REVISED BIOSTRATIGRAPHY BASED ON CALCAREOUS NANNOFOSSILS OF THE CITADELLE SECTION, ZAKYNTHOS ISLAND, GREECE

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Abstract: The quantitative analysis of calcareous nannofossil assemblages resulted in a revised biostrati-graphy of the Citadelle section in the eastern part of Zakynthos island. The derived data indicate an uppermost Pliocene age. No precise indication of Pleistocene nannoplankton were observed in the studied Citadelle samples.

Introduction

Zakynthos island (Ionian Sea, western Greece), is situated in the external part of the Hellenides, a NNW-SSE-trending orogenic belt. In the concept of Aubouin (1959), the Alpine framework on which the Neogene basins of Zakynthos are developed consists of the two zones of isopics in the external Hellenides: the Ionian and the Pre-Apulian Zones. Because of its important location in the Hellenic orogenic belt, Zakynthos has been the subject of several geological studies. The well-developed Miocene, Pliocene and Pleistocene successions have particularly attracted the interest of detailed biostratigraphic investigations (Dermitzakis, 1978; Dermitzakis *et al.*, 1979; Dermitzakis & Georgiades-Dikeoulia, 1987; Triantaphyllou, 1993; Triantaphyllou *et al.*, 1997).

The Plio-Pleistocene terrigenous-clastic sediments on the island are mainly composed of marls, silts, silty clays, sandstones and calcarenites. These deposits are well-exposed in the southeastern and eastern parts of the island, and their biostratigraphic location has been studied tentatively (Triantaphyllou, 1993; Triantaphyllou *et al.*, 1997) resulting in the recognition of the Pliocene-Pleistocene boundary, based on calcareous nannofossil biostratigraphic events. Sediments of the same age have also been determined in the eastern and northeastern part of Zakynthos and have been studied by Blanc-Vernet & Keraudren (1970) and Bizon & Mirkou (1969).

The Citadelle section, located in the same area, has been studied (calcareous nannofossils and planktonic foraminifera) by Bizon & Müller (1977). These authors recognised the calcareous nannoplankton biozones NN16, NN17/18 and NN19 of Martini (1971). According to them, the extinction of the nannoplankton species *Calcidiscus macintyrei* and the planktonic foraminifera *Globigerinoides obliquus* indicated the Pliocene/Pleistocene boundary in these deposits. However, the determination of this age on the basis of calcareous nannofossils seems to be problematic, as the philosophy of Plio-Pleistocene biostratigraphy has been essentially reviewed in recent years.

Therefore, the main goal of the study presented here was the biostratigraphic analysis of the Citadelle section sediments, using calcareous nannofossils and planktonic foraminifera, with the intention of establishing a precise biostratigraphy for the area.

Material and methods

The Citadelle section is one of the most representative in Zakynthos for the Upper Pliocene-Lower Pleistocene interval. A total number of 70 samples were collected from the studied sequence. It should be noted that it was impossible to get samples from the uppermost part of the section due to major difficulties in gaining access to the area.

Light microscope techniques were used for the examination of the smear slides, which were prepared using standard methods. Additionally, SEM analysis was applied to several samples.

The calcareous nannofossil taxonomy and zonation are after Raffi & Rio (1979), Rio (1982), Rio *et al.* (1990) and Raffi *et al.* (1993), to which the reader is referred. The quantitative methods of biostratigraphic analysis used in the present study are those proposed by Rio *et al.* (1990):

- counting of the index species *versus* a fixed number of taxonomically-related forms (discoasterids, counts of 50 specimens of the genus);
- semiquantitative estimation of the presence of index species in relation to a specific number (40) of fields of view (number of specimens of the index species in a fixed area of a slide).

The first method was applied to *Discoaster* species and *Helicosphaera sellii*. The semiquantitative analyses were based on small *Gephyrocapsa* spp. specimens and *Calcidiscus macintyrei*.

The extraction of consistent biostratigraphic information from the samples required these counting methods to be reproducible (Raffi *et al.*, 1993). The determination of the biostratigraphic events, and the evaluation of the relative abundances of the index species, have been estimated on the philosophical basis of Rio *et al.* (1990), with minor alternations due to the nature of the studied sediments.

Description of the section

A sequence of Pliocene marly sediments over 200m thick, with a distinct cyclicity, is exposed northwards of Zakynthos city in the eastern part of the island (Figure 1). The sequence of sediments shows an average dip of 12°NE and can be divided into two formations (Figure 2). The lower one, the Citadelle Formation, consists at its base of a monotonous sequence of sediments, characterised by alternations of bluish marls and sapropelitic layers. The middle and upper part of the section is characterised by a periodical increase of terrestrial material, represented by coarse-grained horizons, indicating a high sedimentation rate. These coarse-grained horizons have an approximate thickness of 0.3-1.3m. Calcarenites of the Kryoneri Formation unconformably overlie the uppermost part of the section.

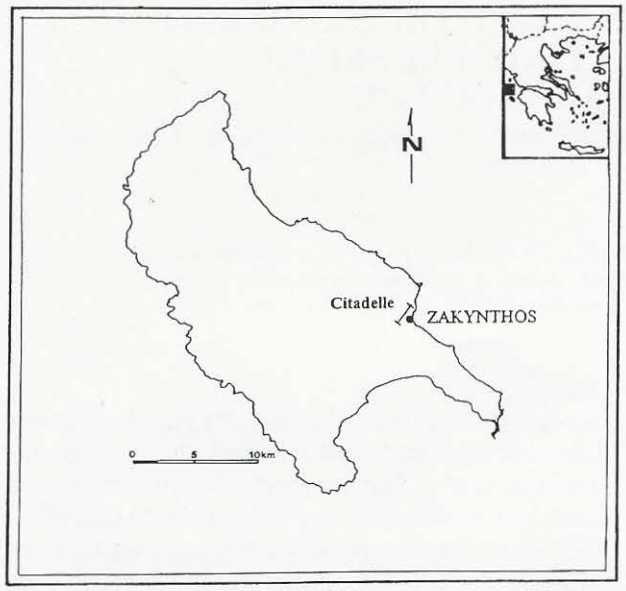

Figure 1: Location of the Citadelle section on the island of Zakynthos.

Biostratigraphy and chronostratigraphy

The biostratigraphic analysis based on planktonic foraminifera revealed the presence of *Globorotalia inflata* throughout the section, along with *Neogloboquadrina atlantica*, *Globigerinoides ruber*, *Globorotalia scitula*, *Globigerina quinqueloba* and *Globigerina bulloides*. Although Bizon & Müller (1977) considered the first occcurrence (FO) of *G. inflata* in the Mediterranean as a diachronous event, Rio *et al.* (1984a, b), Raffi & Sprovieri (1985) and Sprovieri (1992) have proved that this opinion is not warranted.

Concerning calcareous nannofossils, it should be noted that the *in situ* nannoflora is characterised by low abundance and a poor state of preservation. The presence of Eocene, Oligocene and Miocene reworked and recrystallised specimens is common. These features can be correlated with the periodical increase of terrestrial material going upwards in the section.

The quantitative analysis of Pliocene discoasterid species led to the conclusion that these have been reworked, as different species with different stratigraphic ranges were found co-existing (Figure 2). However, the presence of the three-rayed *Discoaster brouweri* variety (*D. triradiatus*) at 15-20m above the base of the section is very important. *D. triradiatus* specimens have had little chance to have been reworked, as these forms are mainly typical of the uppermost part of *D. brouweri*'s stratigraphic range (Takayama, 1970; Backman & Shackleton, 1983; Rio *et al.*, 1984b; Backman & Pestiaux, 1986). The rest of the nannofossil assemblages consist of well-developed specimens of *Pseudoemiliania lacunosa*, *Helicosphaera sellii* (Figure 3), abundant small *Gephyrocapsa* spp. (<3.5μm) with several transitional forms to normal-sized gephyrocapsids (ranging in size between 4μm and 5.5μm, with a bar and a relatively open central area: see Raffi *et al.*, 1993) and sporadic *C. macintyrei*. No normal-sized gephyrocapsids were observed.

Semiquantitative analysis (Figure 3) showed that wide-range frequency oscillations of *C. macintyrei* may

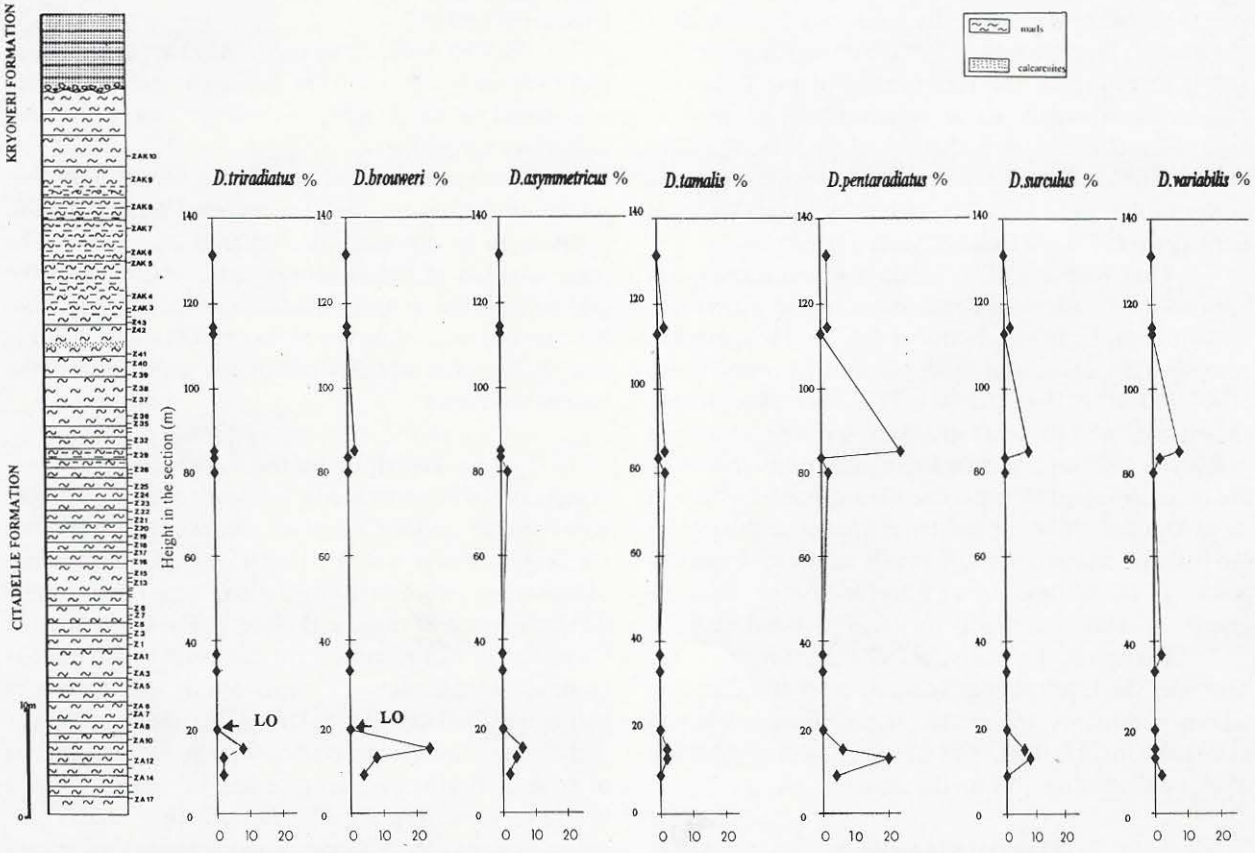

Figure 2: Lithostratigraphic column for the Citadelle section. Height of the section (m) and location of the samples are also shown. Abundance of discoasterids is relative to 50 specimens of *Discoaster* spp. (the percentages of *D. triradiatus* are plotted *versus* the total number of *D. brouweri*).

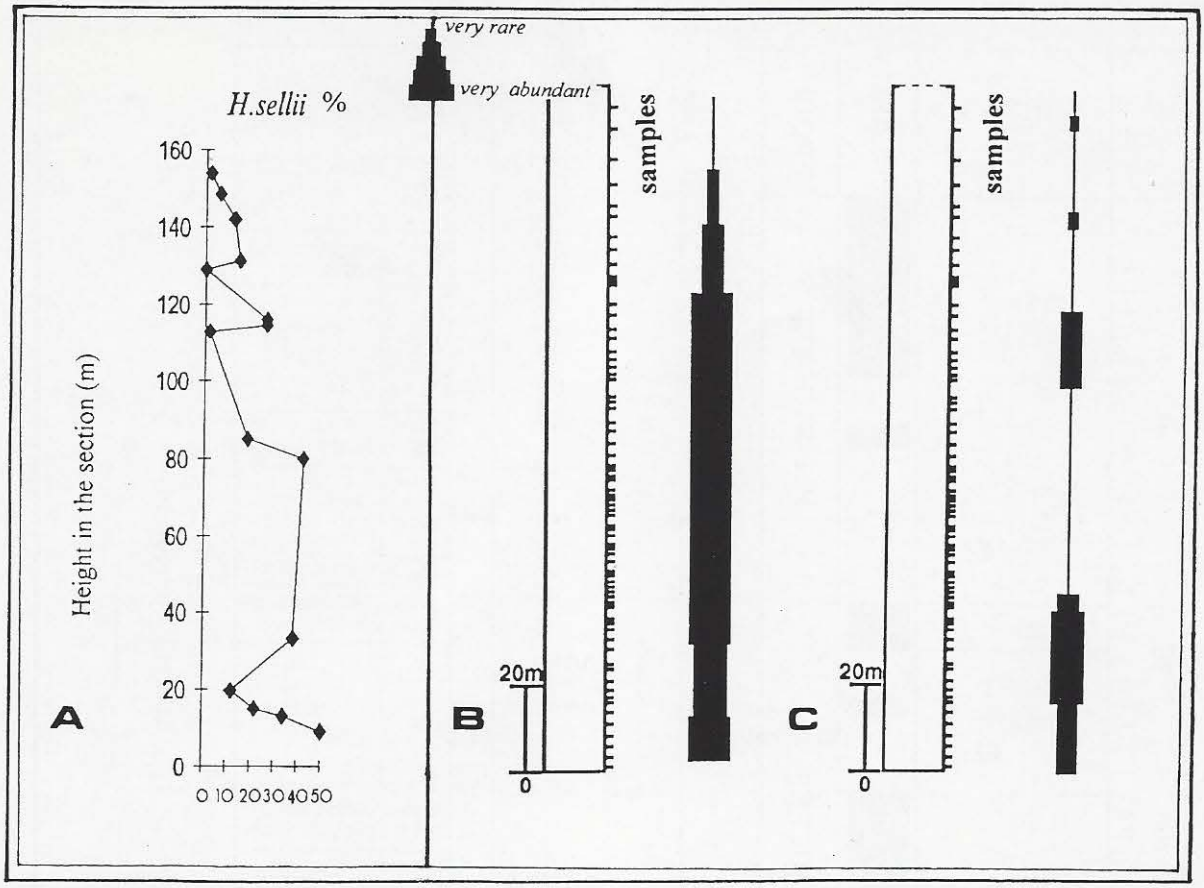

Figure 3: (A) Relative abundance of *Helicosphaera sellii* to 50 specimens of the genus; (B) semiquantitative analysis of small *Gephyrocapsa* spp.; (C) semiquantitative analysis of *Calcidiscus macintyrei*.

reflect the influence of primary production, yet the phenomenon can be correlated with the periodical increase of terrestrial material in the depositional environment of the studied sediments. Consequently, it is obvious that *C. macintyrei* does not represent a good marker-species in this section; in fact, it is practically impossible to determine its extinction level.

The presence of *D. triradiatus*, along with the continuous presence of *G. inflata*, allows the correlation of the lower part of the section with the upper part of MNN18 (Rio *et al.*, 1990), above the FO of *G. inflata*, or NN18 (Martini, 1971) and CN12d (Okada & Bukry, 1980). Additionally, the MNN18/MNN19a zonal boundary can be recognised at 15-20m above the base of the section. The rest of the sequence, according to the available data, can be correlated with MNN19a (Rio *et al.*, 1990), or NN19 (Martini, 1971) and CN13a (Okada & Bukry, 1980). Concerning planktonic foraminifera, these biozones can be correlated with the lower part of biostratigraphic interval IX (Spaak, 1983) and the MPL6 biozone (Cita, 1975, emended). This indicates the uppermost Pliocene (Figure 4).

The available data suggest that the Citadelle sediments are biostratigraphically close to the Pliocene/Pleistocene boundary. However, no clear Pleistocene evidence (presence of normal-sized gephyrocapsids) was found during the analyses. Additionally, the presence of *Hyalinea balthica*, a species that was found in the uppermost part of the Citadelle section by Bizon & Müller (1977), was not found in this study, possibly due to difficulties in sampling the uppermost part of the Citadelle Formation.

Conclusions

Biostratigraphic analysis of the marly deposits of the Citadelle section has led to the revision of its stratigraphic location.

-The data derived from the present study (determination of the three-rayed *D. brouweri* variety, *D. triradiatus*) suggest that the lowermost part of the sequence can be assigned to MNN18 of Rio *et al.* (1990).

-The last occurrence of *D. triradiatus* at ~15-20m above the base of the section allows the recognition of the MNN18/MNN19 zonal boundary.

- The rest of the sequence can be correlated with MNN19a.

- The data indicate an uppermost Pliocene age. No indication of a Pleistocene age was determined in the studied Citadelle samples.

Acknowledgments

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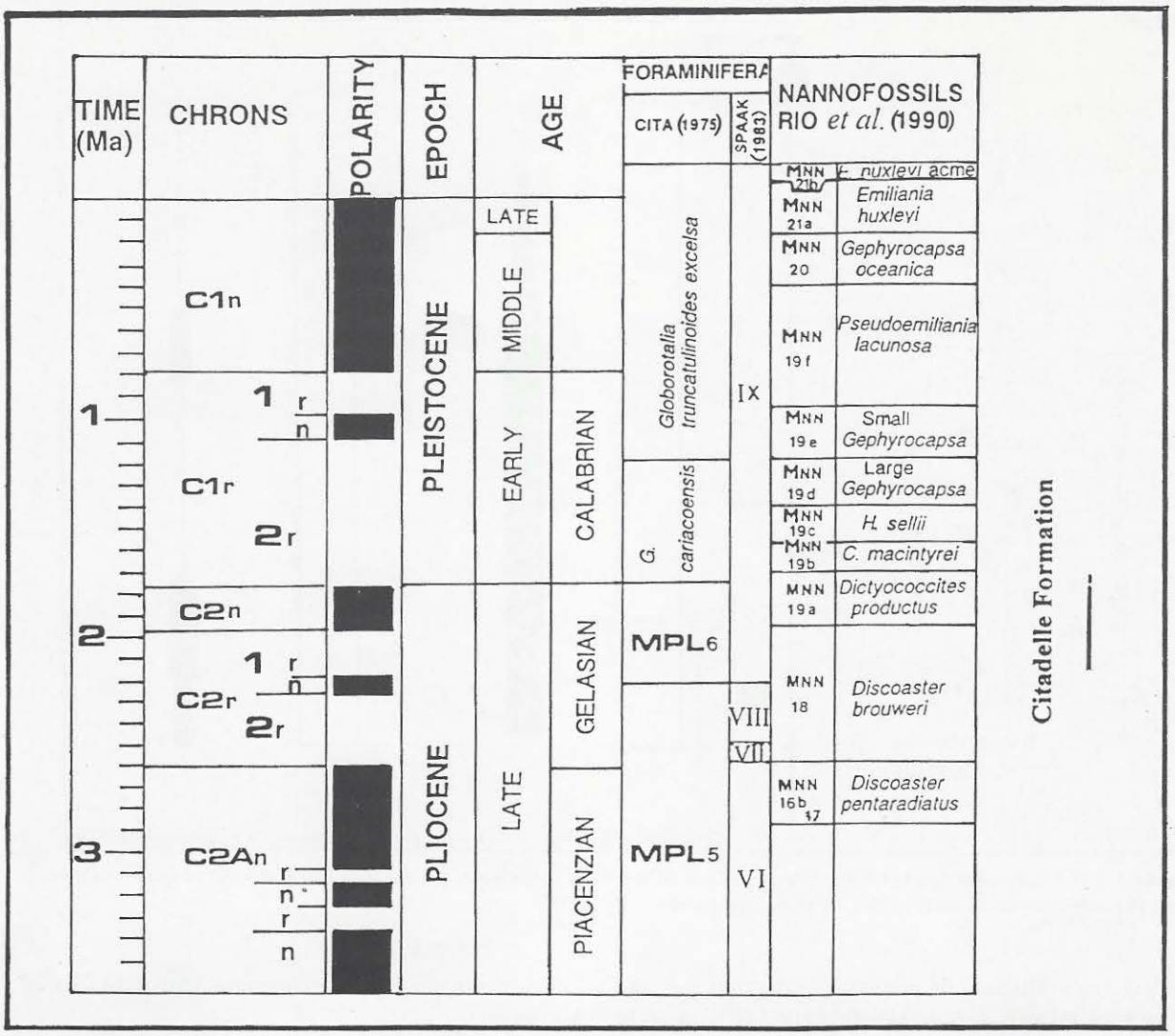

Figure 4. Stratigraphic location of the Citadelle section based on calcareous plankton biostratigraphy in the Mediterranean. Magnetostratigraphy and age assignments are based on Berggren *et al.* (1995a, b).

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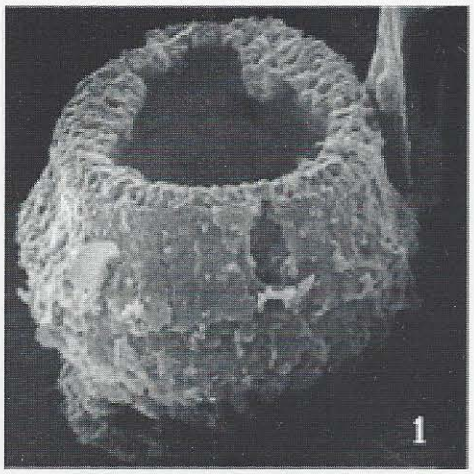
PLATE 1

Fig.1: ***Scyphosphaera*** **sp..** Sample ZA12.
Fig.2: ***Calcidiscus macintyrei*** **(Bukry & Bramlette) Loeblich & Tappan**. Sample ZA12.
Fig.3: ***Pseudoemiliania lacunosa*** **(Kamptner) Gartner**. Sample Z43.
Fig.4: ***Calcidiscus macintyrei*** **(Bukry & Bramlette) Loeblich & Tappan**. Sample ZA11.
Figs 5, 6: ***Discoaster brouweri*** **(Tan Sin Hok)**. Sample ZA11.
Fig.7: ***Discoaster tamalis*** **Kamptner**. Sample ZA11.
Fig.8: ***Discoaster brouweri*** **(Tan Sin Hok)**. Sample ZA11.
Figs 9, 10: ***Discoaster triradiatus*** **Tan Sin Hok**. Sample ZA11.
Fig.11: ***Scyphosphaera*** **sp.**. Sample ZA11.
Fig.12: ***Helicosphaera sellii*** **(Bukry & Bramlette) Jafar & Martini**. Sample Z28.
Fig.13. Small ***Gephyrocapsa*** **spp.**. Sample Z28.

Plate 1



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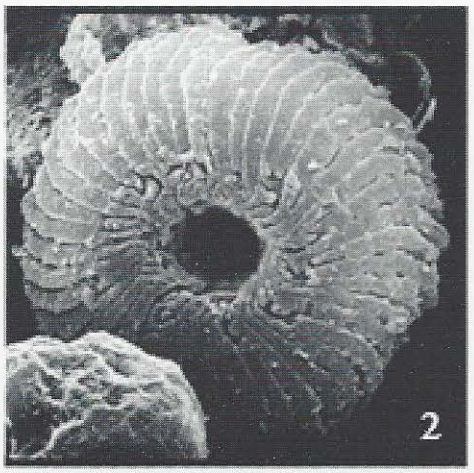

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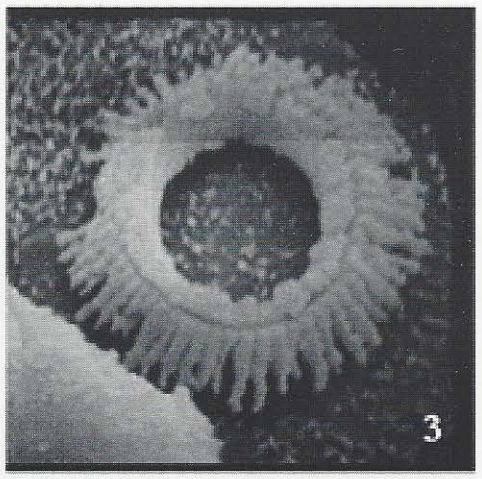

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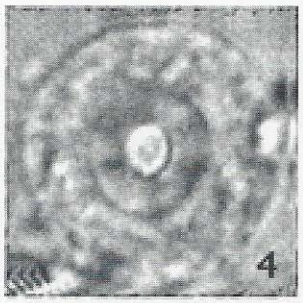

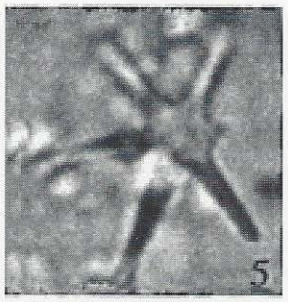

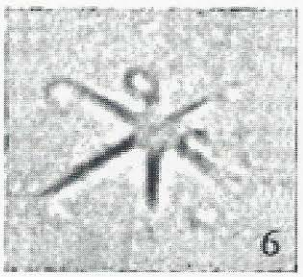

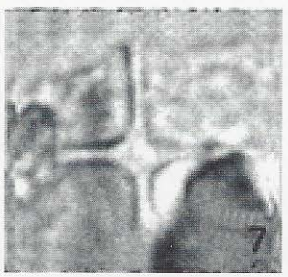

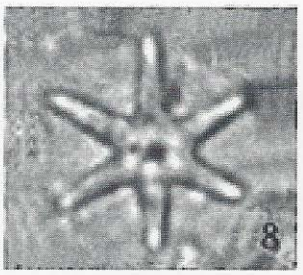

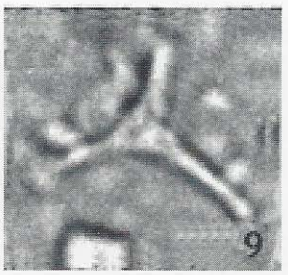

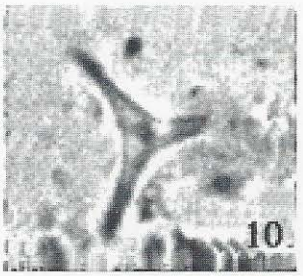

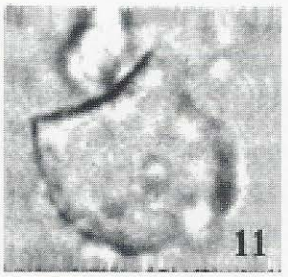

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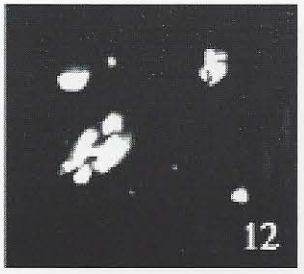

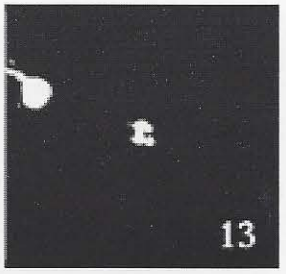

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