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Quaternary Calcareous Nannofossils from the Antarctic Region

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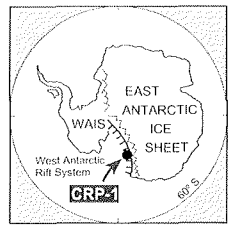
Abstract - Although calcareous nannofossils are generally thought to be absent in Quaternary sediments of the high latitudes of the Antarctic, a number of occurrences are being reported as this region is explored by ice- and ship-based coring techniques. We document the consistent occurrence of *Thoracosphaera* (a calcareous dinoflagellate) in bioclastic Quaternary sediments (1.1-0.8 Ma) of the CRP-1 drillhole at 77° South, Victoria Land Basin in the Ross Sea. We also recorded the occasional occurrence of placoliths in Operation Deep Freeze cores from that region as well in SEDANO piston cores along the Antarctic Peninsula. In each case these occurrences seem to denote relatively warm intervals during an otherwise glacially dominated climate regime.



INTRODUCTION

One of the surprising palaeontological discoveries made during the drilling of CRP-1 was the detection of calcareous dinoflagellates (*Thoracosphaera* Stradner, 1961) in the Quaternary carbonate of lithologic Unit 3.1 (Cape Roberts Science Team, 1998, p. 55). Because their occurrence may have important palaeoenvironmetal implications, a follow-up study to confirm and document our initial observations has been made by a detailed analysis, aided by scanning electronic microscopy (SEM).

The thoracospherids were found during a routine search of CRP-1 samples for calcareous nannofossils. Because thoracosphaerids have the size range (2 to 30 μm), chemical composition and planktonic habit of calcareous nannofossils, they have often been included in this group. From a taxonomic point of view, however, Cenozoic thoracosphaerids have been shown to have a dinoflagellate cyst morphology (Futterer, 1976; Inouye & Pienaar, 1983; Dale, 1996), they thus belong to the calcareous dinoflagellates. Nonetheless, thoracosphaerids have not been reported previously from the Quaternary of the Antarctic, nor have Quaternary calcareous nannofossils of any kind been reported from such a high Southern Ocean latitude (77°S). No modern calcareous nannoplankton live today south of the Antarctic Divergence (Findlay, 1998).

Although calcareous nannofossils are of limited biostratigraphic value at these latitudes, interest in this finding is high because their presence appears to be related to palaeoclimatic fluctuations in the study area during the Quaternary.

BACKGROUND

The ice sheet presently blankets an area of about 13.6 million square kilometres. The Transantarctic Mountains separate two different provinces, of which the eastern component has the largest amount of ice (corresponding to 60 m of sea level equivalent; Barrett, 1996).

An increase in global average Earth temperatures, caused in part by human impact related to CO_2 releases, underscores the importance of studying the global change aspect of palaeoclimate history in order to reveal the climatic evolution on the Earth. Particular attention is focused on the Quaternary, a time of rapid climatic changes. Study of this, the most recent geologic record, will provide information relative to global climatic evolution.

An understanding of the relationship between ice sheet growth, ocean circulation and palaeoproductivity is also basic to the comprehension of climatic changes. Within this framework, palaeoproductivity plays a fundamental role in understanding palaeoclimate and, in turn, future climate evolution.

Geochemical and sedimentological data on sediments from mid-low latitudes (Dymond et al., 1992) has revealed a cyclicity in palaeoproductivity, the application of barium variation as a response to glacial-interglacial cycles, was developed for the Antarctic sediments by Shimmield et al. (1994). These data infer high productivity during interglacials and, on the other hand, low productivity during glacial intervals (Bonn et al., 1994).

A detailed survey of Quaternary calcareous nannofossil assemblages in Southern Ocean sediments would be useful to help evaluate palaeoproductivity inferred from geochemical and isotopic data. It would be especially important to reconstruct a map of their distribution because nannoplankton have apparently been responsible in part for primary productivity in this region. Circum-antarctic ocean palaeoproductivity is related to the advance and retreat of ice, which in turn is related to climatic changes. The presence of nannofossils in this environment is tied to these conditions, and their evaluation will help provide a more robust palaeoclimatic interpretation.

PREVIOUS WORK

Hitherto, calcareous nannofossils have been reported infrequently in sediments with low carbonate content, such as those of the Antarctic regions, at latitudes higher than 65°S (Fig. 1). Previous studies (Wei & Wise, 1990; Wei & Thierstein, 1991; Wei & Wise, 1992) from ODP Legs 119 and 120 reported differentiated associations at lower latitude. Sites 119-736 and 119-738 (between 60°S and 65°S respectively) yielded a nannofossil assemblage typical of the Pleistocene with *Gephyrocapsa oceanica* and *Coccolithus pelagicus*. At the more southerly Site 119-744, which is of the same age according to diatom stratigraphy, only few *C. pelagicus* were found. At Site 120-747 the presence of *E. huxley* indicates a late Pleistocene age, while at Sites 120-748 and 120-751, it was absent. The latter sediments are probably older than late Pliocene. At Sites 113-689 and 113-690 (the southernmost), Pleistocene was indicated by diatoms along with the rare nannofossil, *Pseudoemiliania lacunosa*.

During the first drilling season of the Cape Roberts Project, a thick Quaternary sequence, which includes an unusual bioclastic carbonate facies, was recovered. Within this facies, rare calcareous nannofossils (thoracosphaerids) were detected for the first time in the Quaternary of the Ross Sea, at considerably higher latitude (77°S) than for any other Southern Ocean cores thus far analyzed (Cape Roberts Science Team, 1998a).

The carbonate, lithostratigraphic Unit 3-1, is essentially a hash of invertebrate macrofossil shells within an otherwise clastic-bearing glacial or glaciomarine sequence. Part of the material has been winnowed and other parts not. The best preserved and most abundant thoracosphaerids were recorded only as fragments in closely spaced samples from the finest sediments, which are unwinnowed muds. Only one complete test was found (Plate 1e) although some fragments were quite large (up to 40 mm). One sample from winnowed material (32.95 mbsf) was barren (Fig. 2).

Other Quaternary lithostratigraphic units (1, 2, and 4) were searched for calcareous nannofossils; these all appeared to be barren, based on our examination of 7 samples. A study of 71 samples in the Miocene sequence provided similar results, with thoracosphaerids present only in a clast. The Miocene section will not be further discussed here (see Cape Roberts Science Team, 1998b, for additional details).

METHODS

Different procedures have been applied to study the samples. For the light microscope observation, smear slides were made. Samples have also been analysed in the scanning electronic microscope, where we applied a correlated technique that allows observation of the same object in both the light microscope (LM) and scanning electronic microscope (Wind, 1975, pers. comm.; see description in De Kaenel & Villa, 1996). This technique provides a more accurate taxonomic assignment as well as a detailed study of the fossil structure, particularly for the calcareous dinoflagellates, which are still not well known in the Antarctic.

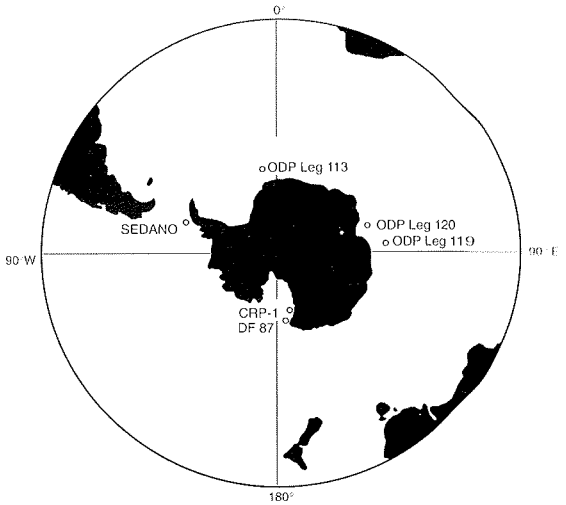


Fig. 1 - Location map of CRP-1, SEDANO and Deep Freeze cores, and ODP Legs.

Full taxonomic names of species are given in table 1. Bibiographic references for these names are ginven in Perch-Nielsen (1985).

Tab. - Species list mentioned in the text.

Calcidiscus leptoporus (Murray & Blackman) Loeblich & Tappan, 1978
Coccolithus pelagicus (Wallich) Schiller, 1930
Emiliania huxley (Lohmann) Hay & Mohler in Hay et al., 1967
Gephyrocapsa ericsonii McInyre & Be, 1967
Reticulofenestra producta (Kamptner) Wei & Thierstein, 1991
Thoracosphaera hiemi Kamptner, 1941
Thoracosphaera saxea Stradner, 1961

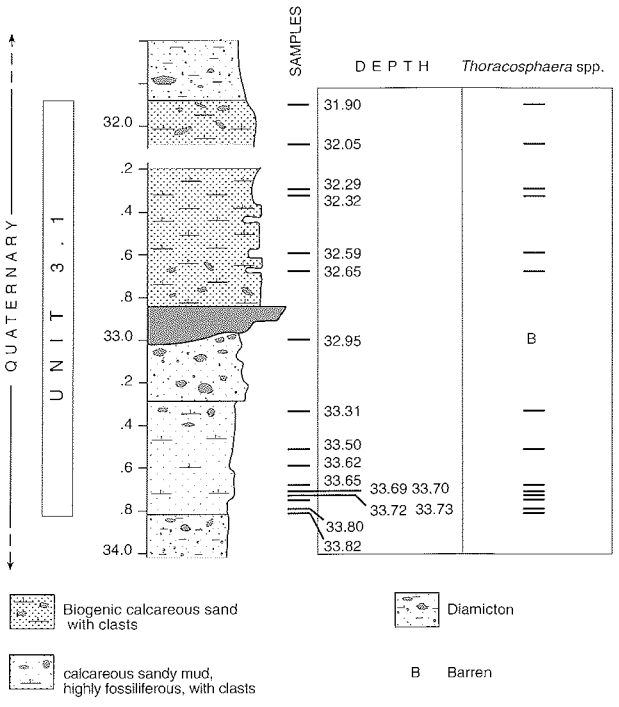


Fig. 2 - Distribution of thoracosphaerids in CRP-1 lithologic Unit 3.1.

RESULTS

CRP-1

All but one of the 17 Quaternary samples examined contained thoracosphaerid fragments (Fig. 2), as well rare to few triradiate spicules of *Calcispongia*, Class Calcarea (Plate 2a & b). Although in the light microscope the fragments undoubtedly belong to the thoracosphaerids, when examined in the scanning electronic microscope, some show an unknown pattern for a thoracosphaerid structure.

For example, in plate 1a, the thoracosphaerid fragment in polarized light shows definite but only occasional perforated platelets. In the scanning electronic microscope (Plate 1b) the pores in this same fragment are still visible, but sutures between the platelets are not as clear. Similarly, in correlated micrographs of another fragment (Plate 1c & d), pores are visible in both the light microscope and scanning electronic microscope, but in the latter sutures are not clearly defined. In plate 2c only one platelet appears to be perforated, whereas in the matching scanning electronic microscope micrograph (Plate 2d), two pores are actually present but again, the suture is barely visible. It is interesting to note that in plate 2e-h, dissolution is quite evident, whereas in plate 2g, the wall structure exhibits laminae.

The presence of pores suggests a possible relation with *Thoracosphaera heimi* (Kamptner, 1941), whereas the interdigitated sutures seen in some fragments are reminiscent of *T. saxea* (Stradner, 1961), which has no pores. However further investigations, following the same procedures, on better preserved samples, are required in the future to better understand the structure and taxonomy of these forms, and whether new species are present at these latitudes.

ANCILLARY STUDIES

The above results from CRP-1 led us to initiate a preliminary investigation of other Quaternary carbonate or carbonate-bearing sediments previously cored in the Antarctic region, in order to search for the possible presence of additional calcareous nannofossils.

Two sets of piston cores were examined, one from the northwestern Ross Sea continental shelf, and the other from the continental rise along the Antarctic Peninsula.

Operation Deep Freeze piston cores, stored at the FSU Antarctic Marine Geology Research Facility, recovered Quaternary bioclastic carbonate in the Ross Sea and along the outer continental shelf and the upper slope of the Mauson and Pennel Banks (Fig. 1). Anderson et al. (1990) and Taviani et al. (1993) reported the presence of carbonate in these cores and provided lithological description as well as Carbon-14 age dates. Accordingly, we took a total of 10 samples from cores DF87-8, DF87-9, DF87-15, and DF87-21. Most of these cores yielded rare nannofossils including *C. pelagicus, R. producta, Gephyrocapsa* sp. and *Thoracosphaera* sp. (Fig. 3).

The SEDANO program (SEdiment Drifts of the ANtarctic Offshore), funded by the Italian *Programma Nazionale di Ricerche in Antartide* (PNRA) with the participation of the British Antarctic Survey, recovered 9 cores off the Antarctic Peninsula (Fig. 1). The goals of the project are the quantitative analysis of sedimentation controlled by bottom current on the Pacific margin of the Antarctic Peninsula and the identification of the sedimentary processes controlling the deposition of large sedimentary bodies, interpreted as sedimentary drifts, on the continental rise of this margin between 64°S and 69°S (Camerlenghi et al., 1997).

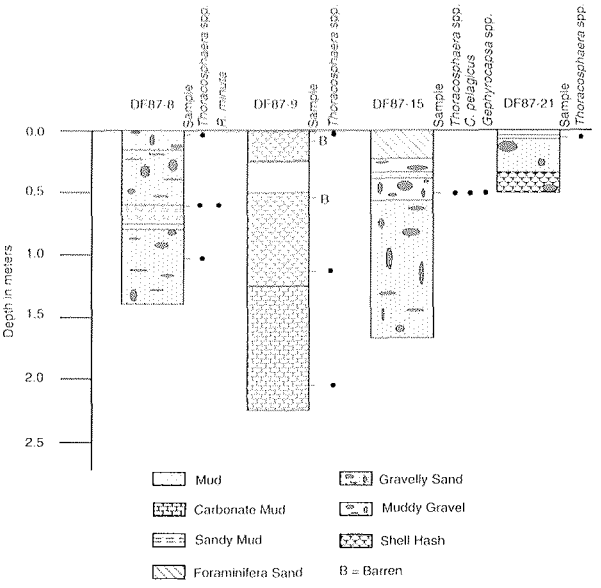


Fig. 3 - Distribution of nannofossils in Deep Freeze cores examined in this paper.

Core SED-6 (67.3°S and 77.6°W) is 5.88 m thick. On a total of ten samples, only those taken between 330 and 375 cm contain rather diverse yet scarce nannofossils, including: *Gephyrocapsa ericsonii, Calcidiscus leptoporus* (5 mm, a small size as postulated by Knappertsbusch et al., 1997, for high latitudes), *Coccolithus pelagicus*, *Helicosphaera* sp. and *Emiliania huxley*. The presence of the latter provides a maximum late Pleistocene age.

DISCUSSION

Even though thoracosphaerids are not biostratigraphically useful, because of their long ranges and slow rate of evolution, they provide useful information for the palaeoenvironmental reconstruction of the late Quaternary, which is known to have been subject to rapid environmental changes related to climate. The presence of thoracosphaerids in the Quaternary, therefore, suggests either a peculiar adaptation to this environment, due to their ability to develop cysts, or to warmer conditions at the time of their deposition, or a combination of both.

As the late Neogene/Quaternary were times of sharp climatic changes, such conditions may have favored the presence of thoracosphaerids as opposed to other calcareous nannoplankton. Both calcareous nannofossils and dinoflagellates, however, generally prefer warmer waters (Dale, 1996), therefore the presence of either would suggest

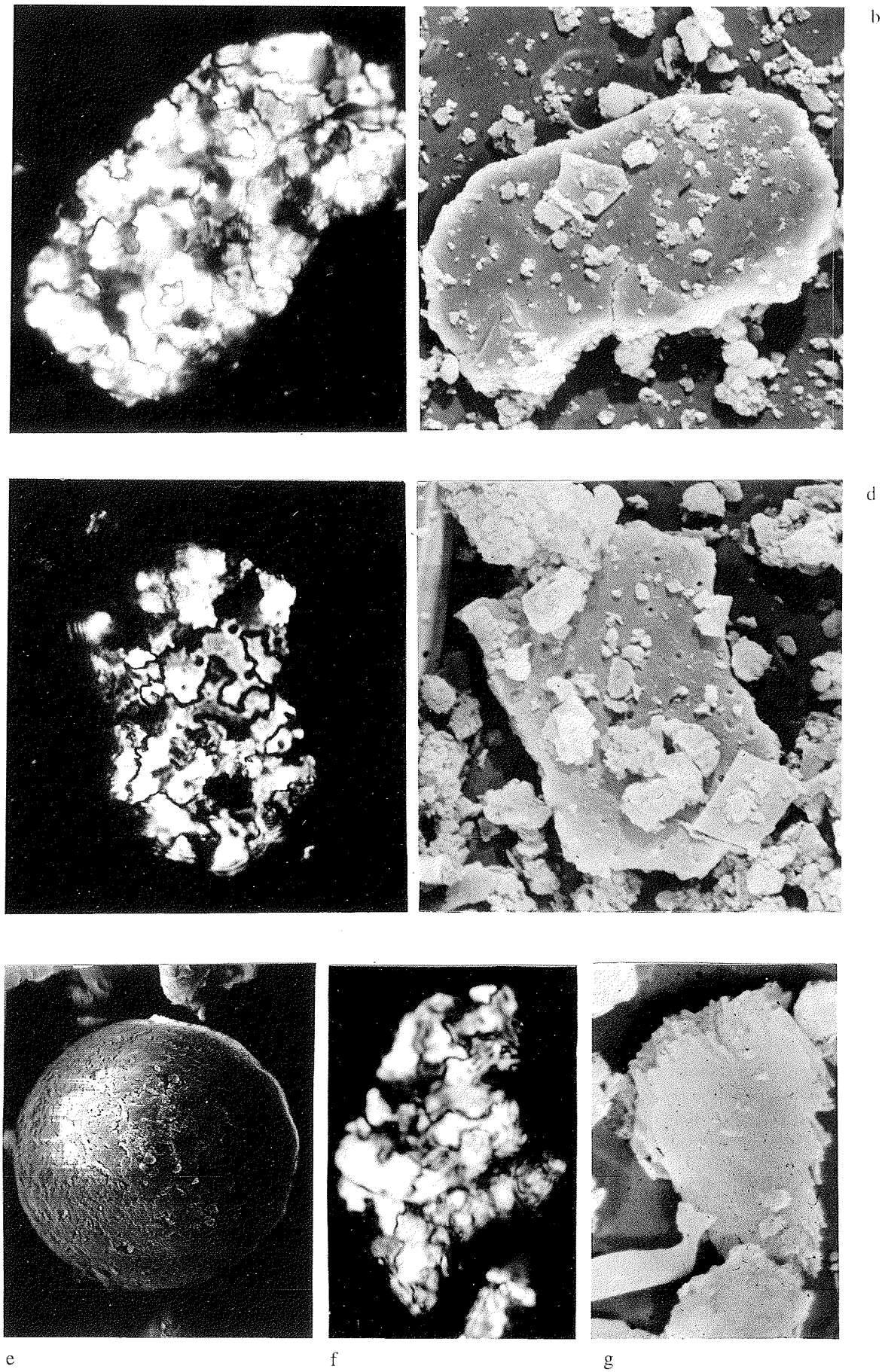


Plate 1 - a & b) Thoracospahera fragment, sample 33.82; a: LM X 1400, b: SEM X 1700; *c & d) Thoracospahera* fragment, sample 33.82; c: LM X 1400, d: SEM X 1700; *e) Thoracospahera sp*, sample 33,82; SEM X 3100; *f & g) - Thoracospahera* fragment, sample 32.65; f: LM X 1400, g: SEM X 1300.

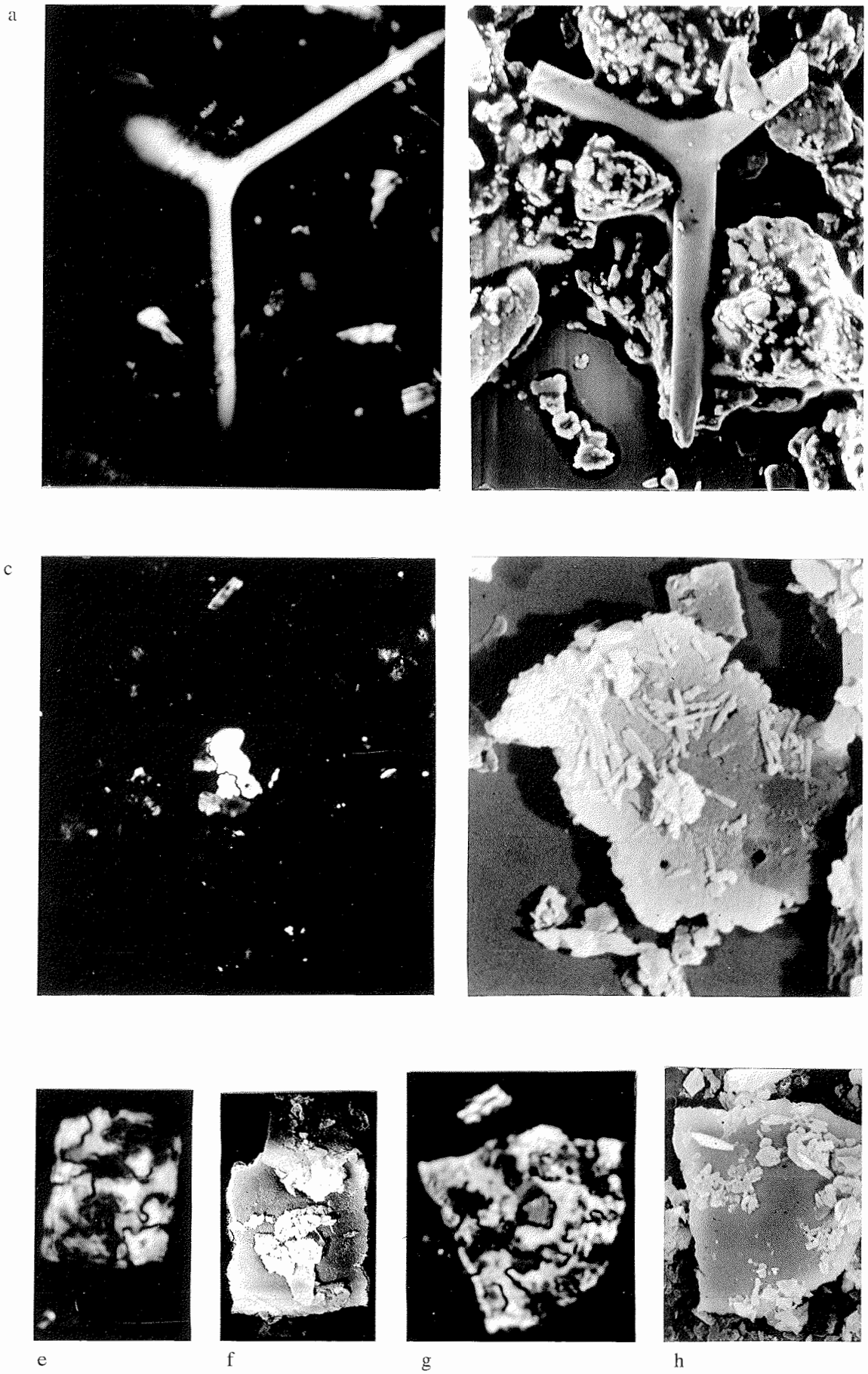


Plate 2 – a & b) Calcisponge spicule, sample 32.32; a: LM X 1060, b: SEM X 1100; *c & d) Thoracospahera* fragment, sample 33.82; c: LM X 1700, d: SEM X 7300; *e & f) Thoracospahera* fragment, sample 33.31; e: LM X 1200, f: SEM X 1250; *g & h) Thoracospahera* fragment sample 32.65; g: LM X 1400, g: SEM X 1400.

relatively warmer conditions for the deposition of lithostratigraphic Unit 3-1.

We should also bear in mind that the preservation of calcareous nannofossils in lithostratigraphic Unit 3.1 may have been enhanced by the presence of abundant carbonate in the sediment, which may have served to buffer the pore water fluids, thereby preventing their dissolution. This might also account in part for the presence of other calcareous microfossils preserved in these sediments such as sponge spicules (Plate 2a & b) and abundant foraminifers (Webb & Strong, this volume).

Taviani et al. (1993) interpreted the presence of carbonates recovered in Deep Freeze cores as a reflection of a glacial marine facies (isotopic Stage 3), rather than an interglacial to glacial transition as some might infer. Taviani et al. (1993) note similarities between their upper Pleistocene fauna and those living in the Ross Sea today. Beside their interpretation we suggest a possible warmer period for the carbonate intervals in question, particularly for that of Unit 3.1.

In SEDANO Core 6, the brown lithological Unit C, which contains the nannofossils, has been interpreted as an interglacial (Camerlenghi et al., 1997). The oxygen isotopic record is not available. However, on the basis of geochemical data which revealed hight organic barium, as well high biogenic carbon content (Pudsey & Camerlenghi, 1998), Unit C has been interpreted as corresponding to isotopic Stage 5. The latter is regarded as an interglacial interval (to use Northern Hemisphere terminology), an interpretation in agreement with our inference, which relates the presence of nannofossils in the Antarctic to warmer conditions, such as during glacial retreat.

Samples from different areas enabled us to gather and compare some of the first data on Quaternary calcareous nannofossils from the high latitude of the Antarctic. Although these occurrences are few, we believe such studies will contribute to a better understanding of ice sheet fluctuations in the Antarctic region through time.

Detailed monitoring of the presence of nannofossils and calcareous dinoflagellates in the circum-antarctic areas at latitude south of 65°S, including the reconstruction of their distribution modality and the elements that drive the assemblage variations, will be the goals of future research.

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