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A new occurrence of siliceous microfossils of Neogene deposits of the city of Heraklion, Crete, Greece

Dimitrios Frydas & Panayiotis Stefanopoulos

Abstract: Assemblages of Upper Zanclean to Lower Piacenzian siliceous microfossils was studied from a new occurrence of diatomite beds of the city of Heraklion, Crete. The selected associations were studied for their stratigraphy and taxonomy. 29 taxa of diatoms and 12 taxa of silicoflagellates could be identified. The associations of the diatoms belong to the subzone *Thalassiosira leptopus* whereas the silicoflagelates belong to the subzone *Dictyocha fibula ausonia.*

Keywords: Diatoms, Silicoflagellates, Biostratigraphy, Taxonomy

Zusammenfassung: Aus dem oberen Zanclium /unteren Piacenzium der Stadt Heraklion, Kreta, wurden die Vergesellschaftungen von kieseligen Microfossilien untersucht, die aus einem neuen Diatomit-Vorkommen stammen. Die Assoziationen wurden hinsichtlich ihrer Stratigraphie und Taxonomie untersucht. 29 Diatomeen- sowie 12 Silicoflagellaten-Arten konnten bestimmnt werden, die entsprechend in die Subzonen *Thalassiosira leptopus* und *Dictyocha fibula ausonia* eingestuft wurden.

Schlüsselwörter: Diatomeen, Silicoflagellaten, Biostratigraphie, Taxonomie

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1. Introduction

The Neogene sequence of the studied area is strongly faulted. The fault systems already existed during the sedimentation and they delimitated a number of small basins, which were separated by shoals and small islands. Two orthogonal systems of NNE-ENE and NNE-WNW trending fault influenced and controlled the paleogeographical evolution of four small individual basins, which were generally separated by the presence of “intrabasinal” basement high (Meulenkamp et al. 1979, Mascle et al. 1981-1982, Jonkers 1984). These four adjacent are Finikia – Agios Vlasios, Kallithea, Prassas and Aitania that have been investigated for both silicoflagellates and diatoms (Frydas 1990, 1999, 2004, Frydas et al. 2008).

On the island of Crete two sedimentation cycles are distinguished, ranging the late Miocene and Pliocene, respectively (Christodoulou 1963, Frydas & Keupp 1996). Deposits of more than 500 m in thickness comprise the above two cycles within the Neogene basins. During the late Miocene Mediterranean “salinity crisis”, rhythmic alternations of thick evaporites, sandstone and diatomites were deposited.

The extensive literature on the geology and stratigraphy of the Neogene of Crete, in which the paleontology is mainly concerned with invertebrated macrofossils as well as microfossils, has been previously discussed by Frydas (1999). According to Jonkers (1984), Theodoridis (1984) and Driever (1988) reported Pliocene benthic foraminifera and Miocene and Pliocene calcareous nannofossils, respectively. Through a common research program between the institutes of Paleontology of the FU Berlin and Patras a detailed stratigraphy concerning Upper Cenozoic calcareous nannofossils (Frydas & Keupp 1996), silicoflagellates (Frydas 1989, 1990, 1993, 2004, Frydas & Avramidis 2001) and marine diatoms (Frydas 1999, Frydas & Keupp 2000) have been undertaken for the first time in northwestern Crete.

Correlation of the Crete Neogene to the biostratigraphic international zonal scheme developed for diatoms and silicoflagellates (Barron 1985a, b, Bukry 1981) is discussed elsewhere (Frydas 1999, 2004, Frydas et al. 2008). The aim of the present paper is the stratigraphical investigation of Upper Cenozoic opal phytoplankton assemblages (diatoms and silicoflagellates) for the western part of the Heraklion city in Crete.

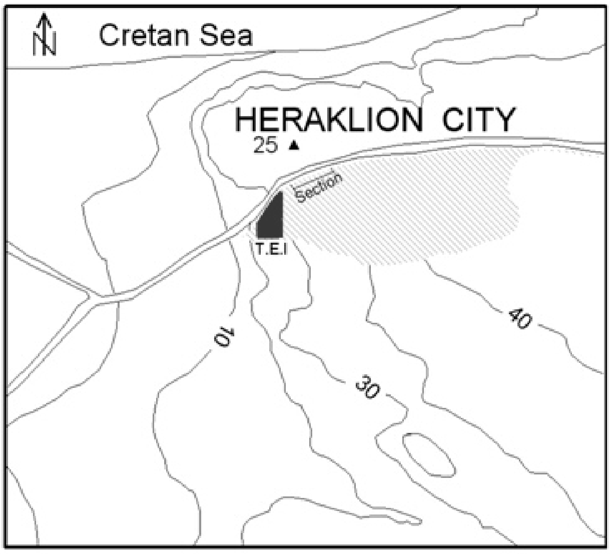

Fig. 1. Location of studied section

2. Section of Heraklion

The studied outcrop is located in the area of the Technical Educational Institute (T.E.I) in the Herakion city. During an excavation on October 2008 for setting the foundation of an apartment house, diatomite beds of about 1.80 m thickness were observed. This was the first time that diatomite occurrences we found in the city of Heraklion (Fig. 1). The sediments of this section belong to the top of the Finikia unit (late Early Pliocene, to early Late Pliocene), which are found in the western Heraklion area (Frydas 2004), as well as in the north-eastern and southern hills of the Messara-plain in the southern Heraklion district (Frydas et al. 2008). The investigated section represents an alternation of yellowish-grey homogenous marls and white grayish laminated diatomite beds, which generally appear on the top part of the section (Fig. 2). A rich opal phytoplankton assemblage containing both diatom and silicoflagellates as well as same radiolarian species has been observed in the diatomaceous layers from the outcrop.

3. Biostratigraphy

The diatoms section can be correlated with the well-known tropical/subtropical diatom zonation (Barron 1985a, b, Baldauf & Iwai 1995, Frydas 1999, 2004, Frydas & Keupp 2000, Frydas et al. 2008) which are based on low-latitude, or cosmopolitan marker species. The silicoflagellates of the section can be correlated with the standard zonation of Bukry (1981) and Perch-Nielsen (1985). The taxonomy of both groups is discussed in detail, including a synonymy list, by Frydas (1990, 1991, 2004) and Frydas & Avramidis (2001). The magnetostratigraphic time scale used in this work (Fig. 3.) is based on biostratigraphic ages given by Shackleton et al. (1995).

3.1 Diatoms

3.1.1 *Thalassiosira leptopus* acme subzone

The low-latitude *Nitzschia jouseae* biozone of Barron (1985a, b) is defined as the interval from the first occurrence of *Nitzschia jouseae* to the first occurrence of *Rhizosolenia praebergonii* (early Pliocene to early late-Pliocene). According to Burckle and Trainer (1979) the last occurrence of *Nitzschia jouseae* was observed at 2.6 Ma above the first occurrence of *Rhizosolenia praebergonii* at 2.94 Ma. Baldauf & Iwai (1995) proposed to replace, where needed, *Rhizosolenia praebergonii* zone with the *Nitzschia marina* zone. Moreover, *Rhizosolenia praebergonii* is rare outside the equatorial Pacific, and Baldauf & Iwai (1995) favor the use of a *Nitzschia jouseae* zone based on the total range of *Nitzschia jouseae.* Heraklion section is characterized by warm-water planktic species such as *Azpeitia vetustissima*, *Nitzschia jouseae, Thalassio-nema nitzschioides*, *Thalassiosira leptopus* and *Triceratium balearicum* (Plate 2).

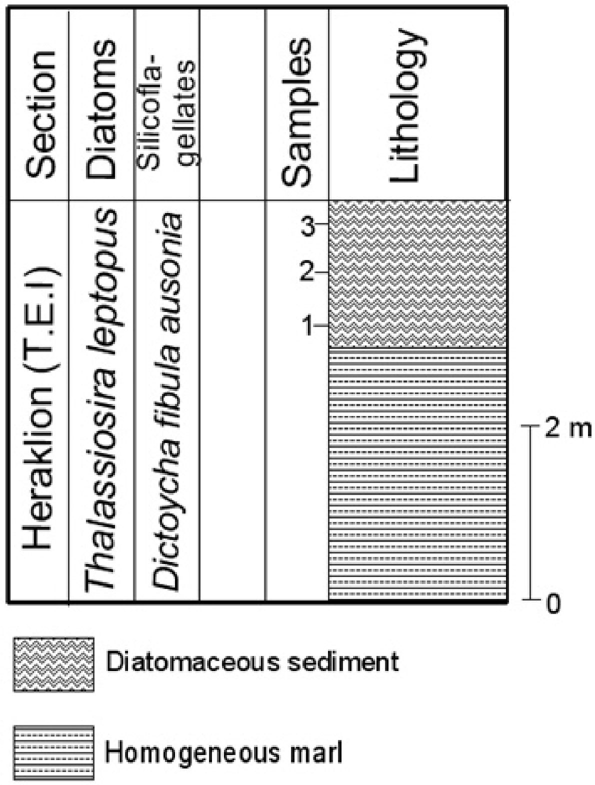

Fig. 2. Litho and Biostratigraphy. Diatom and silicoflagellate Stratigraphy and position of three samples in the same laminated diatomite beds of the Heraklion (T.E.I.) outcrop

In our material we observed the dominance of *Thalassiosira leptopus*, a warm water species, which is common to abundant in the three examinated samples (Figs. 2, 3). In addition, the dominance of the silicoflagellate species *Dictyocha fibula ausonia* and *Dictyocha hellenica* indicates also a warm-water environment.

The *Thalassiosira leptopus* subzone can be correlated approximetely with :

- The *Thalassiosira leptopus* subzone of diatoms from Fortessa, Marathis and Kallithea sections in central Heraklion area (Frydas 1999).
- The upper part of the *N. jouseae* biozone from Asteri and Kalyves sections in the nothern part of the Rethymnon province (Frydas & Keupp 2000).
- The diatoms associations from Capo Rosselo (Lower Pliocene) section in Sicily (Schrader & Gersonde 1978).

3.1.2. *Dictyocha fibula ausonia* acme subzone

Subzone corresponding to the interval, which includes the acme beginning of *Dictyocha hellenica* (Lower Piacenzian) to the acme beginning of *Distephanus boliviensis* major (Frydas 1996, Frydas & Avramidis 2001). The silicoflagellate association from Heraklion section (Plate 1) belongs to this subzone which is equivalant to subzone CN12a (*Discoaster tamalis*) sensu Okaka & Bukry (1980), or the lower part of the NN15 (*D. surculus*) biozone of Martini & Müller (1986), or the subzone CN12aB (*D. tamalis*) of Raffi & Flores (1995). This acme subzone can be correlated with the following zones / subzones.

- The lower part of the *Dictyocha stapedia stapedia* zone (Martini 1971b, Bukry 1981, Frydas 1989)
- The subzone *Dictyocha* cf. *neonautica* (sensu Bukry 1981) for the upper part of the sections Marathitis, Aghios Vlassios (Frydas 1990) as well as section Gournes, to which belong all three sections in the Finikia-Aghios Vlassios unit (Frydas 1996) in central Crete and the NN16-17D (*Gephyrocapsa Acme*-subzone) of Driever (1988).

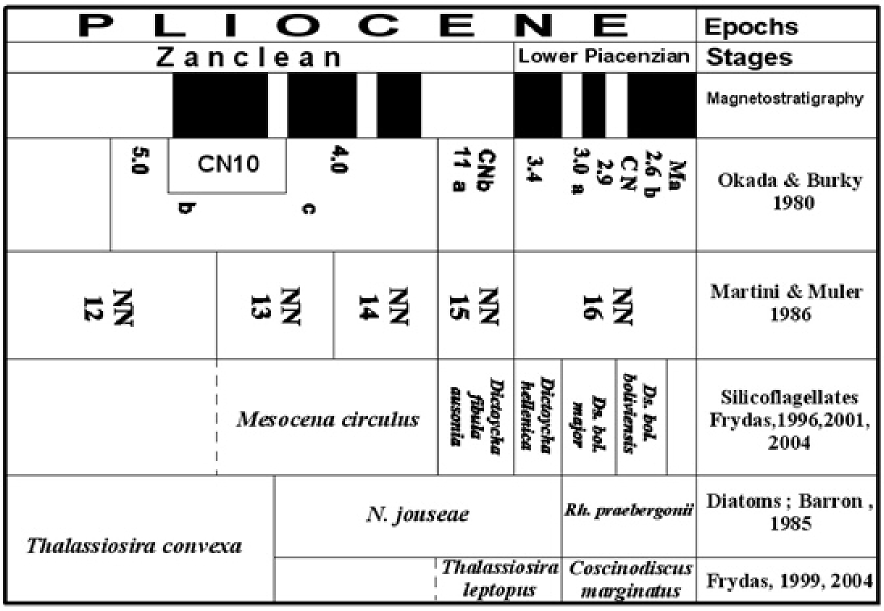

Fig. 3. Correlation of the studied section based on phytoplankton biostratigraphy and comparison with diatoms and silicoflagellate blo-or (sub) zones as well as the magnetostratigraphic scale (Shackleton et al., 1995)

4. Discussion

Danelian & Alexander (2000) suggested that the Pliocene diatomite sediments in the Heraklion District are probably linked to climate-driven changes in surface runoff (i.e. warmer temperatures and/or lower salinities), which influenced the levels of primary productivity. The implications of these hydrological changes would have had a profound influence on the local accumulation of diatom-rich sediments in the small fault-bound basins of Crete. The formation of diatomites of similar age and setting (i.e. early Piacenzian diatomites in the Bianco section, Italy) were also interpreted in terms of coastal upwelling induced by climate-driven changes in the local oceanography (Rio et al. 1989, Thunell et al. 1990). According to Hilgen (1991) individual sapropels in the Eastern Mediterranean can be correlated with minima of the precessional cycle. Other studies support the precessional cycle as the dominant factor influencing lower to upper Pliocene climatic evolution (Tiedemann et al. 1994). In the absence of high resolution stratigraphic control we can only speculate as to the precise nature of astronomical forcing behind the diatomite-marl cycles studied herein.

5. Acknowledgements

We are grateful to the Ministry of Development, General Secretary for Research and Technology , for financial support during my field work. We thank Prof. Dr. H. Keupp and W. Müller (Free University of Berlin, Institute of Paleontology) for technical assistance in the scanning electron microscopy.

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7. Appendix A. Taxonomy

A1. Diatoms. Taxonomy according to Frydas (1999) and Frydas & Hemleben (2007)

Actinocyclus curvatulus Janisch in Schmidt, 1874

A. octonarius Ehrenberg, 1837

A. octonarius var. *tenella* (Brebisson, 1854) Hendey, 1964

Actinoptychus senarius (Ehrenberg, 1837) Ehrenberg, 1843

Asteromplalus sp. Ehrenberg, 1845

Azpeitia vetustissima (Pantocsek, 1886) Sims in Fryxell, et al. 1986

Biddulphia pulchella Gray, 1821

B. tyomeyi (Bailey, 1844) Roper, 1859

Chaetoceros gastridium (Ehrenberg, 1846) Brightwell, 1973

Cocconeis scutellum Ehrenberg, 1837

Cascinodiscus argus Ehrenberg, 1837

C. asteromphalus Ehrenberg, 1846

C. oculus-iridis Ehrenberg, 1841

C. lineatus Ehrenberg, 1841

C. radiatus Ehrenberg, 1843

Diploneis advena (A.Schmidt) Cleve

Diploneis smithii (W.Smith, 1853) Brebisson, 1894

Hemidiscus cuneiformis Wallich, 1930

Nitzschia jouseae Burckle, 1972

Rhizosolenia hebetata (Hensen, 1887) Gran, 1905
Stephanopyxis corona (Ehrenberg, 1854) Grunow, 1882
S. turris (Greville & Arnott, 1857) Ralf in Pritchard, 1861
Surirella ovata Kutzing, 1844
Synedra fulgens (Greville, 1866) W.Smith, 1856
Thalassionema nitzschioides (Grunow, 1862) in Van Heurck, 1881
Thalassiosira eccentrica (Ehrenberg, 1845) Fryxell and Hasle, 1972
T. leptopus (Ehrenberg, 1840) Hasle and Fryxell, 1977
Thalassiothrix longissima (Cleve, 1873) Cleve and Grunow, 1880
Triceratium balearicum (Cleve and Grunow, 1880) Hustedt, 1930

A2. Silicoflagellates. Taxonomy according to Perch-Nielsen (1985b), Frydas (1990, 1991, 1996, 2004) and Frydas and Avramidis (2001)

Dictyocha fibula Ehrenberg, 1849
D. hellenica Frydas in Frydas & Avramidis, 2001
D. fibula ausonia (Deflandre, 1950) Mc Cartney et al., 1995
D. fibula minosii Frydas, in Frydas & Avramidis, 2001
D. fibula mutobilis (Deflandre, 1950) Mc Cartney et al., 1995
D. perlaevis perlaevis Frenguelli, 1951
D. stapedia aspinosa Bukry, 1976
D. stapedia stapedia Haeckel, 1887
Distephanus boliviensis binoculus Ciesielski, 1975
Ds. boliviensis boliviensis (Frenguelli, 1940) Bukry, 1979
Ds. speculum quintus (Bukry and Foster, 1973) Bukry, 1975
Ds. speculum speculum (Ehrenberg, 1839) Glezer, 1966

Plate 1 Silicoflagellates

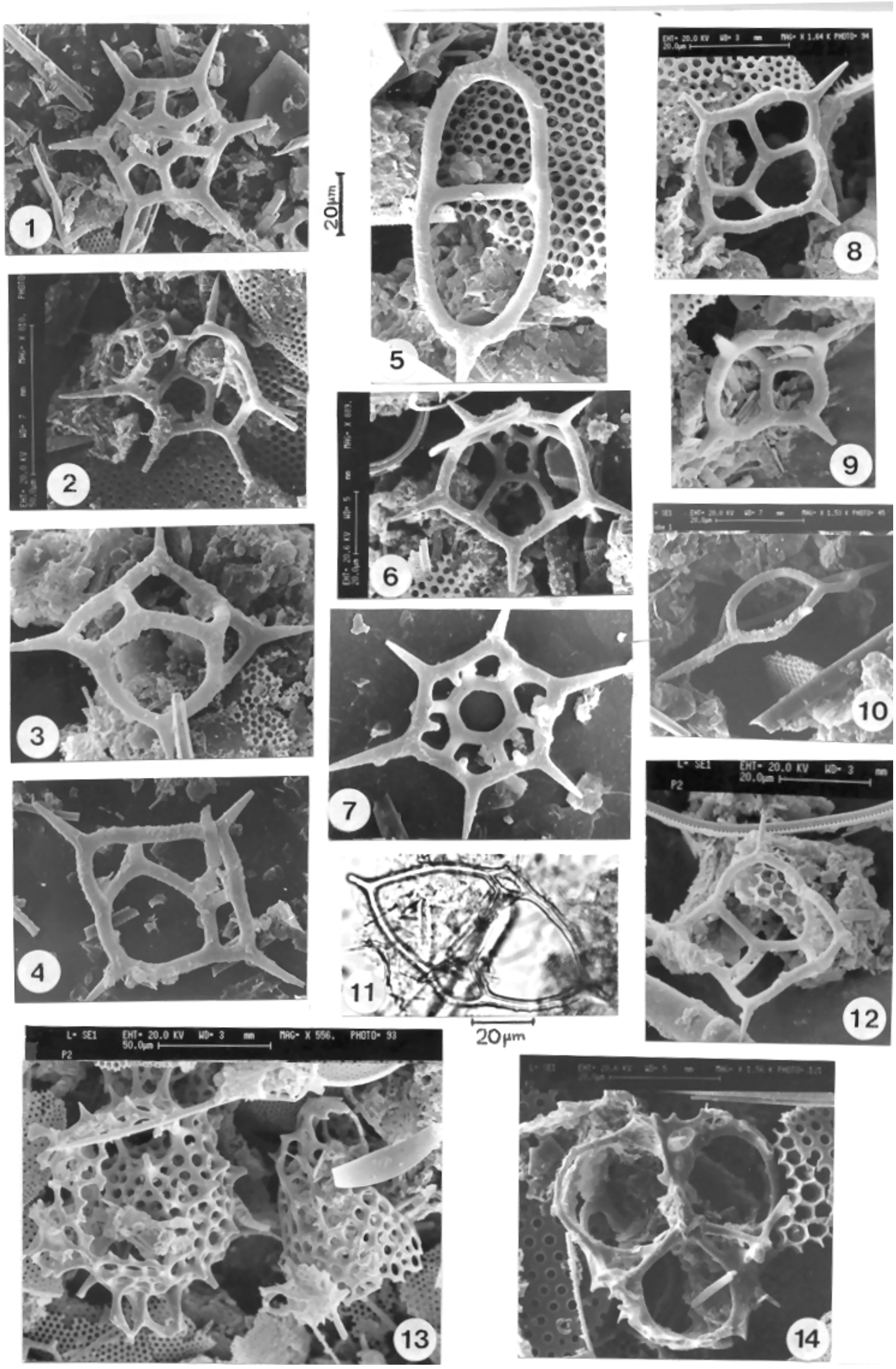

Fig. 1 & 2: *Distephanus boliviensis boliviensis* (Frenguelli) 1: Apical ring, 2: Basal ring
Fig. 3 & 4: *Dictyocha stapedia aspinosa* (Bukry) 1: Apical ring, 2: Basal ring
Fig. 5: *Dictyocha fibula minosii* / *D. hellenica* (Frydas) (transitional form)
Fig. 6: *Distephanus speculum quintus* (Bukry & Foster)
Fig. 7: *Distephanus speculum speculum* (Ehrenberg)
Fig. 8-10: *Dictyocha fibula* (Ehrenberg) 8,9: Basal ring, 10:Lateral view
Fig. 11: *Dictyocha fibula ausonia* (Deflandre); Optical microscopy
Fig. 12: *Dictyocha perlaevis perlaevis* (Frenguelli) (Basal ring)
Fig. 13 & 14: Radiolaria sp.

Plate 2 Diatoms

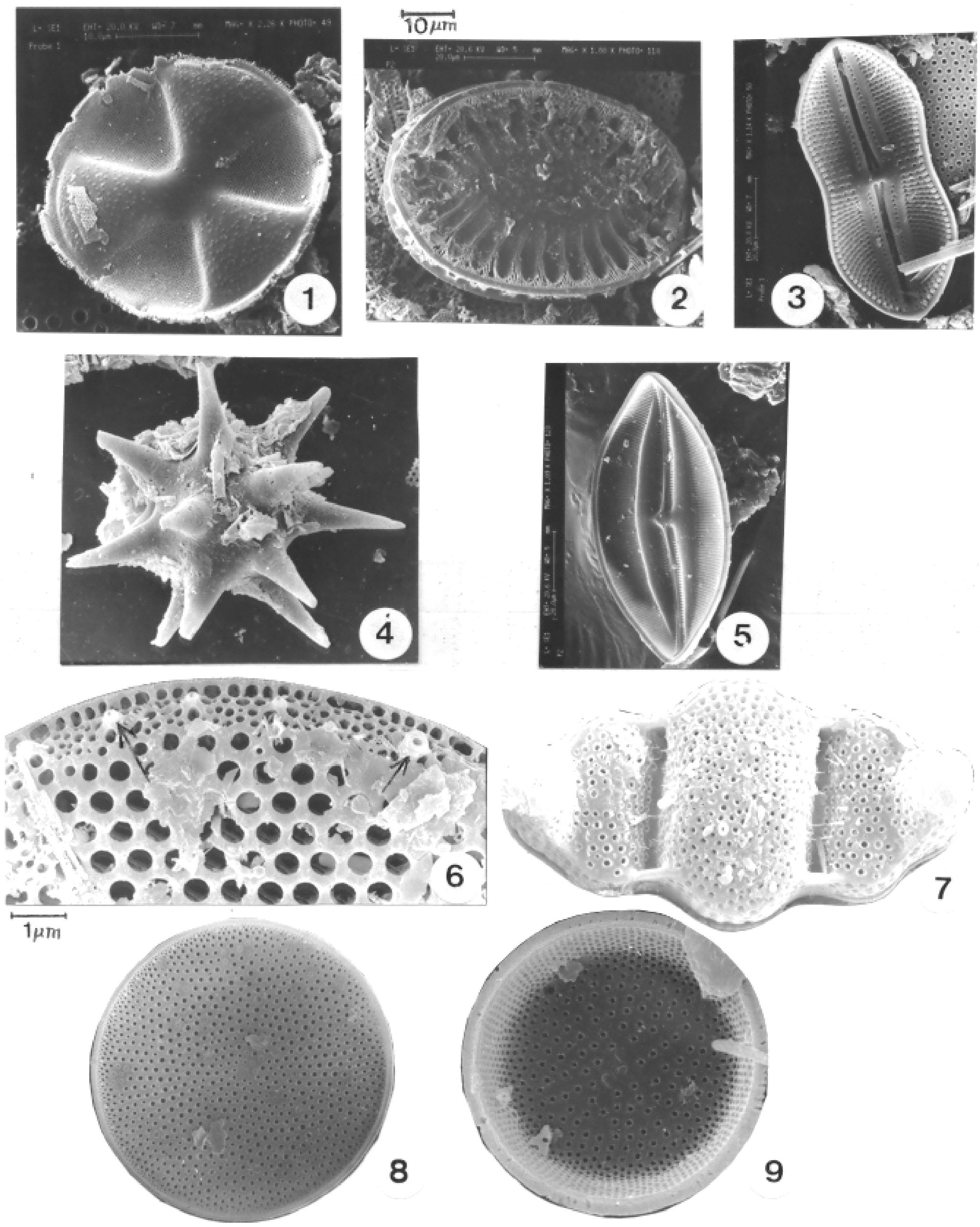

Fig. 1: *Actinoptychus senarius* (Ehrenberg)

Fig. 2: *Surirella ovata* (Kutzing)

Fig. 3: *Diplomeis* cf. *advena* (A.Schmidt) Cleve

Fig. 4: *Spongaster* (Sponge sclere)

Fig. 5: *Diploneis smithii* (Brebisson) Cleve

Fig. 6: *Thalassiosira leptopus* (Ehrenberg) Hasle & Fryxell (Arrows indicate two well developed fultopartulae on the external valve mantle where pass throught the fibroid mucons useful for the movement and the rotation of the diatom whilst he is alive)

Fig. 7: *Biddulphia tuomeyi* (Bailey) Roper

Fig. 8: *Coscinodiscus radiatus* (Ehrenberg)

Fig. 9: *Actinocyclus octonarius* var. *tenella* (Brebisson) Hendey