromphalus flabellatus*: the same cell in different focus; C. *Asteromphalus hookeri*: in valve view with 9 rays; D-I. *Odontella aurita*: different cells showing the shape and size variation, D-G. live cells, with chromatophores in D and F; the surface areolation is clearly visible in H; one of the spines is visible in the center in I (arrow).
(Scale Bars, A=5.57 µm; B=5.13 µm; C=5.66 µm; D=6.42 µm; E=6.90 µm; F=8.00 µm; G &H=7.06 µm).

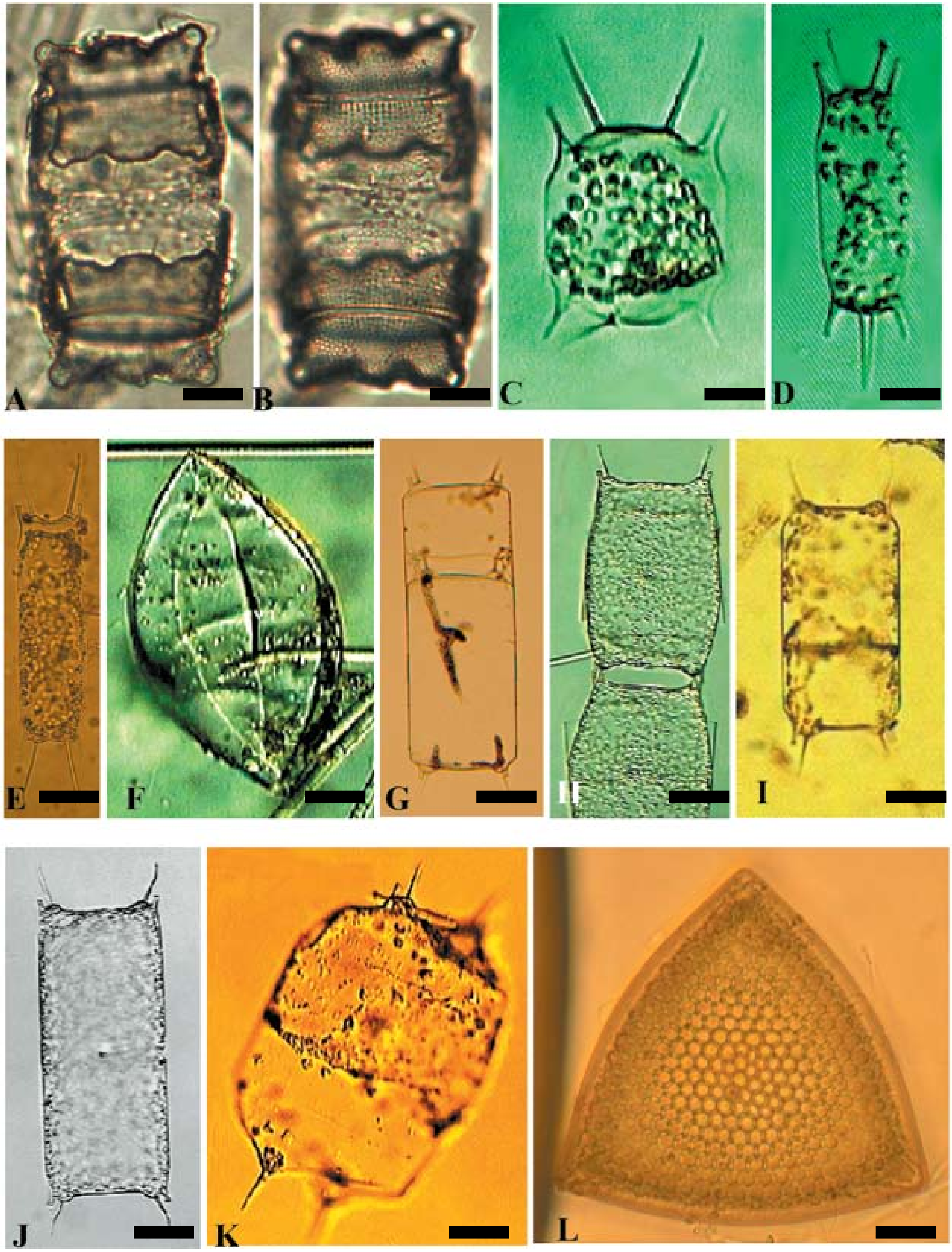

Plate 17. Light micrographs of A-B. *Odontella aurita*: the same typical cells, in broad girdle view, in different focus; C-E. *Odontella mobiliensis*: different cells with chromatophores and long straight spines; F-K. *Odontella sinensis*: different cells in different views; F. in girdle view; G-K. in valve view with two spines which originate close to the base of the processes; the two cells united by their spines clearly visible in H; L. *Triceratium* cf. *broeckii*: in valve view with three small horn like processes.
(Scale Bars, A&B=11.61 µm; C=13.94 µm; D=15.95 µm; E=16.16 µm; F=9.51 µm; G=31.70 µm; H=41.61 µm; I=32.43 µm; J=41.49 µm; K=40.20 µm; L=14.83 µm).

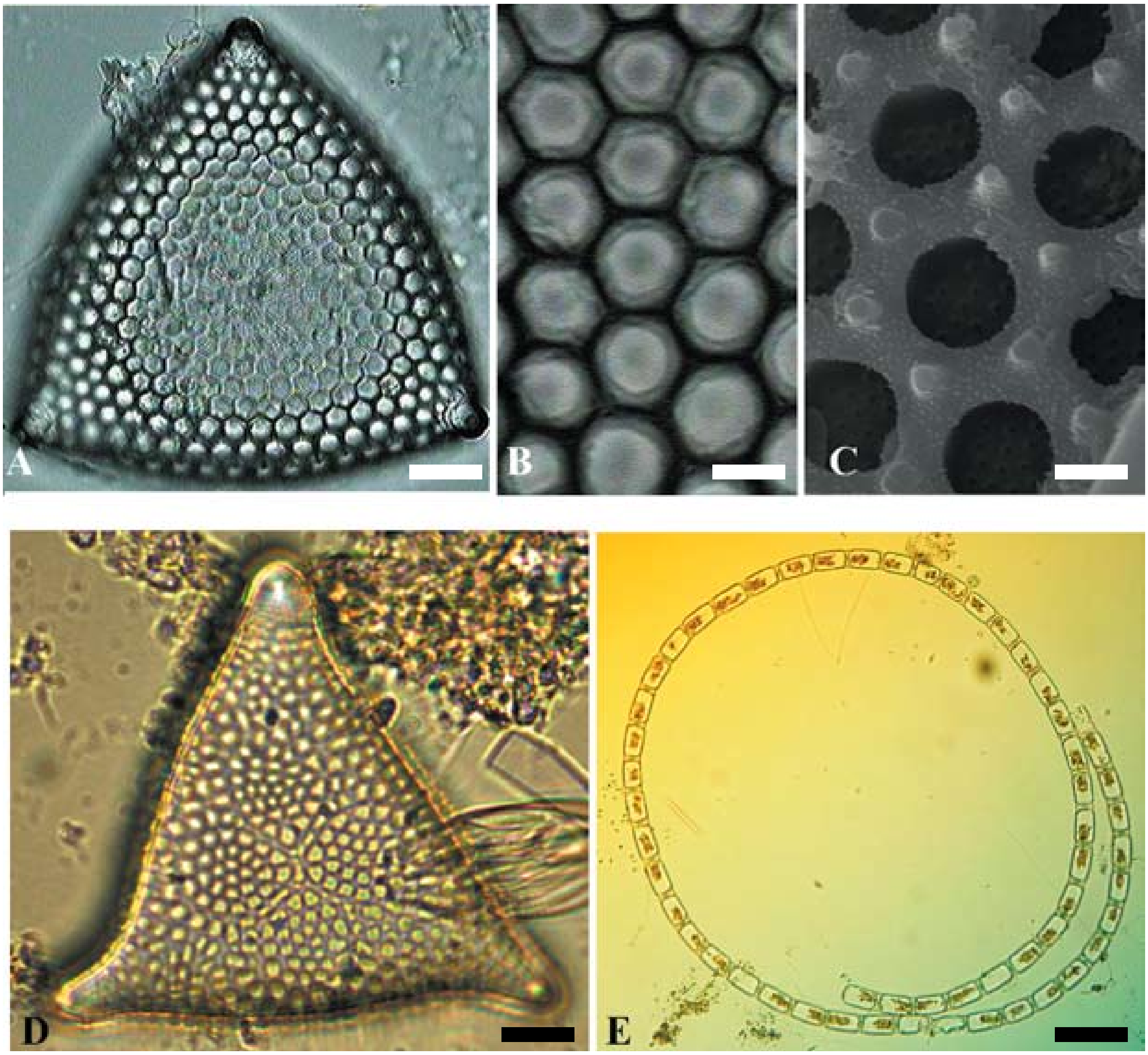

Plate 18. Light micrographs of A-B. *Triceratium* cf. *broeckii*: A. entire view; B. surface areolation magnified; C. Scanning electron micrographs of areolation; D. *Triceratium reticulum*: in valve view with irregularly distributed areolation; E. *Lampriscus shadboltianum*: cells united in circular chain. (Scale Bars, A=13.28 μm; B&C = MC; D=13.57 μm; E=100.00 μm).

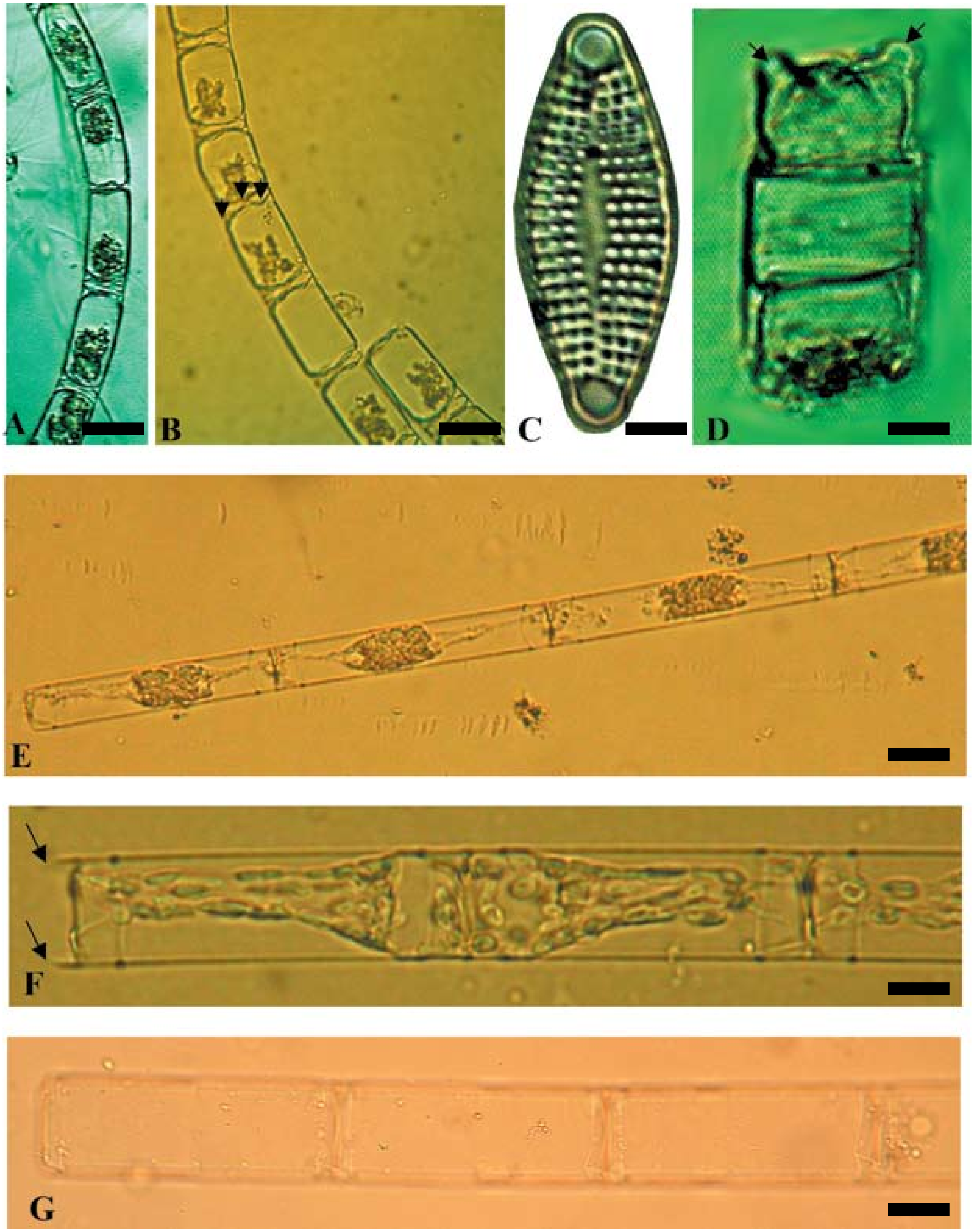

Plate 19. Light micrographs of A-B. *Lampriscus shadboltianum*: cells united by their edges in chains, showing three edges at the end of each cell which indicated by arrows in B; C. *Dimeregramma minor*: in valve view with radiate striae; D. *Biddulphia pulchella*: in valve view with two globular processes (arrows); E-F. *Cerataulina bicornis*: E. cells united by their processes (arrows) forming a straight chain, F. cell magnified showing clearly the processes and the connection with other cell; G. *Cerataulina dentata*: cells united forming straight chain.

(Scale Bars, A=35.33 μm; B=32.00 μm; C=2.85 μm; D=12.73 μm; E=17.02 μm; F=6.72 μm; G=26.53 μm).

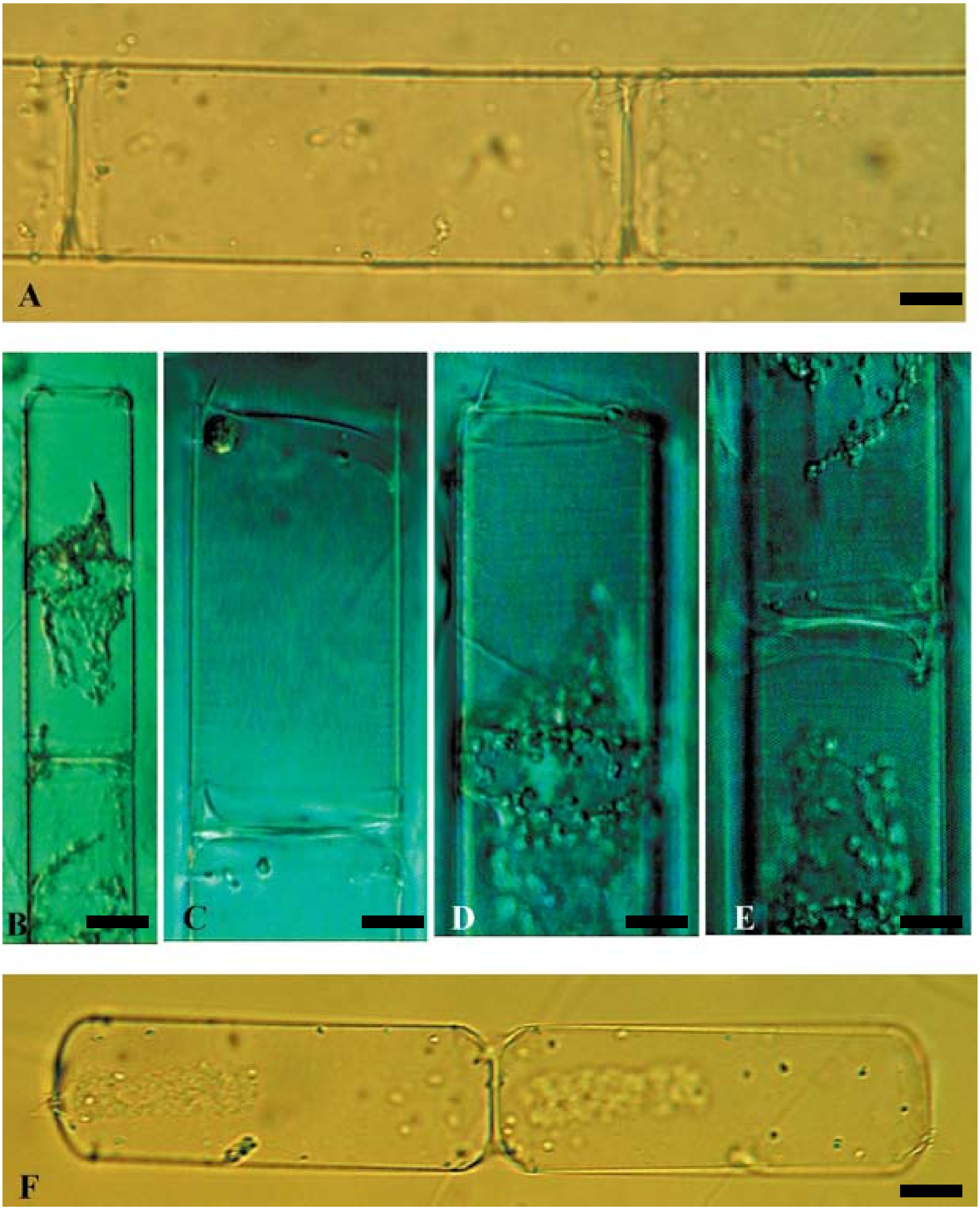

Plate 20. Light micrographs of A-E. *Cerataulina dentata*: in different focus showing the processes at the end of each cell by which they connected to each other and the bands pattern which is clearly visible on D and E; F. *Cerataulina pelagica*: two cells connected by therr processes.
(Scale Bars, A=14.44 μm; B=26.47 μm; C=13.24 μm; D&E=14.52 μm; F=17.86 μm)

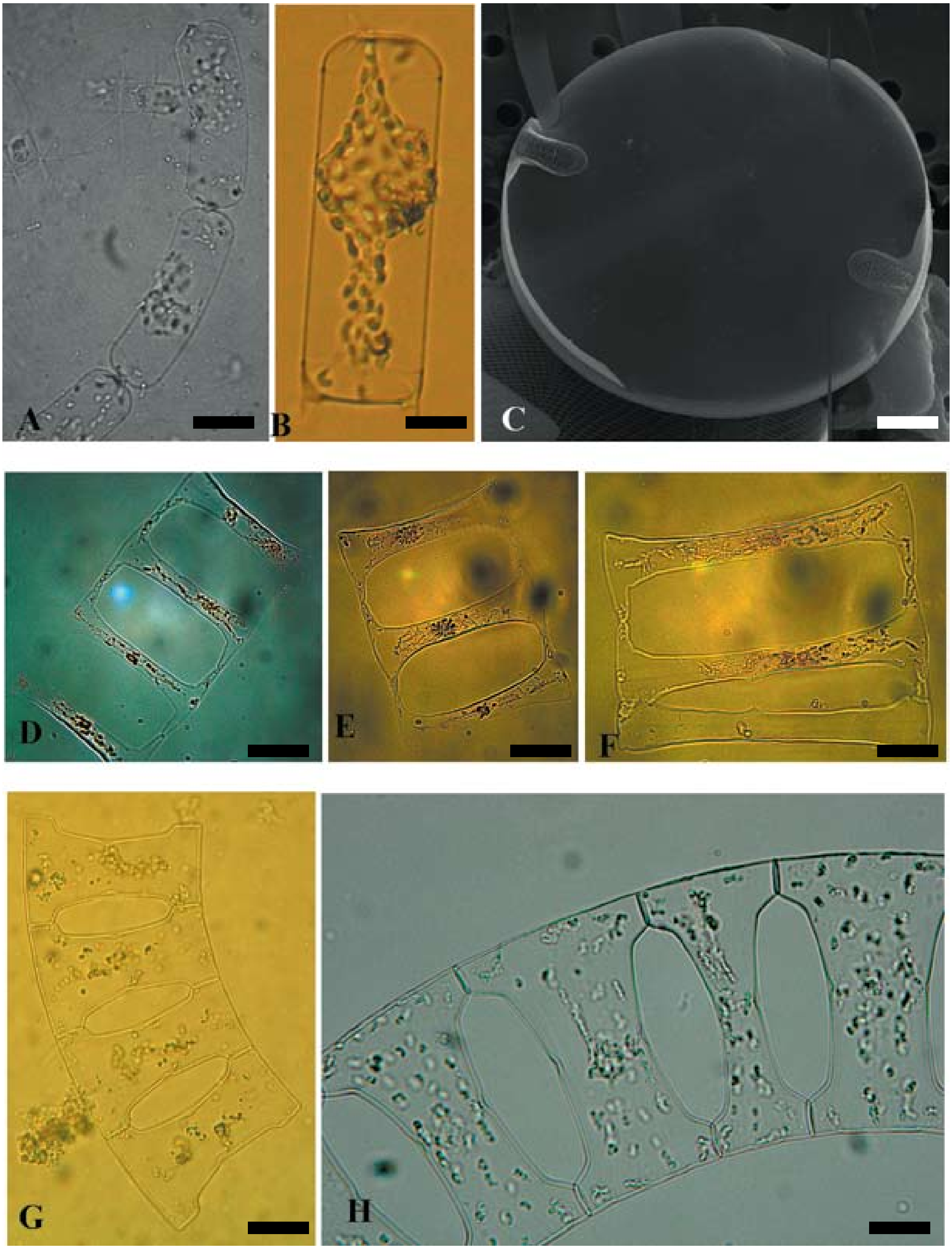

Plate 21. Light micrographs of A-C. *Cerataulina pelagica*: A. cells united in a curved chain, B. one cell showing the clearly the two processes at the end of the cell; D-F. *Climacodium frauenfeldianum*: different cells connected to each other by their processes; G-H. *Eucampia zodiacus*: parts of two curved chains, in broad girdle view, more magnified on H showing clearly the cells united by their blunt processes. (Photos A, B, D - H by by Dr. M. Saburova).
(Scale Bars, A=39.60 µm; B=20.84 µm; C=5.58 µm; D=31.20 µm; E=26.90 µm; F=15.00 µm; G=21.38 µm; H=13.48 µm).

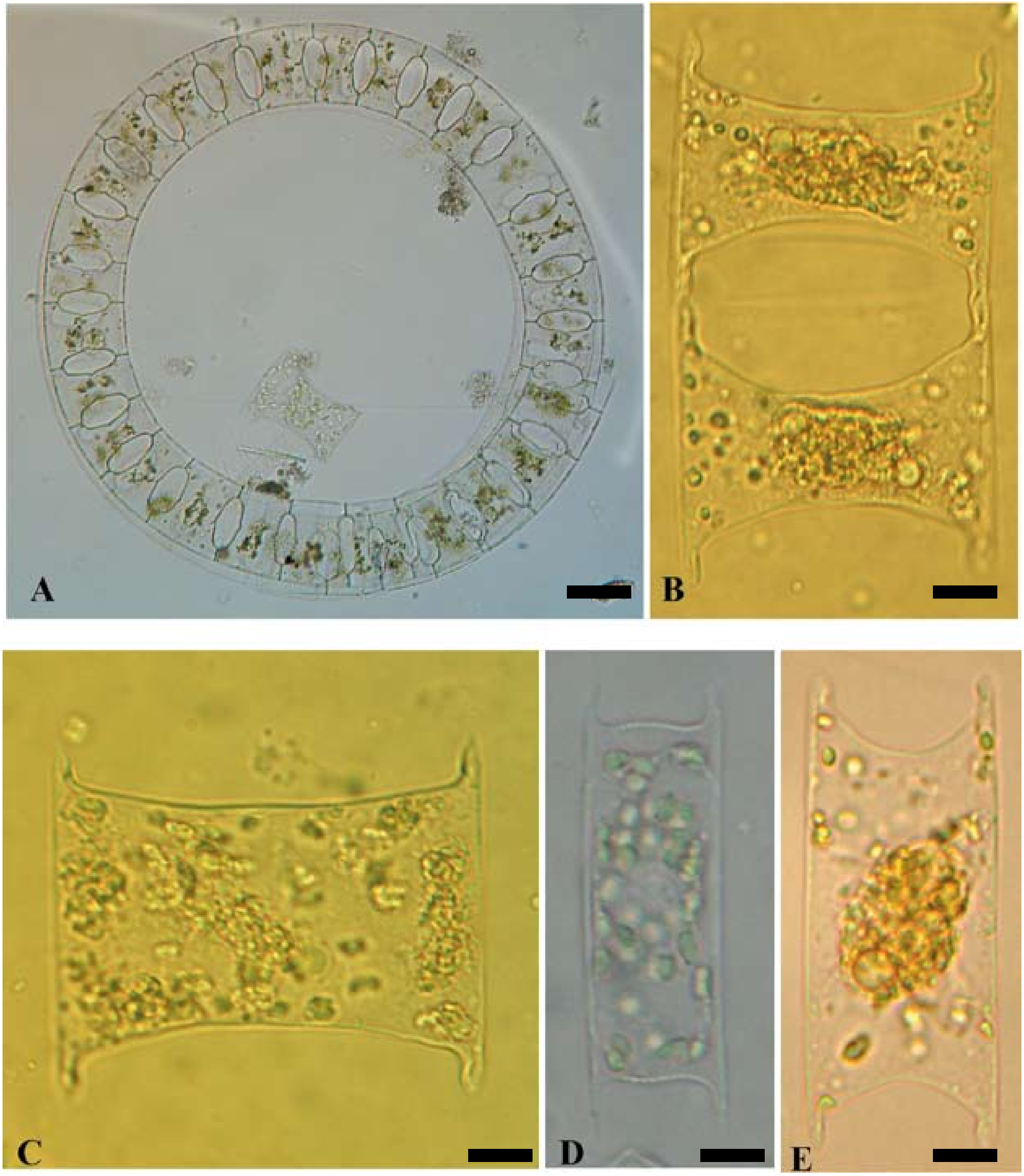

Plate 22. Light micrographs of A. *Eucampia zodiacus*: in a circular chain; B-C. *Hemiaulus membranaceus*: B. two cells united by their processes; C. one cell shows the processes at each side of the cell; D-E. *Hemiaulus sinensis*: two different cells in valve view, showing their processes at each side of the cell. (Scale Bars, A=51.67 µm; B=12.76 µm; C=12.12 µm; D=16.67 µm; E=11.67 µm).

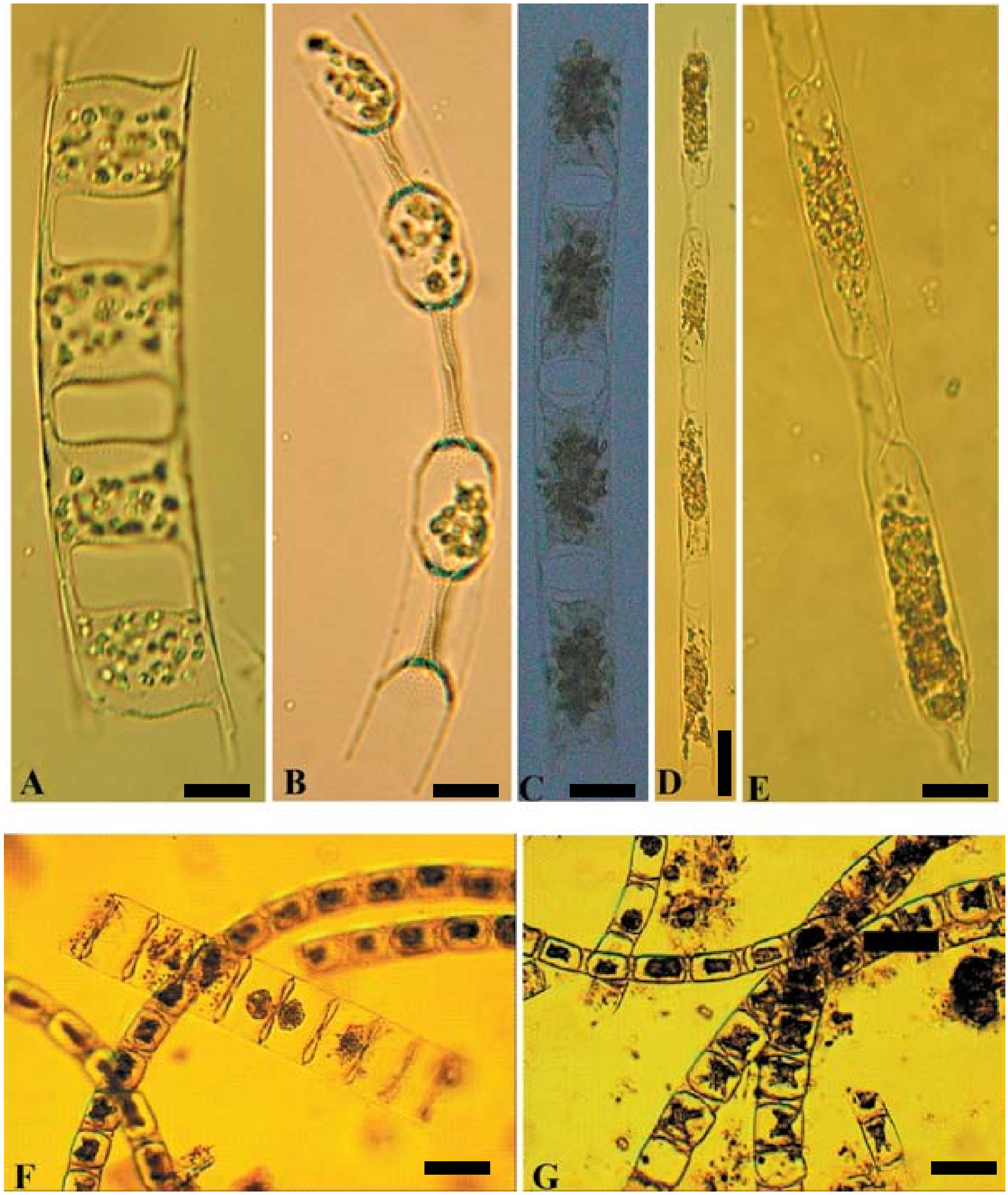

Plate 23. Light micrographs of A-E. *Hemiaulus sinensis*: Chains in broad and narrow girdle views: the cells connected by their processes and claws; F-G. *Bellerochea horologicalis*: cell united to each other with clearly narrow space in between showing narrow and broad chains.
Scale Bars, A=16.96 µm; B=18.57 µm; C=30.00 µm; D=33.17 µm; E=16.59 µm; F=51.67 µm; G=82.67 µm).

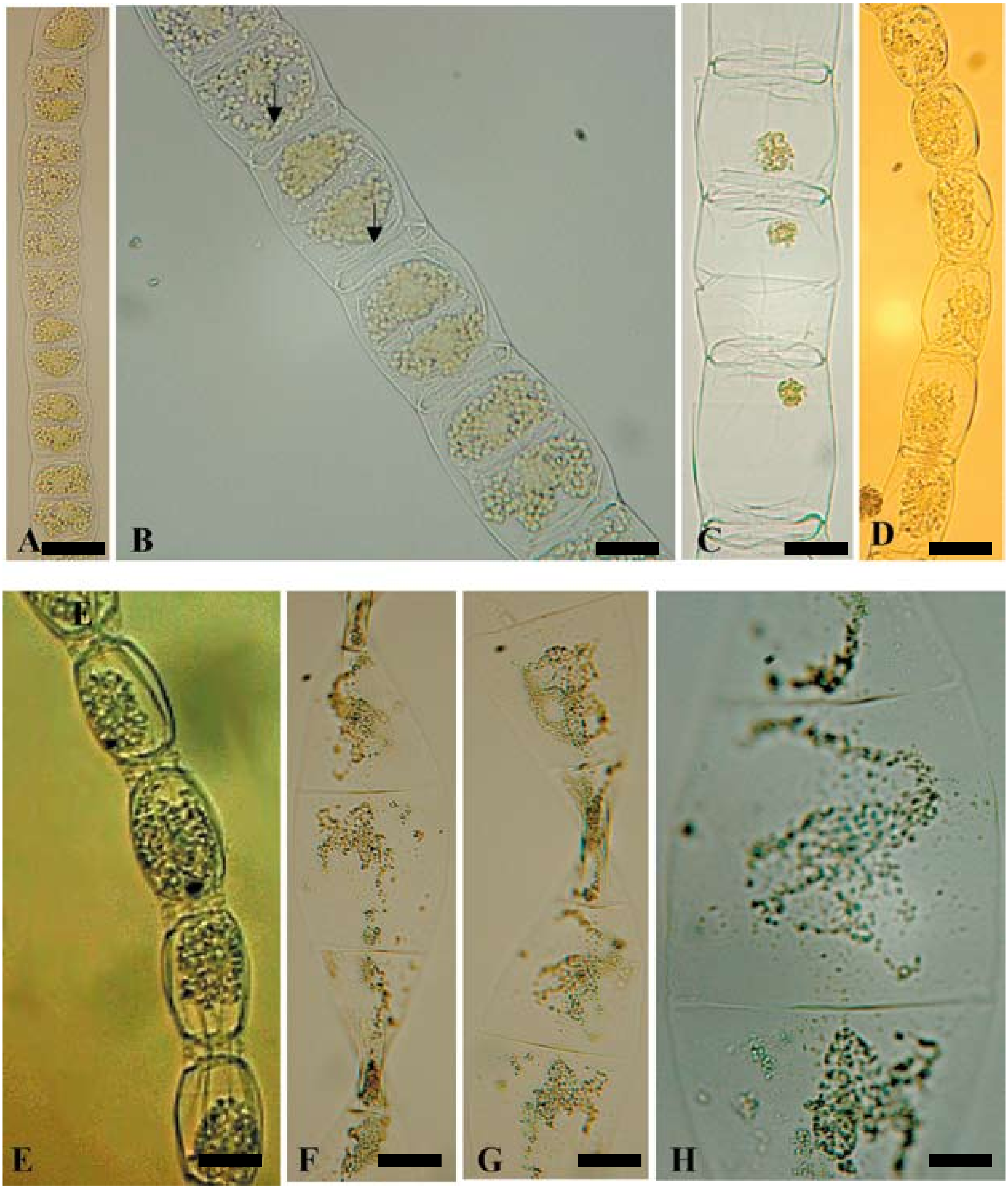

Plate 24. Light micrographs of A-E. *Bellerochea malleus*: Parts of chains showing the intracellular spaces between cells (see arrows in C); F-H. *Helicotheca thamensis*: F-G. typical chains, twisted about the pervalvar axis and the adhering cells connected without leaving space, H. more magnification of one cell.

(Scale Bars, A=41.00 µm; B=22.38 µm; C=20.87 µm; D=27.21 µm; E=21.03 µm; F=42.00 µm; G=42.40 µm; H=22.83 µm).

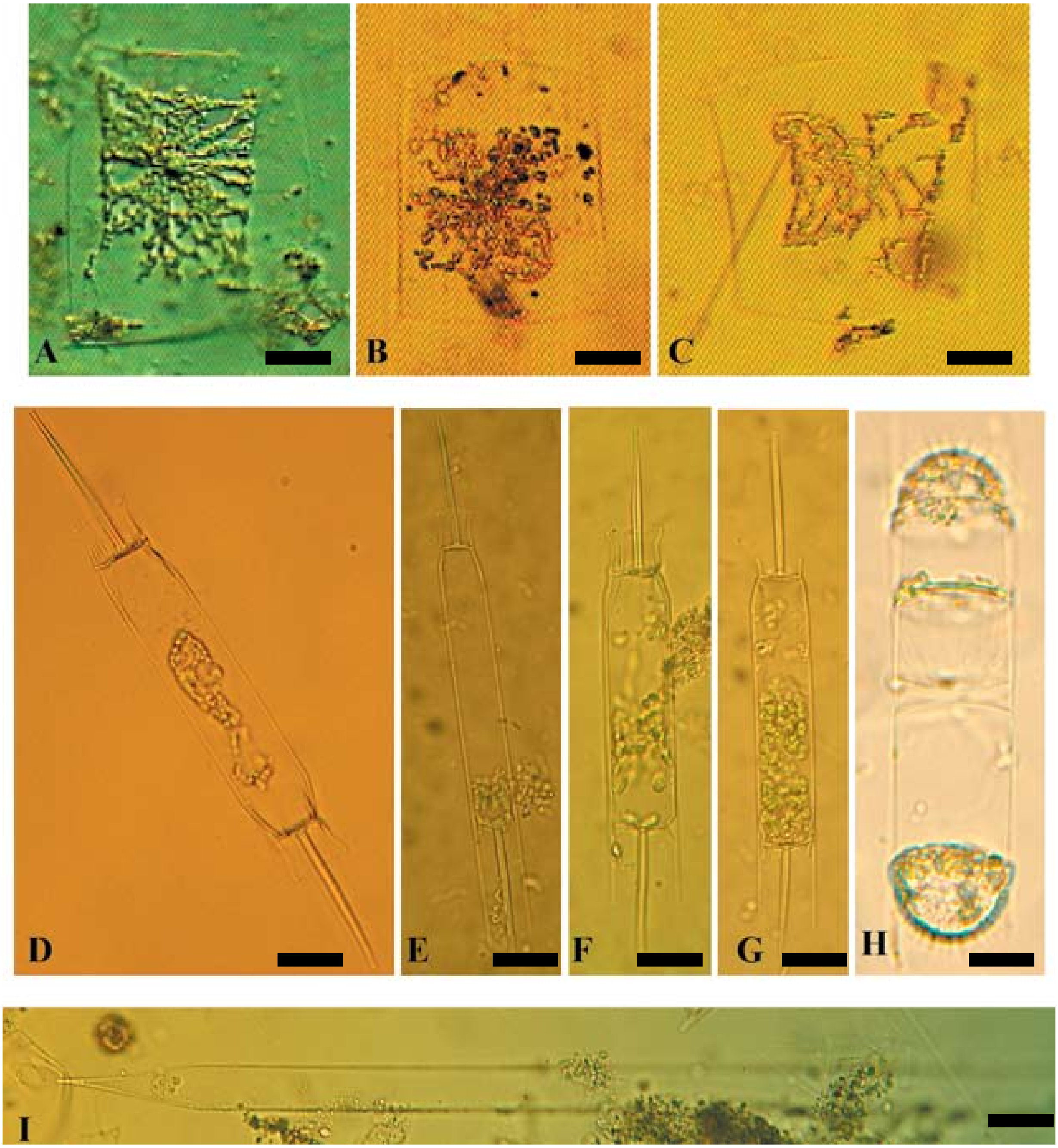

Plate 25. Light micrographs of A-C. *Helicotheca thamensis*: different cells in different views; D-G. *Ditylum brightwelli*: different cells with clearly cylindrical appearance with stout spines; H. *Corethron criophilum*: cells with cylindrical mantle and arched hemispherical valves, circle of long slender setae at edge of valve; I. *Rhizosolenia bergonii*: part of cell with cylindrical region, elongated cone-shaped valves and short apical process.
(Scale Bars, A=25.56 μm; B=27.56 μm; C=27.07 μm; D=24.20 μm; E=27.50 μm; F=30.25 μm; G=28.81 μm; H=21.11 μm; I=32.86 μm).

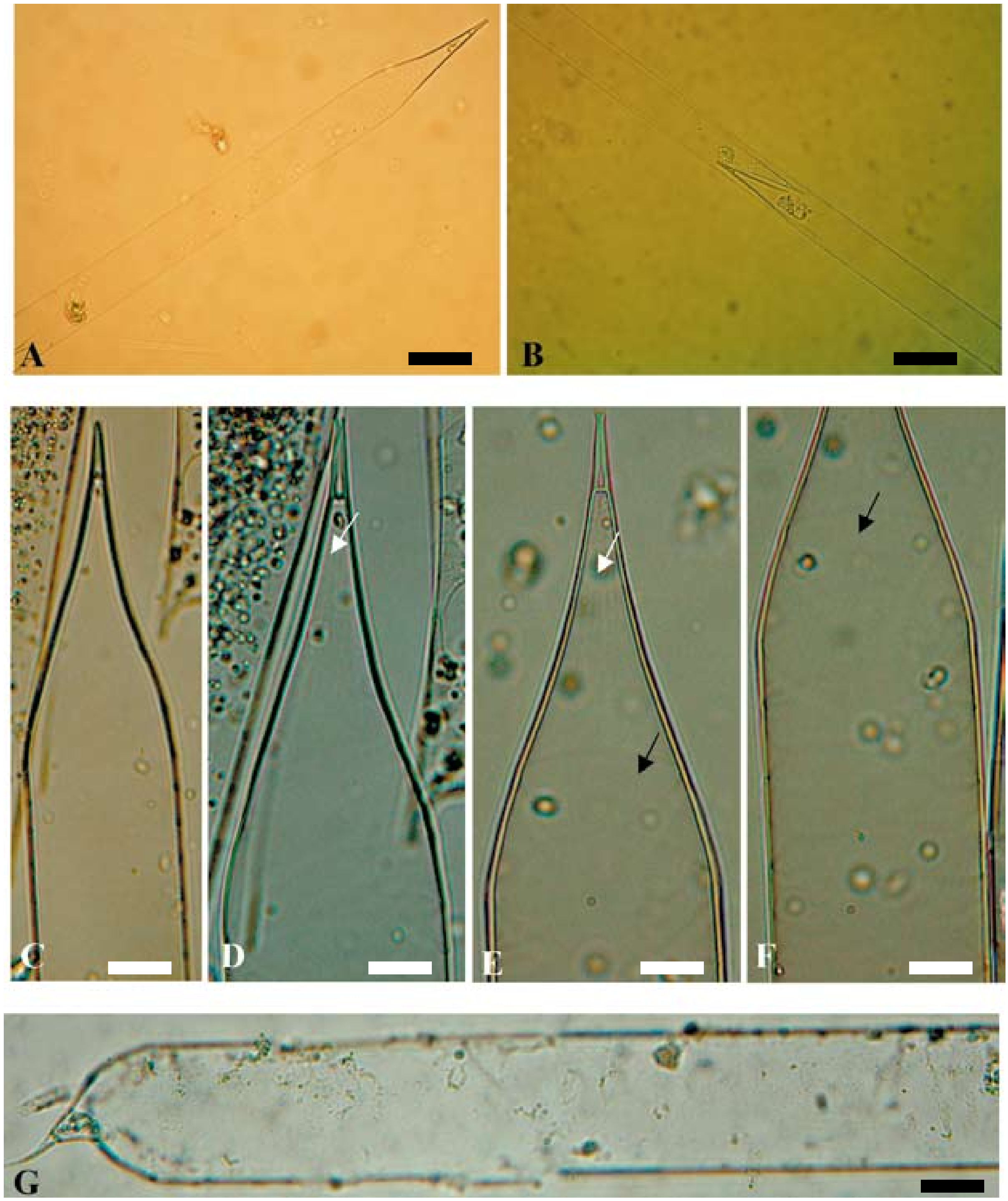

Plate 26. Light micrographs of A-F. *Rhizosolenia bergonii*: A. another part of cell, B. connection of two cells, C-F. cell magnified, showing clearly straight apical process, centrally located, traversed by a canal in center, walls of valve moderately robust, with rows of punctuations beginning below the process which slightly visible on D and F (white arrows) and below it the intercalary bands scale like (black arrows on E and F); G. *Rhizosolenia cochlea*: part of cell.
(Scale Bars, A=35.71 µm; B=40.00 µm; C=38.75 µm; D=26.57 µm; E=24.80 µm; F=26.57 µm; G=31.82 µm).

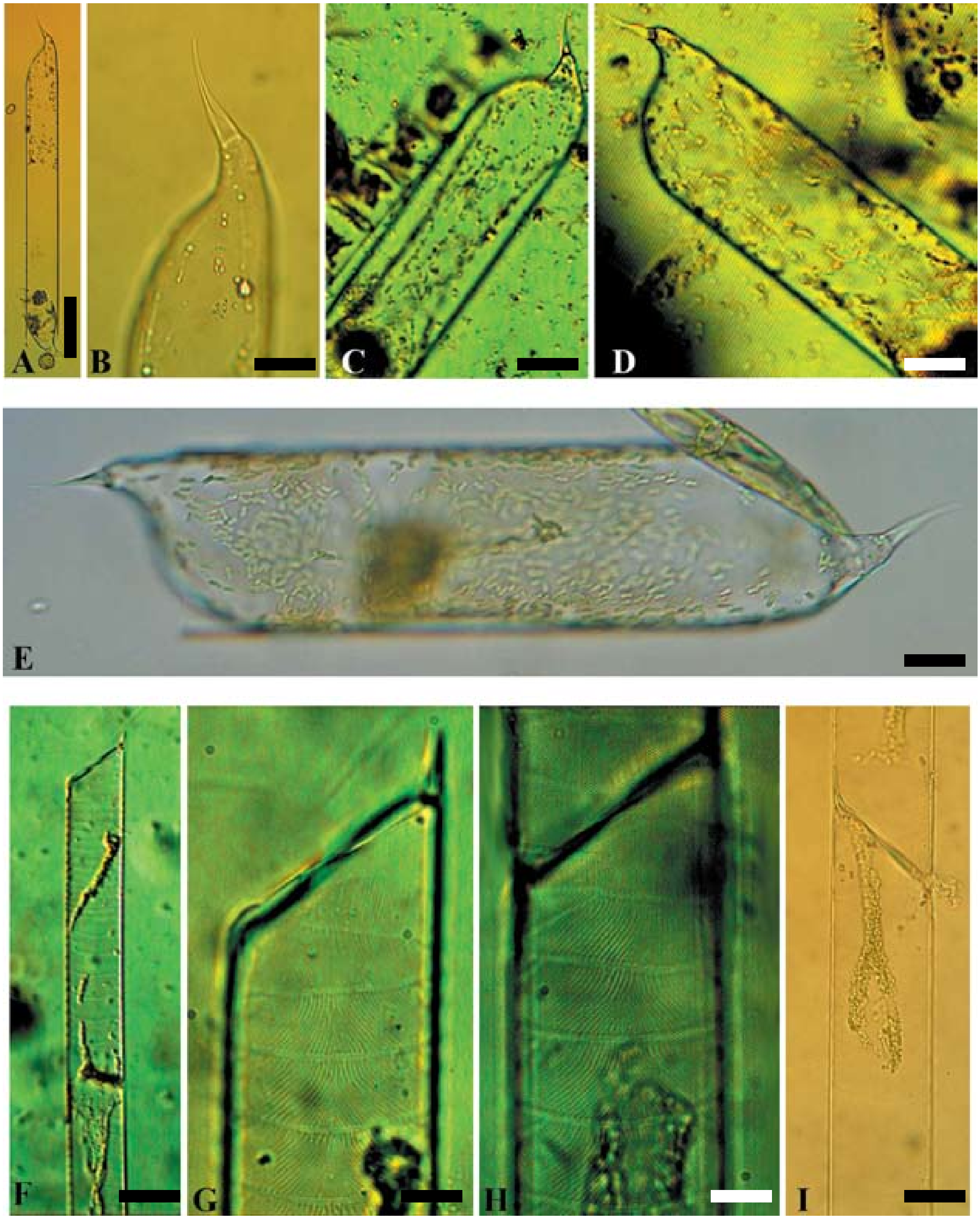

Plate 27. Light micrographs of A-E. *Rhizosolenia cochlea*: A. The whole cell in low magnification, B. part of the same cell magnified showing clearly the large spine, C. one side of another cell, D. the other side, E. the whole of another wide and big cell ; F-I. *Rhizosolenia imbricata*: F. part of cell, G. upper part more magnified, H. other part more magnified showing clearly the intercalary bands, I. the connection of two cells exactly by their ends.

(Scale Bars, A=100.00 μm; B=21.74 μm; C=55.56 μm; D=45.45 μm; E=26.67 μm; F=50.00 μm; G=12.86 μm; H=13.24 μm; I=26.47 μm).

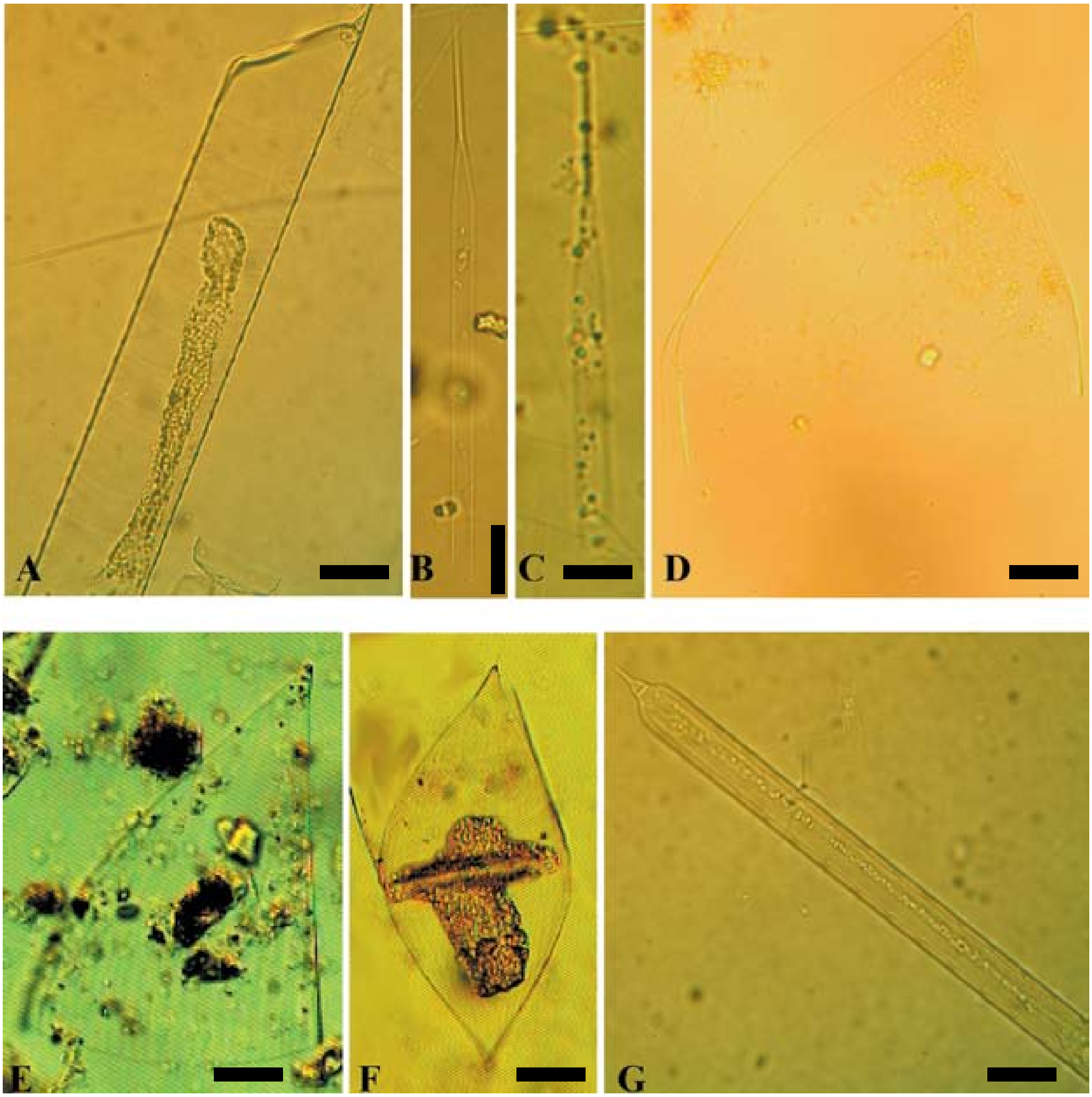

Plate 28. Light micrographs of A. *Rhizosolenia imbricata*: part of cell showing clearly the process and the intercalary bands; B-C. *Rhizosolenia* cf. *pungens*: very thin cell with long spine; D-F. *Rhizosolenia robusta*: D. part of cell, E. another part of cell with punctuation, F. whole cell with two pointed processes; G. *Rhizosolenia shrubsolei*: part of cell.
(Scale Bars, A=28.13 µm; B=40.00 µm; C=22.00 µm; D=31.67 µm; E=40.95 µm; F=58.93 µm; G=28.57 µm).

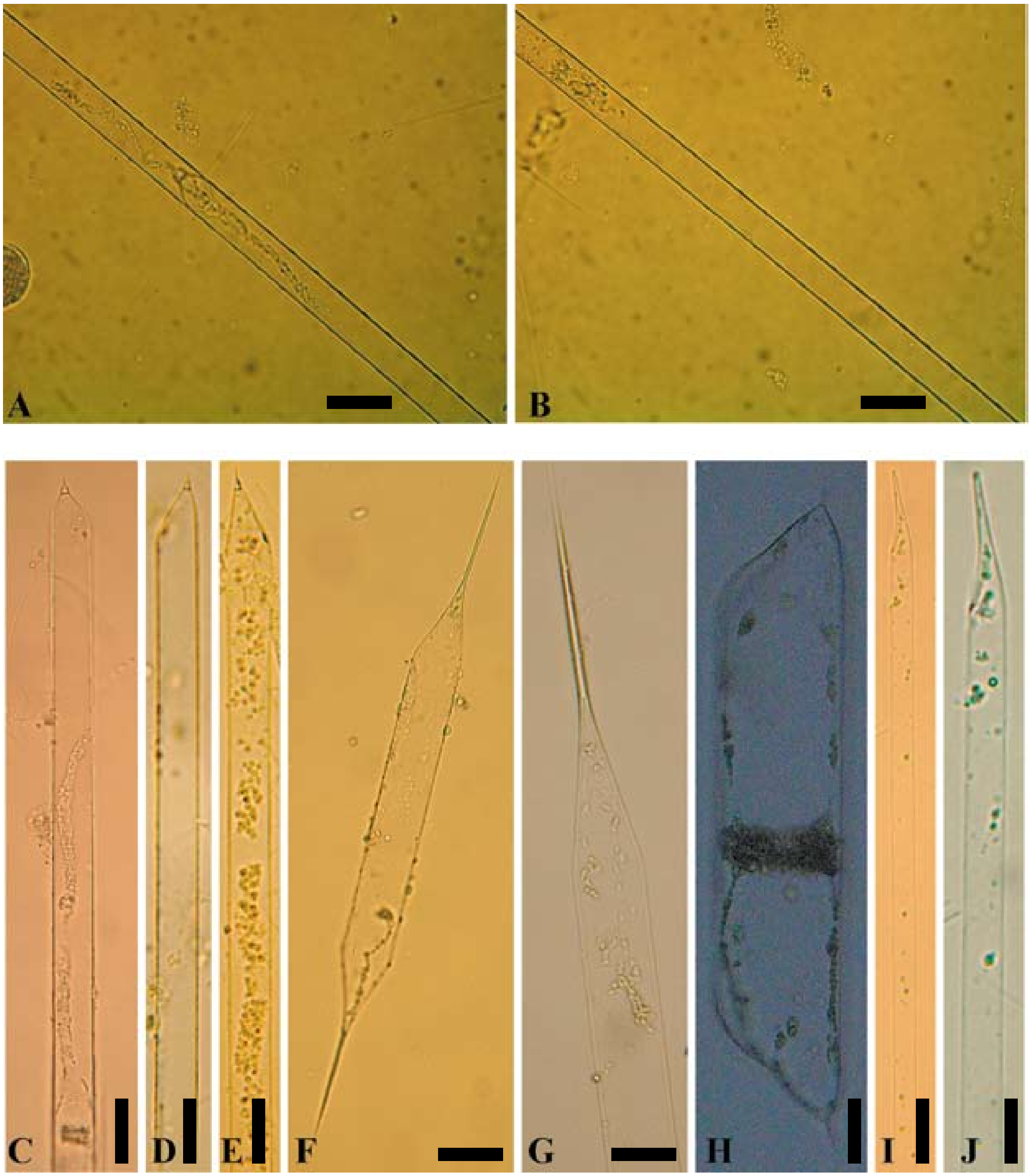

Plate 29. Light micrographs of A-E. *Rhizosolenia shrubsolei*: A.connection between two cells, B. elongate part showing the intercalary bands, C-E. different parts of cells in different views; F-G. *Rhizosolenia setigera*: cylindrical, straight cell with long and straight spine, F. whole cell, G. part of another cell; H. *Rhizosolenia* sp. 1: whole wide cell; I-J. *Proboscia alata* f. *gracillima*: elongate cell in different magnification without spine.

(Scale Bars, A&B=40.00 C=21.67 µm; D=20.83 µm; E=28.33 µm; F=18.75 µm; G=25.45 µm; H=25.26 µm; I=20.00 µm; J=11.50 µm).

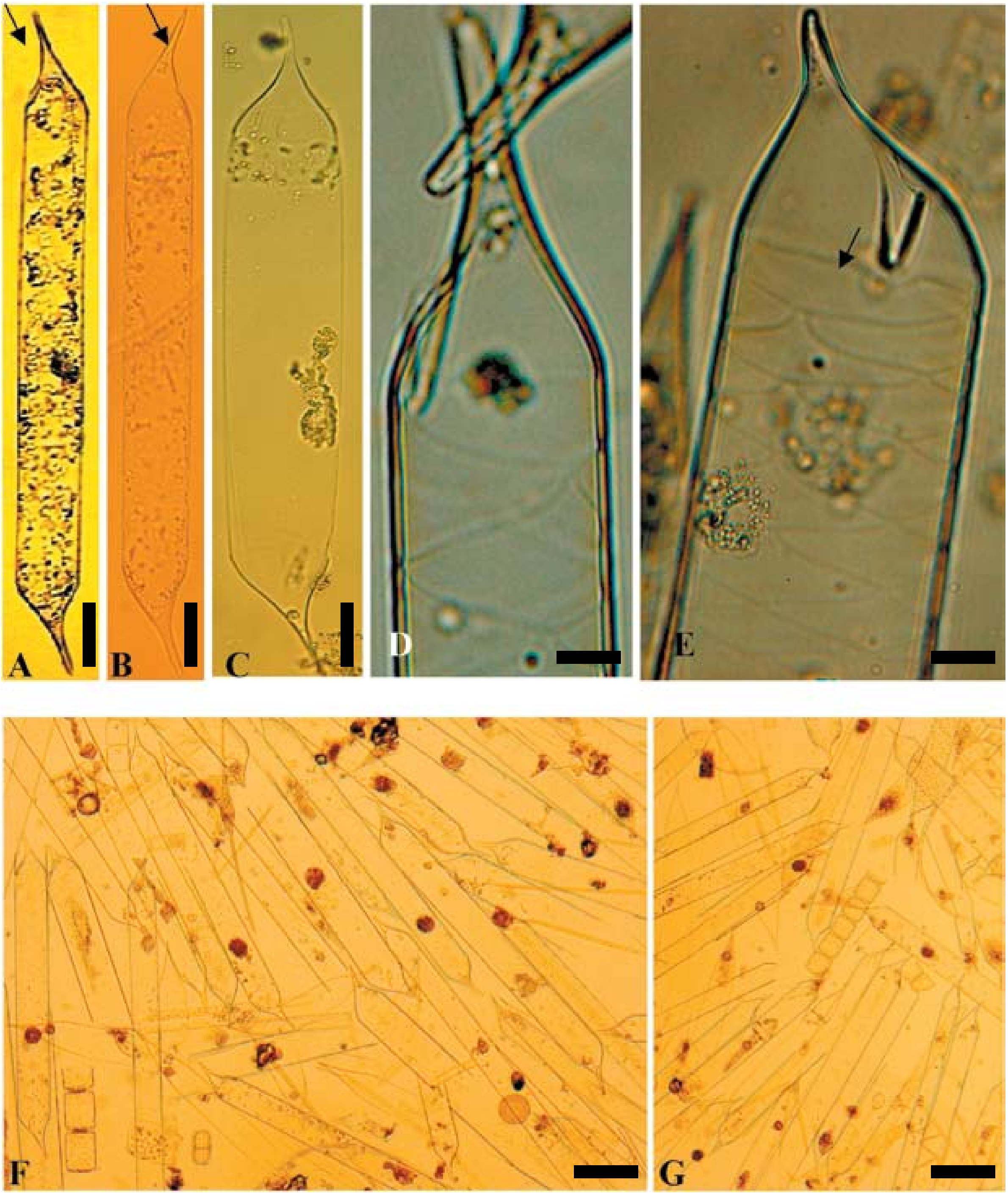

Plate 30. Light micrographs of A-B. *Proboscia alata* (scale bar = 22.10 µm): different cells with numerous chloroplasts and short longitudinal slit at both ends of the cells (Proboscis) are indicated by arrows, C-E. *Proboscia alata* f. *indica*: C. whole broad cell, D. showing the connecting of two cells by their elongate ends (arrow), E. shows clearly the intercalary bands (arrow); F-G. A bloom of *Proboscia alata*.
(Scale Bars, A&B=44.00 µm; C=26.67 µm; D=29.41 µm; E=13.81 µm; F=70.00 µm; G=84.00 µm).

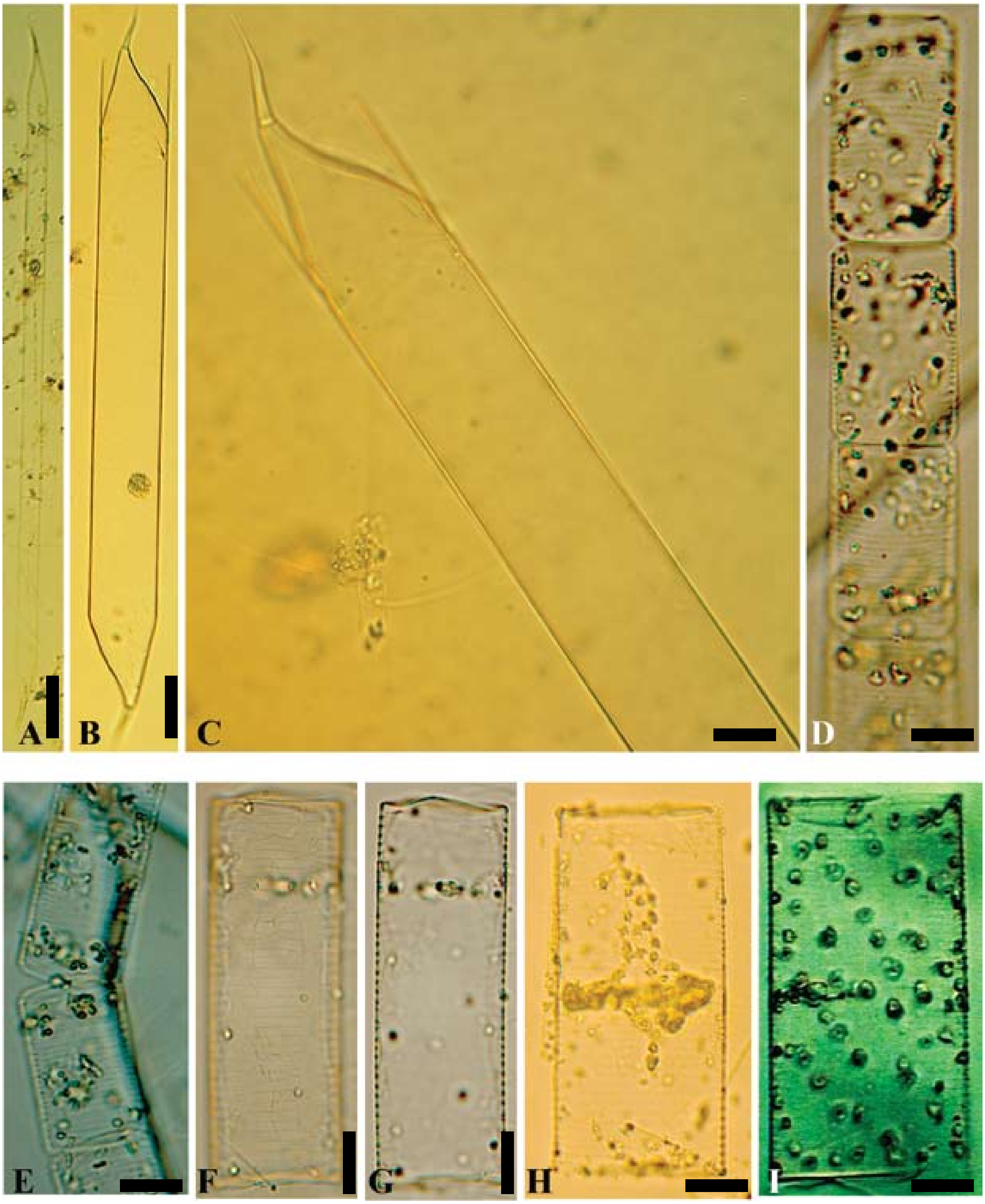

Plate 31. Light micrographs of A-C. *Pseudosolenia calcar-avis*: cells in different magnification with conical shape and strong process; D-I. *Guinardia flaccida*: D-E. cells united in chains by whole valve surface, F-I. different cells in different views with intercalary bands and irregular tooth at the margin which clearly visible in F and G.

(Scale Bars, A=166.67 µm; B=45.45 µm; C=21.74 µm; D=13.78 µm; E=18.52 µm; F=29.55 µm; G=29.52 µm; H=35.56 µm; I=25.63 µm).

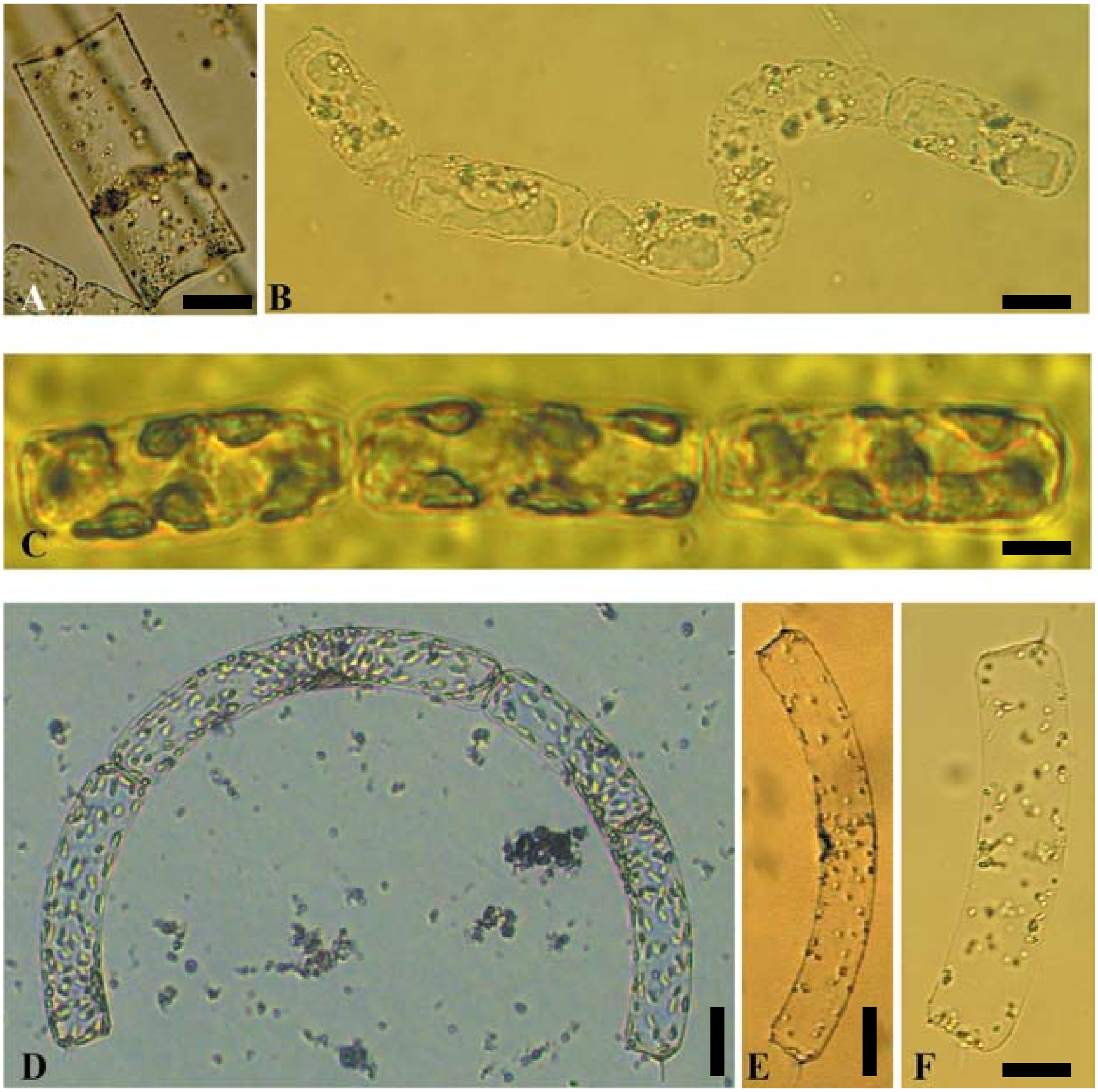

Plate 32. Light micrographs of A. *Guinardia flaccida*: another flat cell; B-C. *Guinardia delicatula*: cells united in short chains and have short marginal spine; D-F. *Guinardia striata*: D. part of short curved chain with numerous chromatophores, E-F. two different single cells with strong spine at the margin.
(Scale Bars, A=52.94 µm; B=17.27 µm; C=11.76 µm; D=30.59 µm; E=32.50 µm; F=21.54 µm).

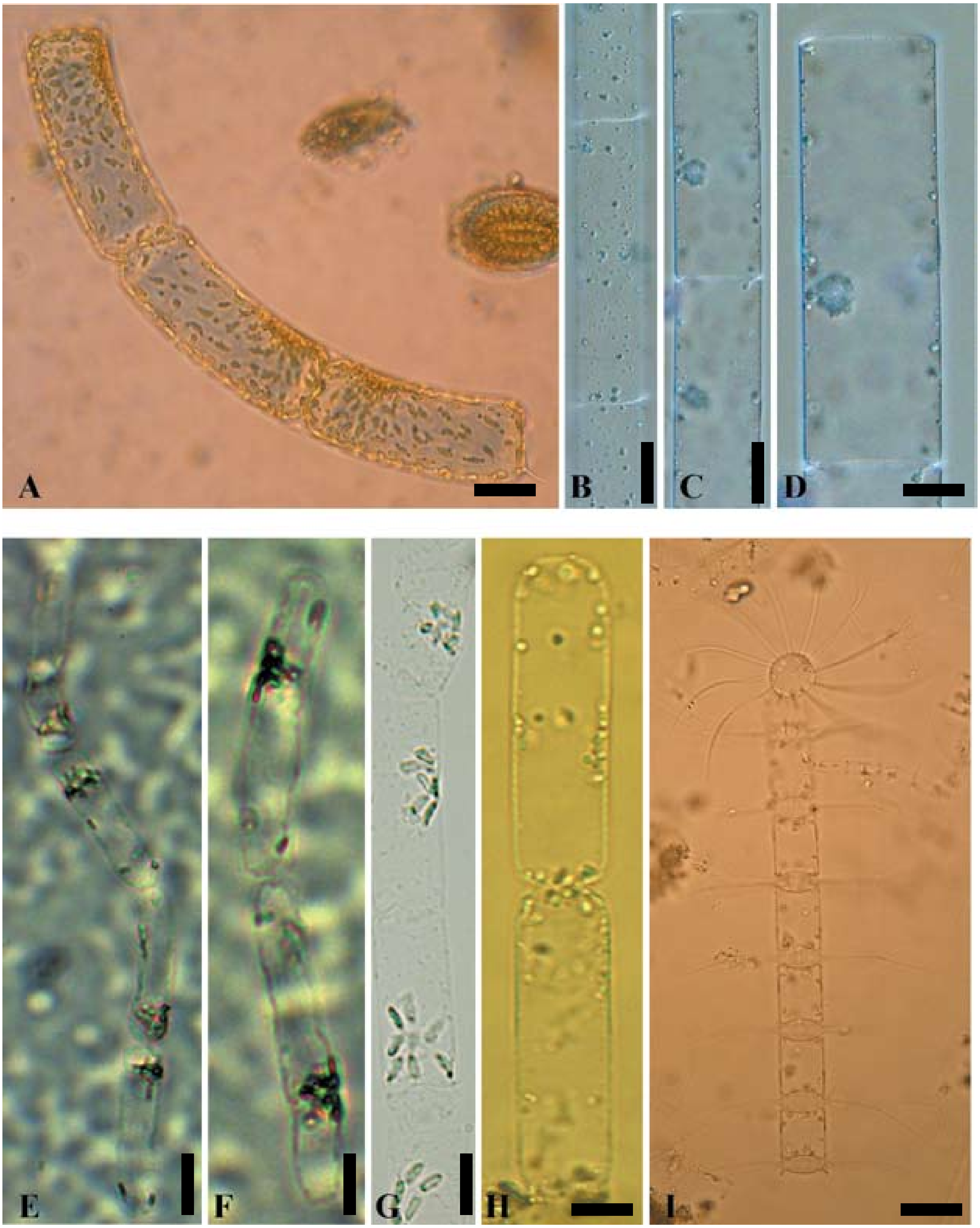

Plate 33. Light micrographs of A. *Guinardia striata*: another part of chain with three cells; B-D. *Guinardia* sp. 1: B-C. small part of united cells forming straight chain, D. one cell magnified; E-H. *Dactyliosolen fragilissimus*: cells cylindrical with rounded ends united in short chains; I. *Bacteriastrum delicatulum*: girdle view of part of a chain.

(Scale Bars, A=19.29 µm; B=20.91 µm; C=16.43 µm; D=10.45 µm; E=26.67 µm; F=17.78 µm; G=14.17 µm; H=9.47 µm; I=20.00 µm).

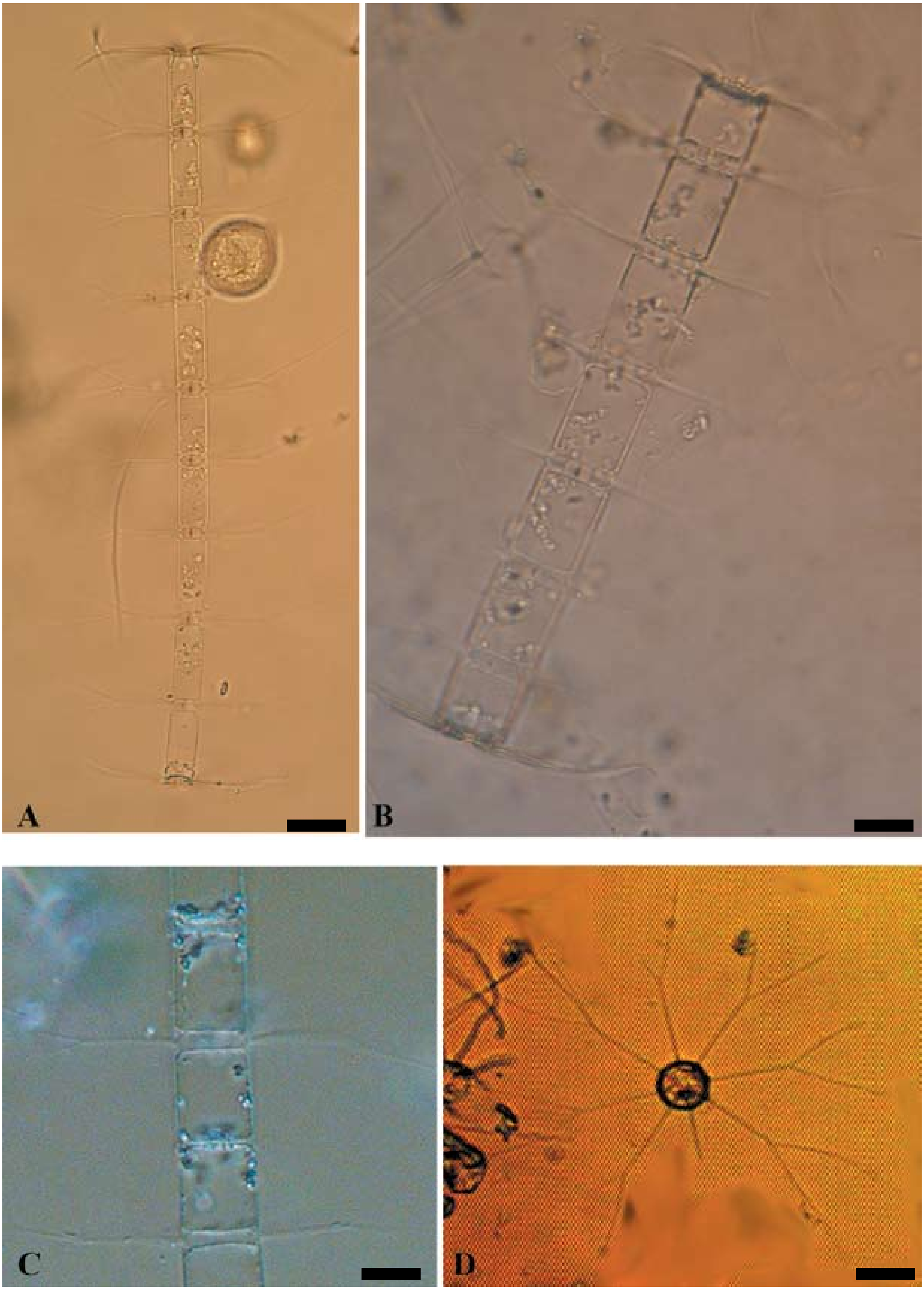

Plate 34. Light micrographs of A-D. *Bacteriastrum delicatulum*: A-B. two different entire chains in girdle view; C. part of another chain in girdle view; D. valve view showing inner setae. (Scale Bars, A=32.00 μm; B=13.33 μm; C=15.83 μm; D=23.33 μm).

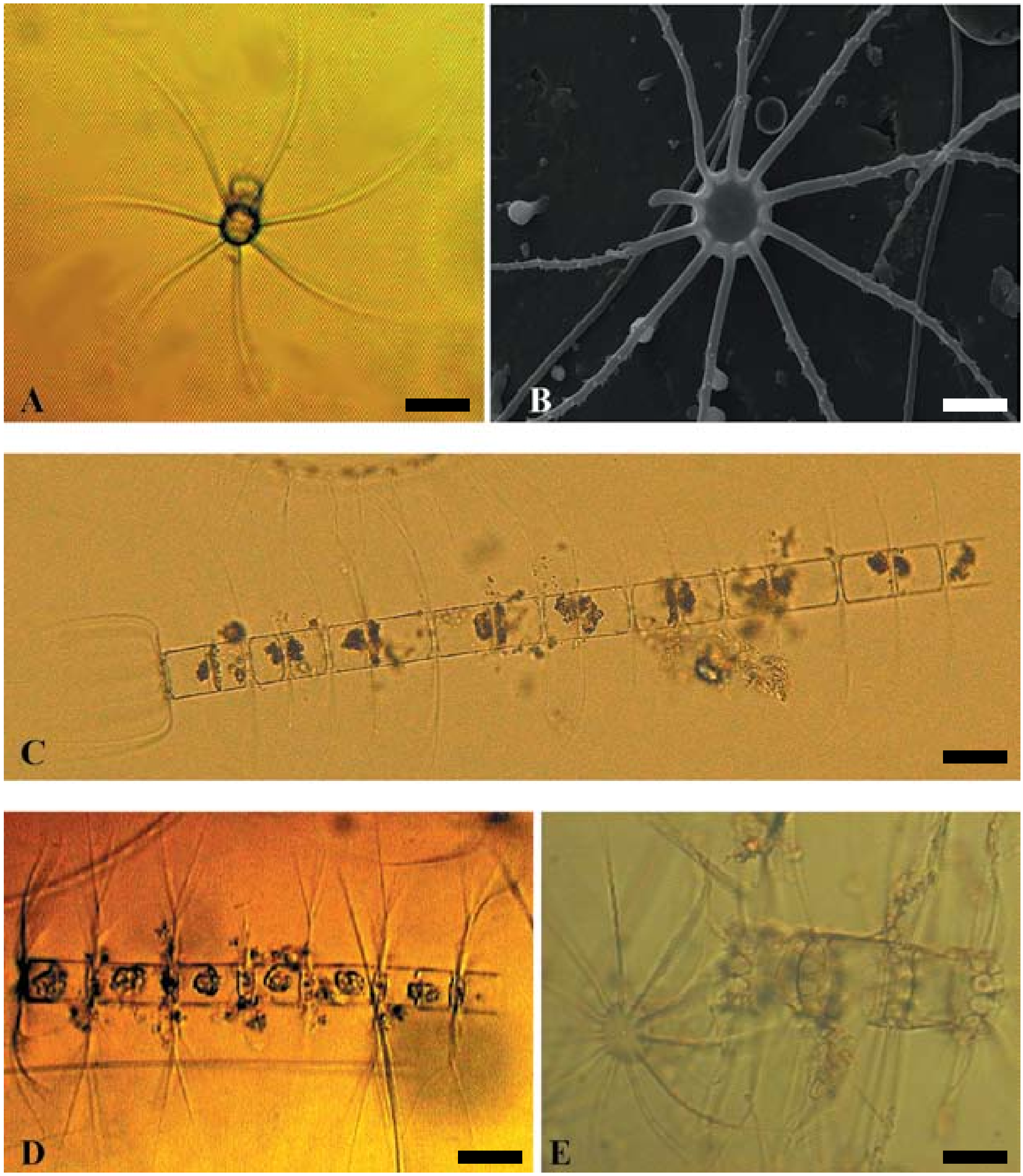

Plate 35. Light micrographs of A-B. *Bacteriastrum delicatulum*: A. valve view showing terminal seta, B. Scanning electron micrograph of valve view; C. *Bacteriastrum* cf. *elegans*: part of chain in girdle view; D-E. *Bacteriastrum hyalinum*: girdle view of parts of chains.
(Scale Bars, A=23.33 µm; B=10.00 µm; C=30.00 µm; D=33.33 µm; E=15.38 µm).

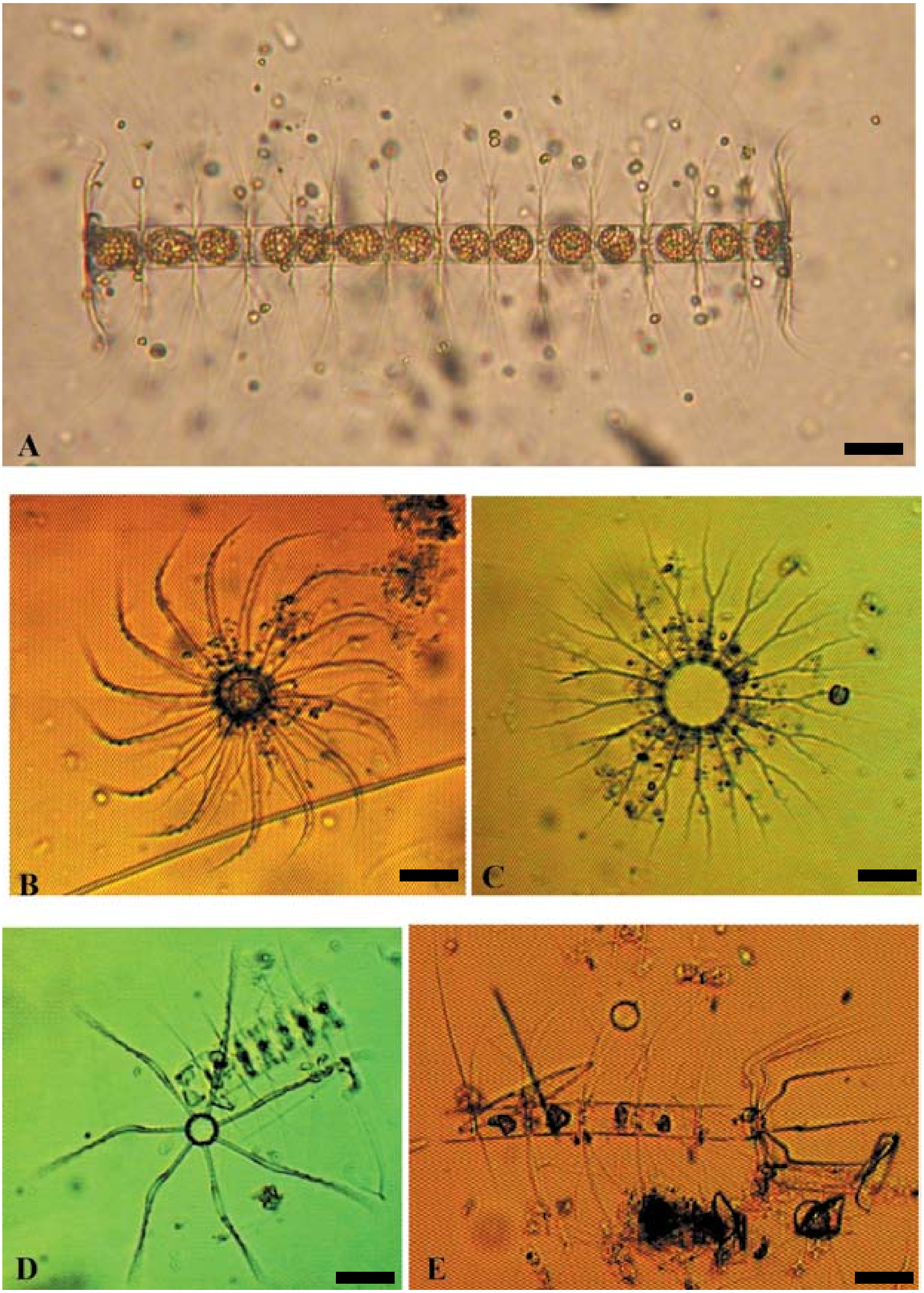

Plate 36 Light micrographs of A-C. *Bacteriastrum hyalinum*: A. entire chain in girdle view, B-C. valve view of two different cells showing inner setae; D-E. *Bacteriastrum varians* var. *hispida*: D. valve view showing terminal setae, E. part of chain in girdle view.
(Scale Bars, A=28.57 µm; B=27.00 µm; C=23.33 µm; D=36.00 µm; E=42.00 µm).

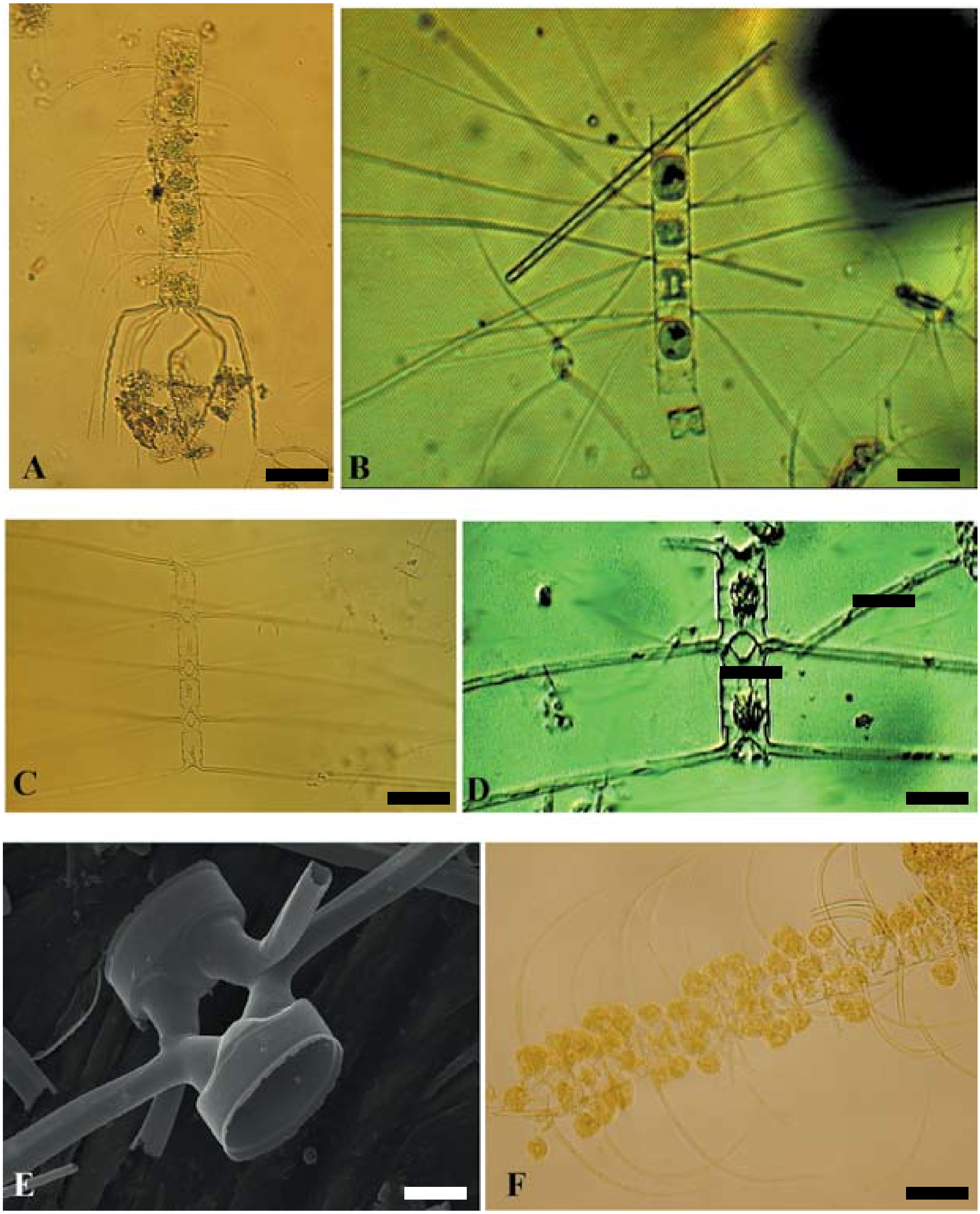

Plate 37. Light micrographs of A. *Bacteriastrum varians*: part of another chain in girdle view; B. *Chaetoceros affinis*: narrow chain with inner setae; C-E. *Chaetoceros atlanticus*: C-D. part of the two chains with inner setae, E. scanning electron migrograph of one cell; Light micrograph of F. *Chaetoceros coarctatus*: part of chain, long and robust in appearance, with no aperture and the setae curve downwards.
(Scale Bars, A=38.57 μm; B=41.67 μm; C=66.67 μm; D=26.25 μm; E=8.80 μm; F=55.71 μm).

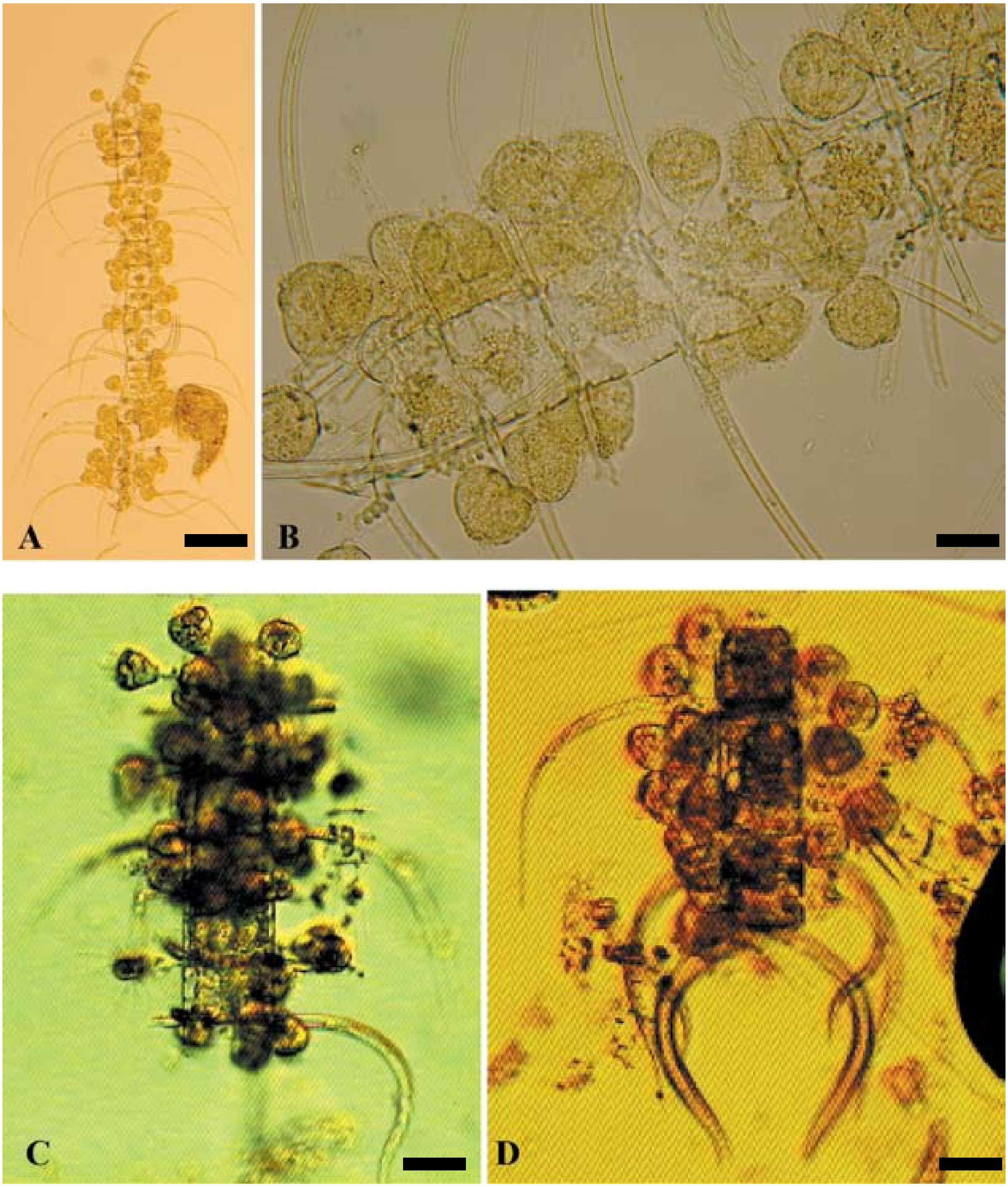

Plate 38. Light micrographs of A-D. *Chaetoceros coarctatus*: A. part of chain, B. more magnified, C-D. two different short part of chains showing posterior terminal setae which are large and strongly curved.
(Scale Bars, A=97.50 µm; B=19.50 µm; C=36.67 µm; D=40.74 µm).

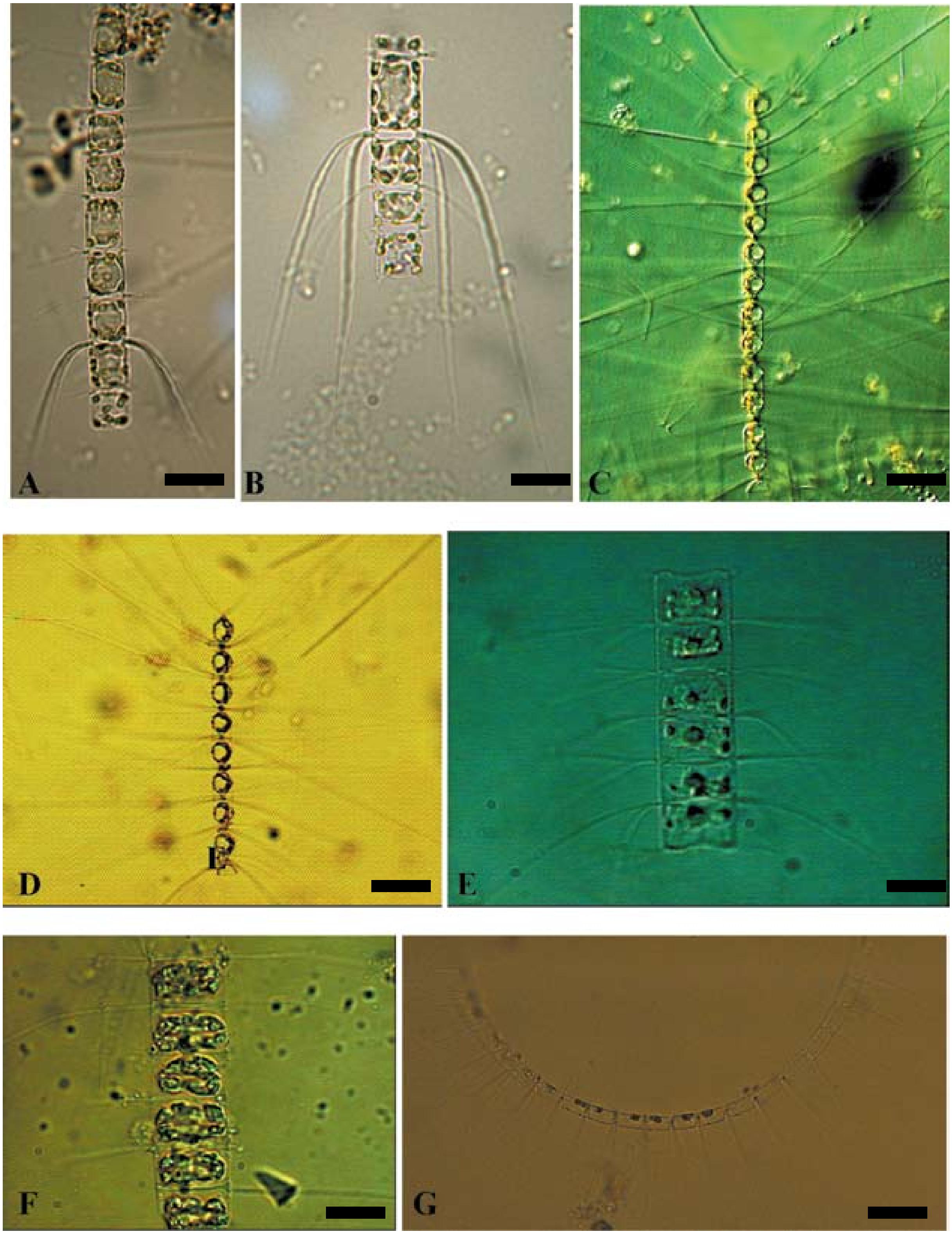

Plate 39. Light micrographs of A-D. *Chaetoceros compressus*: A-B. part of chains in broad girdle view with thickened setae, C-D. part of other chains in narrow girdle view; E-F. *Chaetoceros* cf. *costatus*: part of two different chains; G. *Chaetoceros curvisetum*: part of chain in narrow girdle view.
(Scale Bars, A=34.29 µm; B=26.67 µm; C=57.14 µm; D=66.67 µm; E=15.38 µm; F=20.00 µm; G=110.00 µm).

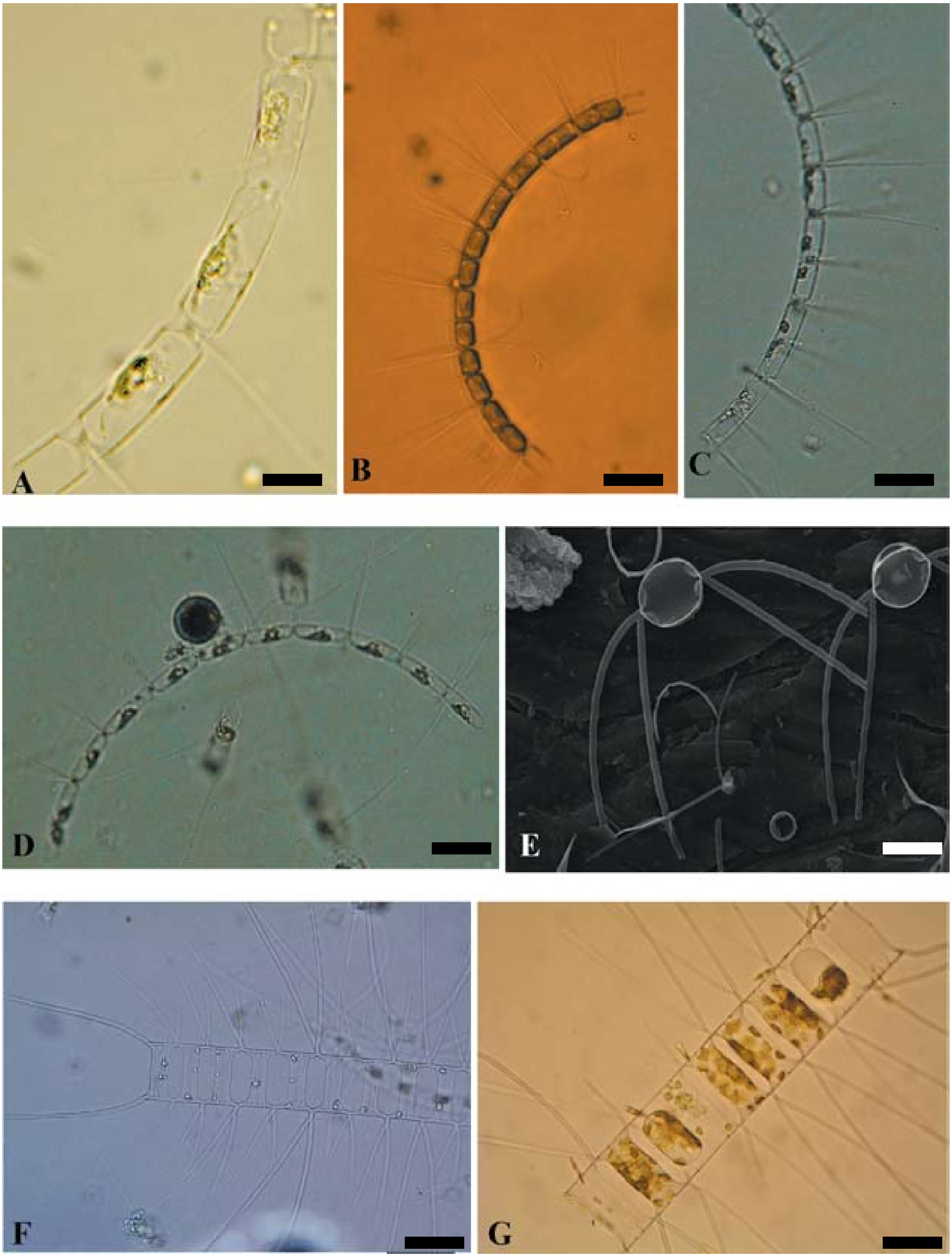

Plate 40. Light micrographs of A-D. *Chaetoceros curvisetum*: part of four different curved chains in narrow girdle view, E. scanning electron micrograph of same species: two cells; Light micrographs of F-G. *Chaetoceros decipiens*: two different part of chains in broad girdle view.
(Scale Bars, A=26.25 µm; B=76.67 µm; C=70.00 µm; D=105.00 µm; E=20.00 µm; F=15.00 µm; G=11.43 µm).

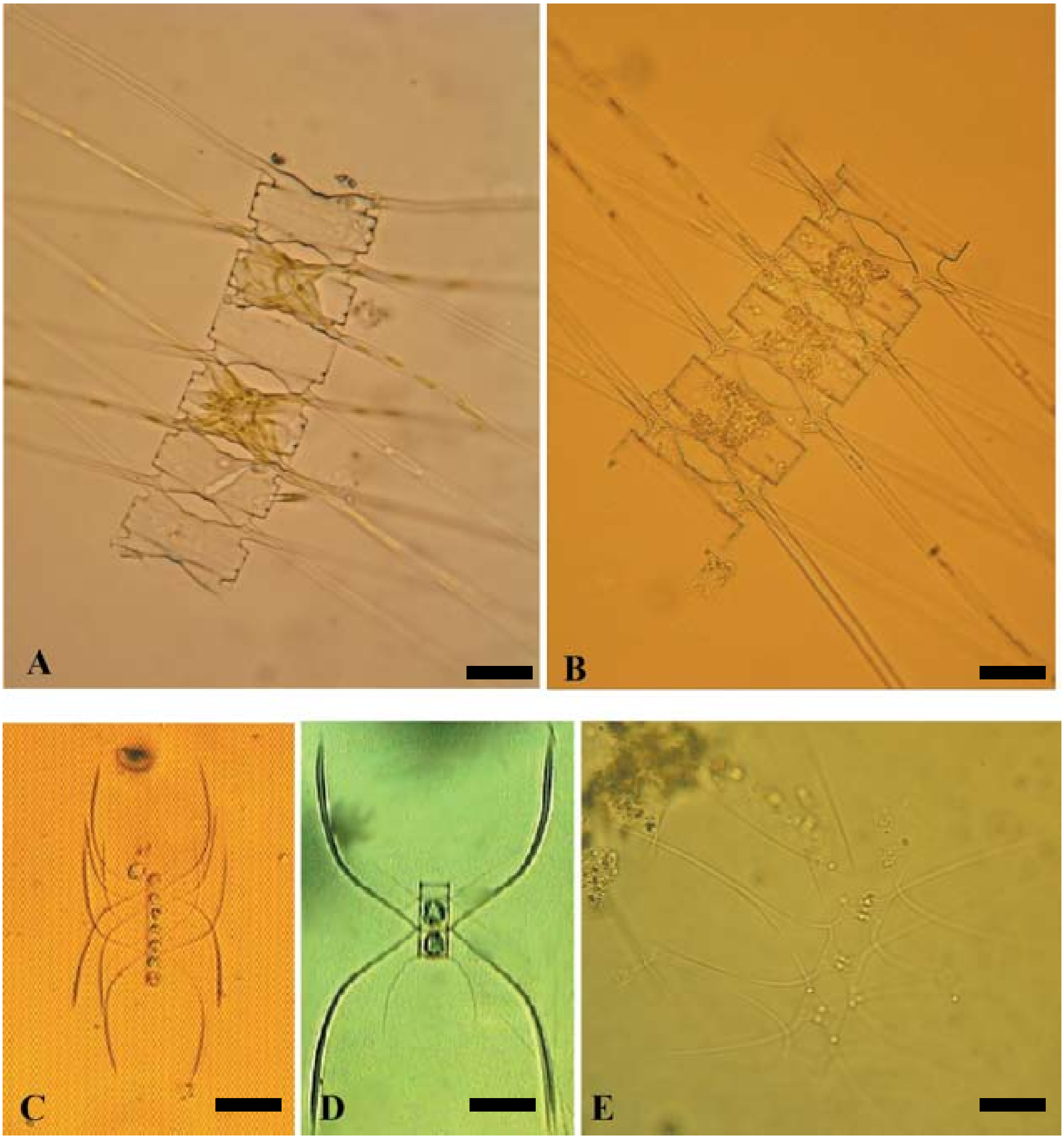

Plate 41. Light micrographs of A-B. *Chaetoceros denticulatus*: two different part of chains in broad girdle view with clearly visible small tooth on each side of the inner side of setae; C-D. *Chaetoceros diversus*: two typical chains; E. *Chaetoceros didymus*: part of chain in girdle view.
(Scale Bars, A=27.37 µm; B=26.36 µm; C=60.00 µm; D=26.67 µm; E=25.00 µm).

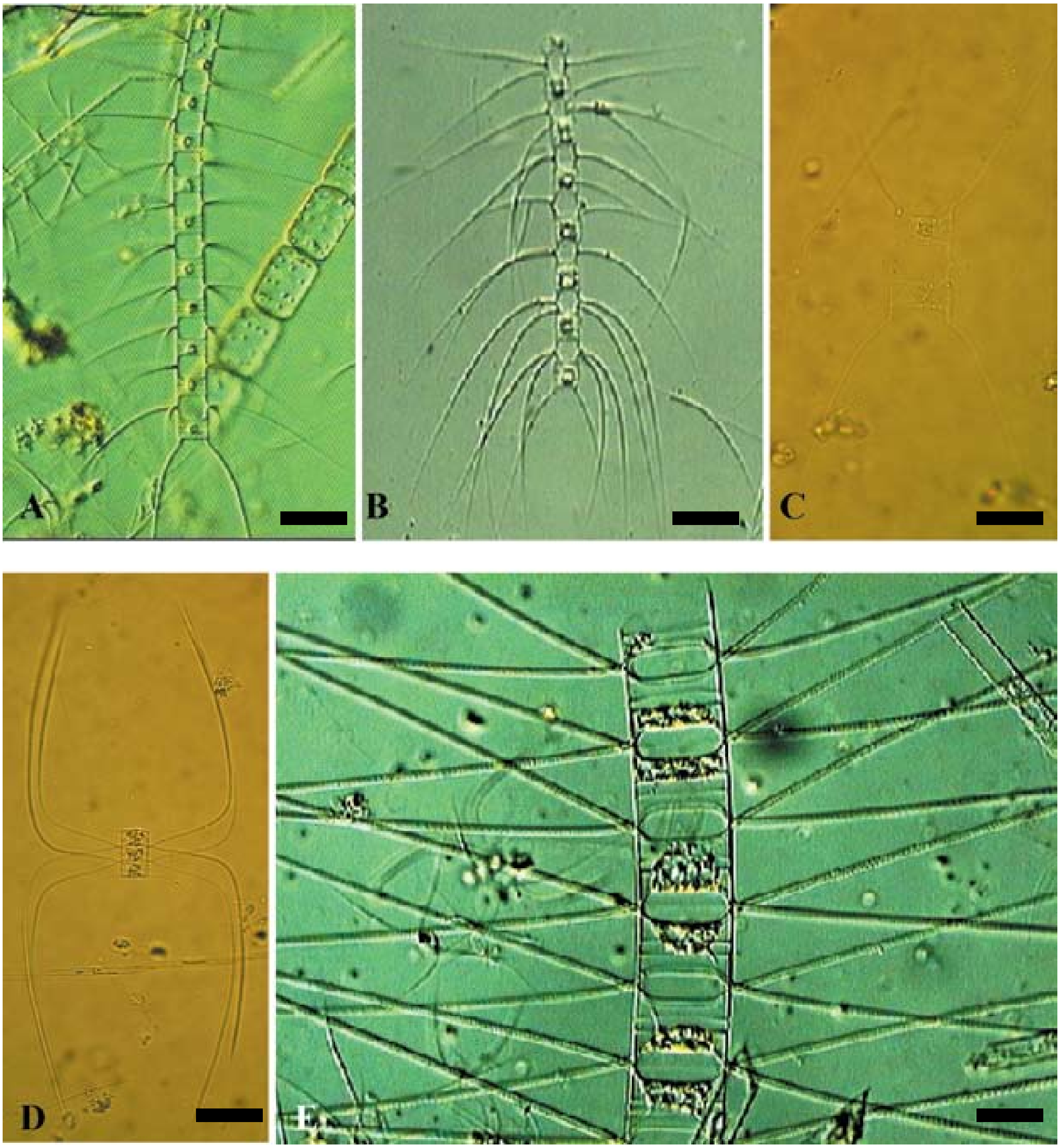

Plate 42. Light micrographs of A-C. *Chaetoceros laciniosus*: A-B. part of two different long chains, C. two cells with anterior and posterior terminal setae; D. *Chaetoceros laevis*: typical chain, broad girdle view; E. *Chaetoceros lorenzianus*: part of chain in broad girdle view.
(Scale Bars, A=47.50 µm; B=60.00 µm; C=19.44 µm; D=31.25 µm; E=27.33 µm).

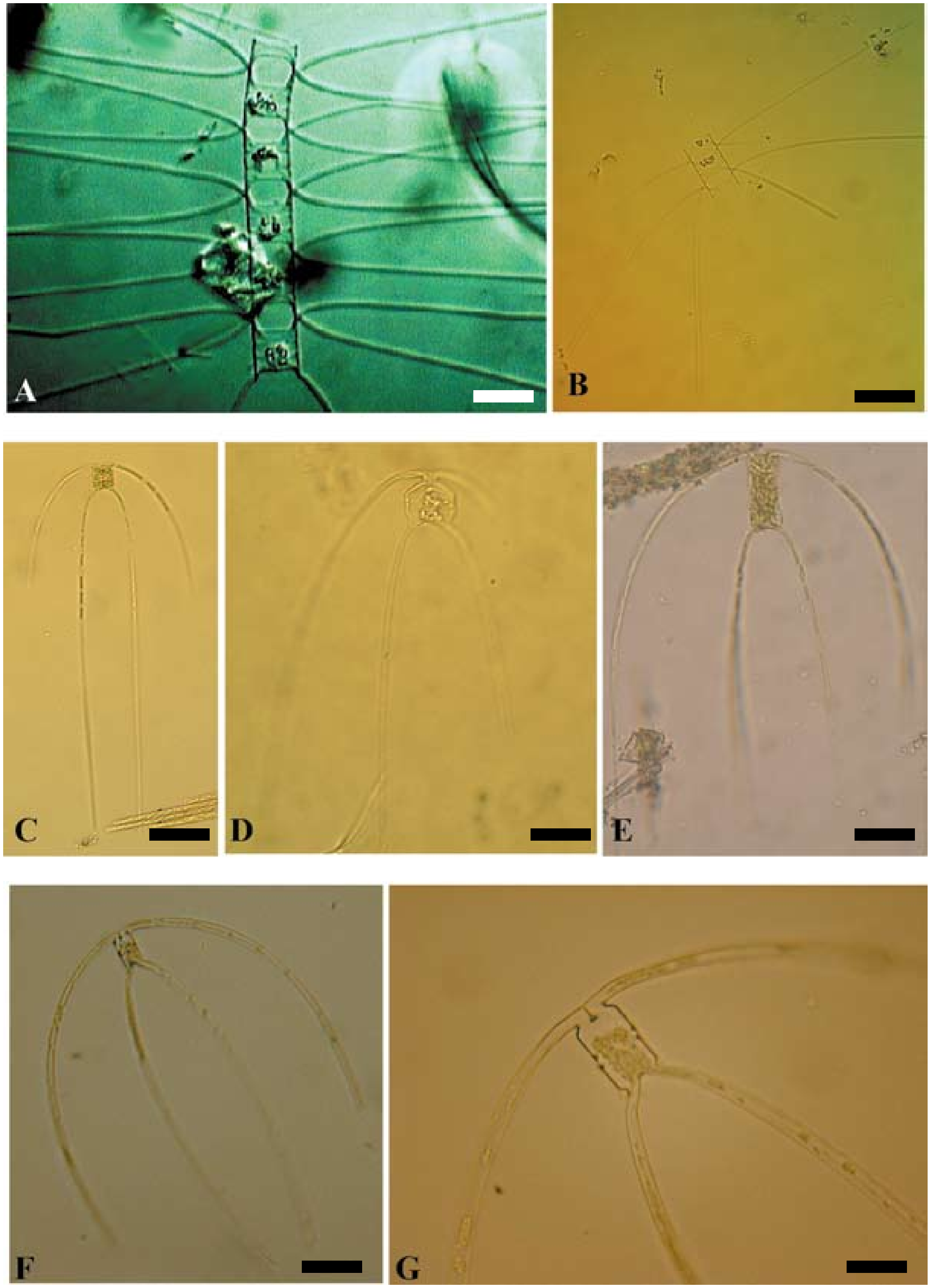

Plate 43. Light micrographs of A-B. *Chaetoceros lorenzianus*: A. part of another chain in broad giirdle view, B. part of two cells; C-G. *Chaetoceros peruvianus*: different single cells in different vews with upper and lower valve setae, more magnified of the upper section on G.
(Scale Bars, A=49.33 µm; B=40.00 µm; C=58.33 µm; D=21.88 µm; E=32.00 µm; F=52.00 µm; G=19.50 µm).

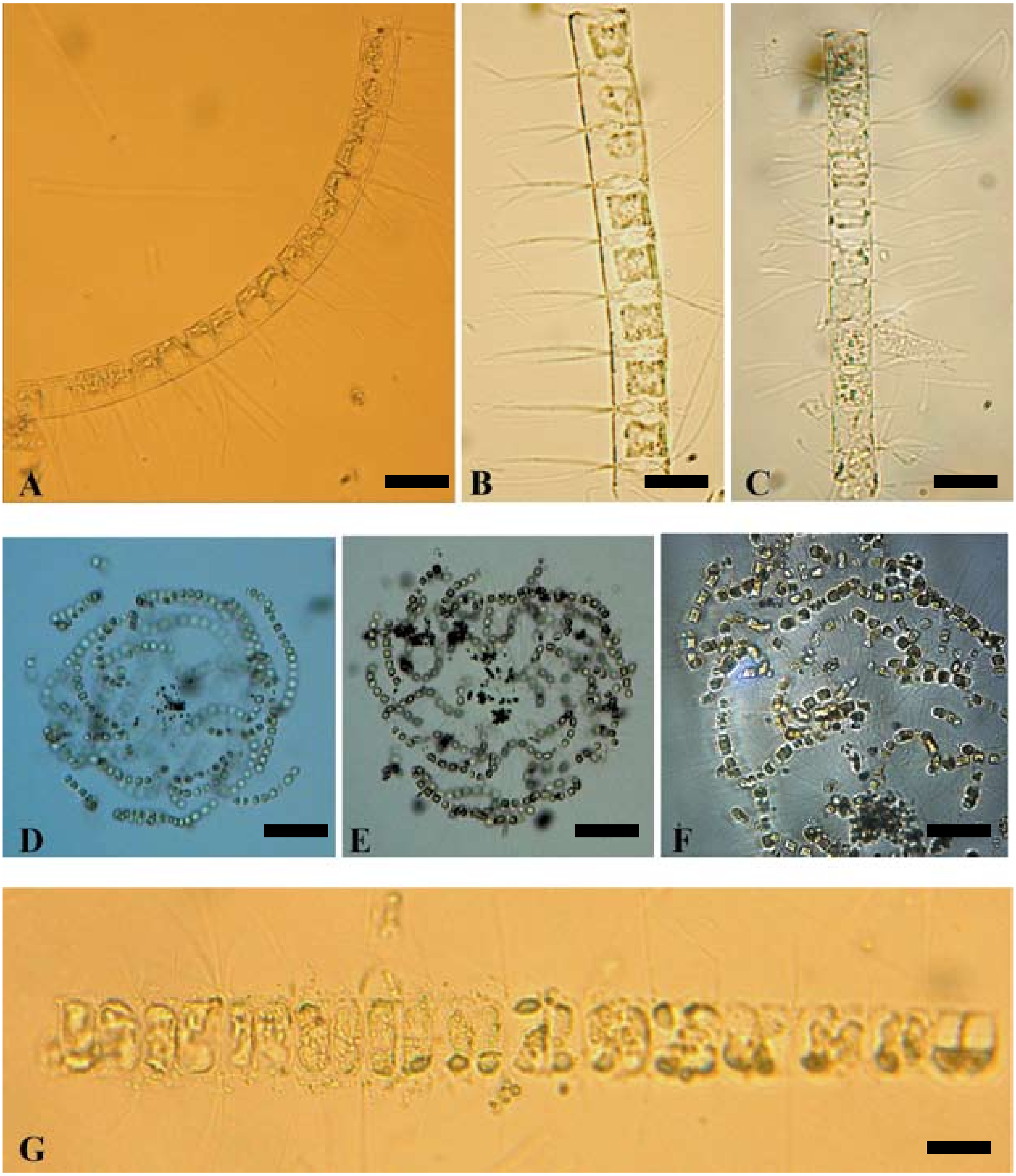

Plate 44. Light micrographs of A-C. *Chaetoceros pseudocurvisetum*: A- B. chain in girdle view, showing one chromatophore/cell and the fusion of the setae on one side, C. chain in broad girdle view; D-F. *Chaetoceros socialis*: typical circular colony, more magnified on F; G. *Chaetoceros tortissimum*: chain in broad girdle view. (Photos D - F by Dr. M. Saburova).
(Scale Bars, A=26.67 µm; B=20.00 µm; C=28.57 µm; D&E=56.00 µm; F=31.00 µm; G=15.33 µm).

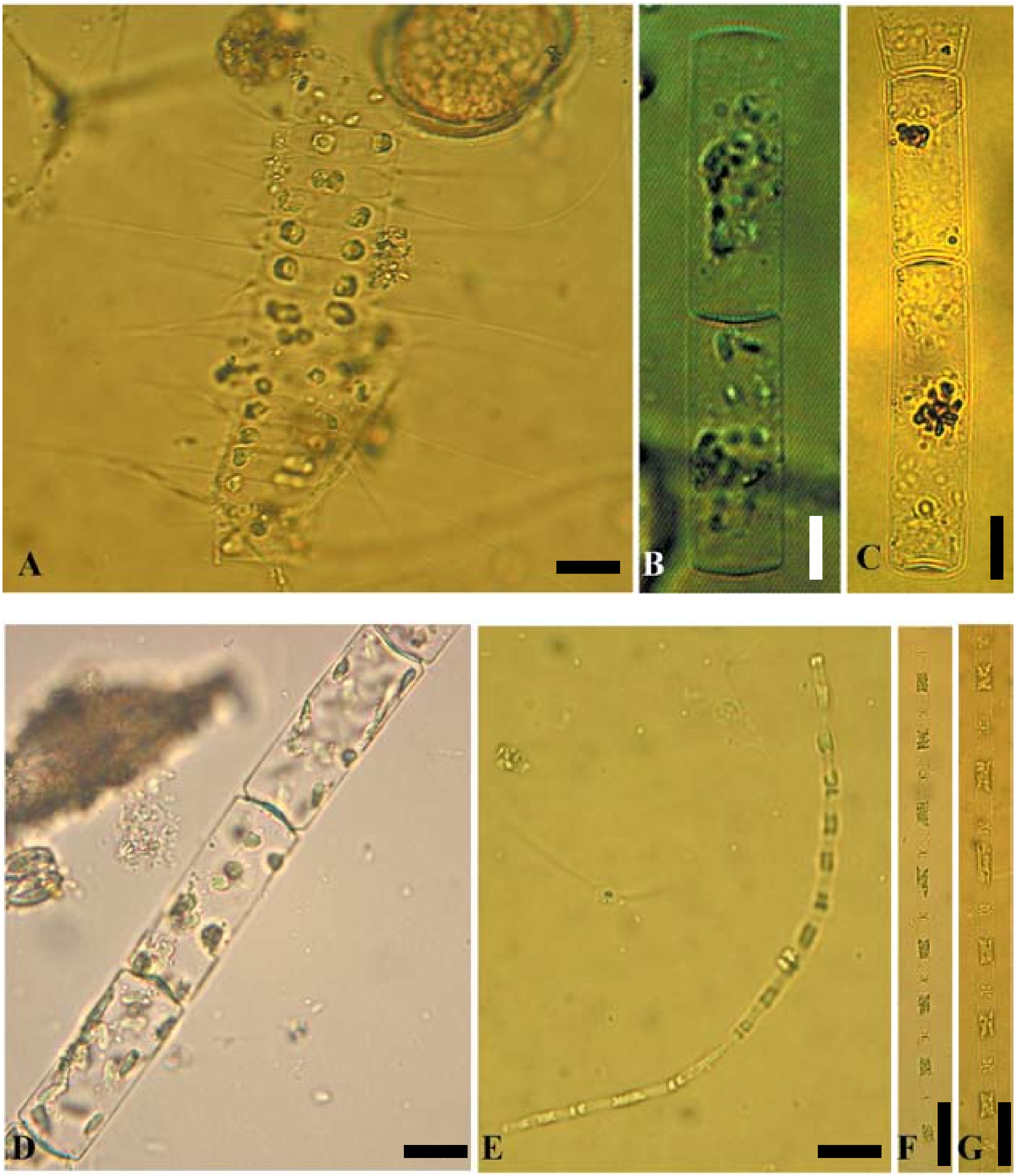

Plate 45. Light micrographs of A. *Chaetoceros tortissimum*: another part of chain in broad girdle view; B-D. *Leptocylindrus danicus*: parts of striaght chains, with chromatophores clearly visible on D, with rounded plates; E-G. *Leptocylindrus minimus*: Parts of chains, with two elongate plates of chlorophyll. (Scale Bars, A=13.89 µm;B=8.67 µm; C=10.38 µm; D=12.50 µm; E=23.00 µm; F=33.33 µm; G=20.00 µm).

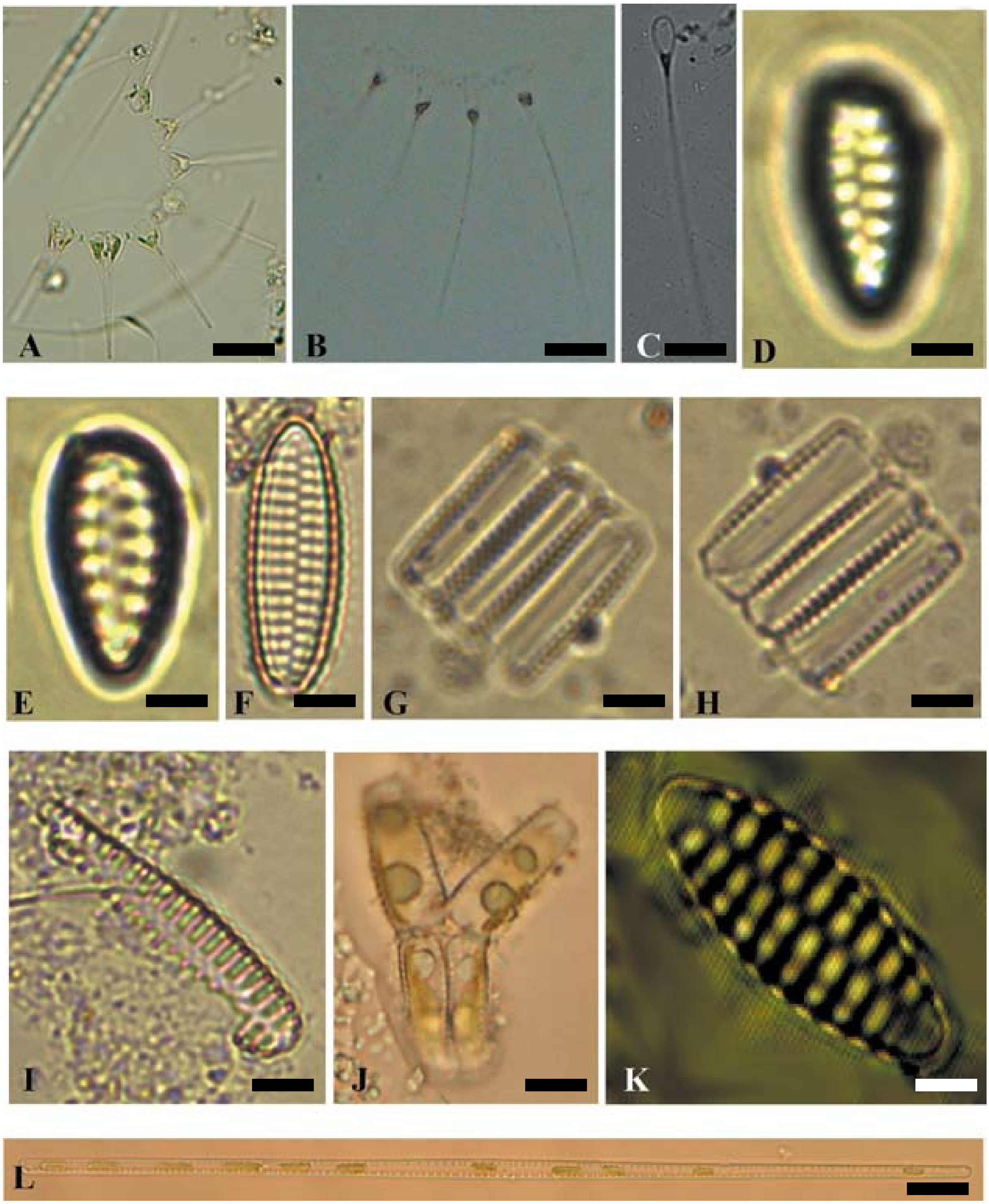

Plate 46. Light micrographs of A-C. *Asterionellopsis glacialis*: A-B. colonies, C. cell in valve view; D-E. *Fragilaria* cf. *martyi*: same cell in different focus; F-H. *Fragilaria* sp. 1: F. valve view, G-H. same part of chain in girdle view in different focus; I-J. *Opephora schwartzii*: I. valve view, J. colony in girdle view; K. *Opephora* sp. 1: valve view; L. *Synedra* sp. 1: valve view.
(Scale Bars, A=20.50 µm; B=13.24 µm; C=9.40 µm; D=3.90 µm; E=3.81 µm; F=5.11 µm; G=6.29 µm; H=6.47 µm; I=10.54 µm; J=23.12 µm; K=10.16 µm; L=21.33 µm).

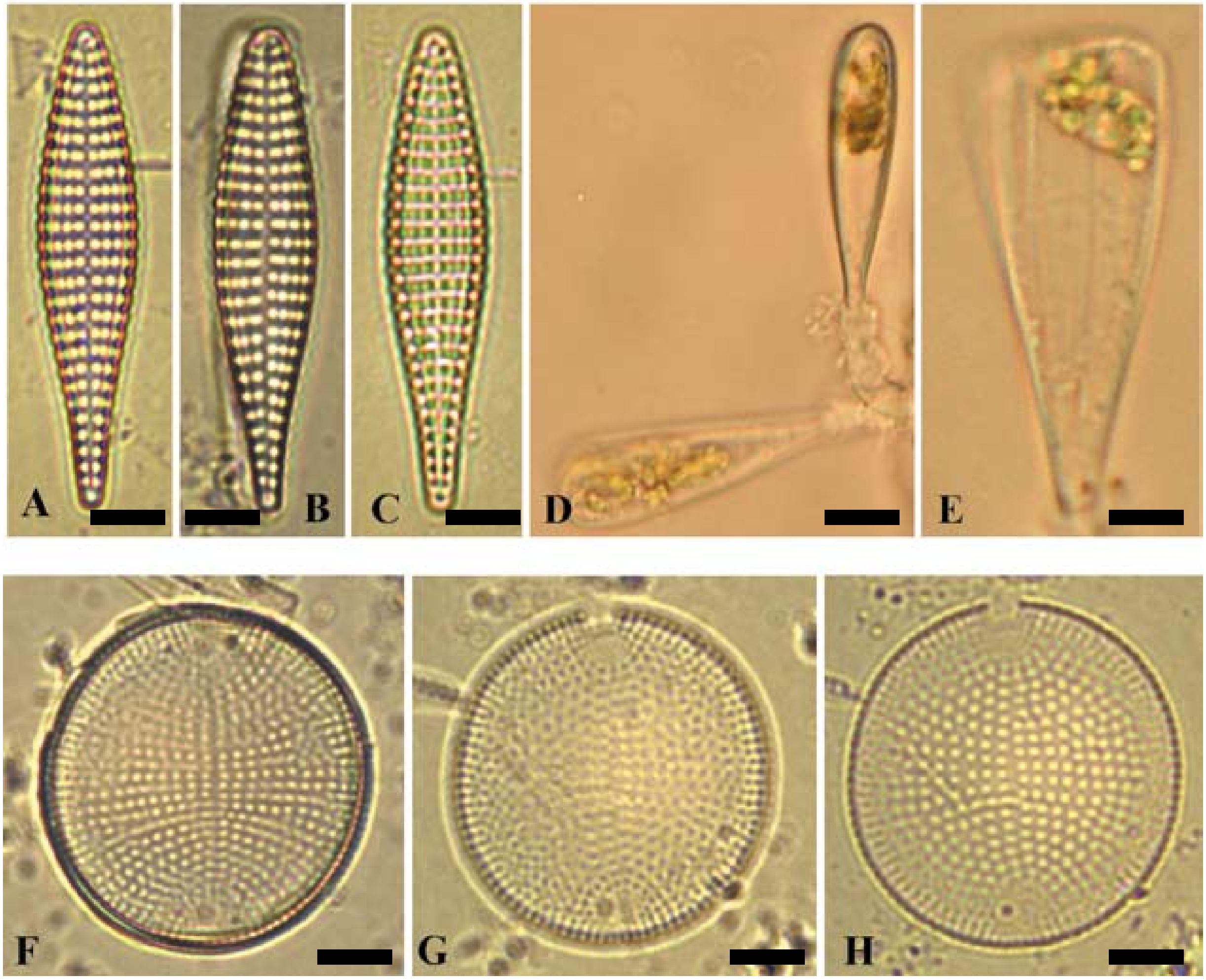

Plate 47. Light micrographs of A-C. *Trachysphenia australis*: A-C. same cell in different focus, D-E. *Licmophora* sp. 1: D. two cells in different views, E. one cell magnified; F-H. *Diplomenora cocconeiformis*: same cell in different focus.
(Scale Bars, A-C=4.92 µm; D=17.11 µm; E=14.06 µm; F-H=5.13 µm).

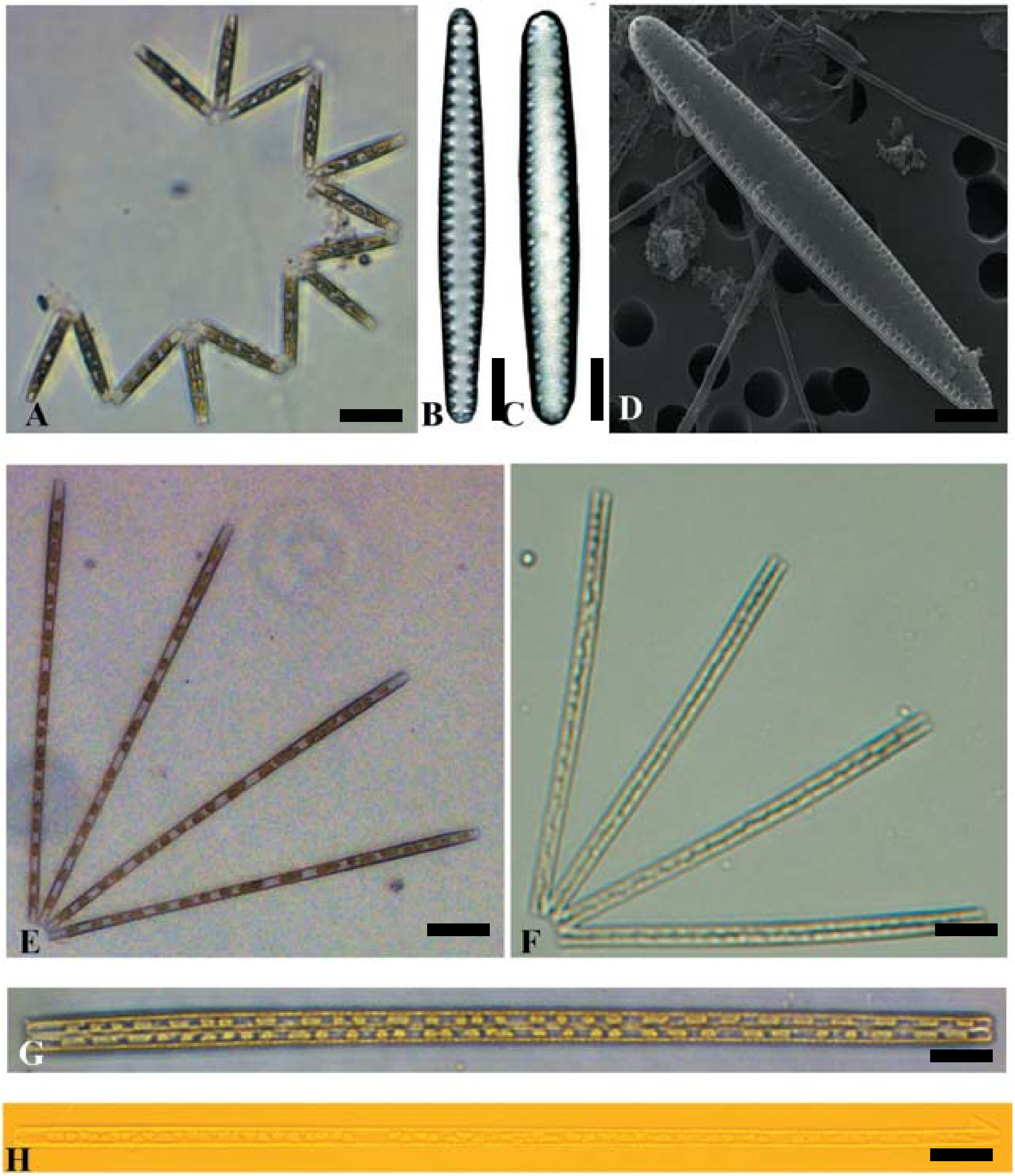

Plate 48. Light micrographs of A-C. *Thalassionema nitzschioides*: A. chain in girdle view, B-C. cells in valve view, D. Scanning electron micrographs of the cell in valve view; Light micrographs of E-G. *Thalassionema frauenfeldii*: E-F. colony of four cells, girdle view, G. one divided cell; H. *Thalassiothrix* cf. *longissima*: one long cell.
(Scale Bars, A=26.88 μm; B=7.27 μm; C=6.92 μm; D=5.58 μm; E=16.90 μm; F=16.52 μm; G=7.59 μm; H=10.00 μm).

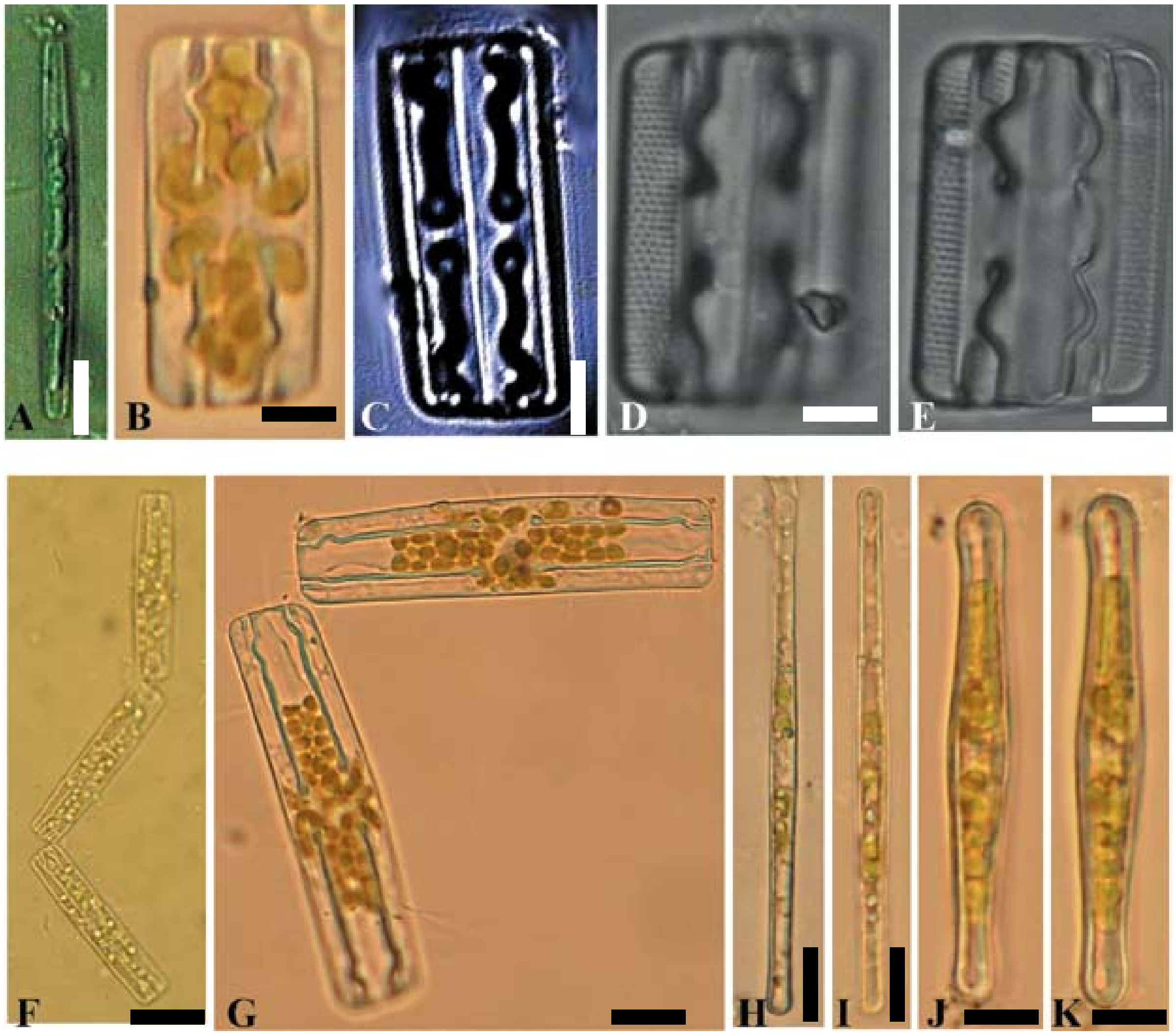

Plate 49. Light micrographs of A. *Rhabdonema* sp. 1: one cell; B-E. *Grammatophora marina*: cells in broad girdle view, B-D. different cells, D-E. the same cell in different focus; F-I. *Grammatophora oceanica*: F. girdle view of chain, G. two cells in broad girdle view united to each other, H-I. valve view of cell; J-K. *Gramatophora* sp.1.

(Scale Bars, A=7.73 μm; B=13.60 μm; C=12.50 μm; D=12.40 μm; E=12.65 μm; F=29.20 μm; G=13.04 μm; H&I=12.71 μm; J=11.62 μm; K=11.45 μm).

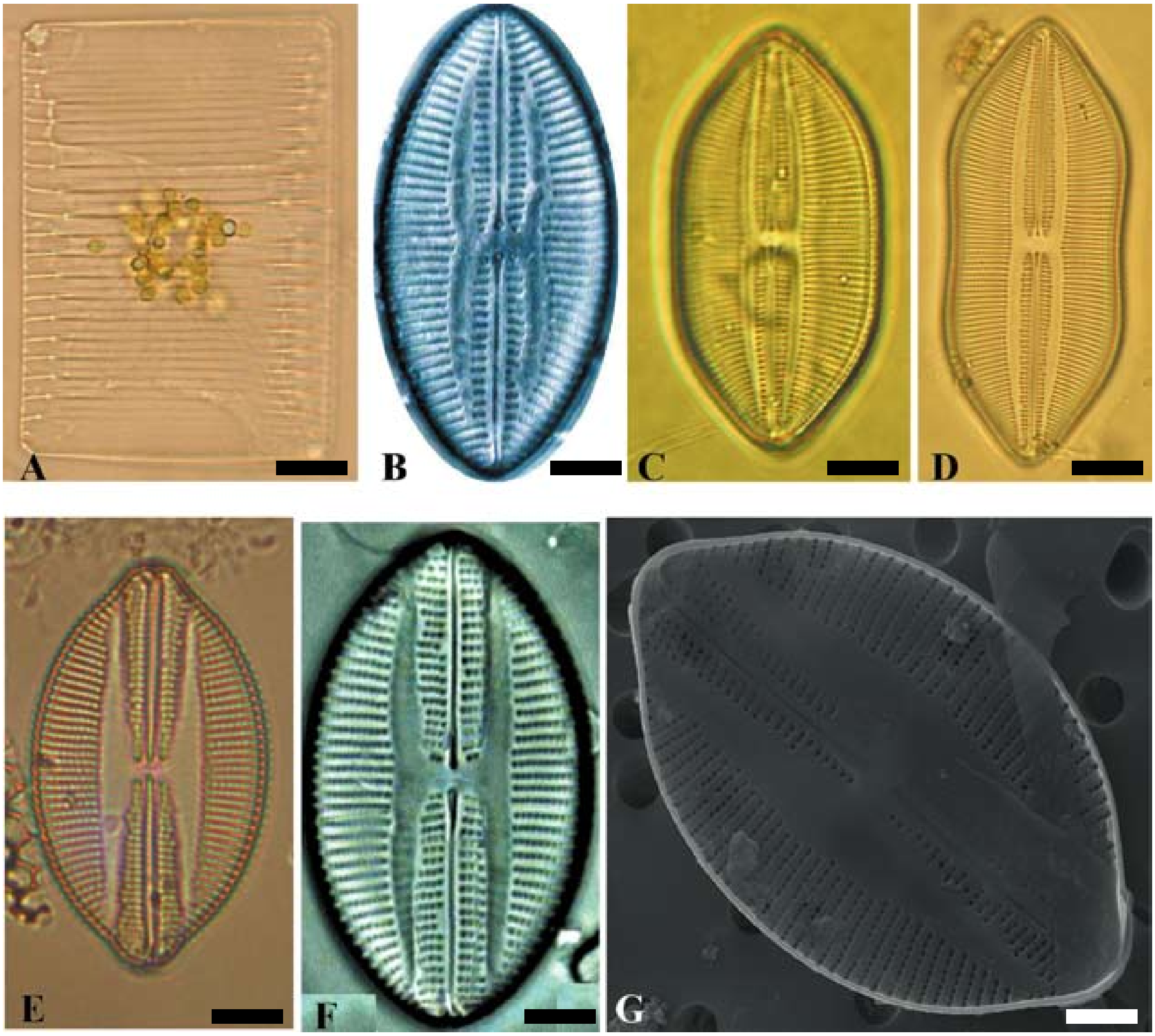

Plate 50. Light micrographs of A. *Striatella unipunctata*: cells colonial, united by their corners to form zigzag chain, in broad girdle view with slightly rounded corners; B. *Lyrella* cf. *abrupta*: in valve view; C-D. *Lyrella atlantica*: two different cells, in valve view; E-F. *Lyrella clavata*: E-F. two different cells, in valve view G. scanning electron micrograph of same species.
(Scale Bars, A=16.59 µm; B=4.48 µm; C=16.67 µm; D=15.87 µm; E=4.74 µm; F=4.00 µm; G=3.16 µm).

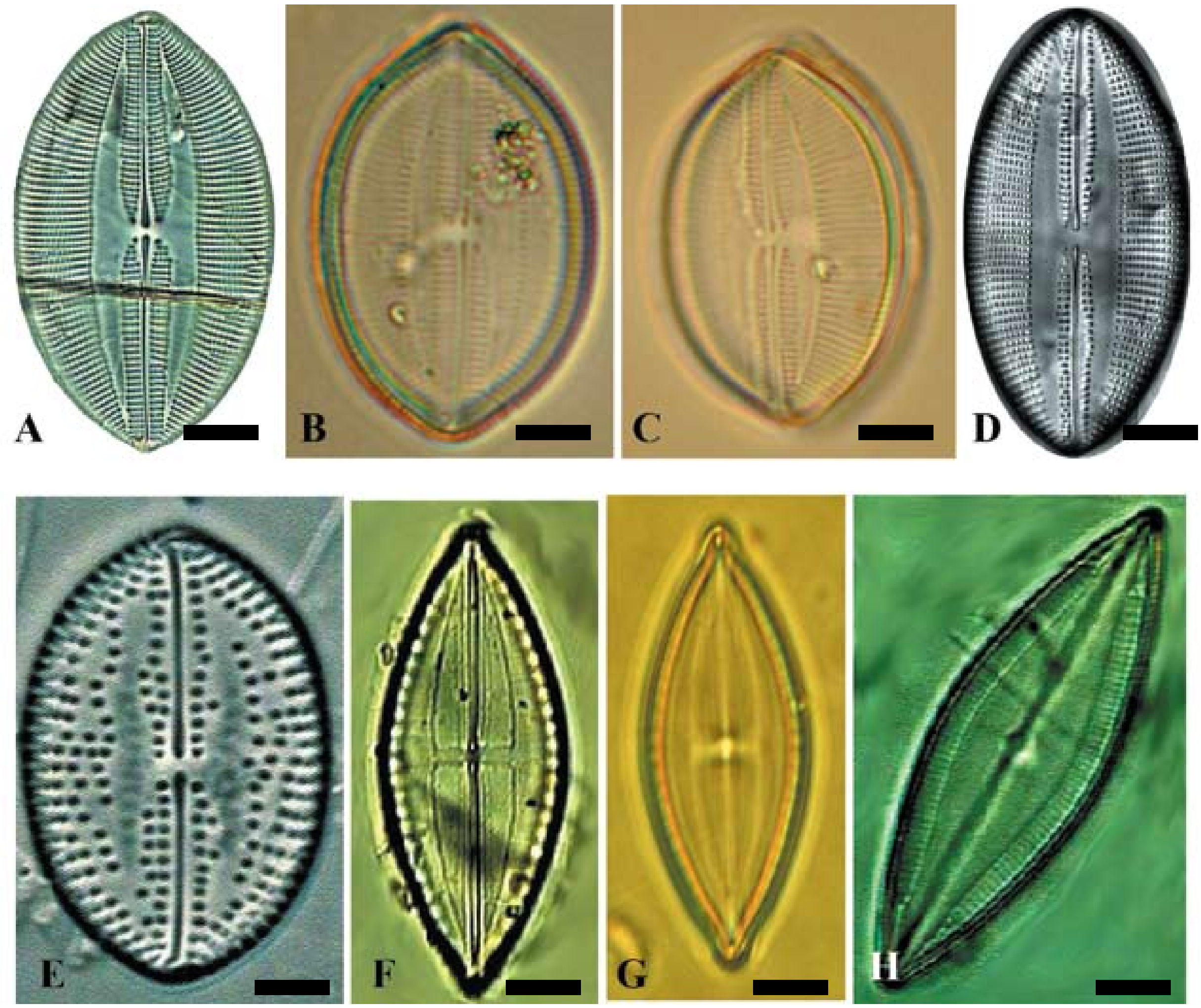

Plate 51. Light micrographs of A. *Lyrella fogedii*: in valve view; B-C. *Lyrella* cf. *hennedyi*: two different cells, in valve view; D. *Lyrella spectabilis*: in valve view; E. *Lyrella* sp. 1: in valve view; F-G. *Mastogloia* cf. *arabica*: different cells; H. *Mastogloia decussata*: showing how the loculi form a complete band around the valve margin.

(Scale Bars, A=6.05 µm; B=8.01 µm; C=8.90 µm; D=9.78 µm; E=2.87 µm; F=11.88 µm; G=9.58 µm; H=10.00 µm).

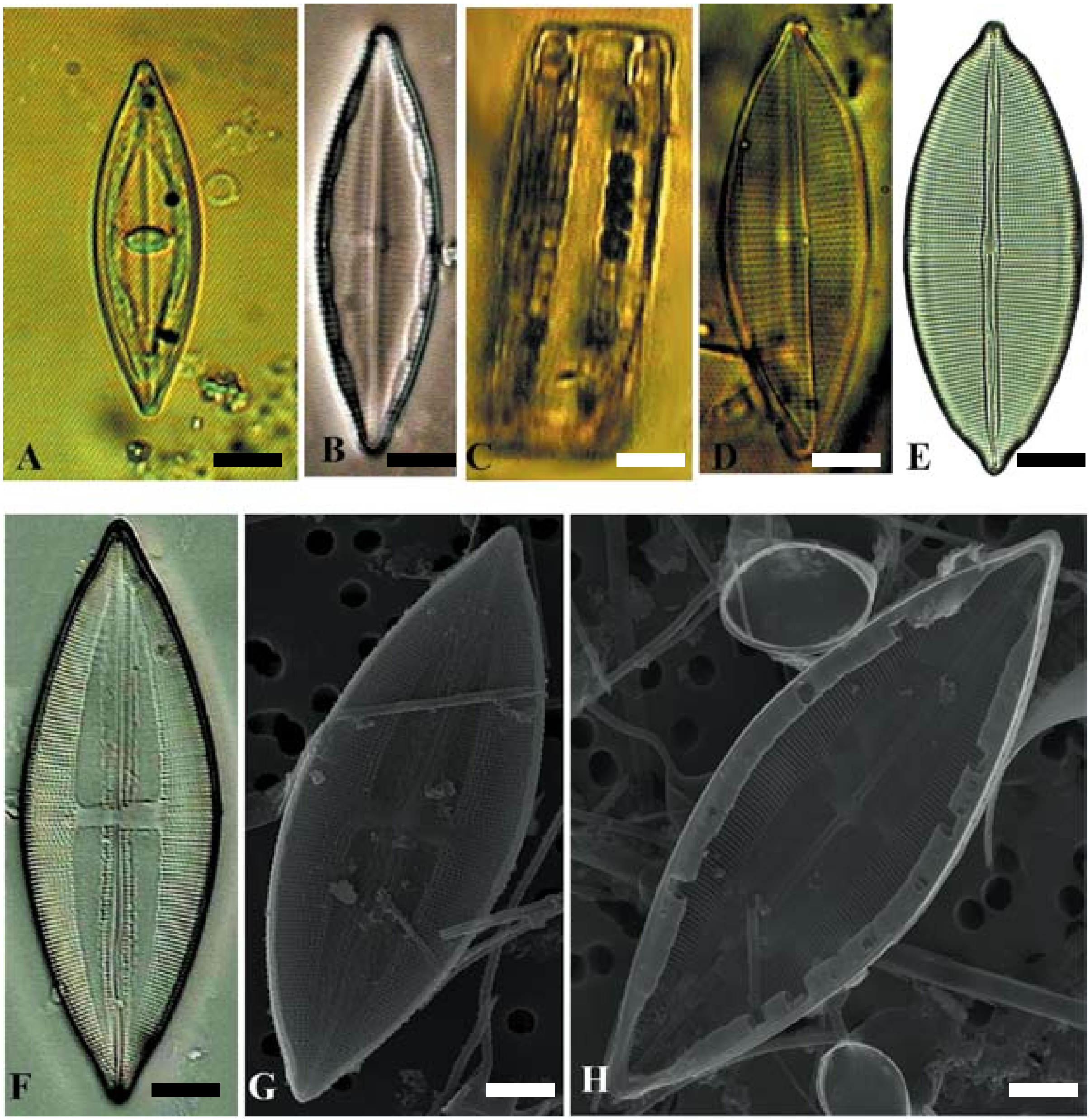

Plate 52. Light micrographs of A. *Mastogloia erythraea*: valve view; B. *Mastogloia linearis*: valve view; C. *Mastogloia Mac-Donaldii*: in girdle view; D. *Mastogloia* sp. 1: valve view; E. *Mastogloia* sp. 2: valve view; F. *Mastogloia* sp. 3: valve view, G-H. scanning electron micrograph of same species.
(Scale Bars, A=12.04 µm; B=4.60 µm; C=5.94 µm; D=6.98 µm; E=5.58 µm; F=4.94 µm; G=4.92 µm; H=4.14 µm).

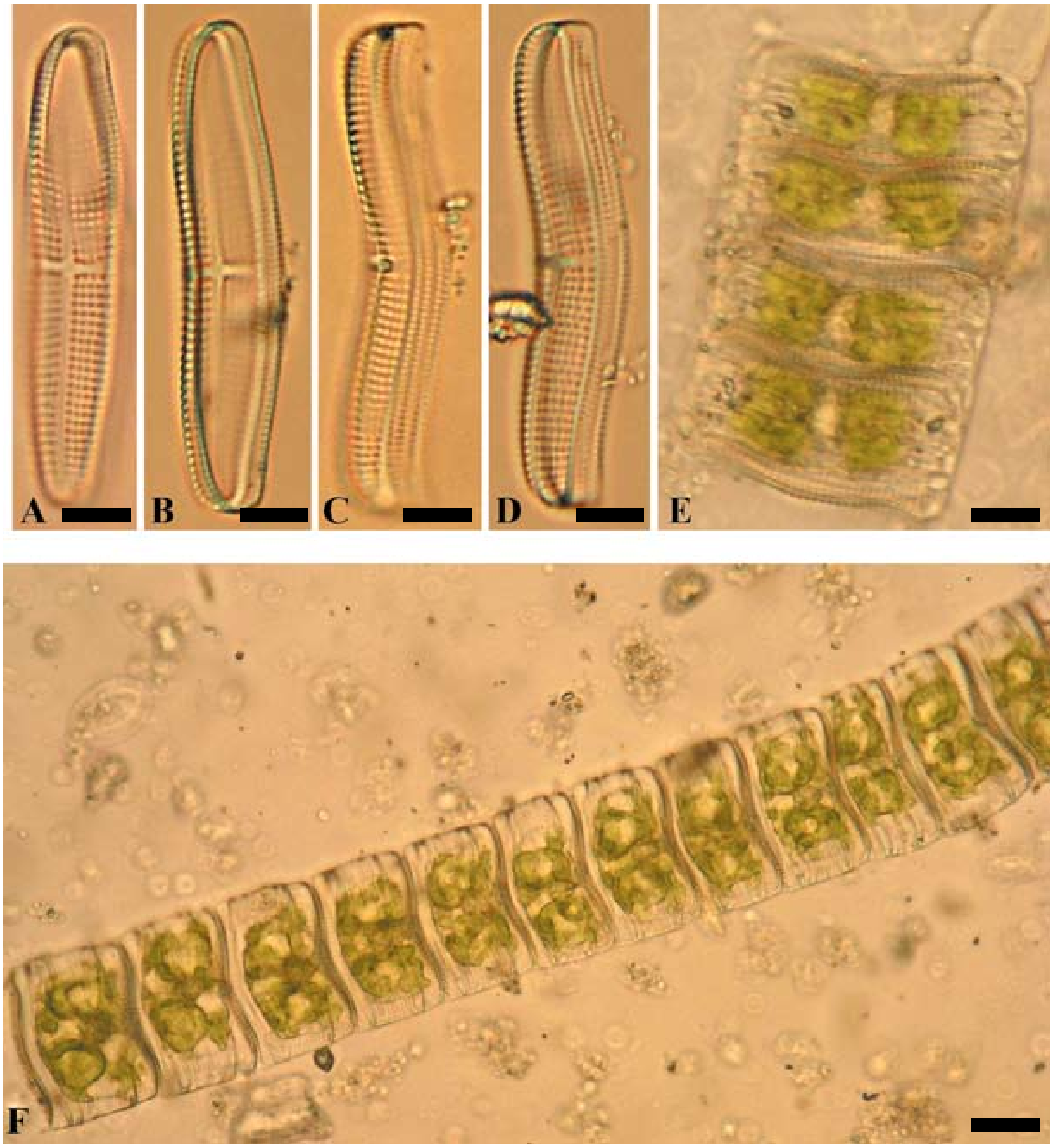

Plate 53. Light micrographs of: A-F. *Achnanthes brevipes* v. *intermedia*: valve view, B. side of the cell, C-D. girdle view, E. chain of four cells, girdle view, F. part of long chain, girdle view.
(Scale Bars, A-D=8.61 µm; E=14.71 µm; F=24.00 µm).

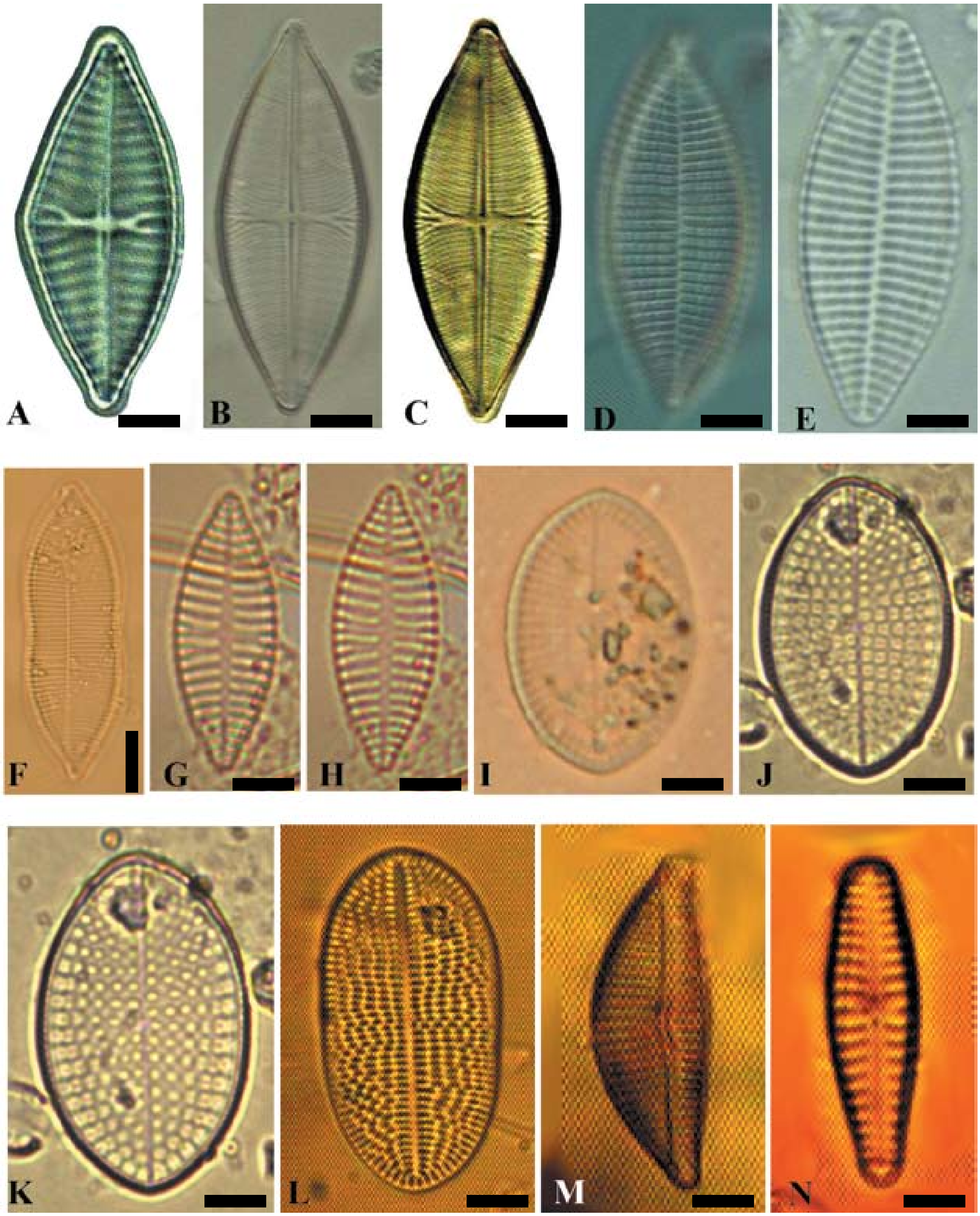

Plate 54. Light micrographs of A-E. *Achnanthes* cf. *fimbriata*: A-C. ventral valve view; D-E. dorsal valve view; F. *Achnanthes* sp. 1: valve view; G-H. *Planothidium* sp.1: same cell in different focus; I-K. *Cocconeis* cf. *guttata*: in different focus, I. live sample, J-K. cleaned material; L. *Cocconeis placentula*: valve view; M. *Cymbella* sp.1: valve view; N. *Gomphonema* sp.1: valve view.
(Scale Bars, A=3.02 μm; B=3.07 μm; C=3.00 μm; D=2.84 μm; E=2.58 μm; F=4.68 μm; G & H=4.57 μm; I=5.11 μm; J=4.80 μm; K=4.20 μm; L=4.29 μm; M=5.00 μm; N=3.33 μm).

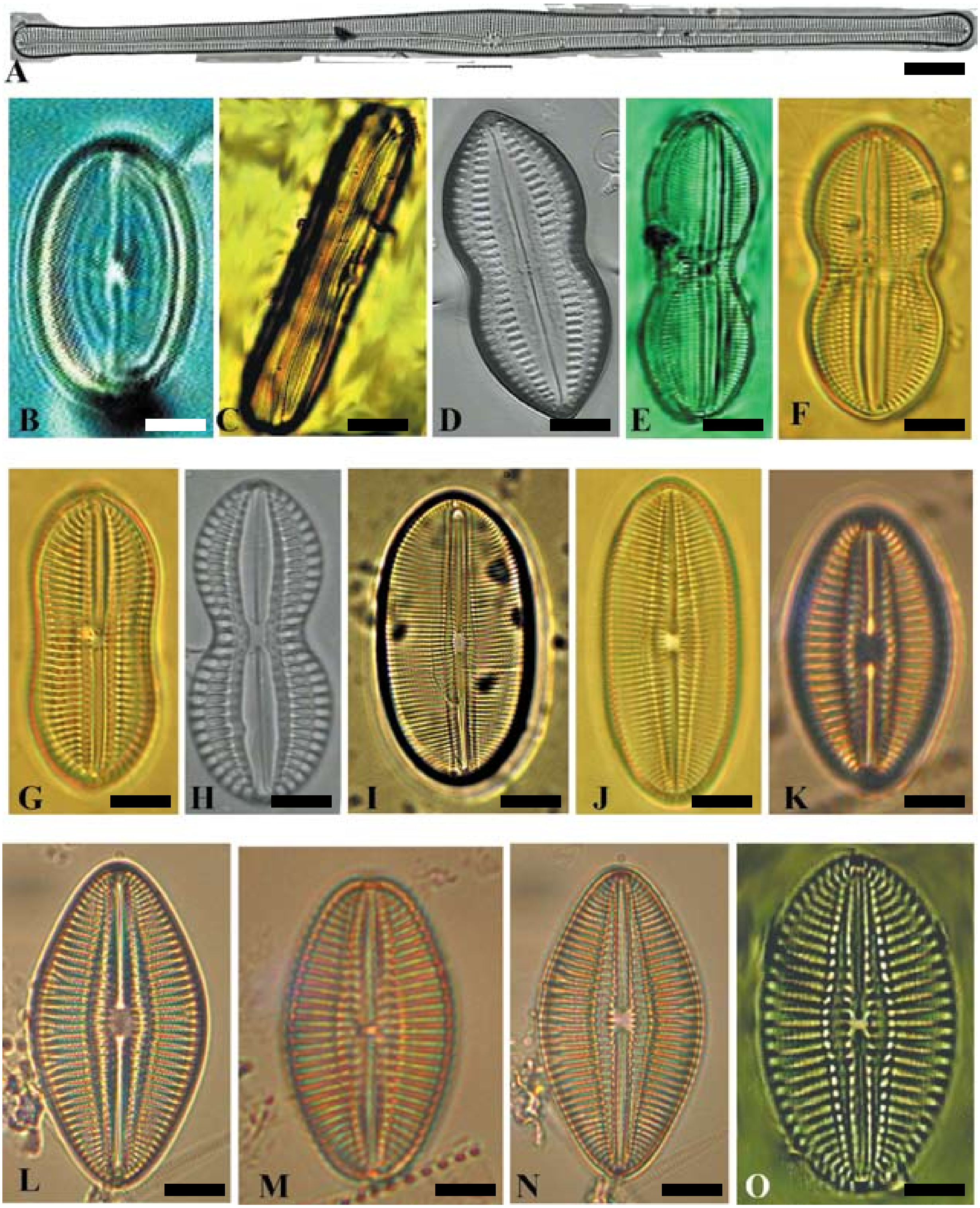

Plate 55. Light micrographs of A. *Berkeleya scopulorum* var. *perlonga*: elongate cell in valve view; B. *Fallacia* cf. *arenaria*: valve view; C. *Caloneis* cf. *westii*: side of cell ; D. *Oestrupia musca*: valve view; E. *Diploneis chersonensis*: valve view; F. *Diploneis didyma*: valve view; G. *Diploneis* aff. *gemmatula*: valve view; H. *Diploneis interrupta*: valve view; I. *Diploneis litoralis*: valve view; J-O. *Diploneis smithii*: different cells in different focus and views.

(Scale Bars, A=11.19 μm; B=1.34 μm; C=14.07 μm; D=18.68 μm; E=14.42 μm; F=11.50 μm; G=15.00 μm; H=6.30 μm; I=11.54 μm; J=6.11 μm; K=7.67 μm; L=6.94 μm; M=7.45 μm; N=7.52 μm; O=10.30 μm).

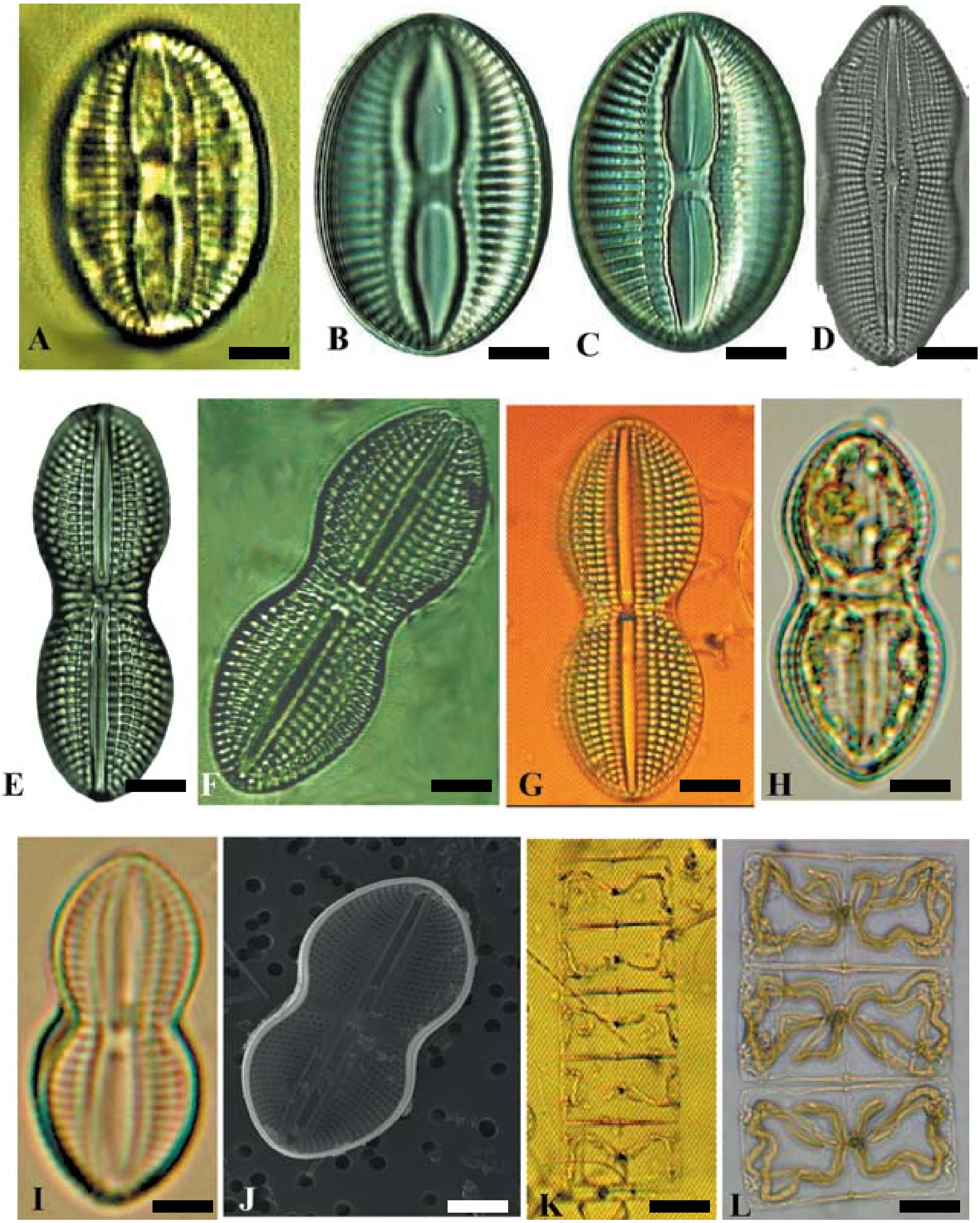

Plate 56. Light micrographs of A-C. *Diploneis suborbicularis*: different cells in different views; D. *Diploneis vacillans* var. *renitens*: valve view; E-G. *Diploneis weissflogii* : valve view, different cells in different focus; H-I. *Diploneis* sp. 1: valve view; J. *Diploneis* sp. 2: valve view; K-L. *Meuniera membranacea*: two different chains in girdle view.
(Scale Bars, A=6.94 µm; B&C=3.51 µm; D=8.14 µm; E=7.35 µm; F=6.44 µm; G=7.62 µm; H=7.33 µm; I=4.71 µm; J=8.85 µm; K=31.20 µm; L=19.17 µm).

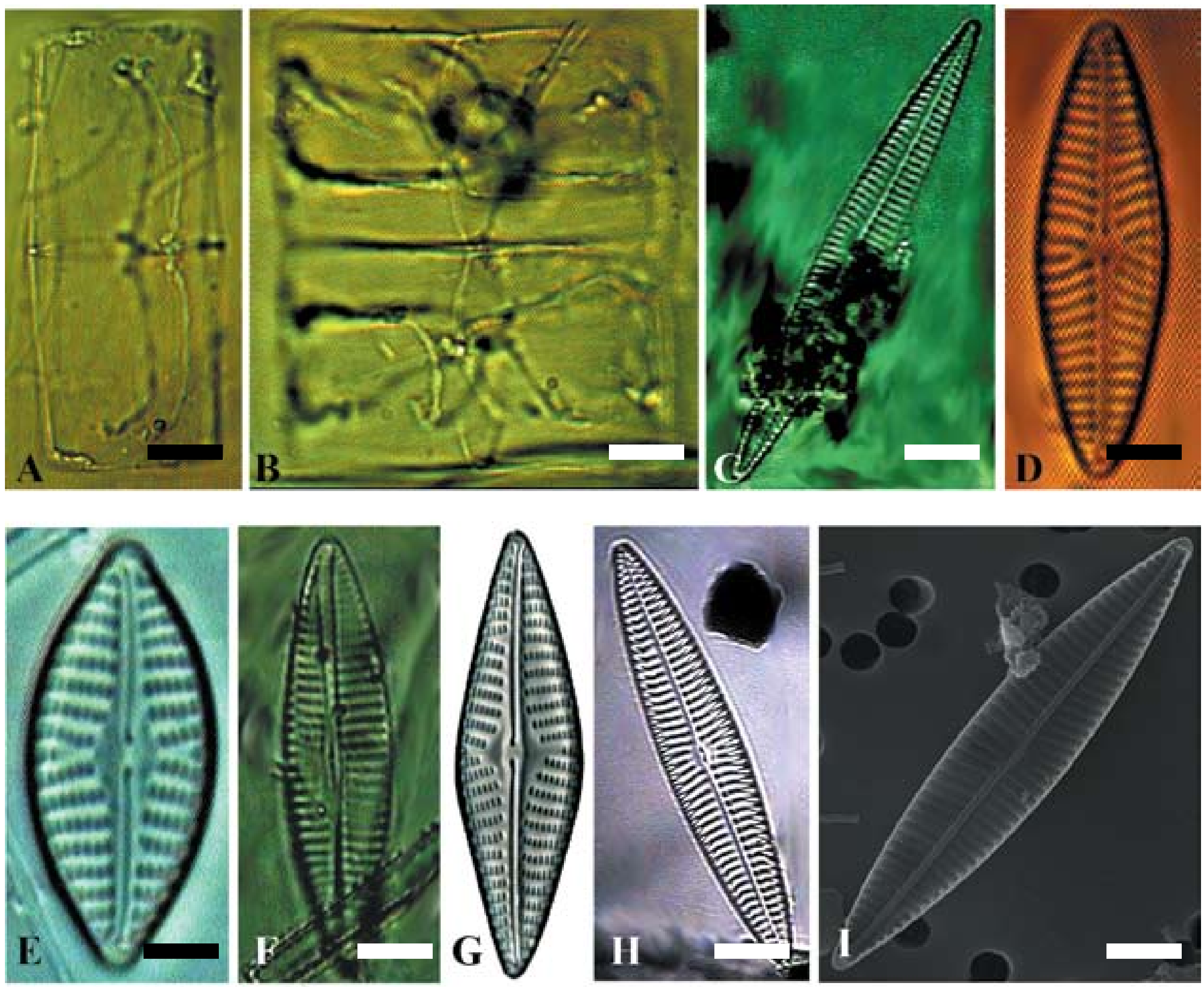

Plate 57. Light micrographs of: A-B. *Meuniera membranacea*: A. one cell magnified, B. two connected cells magnified; C. *Navicula directa* var. *remota*: valve view; D. *Navicula* cf. *erifuga*: valve view; E. *Navicula perhombus*: valve view; F. *Navicula* sp. 1: valve view; G. *Navicula* sp. 2: valve view; H. *Navicula* sp. 3: valve view, I. scanning electron micrograph of same species.
(Scale Bars, A=10.17 μm; B=11.92 μm; C=14.29 μm; D=3.77 μm; E=2.65 μm; F=6.21 μm; G=6.17 μm; H=14.43 μm; I=12.75 μm).

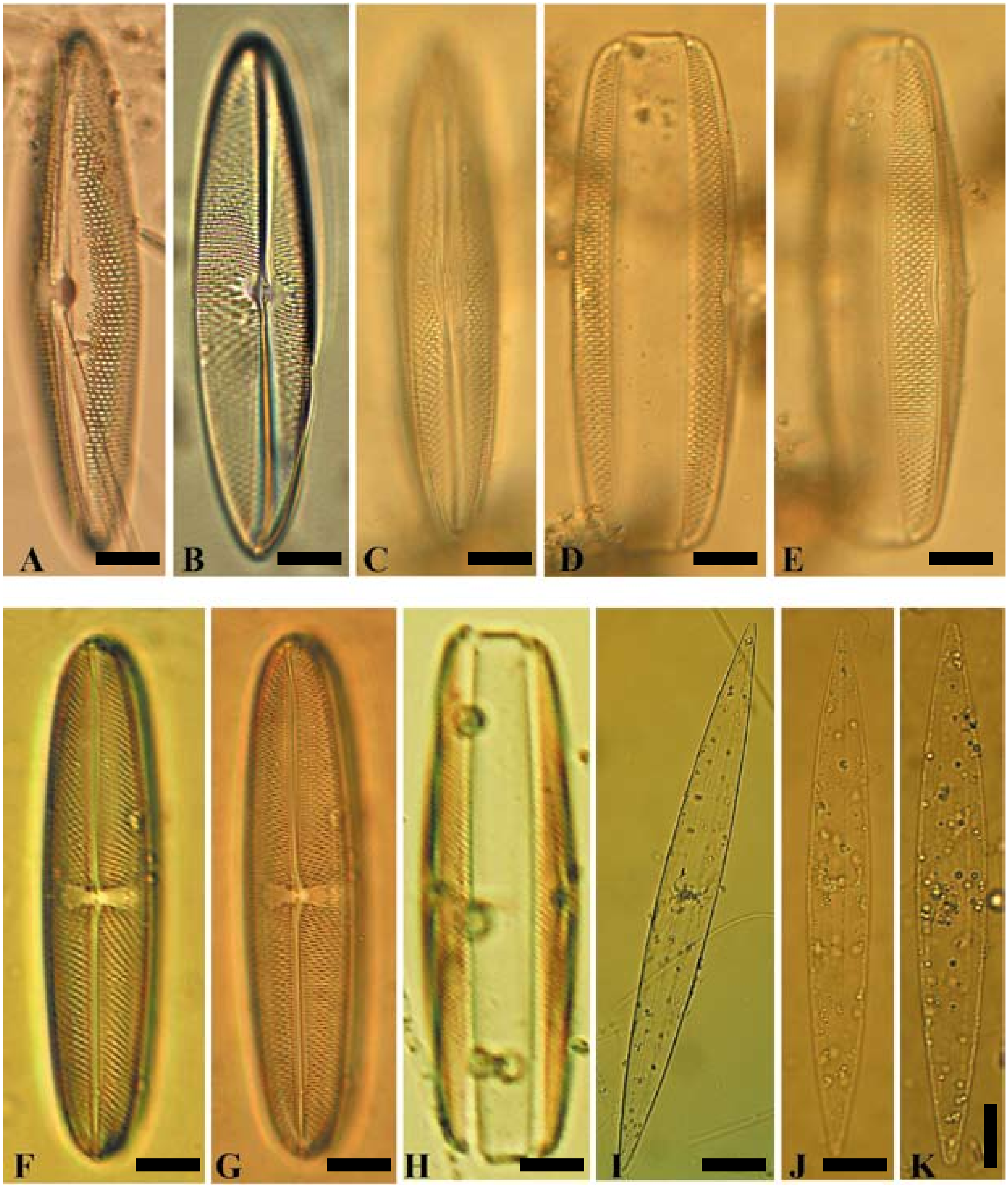

Plate 58. Light micrographs of: A-E. *Trachyneis antillarum*: A-C. valve view, different cells in different sides, D-E. girdle view; F-H. *Trachyneis aspera*: F-G. valve view, H. girdle view; I-K. *Haslea* cf. *balearica*: valve view.
(Scale Bars, A&B=10.48 µm; C=10.88 µm; D&E=10.74 µm; F&G=17.99 µm; H=17.77 µm; I=22.47 µm; J=24.40 µm; K=20.59 µm).

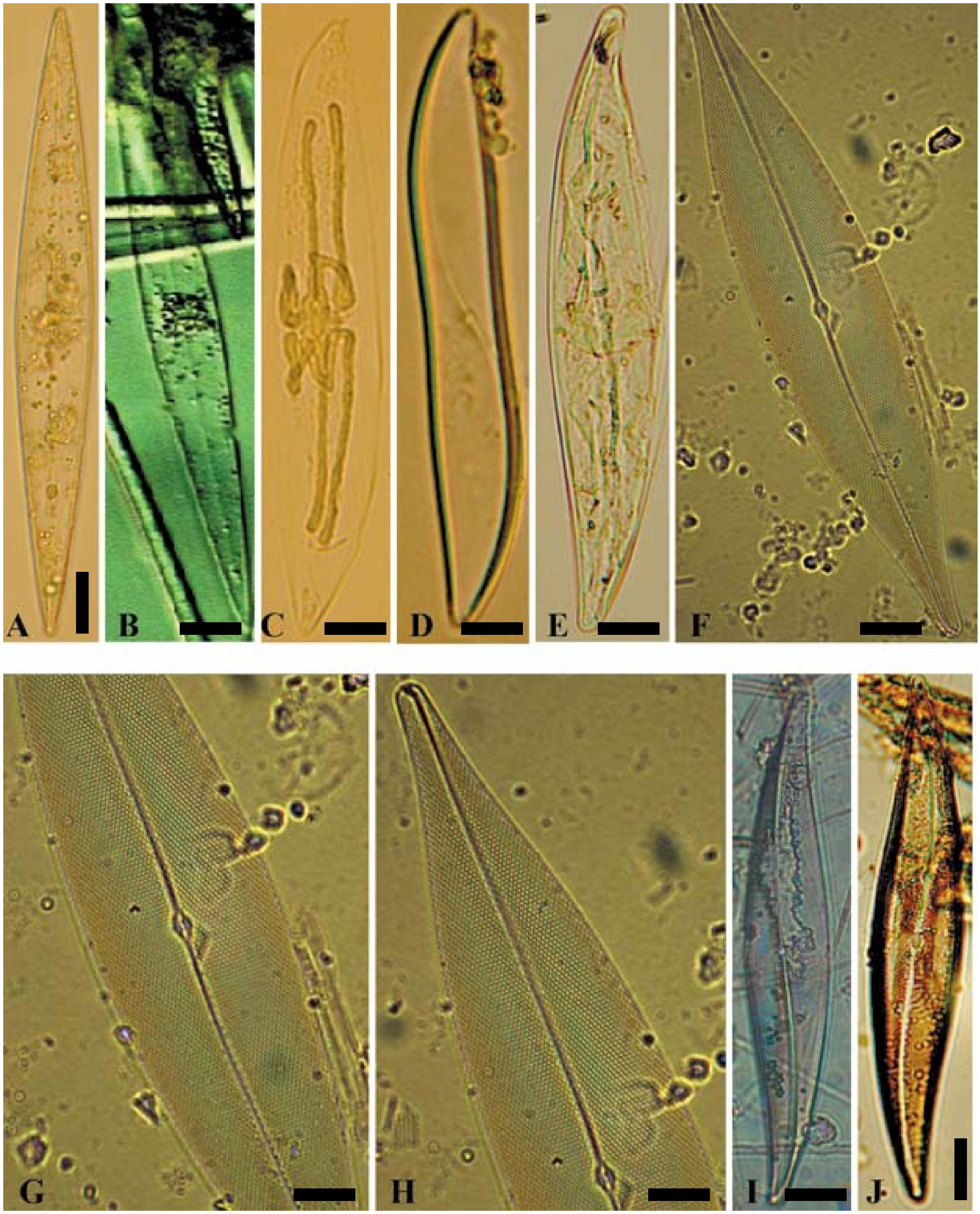

Plate 59. Light micrographs of: A. *Haslea* sp.1: valve view; B. *Haslea* sp.2: valve view; C-D. *Donkinia* sp.: C. with chlorophyll, D. showing the raphe; E-H. *Pleurosigma cuspidatum*: E. live cell, F. entire cell, G. middle-region magnified, H. one side magnified; I-J. *Pleurosigma diverse-striatum*: different cells. (Scale Bars, A=22.53 μm; B=22.38 μm; C=19.00 μm; D=9.54 μm; E=12.55 μm; F=10.05 μm; G&H=6.70 μm; I=14.05 μm; J=14.43 μm).

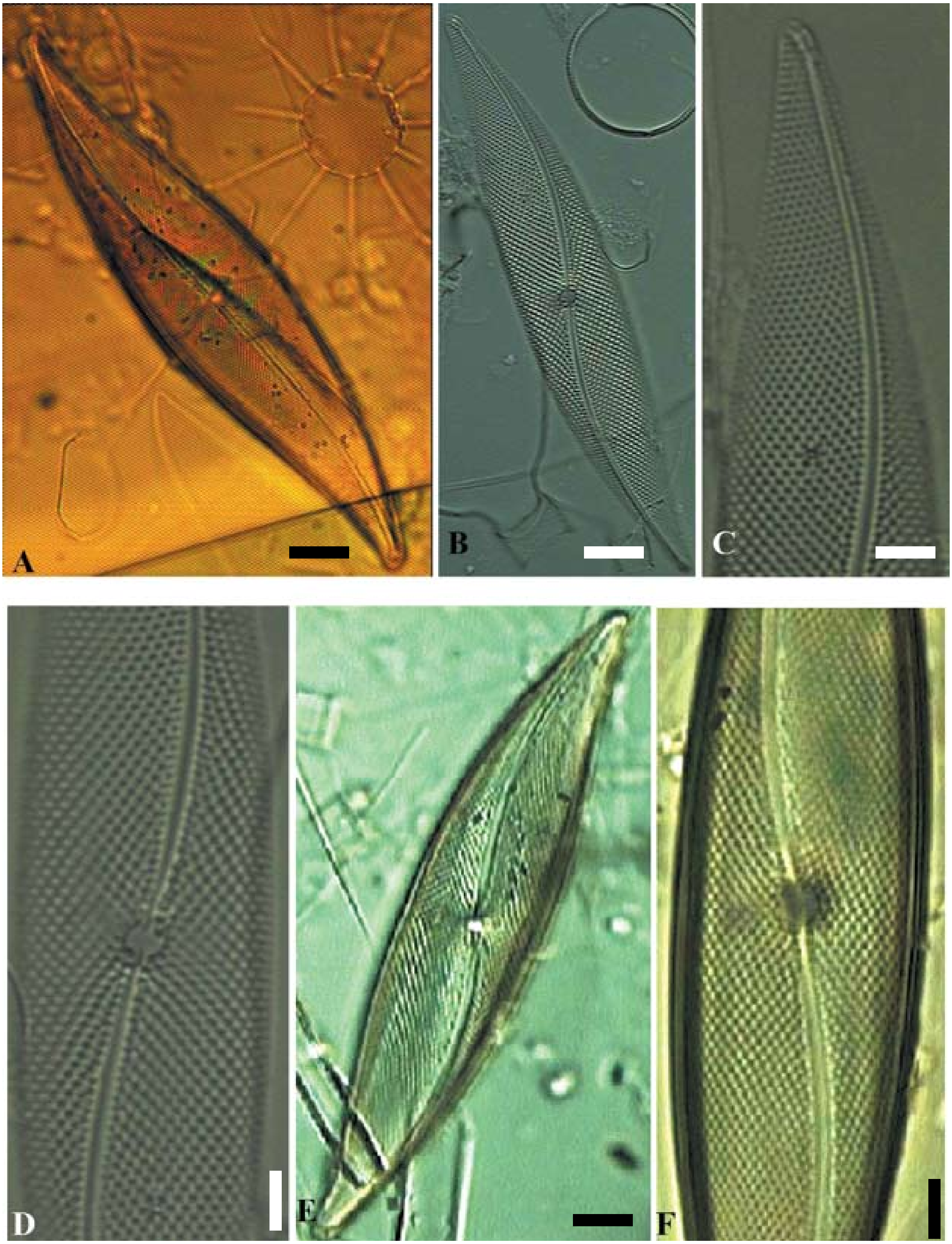

Plate 60. Light micrographs of A-F. *Pleurosigma diverse-striatum*: A. entire cell, B-D. the same cell, B. entire view, C. one side magnified, D. middle region magnified; E-F. the same cell, E. entire view, F. middle region magnified.
(Scale Bars, A=10.00 µm; B=11.37 µm; C=6.67 µm; D=5.45 µm; E=6.40 µm; F=3.72 µm).

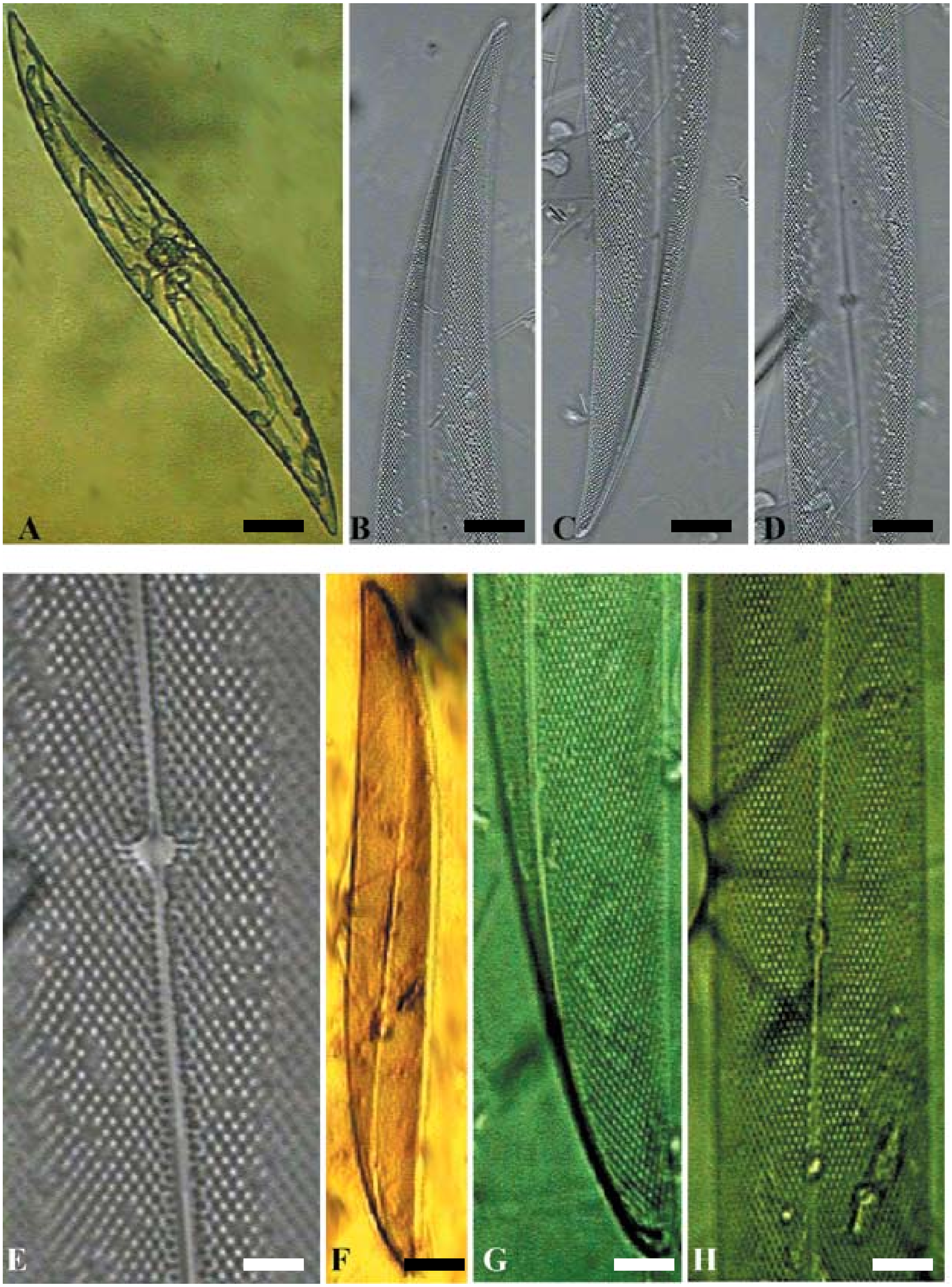

Plate 61. Light micrographs of A-E. *Pleurosigma* cf. *elongatum*: A. entire view from preserved material, B-E. same cell from cleaned material, B-C. two sides of the cell, D. middle region, E. middle region magnified.; F-H. *Pleurosigma formosum*: F. entire view, G. one side magnified, H. middle region magnified.

(Scale Bars, A=16.08 µm; B=15.71 µm; C&D=15.00 µm; E=7.86 µm; F=15.38 µm; G=6.25 µm; H=5.56 µm).

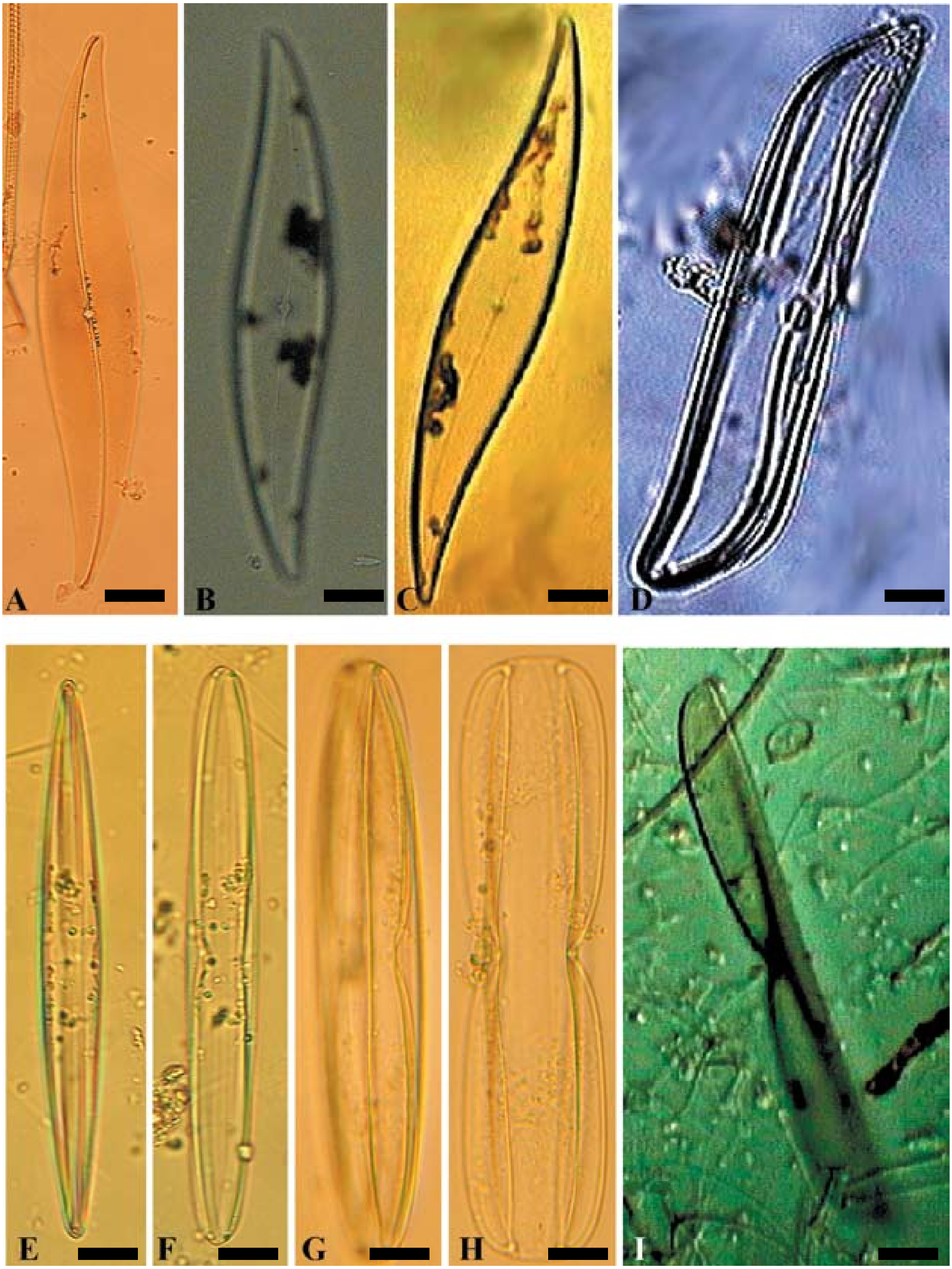

Plate 62. Light micrographs of A-C. *Pleurosigma* cf. *strigosum*: valve view; D. *Gyrosigma diminutum*: girdle view; E-I. *Plagiotropis lepidoptera*: cell in girdle view from different sides.
(Scale Bars, A=17.85 µm; B=19.23 µm; C=16.57 µm; D=14.06 µm; E=15.72 µm; F=15.15 µm; G=14.70 µm; H=14.55 µm; I=15.17 µm).

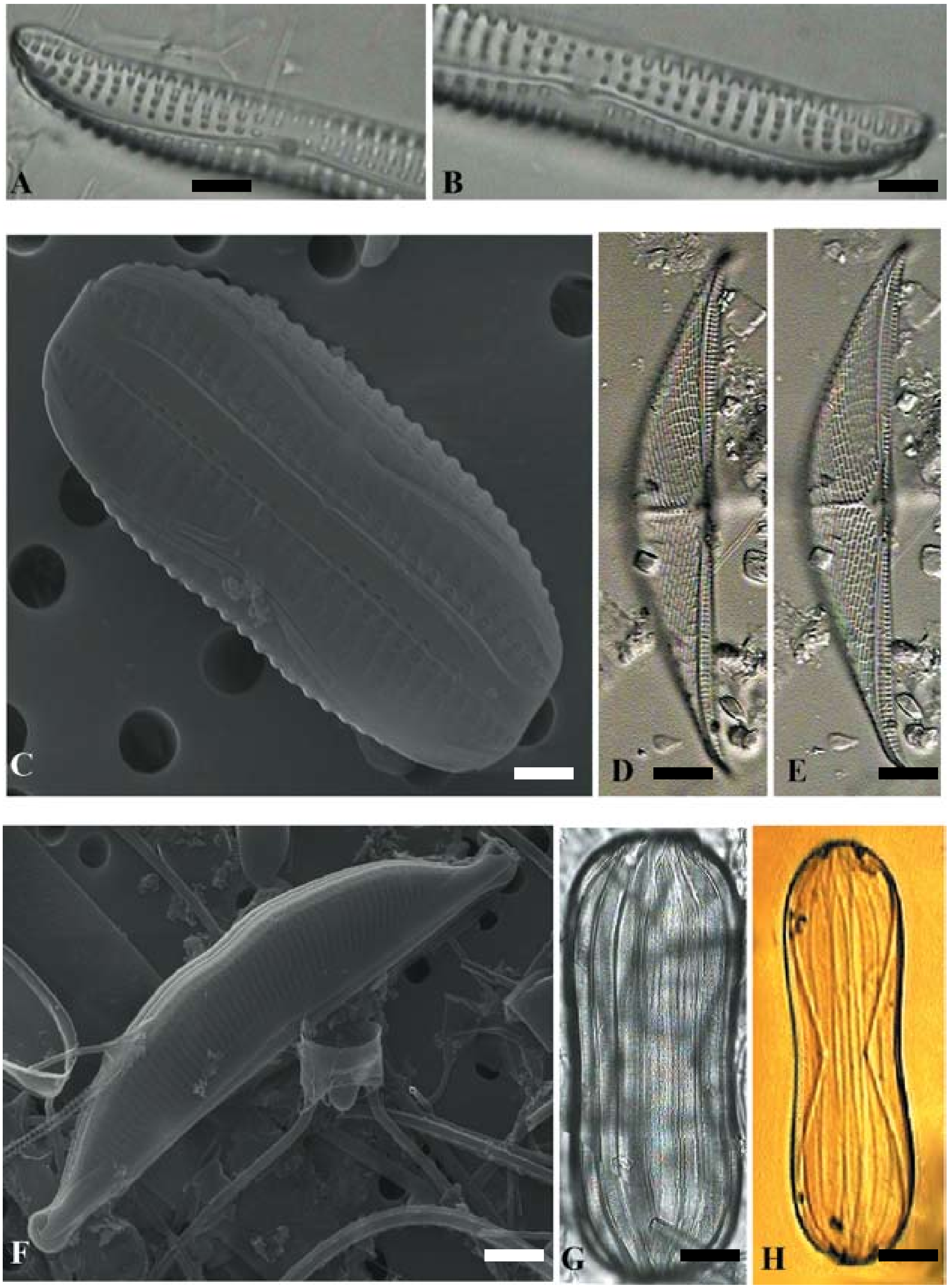

Plate 63. Light micrographs of A-C. *Amphora crassa*: A-B. the two parts of cell, C. girdle view; D-E. *Amphora decussata*: the same cell in different focus; F. *Amphora granulata* var. *biggibbosa*: valve view; G. *Amphora obtusa*: girdle view; H. *Amphora cf. obtusa*: girdle view.
(Scale Bars, A=13.13 μm; B=11.67 μm; C=6.41 μm; D&E=2.91 μm; F=5.24 μm; G=16.36 μm; H=18.04 μm).

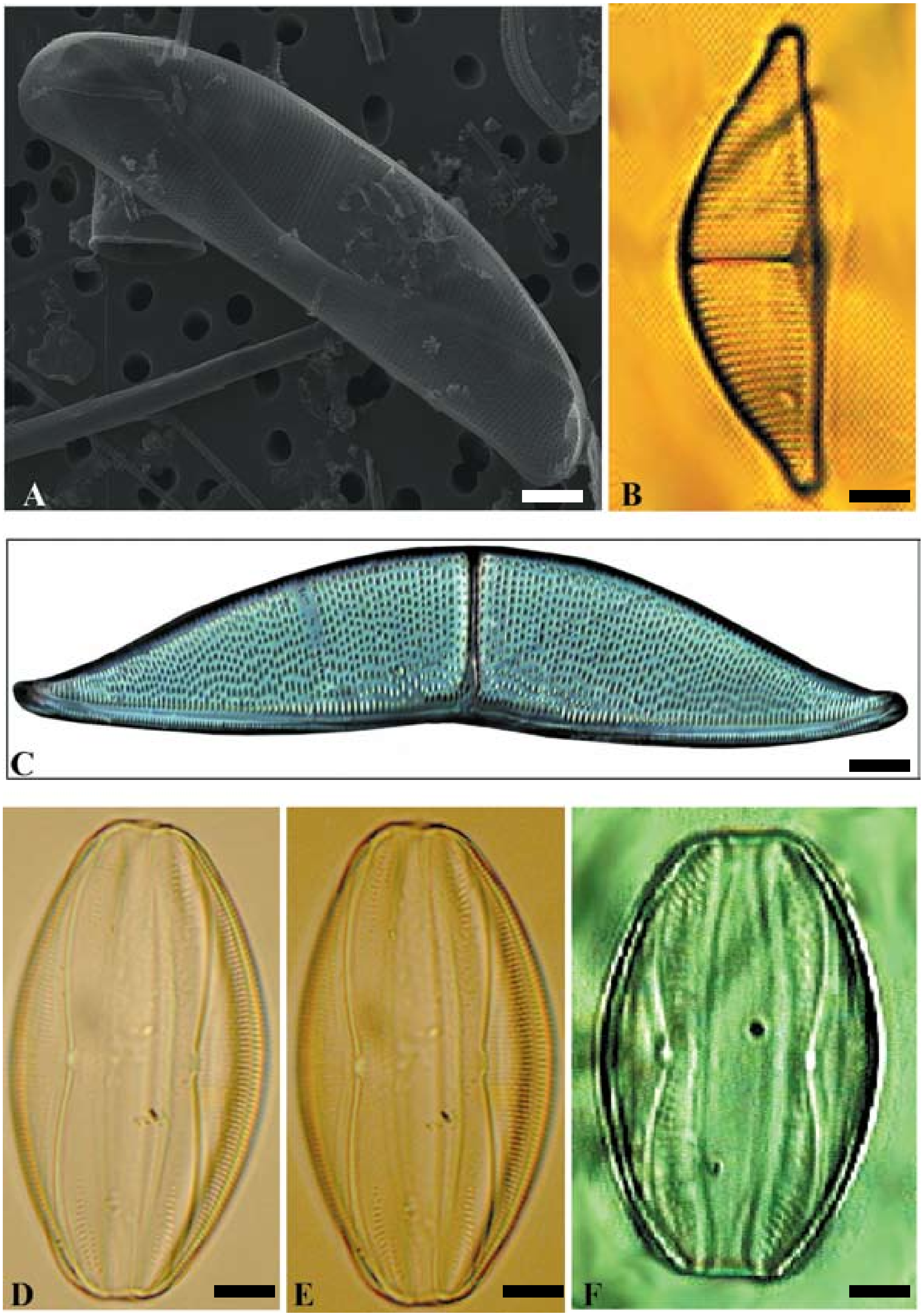

Plate 64. Scanning electron micrograph of A. *Amphora obtusa*: valve view; Light micrographs of B-C. *Amphora ostrearia*: valve view; D-F. *Amphora proteus*: D-E. the same cell in different focus, girdle view, F. other cell, girdle view.
(Scale Bars, A=11.80 µm; B=5.45 µm; C=5.67 µm; D&E=9.37 µm; F=6.76 µm).

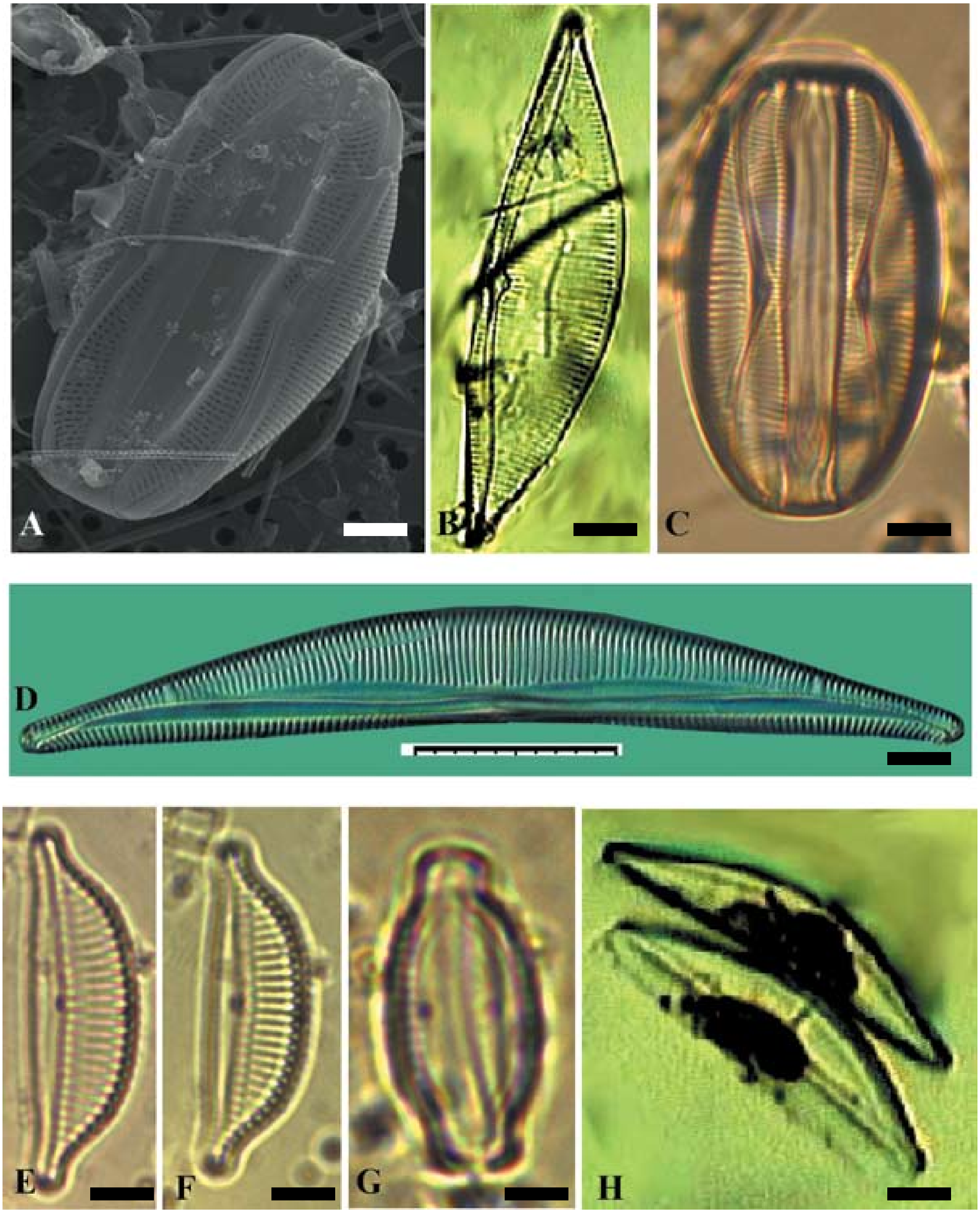

Plate 65. Scanning electron micrograph of A. *Amphora proteus*: girdle view; Light micrographs of B. *Amphora rhombica*: valve view; C. *Amphora spectabilis*: girdle view; D. *Amphora sulcata*: valve view; E-G. *Amphora* cf. *turgida*: E-F. valve view in different focus, G. girdle view; H. *Amphora* sp.1: two cells.
(Scale Bars, A=8.64 µm; B=10.47 µm; C=10.56 µm; D=3.15 µm; E&F=3.39 µm; G=3.81 µm; H=10.16 µm).

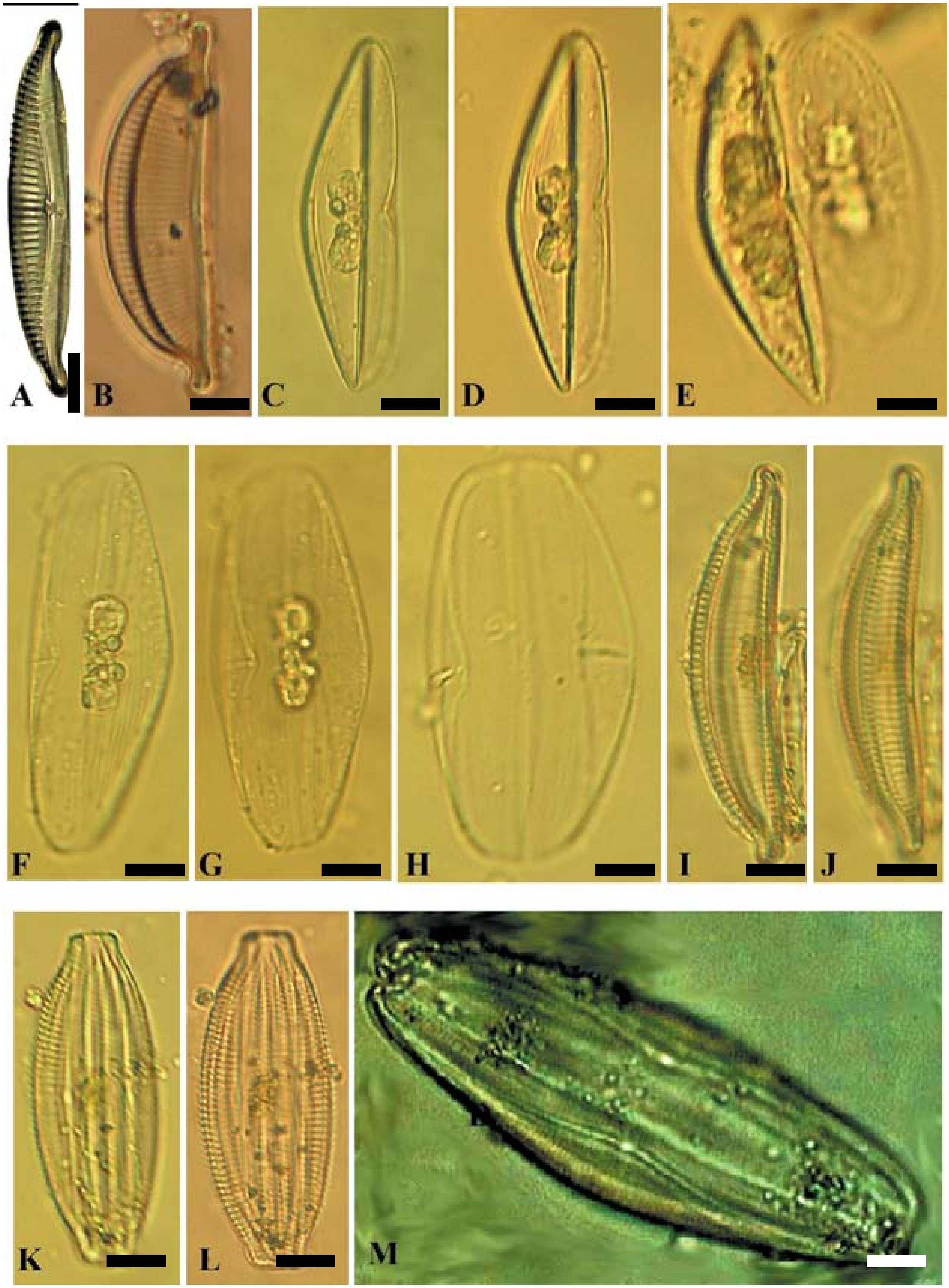

Plate 66. Light micrographs of A. *Amphora* sp.2: valve view; B. *Amphora* sp.3: valve view; C-H. *Amphora* sp.4: C-E. valve view; F-H. girdle view; I-L. *Amphora* sp. 5: I-J. valve view, K-L. girdle view; M. *Amphora* sp.6: girdle view.
(Scale Bars, A=5.31 µm; B=5.13 µm; C&D=15.83 µm; E=14.36 µm; F=14.62 µm; G=15.08 µm; H=14.18 µm; I&J=11.74 µm; K&L=13.84 µm; M=18.06 µm).

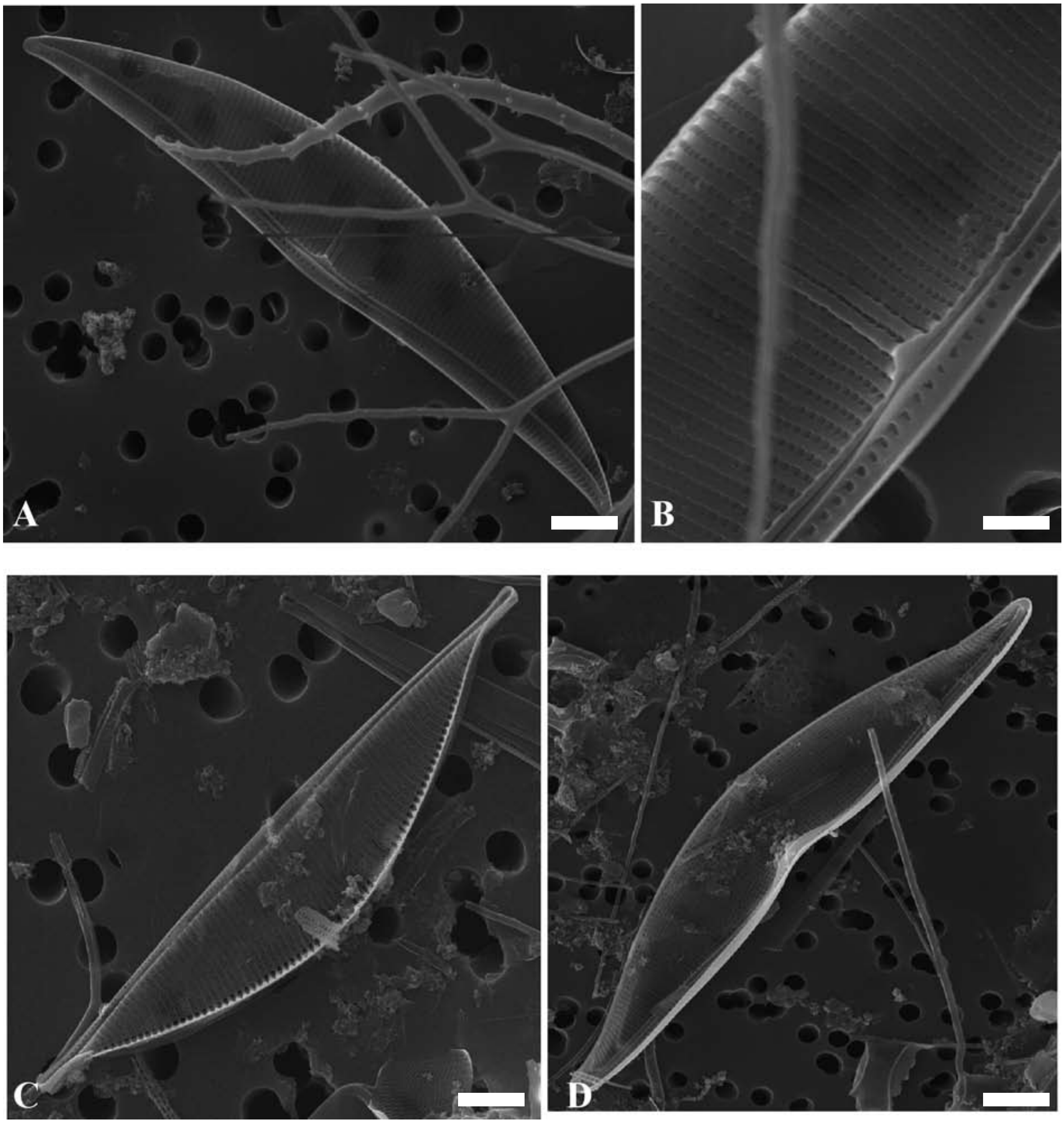

Plate 67. Scanning electron micrographs of A-B. *Amphora* sp.7: A. entire view; B. middle region magnified; C. *Amphora* sp.8: entire view; D. *Amphora* sp.9: entire view.
(Scale Bars, A=17.75 μm; B=6.12 μm; C=18.21 μm; D=20.63 μm).

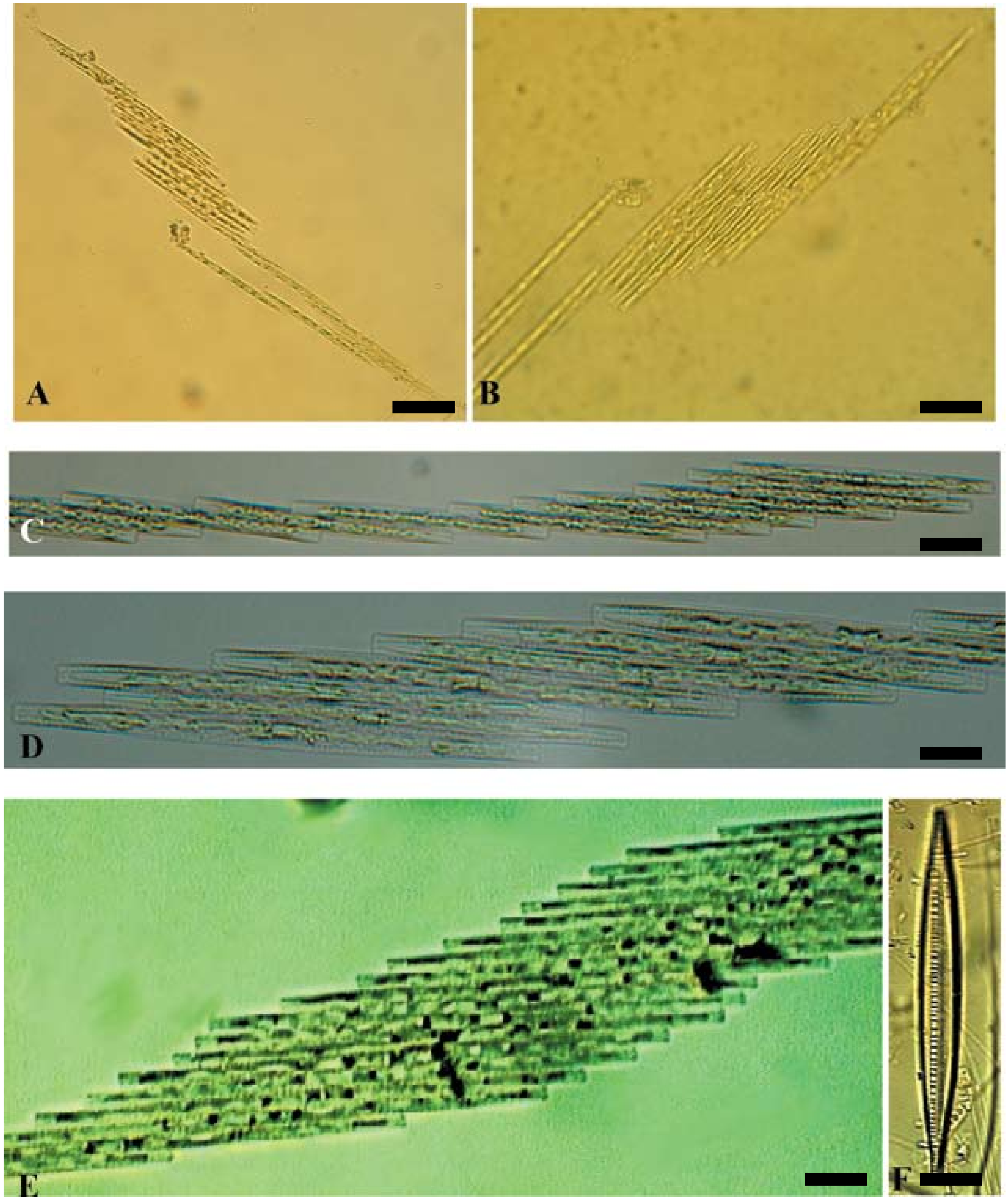

Plate 68. Light micrographs of A-E. *Bacillaria paxillifera*: different cells in colony, girdle view, D. the same colony on C in more magnification; E. another long colony, F. *Bacillaria socialis*: cell in valve view. (Scale Bars, A =46.00 µm; B=30.67 µm;C=16.67 µm; D=10.00 µm; E=25.00 µm; F=10.57 µm).

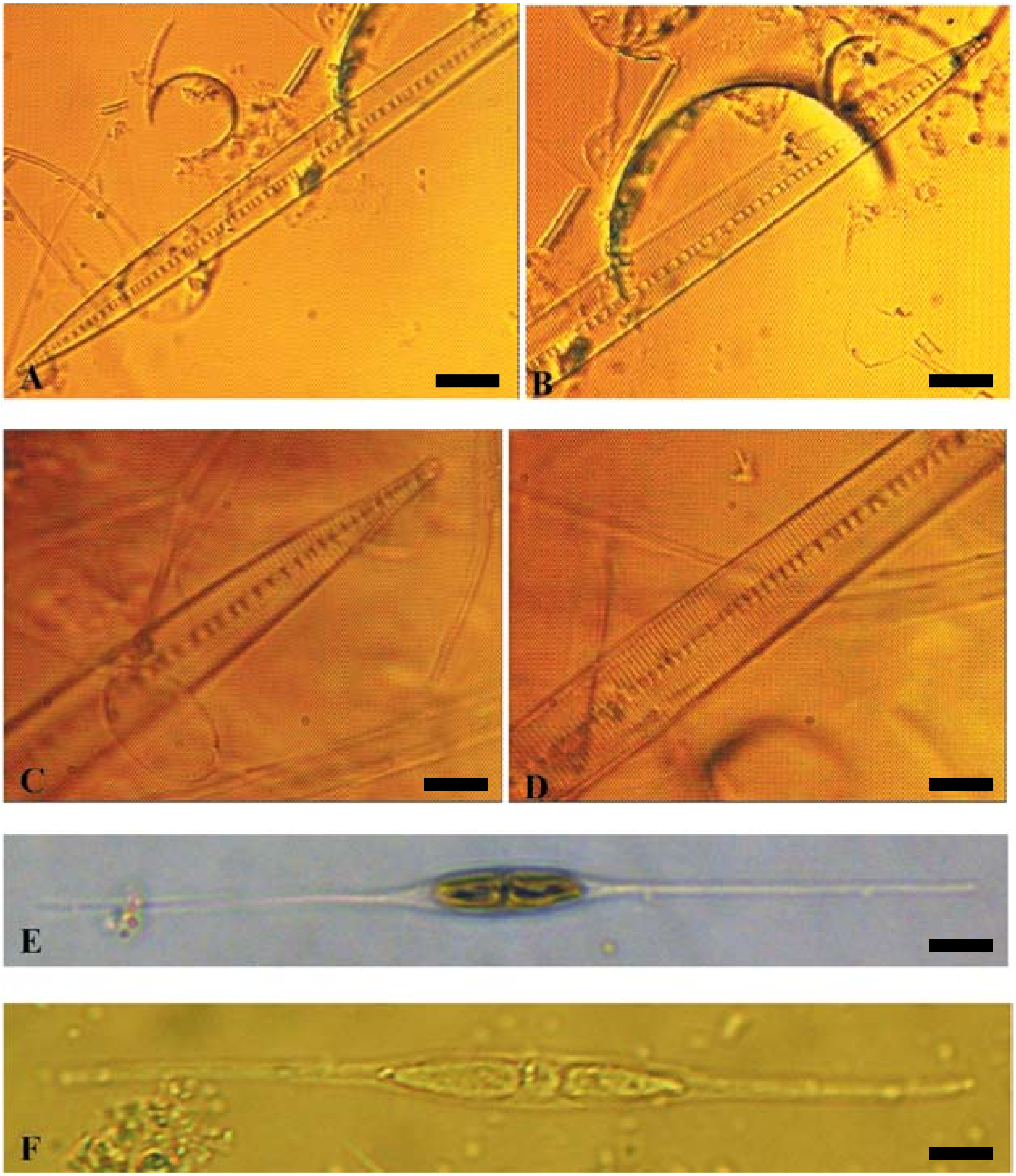

Plate 69. Light micrographs of A-D. *Bacillaria socialis*: A. one part of the cell, B. the other part, C. the part more magnified, D. middle part more magnified showing clearly the fibualae; E. *Cylindrotheca closterium*: girdle view; F. *Cylindrotheca* sp.1: girdle view.
(Scale Bars, A=10.00 μm; B=8.00 μm; C=6.15 μm; D=5.33 μm; E=4.83 μm; F=7.24 μm).

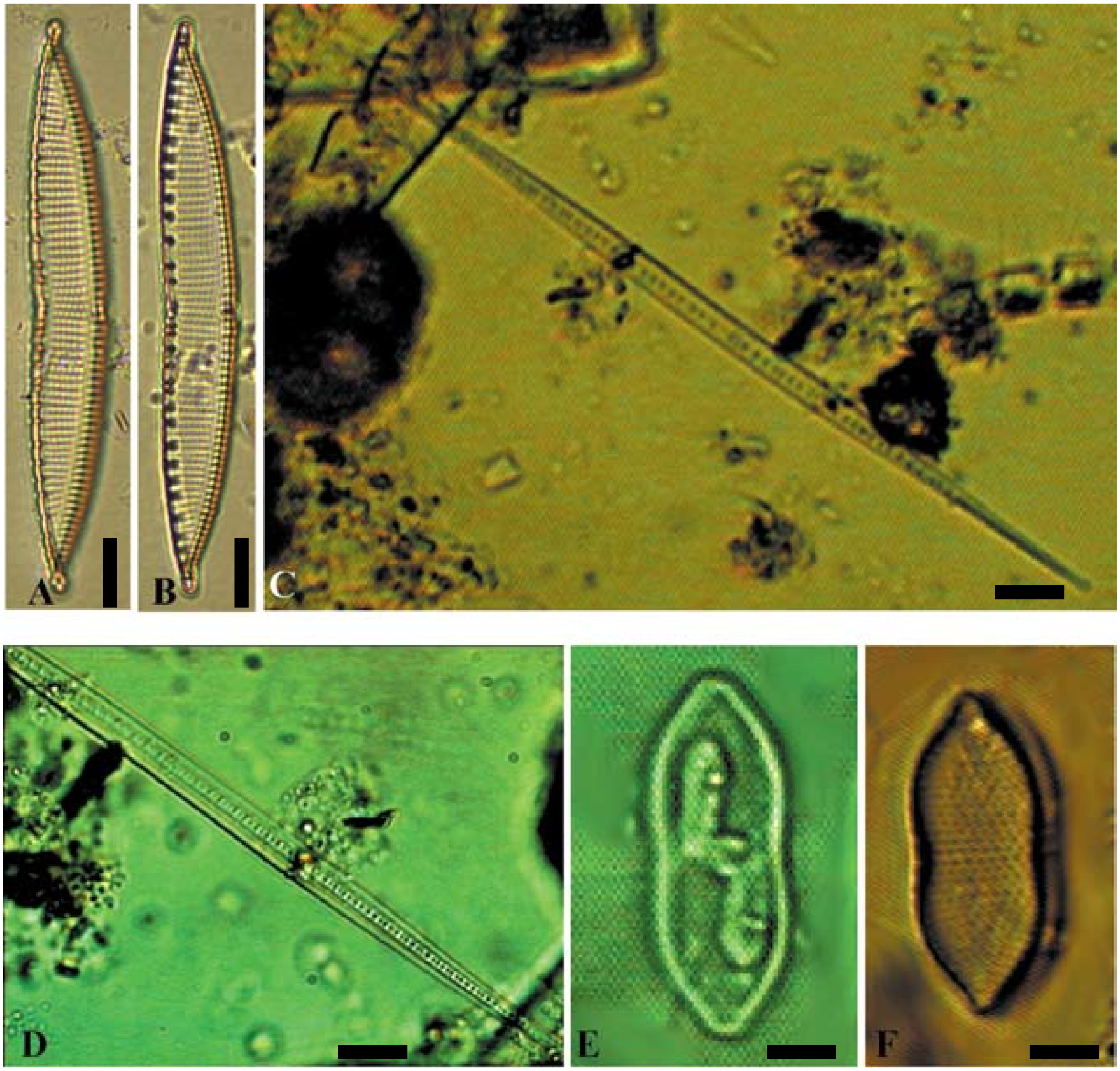

Plate 70. Light micrographs of A-B.*Hantzschia amphioxis*: the same cell in different focus, valve view showing clearly the radiate striae and the keel punctuations; C-D. *Nitzschia behrei*: C. entire view, D. cell part magnified showing clearly the fibulae; E-F. *Nitzschia coarctata*: entire view.
(Scale Bars, A&B=6.81 μm; C=17.50 μm; D=14.00 μm; E=6.92 μm; F=3.83 μm).

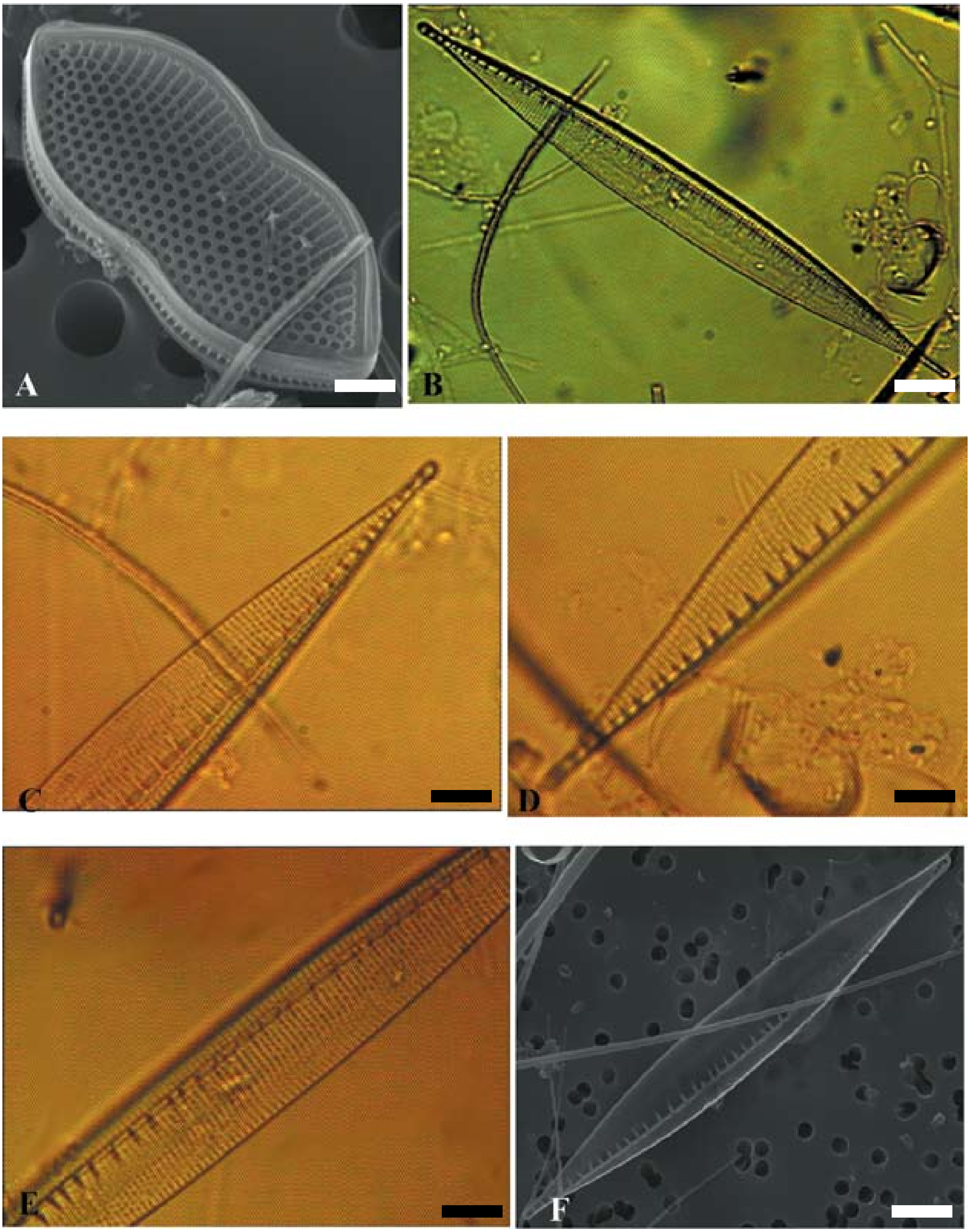

Plate 71. Scanning electron micrograph of A. *Nitzschia coarctata*: entire view; Light micrographs of B-E. *Nitzschia* cf. *fluminensis*: B. entire cell, C. one side magnified, D. other side magnified, E. middle region magnified; F. Scanning electron micrograph of *Nitzschia* cf. *fluminensis*: entire view.
(Scale Bars, A=4.15 μm; B=4.55 μm; C=5.29 μm; D=6.43 μm; E=5.00; F=6.52 μm).

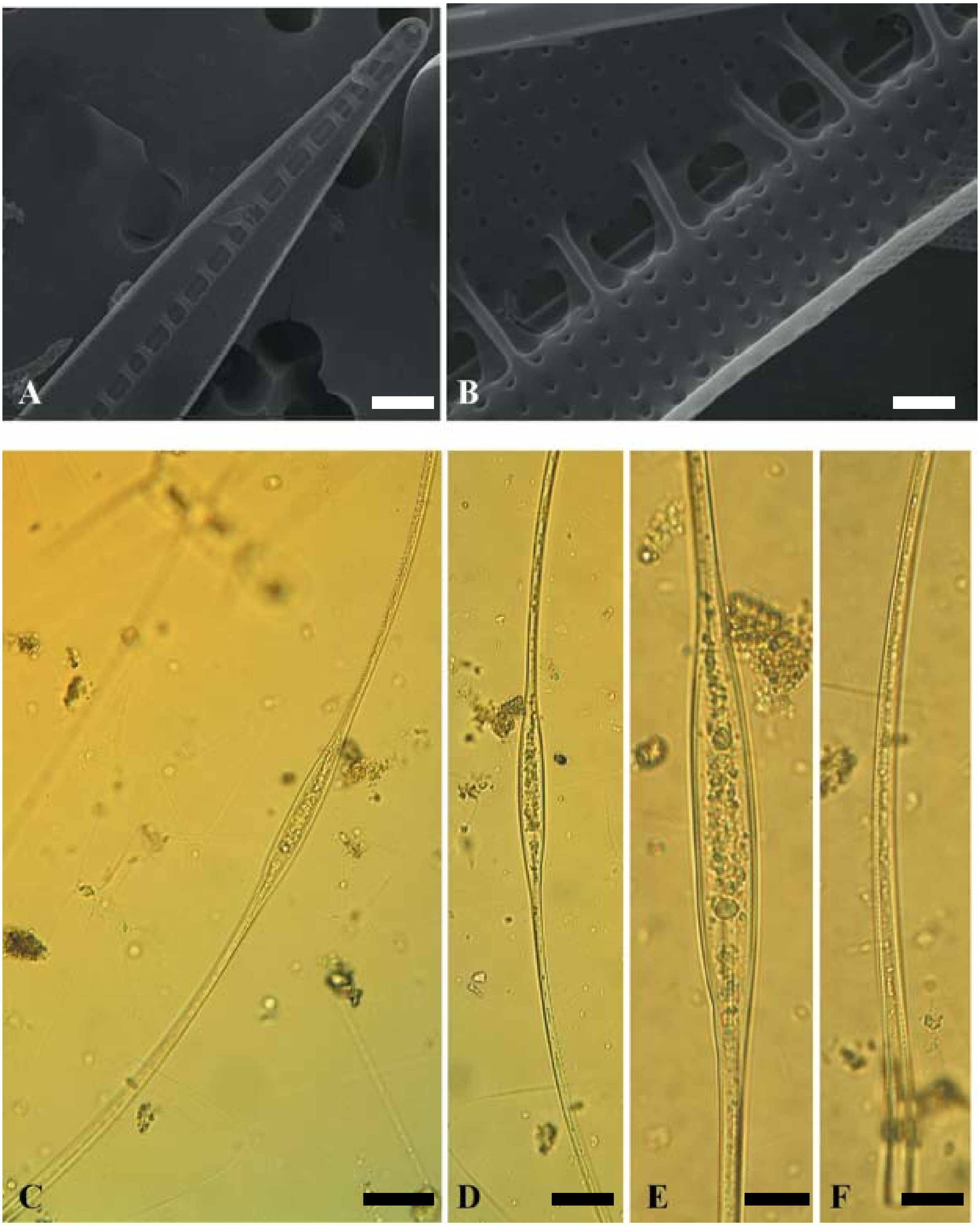

Plate 72. Scanning electron micrographs of A-B. *Nitzschia* cf*. fluminensis*: magnified parts of the previous cell A. one side of cell, B. part of cell in more magnification showing clearly the fibulae spaces contained; Light micrographs of C-F. *Nitzschia longissima*: same cell, C-D. middle part in different magnification, E. middle part magnified, F. one side magnified.
(Scale Bars, A=3.75 µm; B=0.79 µm; C&D=15.00 µm; E=6.00 µm; F=5.00 µm).

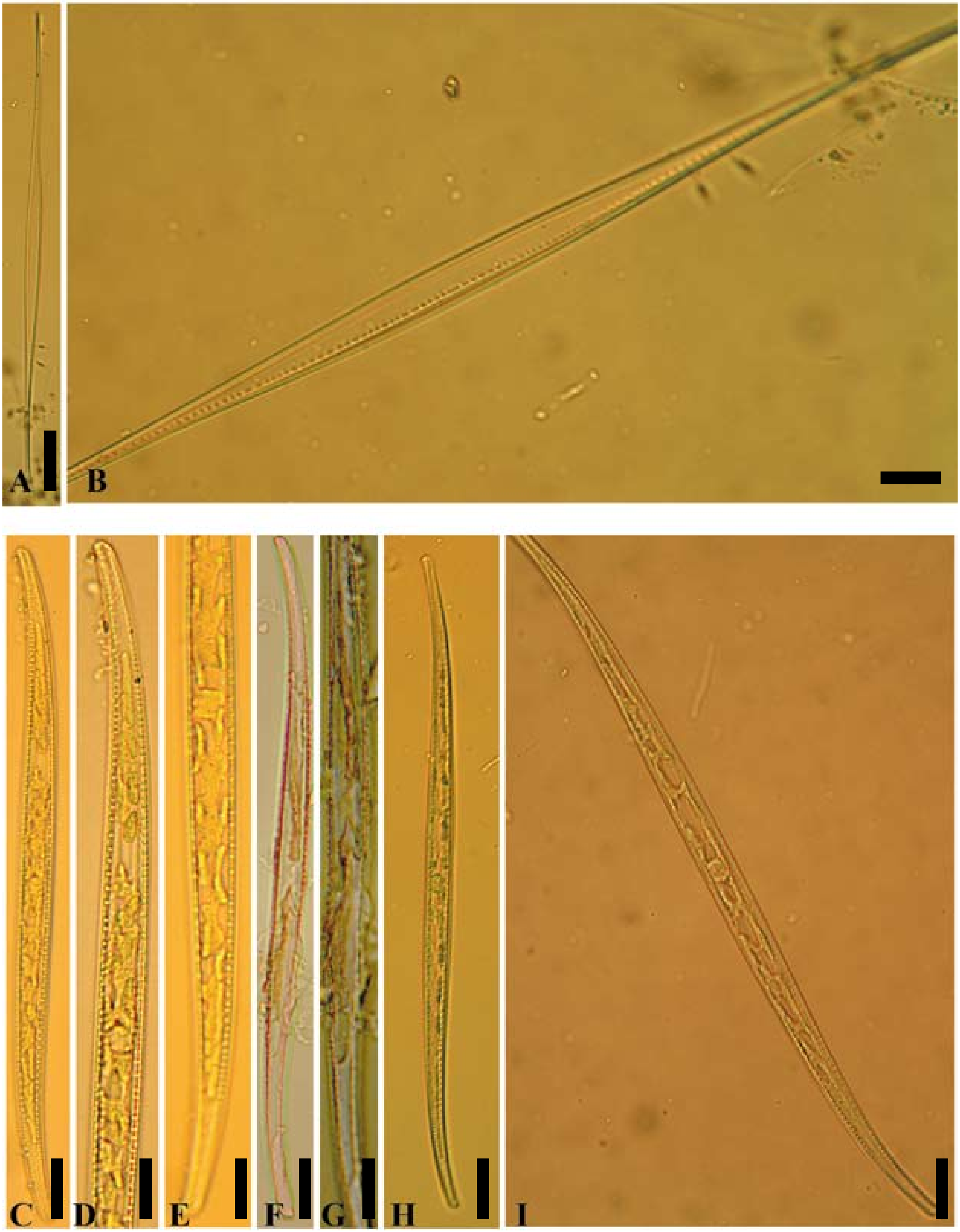

Plate 73. Light micrographs of A-B. *Nitzschia longissima*: another cell, A. entire view, B. middle part magnified showing clearly the fibulae space; C-I. *Nitzschia lorenziana*: C-E. same cell: C. entire cell, D-E. two different sides magnified, F-G. another cell: F. Entire view, G. part of cell magnified, H-I. another cell: H. Entire view, I. part of cell magnified.
(Scale Bars, A=49.04 µm; B=17.86 µm; C=22.32 µm; D=17.33 µm; E=18.57 µm; F=13.60 µm; G=15.42 µm; H=25.46 µm; I=17.97 µm).

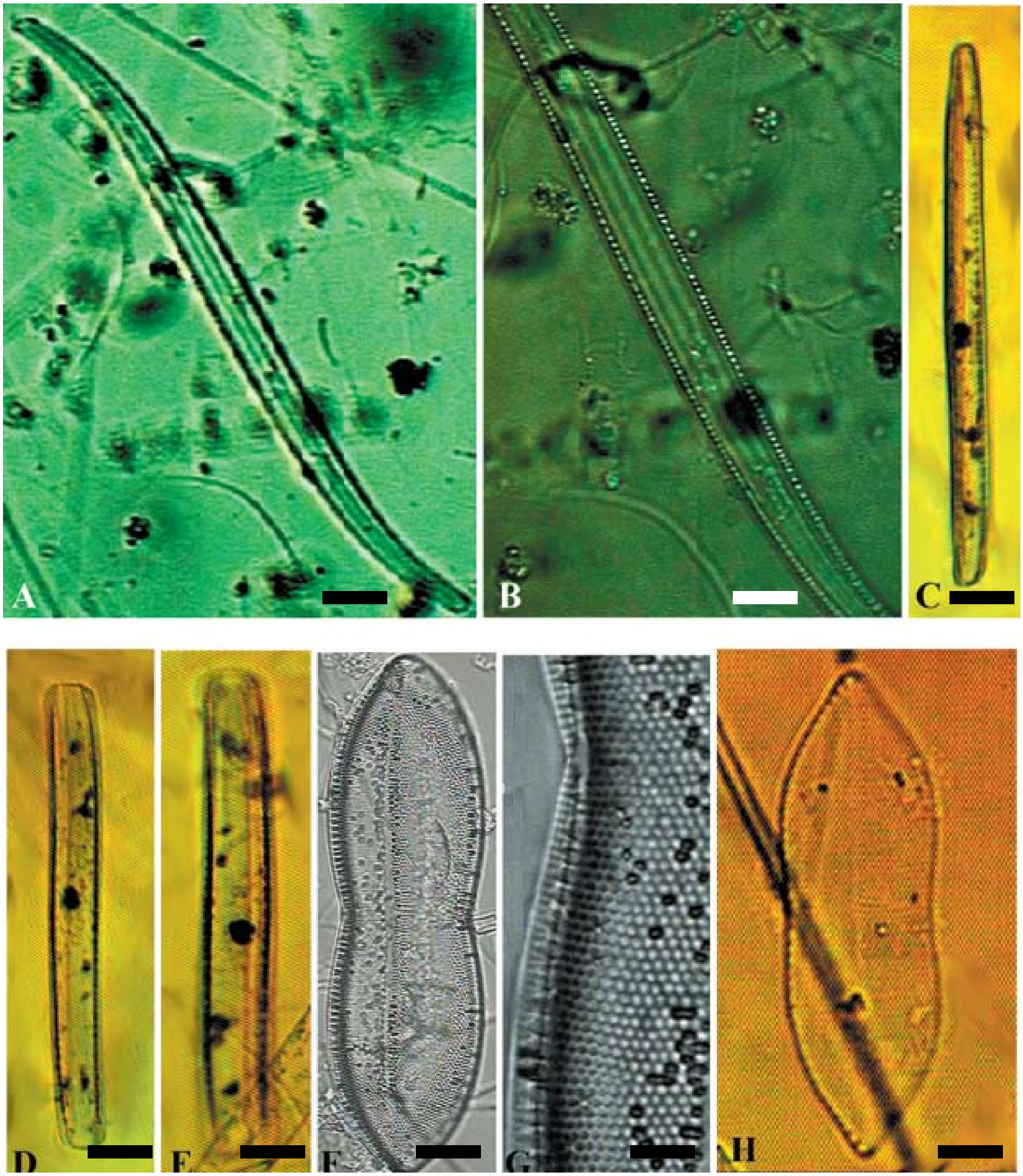

Plate 74. Light micrographs of A-B. *Nitzschia* cf. *sigma*: A. entire cell, B. part of cell magnified; C-E. *Nitzschia* cf. *sigmoidea*: entire view form low to high magnifications; F-G. *Nitzschia panduriformis*: F. entire view, G. side of cell magnified; H. *Nitzschia* sp.1: entire view.
(Scale Bars, A=18.57 µm; B=13.00 µm; C=26.02 µm; D=30.00 µm; E=27.69 µm; F=8.94 µm; G=MC; H=4.24 µm).

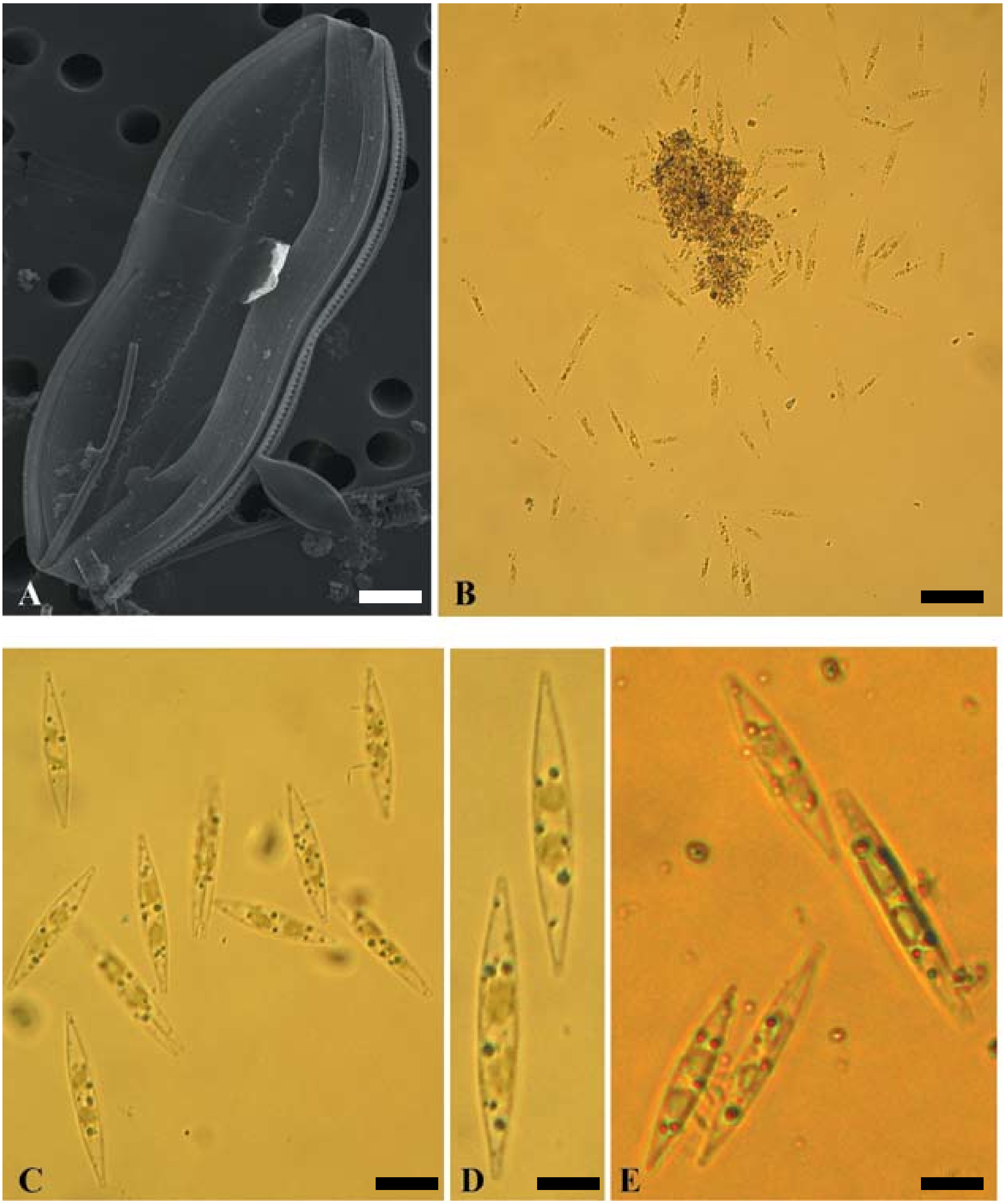

Plate 75. Scanning electron micrograph of A. *Nitzschia* sp.1: entire view; Light micrographs of B-E. *Nitzschia* sp. 2: B. bloom in low magnification, C. some of cells from the same bloom magnified, D. two cells magnified, E. another cells accumulate together.
(Scale Bars, A=11.00 μm; B=100.00 μm; C=28.57 μm; D=16.67 μm; E=20.00 μm).

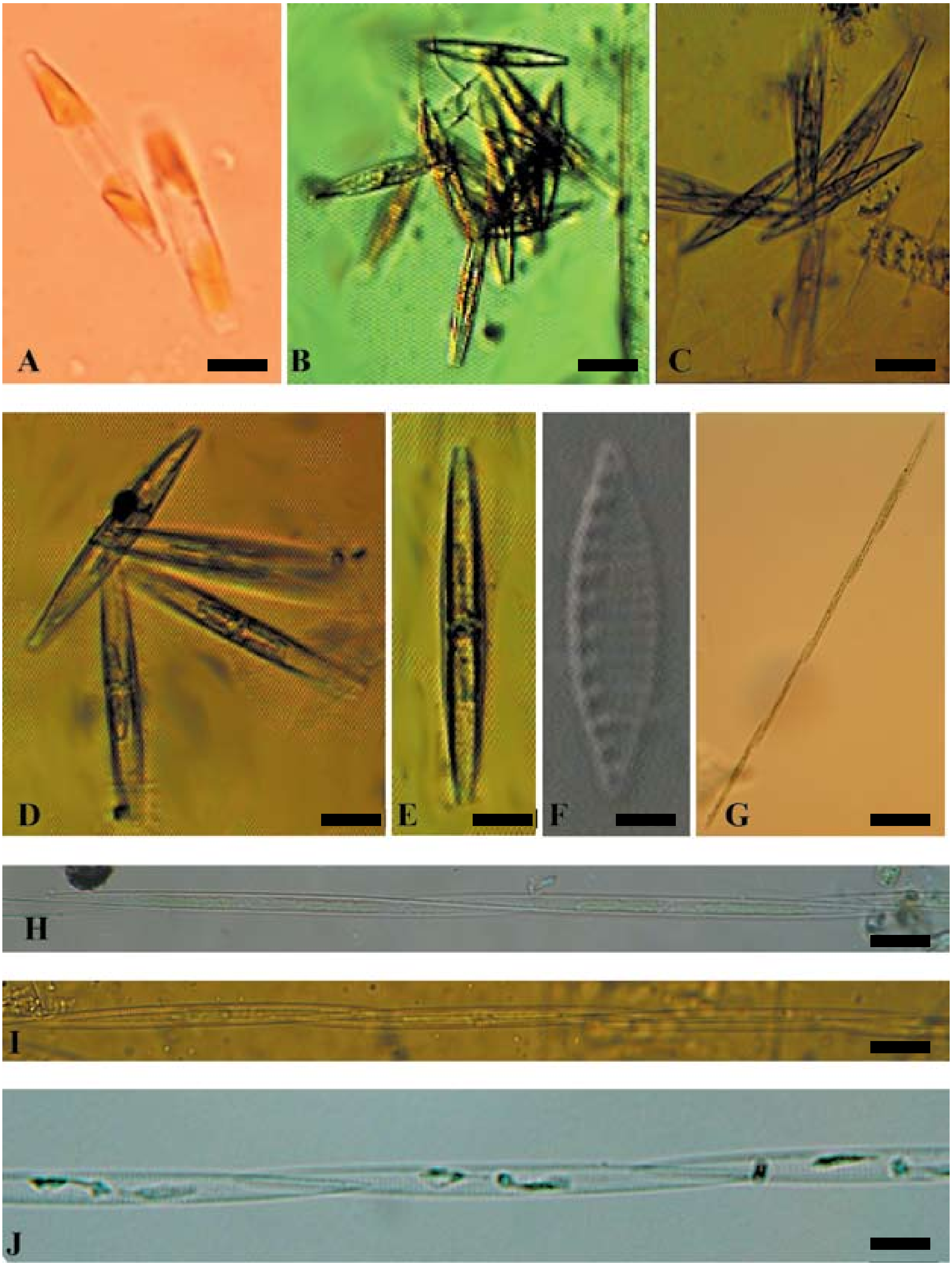

Plate 76. Light micrographs of A. *Nitzschia* sp.3: another cells; B-E. *Nitzschia* sp.4: B-D. colony, E. one cell magnified; F. *Nitzschia* sp.5: valve view; G-J. *Peudo-nitzschia seriata* group: chains of different cells varied in size.
(Scale Bars, A=17.50 μm; B&C=32.50 μm; D=25.00 μm; E=21.43 μm; F=10.00 μm; G=150.00 μm; H=16.67 μm; I=12.50 μm; J=10.00 μm).

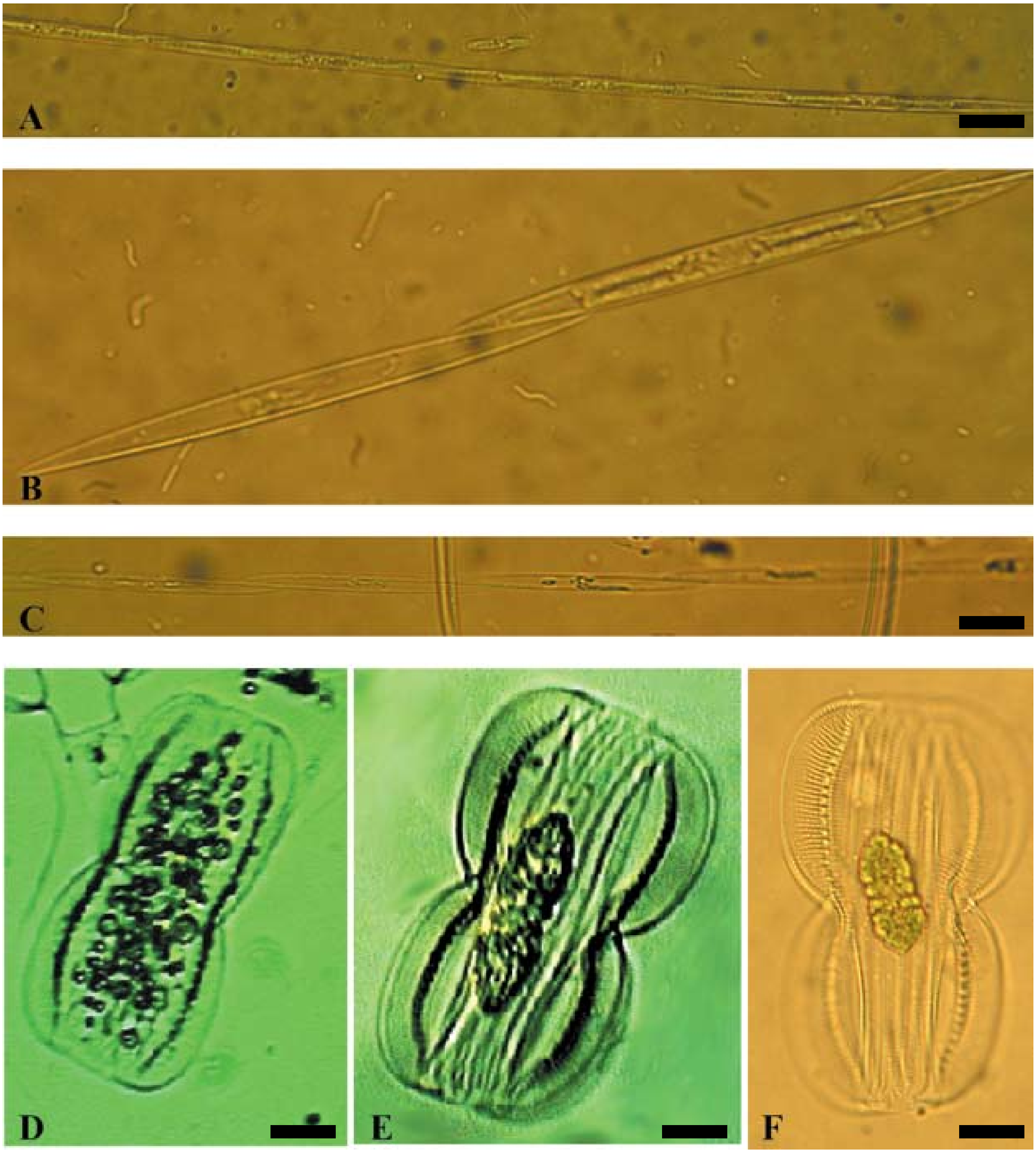

Plate 77. Light micrographs of A-B. *Peudo-nitzschia seriata* group: another chains of different cells varied in size; C. *Peudo-nitzschia delicatissima* group: chain of thin cells; D-F. *Entomoneis sulcata*: different cells in valve view: D-E. from preserved material, F. from cleaned material.
(Scale Bars, A=25.00 µm; B=8.33 µm; C=12.50 µm; D=14.67 µm; E=16.67 µm; F=25.00 µm).

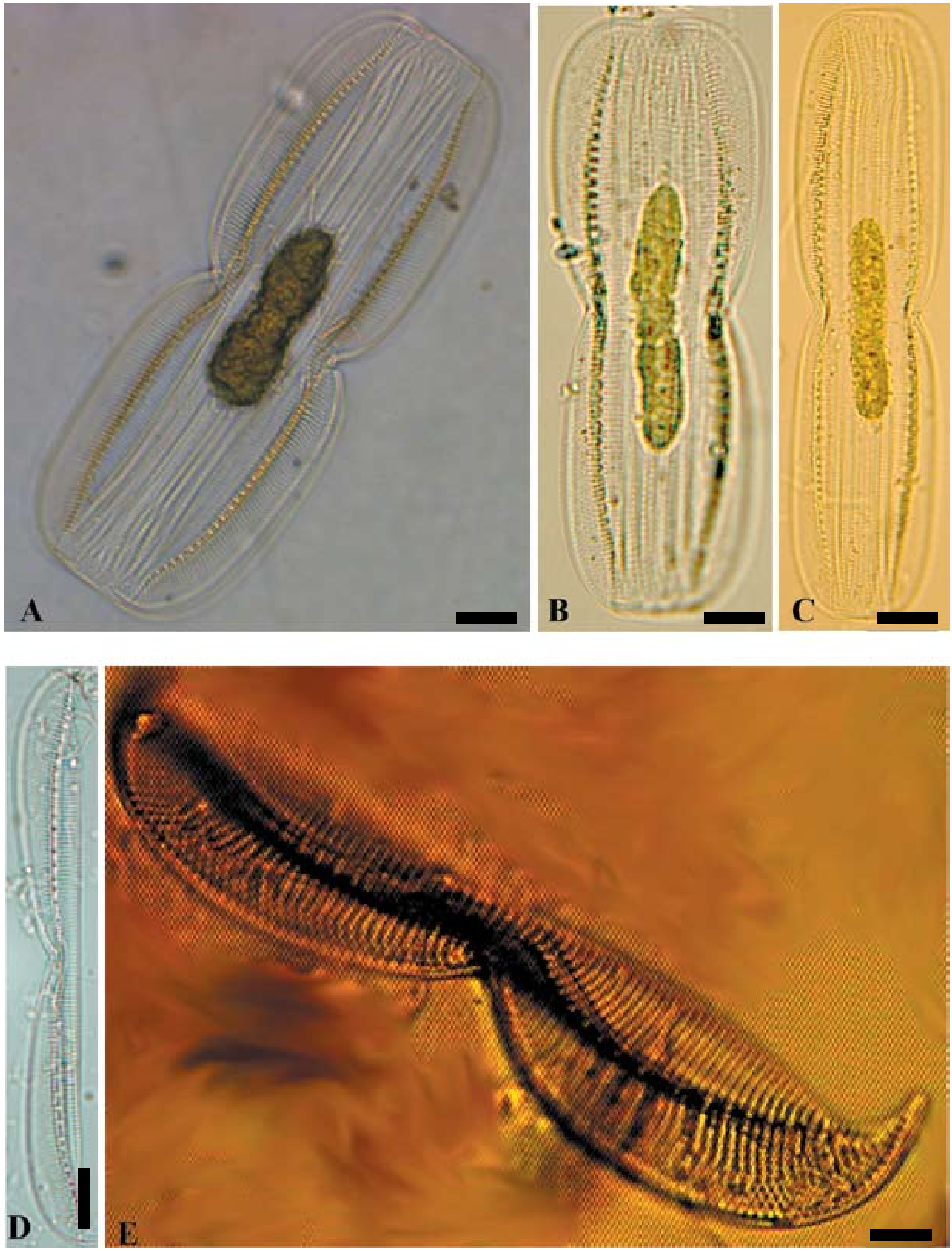

Plate 78. Light micrographs of A-E *Entomoneis sulcata*: A-C. different cells, in valve view with highly constricted in the middle part and large part of chlorophyll in the center of the cell, D-E. in girdle view.
(Scale Bars, A=12.34 µm; B&C=11.50 µm; D=13.10 µm; E=7.33 µm).

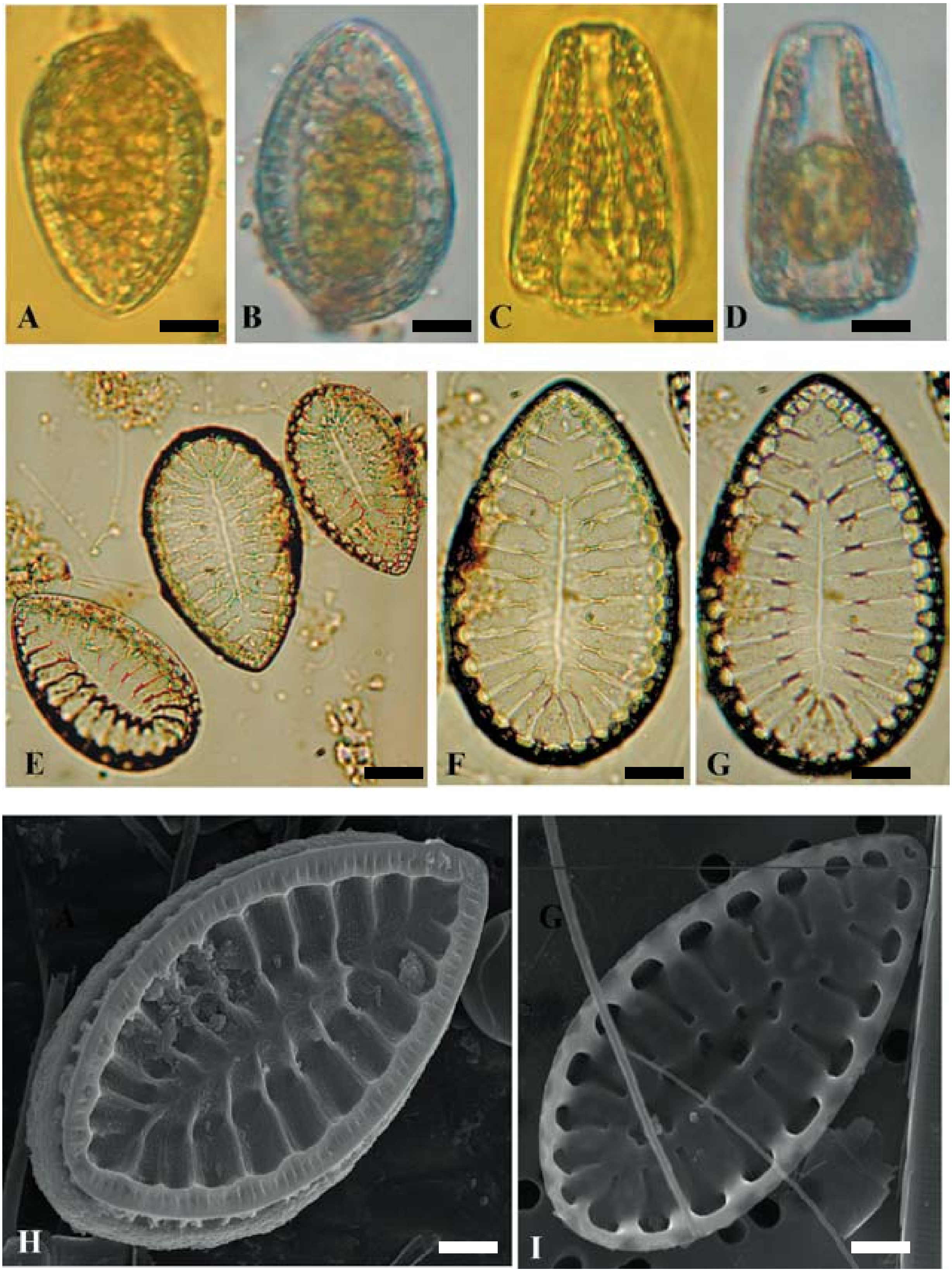

Plate 79. Light micrographs of: A-G. *Surirella fastuosa*: A-D. from preserved material, A-B. valve view, C-D. girdle view; E-G. from cleaned material, H-I. Scanning electron micrographs of different cells of same species.

(Scale Bars, A=7.76 µm; B=7.31 µm; C&D=7.88 µm; E=12.09 µm; F=7.88 µm; G=7.54 µm; H=4.68 µm; I=4.89 µm).

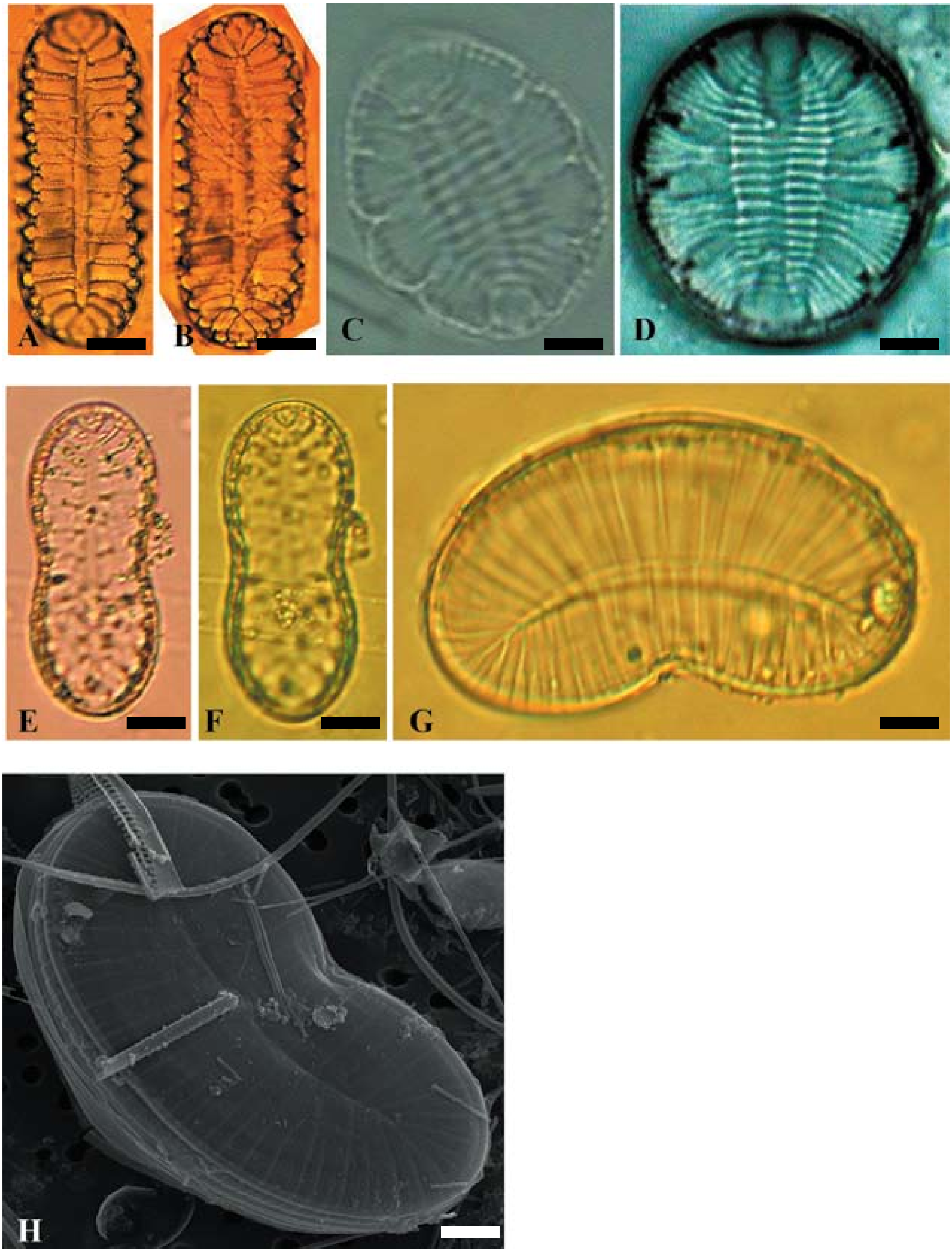

Plate 80. Light micrographs of: A-B. *Surirella* cf. *hybrida*: valve view in different focus; C-D. *Surirella scalaris*: different cells in valve view; E-F. *Surirella* sp.1: the same cell in different focus; G. *Plagiodiscus nervatus*: valve view; H. Scanning electron micrograph of same species.
(Scale Bars, A&B=14.31 µm; C=2.96 µm; D=2.83 µm; E&F=11.56 µm; G=7.44 µm; H=6.85 µm).

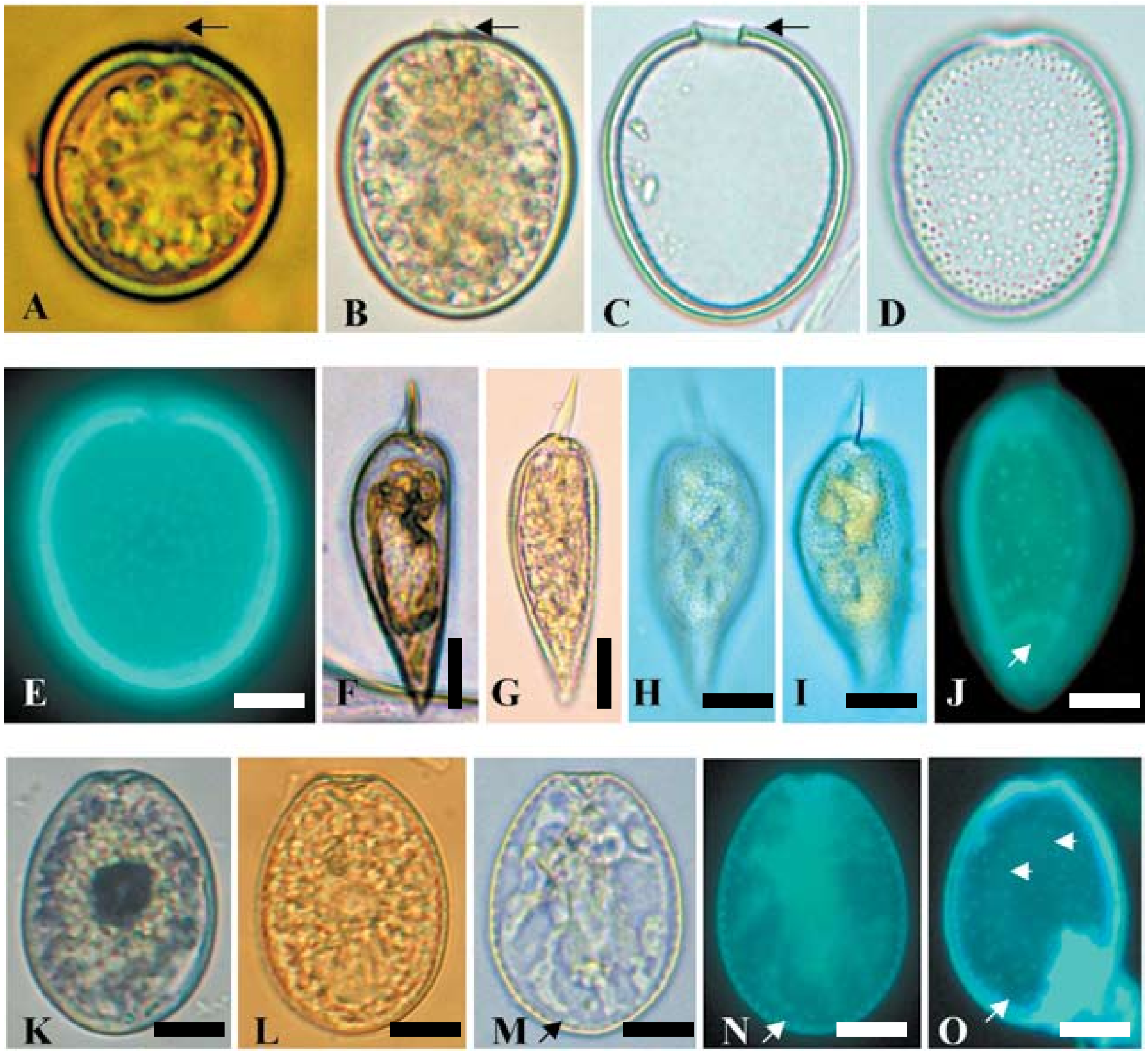

Plate 1. Light micrographs of A. *Prorocentrum balticum*: cell in valve view, the apical spines are just visible (arrow); B-E. *Prorocentrum compressum*: B. cell with chloroplasts, the apical spines are visible (arrow), C. empty valve seen from inside with clearly apical spines (arrow), D-E. showing the valve pores scattered randomly over the valve surface; F-J. *Prorocentrum gracile* in different morphology showing the large apical spines, J. the valve pores forming fine lines (arrow) on the posterior part of the valve; K-O. *Prorocentrum lima* in different views, K-L. note the conspicuous central pyrenoid, M-N. the arrow points to the marginal pores, O. cell in right valve view showing the valve pores scattered on the valve surface (arrow) and the marginal pores (arrows). (Figs A-D, F-I and K-M, LM, bright field; E, J and N-O, LM, epifluorescence).

(Scale Bars, A=3.14 µm; B-D=9.38 µm; C=9.15 µm; E=10.00 µm; F=13.50 µm; G=13.59 µm; H&I=14.19 µm; J=9.79 µm; K=9.73 µm; L=11.35 µm; M=11.35 µm; N=10.81 µm; O=10.56 µm).

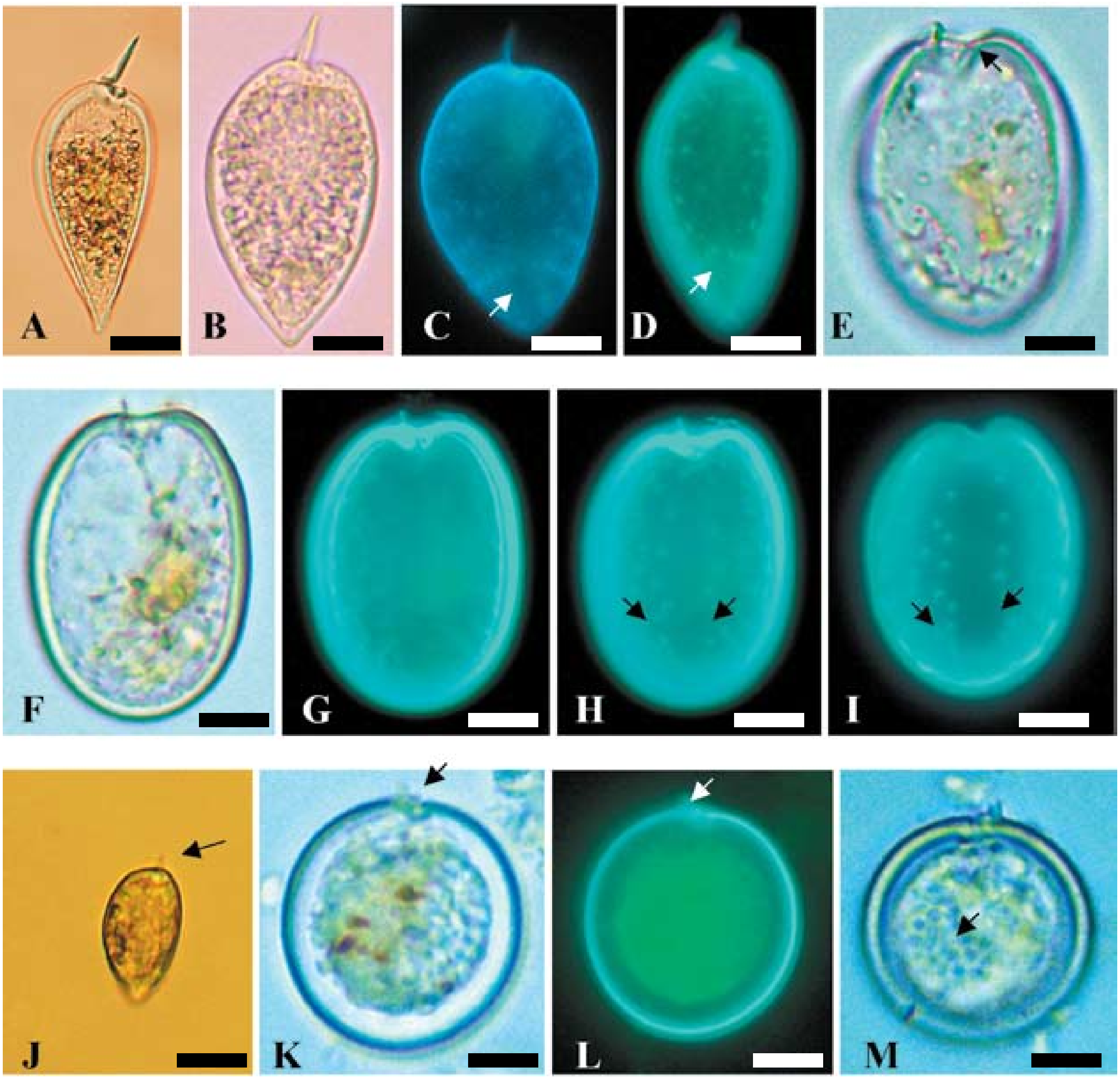

Plate 2. Light micrographs of A-D. *Prorocentrum micans* in different views: A-B. different cells with chloroplast, C-D. shows the valve pores and fine lines more or less perpendicular to the edge of the valve (arrows) formed by these on the posterior part of the valve; E-I. *Prorocentrum rhathymum*: E-G. cell in right valve view, the apical tooth is indicated by an arrow, H-I. two different empty valves showing the valve pores, which form line patterns in the posterior part of the valve; J. *Prorocentrum triestinum*: the small apical tooth is indicated by an arrow; K-M. *Prorocentrum* sp.1: K-L. broad valve view with tiny tooth projection (arrows), M. shows the areolation of the valve surface (arrow). (Figs A-B, E-F, J-K and M, LM, bright field; C-D, G-I and L, LM, epifluorescence).

(Scale Bars, A=10.96 µm; B=10.98 µm; C=10.51 µm; D=10.24 µm; E&F=6.59 µm; G=7.14 µm; H=7.50 µm; I=7.18 µm; J=11.50 µm; K=4.86 µm; L=4.69 µm; M=4.39 µm).

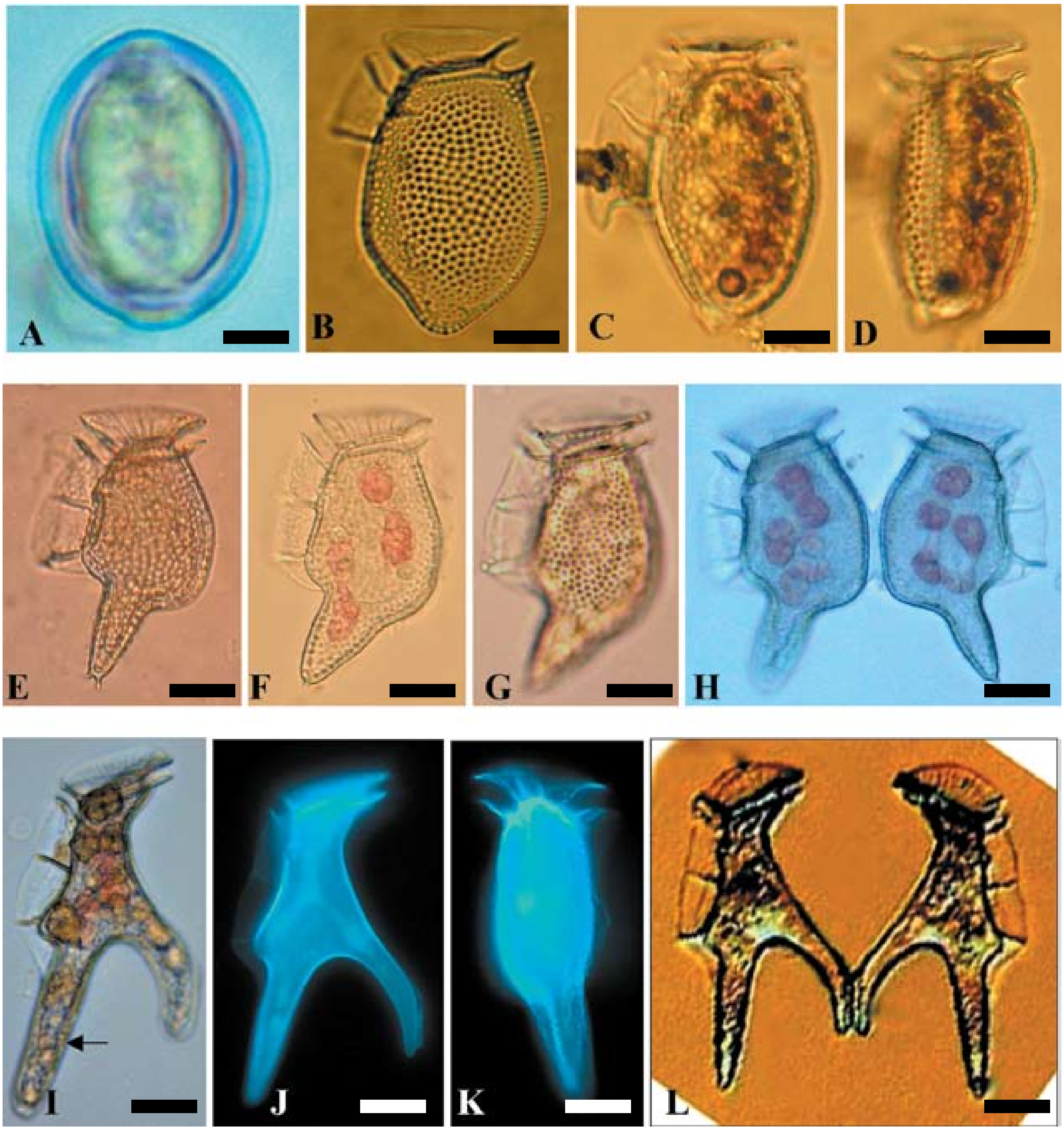

Plate 3. Light micrographs of A. *Prorocentrum* sp.1: cell in lateral view; B-D. *Dinophysis acuta* in different views, B. showing the valve pores scattered on the valve surface, C-D *Dinophysis* sp., D. shows the girdle view of the cell; E-H. *Dinophysis caudata*: different cells in different focus show the variation in size and shape, note particularly the variation in shape of the antapical horn, E-G. left valve view with clearly visible areolated valve surface, H. late division stage with chlorophyll, these stages are often seen in the plankton; I-L. *Dinophysis miles*: different cells in different views, I-J. left valve view shows the straight ventral process (arrow), K. cell in lateral view, L. late division stage, these stages are often seen in the plankton. (Figs A-I and L, LM, bright field; J-K, LM, epifluorescence).
(Scale Bars, A=3.44 µm; B=17.45 µm; C =16.28 µm; D=14.89 µm; E=21.71 µm; F=22.56 µm; G=21.95 µm; H=21.59 µm; I=11.64 µm; J=11.40 µm; K=11.00 µm; L=13.73 µm).

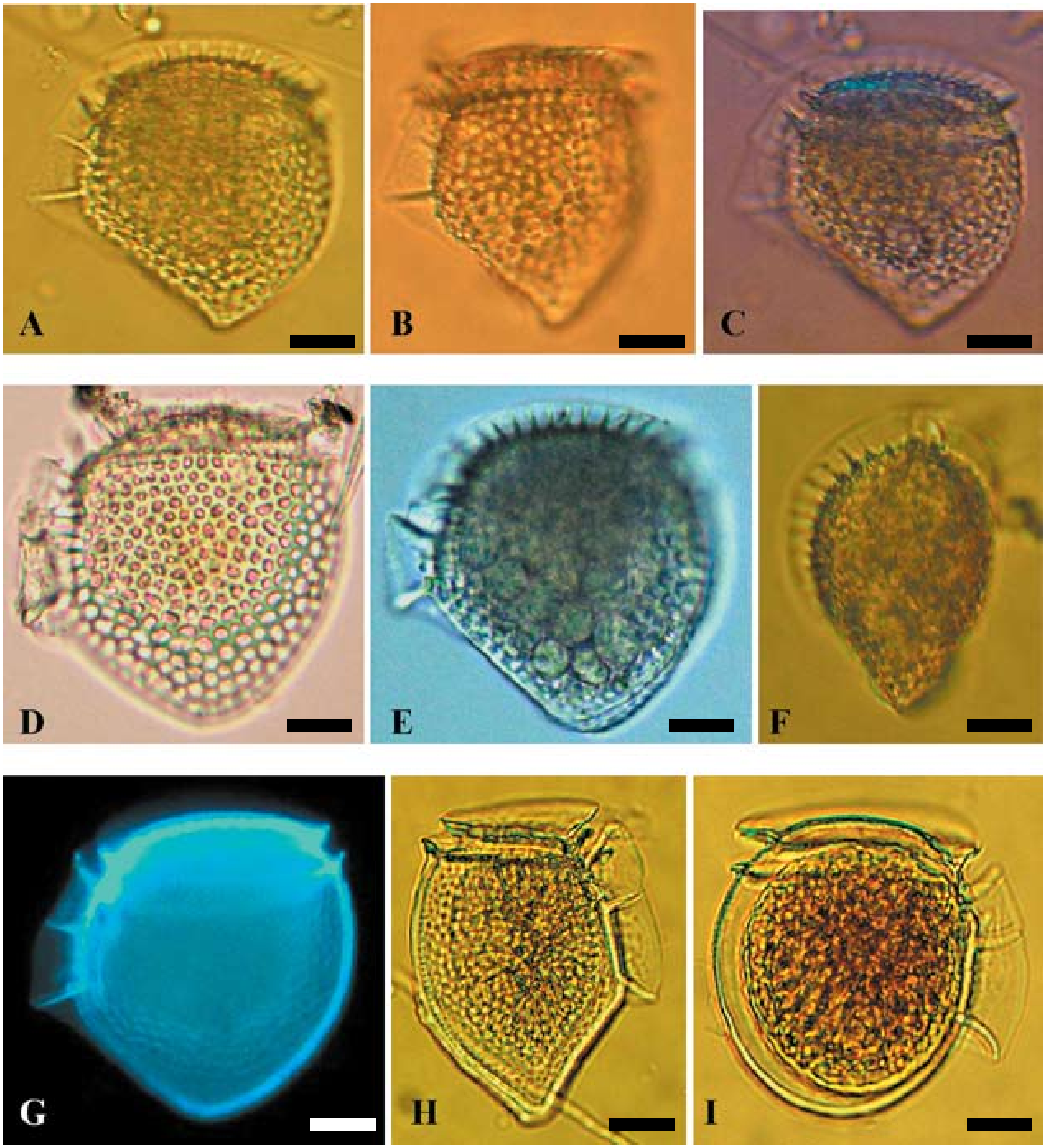

Plate 4. Light micrographs of A-G. *Dinophysis mitra*: different cells in different views showing the broad wedge-shaped form, A-D. note the course reticulation of the thecal plates and the epicone which is visible above the cingulum; A-G. Seen in left value view, except F which shows the cell in the lateral view, E. the cell contents often give a dark brown appearance to this species; H. *Dinophysis norvegica*: right valve view which are clearly pointed at the posterior part; I. *Dinophysis rotundata*: right valve view which are rounded at the posterior part. (Figs A-F and H-I, LM, bright field; G, LM, epifluorescence). (Scale Bars, A=12.00 µm; B=11.93 µm; C=12.50 µm; D=12.80 µm; E=12.28 µm; F=14.63 µm; G=13.19 µm; H=12.00 µm; I=9.90 µm).

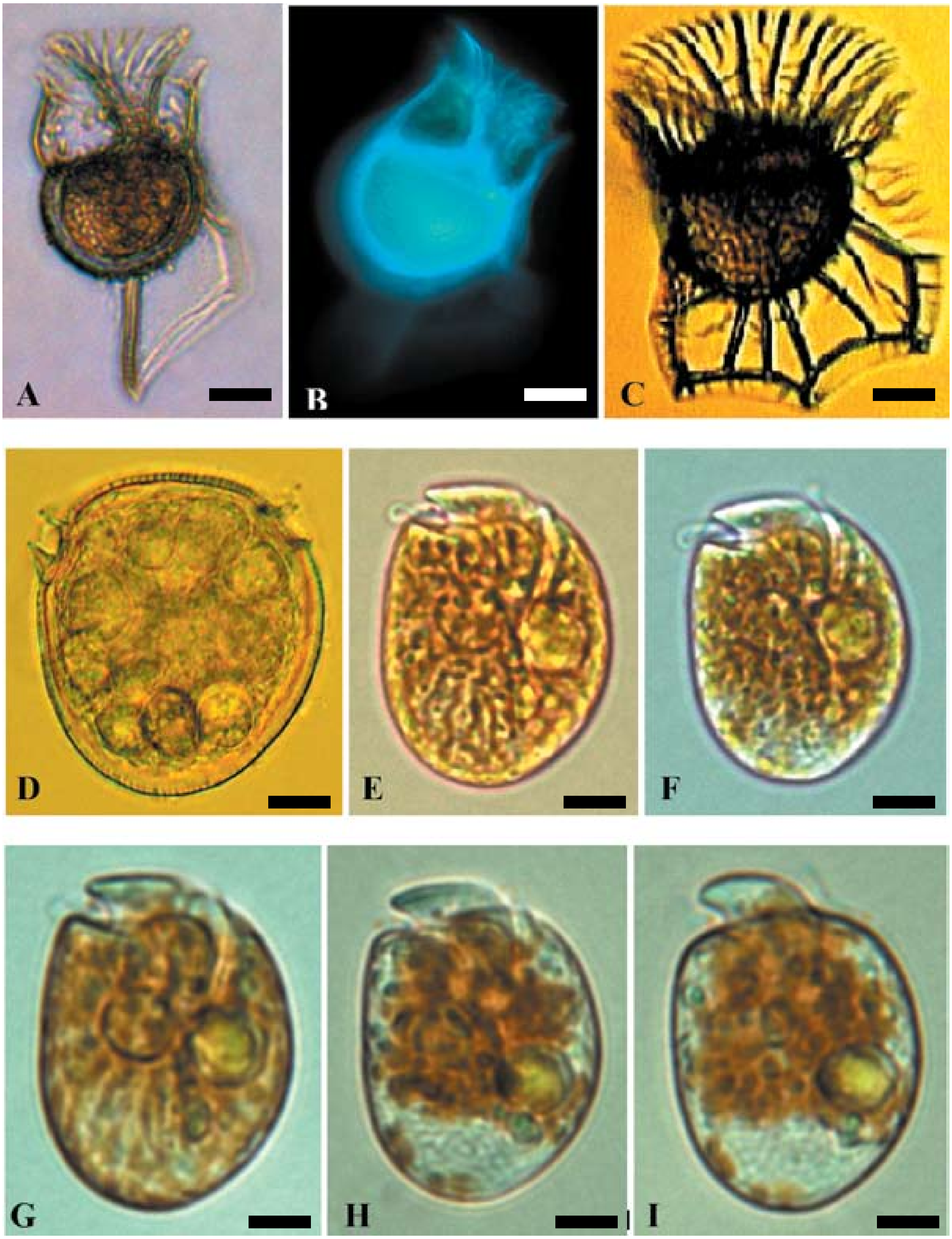

Plate 5. Light micrographs of A-B. *Histioneis costata*: right valve view, the body surface markings of pores or areolae and the anterior girdle list is strongly ribbed; C. *Ornithocercus magnificus*: right valve view with extensive sulcal and cingular list and rib systems, the surface is areolated; D. *Pseudophalacroma nasutum*: cell with chloroplasts; E-I. *Amphidinium* sp. 1: E-F. same cell with clearly visible flagella, food vacuole and nucleus, G-I. another cell. (Figs A and C-I, LM, bright field; B, LM, epifluorescence). (Scale Bars, A=13.11 µm; B=6.70 µm; C=12.92 µm; D=9.23 µm; E=3.67 µm; F=3.40 µm; G&I=3.33 µm; H=3.53 µm).

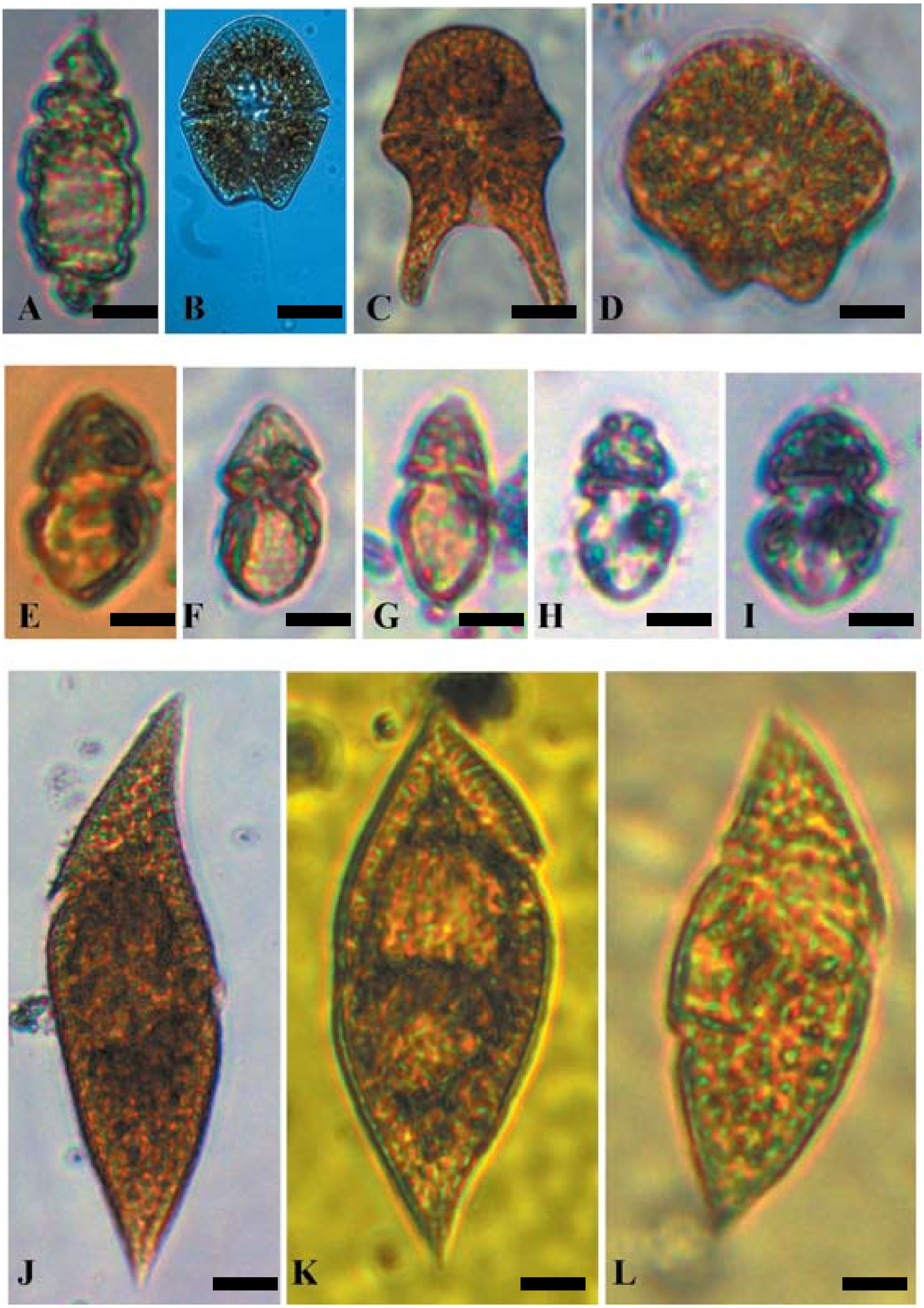

Plate 6. Light micrographs of A. *Cochlodinium* sp. 1: showing the cell shape; B-D. *Akashiwo sanguinea*: B. the typical cellular form of live cell which are taken from the culture with clearly visible flagellum, C-D. from the preserved sample; E-I. *Gymnodinium* spp. cf. cells in different morphological forms; J-L. *Gyrodinium* spp.: the two ends are clearly tapered and the epitheca constitutes the 20% of the cell which characterize this genus, J. *Gyrodinium* sp. 1; K. *Gyrodinium* sp. 2; L. *Gyrodinium* sp. 3. (LM, bright field).

(Scale Bars, A=10.58 µm; B=16.67 µm; C=18.26 µm; D=14.39 µm; E=3.33 µm; F&G=3.23 µm; H=3.00 µm; I=0.33 µm; J=6.09 µm; K=6.29 µm; L=5.35 µm).

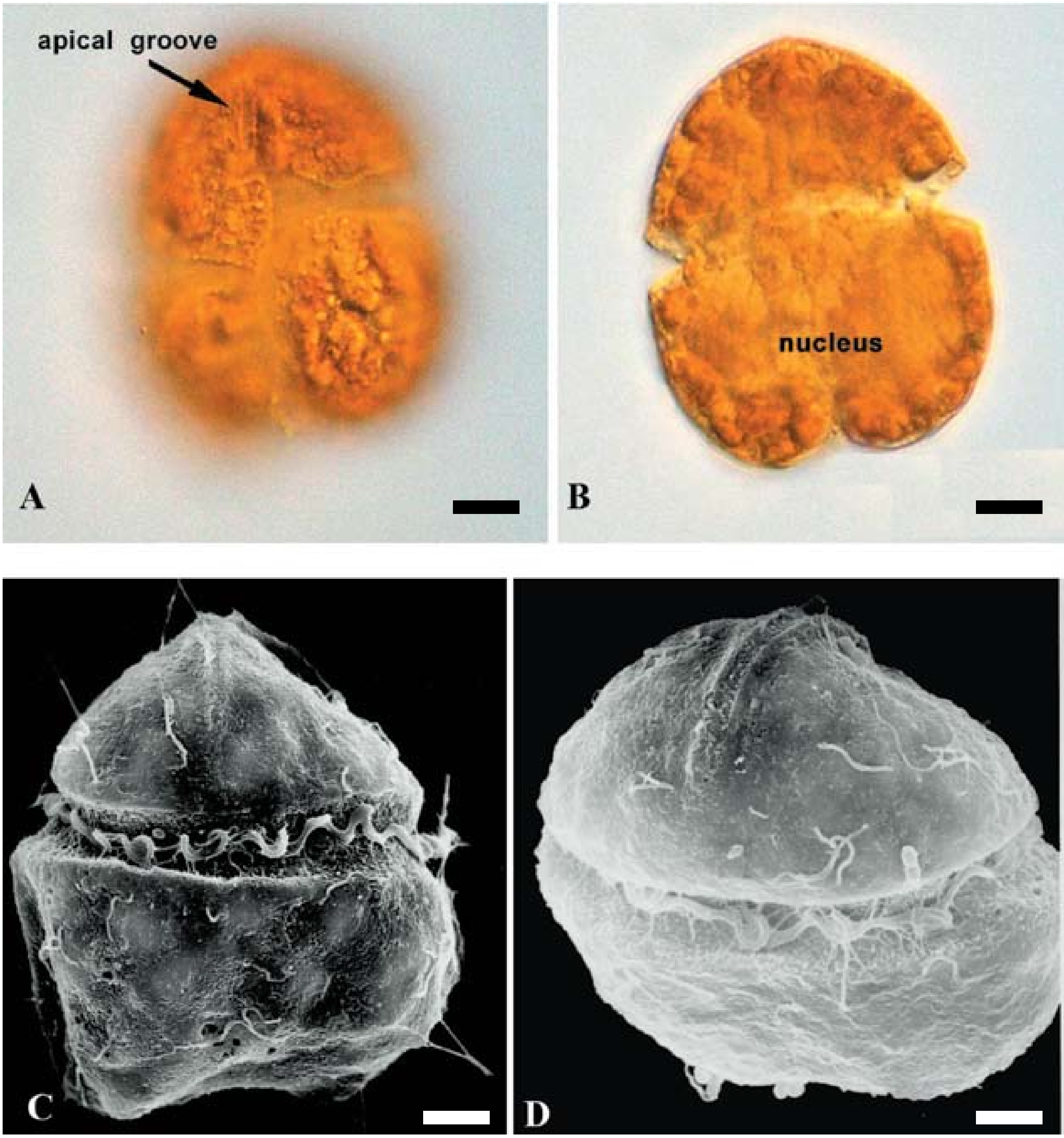

Plate 7. Light micrographs of A-B. *Karenia selliformis*: A. ventral view indicates the straight apical groove; B. dorsal view shows the nucleus in the center (LM, bright field); C-D. Scanning electron micrographs of C-D. K. *selliformis*: dorsal view with clearly visible apical groove, cingulum and transverse flagellum. (Scale Bars, A=4.59 µm; B=4.31 µm; C=3.68 µm; D=3.84 µm).

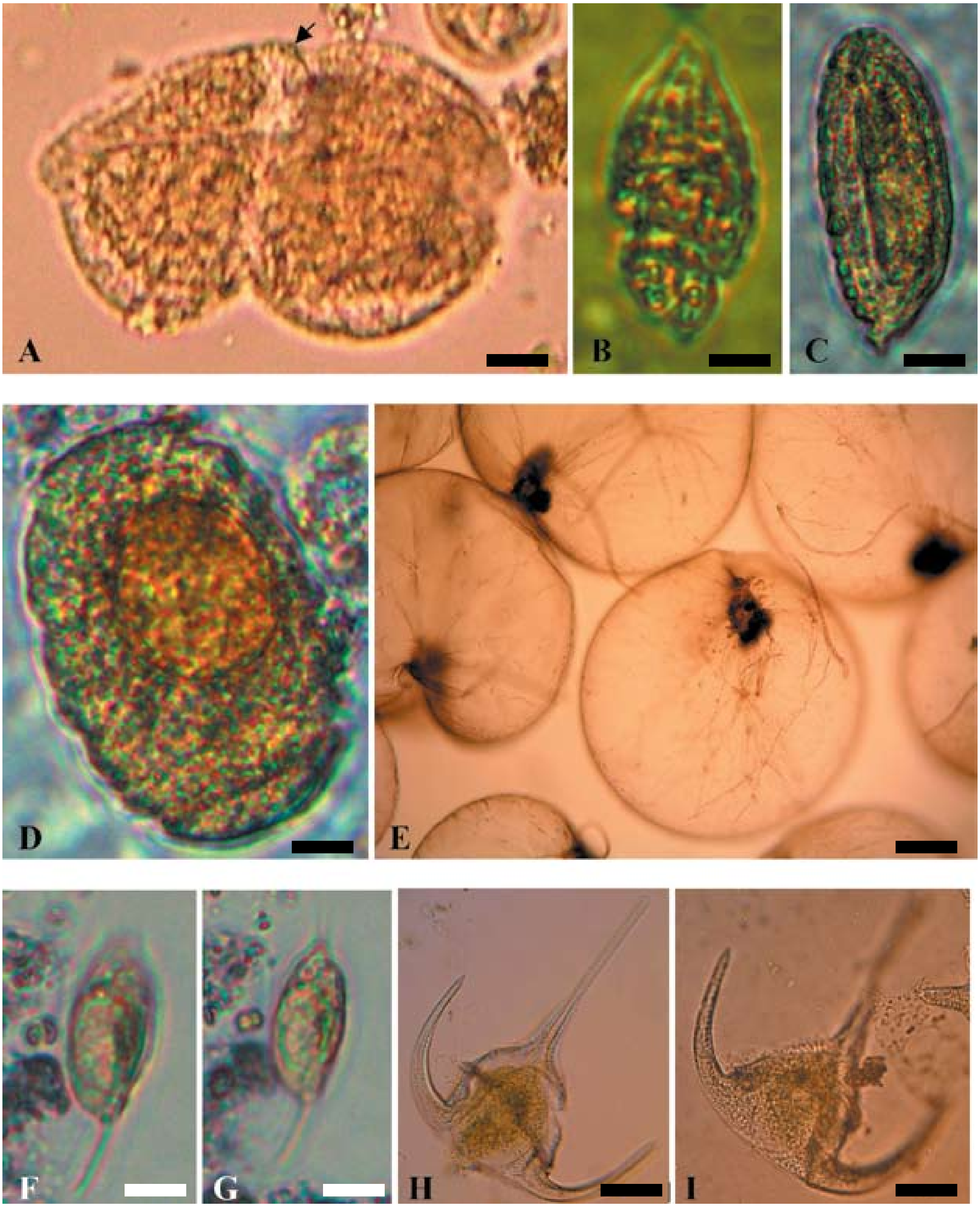

Plate 8. Light micrographs of A. *Karenia* cf. *brevis*: A broad cell with clearly visible small cap at the top of the epitheca; B. *Katodinium glaucum*; C. *Torodinium robustum*; D. *Polykrikos schwartzi*: with colonial organization consisting of 8 gymnodinioid individuals joined in a chain; E. *Noctiluca scintillans*: a bloom of live cells with very deep sulcus forming an apical trough and clearly visible longitudinal flagellum; F-G. *Pronoctiluca pelagica*: with anterior tentacle; H-I. *Ceratium breve*. (LM, bright field).
(Scale Bars, A=2.44 µm; B=2.84 µm; C=5.00 µm; D=15.22 µm; E=150.00 µm; F=10.00 µm; G=11.11 µm; H=23.53 µm; I=36.36 µm).

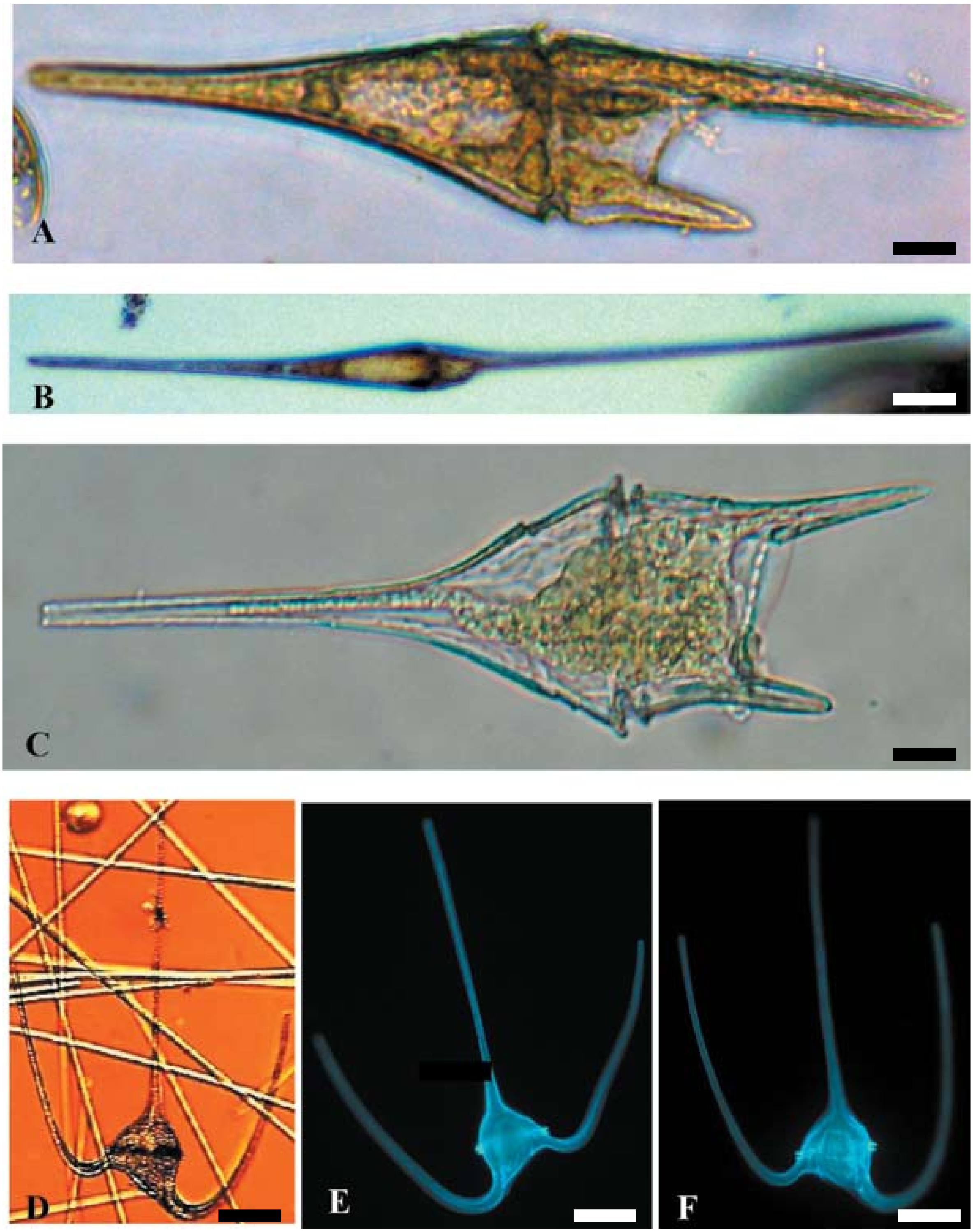

Plate 9. Light micrographs of A. *Ceratium furca*: the epitheca tapering into apical horn and the antapicals are strong, unequal and straight; B. *Ceratium fusus*: with gently tapering apical horn and left long antapical which is slightly curved; C. *Ceratium lineatum*: epitheca forming equilateral triangle with a sharp transition into long apical horn and the hypotheca has two unequal antapical horns which are straight but diverge slightly; D-F. *Ceratium massiliense*: long apical horned and the antapicals arising at right angles to each other, then bending sharply through a right angle and becoming straight or curved. (Figs A-D, LM, bright field; E-F, LM, epifluorescence).
(Scale Bars, A=10.73 µm; B=25.00 µm; C=5.73 µm; D=50.00 µm; E=62.73 µm; F=47.69 µm).

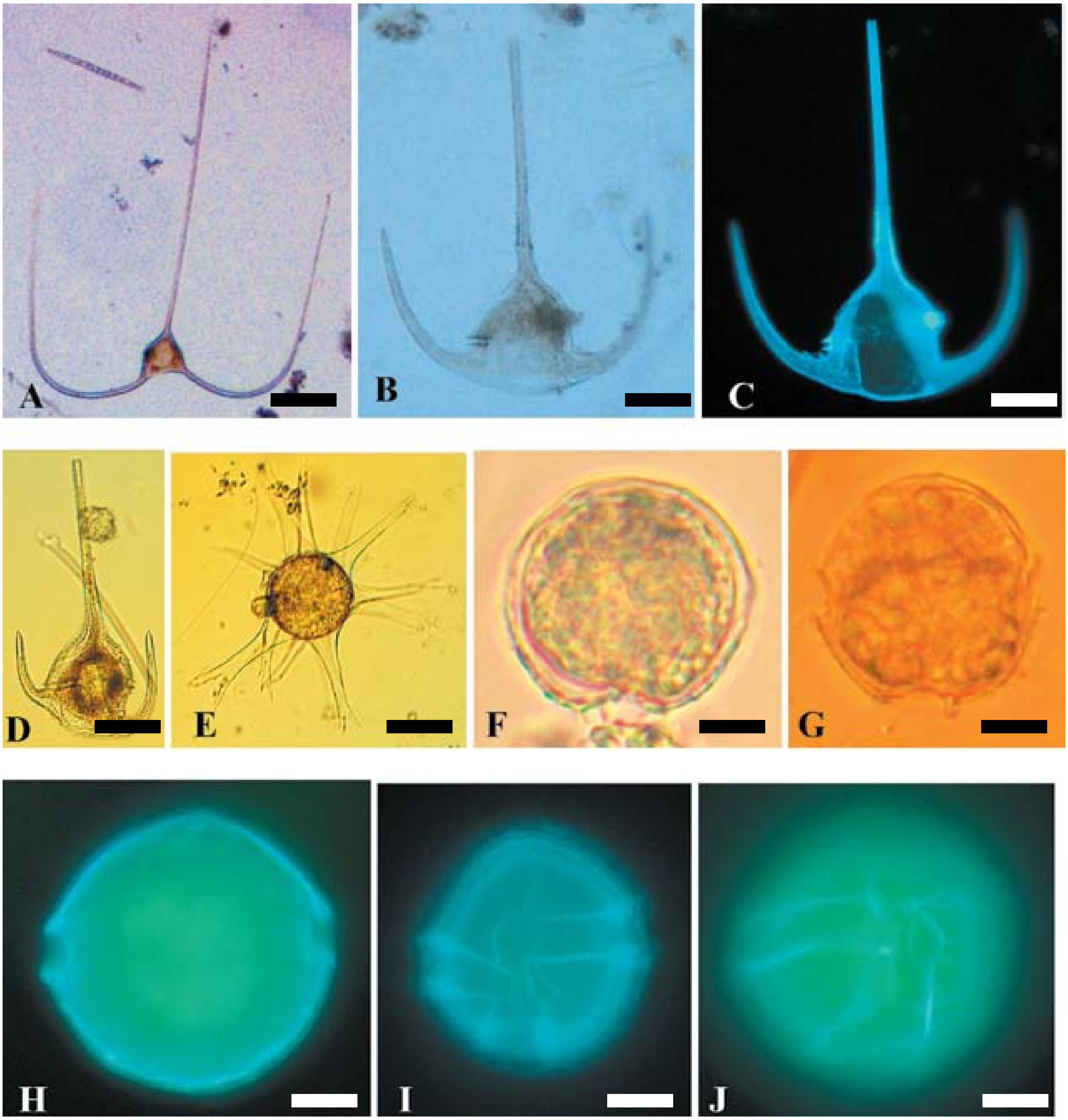

Plate 10. Light micrographs of A. *Ceratium trichoceros*: small body, the antapicals beginning parallel to girdle and curved until they parallel with apical horn forming a flat-bottmed U; B-C. *Ceratium tripos*: cell body broad as its long, the epitheca leading sharply into long straight horn, the antapicals continuous with slightly flattened base, then sharply curved forward making an acute angle with apical horn; D. *Ceratium* sp. 1: the cell body is rounded with two antapicals one is shorter than the other; E. *Cladopyxis hemibrachiata*: ovate to spherical cell with branched spines or processes; F-J. *Alexandrium insuetum*: F-H. cell in ventral view showing the cell shape, I-J. ventral view showing the cingular displacement and sulcus. (Figs A-B and D-G, LM, bright field; C and H-J, LM, epifluorescence).
(Scale Bars, A=70.00 μm; B=43.75 μm; C=41.67 μm; D=57.14 μm; E=61.54 μm; F=7.71 μm; G=8.00 μm; H=6.51 μm; I=7.14 μm; J=5.56 μm).

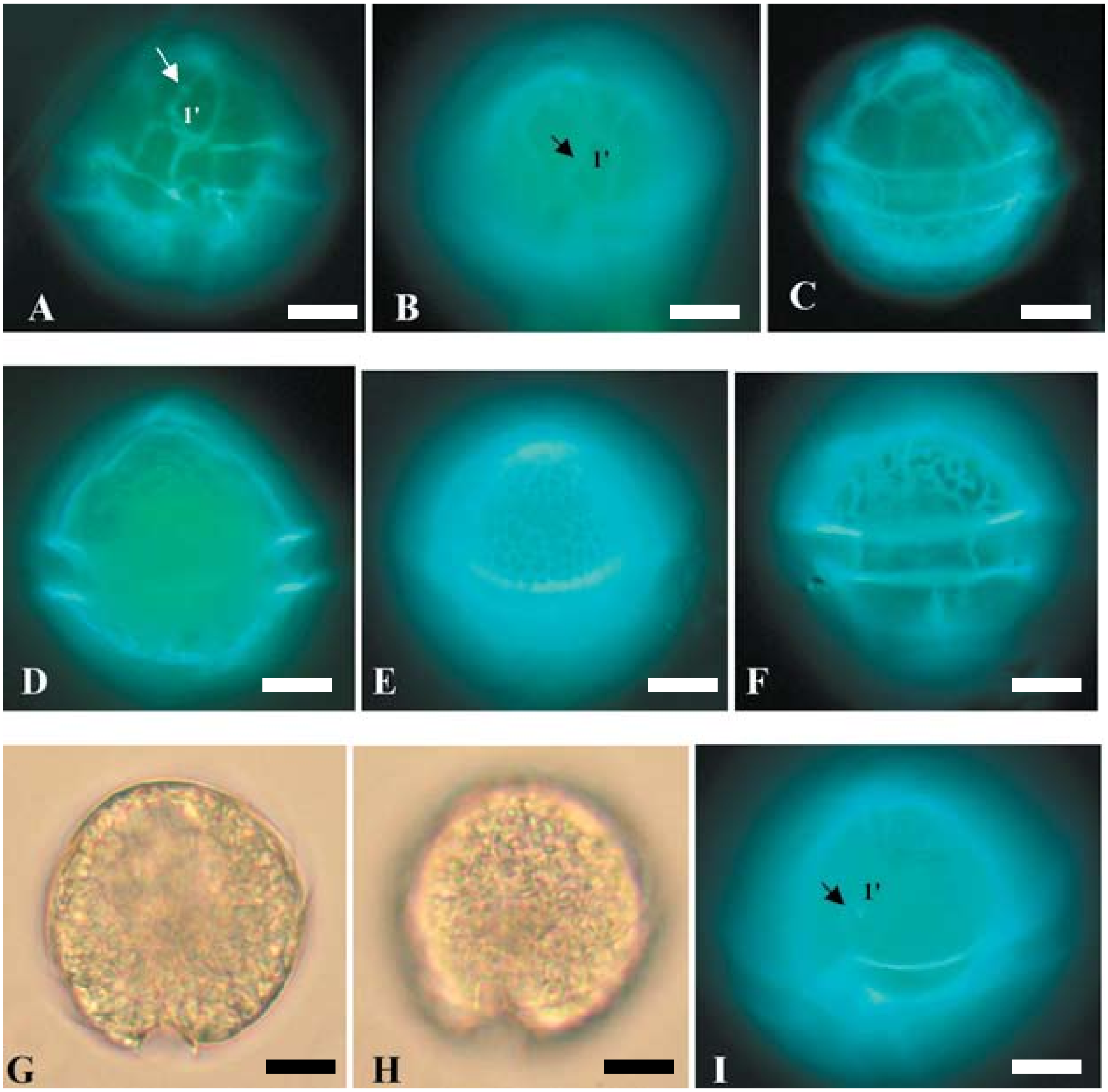

Plate 11. Light micrographs of A-F. *Alexandrium insuetum*: A-B. ventral view showing small ventral pore on the first apical plate at the middle of the right margin adjoining the 4’ plate (arrows), C-F. showing the pronounced reticulation of the thecal plates at different sides of the cell; G-I. *Alexandrium leei*: G-H. ventral view showing the cell shape, I. ventral view showing the position of ventral pore inside the 1’ plate with an arrow (Figs G-H, LM, bright field; A-F and I, LM, epifluorescence).
(Scale Bars, A&C =6.76 μm; B,D-F= 6.25 μm; G=10.26 μm; H&I=10.00 μm).

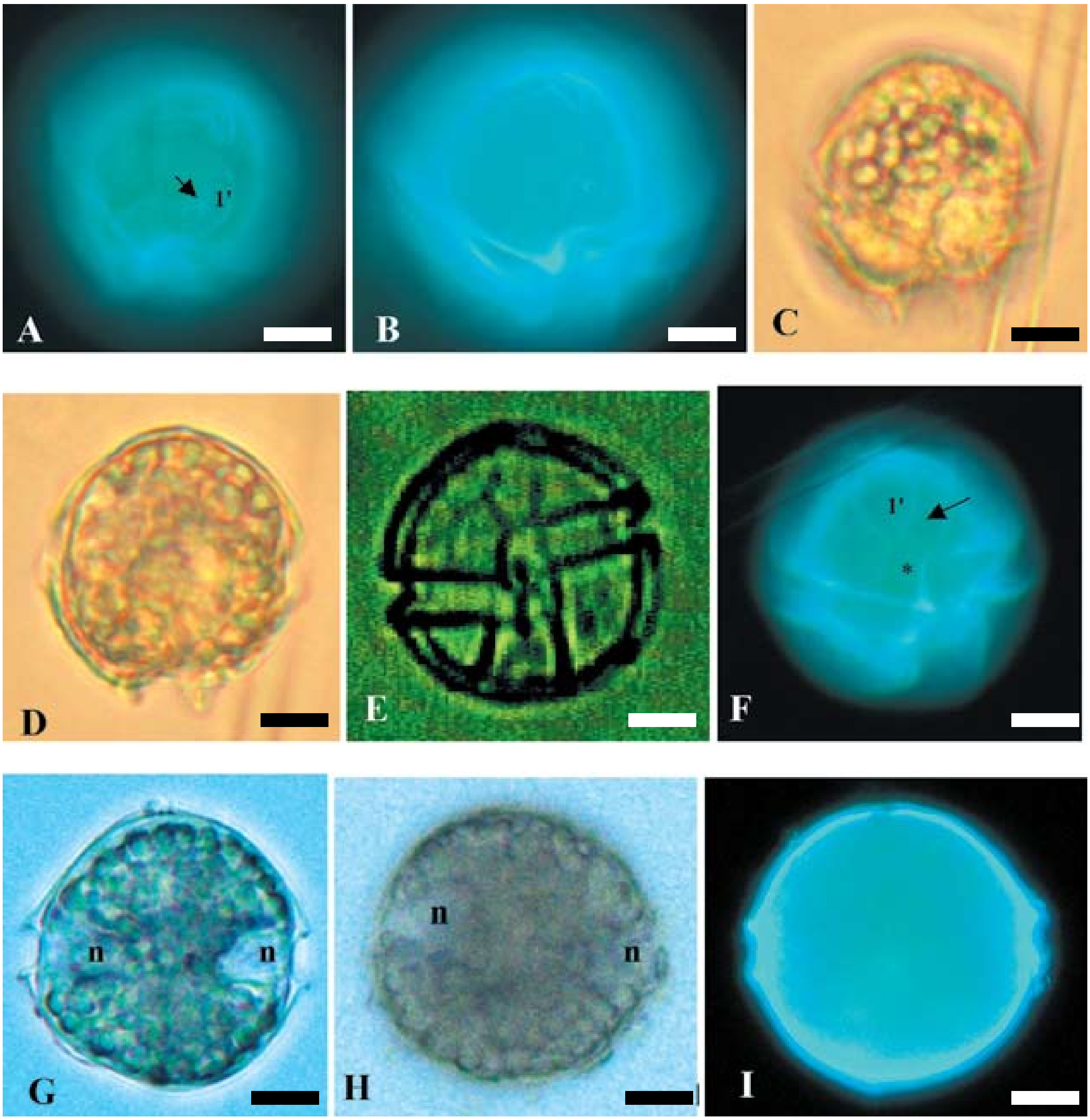

Plate 12. Light micrographs of A-B. *Alexandrium leei*: ventral view showing the position of ventral pore inside the 1' plate; C-F. *Alexandrium minutum*: C-D. ventral view showing the cell shape, E. ventral view showing the cell shape, plates and the cingular displacement, F. cell in side of ventral view showing the 1' plate with the ventral pore (arrow), the narrow 6'' plate (as terisks); G-I. *Alexandrium tamarense*: G-H. nucleus (n), I. showing the cell shape (Figs C-E and G-H, LM, bright field; A-B, F and I, LM, epifluorescence).
(Scale Bars, A=12.67 µm; B=10.56 µm; C=6.67 µm; D=5.95 µm; E=5.00 µm; F=5.95 µm; G=9.76 µm; H=9.52 µm; I=9.32 µm).

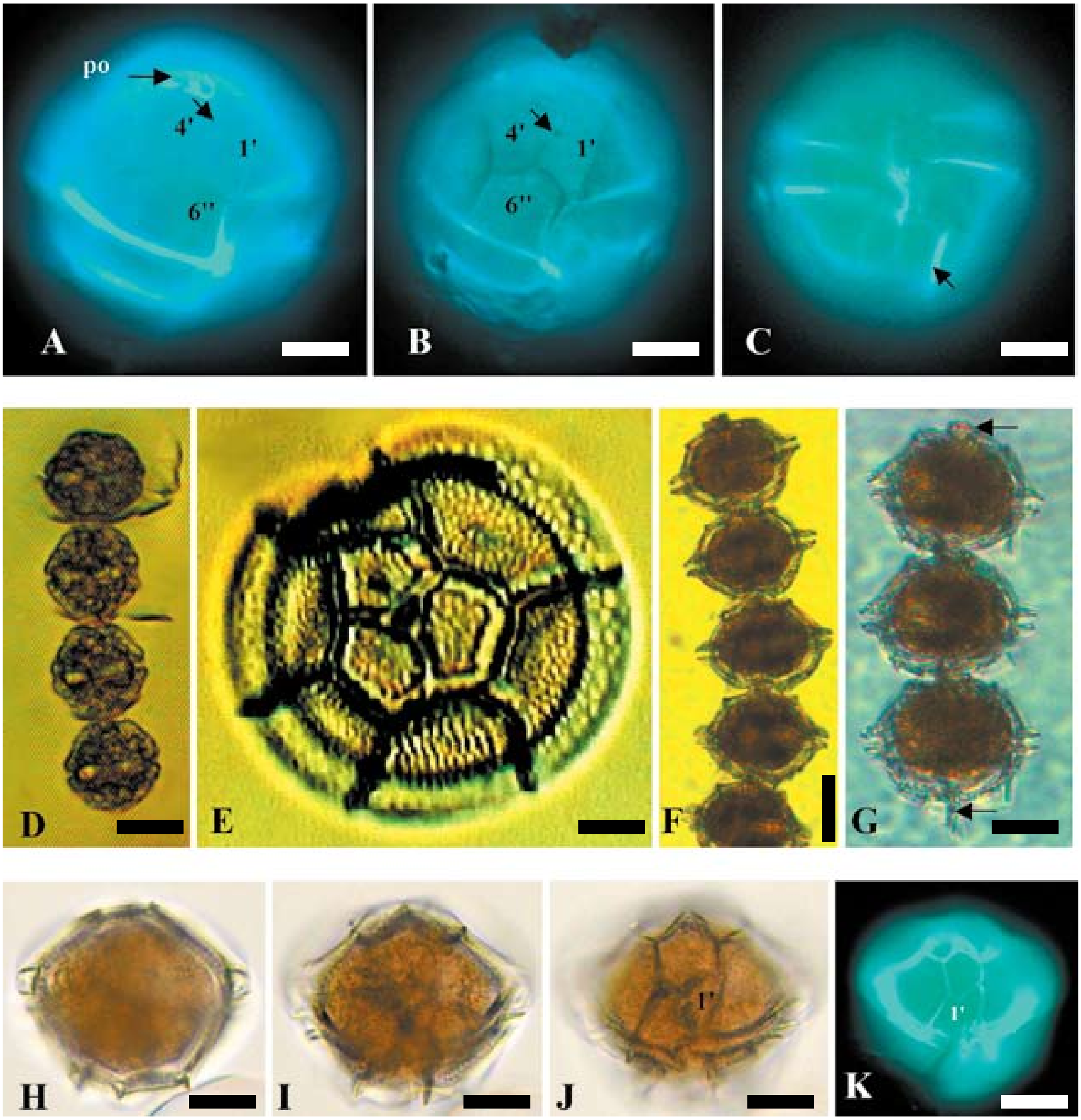

Plate 13. Light micrographs of A-C. *Alexandrium tamarense*: A-B. ventral pore indicated by arrows and the apical pore is indicted on A, C. the left sulcal wing or list with an arrow; D. *Alexandrium* sp.1: part of chain; E. *Goniodoma polyedricum*: showing the apical part surrounded by wing, the epitheca is seen here from the inside (mirror-image); F-K. *Pyrodinium bahamense* var. *compressum*: F-G. in different magnification, note the chain-forming habit, G. with a short apical spine and a long antapical spine (arrows), H. Cell in lower focus showing the angular outline, I-J. The same cell in ventral view and in different focus, J-K. The 1'-plate is indicated, (Figs D-J, LM, bright field; A-C and K, LM, epifluorescence).

(Scale Bars, A=8.70 μm; B=9.76 μm; C=9.52 μm; D=23.33 μm; E=14.81 μm; F=31.33 μm; G=22.38 μm; H&I=14.67 μm; J=14.52 μm; K=14.52 μm).

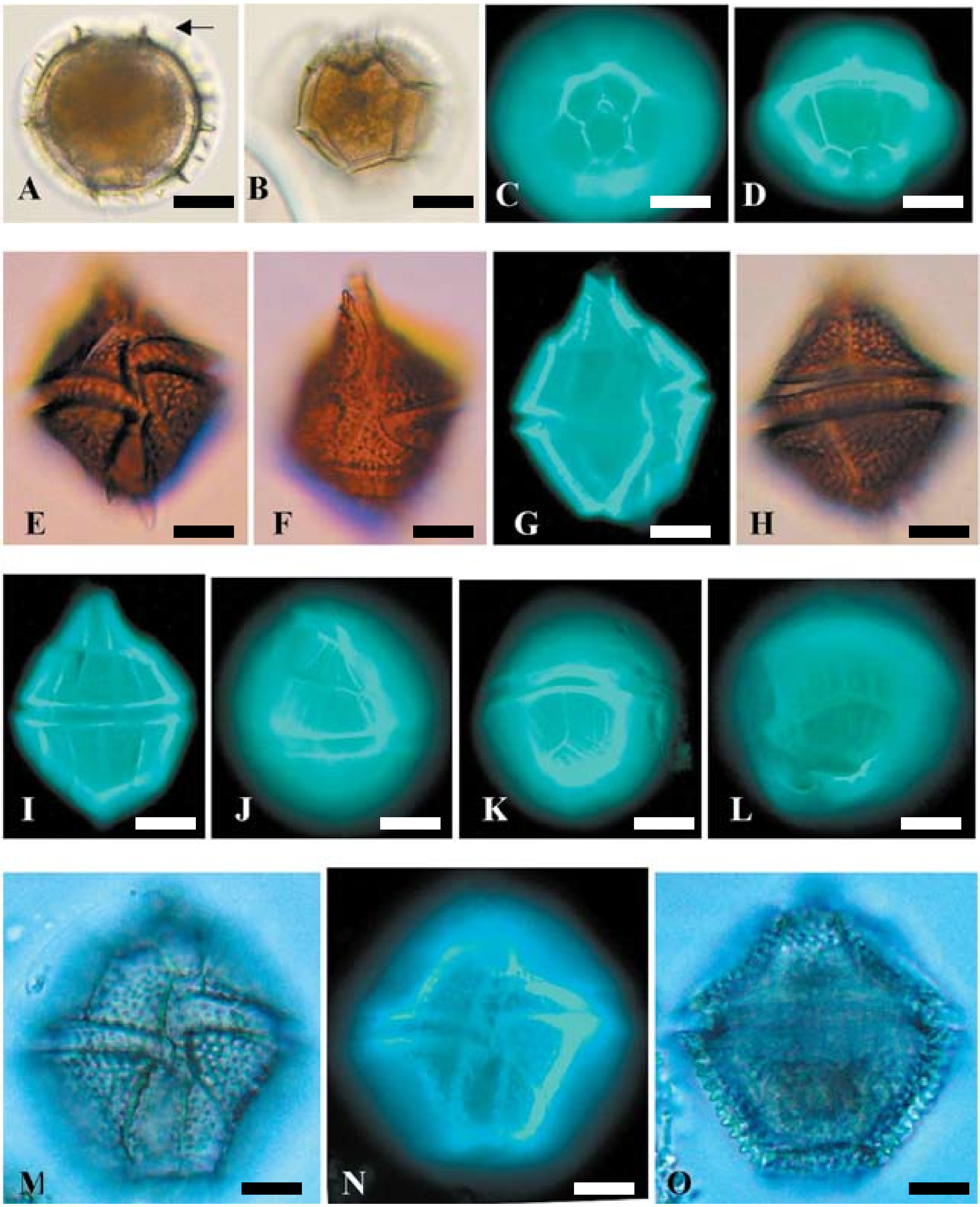

Plate 14. Light micrographs of A-D. *Pyrodinium bahamense* var. *compressum*: A. Apical view, the anterior cingular list is indicated by an arrow, B-C. apical part, D. antapical part; E-I. *Gonyaulax polygramma* in different angles: E. ventral view; F. side of epitheca, G. side of the cell; H-I. dorsal view; J-L. *Gonyaulax* sp.1 in different angles showing narrow lines on the surface; M-O. *Lingulodinium polyedrum* in different views: M-N. ventral view; O. dorsal view. (Figs A-B, C-F, H, M and O, LM, bright field; C-D, G, I-L and N, LM, epifluorescence).
(Scale Bars, A=14.38 µm; B=21.43 µm; C=15.17 µm; D=13.75 µm; E=8.55 µm; F=8.67 µm; G=10.24 µm; H=10.29 µm; I&J=10.00 µm; K=8.79 µm; L=8.06 µm; M&N=11.11 µm; O=10.64 µm).

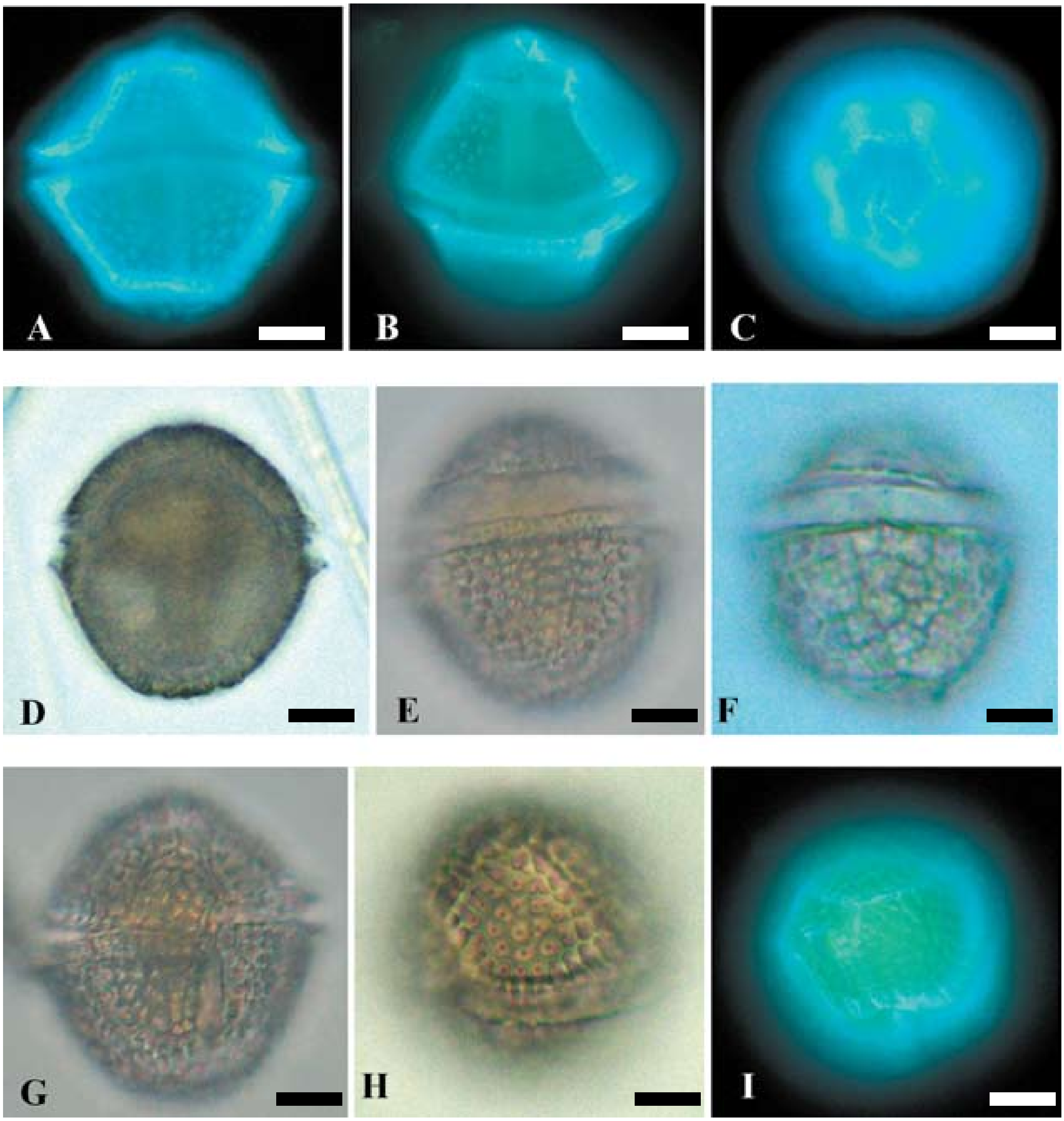

Plate 15. Light micrographs of A-C. *Lingulodinium polyedrum* in different angles: A-B. dorsal view, C. side of epitheca, D. the apical pore; D-I. *Protoceratium reticulatum* in different views: they are clearly areolated (E-I), D. dorsal view, G. ventral view. (Figs D-H, LM, bright field; A-C and I, LM, epifluorescence).

(Scale Bars, A=11.90 µm; B&C=12.20 µm; D=13.28 µm; E=10.98 µm; F=12.50 µm; G=11.71 µm; H=10.49 µm; I=11.17 µm).

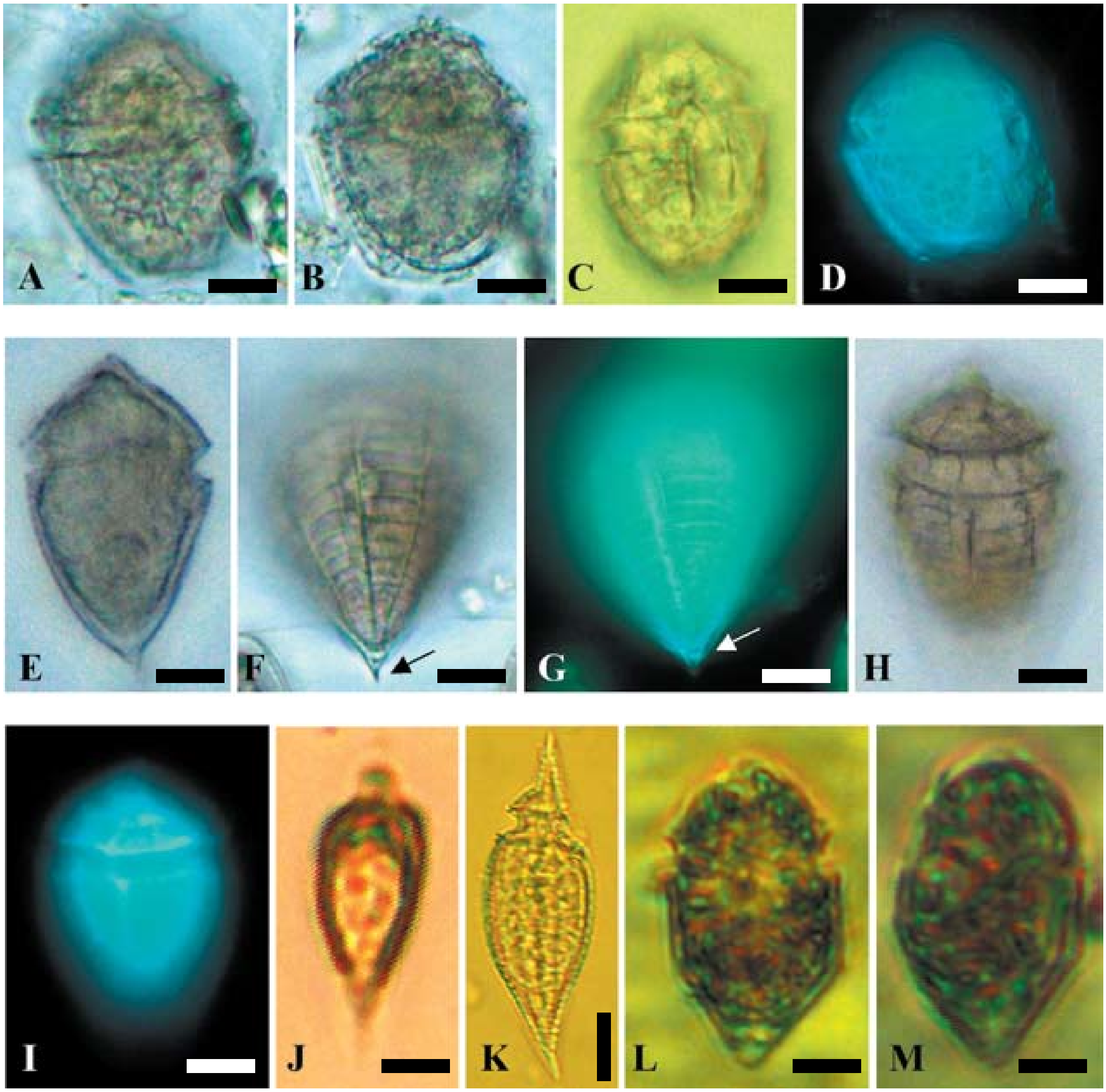

Plate 16. Light micrographs of A-D. *Protoceratium* sp.1; E-I. *Corythodinium tesselatum*: F-G. the thick antapical spine are clearly visible at the end of the cell (arrows), F-H. the cell surface characterize by a horizontal striae; J. *Oxytoxum gracile*: with small projection at the upper of the cell and antapical spine at the end of the cell; K. *Oxytoxum sceptrum*: pointed at the two ends of cell; L-M. *Oxytoxum* sp.1 in different focus. (Figs A-C, E-F, H and J-M, LM, bright field; D, G and I, LM, epifluorescence).
(Scale Bars, A-D=10.26 µm; E=12.50 µm; F&G=12.88 µm; H=14.67 µm; I=16.92 µm; J=6.50 µm; K=11.27 µm; L&M=4.35 µm).

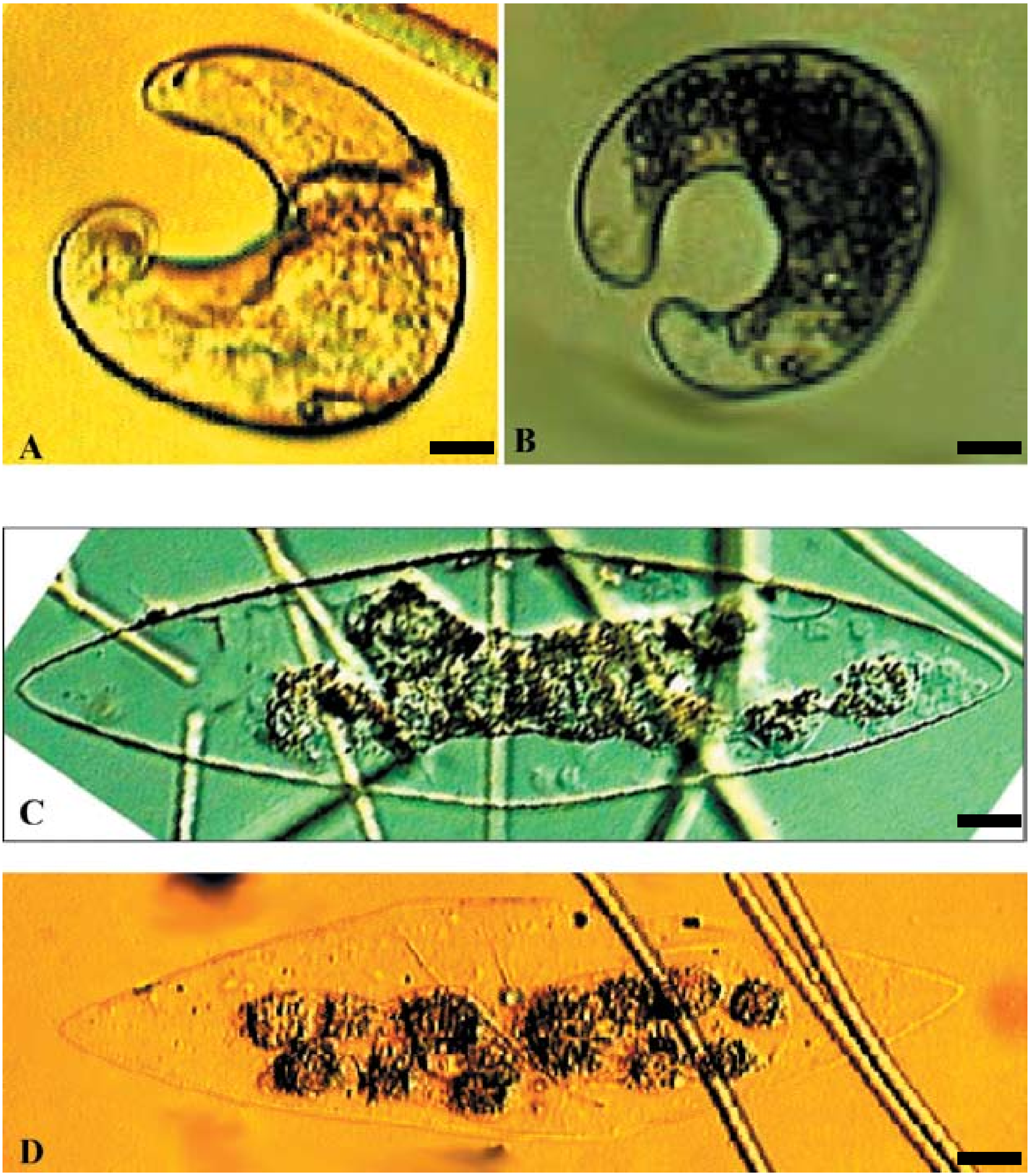

Plate 17. Light micrographs of A-B. *Pyrocystis obtusa*: lunate body with blunt ends directed toward each other; C-D. *Pyrocystis fusiformis*: wider cell with two rounded ends and dead cells inside it (LM, bright field).
(Scale Bars, A=13.14 μm; B=14.83 μm; C=29.62 μm; D=28.52 μm).

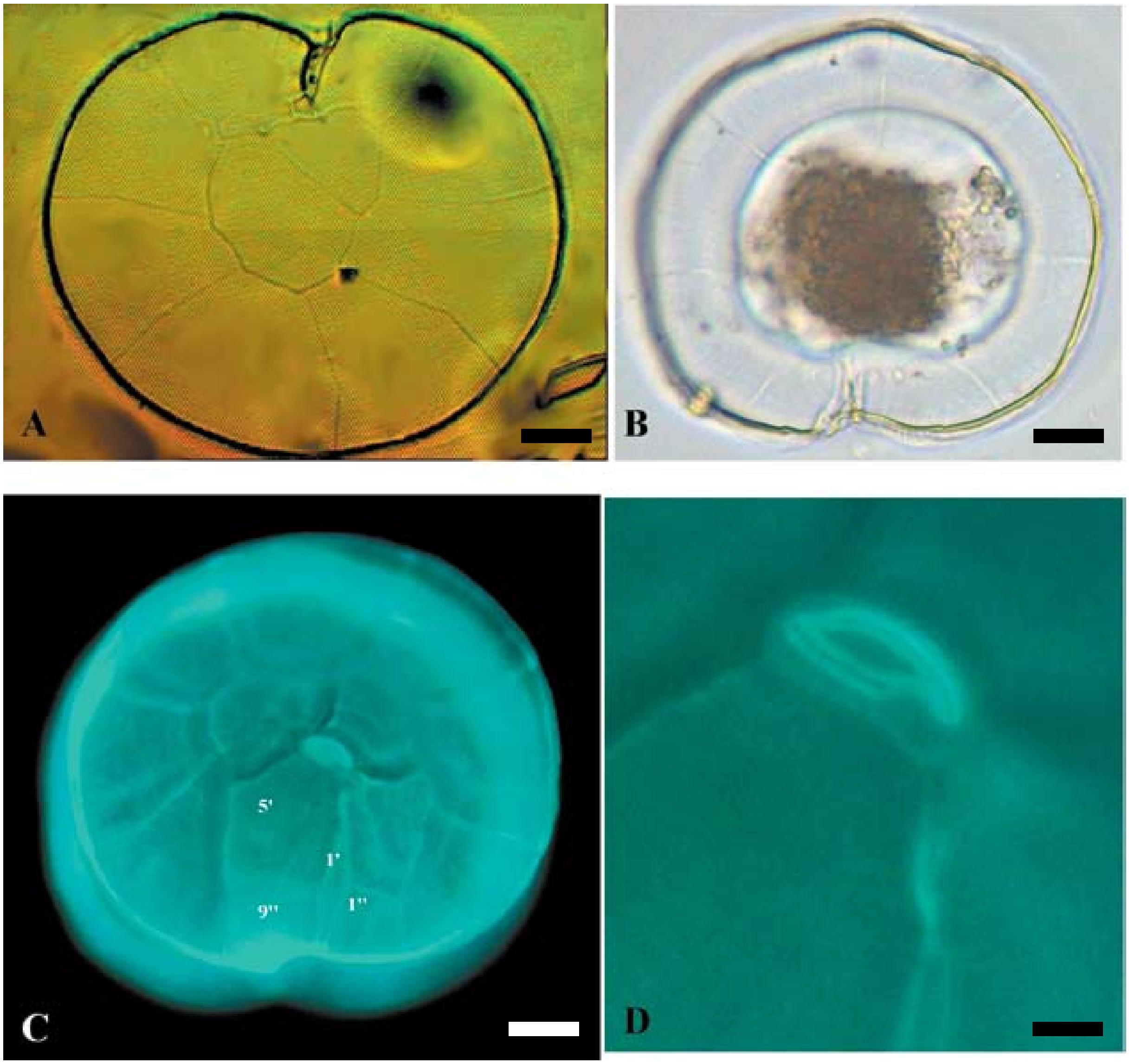

Plate 18. Light micrographs of: A-D. *Pyrophacus horologicum*: A-B. the same cell in apical view; C. the 1', 5' and the 1'', 9'' plates are indicated, D. apical pore area showing the two slit-like in highly magnification (Figs A-B, LM, bright field; C-D, LM, epifluorescence).
(Scale Bars, A=21.62 µm; B=13.48 µm; C=12.71 µm; D=3.29 µm).

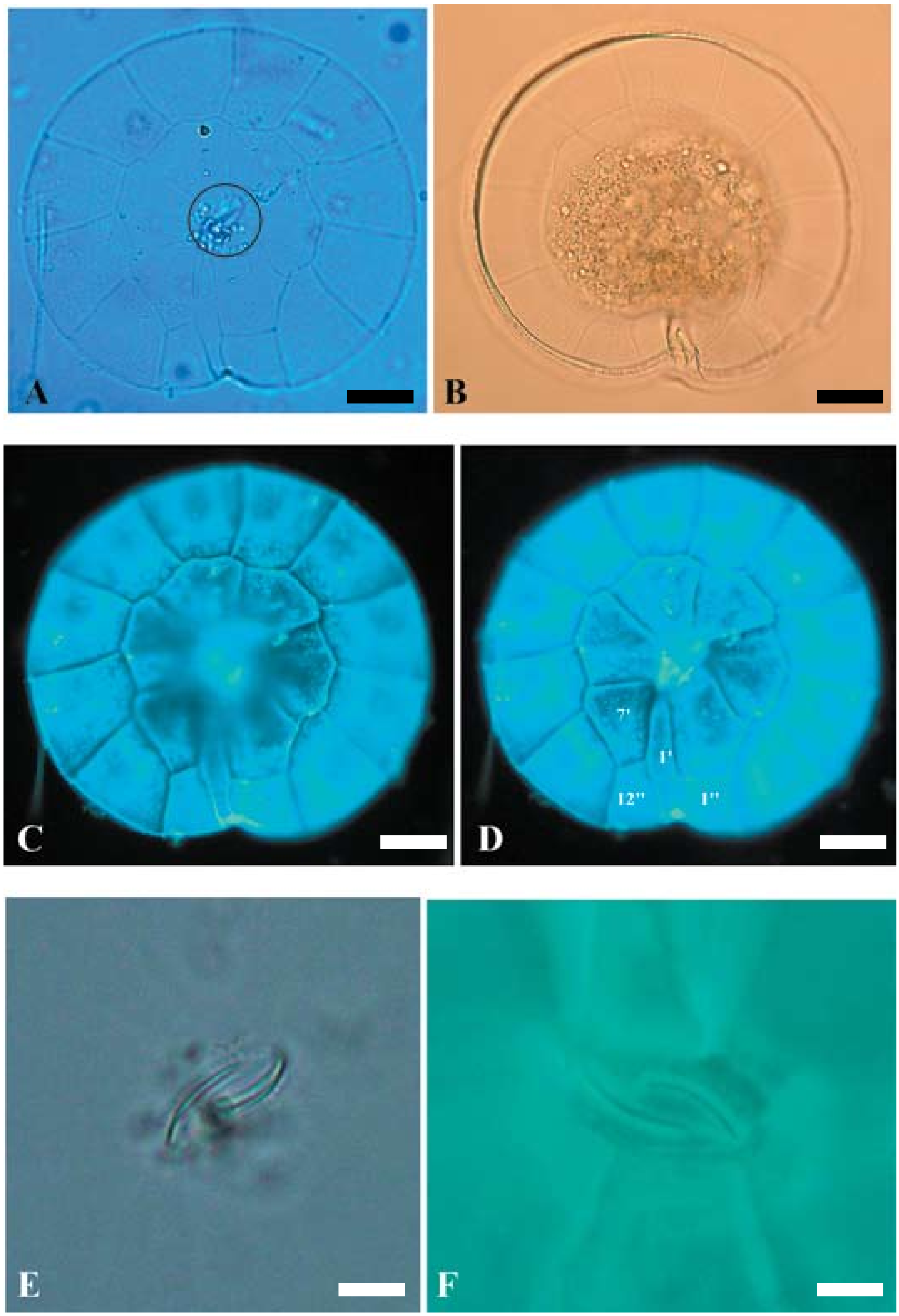

Plate 19. Light micrographs of A-F. *Pyrophacus steinii*: A. cell in apical view, low focus, the plates are barely visible, in higher focus, the apical pore area with the two charac-teristic apical pores becomes visible (indicated by a circle in A), B. apical view of different cell, C-D. same cell of A, apical view, the 1st and 7th apical plates, and the 1st and 12th pre-cingular plates are indicated, E. apical pore area encircled in A, F. apical pore area of a different cell. (Figs A-B and E-F, LM, bright field; C-D, LM, epifluorescence).
(Scale Bars, A=15.83 µm; B=16.81 µm; C=15.57 µm; D=15.83 µm; E=4.45 µm; F=4.90 µm).

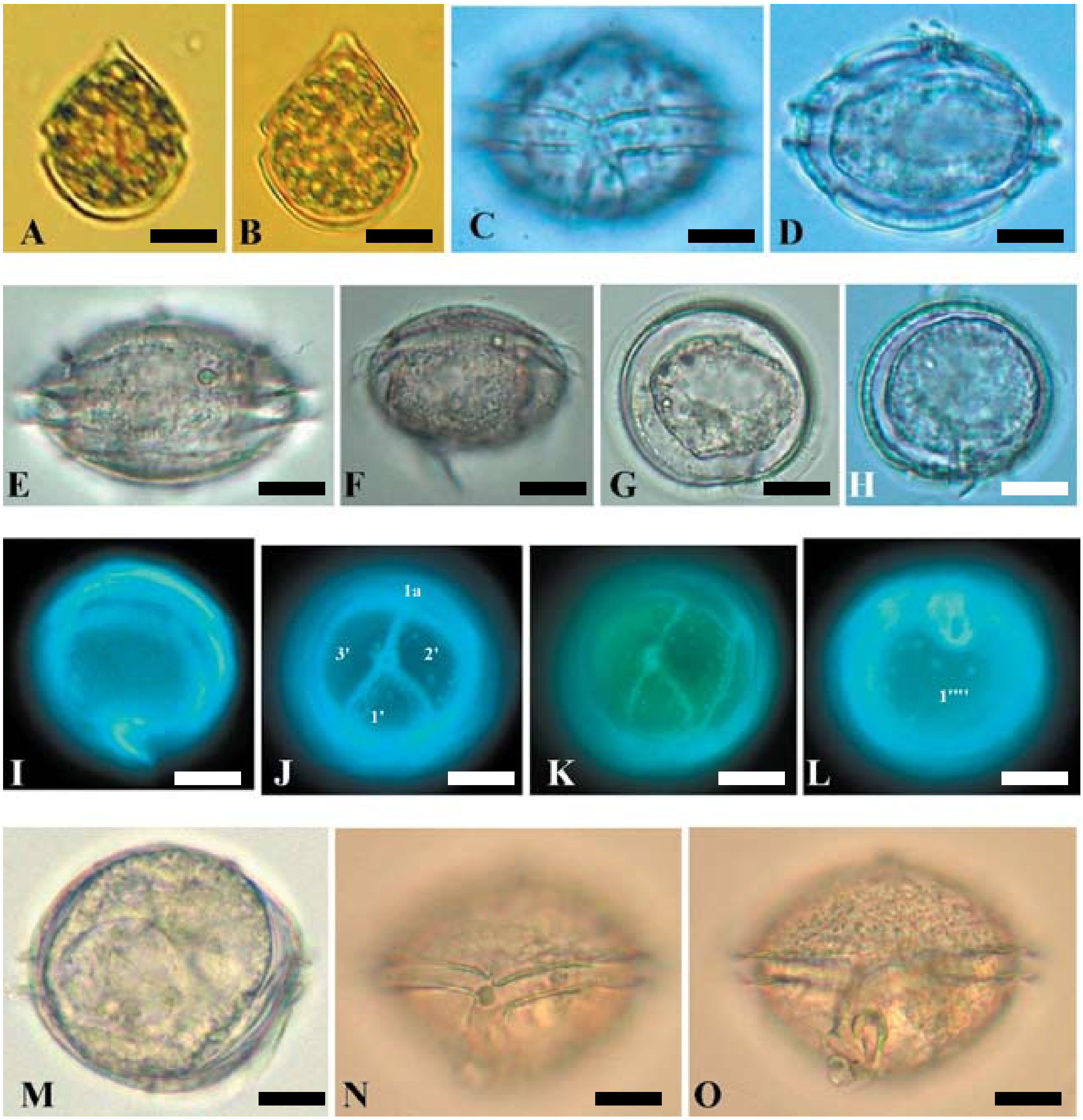

Plate 20. Light micrographs of A-B. *Scrippsiella trochoidea*: cell in ventral view; C-L. *Diplopsalis lenticula*: C. ventral view, C-E. same cell in high and low focus, ventral view, F-I. showing the well-developed wing, the epitheca with three apical plates and one anterior intercalary plate are indicated, L. the hypotheca with one antapical plate is indicated; M-O. *Diplopsalopsis orbicularis*: M-O. the cell in ventral view in different focus (Figs A-H and M-O, LM, bright field; I-L, LM, epifluorescence).
(Scale Bars, A=10.19 µm; B=8.87 µm; C&D=10.53 µm; E=10.00 µm; F= 13.00 µm; G=11.47 µm; H=12.19 µm; I-K=12.58 µm;L=12.00 µm;M=11.62 µm; N=13.03 µm; O=12.65 µm).

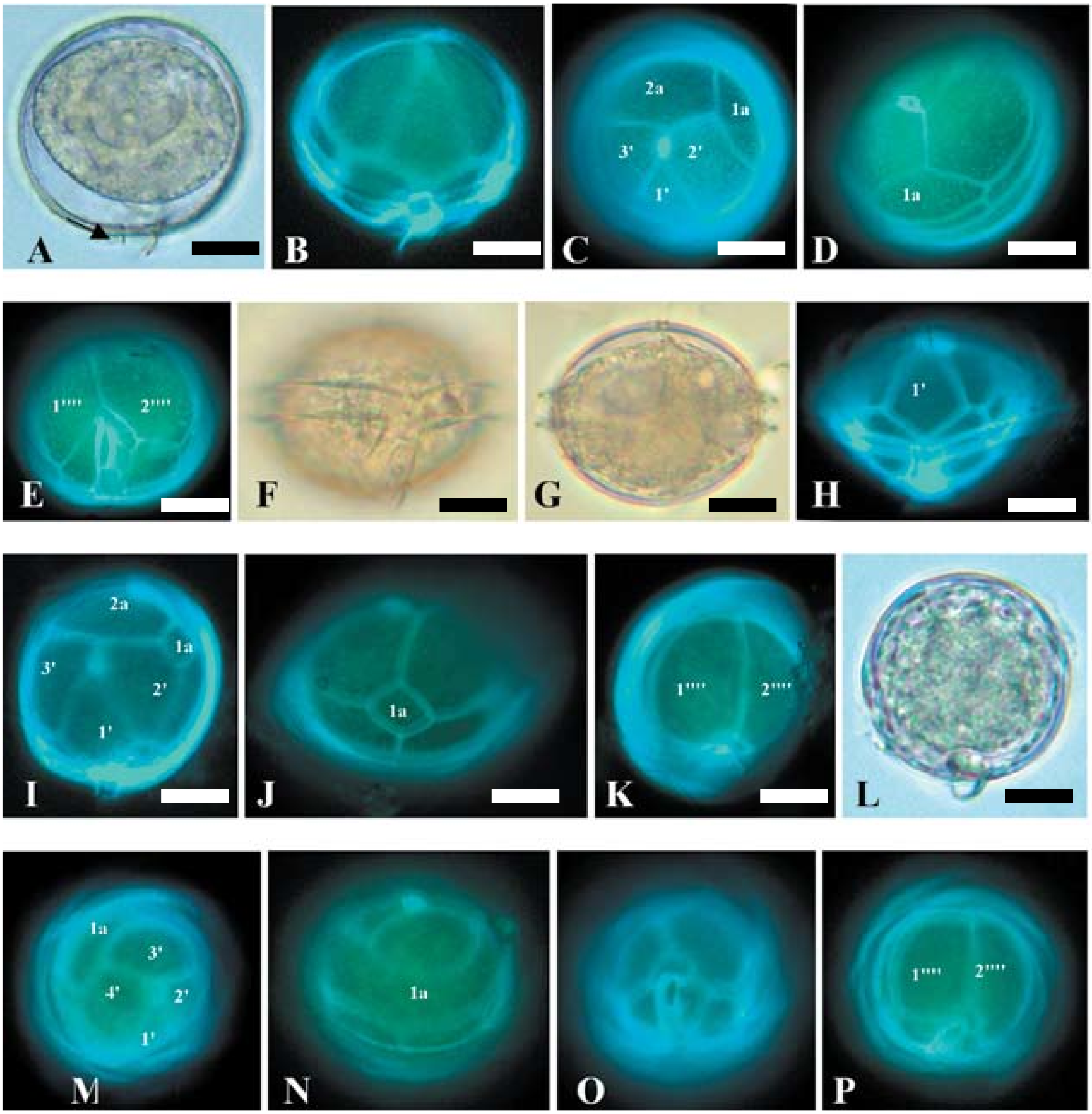

Plate 21. Light micrographs of A-E. *Diplopsalopsis orbicularis*: A-B. showing the sulcal list on the posterior part of the cell (arrows), C. the epitheca with three apical plates and two anterior intercalary plates are indicated, D. the two intercalary plates in high magnification, E. the hypotheca with two antapical plates are indicated; F-K. *Diplopelta parva*: F-H. the cell in ventral view, I. the epitheca with three apical plates and two anterior intercalary plates are indicated, J. the high magnification of the first intercalary plate showing the diamond shape of the plate, K. the hypotheca with two unequal antapical plates are indicated; L-P. *Oblea rotunda*: L. the cell in ventral view showing the small wing, M. the epitheca with four apical plates and one anterior intercalary plate is indicated, N. the high magnification of the first intercalary plate. O-P. the hypotheca with two antapical plate is indicated; (A, F-G and L, LM, bright field; B-E, H-K and M-P, LM, epifluorescence).

(Scale Bars, A-D=13.88 µm; E=15.73 µm; F-H=10.94 µm; I=11.67 µm; J=9.46 µm; K=11.67 µm; L=8.71 µm; M=9.64 µm; N-P=9.00 µm).

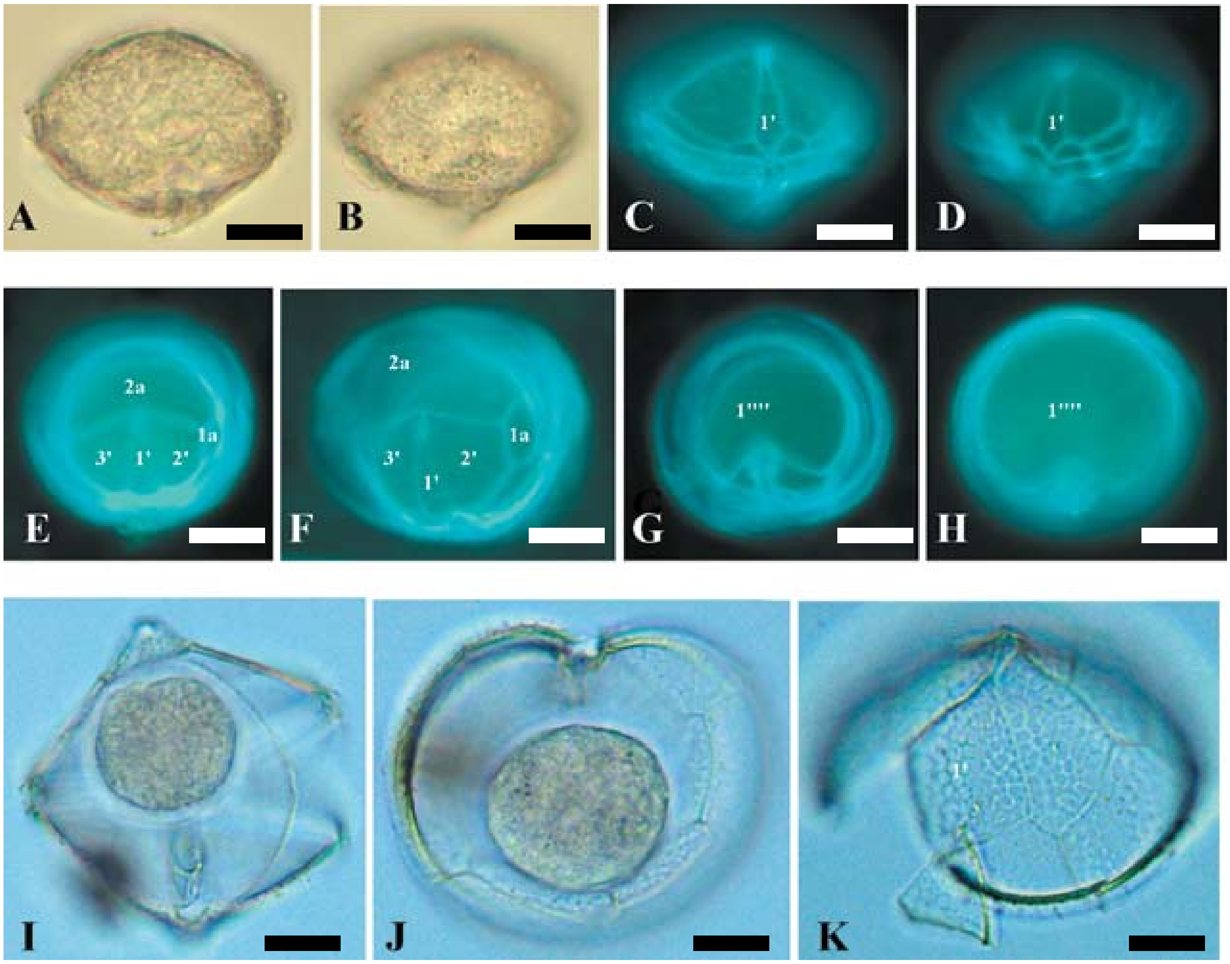

Plate 22. Light micrographs of A-H. *Preperidinium meunieri*: A-B. the cell in ventral view, C-D. cell in ventral view with first apical plate is indicated, E-F. the epitheca with three apical plates and two anterior intercalary plates are indicated, G-H. the hypotheca with one antapical plate is indicated; I-K. *Protoperidinium biconicum*: the same cell in different angles, M. cell in ventral view, the epitheca and hypotheca are slightly separated, N. Apical view, O. oblique ventral view, the ortho-shaped 1' plate is indicated.

(Scale Bars, A=13.64 μm; B-D=14.06 μm; E=18.00 μm; F=15.52 μm; G=14.52 μm; H=13.64 μm; I=17.95 μm; J=15.19 μm; K=14.63 μm).

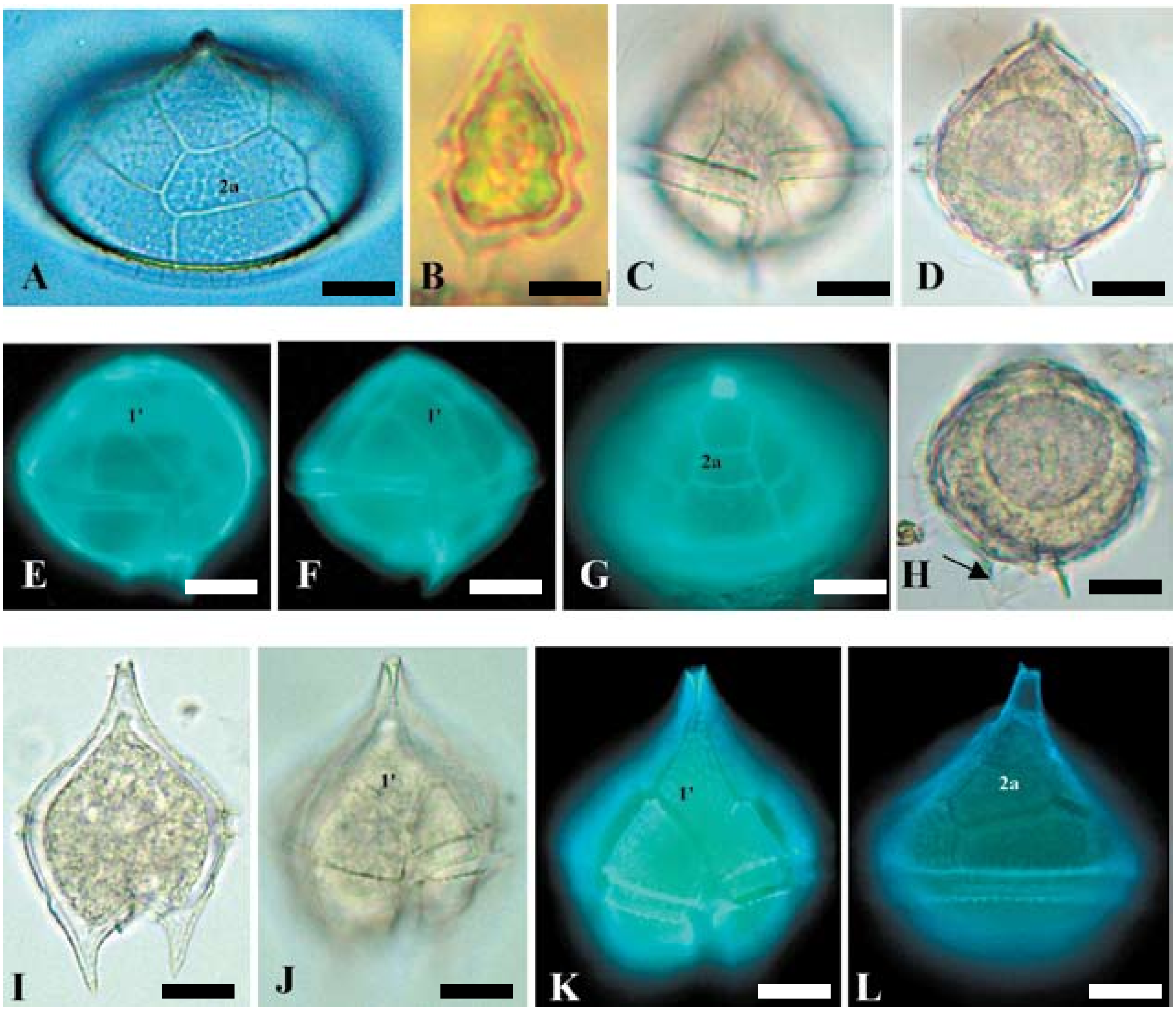

Plate 23. Light micrographs of A. *Protoperidinium biconicum*: A. dorsal view, the hexa-shaped 2a plate is indicated; B. Protoperidinium bipes: cell with triangular epitheca ending in a long apical horn and a shorter hypotheca; C-H. *Protoperidinium cerasus*: C-D. the same cell in high and low focus, ventral view, note that in this view the two antapical spines point in the same direction, E-F. ventral view, the meta-shaped 1' plate is indicated, G. dorsal view, the quadra-shaped 2a plate is indicated, H. oblique lateral-dorsal posterior view showing the well-developed wing on right antapical spine (arrow); I-L. *Protoperidinium claudicans*: the same cell in different angles, I. cell in ventral view, note the apical and antapical horns (arrows), J-K. ventral view showing the ortho shape of the 1' plate (indicated), L. Dorsal view showing the penta shape of the 2a plate (indicated), the thecal plates are slightly reticulated. (A-D and H-J, LM, bright field; E-G and K-L, LM, epifluorescence).
(Scale Bars, A=16.46 µm; B=8.18 µm; C-E=14.06 µm; F=13.64 µm; G=11.54 µm; H=14.52 µm; I&J=17.54 µm; K&L=13.89 µm).

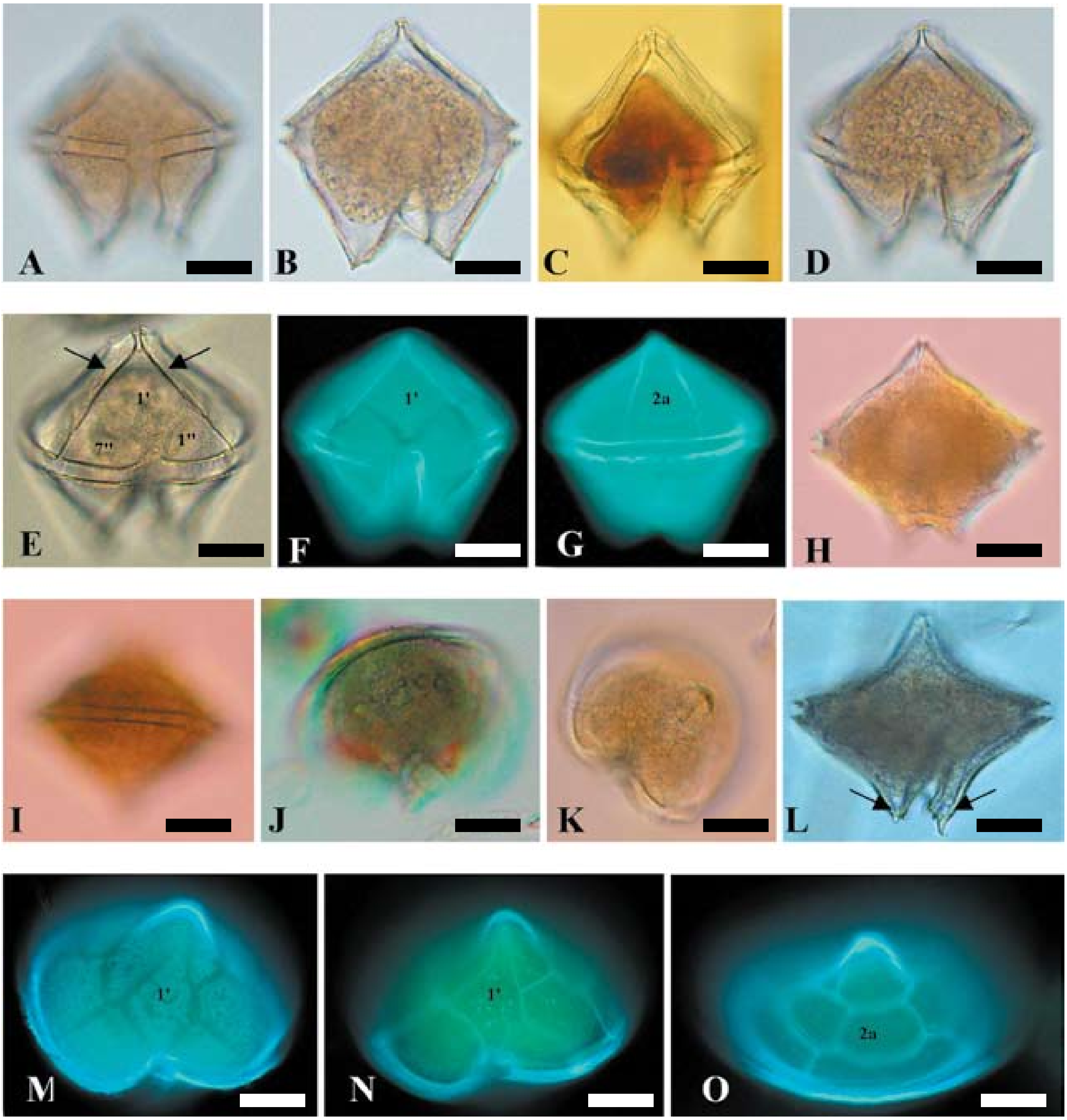

Plate 24. Light micrographs of A-G. *Protoperidinium conicum*: A-B.The same cell, ventral view, in high and low focus, showing the cell outline, C-E. Three different cells, ventral view, showing straight lines formed by the sutures lining the 1', 1', and 7'' plates, arrows in E, F. ventral view, the ortho-shaped 1'-plate is indicated, G. Dorsal view, the hexa-shaped 2a plate is indicated; H-K. *Protoperidinium crassipes*: H. ventral view, I. cell in different angle shows the cingulum, J. showing the antapical part without claws, K. the apical part ; L-O. *Protoperidinium curtipes*: L. ventral view, optical section, showing the cell shape and the 'claw'-like antapical spines (arrows); the arrowhead points to the left sulcal list, M-N. The epitheca showing the meta-configuration of the 1' plate (indicated), O. Dorsal view of the epitheca; the quadra 2a plate is indicated. (A-E, H and I-L, LM, bright field; F-G and M-O, LM, epifluorescence).
(Scale Bars, A=26.33 µm; B=23.24 µm; C=24.24 µm; D=24.57 µm; E=27.27 µm; F=30.00 µm; G=28.13 µm; H=22.42 µm; I=26.43 µm;J=20.00 µm; K=23.87 µm; L =25.68 µm; M-O=22.62 µm).

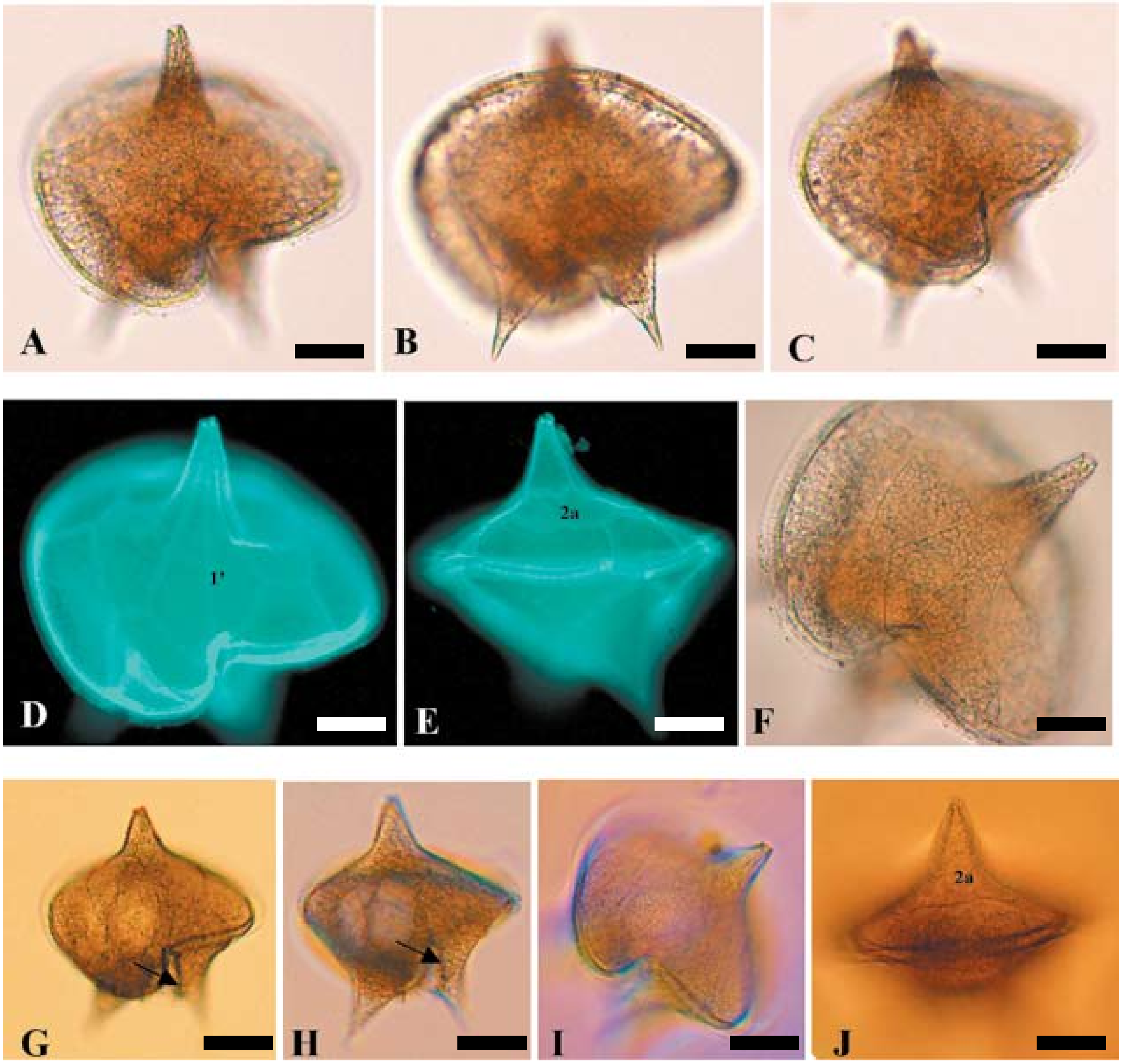

Plate 25. Light micrographs of A-J. *Protoperidinium depressum*: A-C. the same cell in different focus and from a different angle illustrating the strongly asymmetrical shape of the cell, all in ventral view, D-E. The cell showing the ortho-shape of the 1’ plate (indicated), E. Dorsal view, showing the small quadra 2a plate (indicated), F. Detail showing the reticulation of the thecal plates; G-J. The different cell: G-I. in high and low focus, ventral view, showing the apical and antapical horns; the left sulcal lists are indicated by arrows (G-H), J. Dorsal view, showing the quadra 2a plate. (A-C and F-J, LM, bright field; D-E, LM, epifluorescence).
(Scale Bars, A=29.59 μm; B=30.21 μm; C=33.72 μm; D=30.61 μm; E=34.09 μm; F=26.32 μm; G=46.97 μm; H=45.14 μm; I=42.29 μm; J=45.15 μm).

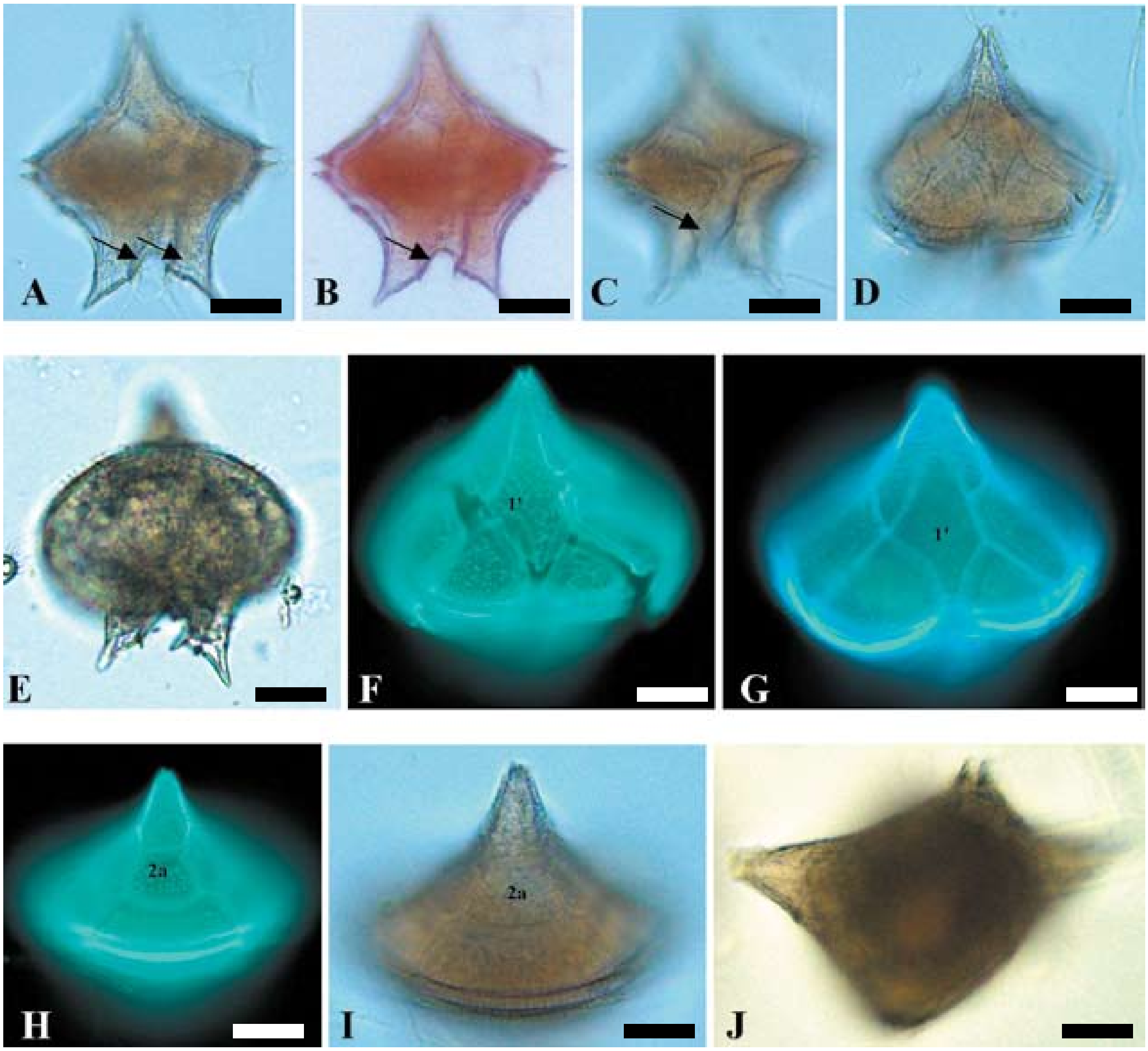

Plate 26. Light micrographs of A-J. *Protoperidinium divergens*: A-E. The same cell in high and low focus, ventral view, showing the apical and antapical horns; the sulcal lists are indicated by arrows (A-C), F-G. Cell in ventral view, the 1' plate is indicated, H-I. Cell in dorsal view, the 2a plate is indicated, note the spiny surface of plates, J. Cell in lateral view, note the bending longitudinal axis. (A-E and I-J, LM, bright field; F-H, LM, epifluorescence).
(Scale Bars, A&B=26.56 µm; C=29.82 µm; D=25.00 µm; E=22.67 µm; F=20.00 µm; G=19.15 µm; H=23.68 µm; I=21.43 µm; J=21.95 µm).

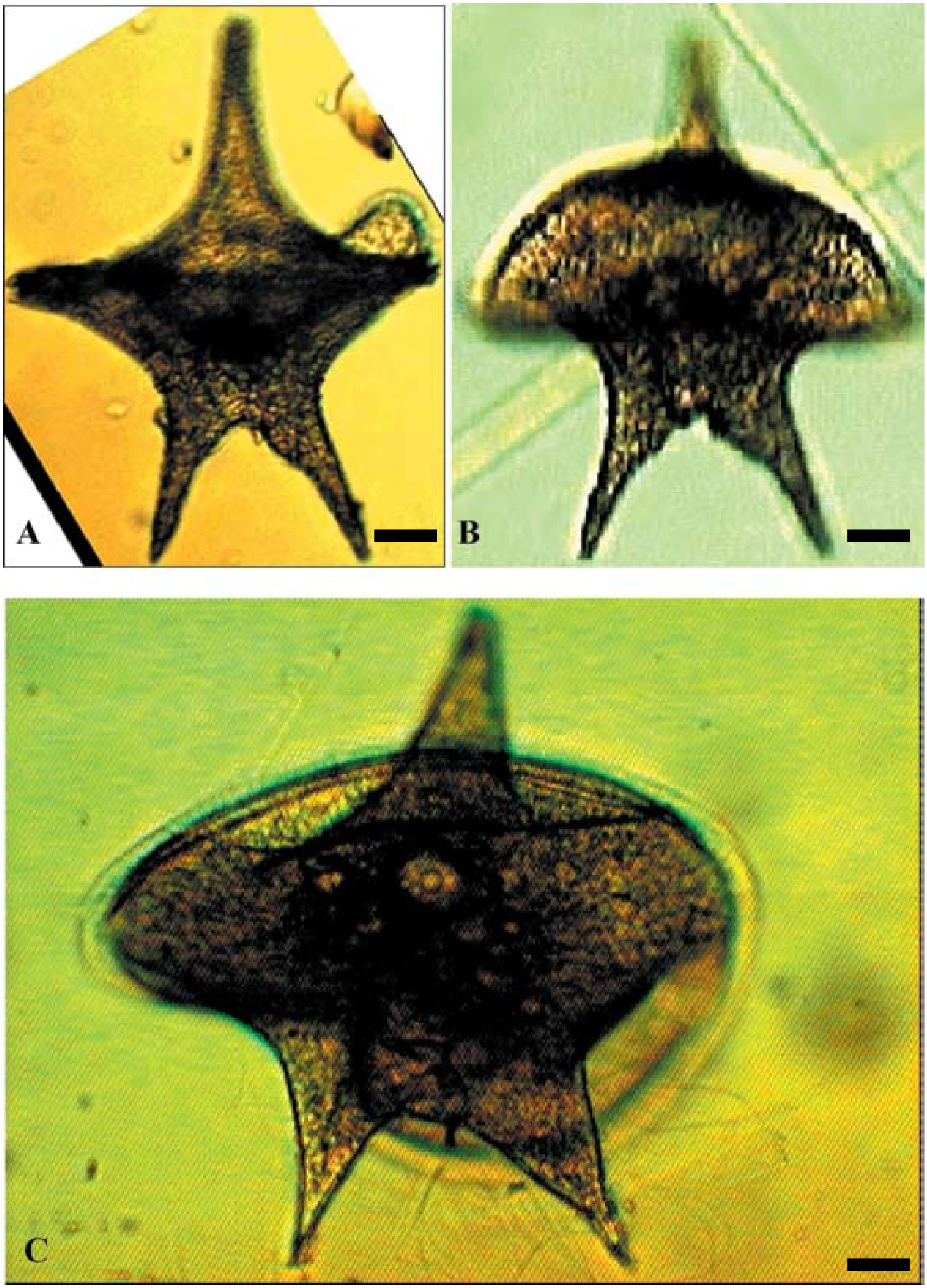

Plate 27. Light micrographs of A-C. *Protoperidinium elegans*: the same cell in different focus and from a different angle showing long apical and antapical horns. (LM, bright field).
(Scale Bars, A =26.84 μm; B=25.35 μm; C=17.72 μm).

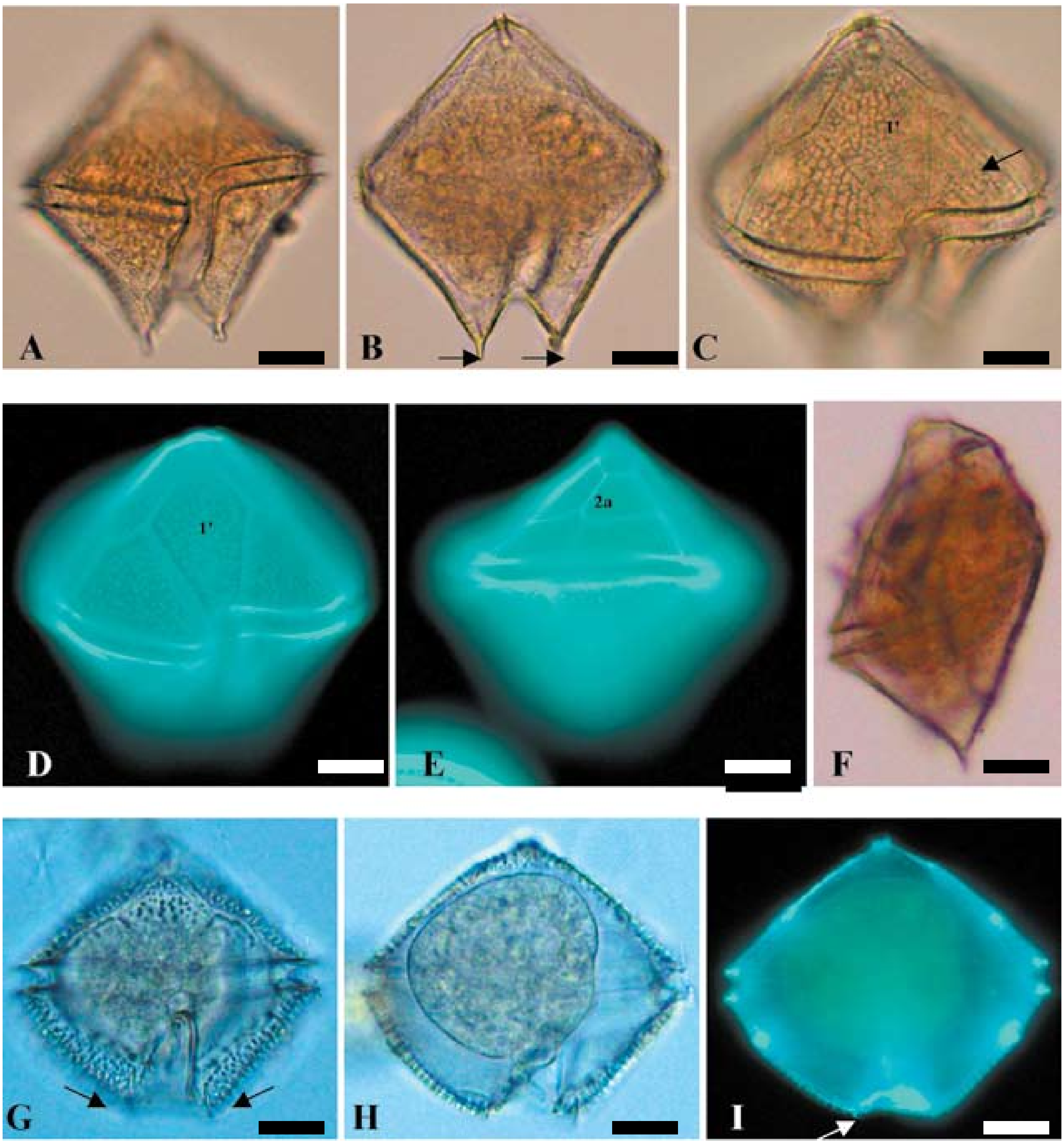

Plate 28. Light micrographs of A-F. *Protoperidinium leonis*: A-B. the same cell in high and low focus, ventral view, showing the outline of the cell and antapical spines (arrows), C. cell in high magnification, ventral view, showing the lined reticulation of the theca (arrow), D. ventral view, the ortho-shaped 1' plate is indicated, E. dorsal view, the hexa-shaped 2a plate is indicated, F. cell in lateral view, note the bending longitudinal axis; G-I. *Protoperidinium marie-lebourae*: G. Cell in ventral view showing the cingulum, sulcus, spiny plates and antapical spines (arrows), H. with a big food vacuoles, I. Optical section showing the cell outline and the antiapical horn with tiny spine (arrow). (A-C, F-H, LM, bright field; D-E and I, LM, epifluorescence). (Scale Bars, A=13.80 µm; B=13.27 µm; C-E=10.91 µm; F=15.38 µm; G=12.79 µm; H=11.83 µm; I=11.22 µm).

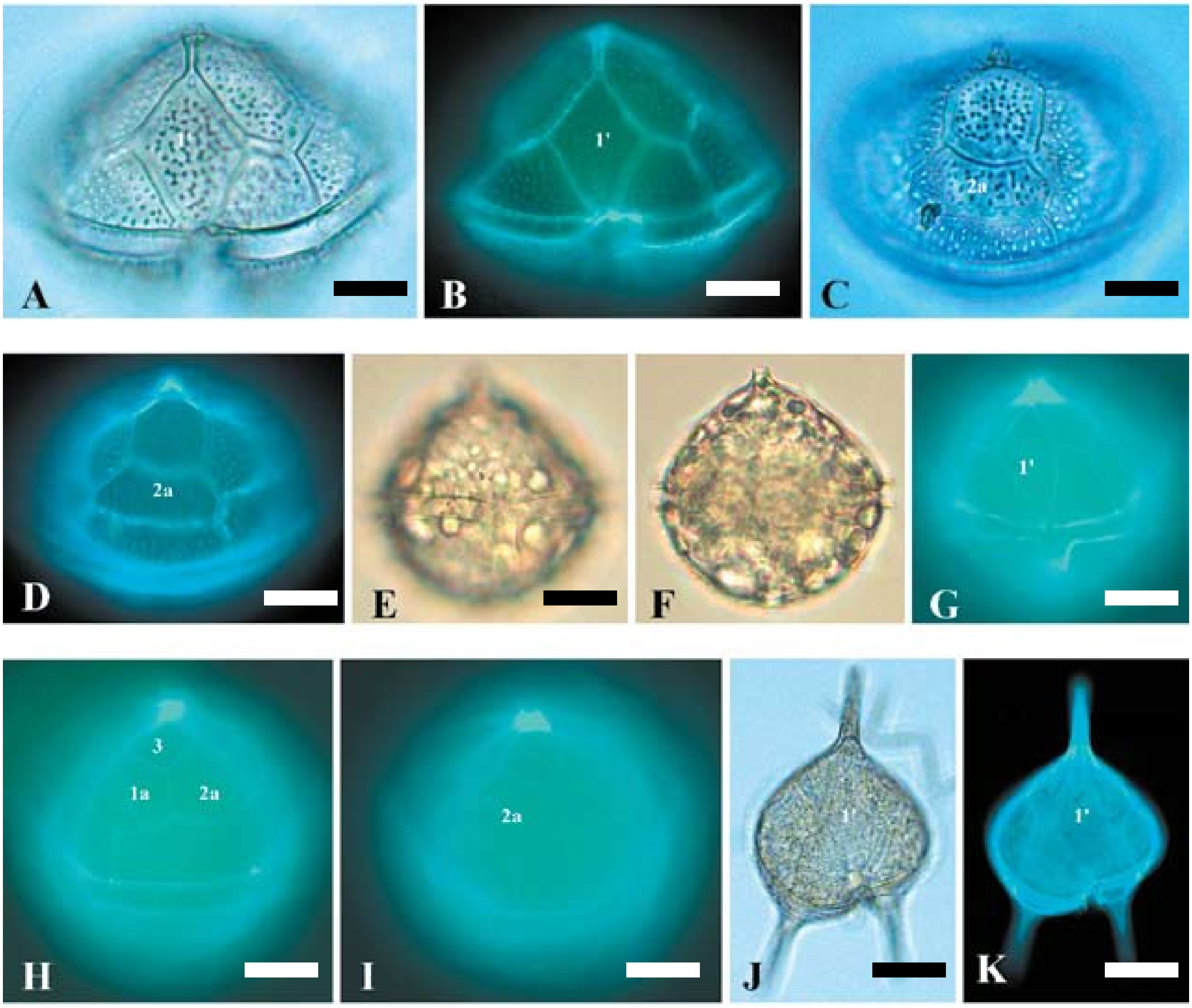

Plate 29. Light micrographs of A-D. *Protoperidinium marie-lebourae*: A-B. ventral view, high focus, the ortho-shaped 1’ plate is indicated, C-D. dorsal view, the hexa-shaped 2a plate is indicated; E-I. *Protoperidinium minutum*: E-F. same cell in high and low focus, ventral view, showing broad pear-shaped outline, G. Cell in ventral view, the ortho-shaped 1’ plate is indicated, H. Cell in dorsal view showing the 2 intercalary plates, indicated, I. cell in dorsal view showing the hexa-shaped 2a plate is indicated; J-K. *Protoperidinium murrayi*: same cell showing the ortho shape of the 1’ plate (indicated). (A, C, E-F and G, LM, bright field; B, D, G, H-I and K, LM, epifluorescence).
(Scale Bars, A=10.87 µm; B=11.91 µm; C=11.55 µm; D=14.00 µm; E-G=12.67 µm; H&I=10.86 µm; J&K=49.17 µm).

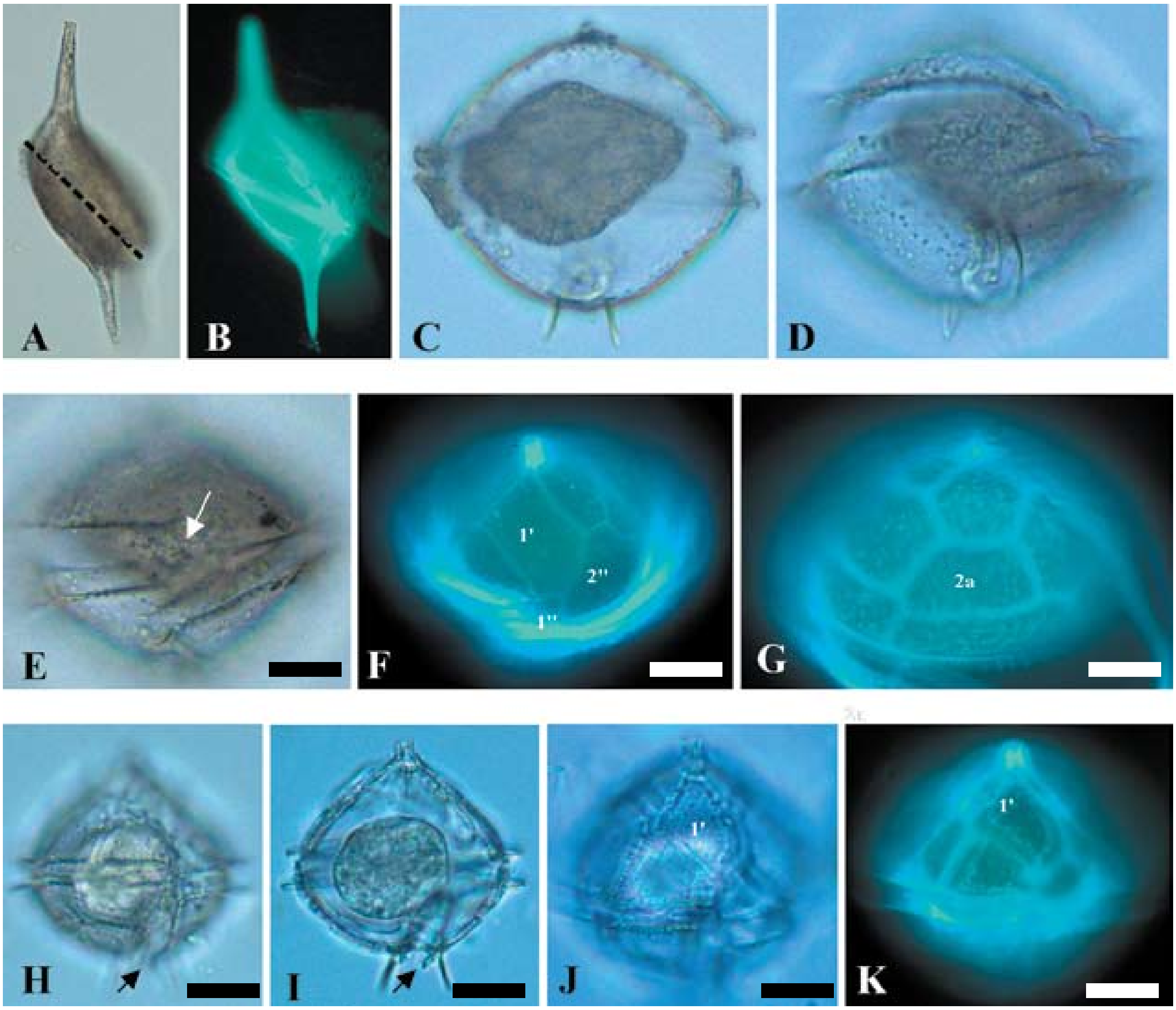

Plate 30. Light micrographs of A-B. *Protoperidinium murrayi*: cell in lateral view, note the bending longitudinal axis; the cingulum is indicated by the stippled line on A; C-G. *Protoperidinium ovatum*: C-E. same cell in high and low focus, ventral view showing the ascending cingulum and the overhang (arrow), F. ventral view, the meta-shaped 1' plate is indicated, G. dorsal view, the penta-shaped 2a plate is indicated; H-K. *Protoperidinium pellucidum*: H. cell in ventral view showing the slightly ascending cingulum, I. same cell in lower focus showing the antapcial spines and the left sulcal list which in this focal level looks like a third spine (arrow), J-K. The 'para' 1' plate (indicated). (A, C-E and H-J, LM, bright field; B, F-G and K, LM, epifluorescence).

(Scale Bars, A=24.09 µm;B=23.56 µm; C=11.84 µm; D=12.79 µm; E=13.41 µm; F=12.79 µm; G=11.22 µm; H=16.67 µm; I=15.00 µm; J=13.64 µm; K=14.52 µm).

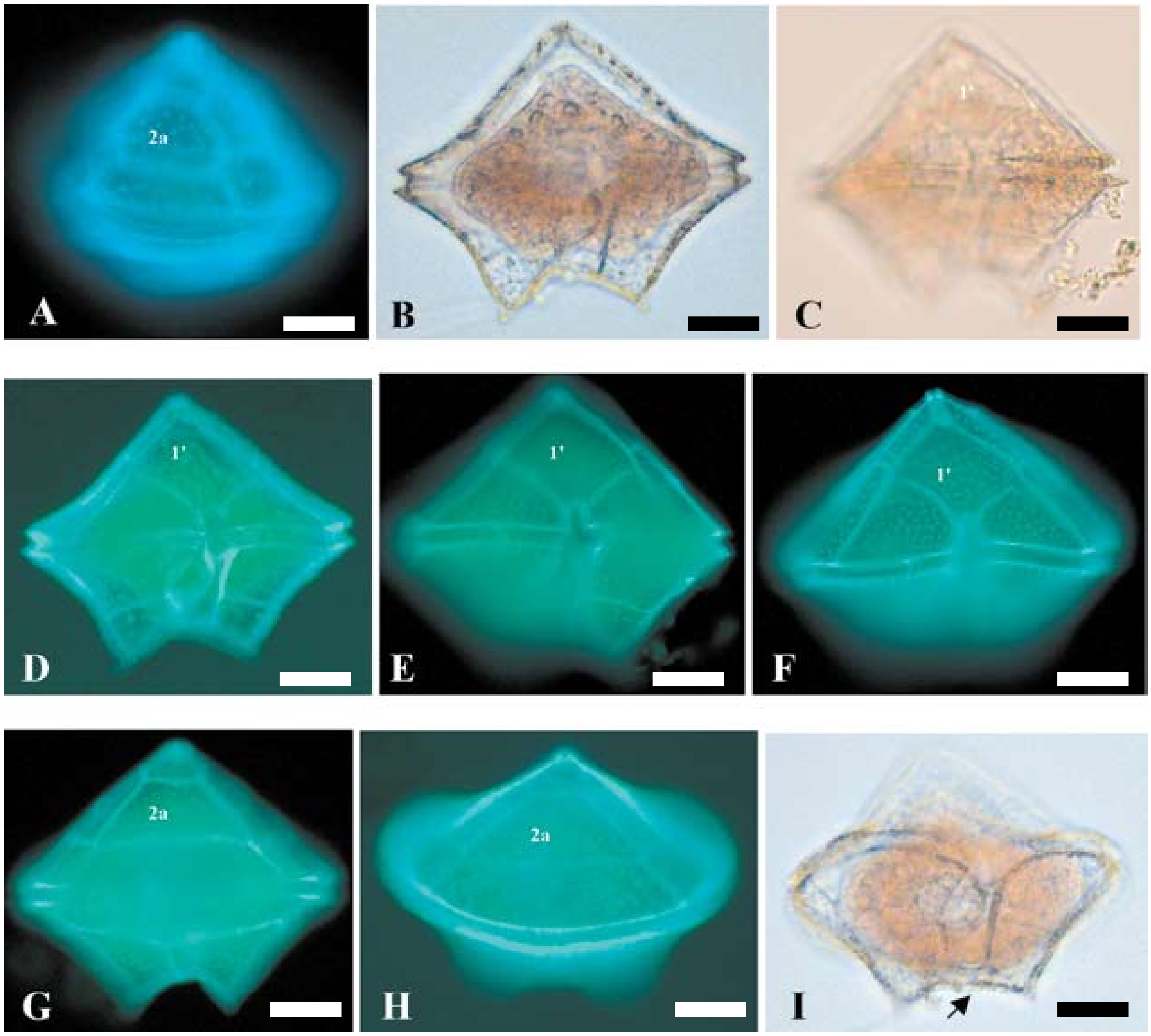

Plate 31. Light micrographs of A. *Protoperidinium pellucidum*: the 'hexa' 2a plate (indicated); B-I. *Protoperidinium pentagonum*: B-C. cell in ventral view showing the left sulcal list and the pentagonal cell outline, C-F. ventral view in fifferent focus showing the ortho shape of the 1' plate (indicated), F. showing the fine reticulation of thecal plates; G-H. dorsal view showing the hexa-shape of the 2a plates (indicated), I. the same cell in ventral, oblique antapical view showing the sulcus which does not reach the antapical end of the cell (arrow). (B-C and I, LM, bright field; A and D-H, LM, epifluorescence). (Scale Bars, A=10.98 μm; B=17.45 μm; C=19.52 μm; D=18.22 μm; E-I=17.08 μm).

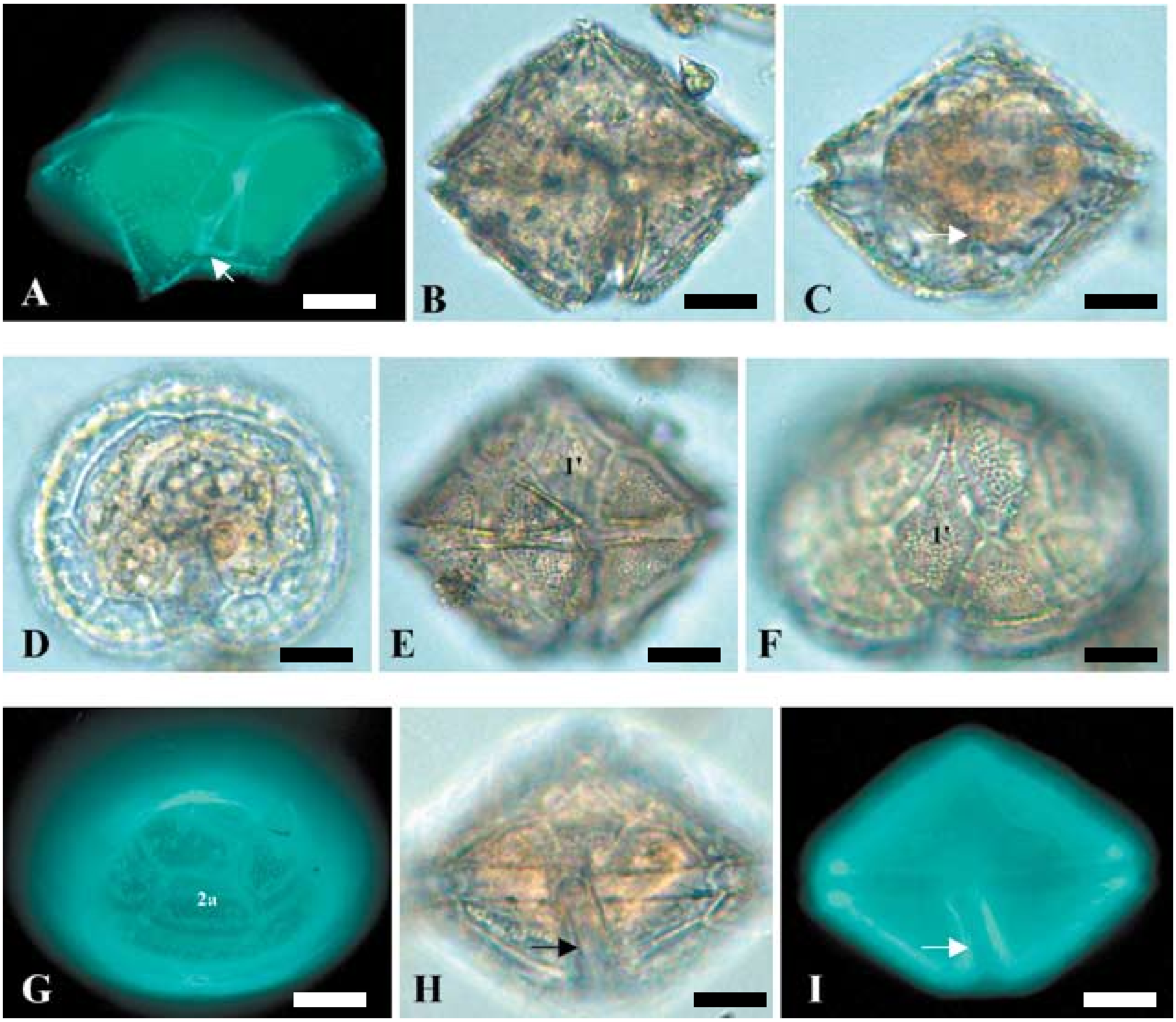

Plate 32. Light micrographs of A. *Protoperidinium pentagonum*: the same cell showing the sulcus which does not reach the antapical end of the cell, B-I. *Protoperidinium punctulatum*: B-C. the same cell in high and low focus, ventral view, showing the cell outline and the 'ragged' appearance, D. apical view, E-F. ventral view showing the ortho-shape of the 1' plate, G. dorsal view, detail showing the penta-shaped 2a plate, H-I. ventral view, the narrow sulcus is indicated by an arrows. (B-F and H, LM, bright field; A, G and I, LM, epifluorescence).
(Scale Bars, A=17.08 µm; B-D=15.11 µm; E=14.17 µm; F=12.36 µm; G-I=14.78 µm).

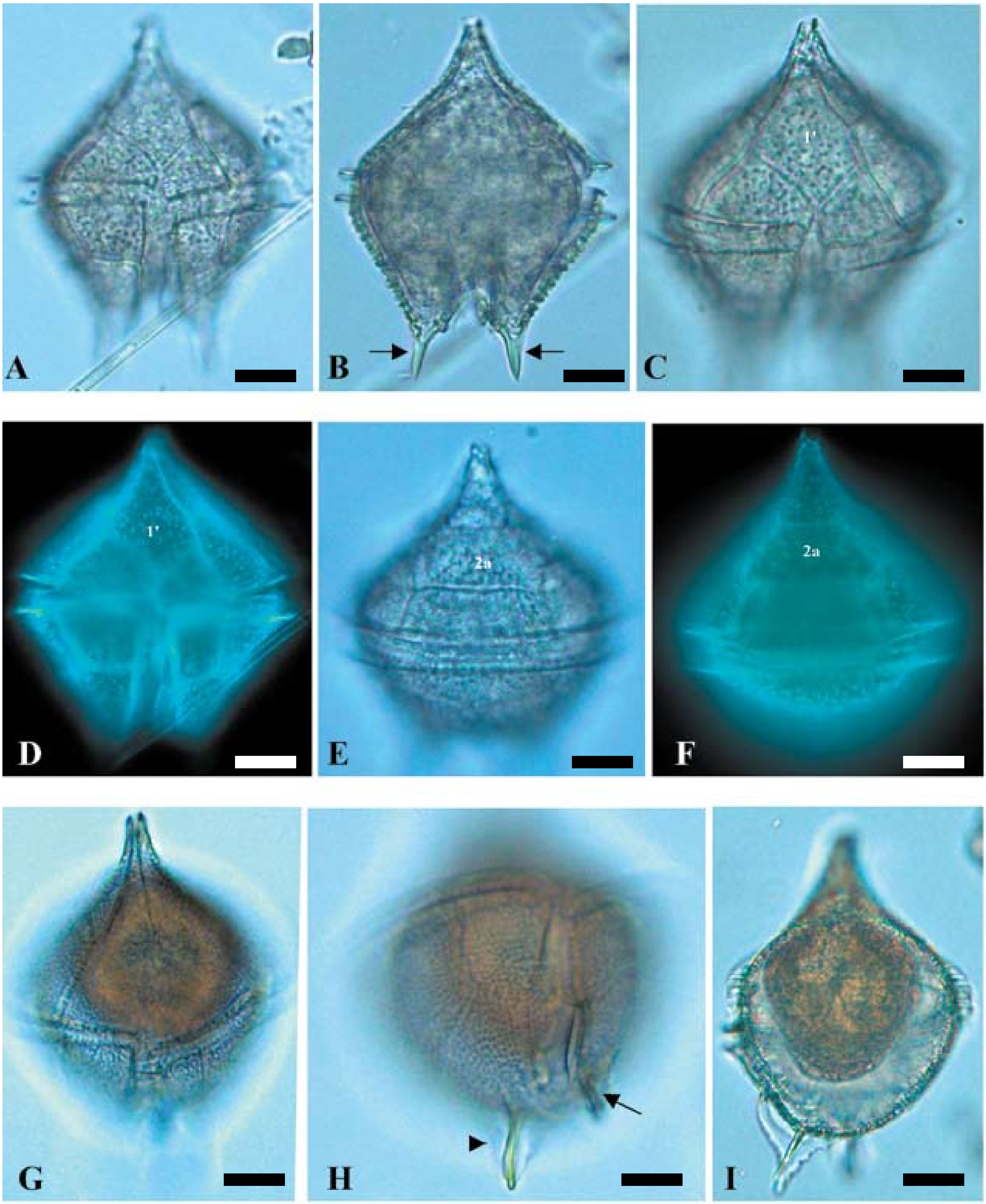

Plate 33. Light micrographs of A-F. *Protoperidinium spiniferum*: A. cell in ventral view, high focus, showing the slightly ascending girdle, B. the same cell in lower focus showing the cell outline and the two antapical horns which both carry conspicuous spines (arrows), C-D. Detail showing the meta-shape of the 1' plate (indicated), E-F. detail showing the hexa-shape of the 2a plate (indicated); G-I. *Protoperidinium steinii*: G. cell in ventral, oblique apical, H. the same cell in oblique antapical view, the latter showing the asymmetrical position of the antapical spines, the arrow points to the spines that connects to the left sulcal list, and the arrow head to the right spine, I. cell in left lateral view. (A-C, E and G-I, LM, bright field; D and F, LM, epifluorescence).

(Scale Bars, A=12.20 µm; B=18.29 µm; C=10.20 µm; D=11.11 µm; E=11.36 µm; F=12.50 µm; G=14.87 µm; H=12.89 µm; I=15.68 µm).

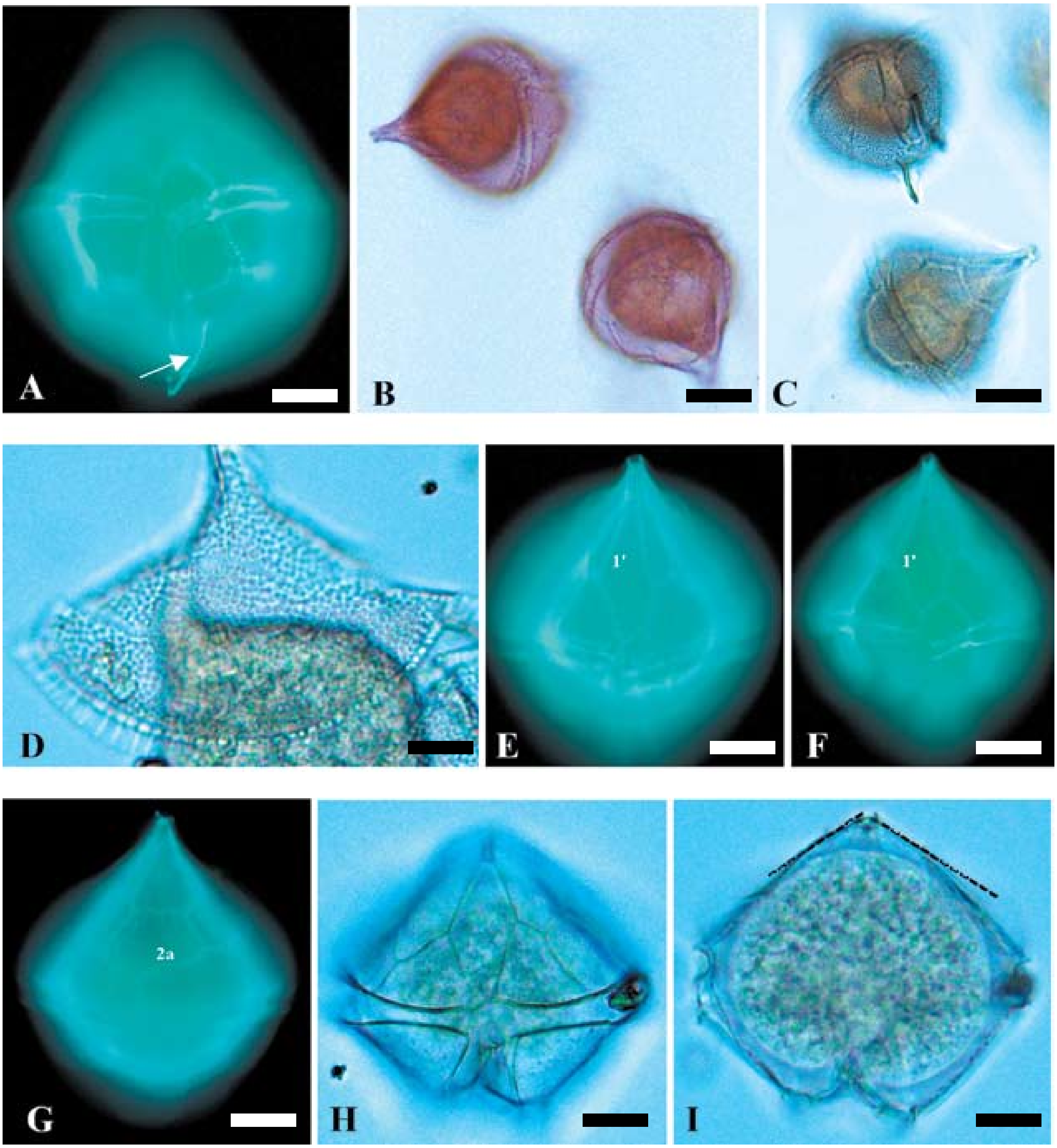

Plate 34. Light micrographs of A-G. *Protoperidinium steinii*: A. cell in ventral, oblique antapical view showing the conspicuous left spine with wings (arrows), B-C. two cells in low and high magnifications showing the general appearance of this species, D. detail showing the reticulated thecal plates, E-F. ventral view, the meta-shaped 1' plate is indicated, G. dorsal view, the penta-shaped 2a plate is indicated; H-I. *Protoperidinium subinerme*: The same cell in high and low focus, ventral view, note the angle which is >100°, between the contours of the apex (indicated by stippled lines in Fig. 2). (B-D and H-I, LM, bright field; A and E-G, LM, epifluorescence).

(Scale Bars, A=15.95 µm; B=25.00 µm; C=26.09 µm; D=MC; E&F=16.67 µm; G=15.71 µm; H=15.11 µm; I=14.17 µm).

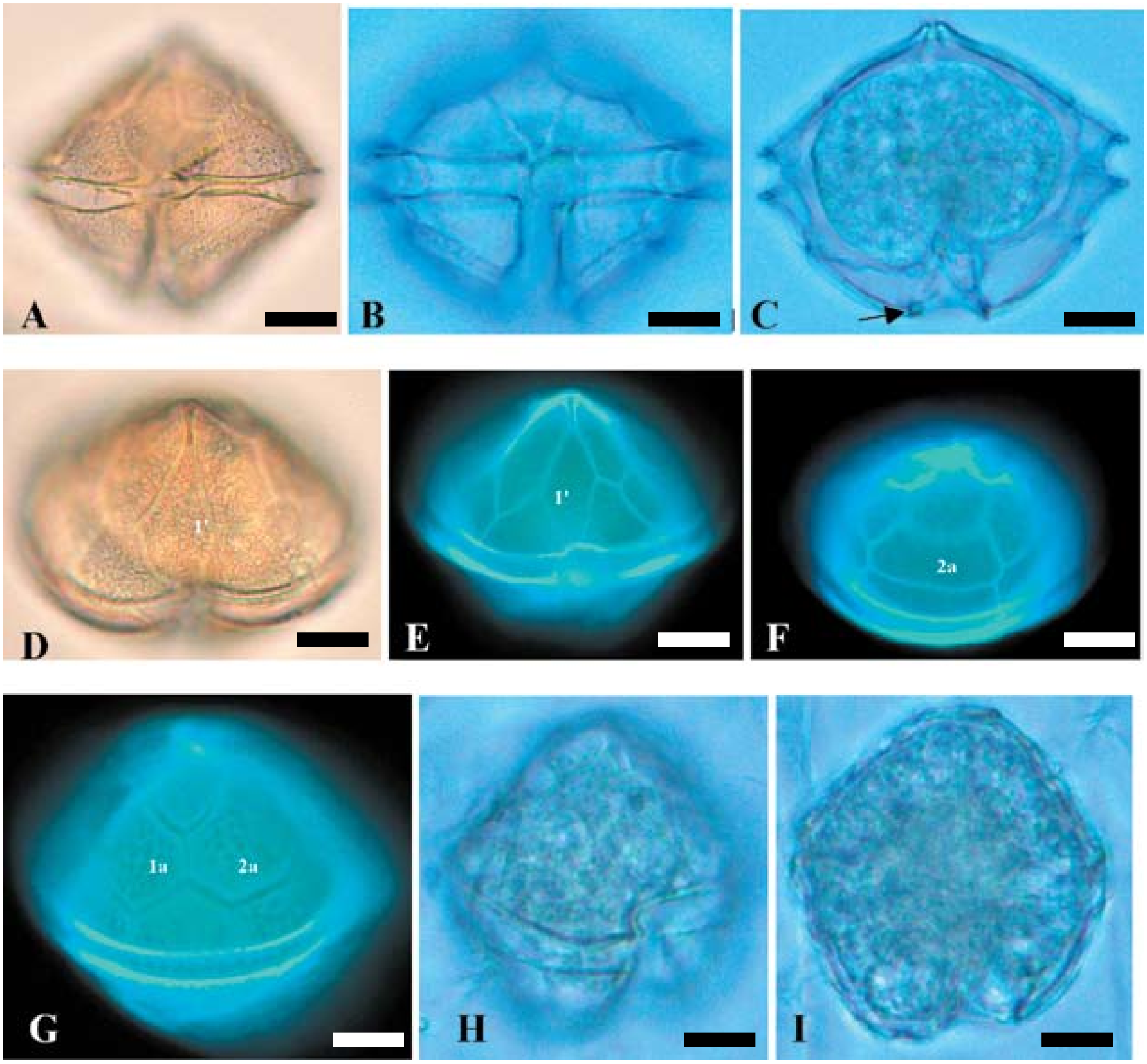

Plate 35. Light micrographs of A-F. *Protoperidinium subinerme*: A-C. three different cells in high and low focus, one of the antapical spines is indicated by an arrow, D-E. ventral view, the ortho-shaped 1' plate is indicated, F. dorsal view, the hexa-shaped 2a plate is indicated; G. *Protoperidinium thorianum*: cell in dorsal view, showing the two anterior intercalary plates, indicated; H-I. *Protoperidinium ventricum*: the same cell in high and low focus ventral view. (A-D and H-I, LM, bright field; E-G, LM, epifluorescence). (Scale Bars, A=16.67 µm; B=16.34 µm; C=14.58 µm; D=14.89 µm; E=16.28 µm; F=17.95 µm; G=12.00 µm; H=10.00 µm; I=9.57 µm).

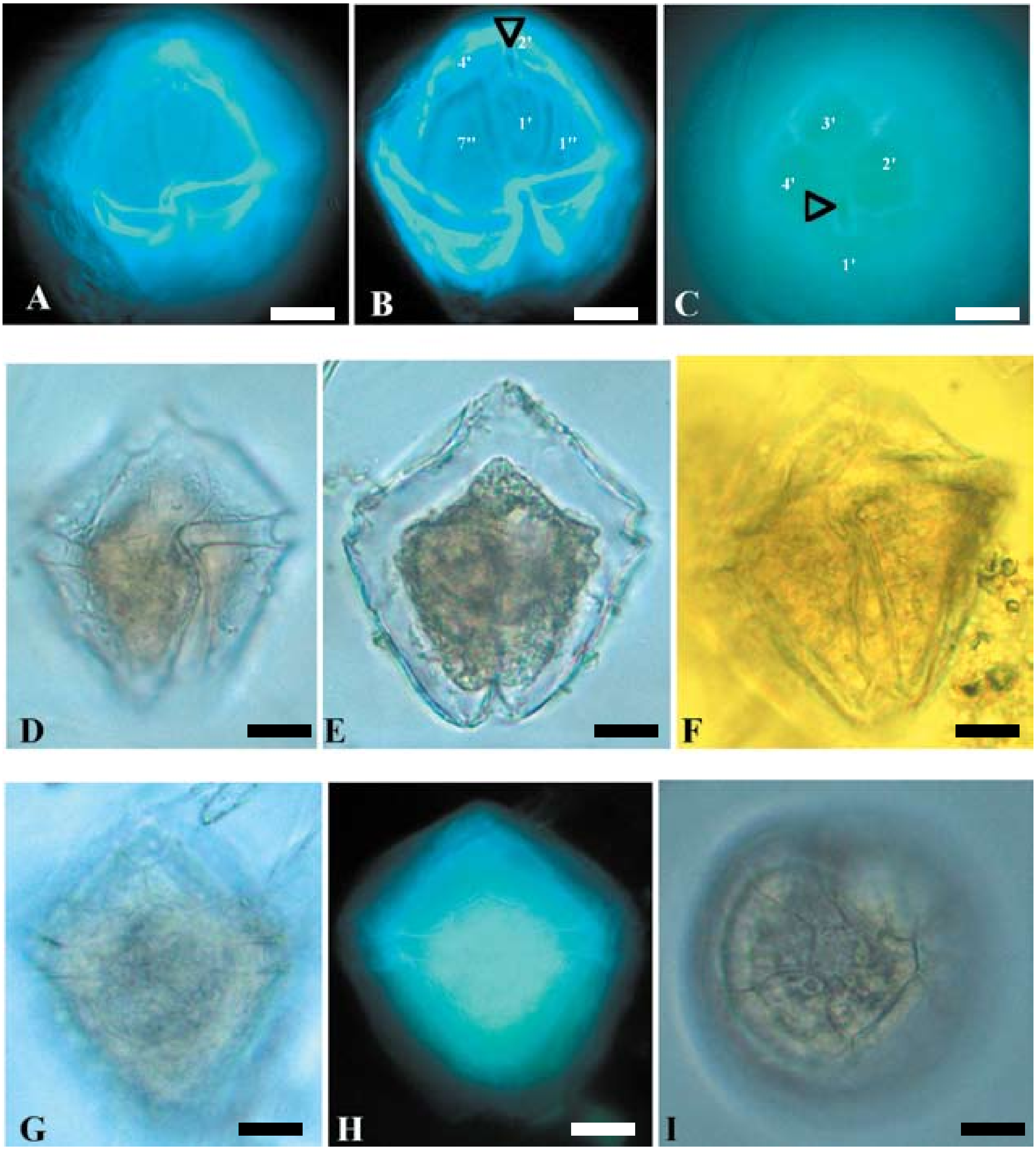

Plate 36. Light micrographs of A-C. *Protoperidinium ventricum*: A. cell in ventral view showing the left-hand displacement of the girdle, B. Cell in ventral view, the apical plates are indicated and the apical pore is indicated by an arrowhead, C. Cell in oblique apical view, the apical plates are indicated and the apical pore is indicated by an arrowhead; D-I. *Protoperidinium* sp.1: D-G. same cell in high and low focus, ventral view, I. apical view. (D-G and I, LM, bright field; A-C and H, LM, epifluorescence).
(Scale Bars, A=11.94 µm; B=10.00 µm; C=8.82 µm; D=14.47 µm; E&F=12.22 µm; G&I=12.50 µm; H=13.75 µm µm).

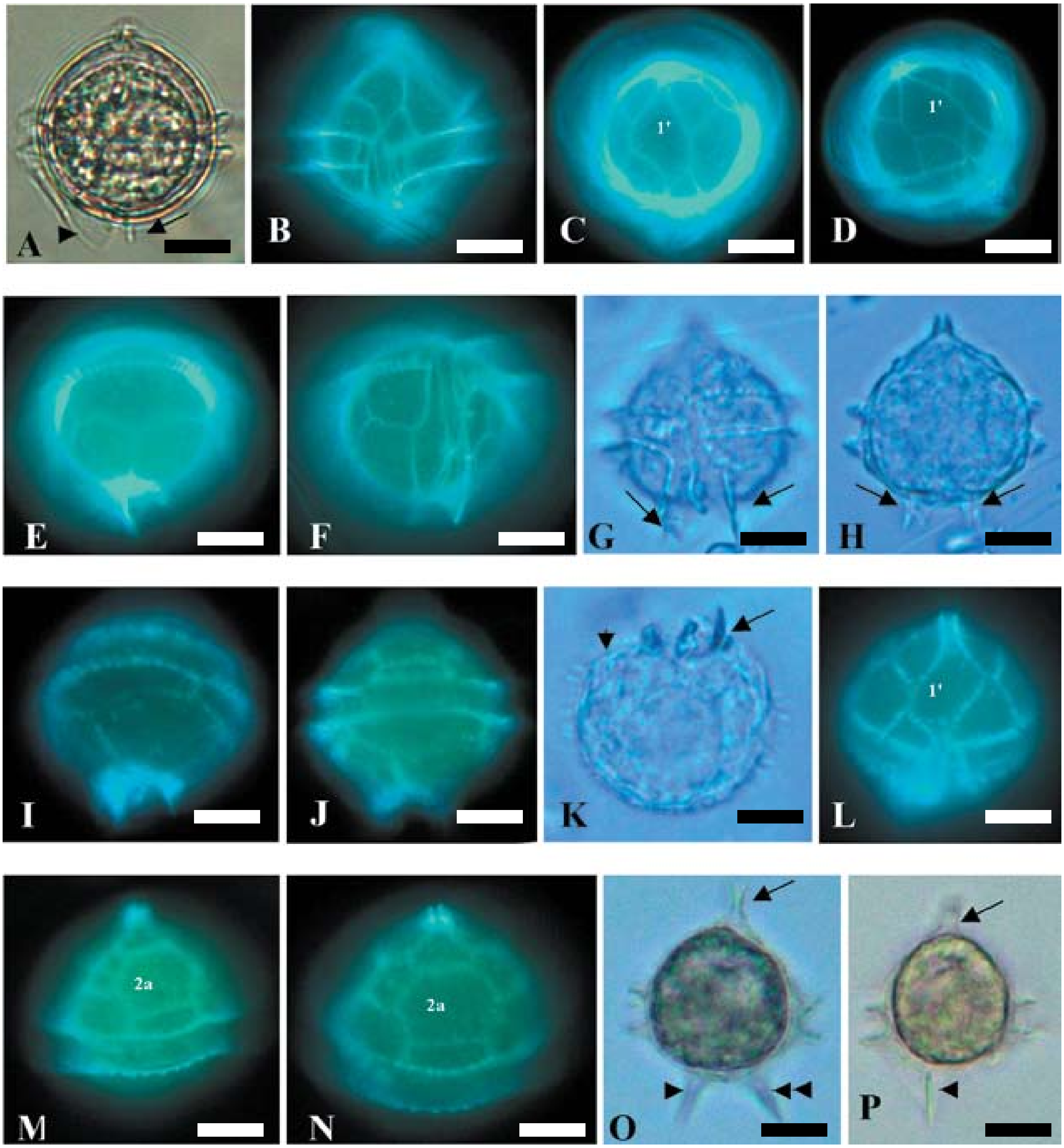

Plate 37. Light micrographs of A-F. *Protoperidinium* sp.2 in different morphology: A. Cell in ventral view, showing the conspicuous right spine with wing (arrowhead) and the left antapical spines is indicated by an arrow, B. Ventral view showing the cingulum, C-D. The para-shaped 1' plate is indicated, E. The two antapicals spines are clearly visible, F. Showing the sulcus of the cell; G-N. *Protoperidinium* sp.3: G-H. The same cell in ventral view with two antapical spines (arrows); I. The two antiapicals with their spines in high focus; J. Cell in dorsl view; K. Showing the sulcal list (arrow) and the cingulum (arrowhead), L. The 'meta' 1' plate (indicated), M-N. The 'hexa' 2a plate (indicated); O-P. *Protoperidinium* sp.4: Cell in ventral view with clearly visible elongated apical horn (arrows) and antapical spines (arrowheads). (A, G-H, K-L and O-P, LM, bright field; B-F, I-G and M-N , LM, epifluorescence).
(Scale Bars, A-F=10.17 µm; G&H=10.29 µm; I-M=9.17 µm; N=8.09 µm; O=7.95 µm; P=9.21 µm).

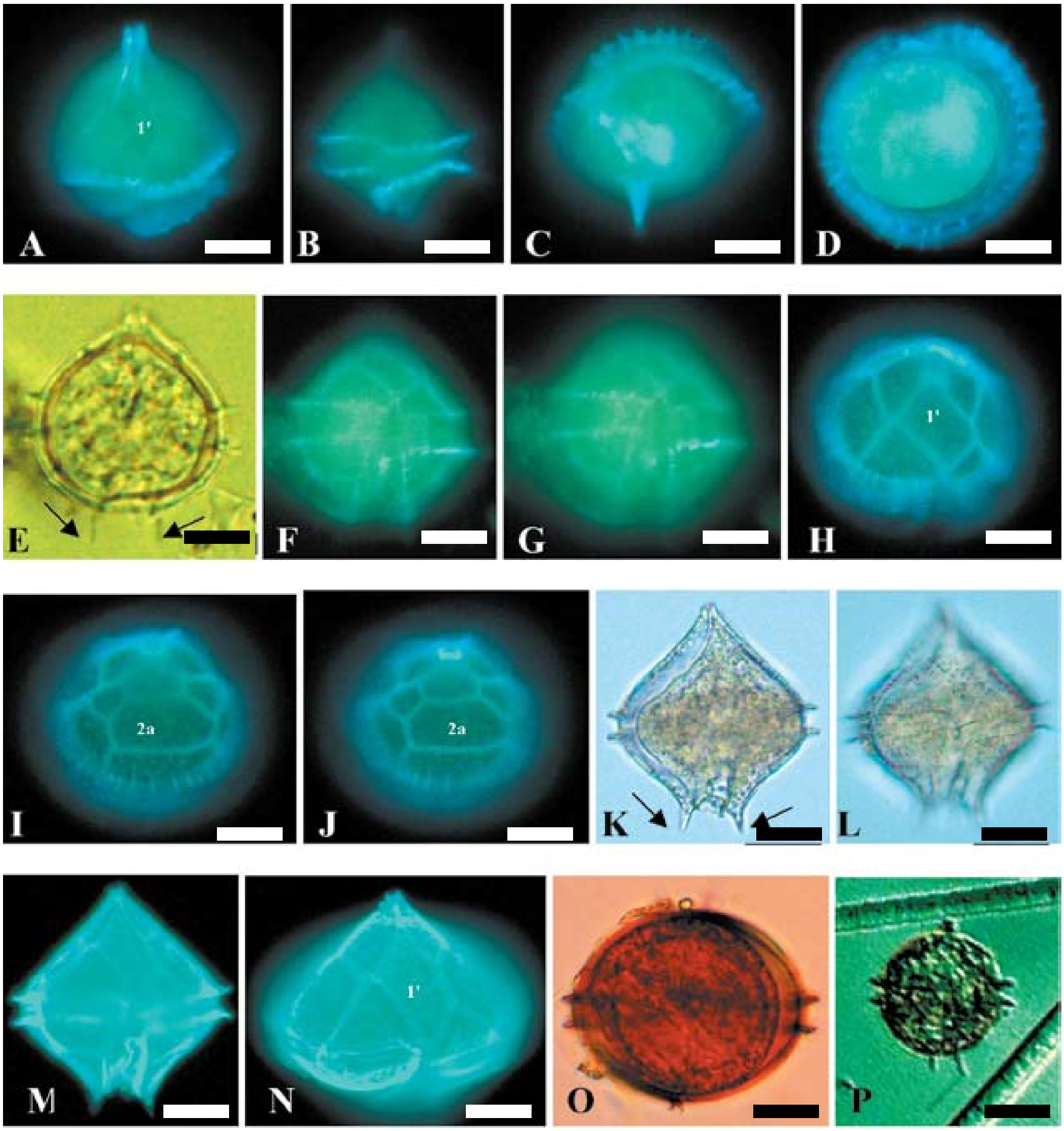

Plate 38. Light micrographs of A-D. *Protoperidinium* sp. 4: A. The 'meta' 1' plate (indicated), B-D. Showing the cingulum with clearly visible ribs on it; E-J. *Protoperidinium* sp.5: E-G. The same cell in ventral view, the two antapical spines are shown by arrows in E, H. The 'meta' 1' plate (indicated), I-J. The 'hexa' 2a plate (indicated); K-N. *Protoperidinium* sp.6: K-M. The same cell in high and lower focus showing the cell outline and the two antapical horns which both carry conspicuous spines (arrows), N. The 'meta' 1' plate is indicated; O. *Protoperidinium* sp.7 (globules-group): Cell in ventral view; P. *Protoperidinium* sp.8 (globules-group): Cell in ventral view. (E, K-L and O-P, LM, bright field; A-D, F-J and M-N, LM, epifluorescence).
(Scale Bars, A=5.83 µm; B=7.29 µm; C=5.30 µm; D=5.22 µm; E&G=9.00 µm; F=9.31 µm; H&I=8.71 µm; J=9.00 µm; K=13.10 µm; L=13.57 µm; M=12.26 µm; N=10.56 µm; O=14.00 µm; P=10.26 µm).

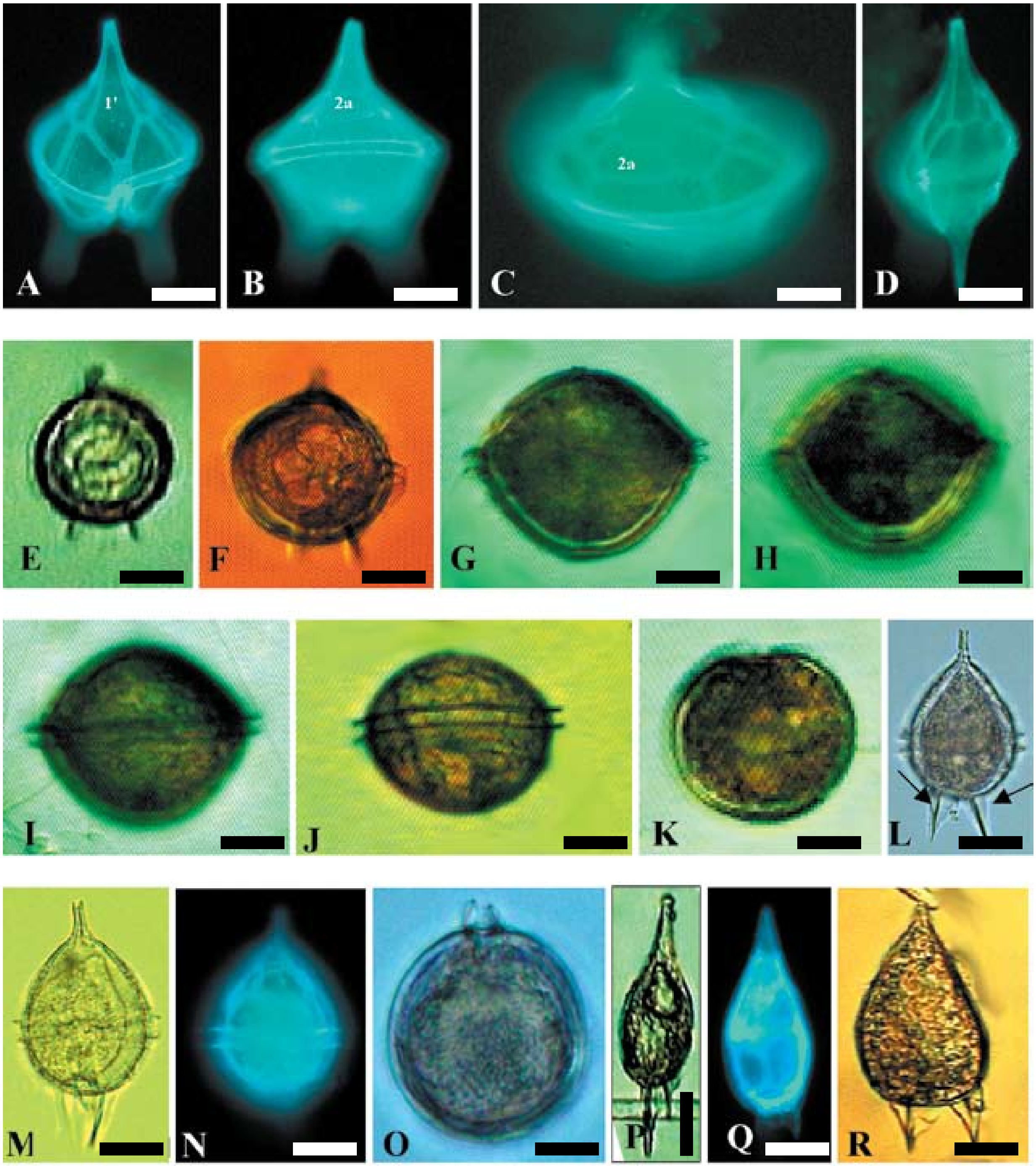

Plate 39. Light micrographs of A-D. *Protoperidinium* sp. 9: A. ventral view showing the ortho shape of the 1' plate (indicated); note the apical and antapical horns, B-C. dorsal view showing the penta shape of the 2a plate (indicated), D. Girdle view showing the side of the cell which is straight; E. *Protoperidinium* sp.10; F. Protoperidinium sp.11; G-K. *Protoperidinium* sp.12; L-N. *Protoperidinium* sp.13, the two antapicals spines with wings are shown in L by arrows; O. *Blepharocysta splendormaris*; P-Q. *Podolampas palmipes*; R. *Podolampas bipes*. (E-M, O-P and R, LM, bright field; A-D, N and Q, LM, epifluorescence).

(Scale Bars, A&B=33.33 µm; C=19.15 µm; D=26.67 µm; E=11.36 µm; F=26.15 µm; G&H=20.00 µm; I=21.88 µm; J&K=23.33 µm; L=22.29 µm; M&N=19.50 µm; O=21.94 µm; P=22.92 µm; Q=19.64 µm; R=26.67 µm).

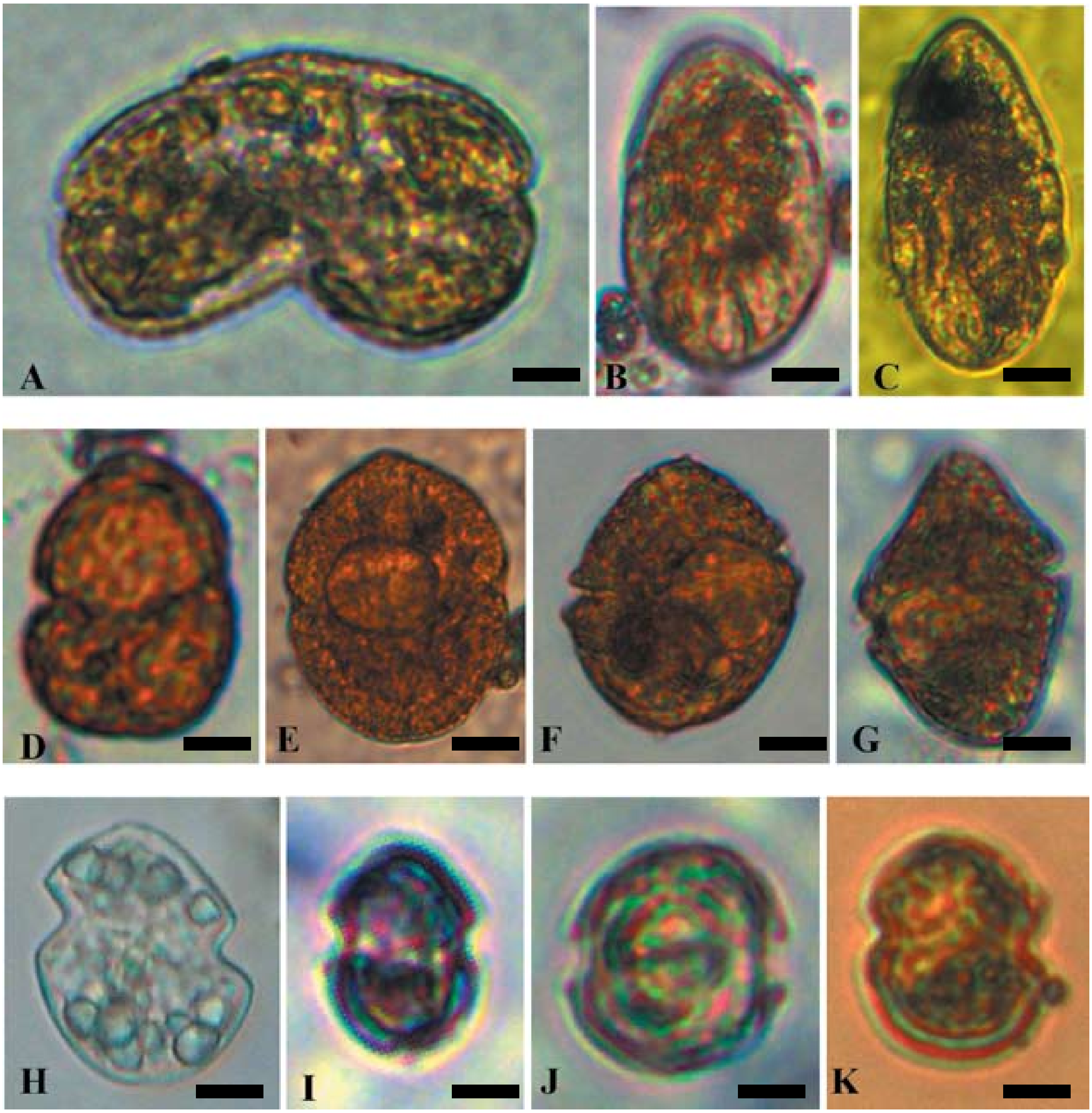

Plate 40. Light micrographs of A-G. Unarmored dinoflagellate spp.; H-K. Armored dinoflagellate spp. (LM, bright field).
(Scale Bars, A=10.07 μm; B=10.39 μm; C=16.35 μm; D=6.51 μm; E=9.55 μm; F=9.51 μm; G=13.33 μm; H=3.85 μm; I=3.87 μm; J=5.43 μm; K=5.88 μm).

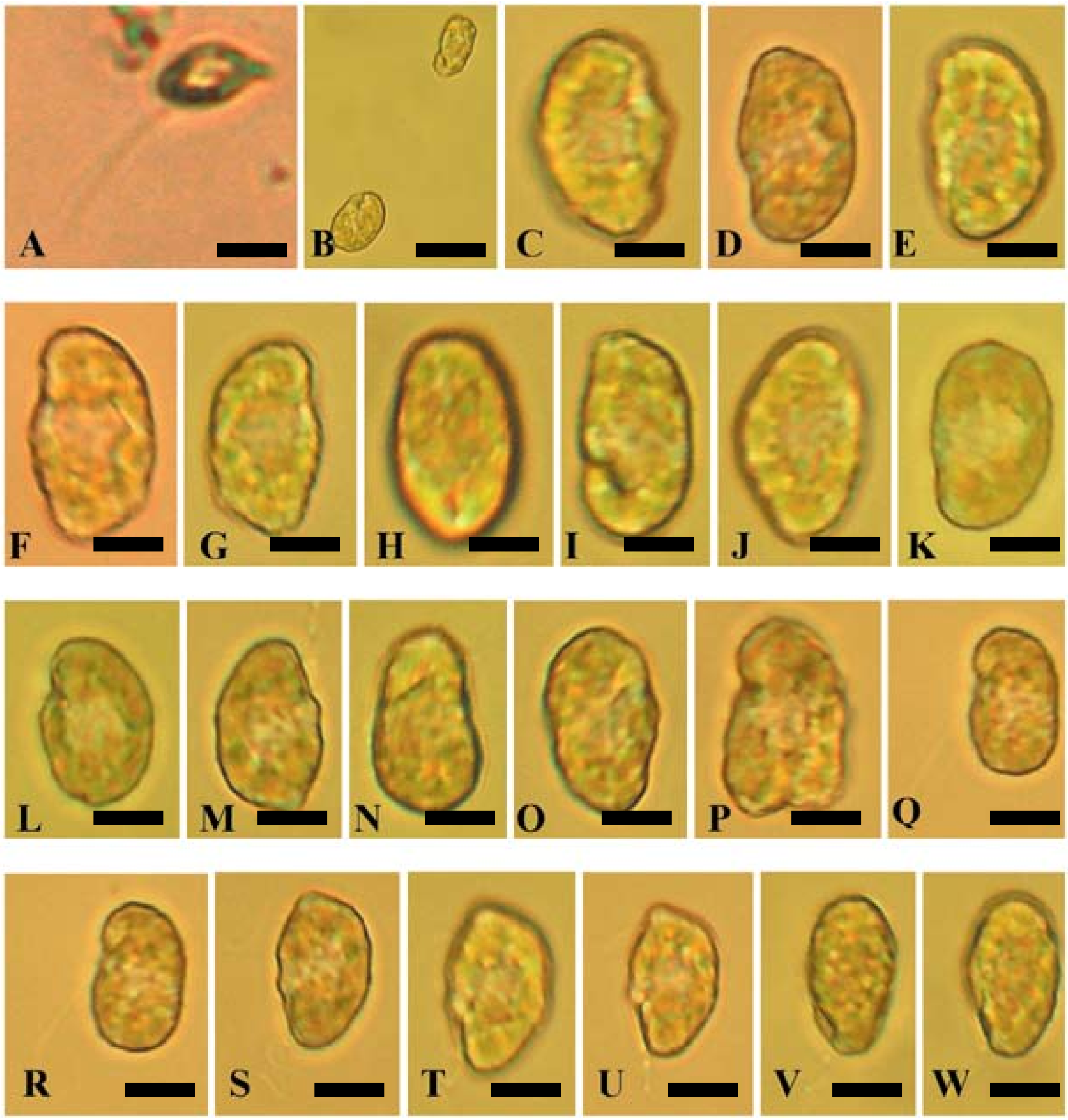

Plate 1. Light micrographs of A. cf. *Plagioselmis* sp.1: with flagella; B-W. *Heterosigma akashiwo*: different views in different magnifications, with visible flagella in Q-W.
(Scale Bars, A=8.89 µm; B=15.00 µm; C=12.00 µm; D=13.94 µm; E=12.22 µm; F=13.89 µm; G=14.38 µm; H=13.33 µm; I=15.00 µm; J=12.11 µm; K=12.22 µm; L=11.76 µm; M&N=14.00 µm; O=12.50 µm; P=12.35 µm; Q=8.33 µm; R=8.46 µm; S=9.23 µm; T=7.50 µm; U=8.46 µm; V=10.43 µm; W=9.23 µm).

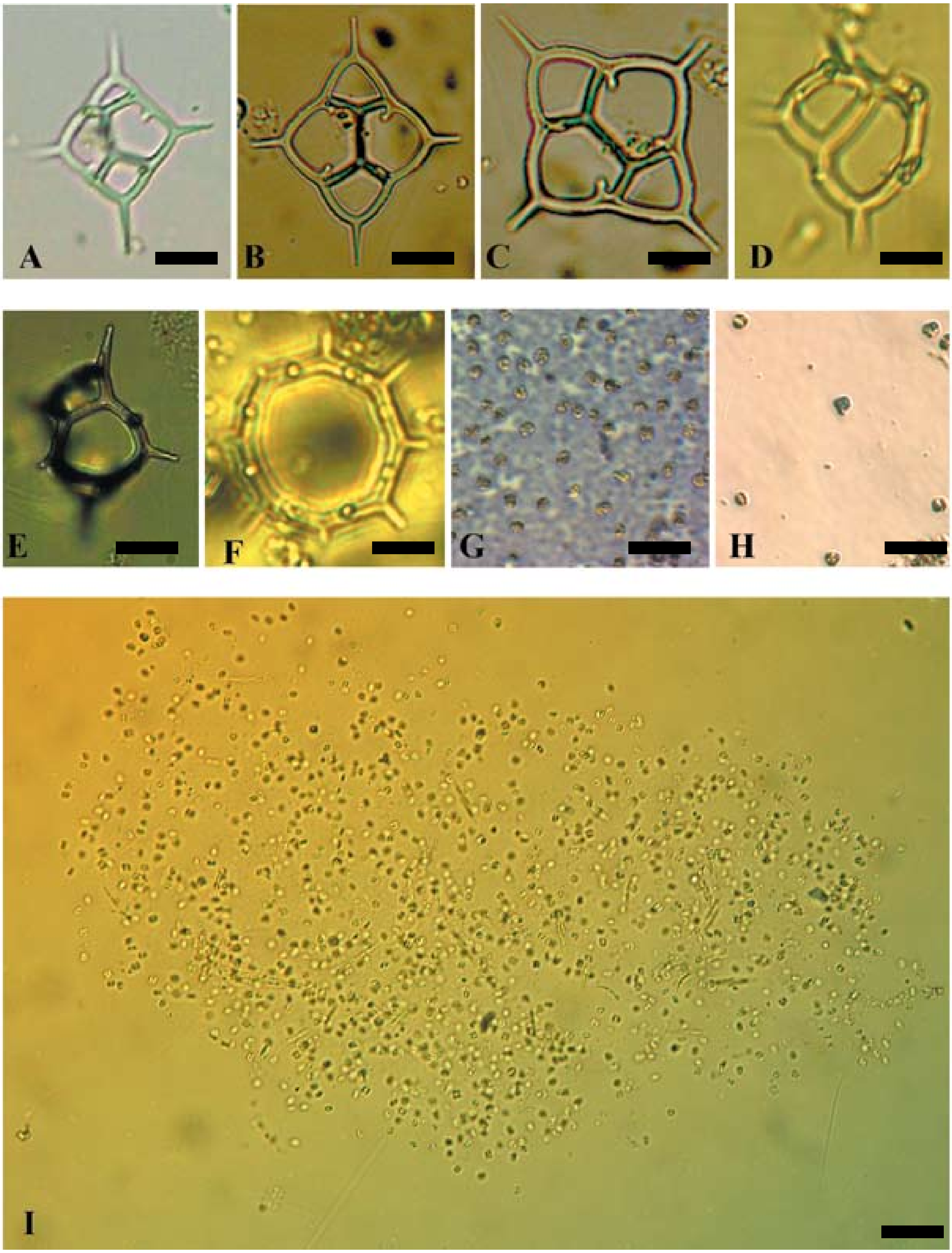

Plate 2. Light micrographs of A-E. *Dictyocha fibula*: A-C. in different magnifications, D-E. side of the cell; F. *Dictyocha speculum*: in circular view; G-I. *Phaeocystis* sp.1.
(Scale Bars, A=18.44 µm; B=15.24 µm; C=11.53 µm; D =11.54 µm; E=12.77 µm; F=10.67 µm; G&H=25.00 µm; I=33.33 µm).

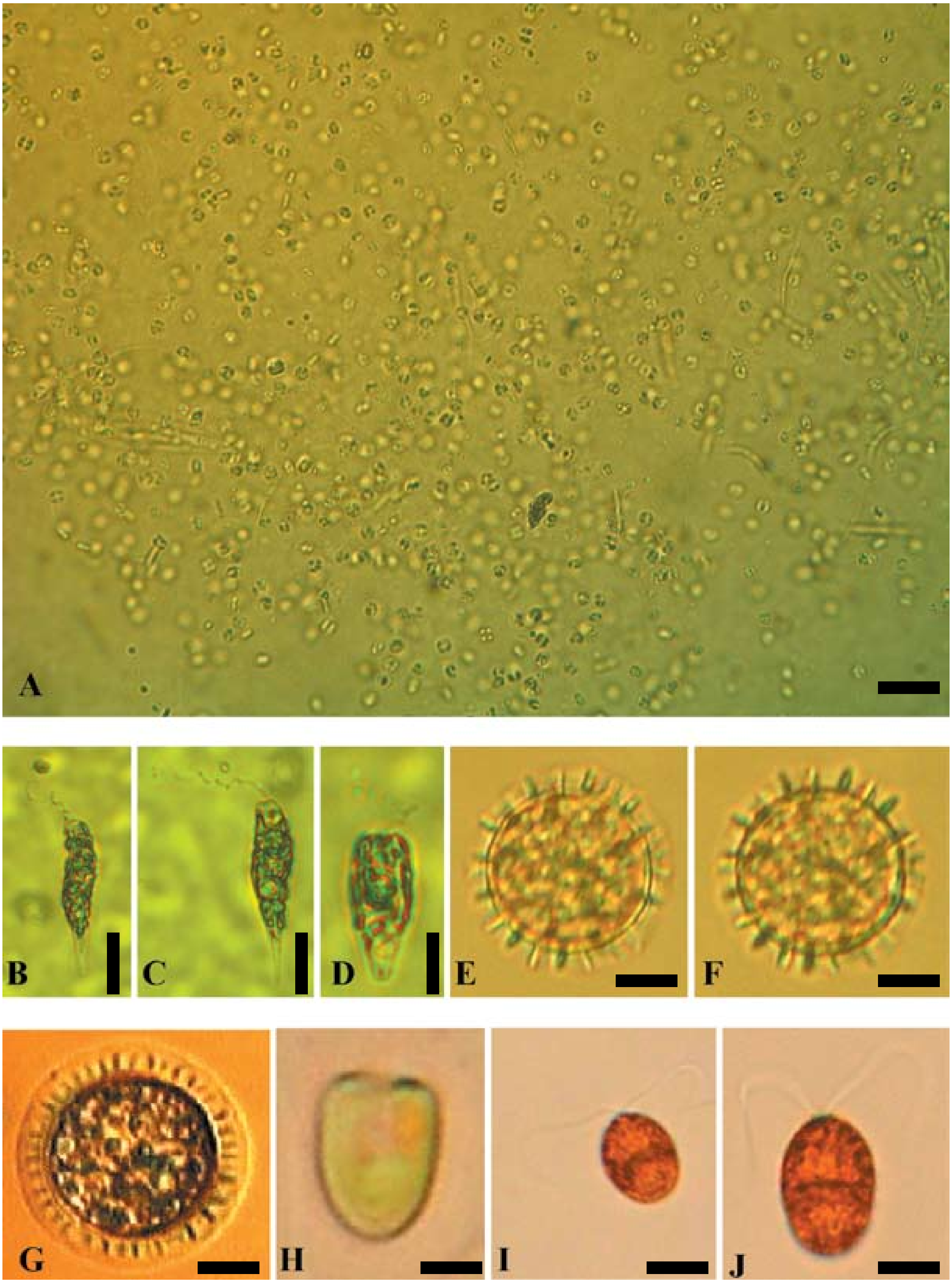

Plate 3. Light micrographs of A. *Phaeocystis* sp.1; B-C. *Eutreptiella* sp.1: elongate cell with coiled flagella; D. *Eutreptiella* sp.2: more wider with coiled flagella; E-G. *Pterosperma undulatum*; E-F. same cell in different focus, G. another cell; H. *Pyramimonas* sp.1: cell from preserved material disappear the number of flagella; I-J. *Dunaliella salina*: two different cells with clearly visible two flagella at the top of the cell.
(Scale Bars, A=25.00 μm; B=16.23 μm; C=15.59 μm; D=10.00 μm; E&F=10.29 μm; G=10.86 μm; H=2.22 μm; I=11.61 μm; J=10.00 μm).

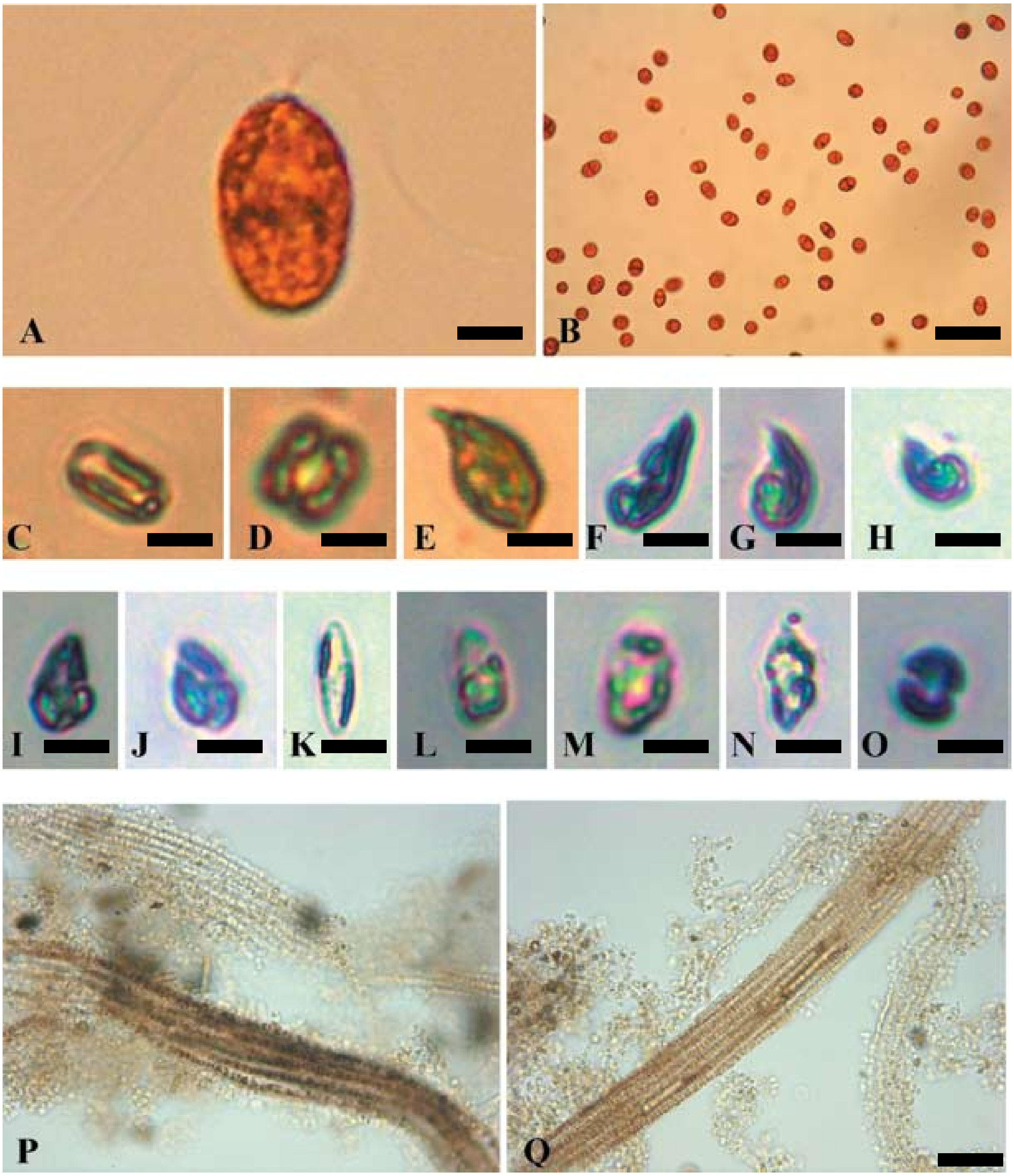

Plate 4. Light micrographs of A-B. *Dunaliella salina*: A. one species, oval in shape; B. bloom of cells; C-O. Other naked flagellates spp.: different species in different views; P-Q. *Trichodesmium erythraeum*: different colonies of cells from a big blooms.
(Scale Bars, A=7.27 µm; B=70.00 µm; C=2.65 µm; D=3.33 µm; E=3.14 µm; F=3.15 µm;G=2.65 µm; H=3.25 µm; I,J&L=3.33 µm; K=3.53 µm; M=2.88 µm; N=3.75 µm; O=3.64 µm; P=100.00 µm; Q=75.00 µm).

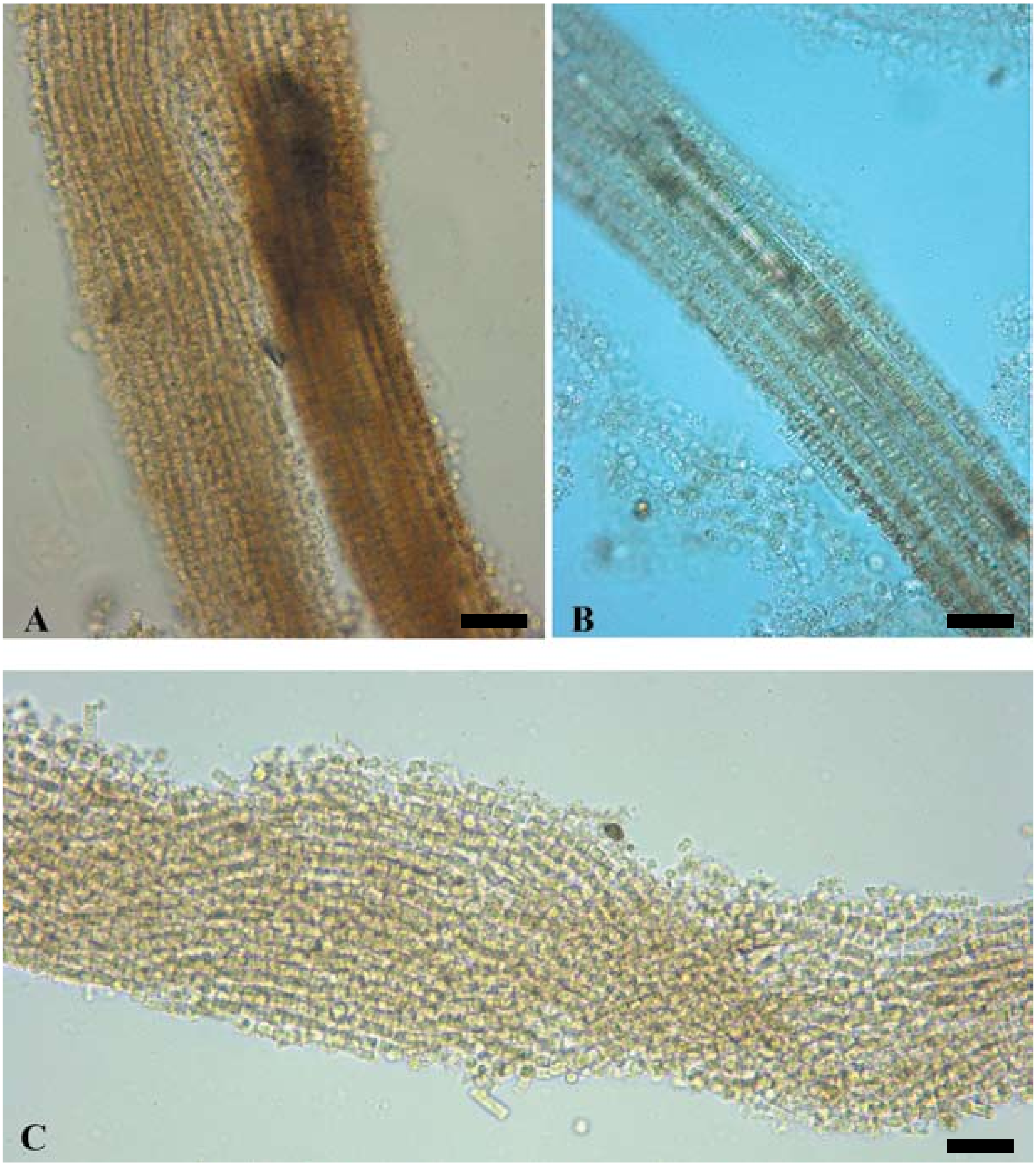

Plate 5. Light micrographs of A-C. *Trichodesmium erythraeum*: different colonies of cells from a bloom at different magnifications.
(Scale Bars, A&C=50.00 µm; B=25.00 µm).

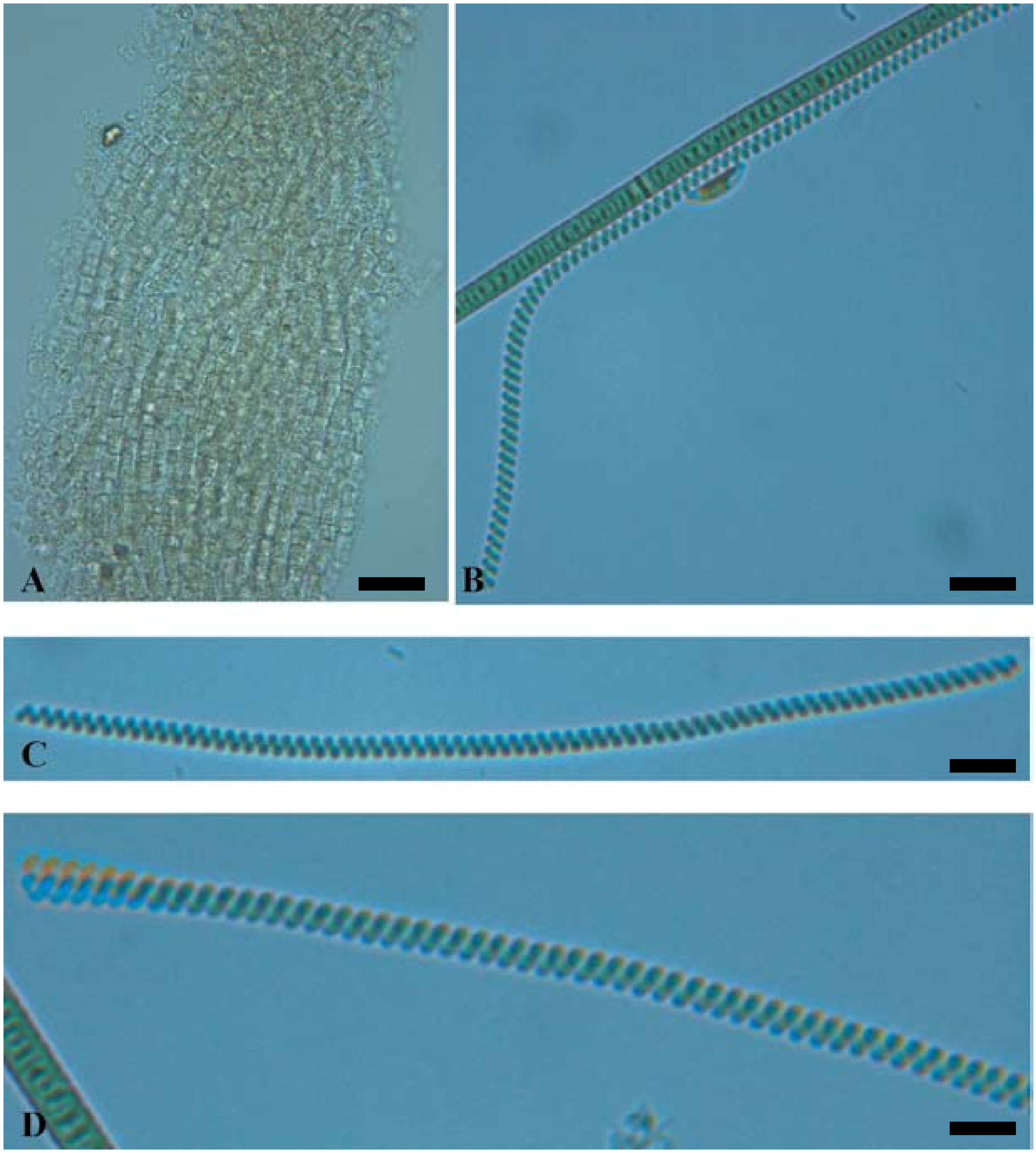

Plate 6. Light micrographs of A. *Trichodesmium erythraeum*: colony of cells; B-D. *Spirulina* sp.1: different cells at different focus and magnifications.
(Scale Bars, A=50.00 µm; B=25.00 µm; C=18.75 µm;D=15.00 µm).

Fig. 1. *Dunaliella salina* bloom (benign bloom): at Shuwaikh beach in October 2004 (photos by Abdul Mohsin Al-Haroon).

Fig. 2. *Phaeocystis* sp. blooms: A. a bloom red to brown in color at the South-East of Bubiyan Island in 2004; B. a bloom red in color at the MFD Marina (Salmiyah) in 2006 (photos by Dr. F. Al-Yamani).

Fig. 3. *Phaeocystis* sp. blooms: A. red to brown in colour (photos A-C by Dr. I. Polikarpov, and D and E by Dr. A. M'harzi).

Fig. 4. *Karenia selliformis* bloom in September 1999 (photos by Abdul Rahman Abdul Ghaffar).

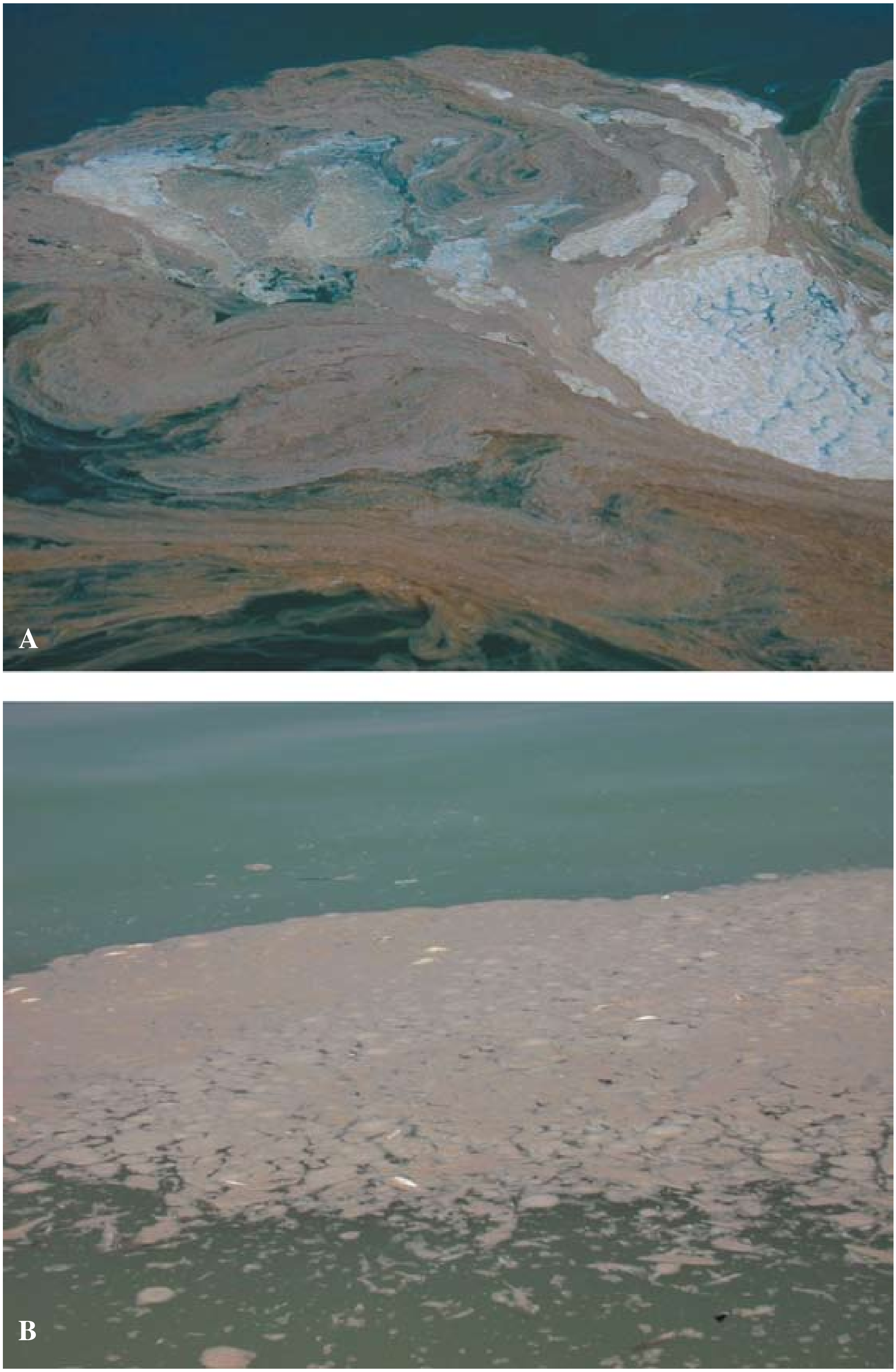

Fig. 5. *Trichodesmium erythraeum* bloom in May 2000 at A. Om-Almaradem and at B. off Al-Ahmadi in Kuwait's waters (photos by Abdul Rahman Abdul Ghaffar).

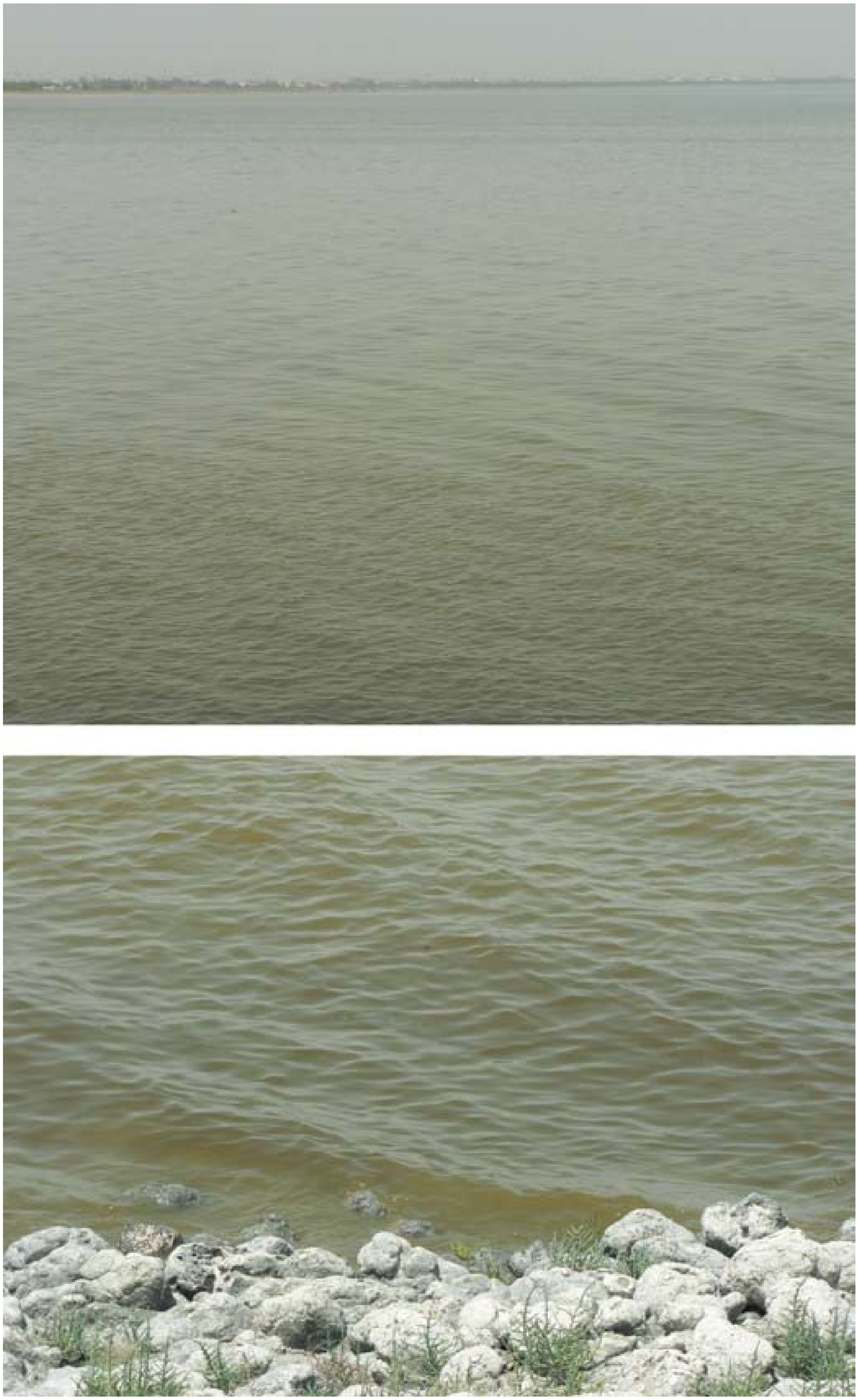

Fig. 6. *Heterosigma akashiwo* bloom: at the MFD Marina, Salmiyah 2006 (photos by Dr. F. Al-Yamani).

Fig. 7. *Pseudo-nitzschia* sp. bloom in Kuwait's waters (photos by Dr. F. Al-Yamani).

Marine Phytoplankton Atlas of
Kuwait's Waters

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